SI (Metric) Handbook

Elisa A. Artusa

Technical Memorandum 109197

March 1994

FOREWORD

This handbook is a guide to the application of the International System of Units (abbreviated SI), the modern metric system. As a result of Federal legislation, SI is identified as the primary measurement system for Government use. This document is a consolidation of various specifications and standards, primarily ANSI/IEEE Std 268 and ASTM E380, recognized by the Metrication Operating Committee of the Interagency Council on Metric Policy as authoritative sources on SI for use by the Federal Government. The information in this handbook is presented with sufficient detail to assist those personnel who may not have had formal training in using either SI or other metric systems.

This guide provides information for an understanding of SI units, symbols, and prefixes; style and usage in documentation in both the United States and in international business; conversion techniques; limits, fits, and tolerance data; and drawing and technical writing guidelines. Also provided is information on SI usage for specialized applications like data processing and computer programming, science, engineering, and construction. Related information in the appendixes include legislative documents, historical and biographical data, a list of metric documentation, rules for determining significant digits and rounding, conversion factors, shorthand notation, and a unit index.

Requests for information, corrections, or additions to this document should be directed to NASA, Engineering Development Directorate, DM-MED-33, Kennedy Space Center, Florida 32899. Requests for additional copies of this document should be sent to Forms Warehouse, Kennedy Space Center, Florida 32899.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (cont)

ABBREVIATIONS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
A&E	architectural and engineering
ACI	American Concrete Institute
AIA	American Institute of Architects
ANMC	American National Metric Council
ANSI	American National Standards Institute
ASAE	American Society of Agricultural Engineers
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASRM	Advanced Solid Rocket Motor
ASTM	American Society for Testing and Materials
AWG	American wire gage
AWS	American Welding Society
BOCA	Building Officials and Code Administrators
CADD	Computer-Aided Drafting and Design
CAE	Computer-Aided Engineering
CBD	Commerce Business Daily
CGPM	General Conference on Weights and Measures
cgs	centimeter-gram-second
CIPM	International Committee on Weights and Measures
CM	construction management
CMU	concrete masonry unit
CSI	Construction Specifications Institute
DN	diameter nominal
EMU	electromagnetic unit
ESU	electrostatic unit
FED	federal
GPO	Government Printing Office
GSA	General Services Administration
GSM	gross square meters
Hg	mercury
H_2O	water
HVAC	heating, ventilating, and air conditioning
IBWM	International Bureau of Weights and Measures
ICD	Interface Control Document
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardizaton
IT	International Tolerance
ITS	International Temperature System

ABBREVIATIONS AND ACRONYMS (cont)

KHB	KSC handbook
KMI	KSC management instruction
KSC	John F. Kennedy Space Center
MIL	military
MKS	meter-kilogram-second
MKSA	meter-kilogram-second-ampere
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NBC	National Building Code
NFPA	National Fire Protection Association
NIBS	National Institute of Building Sciences
NIST	National Institute of Standards and Technology
NMI	NASA management instruction
NPS	nominal pipe size
NPT	National Standard Pipe Taper
NSG	National Geodetic Survey
O&M	operation and maintenance
OSF	Office of Space Flight
OSSD	Office of Space Systems Development
RFP	request for proposal
RH	relative humidity
SAE	Society of Automotive Engineers
SI	International System of Units
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
SME	Society of Manufacturing Engineers
STD, Std	standard
STP	standard temperature and pressure
UPS	uninterruptable power supply
UL	Underwriters Laboratories Inc.
USGS	U.S. Geological Survey
U.S.	United States

SYMBOLS

a	acceleration
a	atto (prefix), annum
A	ampere
AU	astronomic unit (UA in French)
b	barn
bar	bar
Bq	becquerel
Btu	British thermal unit
Btu/hr	British thermal unit per hour
c	centi (prefix)
C	coulomb
cd	candela
Ci	curie
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
cps	cycles per second
C_w	warping constant
d	day, deci (prefix)
da	deka or deca (prefix)
dam^2	square dekameter
dB	decibel
dm	decimeter
dm^3	cubic decimeter
E	exa (prefix)
eV	electronvolt
f	femto (prefix)
F	force
F	farad
F_g	force due to gravity
fm	femtometer
fm^2	square femtometer
ft^2	square feet
g	gravitational acceleration
g	gram
G	giga (prefix)
gal	gallon
Gy	gray
h	hour, hecto (prefix)
H	henry

SYMBOLS (cont)

ha	hectare
Hg	mercury
hm	hectometer
hm^2	square hectometer
hr	hour (non-SI)
Hz	hertz
I	second moment of area (moment of inertia)
inHg	inch of mercury
inH_2O	inch of water
J	torsional constant
J	joule
k	kilo (prefix)
K	kelvin
kg	kilogram
kg_f	kilogram-force
kip	kilopound (1000 lb_f)
klx	kilolux
km	kilometer
km^2	square kilometer
kp	kilopond
kPa	kilopascals
ksi	kip per square inch
kW	kilowatt
kW·h, kWh	kilowatthour
L, l	liter
lb	pound (mass)
lb_f	pound-force
lm	lumen
lx	lux
m	mass
m	meter, milli (prefix)
m^2	square meter
m^3	cubic meter
m^4	meter to the fourth power
m^6	meter to the sixth power
M	mega (prefix)
mbar	millibar
MCF	thousands of cubic feet
MCM	thousands of circular mils
Mg	megagram
mGy	milligray
min	minute (time)

SYMBOLS (cont)

MJ	megajoule
mm	millimeter
MM	millions
mm^2	square millimeter
mm^3	cubic millimeter
mm^4	millimeter to the fourth power
mm^6	millimeter to the sixth power
m/m	meter per meter
mmHg	millimeter of mercury
mol	mole
MPa	megapascal
m/s^2	meter per second squared
mSv	millisievert
n	nano (prefix)
N	newton
nm	nanometer
nT	nanotesla
p	pico (prefix)
P	peta (prefix)
Pa	pascal
pc	parsec
pdl	poundal
pF	picofarad
pH	per hydrogen
psf	pound per square foot
psi	pound per square inch
pW	picowatt
R	roentgen
rad	radian
rd	rad
rem	rem
s	second
S	siemens
sr	steradian
Sv	sievert
t	temperature (in degree Celsius)
T	thermodynamic temperature (in kelvin)
T	tesla, tera (prefix)
T_o	273.15 kelvin
u	atomic mass unit
V	volt
W	weight

SYMBOLS (cont)

W	watt
Wb	weber
y	yocto (prefix)
Y	yetta (prefix)
z	zepto (prefix)
Z	modulus of section
Z	zetta (prefix)
μ	micro (prefix)
μg	microgram
μL	microliter
μm	micrometer
μPa	micropascal
Ω	ohm
π	pi (3.14159)
ν	tangential linear velocity
ω	angular velocity
°	degree of arc
°C	degree Celsius
°F	degree Fahrenheit
′	minute of arc, foot
″	second of arc
"	inch
/	per
%	percent

UNITS AND SYMBOLS

Quantity	Quantity Symbol	Unit	Unit Symbol	Formula
amount of substance	n	mole	mol	
angular frequency	ω	radian per second	rad/s	
area	A	hectare	ha	
capacitance	C	farad	F	C/V
Celsius temperature	t	degree Celsius	°C	
charge	Q	coulomb	C	A·s
conductance	G	siemens	S	A/V
conductivity	σ	siemens per meter	S/m	
current	I	ampere	A	
electric field strength	E	volt per meter	V/m	
electric flux density	D	coulomb per square meter	C/m^2	
energy, work	W	joule	J	N·m
force	F	newton	N	$kg{\cdot}m/s^2$
frequency	f	hertz	Hz	1/s
inductance	L	henry	H	Wb/A
length	l	meter	m	
luminous intensity	I	candela	cd	
magnetic field strength	H	ampere per meter	A/m	
magnetic flux density	B	tesla	T	Wb/m^2
magnetic flux	Φ	weber	Wb	V·s
magnetomotive force	F	ampere	A	
mass	m	kilogram	kg	
permeability	μ	henry per meter	H/m	
permittivity	ε	farad per meter	F/m	
plane angle	θ	radian	rad	
power	P	watt	W	J/s
pressure	p	pascal	Pa	N/m^2
Rankine temperature	T_R	degree Rankine	°R	
relative permeability	μ_r	(pure number)		
relative permittivity	ε_r	(pure number)		
reluctance	R	ampere per weber	A/Wb	
resistance	R	ohm	Ω	V/A
resistivity	ρ	ohm-meter	Ω·m	
solid angle	Ω	steradian	sr	
specific impulse	I_{sp}	second	s	
thermodynamic temperature	T_K	kelvin	K	
voltage, potential	V	volt	V	W/A

SECTION I

INTRODUCTION

1.1 SCOPE

The Omnibus Trade and Competitiveness Act of 1988 declares that the metric system is the preferred system of weights and measures for the United States (U.S.) trade and commerce. The Act was followed by Executive Order 12770 which specified that the Federal Government must conduct business using the International System of Units (SI) as the primary measurement system and requires that each Federal agency convert to the metric system to the extent economically feasible by 1992. A transition period for NASA's metrication from the inch-pound system extends to the end of 1995.

This handbook is a guide to the application of SI. Sections include descriptions of basic, derived, and supplementary units and unit symbols; prefixes and prefix symbols; style and usage; conversion techniques; limits, fits, and tolerance information, drawing and technical writing guidelines; keyboard applications; and science, engineering, and construction information. The appendixes provide supplementary information as listed below:

Appendix A:	Executive Order 12770
Appendix B:	Historical and biographical information
Appendix C:	Reference list of metric documentation available through Government agencies, publishers, and industry organizations
Appendix D:	Guidelines for determining significant digits and rounding
Appendix E:	Examples for writing shorthand forms for metric terminology
Appendix F:	Listing of physical constants in metric
Appendix G:	Various tables of conversion factors including an alphabetical listing, a classified listing by physical quantity, and decimal equivalents of inches and millimeters
Appendix H:	Examples in determining tolerances and tables of preferred tolerance zones and fits

Appendix I: Index referencing SI units throughout this document

Appendix J: References

1.2 DEFINITIONS

The following definitions apply to this section. Additional definitions are listed in other sections of this handbook where the definitions pertain to the discussion.

a. Decimal System - A system of numbers that uses multiples and sub-multiples in powers of ten.

b. Design, Inch-Pound - An inch-pound design is one which uses only inch-pound units for all measurements and specifications.

c. Design, Metric - A metric design is a design that uses only metric units for all measurements and specifications.

d. Design, Soft Metric - A soft metric design is accomplished when an inch-pound design is defined in equivalent metric units.

e. Hybrid System - A hybrid system is one that incorporates both metric and inch-pound designs in its major components.

f. Inch-Pound Units - Inch-pound units are based upon the inch, foot, and yard linear measurements and the pound as commonly used in the U.S. and defined by the National Institute of Standards and Technology (NIST) (formerly the National Bureau of Standards). It should be noted that some units as used previously in other countries (like the gallon) have the same unit names but may differ in magnitude. For purposes of this document, inch-pound units include other units, like the degree Fahrenheit (°F), used extensively in the U.S.

g. Metrication - Metrication is the process or act of converting from an existing system of units to the metric system.

h. System, Inch-Pound - The inch-pound system is a system of weights and measures, using inch-pound units, used in the U.S. since its founding, through its use by governments and the general public. It has also been referred to as the "English system," "customary system," and the "U.S. system." This system was the primary system of weights and measures in the U.S. prior to the Metric Conversion Act of 1975.

i. System, Metric - The measurement system that uses the meter, kilogram, second, ampere, and kelvin for length, mass, time, electric current, and temperature, respectively, and other units derived from these. The system evolved into the SI.

j. The International System of Units (SI) - SI is the modernized version of the metric system based on the meter, kilogram, and second (MKS) units.

1.3 THE INTERNATIONAL SYSTEM OF UNITS (SI)

The modernized version of the metric system, Le Système International d'Unités (International System of Units), abbreviated SI, was developed in 1960 and was established as the preferred system of measurement in the United States with the enactment of the Metric Conversion Act of 1975 and as amended by the Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418). This law was followed in 1990 with Executive Order 12770, which specified that the Federal Government must conduct business using SI, as the primary measurement system. SI is interpreted or modified for use in the U.S. by the Secretary of Commerce (55 FR 52242, December 20, 1992). The name "Le Système International d'Unités" and its abbreviation were adopted by the 11th General Conference on Weights and Measures [Conférence Générale des Poids et Mesures (CGPM)] in 1960.

SI is a decimal system composed of basic, supplementary, and derived units. Since the metric system has evolved over 200 years, there is widespread usage of obsolete and improper metric units and practices, particularly in those countries that began using the metric system long ago and use units that are part of the centimeter-gram-second (cgs) metric system. SI is the form of the metric system that is preferred for all applications for the Government.

1.4 PROGRAM AND PROJECT USE OF SI

The NASA Management Instruction (NMI) 8010.2 is the NASA response to Executive Order 12770 and establishes policy and responsibilities for use of the metric measurement system in NASA programs. According to the metric transition plan developed by the Office of Space Flight (OSF) for the OSF and the Office of Space Systems Development (OSSD), the metric system of measurement has been adopted as the primary system of units for all OSF institutional activities. Metric units are required in all requests for proposal (RFP's) for program new-starts for which phase C/D (or equivalent acquisition) is initiated after October 1, 1990. All programs in an earlier phase will be converted to metric at the start of the next program phase. Programs in development (phase D) or operational (phase E) phases as of October 1, 1990, are exempt. Major programs exempted include:

a. Space Shuttle

b. Space Station Freedom

c. Flight Telerobotic Servicer

d. Advanced Solid Rocket Motor (ASRM)

e. Extended Duration Orbiter

f. Existing expendable launch systems

Future procurements for components, subsystems, and systems within exempted programs are also exempted. However, existing and new inch-pound drawings and documentation shall include metric dimensions, as needed, to support interfaces with new metric hardware or metric-based operations. Generally, institutional activities primarily supporting ongoing exempted programs are exempt from using metric units after approval of a waiver.

New or replaceable test equipment, manufacturing equipment, machine tooling, etc., will use the metric system of measurement when it is most cost effective for the program or project, regardless of the program exemption classification. Exceptions and deviations to this policy must be approved by the John F. Kennedy Space Center (KSC) Metric Coordinator as designated in the KSC Management Instruction (KMI) 8010.2.

Refer to section VI of this document for guidelines for determining when conversion to metric is required and for methods of conversion. For more information on KSC's metric transition plan, see the KSC Handbook (KHB) 8010.2.

1.5 WAIVERS

Waivers may be granted on a case-by-case basis. The OSF Metric Transition Plan states that waivers to the required use of metric units will be permitted for individual programs and discrete elements within programs where it can be demonstrated that metrication is impractical or adversely affects overall system/program costs, schedule, or performance. Any program that receives a waiver in transition from one early program phase to another must reapply for a waiver when advancing to a subsequent phase of development. Justifications for waivers must address cost and budget, logistic support, schedules, operational requirements, safety, ability of Government activities and industry to respond in a timely manner, and the effect of the waiver on metrication of other program elements. Refer to the OSF Metric Transition Plan for a complete description of the waiver process.

1.6 PROJECT PHASES

The following paragraphs briefly describe the phases of a project and the respective measurement system issues to be considered. Refer to section XI for information specific to construction projects.

1.6.1 MISSION NEEDS AND CONCEPTUAL/PRELIMINARY STUDIES (PHASE A). The measurement system to be used for a project is defined in Phase A. Preliminary studies and field investigations should be conducted in SI measures for metric and hybrid projects. If the measurement system to be used cannot be identified in this phase, it is recommended that the project begin using SI measurements. Waiving the use of the metric system cannot be authorized until some study and evaluation have been performed; therefore, no time would be lost in converting a project after work has been done.

1.6.2 CONCEPT DEFINITION (PHASE B). Phase B efforts continue to use SI measurements while the project is being defined. Costs are estimated using metric quantities of products and materials. Specifications are defined in SI units only for metric projects. Statements of work clearly describe the project as being metric and are written with all units in the project's measurement system. Clearly state that the project is a metric project and that all responses must be in SI units. If it is uncertain whether or not a project will be metric, state that it is possible that the project may be metric.

1.6.3 ACQUISITION. Announcements published for projects should clearly identify the project as being metric. Procurement of materials and components for metric items and systems, including soft metric items, shall be procured in metric quantities. Procurement for existing inch-pound items and systems should continue to be procured in inch-pound quantities unless the system is converted to metric.

1.6.4 DESIGN AND DEVELOPMENT (PHASE C).

1.6.4.1 Hardware. New hardware shall be designed with SI as the baseline measurement system unless a waiver is granted permitting the use of inch-pound units. Existing hardware designed in inch-pound units should remain in inch-pound units with interfaces with metric hardware being soft-converted to show SI measurements. Hybrid systems may show dual measurements at interfaces as necessary. Waivered programs will be required to use dual units on drawings and documentation that support metric operations or interfaces. Product selection should include consideration of replacement parts in the required measurement units.

Instrumentation designed for use in flight and ground support systems should have user-selectable measurement units for display and printout. The user should be able to select between SI units and inch-pound units.

1.6.4.2 Software. Mission and flight operations software should provide user-selectable measurement units for visual display and printout. The selected measurement system should be clearly defined.

1.6.5 FABRICATION, INTEGRATION, TEST, AND EVALUATION (PHASE D).

1.6.5.1 Tooling, Fabrication, and Assembly. Tools shall be compatible with the design units of the hardware. Tools may be used that are designed in an alternate measurement system as long as the product meets the requirements in the proper measurement system.

1.6.5.2 Test Equipment. Test equipment shall provide dual output capability where the user may select the measurement system for video display and printout.

1.6.5.3 Inspection and Acceptance Testing. Inspection documents and all qualification, in-process, and acceptance test reports shall use the same units as the design specifications. All inspections and testing shall be conducted in those units.

1.6.6 OPERATION AND MAINTENANCE (PHASE E). All operation and maintenance documentation shall be provided in the measurement units of the project's hardware. Programs waived from using SI units shall use dual units on drawings and documentation that support metric operations or interfaces [e.g., Interface Control Document (ICD)]. Likewise, operational programs shall use dual units (soft metric) on new drawings or documentation that support metric operations or interfaces. Refer to sections VIII and IX for information on using dual units in drawings and documentation, respectively.

1.7 TRAINING PERSONNEL TO USE SI

Training employees to perform their responsibilities using SI should be done just before the employees will use the new knowledge on the job. Employees may require retraining if trained any earlier; and training too late may lead to additional costs for employees to convert work already done improperly or in another measurement system.

1.8 APPLICABLE DOCUMENTS

1.8.1 GOVERNMENTAL.

<u>Federal</u>

Executive Order 12770	Federal Register, Volume 56, No. 145, Metric Usage in Federal Government Programs

<u>National Institute of Standards and Technology (NIST)</u>

NIST Technical Note 1265	Guidelines for Realizing the International Temperature Scale of 1990 (ITS-90)

<u>U.S. General Services Administration (GSA)</u>

	Metric Design Guide
	National Stock Number Guide to Commonly Used Metric Tools
	Standardization and Control of Industrial-Quality Tools

<u>U.S. Government Printing Office</u>

	Style Manual

<u>National Aeronautics and Space Administration (NASA)</u>

NMI 8010.2	Use of the Metric System of Measurement in NASA Programs
	Office of Space Flight Metric Transition Plan

John F. Kennedy Space Center (KSC), NASA

KMI 8010.2	Use of the Metric System of Measurement in KSC Facilities, Systems, and Equipment
KHB 8010.2	KSC Metric Transition Plan
GP-435	Engineering Drawing Practices

1.8.2 NONGOVERNMENTAL.

American National Standards Institute (ANSI)

ANSI B4.2	Preferred Metric Limits and Fits
ANSI B4.3	General Tolerances for Metric Dimensioned Products
ANSI X3.50	Representations for U.S. Customary, SI, and Other Units To Be Used in Systems With Limited Character Sets

American Society of Testing and Materials (ASTM)

ASTM A6/A6M	Standard Specification for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use
ASTM A53	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A325M	Standard Specification for High-Strength Bolts for Structural Steel Joints (Metric)
ASTM A490M	Standard Specification for High-Strength Steel Bolts, Classes 10.9 and 10.9.3 for Structural Steel Joints (Metric)

ASTM A615M	Standard Specification for Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate and Lower Temperature Service
ASTM A616M	Standard Specification for Rail-Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A617M	Standard Specification for Axle-Steel Deformed and Plain Bars for Concrete Reinforcement
ASTM A706M	Standard Specification for Flanges, Forged, Carbon and Alloy Steel for Low-Temperature Service
ASTM A775M	Standard Specification for Epoxy-Coated Reinforcing Steel Bars
ASTM B88M	Standard Specification for Seamless Copper Water Tube (Metric)
ASTM B682	Standard Specifications for Standard Metric Sizes of Electrical Conductors
ASTM E380	Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)
ASTM E621	Standard Practice for the Use of Metric (SI) Units in Building Design and Construction

Institute of Electrical and Electronics Engineers (IEEE)

IEEE Std 260	Standard Letter Symbols for Units of Measurement (SI Units, Customary Inch-Pound Units, and Certain Other Units)
ANSI/IEEE Std 268	American National Standard for Metric Practice

International Organization for Standardization (ISO)

ISO 31	General Principles Concerning Quantities, Units and Symbols
ISO 1000	SI Units and Recommendations for the Use of Their Multiples and Certain Other Units

SECTION II

SI UNITS AND SYMBOLS

2.1 INTRODUCTION

SI units are categorized into three classes: base units, supplementary units, and derived units. In this section, these units are described in their basic form. Refer to section III for information on the proper addition of prefixes to unit names. If a particular unit is not discussed in this section, it may not be an acceptable SI unit or temporary unit. In this situation, refer to appendix G for the conversion factor and the proper SI unit.

2.2 DEFINITIONS

The following definitions apply to the discussion of SI units and symbols.

a. Base Unit - A base unit is a unit from which other units are derived. Its characteristics and properties are not defined by any other units.

b. Derived Unit - A derived unit is a unit that is formed by combining one or more base units, supplementary units, and/or other derived units into algebraic relations that link the corresponding quantities.

c. SI Units - SI units are the basic measurement units comprising the International System of Units. These units include the base, supplementary, and derived units along with their decimal multiples and submultiples.

d. Supplementary Unit - A supplementary unit is a dimensionless, derived unit which is used in definitions of other derived units and may be used or omitted for dimensionsal consistency.

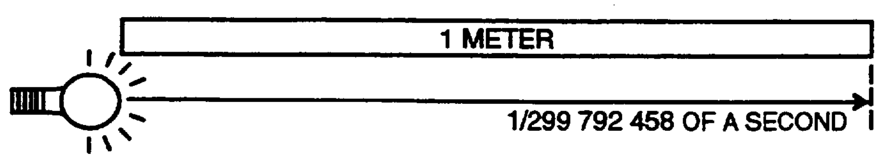
2.3 SI BASE UNITS

In SI there are seven units upon which all derived units are based: meter, kilogram, second, ampere, kelvin, mole, and candela. The base units and their symbols are summarized in table 2-1 and defined, in the following paragraphs, according to the CGPM. Refer to appendix G for the factors used to convert the replaced units to the SI units.

Table 2-1. Base Units

Quantity	SI Unit	SI Symbol	Units To Be Replaced With SI Unit
length	meter	m	inch, foot, yard, mile, rod, parsec, angstrom, chain, fermi, light year, astronomical unit, fathom, micron, mil, pica, point
mass	kilogram	kg	pound, ounce, slug, grain, carat, ton
time	second	s	minute, day, hour, year
electric current	ampere	A	abampere, statampere, gilbert, EMU and ESU of current
temperature	kelvin	K	degree Fahrenheit degree Rankine degree centigrade
amount of substance	mole	mol	---
luminous intensity	candela	cd	candle, candlepower

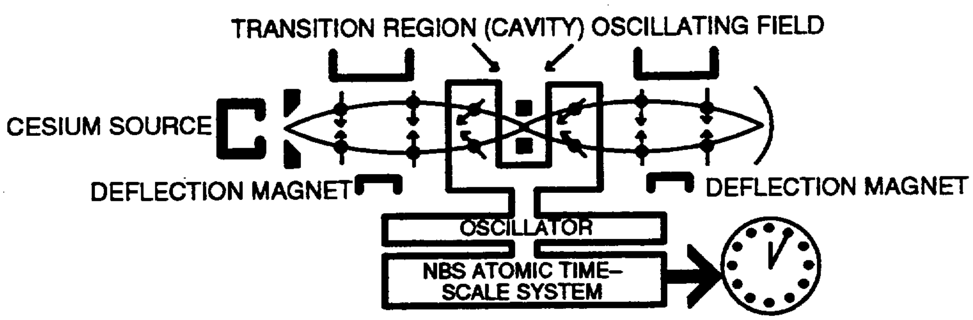
2.3.1 METER. The base unit of length is the meter (m), which is defined as "the length of the path traveled by light in vacuum during a time interval of 1/299 792 458 of a second" [17th CGPM (1983), Resolution 1]. The meter was originally defined by the 1st CGPM with an international prototype constructed so that it would be equal to 1/10 000 000 of the distance from the north pole to the equator along the meridian of the earth running near Dunkirk, France, to Barcelona, Spain. The word "meter" is derived from the Greek word "metron," meaning "a measure."



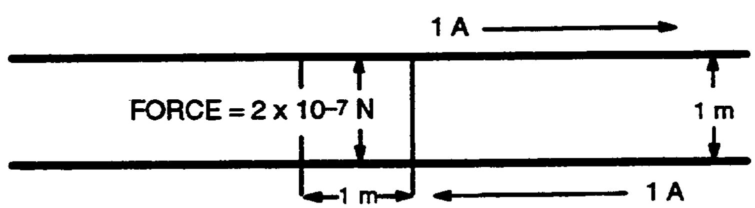
2.3.2 KILOGRAM. The base unit of mass is the kilogram (kg). It is equal to the mass of the international prototype (artifact) of the kilogram" [3rd CGPM (1901)]. The kilogram is the only unit that is still defined by an artifact, which is a cylinder of platinumiridium alloy that is kept by the International Bureau of

Weights and Measures (IBWM) near Paris, France. A duplicate of the artifact is in the custody of NIST and serves as the mass standard for the U.S.

2.3.3 SECOND. The second (s) is the SI base unit of time. It is defined as "the duration of 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" [13th CGPM (1967), Resolution 1]. The following graphic depicts a schematic diagram of an atomic beam "clock" or spectrometer. The atoms whose magnetic moments are "flipped" in the transition region reach the detector. After 9 192 631 770 oscillations occur, the clock shows 1 second passed.



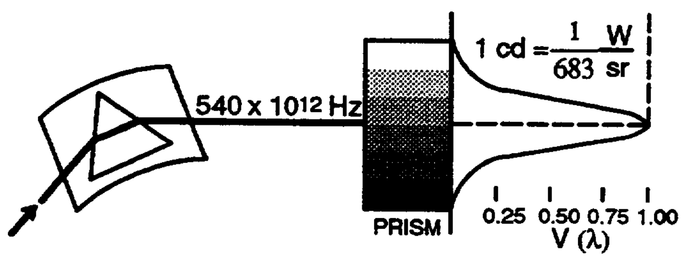
2.3.4 AMPERE. The SI base unit of electric current is the ampere (A). The ampere is defined as "that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per meter of length," if the conductors were straight parallel conductors of infinite length, of negligible circular cross section, and placed 1 meter apart in vacuum [International Committee on Weights and Measures (abbreviated CIPM from official French name Comité International des Poids et Mesures) (1946), Resolution 2, approved by 9th CGPM (1948)].



2.3.5 KELVIN. The base unit of thermodynamic temperature is the kelvin (K), which is "the fraction 1/273.16 of the thermodynamic temperature of the triple point of water" [13th CPGM (1967), Resolution 4]. Note that the degree symbol (°) is not used in the abbreviation for kelvin.

2.3.6 MOLE. The base unit of amount of substance is the mole (mol). One mole is "the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12. 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" [14th CGPM (1971), Resolution 3].

2.3.7 CANDELA. The candela (cd), pronounced can-DELL-a (the final a as in about), is the base unit of luminous intensity. It is defined as "the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 x 10^{12} hertz and that has a radiant intensity in that direction of (1/683) watt per steradian" [16th CGPM (1979), Resolution 3].



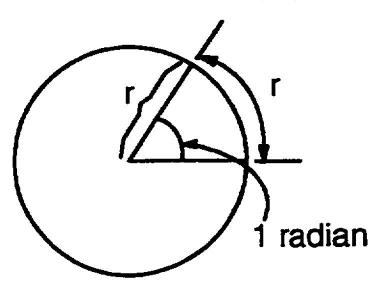
2.4 SI SUPPLEMENTARY UNITS

There are two supplementary SI units: radian and steradian. These units are ratios derived from lengths or areas and are therefore dimensionless. They are used primarily in lighting work and engineering calculations. The supplementary units are summarized in table 2-2.

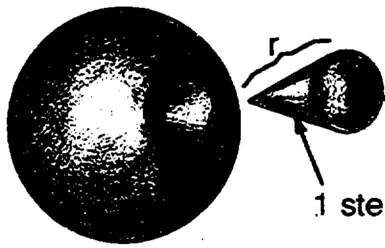
Table 2-2. Supplementary Units

Quantity	SI Unit	SI Symbol	Unit To Be Replaced With SI Unit
plane angle	radian	rad	degree
solid angle	steradian	sr	steradian

2.4.1 RADIAN. A radian (rad) is the plane angle measurement between two radii of a circle which cut off an arc on the circumference equal in length to the radius.



2.4.2 STERADIAN. A steradian (sr) is the solid angle measurement with its vertex in the center of a sphere that cuts off an area of the spherical surface equal to that of a square with sides equal in length to the radius of the sphere.



2.5 SI DERIVED UNITS

Derived units are those units that are formed by combining base units, supplementary units, and other derived units according to algebraic relations linking the corresponding quantities. The symbols are expressed using exponents and mathematical signs for multiplication and division (e.g., m/s or $m{\cdot}s^{-1}$). Derived units are also depicted in terms of other derived units (e.g., $J = N{\cdot}m$). The derived units are detailed in the following paragraphs and summarized in table 2-3. Refer to appendix G for the factors used to convert units to SI units.

2.5.1 HERTZ. The hertz (Hz) is the SI unit for frequency, which is the number of times that a periodic phenomenon occurs during a period of 1 second.

2.5.2 NEWTON. The SI unit for force is the newton (N). The newton is defined as the force that is applied to a body or object, which has a mass of 1 kilogram, that gives the object a linear acceleration of 1 meter per second squared (m/s^2).

2.5.3 PASCAL. The pascal (Pa), pronounced PASS-cal (rhymes with rascal), is the SI unit for pressure or stress. The pascal is equal to a 1-newton force applied over an area of 1 square meter (m^2).

2.5.4 JOULE. The SI unit for energy, work, or a quantity of heat is the joule (J), pronounced JOOL (rhymes with tool). The joule is defined as the energy expended during the application of a 1-newton force that causes a body to rotate or move about a point of rotation and in the direction of the force a distance of 1 meter.

2.5.5 WATT. The watt (W) is the SI unit for power, which is the production of 1 joule of energy during 1 second.

Table 2-3. Derived SI Units With Special Names

Quantity	SI Unit	SI Symbol	Formula	Units To Be Replaced With SI Unit
frequency	hertz	Hz	1/s	cycles per second
force	newton	N	$kg \cdot m/s^2$	dyne, pound-force (lb_f), poundal (pdl), kilopound (kip) (1000 lb_f), ton-force (2000 lb_f), kilogram-force (kg_f), kilopond (kp)
pressure/stress	pascal	Pa	N/m^2	pound per square inch (psi) or square feet (psf), kip per square inch (ksi), bar, torr, atmosphere, inch or millimeter of mercury (inHg, mmHg), inch of water (inH_2O)
energy/work/ quantity of heat	joule	J	$N \cdot m$	British thermal unit (Btu), erg, calorie, electronvolt, foot-pound, kilowatthour, therm, watt-hour, watt-second, ton
power/heat flow rate	watt	W	J/s	Btu per hour (Btu/hr), calorie per minute or second, horsepower, foot-pound per hour or per minute or per second, ton of refrigeration
quantity of electricity/ electric charge	coulomb	C	$A \cdot s$	abcoulomb, ampere hour, faraday, statcoulomb
electric potential	volt	V	W/A	abvolt, statvolt, EMU and ESU of electric potential
capacitance	farad	F	C/V	abfarad, statfarad, EMU and ESU of capacitance

Table 2-3. Derived SI Units With Special Names (cont)

Quantity	SI Unit	SI Symbol	Formula	Units To Be Replaced With SI Unit
resistance	ohm	Ω	V/A	abohm, statohm, EMU and ESU of resistance
conductance	siemens	S	A/s	mho, abmho, statmho, EMU and ESU of resistance
magnetic flux	weber	Wb	V·s	maxwell, unit pole
magnetic flux density	tesla	T	Wb/m^2	gamma, gauss
inductance	henry	H	Wb/A	abhenry, stathenry, EMU and ESU of inductance
temperature	degree Celsius	°C	K - 273.15	degree Fahrenheit, degree Rankine degree centigrade
luminous flux	lumen	lm	cd·sr	---
illuminance	lux	lx	lm/m^2	footcandle, lumen per square foot
activity (of a radionuclide)	becquerel	Bq	1/s	curie
absorbed dose	gray	Gy	J/kg	rad
dose equivalent	sievert	Sv	J/kg	rem

2.5.6 COULOMB. The coulomb (C) (pronounced KOO-lomm), the SI unit for electric charge, is the quantity of electricity transported by a current of 1 ampere during 1 second.

2.5.7 VOLT. The SI unit for electric potential difference and electromotive force is the volt (V). The volt is defined as the difference of electric potential between two points of a conductor carrying a constant current of 1 ampere when the power dissipated between these points is equal to 1 watt.

2.5.8 FARAD. The farad (F), the derived unit for electric capacitance, is the capacitance between the two plates of which there appears a potential difference of 1 volt when it is charged by a quantity of electricity equal to 1 coulomb.

2.5.9 OHM. The ohm (Ω) is the SI unit for electric resistance. An ohm is the electric resistance between two points of a conductor with a constant potential difference of 1 volt applied between these two points producing a current of 1 ampere in the conductor (this conductor not being the source of any electromotive force).

2.5.10 SIEMENS. The unit for electrical conductance, the siemens (S) [pronounced SEE-mens (same as seamen's)], is the electric conductance of a conductor across which an electric potential difference of 1 volt produces a current of 1 ampere.

2.5.11 WEBER. The weber (Wb), the unit used for the flux of magnetic induction, is the magnetic flux produced in a closed circuit equal to an electromotive force of 1 volt as it is reduced to zero at a uniform rate in 1 second.

2.5.12 TESLA. The SI unit tesla (T) represents the magnetic flux density or magnetic induction that is given by a magnetic flux of 1 weber over an area of 1 square meter.

2.5.13 HENRY. The henry (H) is the unit for electric inductance, which is the inductance of a closed circuit in which is produced an electromotive force of 1 volt when the electric current in the circuit varies at a uniform rate of 1 ampere each second.

2.5.14 DEGREE CELSIUS. The degree Celsius (°C) is a derived unit for temperature that is often used in everyday applications. One degree change in temperature is the same in both the Celsius and kelvin scales. Celsius temperature (symbol t) is defined by the following equation, where, by definition, T is the thermodynamic temperature (in kelvin) and $T_o = 273.15$ K.

$$t = T - T_o$$

The term centigrade, the former name for the Celsius scale, is obsolete and shall not be used. When extreme precision with temperature measurements is required, the International Temperature Scale shall be recognized (refer to NIST Technical Note 1265).

2.5.15 LUMEN. The SI unit for luminous flux is the lumen (lm). A lumen is defined as the luminous flux emitted in a solid angle of 1 steradian by a point source that has a uniform intensity of 1 candela.

2.5.16 LUX. The lux (lx), the SI unit for illuminance, is the illuminance produced by a luminous flux of 1 lumen uniformly distributed over a surface area of 1 square meter.

2.5.17 SPECIAL DERIVED SI UNITS. The following paragraphs describe three special derived units used for radioactivity: the becquerel, the gray, and the sievert.

2.5.17.1 Becquerel. The becquerel (Bq) is the derived SI unit for activity, particularly that of a radionuclide. A becquerel is the activity decaying at the rate of 1 spontaneous nuclear transition per second.

2.5.17.2 Gray. The unit gray (Gy) is the absorbed dose of radiation when the ionizing radiation imparts to matter a quantity of energy equal to 1 joule per kilogram. The gray is also used for the ionizing radiation in quantities of specific energy imparted, kerma, and absorbed dose index.

2.5.17.3 Sievert. A sievert (Sv) is the dose equivalent when the absorbed dose of ionizing radiation (in terms of the unit gray) is multiplied by a dimensionless quality factor Q and the product of any other multiplying factors N, stipulated by the International Commission on Radiological Protection, and is equal to 1 joule per kilogram.

2.6 OTHER DERIVED QUANTITIES

It is not practical to list every possible derived unit in terms of SI units. Derived units are easily obtained by applying the conversion factors to the non-SI units. For example, converting a rate of inches per second to centimeters per second requires only to apply the conversion factor relating inches to centimeters. Table 2-4 lists some of the more common derived quantities and their units in SI. Refer to section VI for information on conversion practices and to appendix G for conversion factors.

2.7 OTHER UNITS IN USE WITH SI

2.7.1 UNITS RETAINED FOR PRACTICALITY. Because of unit conventions already established in daily life or specialized fields of work or study, SI units may not always be the most practical choice. The following paragraphs explain the non-SI units that are acceptable alternatives to the SI units and are summarized in table 2-5. Use of these terms shall be limited to the situations described in this section so as to minimize the use of units from other systems and to preserve the advantages of SI as a coherent system. See section XI for a discussion on particular applications.

Table 2-4. Other Derived Units

Quantity	Definition	Formula
wave number	1 per meter	m^{-1}
current density	ampere per square meter	A/m^2
magnetic field strength	ampere per meter	A/m
concentration (amount of a substance)	mole per cubic meter	mol/m^3
specific volume	cubic meter per kilogram	m^3/kg
luminance	candela per square meter	cd/m^2
dynamic viscosity	pascal second	Pa·s
moment of force	newton meter	N·m
surface tension	newton per meter	N/m
heat flux density, irradiance	watt per square meter	W/m^2
heat capacity, entropy	joule per kelvin	J/K
specific heat capacity, specific entropy	joule per kilogram kelvin	J/(kg·K)
specific energy	joule per kilogram	J/kg
thermal conductivity	watt per meter kelvin	W/(m·K)
energy density	joule per cubic meter	J/m^3
electric field strength	volt per meter	V/m
electric charge density	coulomb per cubic meter	C/m^3
electric flux density	coulomb per square meter	C/m^2
permittivity	farad per meter	F/m
permeability	henry per meter	H/m
molar energy	joule per mole	J/mol
molar entropy, molar heat capacity	joule per mole kelvin	J/(mol·K)

Table 2-5. Other Units in Use With SI

Quantity	Unit	Symbol	Definition
time	minute hour day	min h d	1 min = 60 s 1 h = 3600 s 1 d = 86 400 s
plane angle	degree minute second	° ′ ″	1° = (π/180) rad 1′ = (1/60)° = (π/10 800) rad 1″ = (1/60)′ = (π/648 000) rad
area	hectare	ha	1 ha = 1 hm^2 = 10^4 m^2
volume	liter	L*	1 L = 1 dm^3 = 10^{-3} m^3
mass	megagram	Mg	1 Mg = 10^6 g

* The CGPM has also approved the lower case l as an alternate symbol for liter. But, since l may be easily confused with the number 1, only the upper case L is recommended for use in the U.S. See section V for symbols in international usage.

2.7.1.1 Time. The second is the preferred unit for time, particularly for technical calculations, and should be used when practical. Where time is in relation to life customs or calendar cycles, other units may be necessary, like minute, hour, day, week, etc. For example, vehicle speed is in terms of kilometers per hour. Note that the symbol for hour is h, not hr.

2.7.1.2 Plane Angle. The SI unit for plane angle is radian. The use of radians may not be as convenient or practical as the degree (°). Decimal submultiples of a degree (e.g., tenths, hundredths, etc.) shall be used instead of minutes (′) and seconds (″), except in the field of cartography and other specialized areas.

2.7.1.3 Area. In SI, the preferred unit for area is the square meter (m^2). It may be necessary to describe very large or very small areas in terms of another multiple or submultiple of meters. See 11.2.2 for particular applications and the appropriate multiple.

2.7.1.4 Volume. The cubic meter (m^3) is the preferred volume unit in SI. A submultiple of the cubic meter, such as cubic centimeter (cm^3) and cubic decimeter (dm^3), may be more convenient. Instead of the cubic decimeter, the liter (L) may be used but only for volumetric capacity, dry measure, or measures of fluids (liquids and gases). Only the prefixes milli- and micro- should be used with liter (e.g., milliliter, microliter). Use the cubic meter (m^3), and not the liter, for precision measurements. See 11.2.3 for particular applications for volume units.

2.7.1.5 Mass. The SI unit for mass is kilogram. The term "ton" should not be used so as to avoid confusion between long ton (2240 pounds), short ton (2000 pounds), and metric ton (1000 kg). Large masses should be expressed in megagram (Mg), which is equivalent to the metric ton. The metric ton (without a prefix) should only be used in commercial applications. See 11.2.4 for specific applications for mass units.

2.7.1.6 Weight. When using non-SI units, the distinction has to be made as to whether the term pound denotes mass (lb) or force (lb_f). In SI, there are distinct units for mass and force, the kilogram and the newton, respectively. The term "weight" can mean either "mass" or "force," depending on the application. In nontechnical situations, weight usually means mass or the amount of a substance regardless of the effects of gravity. The mass unit of kilogram is used to indicate such measurements as a person's weight, a quantity of a food product, or an amount of construction material (e.g., concrete, rebar, etc.). In scientific and technological situations, the term "weight" usually indicates an applied force that gives a body an acceleration, in the direction of the earth's center, equivalent to the local acceleration of free fall or acceleration due to gravity.

2.7.1.7 Load/Force. Like the term weight, the term load can mean either mass or force. If the load is acting on a mass or body as a result of the vertical (downward) force of gravity, it can be expressed in kilograms. All other loads are expressed in newtons.

2.7.2 UNITS TEMPORARILY IN USE WITH SI. In some cases, non-SI units currently used in certain areas continue to be used on a temporary basis and shall be limited to the situations summarized in table 2-6.

2.7.2.1 Energy. The SI unit for energy is the joule. The use of the kilowatthour (kW·h) may be used but only with respect to electrical energy and shall not be introduced into any new applications. See 11.2.13 for further discussion on the applications for energy units.

2.7.2.2 Pressure and Stress. The SI unit of pressure is pascal. Units using the kilogram-force (kg_f) unit shall not be used (e.g., kg_f/m^2). Although its use is strongly discouraged, the unit bar (bar) may be used. The millibar (mbar) remains in use temporarily in the meteorological profession, but reporting to the public should be in kilopascals (kPa). See 11.2.11 for additional discussion and applications for various pressure units.

Table 2-6. Units Temporarily in Use With SI

Quantity	SI Unit	Temporary Unit	Symbol	Definition
cross-sectional area	square meter (m^2)	barn	b	$= 10^{-28}\ m^2 = 100\ fm^2$
pressure	pascal (Pa)	bar	bar	$= 10^5$ Pa = 0.1 MPa
activity (of a radionuclide)	becquerel (Bq)	curie	Ci	$= 3.7 \times 10^{10}$ Bq
exposure (X and gamma rays)	coulomb per kilogram (C/kg)	roentgen	R	$= 2.58 \times 10^{-4}$ C/kg
absorbed dose	gray (Gy)	rad	rd	= 0.01 Gy = 10 mGy
dose equivalent	sievert (Sv)	rem	rem	= 0.01 Sv = 10 mSv

2.7.3 UNITS RETAINED FOR SPECIALIZED FIELDS. Table 2-7 shows units that are retained for use in specialized fields.

Table 2-7. Units Retained for Specialized Fields

Quantity	Unit	Symbol	Definition
energy	electronvolt	eV	$= 1.602\ 192\ 7 \times 10^{-19}$ J
mass (of an atom)	atomic mass unit	u	$= 1.660\ 565\ 5 \times 10^{-27}$ kg
length	astronomic unit	AU *	$= 1.495\ 979 \times 10^{11}$ m
length	parsec	pc	$= 3.085\ 678 \times 10^{16}$ m

* UA in French, no international symbol

2.8 DISCONTINUED AND MISCELLANEOUS UNITS TO AVOID

2.8.1 CENTIMETER-GRAM-SECOND (CGS) UNITS. Units that are based on the centimeter-gram-second (cgs) version of the metric system are discontinued and shall not be used. The list of these units includes the erg, dyne, gal, poise, stokes, stilb, lambert, phot, gauss, oersted, maxwell, gilbert, biot, and electrostatic and electromagnetic units (i.e., ESU and EMU) of capacitance, of current, of electric potential, of inductance, and of resistance. Refer to appendix G for factors used to convert discontinued units to proper SI units.

2.8.2 UNIT NAMES WITH NON-SI PREFIXES. Any unit using non-SI prefixes, such as ab- and stat- (e.g., abohm, statampere, etc.), shall be avoided. Refer to appendix G for the appropriate conversion factors.

2.8.3 SPECIAL NAMES. Metric units and submultiples that exhibit special names not reflecting correct SI prefixes or base units shall not be used. A list of these units includes the angstrom, fermi, are, micron, millimicron, gamma, mho, γ, λ, candle, and candlepower. Refer to appendix G for the appropriate unit names and conversion factors to be used instead.

2.8.4 MISCELLANEOUS UNITS. There are other units previously used that are not to be used in SI. Some of these units include the calorie, grade, kilogram-force (kg_f), langley, torr, metric carat, metric horsepower, millimeter of mercury, millimeter (centimeter or meter) of water, standard atmosphere, and technical atmosphere. Refer to appendix G for the conversion factors for these and other miscellaneous units.

2.9 NOMINAL DIMENSIONS

Currently, there are no equivalent SI dimensions for many commonly used nominal dimensions (e.g., 2 by 4). Since a nominal dimension is not an exact measure of an item's dimension, several situations may occur: (1) the "name" may remain the same with the actual dimension soft converted; (2) a new metric "name" may replace the old nominal designation with no physical change to the item; or (3) the item may eventually be redesigned to metric dimensions and carry a new "name." Until it is determined what designations some items will carry, it is recommended that the commonly used nominal designation be referred to along with the soft-converted dimensions of the item to avoid confusion. Refer to 9.5.3 for guidelines in specifying nominal sizes in technical writing situations.

2.10 DIMENSIONLESS QUANTITIES - RATIOS AND INDEXES

Many quantities are dimensionless and do not reflect a particular unit. These quantities are usually ratios or indexes (e.g., permeability, refractory index, etc.) and are represented by pure numbers resulting from ratios between two quantities of the same units [e.g., meter per meter (m/m)], which may be expressed by the number 1. These numbers are the same regardless of the measurement system used. Other examples of dimensionless quantities unchanged for SI are relative humidity (RH), specific gravity, decibel (dB), and per hydrogen (pH). Dimensionless expressions for certain decimal fractions, like "percent," "parts per thousand,"

and "parts per million" are commonly used, but may be misunderstood (see 4.4.3). It is preferred that proper exponential forms of these fractions be used.

Examples:	60×10^{-2}	not:	60 percent
	45.3×10^{-3}	not:	45.3 parts per thousand
	1.2×10^{-6}	not:	1.2 parts per million

SECTION III

SI PREFIXES AND DECIMAL SUBMULTIPLES

This section describes the SI prefixes and provides discussion on the proper selection and attachment of the prefixes to the SI units.

3.1 DEFINITIONS

The following definitions apply to the topic of SI prefixes.

a. Multiple - A multiple is a number that is larger than a base number. The multiple is obtained by multiplying the base number by a specific quantity or factor. Since SI is a decimal system, the specific factor is 10.

b. SI Prefix - An SI prefix is any of the 20 two-syllable prefixes approved to be attached to the beginning of an SI unit to show how much larger or smaller a value is compared to the base unit.

c. Submultiple - A submultiple is a fraction or multiple of a base (or derived) unit that is obtained by multiplying or dividing by a factor that is an exact divisor of the base unit.

3.2 USE OF A PREFIX

Prefixes are added to SI base, supplementary, and derived units to indicate how much larger or smaller a value is compared to the base unit. Each prefix represents a specific magnitude as a power of 10 (e.g., 10^3, 10^{-3}, etc.) times that of the base unit. There are 20 prefixes that can be used to form decimal multiples and submultiples. Each prefix also has a one- or two-character symbol used with a unit symbol. Table 3-1 lists all of the SI prefixes and their symbols. Prefixes not listed in the table shall not be used. Table 3-1 also lists the proper pronunciations for each prefix. Note that in every case, the first syllable of each prefix is the syllable stressed. When the prefix is attached to a unit name, the first syllable remains the syllable with the greatest stress, never the second syllable. For example, the unit "kilometer" is pronounced "KILL-oh-mee-ter," and not "kill-AH-ma-ter." Refer to section IV for rules on style and usage of applying prefixes and prefix symbols.

Table 3-1. SI Multiples and Prefixes

Prefix	Pronunciation	Symbol	Multiple/Submultiple
yotta	yot´ tă	Y	1 000 000 000 000 000 000 000 000 $= 10^{24}$
zetta	zet´ tă	Z	1 000 000 000 000 000 000 000 $= 10^{21}$
exa	ex´ ă	E	1 000 000 000 000 000 000 $= 10^{18}$
peta	pet´ ă	P	1 000 000 000 000 000 $= 10^{15}$
tera	ter´ ă	T	1 000 000 000 000 $= 10^{12}$
giga	jig´ ă	G	1 000 000 000 $= 10^{9}$
mega	meg´ ă	M	1 000 000 $= 10^{6}$
kilo	kil´ ō	k	1 000 $= 10^{3}$
hecto	hek´ tō	h	100 $= 10^{2}$
deka	dek´ ă	da	10 $= 10^{1}$
			Base Unit 1 $= 10^{0}$
deci	des´ i	d	0.1 $= 10^{-1}$
centi	sen´ ti	c	0.01 $= 10^{-2}$
milli	mil´ i	m	0.001 $= 10^{-3}$
micro	mi´ kro	µ	0.000 001 $= 10^{-6}$
nano	nan´ ō	n	0.000 000 001 $= 10^{-9}$
pico	pi´ ko	p	0.000 000 000 001 $= 10^{-12}$
femto	fem´ tō	f	0.000 000 000 000 001 $= 10^{-15}$
atto	at´ tō	a	0.000 000 000 000 000 001 $= 10^{-18}$
zepto	zep´ tō	z	0.000 000 000 000 000 000 001 $= 10^{-21}$
yocto	yok´ tō	y	0.000 000 000 000 000 000 000 001 $= 10^{-24}$

3.3 ATTACHMENT OF PREFIXES

Prefixes are never used by themselves to represent unit names. A prefix is attached directly to the unit name without a space or hyphen between the prefix and the base unit. Usually, no changes occur to the prefix or the unit name before combining.

Examples:	megawatt	not:	mega watt or mega-watt
	milliohm	not:	milli ohm or milli-ohm
	kilogram	not:	kilo

When the prefix ends with a vowel and the unit name begins with a vowel, both vowels are retained and pronounced, as shown in the previous examples. The only exception to this rule is that the last vowel of the prefix is dropped to form the following three unit names:

megohm	not:	megaohm
kilohm	not:	kiloohm
hectare	not:	hectoare

Only one prefix may be attached to a base unit name at any one time. Multiple prefixes are not permitted.

Examples:	nanometer (nm)	not:	micromillimeter (μmm)
	picofarad (pF)	not:	micromicrofarad (μμF)

If values are outside the range covered by prefixes (i.e., greater than 10^{24} and less than 10^{-24}), use powers of ten with the base unit and no prefix.

Example:	135.6×10^{-27} seconds	not:	135.6 milliyoctoseconds or 135.6×10^{-3} yoctoseconds

3.4 SELECTION OF THE PROPER PREFIX

When used properly, prefixes indicate orders of magnitude, eliminate nonsignificant digits and leading zeros in decimal fractions, and provide convenient alternatives to the power-of-ten notation.

The proper prefix should be selected so that the value preceding the unit name or symbol is between 1 and 1000. The prefix is attached in its entirety to the beginning of the unit name.

Example: Write "5 000 000 newtons" with the proper prefix.

a.	Rewrite "5 000 000" so the number falls between 1 and 1000 multiplied by a power of 10:	5.0×10^6
b.	From table 3-1, select the prefix that means 10^6:	mega
c.	Attach the prefix directly to the beginning of the unit name:	meganewton
	Answer:	5.0 meganewtons

Example: Write "0.000 000 075 second" with the proper prefix.

a.	Rewrite "0.000 000 075" so the number falls between 1 and 1000 multiplied by a power of 10:	75.0×10^{-9}
b.	From table 3-1, select the prefix that means 10^{-9}:	nano
c.	Attach the prefix directly to the beginning of the unit name:	nanosecond
	Answer:	75.0 nanoseconds

In tables of values of the same quantity (e.g., lengths, pressures, etc.) or in a discussion of such values within a given context, it is preferred that the same unit multiple be used throughout even though some values may end up outside the range 1 to 1000. In some cases, standard conventions for measurements dictate the magnitude of the unit used, such as using only millimeters in engineering drawings, which results in numbers much greater than 1000. Otherwise, use the prefix that is the most prevalent in the particular table.

Example:

Length (millimeters)	Pressure (kilopascals)
250	20.70
25 325	13.65
1 060	0.02
460	0.03
700	1.84

3.5 PREFIX SYMBOLS

Prefix symbols are either upper case or lower case as shown in table 3-1. Prefix symbols are upper case for those representing magnitudes greater than 1 000 000. The prefixes representing magnitudes less than 1 000 000 are in lower case. Attachment of prefix symbols follows the same rules as the attachment of the whole prefix (see 3.3).

3.6 PREFIXES WITH THE UNIT OF MASS

In SI, the base unit kilogram already contains a prefix. Instead of adding another prefix to "kilogram," the mass unit multiples and submultiples are formed by removing the prefix kilo and adding the correct prefix to "gram" (g).

Example: Write "1200 kilograms" with the proper prefix.

a. Convert the prefix "kilo" to its numerical equivalence:	1000
b. Multiply "1 200" by the answer in a.:	1 200 000
c. Rewrite "1 200 000" so the number falls between 1 and 1000 multiplied by a power of 10:	1.2×10^6
d. From table 3-1, select the prefix that means 10^6:	mega
e. Attach the prefix to the beginning of "gram":	megagram
Answer:	1.2 megagrams

3.7 COMMONLY USED PREFIXES

For everyday usage, the most commonly used prefixes are kilo (10^3), centi (10^{-2}), and milli (10^{-3}). For example, mileage is in kilometers per hour, nutritional information of food packaging is in grams and milligrams, and body measurements are in centimeters. In the scientific and technical arenas, additional prefixes most often used include giga (10^9), mega (10^6), micro (10^{-6}), and nano (10^{-9}), as in gigawatt, megapascal, micrometer, and nanosecond, respectively.

Generally, the prefixes centi (10^{-2}), deci (10^{-1}), deka (10^1), and hecto (10^2) are avoided in technical writing except in describing areas (e.g., square centimeters) and volumes (e.g., cubic decimeters), human characteristics (e.g., body measurements, clothing sizes, etc.), and furnishings. Use of these prefixes may result in excessive use of decimals.

SECTION IV

STYLE AND USAGE

4.1 INTRODUCTION

The usage of units and their symbols was determined by international agreement. Attention must be given to the proper use of the symbols to maintain quality communications within the U.S. and in international business. This section provides reading and writing rules for SI units.

Even though several options are available to express some of the rules, for consistency, efforts should be made to select and use only one method throughout an entire document, drawing, or project. All rules explained in sections II and III apply when implementing the practices in this section.

4.2 UNIT NAMES AND SYMBOLS

4.2.1 CAPITALIZATION. A unit name, even if it is named after a person, is treated like a common noun when it is spelled out whereby the unit is capitalized only when it is the first word in the sentence or when it appears with other capitalized groups of words (e.g., part of a title). An exception to this rule is that "Celsius" in the unit "degree Celsius" is always capitalized because the unit is "degree" and "Celsius" is only a modifier for the unit name.

Examples: Meter is the unit for length.
The unit for length is meter.
See the figure "Learning About Meters."
NOTE: ALL DIMENSIONS ARE IN MILLIMETERS.

When the unit name is derived from a proper name, the first letter of the symbol, not the name, is capitalized. All other letter unit symbols are always in the lower case except for the unit "liter," whose symbol is the "L," and symbols for Greek letters.

Examples:

Symbol	Unit name
Pa	pascal (after B. Pascal)
W	watt (after J. Watt)
cd	candela
L	liter

4.2.2 PLURALIZATION. Unit names are pluralized according to standard rules of English grammar. For all numbers greater than 1.0, use a plural unit name. For all decimal numbers less than 1.0, use the singular form of the unit name.

Examples:	0.5 henry, 3.2 henries 1.0 meter, 10.0 meters

Three irregular plurals whose unit names are the same in singular and plural forms are lux, siemens, and hertz.

Examples:	0.02 lux, 1.02 lux 0.75 siemens, 7.75 siemens 1 hertz, 15 hertz

Unit symbols are the same whether they are singular or plural. Never add an s to make a symbol plural; it may be mistaken for the symbol for second.

Example:	The crane capacity is 3000 kg.	not:	The crane capacity is 3000 kgs.

4.2.3 ABBREVIATIONS. Each unit has a designated abbreviation or symbol. The symbols for the basic, supplementary, and derived units are in section II with each unit's description and listed in tables 2-1 through 2-7. No other abbreviations shall be used except for situations that require the use of limited character sets (information processing) where computers are used to communicate with other computers. (See section X.)

Special names and shortened forms of the unit names that are not the designated symbols shall not be used (see 2.8.3). For example, only the symbol "A" is to be used for the unit ampere, never "amp."

A unit symbol is never followed with a period unless it is part of the normal sentence punctuation.

Examples:	The satellite orbit is at 140 km above the earth. or: The altitude of the satellite's orbit is 140 km.	not:	The satellite orbit is at 140 km. above the earth.

4.2.4 APPEARANCE. Unit symbols shall be printed in an upright, nonitalic, Roman-style type regardless of the surrounding text type style.

Example:	*The resistance was* 60 Ω. The current changed from 300 mA to 600 mA.		

Write out the unit name if there is no preceding number or value. A unit symbol shall not be used alone. It is preferred that unit symbols instead of unit names be used with numbers. For example, "60 kg" is preferred to "60 kilograms."

Example:	The mass was measured in kilograms.	not:	The mass was measured in kg.

4.2.5 GREEK SYMBOLS. The unit for resistance is the ohm, abbreviated with the symbol Ω, the Greek letter omega. The prefix for one millionth (10^{-6}) is micro, which is also abbreviated by a Greek letter, mu (μ). When typing the Greek letter is not possible, the unit name should be spelled out in full. The Greek letter name never replaces the symbol. See section X for acceptable symbols and abbreviations to use when Greek letters are not available in keyboard applications.

Examples:	The resistance measured was 1 ohm. or: The resistance measured was 1 Ω.	not:	The resistance measured was 1 omega.
	The paint thickness should be 3 micrometers. or: The paint thickness should be 3 μm.	not:	The paint thickness should be 3 mum.

4.2.6 ATTACHMENTS. Letters are never attached to unit symbols to give additional information about a quantity. Instead, the clarification may be spelled out in parentheses following unit symbol.

Examples:	MW (electrical power)	not:	MWe
	V (ac)	not:	VAC or Vac
	V (dc)	not:	VDC or Vdc
	kJ (thermal energy)	not:	kJt
	kPa (gage)	not:	kPag
	kPa (absolute)	not:	kPaa

In some cases, there are no equivalent abbreviations in SI for inch-pound units (e.g., psia, psig). The same meaning may be conveyed by rephrasing the sentence as shown in the following examples:

Examples:	"... at a gage pressure of 10 kPa ..."	not:	... at 10 kPag ...
	"... at an absolute pressure of 10 kPa ..."	not:	... at 10 kPaa ...

4.3 COMPOUND UNIT NAMES AND SYMBOLS

4.3.1 PRODUCTS. The multiplication of two or more unit names is indicated by a space (preferred) or hyphen between the unit names. An exception to this rule is "watthour" (no space, no hyphen).

Examples:	newton meter or newton-meter	not:	newtonmeter
	pascal second or pascal-second	not:	pascalsecond

A raised dot (·) is used to show a product for unit symbols. For computers and other keyboard (typewriter) applications that are not capable of raising a dot, a dot on the line (period) is acceptable (see section X).

Examples: N·m for newton meter
Pa·s for pascal second

4.3.2 QUOTIENTS. Units formed by dividing one or more units with other units are written by spelling out the entire unit. The division symbol, the slant (/), which is spoken as "per," is always spelled out when the unit names are spelled out. The abbreviation "p" for "per" shall not be used. The slant is used only with unit symbols. Combinations of full unit names and symbols are not correct.

Examples:	watt per square meter	not:	watt/square meter
	km/h	not:	kph or kmph

A slant (/), a horizontal line, or negative exponents are used to indicate quotients when using unit symbols. Do not use more than one slant in the expression unless parentheses are inserted for clarity.

Examples:	m/s or $m \cdot s^{-1}$ or $\frac{m}{s}$		
	J/(mol·K) or $J \cdot mol^{-1} \cdot K^{-1}$ or (J/mol)/K	not:	J/mol/K

Ratios of two like quantities (e.g., length) should be expressed in the same units with the same prefixes. Exceptions to this are in those cases where the unit is defined by industry standards. See section XI for specific situations using ratios.

Examples:	0.06 m/m	not:	60 mm/m
	0.02 m^2/m^2	not:	20 000 mm^2/m^2

4.3.3 POWERS. The modifiers "squared" and "cubed" are placed before the unit name for area and volume units.

Examples: The volume is 1 cubic meter.
The area covered was 30 square millimeters.
The mass per unit area is in kilograms per square meter.

These modifiers are placed after the unit name for all other units. Symbols should be used whenever possible to avoid confusion.

Example: The car is accelerating at 10 meters per second squared.

Exponents attached to a symbol with a prefix are understood to raise the prefix to the same power. The exponent is shown immediately following the unit symbol without a space between.

Examples:	1 $cm^3 = (1 \times 10^{-2}\ m)^3 = 10^{-6}\ m^3$	not:	$(1 \times 10^{-2})\ m^3$
	$7.0 \times 10^{-2}\ m^3$	not:	$7.0 \times 10^{-2}\ m\ ^3$

4.3.4 FORMULAS. Expressions using symbols for mathematical functions (e.g., +, -, x, etc.) are separated on both sides by spaces.

Example:	3.0 x 10^3 kg	not:	3.0x10^3 kg

4.3.5 COMBINATIONS OF UNIT NAMES AND SYMBOLS. Do not mix unit names and symbol names in the same expression. Either spell out the entire unit or use only symbols.

Examples:	J/kg or J·kg^{-1}	not:	joules/kg or J/kilogram or joules·kg^{-1} or J·$kilogram^{-1}$ or joules·$kilogram^{-1}$
	joules per kilogram	not:	joules/kilogram

4.4 NUMBERS

4.4.1 APPEARANCE. A number is never spelled out if it is a measurement value. Fractions are never used. Instead, the number shall be shown as a decimal. The terms like "half," "third," and "quarter" are acceptable when spoken but the number must always appear as a decimal when written.

Examples:	4 seconds	not:	four seconds
	0.5 millimeter	not:	½ millimeter or one half millimeter

4.4.2 DECIMAL MARKERS. A dot or period on the line is used to indicate a decimal. Numbers less than 1.0 are always written with a zero preceding the period.

Examples:	0.123	not:	.123
	-0.45	not:	-.45

4.4.3 NUMBERS GREATER THAN 1000 AND LESS THAN 0.001. A small space is used to separate each grouping of three numbers, instead of using a comma, to indicate thousands, millions, etc., and thousandths, millionths, etc. Note that this practice does not apply to dollar amounts.

Examples:	4 000 000	not:	4,000,000
	0.000 004	not:	0.000,004
	67 890.098 76	not:	67,890.098,76

A space is not necessary for four-digit numbers (on either side of the decimal place) unless the number is in a table with other numbers of more than four digits. It is not necessary to leave spaces in applications where commas are not normally used, as in some engineering drawings and financial statements.

Example:

15 890	458	8436	0.6532	2.699 3
56 548	874	125	8.610	1.883 25
4 002	18	7233	10.479	0.717 11

Words meaning the same as equivalent prefixes (e.g., billion, million, etc.) shall not be used. Names of numbers one billion and larger do not represent the same quantities worldwide. Roman numerals are often used with inch-pound units (e.g., as in MCF for thousands of cubic feet, MCM for thousands of circular mils, MM for millions, etc.) and shall not be used with SI units since they are symbols for other units and prefixes in SI.

Example:	1 megameter	not:	1 million meters

4.5 NUMBER AND UNIT SYMBOL COMBINATIONS

When a number is followed immediately by a unit symbol, there must be a space left between the numerical value and the unit symbol except for plane angle measurements (designated with the degree-minute-second symbology).

Examples:	852 kg	not:	852kg
	369.5 mm	not:	369.5mm
	20°53′21″	not:	20 ° 53 ′ 21″

Sources differ in recommendations about representing the number and symbol in the unit "degree Celsius." ANSI/IEEE Std 268 and the Government Printing Office (GPO) Style Manual dictate that the "degree-Celsius" symbol (°C) should be separated from the temperature value by a space (e.g., 10 °C). But, according to ASTM E380, there should be no space between the number and the symbol. For the purposes of consistency, it is recommended that a space be used before the symbol in all situations except in drawings. For drawings only, where space is limited for notation, the degree-Celsius (°) symbol may be written immediately following the value without a space. In all situations, the degree symbol must stay attached to the letter C.

Examples:	240 °C	not:	240° C
	240°C (drawings only)	not:	240 ° C

Each value shall be shown with a unit name or symbol. This refers particularly to ranges and dimensions, as shown in the following example:

Examples:	20 m by 80 m	not:	20 by 80 m
	25 mm by 100 mm	not:	25 by 100 mm
	600 kPa to 800 kPa	not:	600 to 800 kPa
	23 °C ± 2 °C or (23 ± 2) °C	not:	23 ± 2 °C
	60 % ± 3 % or (60 ± 3) %	not:	60 ± 3 %
	300 x (1 ± 3 %) V	not:	300 V ± 3 % (V and % do not add)

4.6 COMPOUND EXPRESSIONS

4.6.1 MULTIPLE UNITS. Measurements are described using only one form of a base unit. Multiple unit names are not used to define one quantity. Do not mix symbols of different magnitudes for the same quantity in one expression. Instead, select one prefix that best describes the entire number.

Example:	12 010 mm or 12.010 m	not:	12 m 10 mm

4.6.2 PREFIXES IN COMPOUND UNITS. It is recommended that only one prefix be used in a unit expression and that the prefix be used in the numerator.

Examples:	V/m	not:	mV/mm
	GW/m^2	not:	W/mm^2

The exception to this rule is when kilogram appears in the denominator. Kilogram is a base unit that is defined with a prefix attached so it may occur in the denominator of an expression along with a prefixed unit in the numerator.

Example:	MJ/kg	not:	kJ/g

SECTION V

INTERNATIONAL STYLE AND USAGE

This section describes specific rules to follow when using SI for international communications. All rules from sections II, III, and IV apply except as noted in the following paragraphs. Mathematical signs and symbols shall be in accordance with ISO 31. Refer to ISO 31 and ISO 1000 for other units accepted for use with SI.

5.1 UNIT NAME AND PREFIX SPELLING

In international usage, a meter (with the American -er ending) is a device used to measure. The unit for length, "metre," is always spelled with the international -re ending. Similarly, "litre" is the international spelling for the unit of liquid and gas volume. The symbol for litre is either upper case L or lower case l (lower case l is preferred). Also, the prefix deka (10^1) is spelled deca.

Examples: The current reading on the meter was 20 milliampere.
The wall measured 20 metre.

5.2 PLURALIZATION

Unit names are written in singular form only since changing words for plural forms as practiced in the U.S. may cause confusion for those persons not as familiar with the English language.

Examples: The inductance was reduced from 20 henry to 1 henry.
The speed limit is 88 kilometer per hour.
The test duration will be 15 second.
The temperature changed 3 degree Celsius.

5.3 SYMBOLS

Regardless of the surrounding type style, unit and prefix symbols, as defined in sections II and III, are always printed in serif (Roman) typeface. Symbols are never italicized or printed in san-serif (Gothic) type styles.

Examples: *The resistance was* 60 Ω.
The current changed from 300 mA to 600 mA.

Symbols for quantities (e.g., force, pressure, electrical current, etc.) are always shown in italics to differentiate them from unit symbols.

Examples:	$F = m\ a$ (for force)	not:	F, meaning farad
	$P = 250$ W	not:	P, meaning peta

5.4 NUMBERS

Decimal markers are commas, unlike periods used in the U.S. Spaces, as described in 4.4, are used to denote multiples of thousands.

Examples:	0,2 (two tenths)	not:	0.2
	3 000,00 (three thousand)	not:	3,000.00 or 3 000.00
	0,000 1 (ten thousandths)	not:	0.000,1 or 0.000 1

5.5 NUMBERS AND UNITS

When unit names are spelled out, the number preceding the unit shall also be spelled out. Use figures only with unit symbols.

Example:	60 kg or sixty kilogram	not:	60 kilogram or sixty kg

Do not add subscripts or other information between the number and unit name or symbol.

Examples:	$U_{max} = 500$ V	not:	$U = 500\ V_{max}$
	water content is 20 ml/kg	not:	20 ml H_2O/kg or 20 mL of water/kg

5.6 REFERENCING OTHER UNITS

Reference to units other than SI should only be in footnotes or in an informative annex or appendix. Other units for special applications may be used, but true SI units must be given also in a footnote.

5.7 OTHER CONSIDERATIONS

The quantity "weight" is considered a force (gravitational force) and is measured in newton (N). The quantity "mass" is measured in kilogram (kg).

Percentages are "pure numbers" that do not show specific units. Do not use the expressions "percentage by mass" and "percentage by volume," or "% (m/m)" and "% (V/V)." Instead, write, for example, "a mass fraction of 5 %" or "a volume fraction of 7 %."

Distinguish between quantities describing object and identifying the object itself. For example, be clear when describing a "resistor" and "resistance," "coil" (or inductor) and "inductance," "surface" and "area," "body" and "mass," and so on.

SECTION VI

CONVERSION PRACTICES AND CALCULATIONS

6.1 INTRODUCTION

Section VI provides information on hard metric, soft-metric conversion, accuracy and rounding, and significant digits. Examples are given to illustrate the conversion techniques. The conversion practices described in this section, as supported in appendix D, are according to ANSI/IEEE Std 268 and ASTM E380.

Conversions from one unit to another are performed using factors that define the relationship between the two units, whether they are of the same or different measurement systems. Conversion factors may be exact or approximations. This section describes rules that are applicable to both approximations and exact conversion factors. Refer to section VII for information on preferred basic sizes, which may be used as a guide for selecting appropriate conversion values. Refer to appendix G for conversion factors for converting non-SI units.

6.2 DEFINITIONS

a. Conversion Factor - A conversion factor is a number that represents an equivalent relationship between two units. It is a multiplying factor used to convert from a value in terms of a particular unit to a desired unit.

b. Conversion, Hard - A hard conversion is the process of changing a measurement from an inch-pound unit to a nonequivalent metric unit. This process may require a physical change of the item outside established measurement tolerances. The term "hard conversion" is really a misnomer since the original item is not actually "converted." Instead, a new item with independent and unique metric dimensions is created to replace the inch-pound item. The new item is often referred to as being "hard metric."

c. Conversion, Soft - Soft conversion is the process of changing a measurement from an inch-pound unit to an equivalent metric unit within acceptable measurement tolerances and without changing the physical configuration of the item. Soft conversion is performed using conversion factors to achieve a "soft metric" item.

d. Significant Digit - A significant digit is any digit of a number that is necessary to define the specific value or quantity.

6.3 CONVERSION METHODS

The decision on whether to use hard metric or soft-metric conversion is based on knowledge, experience, and common sense. The following paragraphs discuss conversion options.

6.3.1 SOFT-METRIC CONVERSION. Soft conversion is the method of using an accurate conversion factor to redefine a numerical value in metric units. The method should be used if it is necessary only to describe a nonmetric value in SI units, particularly if the numerical value is an actual measurement or a specific limit. Soft conversion should be used when rounded, rational numbers are not standard or usual for the application regardless of the measurement system. The soft conversion can be expressed by either stating only the converted SI units in the requirements as substitution for the inch-pound units, by stating the SI units before the inch-pound units in parentheses in the requirements or vice versa (see 9.5.2), or by providing a table of conversions and/or conversion factors and giving the requirements in only one system.

Example: Soft convert 4.00 inches to millimeters.

Conversion factor: 1 in = 25.4 mm
4.00 in x 25.4 mm/in = 101.6 mm

6.3.2 HARD-METRIC CONVERSION. Hard metric is the method of changing a nonmetric value to a preferred size or to the nearest rounded and rational value in SI units. There are two basic ways of arriving at practical and meaningful metric values when performing hard conversion: size substitution and adaptive conversion. Size substitution is simply replacing the inch-pound size with an existing accepted metric size, which usually conforms to internationally recognized metric modules. The use of preferred types and sizes of parts and materials, especially in accordance with standards determined by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) is encouraged. It may be necessary to alter international or foreign standards to fit domestic needs. Adaptive conversion is the changing from a rounded, rational inch-pound quantity to a rounded, rational metric quantity that is reasonably equivalent (e.g., speed limits).

Example: Hard convert 4.00 inches to millimeters.

Conversion factor: 1 in = 25.4 mm
4.00 in x 25.4 mm/in = 101.6 mm
Nearest rounded, rational value = 100 mm

6.3.3 NO CONVERSION. No conversion is necessary if the original requirements are defined in SI units already (i.e., do not add inch-pound units to metric requirements); if the requirements are for items that will continue to be used without modifications (e.g., tools, spare parts, etc.); or if the items are becoming obsolete. It is also unnecessary to convert requirements that are not measurement sensitive.

6.3.4 ROUND-TRIP CONVERSION. It is not recommended that metric measurements be converted to inch-pound units for manufacture or construction and then converted back to metric. This "round-trip" conversion can cause mistakes in the translation whereby parts and materials delivered are out of tolerance.

6.4 ACCURACY AND ROUNDING

Accurate conversions are obtained by multiplying numerical values by an appropriate conversion factor (see appendix G). In most cases, multiplying a value by a seven-digit conversion factor, as given in the appendixes, results in values implying an accuracy not intended by the original value. Proper conversion procedures include rounding converted quantities to the appropriate number of significant digits corresponding to the intended precision. See appendix D for specific procedures for determining significant digits and performing rounding of numbers. Note that the rules given in this appendix do not apply to conversions of temperature. When converting from whole-degree temperatures in Fahrenheit, the Celsius temperature should be rounded to the nearest tenth of a degree.

Example: Convert 65 °F to degrees Celsius.

°C = (°F - 32) x 5/9
°C = (65 - 32) x 5/9
°C = 18.333 °C, which rounds to 18.3 °C

Consider the practical aspect of measuring when using SI equivalents. If original measurements are made using 1/16-inch increments, for example, a metric scale with divisions of 1 mm is suitable for measuring SI units. Similarly, a gage or caliper graduated in divisions of 0.02 mm would compare to one graduated in divisions of thousandths (0.001) of an inch. Estimates of intended precision should never be smaller than the accuracy of the measurement device or tool and should usually be smaller than one tenth the tolerance if one exists. This rationale also applies to measurements of mass, force, and other quantities.

Generally, before a value is converted or used in a calculation, the number of significant digits must be determined and appropriate rounding performed. First, the intended precision or accuracy of the quantity is established as a guide to the number of digits to keep. Usually, the precision relates to the number of digits in the original value, but sometimes it is not a reliable indicator. For example, 1.1875 may be the accurate decimal representation of 1 3/16, which may have been more adequately expressed as 1.19. Alternately, the value 2 may mean "about 2," or it may mean a very accurate value which should have been written as 2.000. After estimating the precision, the converted dimension is rounded to the minimum number of significant digits so that the number in the last place is equal to or smaller than the converted precision. In special cases, round to the minimum number of significant digits that will maintain the required accuracy. Sometimes deviation from the general practice is done for feasibility, in which case, the word "approximate" is written following the converted value.

When a value represents a minimum or maximum limit, the conversion must result in a value that does not violate the original limit. Care must be given to proper rounding of the converted value so that it has the correct number of significant digits.

6.5 PROFESSIONAL ROUNDING

Professional rounding is applying judgement when converting values so that the converted value is rounded to a preferred size. In each case, the user must determine the acceptable choice, aiming for clean, rounded metric quantities as alternatives. Exact conversions are not used and rounding to whole units is preferred unless precision is required. The following examples illustrates the concept of professional rounding. Refer to 11.1.7 for the discussion of preferred multimodules.

Example: Determine an appropriate width for an unobstructed pedestrian corridor that does not violate the National Building Code (NBC) minimum requirements of 44 inches.

Since soft conversion results in an awkward value of 1118 mm, a clear, rounded, metric size should be selected that is larger than 1118 mm. The most preferred multimodule is 6000 mm, which is not feasible. The next preferred multimodule is 3000 mm, which is also not feasible. The next choice is 1200 mm which is feasible and represents a good choice. Every effort should be made to keep design dimensions in increments of 100 mm, the basic module, or multimodules. This is also the closest dimension to the required width.

Example: For mortar joint thickness, if requirements specified a 3/8-inch joint, use 10 mm, which is rounded from the exact conversion of 9.525 mm.

6.6 SIGNIFICANT DIGITS

During conversion, attention must be given to ensure that converted values retain the same number of significant digits as the original value to maintain the required accuracy. See appendix D for details for determining significant digits after performing particular mathematical operations. The following example illustrates rounding to the proper number of significant digits, which results in a reasonable conversion. The original value of 12 feet contains two significant digits, so the converted value must also have two significant digits. Any additional accuracy would be impractical.

Example: Convert 12 feet to meters.

Conversion factor: 1 ft = 0.3048 m

$$12 \text{ ft} \times \frac{0.3048 \text{ m}}{1 \text{ ft}} = 3.6576 \text{ m, which rounds to } 3.7 \text{ m}$$

6.7 CALCULATIONS

6.7.1 USING CONVERSION FACTORS. Appendix G contains conversion factors to use when converting from inch-pound units and obsolete or discontinued metric units to proper SI units. When performing a conversion, multiply the original value by the conversion factor to obtain the SI unit.

Example: Convert 69.4 lb/in^2 to kilopascals.

Conversion factor: 1 lb/in^2 = 6.895 kPa

$$69.4 \text{ lb/in}^2 \times \frac{6.895 \text{ kPa}}{1 \text{ lb/in}^2} = 478.513 \text{ kPa, which rounds to } 479 \text{ kPa}$$

Example: Convert \$2.30/yd^3 to dollars per cubic meter.

Conversion factor: 1 yd^3 = 0.764 55 m^3

$$\frac{\$2.30}{\text{yd}^3} \times \frac{1 \text{ yd}^3}{0.764\ 55 \text{ m}^3} = \frac{\$3.01}{\text{m}^3}$$

To convert from an SI unit to a non-SI unit, divide the SI unit by the conversion factor (or multiply by the inverse of the conversion factor).

Example: Convert 47.0 kg to pounds.

Conversion factor: 1 lb = 0.454 kg

$$47.0 \text{ kg} \times \frac{1 \text{ lb}}{0.454 \text{ kg}} = 103.524 \text{ lb, which rounds to } 104 \text{ lb}$$

6.7.2 CALCULATIONS OF PREFIXED VALUES. When performing calculations of values that are represented by a unit with a prefix attached, the number should be converted to its base unit and a multiple of 10 (exponential notation). This practice reduces the chances of error.

Example: Determine the total area that is 1.38 km by 0.24 km.

Conversion factor: 1 km = 1000 m

$1.38 \text{ km} = 1.38 \times 10^3 \text{ m}$
$(1.38 \times 10^3) \text{ m} \times 0.24 \text{ m} = 331.2 \text{ m}$

6.7.3 CONVERSIONS OF RATIOS. Occasionally, it is necessary to convert two related quantities. For example, a specification may require that paint coverage be 5 gallons over 100 square feet. Performing independent conversions of both the numerator and denominator would produce a relationship that is impractical and difficult to measure. Instead, the two values should be converted as a single ratio (e.g., 5 gal/100 ft^2) with a reasonable rounded value in the denominator.

Example: Convert 5 gal/100 ft^2 to liters per square meters.

Conversion factors: 1 gal = 3.785 L
1 ft^2 = 0.0929 m^2

Since 1 ft^2 is approximately equal to one-tenth of a square meter, select coverage area to be 10 m^2.

$$\frac{5 \text{ gal}}{100 \text{ ft}^2} \times \frac{3.785 \text{ L}}{\text{gal}} \times \frac{1 \text{ ft}^2}{0.0929 \text{ m}^2} \times \frac{10 \text{ m}^2}{10 \text{ m}^2} = \frac{20.4 \text{ L}}{10 \text{ m}^2} \text{ or } \frac{20 \text{ L}}{10 \text{ m}^2}$$

not: $$\frac{5 \text{ gal} \times 3.785 \text{ L/gal}}{100 \text{ ft}^2 \times 0.0929 \text{ m}^2/\text{ft}^2} = \frac{18.9 \text{ L}}{9.29 \text{ m}^2}$$

6.7.4 CONVERSIONS OF MIXED INCH-POUND UNITS. Convert values of mixed inch-pound units (e.g., 4 feet 2 inches, 3 gallons 6 ounces) by first rewriting the value in terms of the smaller unit. Then, perform the conversion to SI units.

Example: Convert 4 feet 2 inches to meters.

Conversion factor: 1 in = 0.0254 m

Write the length in terms of the smaller unit - inches:
(4 ft x 12 in/ft) + 2 in = (48 + 2) in = 50 in

$$50 \text{ in} \times \frac{0.0254 \text{ m}}{1 \text{ in}} = 1.27 \text{ m}$$

Example: Convert 3 gallons 6 ounces to liters.

Conversion factor: 1 oz = $2.957\ 353 \times 10^{-2}$ L

Write the volume in terms of the smaller unit - ounces:
(3 gal x 128 oz/gal) + 6 oz = (384 + 6) oz = 390 oz

390 oz x ($2.957\ 353 \times 10^{-2}$) L/oz = 11.5 L

SECTION VII

LIMITS, FITS, AND TOLERANCES

7.1 INTRODUCTION

This section describes the International Organization for Standardization (ISO) system of limits, fits, and tolerances for mating parts as approved for general engineering usage in the United States. Information is provided on designation symbols for defining specific dimensional limits on drawings, material stock, tools, gages, etc.; choices for preferred sizes; preferred tolerance zones; and preferred limits and fits for sizes. This information applies primarily to dimensions, particularly to any "hole" or "shaft" that refers generally to a space contained by or containing two parallel faces of any part, such as a thickness of a key and the width of the corresponding slot. This information also pertains to any other application that uses basic sizes and tolerances.

7.2 DEFINITIONS

The following definitions apply to tolerances, limits, and fits. Most of the definitions are illustrated in figure 7-1. These definitions are the same for both a "hole" and a "shaft."

a. Basic Size - The basic size is the size to which deviations or limits are assigned.

b. Deviation - A deviation is the variation from a specified dimension (designated basic size) or design requirement, usually defined by an upper and lower limit.

c. Deviation, Fundamental - The fundamental deviation is the deviation (upper or lower) closest to the basic size.

d. Deviation, Lower - The lower deviation is the algebraic difference between the minimum limit of size and the designated basic size.

e. Deviation, Upper - The upper deviation is the algebraic difference between the maximum limit of size and the designated basic size.

f. Fit, Clearance - A clearance fit is the relationship between the assembled parts when clearance occurs respecting all tolerance conditions.

g. Fit, Interference - An interference fit is the relationship between assembled parts when interference occurs under all tolerance conditions.

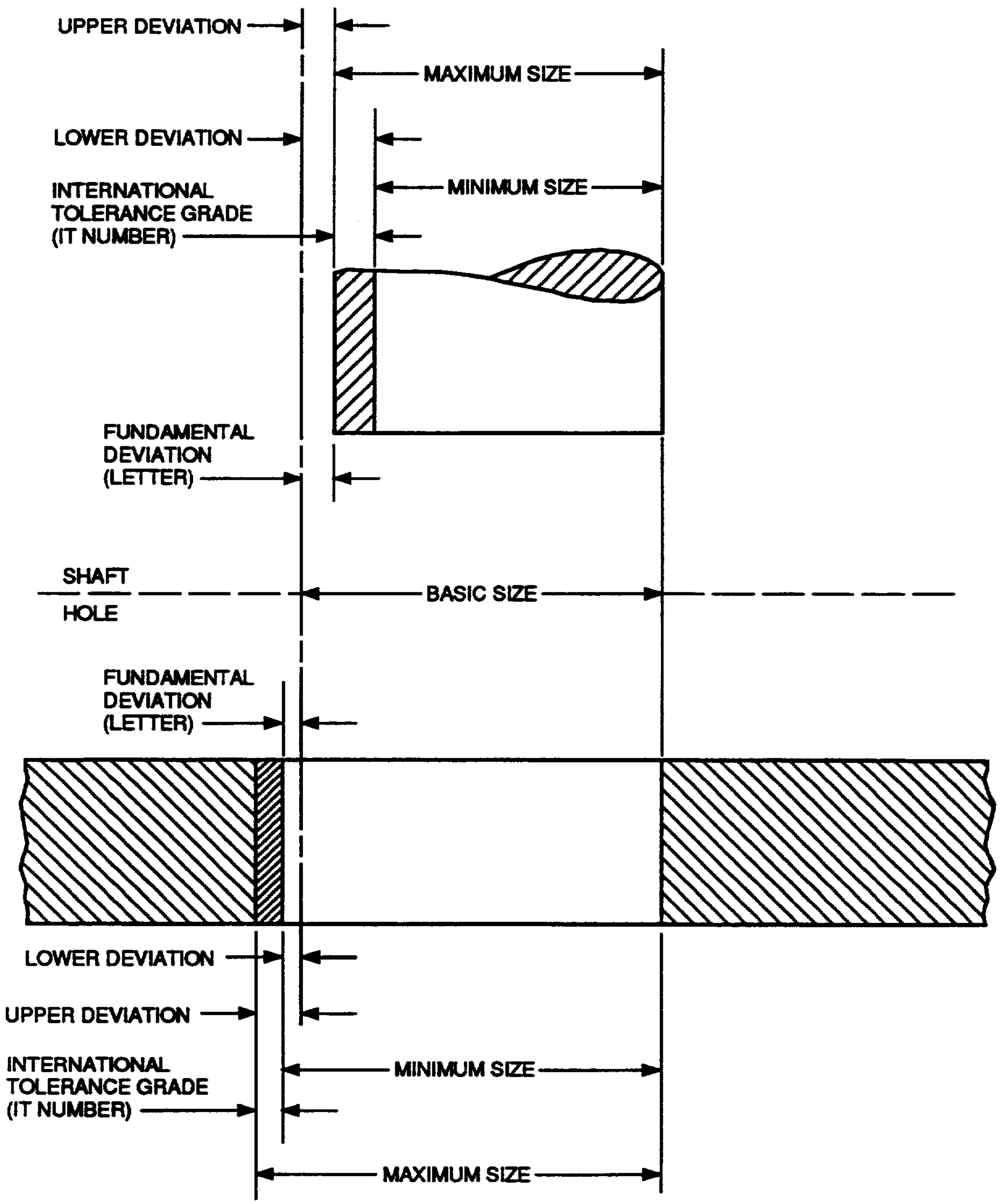


Figure 7-1. Illustration of Definitions

h. Fit, Transition - A transition fit is the relationship between assembled parts when either a clearance or interference fit can result depending on the tolerance conditions of the mating parts.

i. Hole Basis System - The hole basis system of fits is where the minimum hole size is basic.

j. International Tolerance (IT) Grade - The IT Grade is a number designation representing the amount of variation between the maximum and minimum size limits.

k. Tolerance - The tolerance is the difference between the maximum and minimum size limits.

l. Tolerance Zone - A tolerance zone is a zone equal in magnitude to the tolerance as related to the basic size.

m. Shaft Basis System - The shaft basis system of fits is where the maximum shaft size is basic.

7.3 BASIC SIZES

As defined in 7.2, a basic size is the size to which deviations or limits are assigned. The basic size is the same for both members of the fit. The limits assigned to each member express the relationship between the deviation allowed and the basic size. The basic size may actually fall within the tolerance or only one member of the fit or may not fall within the tolerance of either part. This concept is illustrated in the 7.4. The basic size selected should be a preferred size that is closest to the actual size. The following paragraphs explain preferred sizes.

7.3.1 PREFERRED BASIC SIZES. The numbering system provides infinite options for sizing and rating materials, components, and systems. It is practical to establish a set of numbers based on a geometric progression that provides uniformity in basic sizes, as does the Renard series of sizes. The Renard series are currently used by the ISO to determine sizes for basic materials. Manufacturers provide products sized to these series to reduce the number of sizes in a product line, thus reducing inventories. Some products based on these series are electric motors, whereby their ratings are based on the preferred sizes. Using a system of preferred sizes also ensures that the products from different companies are matched in size.

Table 7-1 lists the preferred basic sizes based on the R10 series, which is the preferred series of sizes for engineering purposes. This series gives the user ten incremental sizes in the first-choice category from 1 up to 10, from 10 to 100, and

Table 7-1. Preferred Basic Sizes

Sizes 1 to 10	
Choice	
1st	2nd
1 1.2 1.6	1.1 1.4 1.8
2 2.5	2.2 2.8
3	3.5
4	4.5
5	5.5
6	
	7
8	
	9
10	

Sizes 10 to 100	
Choice	
1st	2nd
10 12 16	11 14 18
20 25	22 28
30	32 35 38
40	42 45 48
50	52 55 58
60	65
	70 75
80	85
	90 95
100	

Sizes 100 to 1000	
Choice	
1st	2nd
100 120 160	110 130 140 150 170 180 190
200 250	210 220 230 240 260 280
300	320 350 380
400	420 450 480
500	520 550 580
600	620 650 680
	700 720 750 780
800	850
	900 950
1000	

from 100 to 1000. For sizes from 1000 to 10 000, multiply the choices in the first column by 1000; from 10 000 to 100 000, multiply the choices in the second column by 1000; and so on. The list can be reduced to an R5 series by selecting every other number in the series. Thus, the first-choice preferred sizes in the R5 series would be 1, 1.6, 2.5, 4, 6, 10, 16, 25, etc.

These sizes are guides for determining basic sizes and are not meant to replace exact functional and dimensional requirements.

7.3.2 OTHER INCREMENTAL SIZING. Another series of incremental sizing is the 1-2-5 series where the numbers increase in multiples of 1, 2, and 5 as follows: 1, 2, 5, 10, 20, 50, 100, 200, 500, etc. This series is practical when used for metric linear sizes in millimeters, shown in table 7-2, by using multiples of 1, 2, and 5 for increasing ranges of sizes. The table shows that from 1 to 20, the R10 series of sizes is convenient. From 20 to 80, the sizes increase by 5; from 80 to 200, the sizes increase by 10; from 200 to 300, the sizes increase by 20, and so on.

Table 7-2. Preferred Basic Millimeter Sizes for Engineering

	Rising by 5	Rising by 10	Rising by 20	Rising by 50
1	20	80	200	300
1.2	25	90	220	350
1.6	30	100	240	400
2	35	110	260	450
2.5	40	120	280	500
3	45	130	300	550
4	50	140		600
5	55	150		650
6	60	160		700
8	65	170		750
10	70	180		800
12	75	190		850
16	80	200		900
20				950
				1000

7.4 TOLERANCE

The amount of variation between maximum and minimum dimensions is defined by the International Tolerance (IT) grade. The tolerance zone, which is based on the fundamental deviation, is the magnitude of the variation and its position relative to the basic size. The tolerance zone's range is designated by a letter; capital letters indicate internal dimensions (i.e., "hole" size) and lower-case letters indicate external dimensions (i.e., "shaft" size).

7.4.1 INTERNATIONAL TOLERANCE GRADE. Grade numbers, which are prefixed by the letters IT (e.g., IT6, IT11), increase in whole number increments as follows: 01, 0, 1, 2, 3, 4, etc. The smaller the grade number, the smaller the variation allowed between the maximum and minimum dimensions resulting in a closer tolerance. Table 7-3 shows the appropriate IT grades for practical applications. Refer to appendix H for a listing of IT grade values for basic sizes up to 3150 mm.

7.4.2 INTERNAL TOLERANCE ZONES (HOLES). For internal tolerance zones, the zones start at A and are positive, which means that both the maximum and minimum limits of the tolerance are positive (e.g., +0.025 +0.015). The tolerance becomes negative as the tolerance zone letters approach the end of the alphabet. The H range is the base or zero line for internal dimensions. This means that the tolerance is described as plus a specific amount and zero (e.g., +0.025 0.000). The JS range (between ranges J and K) designates that the maximum and minimum tolerance is of the same magnitude about the basic size. In other words, the plus and minus tolerance is equal (e.g., ± 0.05). Table 7-4 illustrates the various internal dimension tolerance conditions.

7.4.3 EXTERNAL TOLERANCE ZONES (SHAFTS). External dimensions are identified by lower-case letters with j being the base or zero line where the tolerance is zero minus a specific value (e.g., 0.000 -0.025). As with internal dimensions, the zone js is the tolerance where the minimum and maximum tolerances are equal. In contrast to the internal dimension lettering scheme, the external dimensions are negative at the beginning of the alphabet and positive at the end. Table 7-5 illustrates the tolerance ranges of external dimensions.

7.4.4 PREFERRED TOLERANCE ZONES. Just as there are preferred sizes, there are preferred tolerance zones. The preferred tolerance zones are shown for internal and external dimensions in figures 7-2 and 7-3, respectively. Tables in appendix H list values for these preferred tolerance zones up to 500 mm and give the equations for calculating any tolerance. Refer to ANSI B4.2 for tables of tolerance zones showing maximum and minimum limitations already calculated.

Table 7-3. Applications of International Tolerance Grades

	IT Grade																	
Application	01	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Measuring tools	X	X	X	X	X	X	X	X	X									
Material										X	X	X	X	X	X	X		
Fits							X	X	X	X	X	X	X					
Large manufacturing														X	X	X	X	X
Machining processes																		
Lapping and honing						X	X											
Cylindrical grinding							X	X	X									
Surface grinding							X	X	X	X								
Diamond turning							X	X	X									
Diamond boring							X	X	X									
Broaching							X	X	X	X								
Powder metal-sizes								X	X	X								
Reaming								X	X	X	X	X						
Turning									X	X	X	X	X					
Powder metal-sintered									X	X	X	X						
Boring									X	X	X	X	X					
Milling												X	X					
Planing and shaping												X	X					
Drilling												X	X					
Punching												X	X					
Die casting													X					

Table 7-4. Internal Dimensions Tolerance Conditions

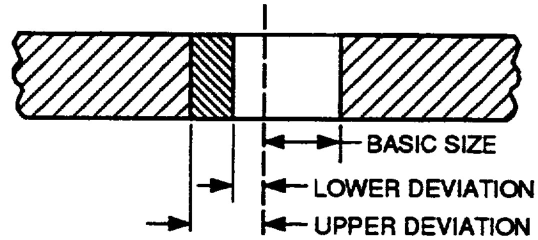
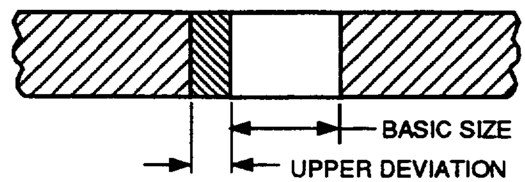
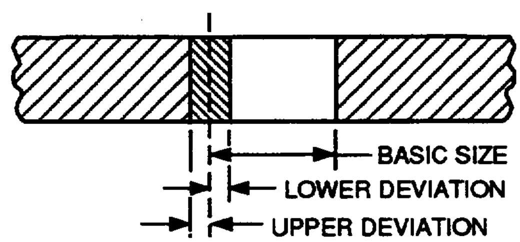
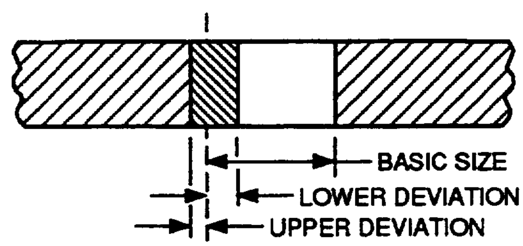
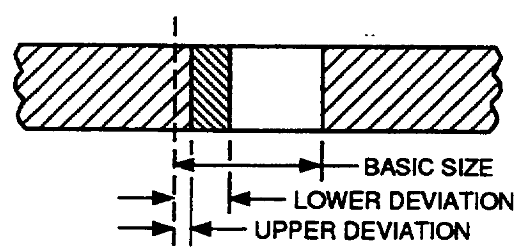
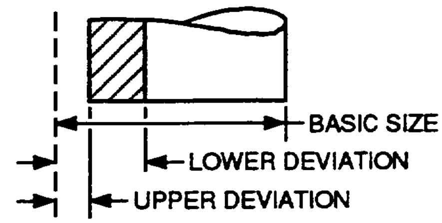
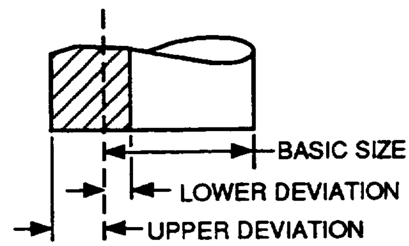
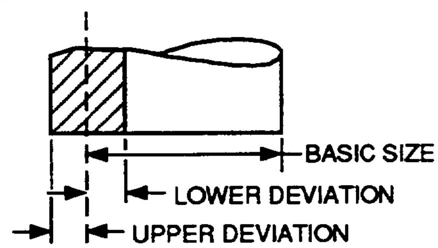
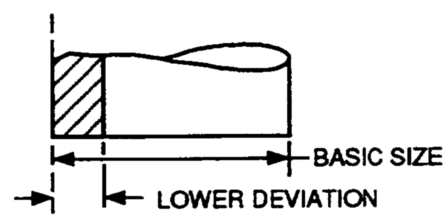
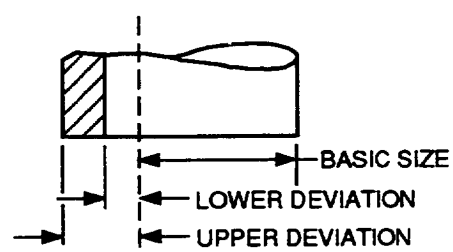
Tolerance Zones	Tolerance Type	Example	Hole Illustration
A through G	Positive	A14: +0.520 +0.270	
H	Zero line (positive)	H16: +0.600 0.000	
JS	Equal	JS12: +0.105 -0.105	
J and K	Positive and negative	K7: +0.006 -0.015	
M through Z	Negative	Z6: -0.166 -0.185	

Table 7-5. External Dimensions Tolerance Conditions

Tolerance Zones	Tolerance Type	Example	Hole Illustration
a through g	Negative	d11: -0.100 -0.290	
j	Positive and negative	j7: +0.013 -0.008	
js	Equal	js9: +0.037 -0.037	
h	Zero line (negative)	h3: 0.000 -0.004	
k through z	Positive	y6: +0.193 +0.174	

							H1		JS1												
							H2		JS2												
							H3		JS3												
							H4		JS4												
						G5	H5		JS5	K5	M5	N5	P5	R5	S5	T5	U5	V5	X5	Y5	Z5
					F6	**G6**	**H6**	J6	**JS6**	**K6**	**M6**	**N6**	**P6**	**R6**	**S6**	**T6**	U6	V6	X6	Y6	Z6
			D7	E7	**F7**	G7	H7	J7	**JS7**	K7	**M7**	N7	P7	**R7**	S7	**T7**	U7	V7	X7	Y7	Z7
		C8	D8	**E8**	F8	G8	H8	J8	**JS8**	**K8**	**M8**	**N8**	**P8**	**R8**	S8	T8	U8	V8	X8	Y8	Z8
A9	B9	C9	D9	**E9**	**F9**	G9	H9		JS9	K9	M9	N9	P9	R9	S9	T9	U9	V9	X9	Y9	Z9
A10	B10	C10	**D10**	**E10**	F10	G10	**H10**		JS10	K10	M10	N10	P10	R10	S10	T10	U10	V10	X10	Y10	Z10
A11	**B11**	C11	D11	E11	F11		H11		JS11												
A12	B12	C12	D12	E12			H12		JS12												
A13	B13	C13					H13		JS13												
A14	B14						H14		JS14												
							H15		JS15												
							H16		JS16												

Legend: First choice tolerance zones encircled
Second choice tolerance zones bold
Third choice tolerance zones not bold

Figure 7-2. Internal Dimensions Preferred Tolerance Zones

							h1		js1												
							h2		js2												
							h3		js3												
						g4	h4		js4	k4	m4	n4	p4	r4	s4	t4	u4	v4	x4	y4	z4
					f5	**g5**	**h5**		**js5**	**k5**	m5	n5	p5	r5	**s5**	t5	u5	v5	x5	y5	z5
				e6	**f6**	g6	h6	j6	**js6**	k6	m6	n6	p6	r6	s6	t6	u6	v6	x6	y6	z6
			d7	**e7**	f7	g7	h7	j7	**js7**	**k7**	m7	**n7**	**p7**	r7	**s7**	t7	**u7**	v7	x7	y7	z7
		c8	**d8**	**e8**	**f8**	g8	**h8**	j8	js8	k8	m8	n8	p8	r8	s8	t8	u8	v8	x8	y8	z8
a9	b9	c9	d9	**e9**	f9	g9	h9		js9	k9	m9	n9	p9	r9	s9	t9	u9	v9	x9	y9	z9
a10	b10	c10	**d10**	e10	f10		**h10**		js10												
a11	**b11**	c11	d11	e11			h11		js11												
a12	b12	c12	d12				h12		js12												
a13	b13	c13					h13		js13												
a14	b14						h14		js14												
							h15		js15												
							h16		js16												

Legend: First choice tolerance zones encircled
Second choice tolerance zones bold
Third choice tolerance zones not bold

Figure 7-3. External Dimensions Preferred Tolerance Zones

7.4.5 GENERAL TOLERANCES.

7.4.5.1 Tolerance Series. Tolerance series are used to define tolerances for various types of dimension applications when unique tolerances are not necessary. Fine and medium tolerance series are used primarily to tolerance machined parts. The coarse series of tolerances is applicable on all types of dimensions. Tolerance series and their variations are shown in table 7-6 for linear dimensions and in table 7-7 for angle and taper dimensions.

Table 7-6. General Tolerance - Linear Dimensions

Basic Dimensions (mm)		0.5 to 3	Over 3 to 6	Over 6 to 30	Over 30 to 120	Over 120 to 315	Over 315 to 1000	Over 1000 to 2000
Permissible Variations (in mm)	Fine Series	± 0.05	± 0.05	± 0.1	± 0.15	± 0.2	± 0.3	± 0.5
	Medium Series	± 0.1	± 0.1	± 0.2	± 0.3	± 0.5	± 0.8	± 1.2
	Coarse Series	—	± 0.2	± 0.5	± 0.8	± 1.2	± 2.0	± 3.0

Table 7-7. General Tolerance - Angle and Taper Dimensions

Length of the Shorter Leg (mm)		Up to 10	Over 10 to 50	Over 50 to 120	Over 120 to 400
Permissible Variations	In Degrees and Minutes	± 1°	± 0°30′	± 0°20′	± 0°10′
	In Millimeters per 100 mm	± 1.8	± 0.9	± 0.6	± 0.3
	In Milliradians	± 18	± 9	± 6	± 3

7.4.5.2 Tolerance Indication. There are three acceptable methods of expressing tolerance data on dimensions. The data may be expressed as the tolerance or specified limits applied directly to the dimension, as specified in other documents referenced on the drawing, or in a general tolerance note referring to all dimensions on a drawing for which tolerances are not otherwise specified. General tolerance notes are used to control dimensions without specified tolerances and expressed as explained in the following paragraphs.

7.4.5.2.1 Linear Dimensions. Permissible variations in linear dimensions may be specified as ± one half of the IT grade.

Example: UNLESS OTHERWISE SPECIFIED, ALL UNTOLERANCED DIMENSIONS ARE ± $\frac{IT11}{2}$.

The variations may also be referenced in a particular series according to a document or listed in a table.

Example: UNLESS OTHERWISE SPECIFIED, THE GENERAL TOLERANCE SPECIFIED IN ANSI B4.3 MEDIUM SERIES APPLIES.

or

Dimensions in mm

GENERAL TOLERANCE
UNLESS OTHERWISE SPECIFIED THE FOLLOWING TOLERANCES ARE APPLICABLE

LINEAR	OVER / TO	0.5 / 6	6 / 30	30 / 120	120 / 315	315 / 1000	1000 / 2000
TOL	±	0.1	0.2	0.3	0.5	0.8	1.2

The variations may be defined as a function of the number of digits following the decimal point in the linear dimension or as a single tolerance value for all untoleranced nominal dimensions. Note that this method is not recommended where the magnitude of the dimensions on the drawing varies appreciably.

Example: UNLESS OTHERWISE SPECIFIED, ALL UNTOLERANCED DIMENSIONS ARE ± 0.8 mm.

or

Dimensions in mm

GENERAL TOLERANCE
UNLESS OTHERWISE SPECIFIED THE FOLLOWING TOLERANCES ARE APPLICABLE

LINEAR		OVER / TO	– / 120	120 / 315	315 / 1000	1000 / –
TOL	ONE DECIMAL	±	0.3	0.5	0.8	1.2
	TWO DECIMALS	±	0.8	1.2	2	3

7.4.5.2.2 Angular Dimensions. General tolerances for angles are based upon the shorter of the two sides forming the angle. The angular tolerance is expressed as either a single value in decimal degrees or in degrees and minutes, as a taper expressed in percentage (number of millimeters per 100 mm), or a taper expressed in milliradians.

Example: UNLESS OTHERWISE SPECIFIED, THE GENERAL TOLERANCES IN ANSI B4.3 APPLY.

or

<table>
<tr><th colspan="4">GENERAL TOLERANCE
UNLESS OTHERWISE SPECIFIED THE FOLLOWING TOLERANCES ARE APPLICABLE</th></tr>
<tr><td colspan="2">LENGTH OF THE SHORTER LEG (mm) OVER
TO</td><td>50
120</td><td>120
400</td></tr>
<tr><td rowspan="2">TOLERANCE</td><td>IN DEGREES AND MINUTES</td><td>±0°20′</td><td>±0°10′</td></tr>
<tr><td>IN MILLIMETERS PER 100 mm</td><td>±0.6</td><td>±0.3</td></tr>
</table>

Example: UNLESS OTHERWISE SPECIFIED, ALL UNTOLERANCED ANGLES ARE 0°30′.

7.5 FITS

Generally, the fit between two parts is classified as either a clearance, transition, or interference fit. These types of fits are defined in 7.2. A fit is further classified as either a hole basis or shaft basis fit. The hole basis fit uses the basic size as the minimum tolerance dimension where the tolerance is described as plus one specific value and zero (e.g., +0.025 0.000). The fundamental deviation for the hole basis system is H (e.g., H10, H13). The shaft basis fit uses the basic size as the maximum tolerance dimension where the tolerance is described as zero minus a specific value (e.g., 0.000 -0.025). The fundamental deviation in the shaft basis system is h (e.g., h9, h11, etc.) Normally, the hole basis system is preferred; however, when a common shaft is used with several holes, the shaft basis system should be used.

As with tolerance and size, there are preferred fits which define combinations of internal and external dimension tolerance zones. Table 7-8 lists and describes the preferred fits for both the hole basis and shaft basis systems. The fits may be customized by selecting other internal or external tolerance zones to achieve the desired clearance. See appendix H for tables of the tolerance zones for these preferred fits.

7.6 TOLERANCE AND FIT NOTATION

Fundamental deviations are designated by "tolerance position letters," which are specific for internal and external dimensions. The tolerance notation showing the maximum and minimum limits of a part is the combination of the tolerance grade number and the tolerance position letter. The complete toleranced size designation is the tolerance symbol written after the basic size value as defined below.

```
00 X 00
|  |  |
|  |  |_______ IT grade (IT number)
|  |_______ Fundamental Deviation (position letter)
|_______Basic Size (nominal)
```

7.6.1 Internal Dimension Symbols. Internal dimension (hole) symbols are written with capital letters. The following example shows a hole with a basic size of 30 mm in the H tolerance zone with a grade of IT8.

Example: 30H8

7.6.2 External Dimension Symbols. External dimension (shaft) symbols are written with lower-case letters. The following example shows a shaft with a basic size of 25 mm in the k tolerance zone with a grade of IT6.

Example: 25k6

7.6.3 Fit Symbols. A fit is indicated by the basic size common to both components followed by a tolerance zone symbol for each component, which is the internal dimension zone followed by the external dimension zone. In this example, the basic size is 20 mm. The hole tolerance zone and IT grade is H8 and the shaft tolerance zone and IT grade is f7.

Example: 20H8/f7

Table 7-8. Preferred Fits

ISO Symbol		Fit	Description
Hole Basis	Shaft Basis		
Clearance Fits:			
H11/c11	C11/h11	Loose running	For wide commercial tolerances or allowances on external members.
H9/d9	D9/h9	Free running	Not for use where accuracy is essential but good for large temperature variations, high running speeds, or heavy journal pressures.
H8/f7	F8/h7	Close running	For running on accurate machines and for accurate location at moderate speeds and journal pressures.
H7/g6	G7/h6	Sliding	Not intended to run freely but to move and turn freely and locate accurately.
H7/h6	H7/h6	Locational clearance	Provides snug fit for locating stationary parts but can be freely assembled and disassembled.
Transition Fits:			
H7/k6	K7/h6	Locational transition	For accurate location, a compromise between clearance and interference.
H7/n6	N7/h6	Locational transition	For more accurate location where greater interference is permissible.
Interference Fits:			
H7/p6	P7/h6	Locational interference	For parts requiring rigidity and alignment with prime accuracy of location but without special bore pressure requirements.
H7/s6*	S7/h6	Medium drive	For ordinary steel parts or shrink fits on light sections, the tightest fit usable with cast iron.
H7/u6	U7/h6	Force	Suitable for parts that can be highly stressed or for shrink fits where the heavy pressing forces required are impractical.

* This is a transition fit for basic sizes in range from 0 mm through 3 mm.

7.6.4 Other Symbol Designations. Three other methods of indicating tolerances are shown in the following examples. The values in parentheses are considered reference values.

Examples: $40H8 \begin{pmatrix} 40.039 \\ 40.000 \end{pmatrix}$

or: $\begin{matrix} 40.039 \\ 40.000 \end{matrix} (40H8)$

or: 40.039 - 40.000 not: 40.039/40.000

When designating tolerance limits, all numbers shall carry the same number of decimal places whether the limits are stated as plus and minus values or as maximum and minimum dimensions. Add zeros when necessary. Upper and lower deviations equal to zero are also shown. Note that the plus or minus sign may be eliminated when showing zero deviation.

Examples:	$\begin{matrix} 28.0 \\ 27.6 \end{matrix}$	not: $\begin{matrix} 28 \\ 27.6 \end{matrix}$
	$33.00 \begin{pmatrix} +0.00 \\ -0.03 \end{pmatrix}$	not: 33.00 -0.03
	$42.00 \begin{pmatrix} +0.04 \\ 0.00 \end{pmatrix}$	not: 42.00 +0.04
	$65.000 \begin{pmatrix} +0.255 \\ -0.100 \end{pmatrix}$	not: $65.000 \begin{pmatrix} +0.255 \\ -0.1 \end{pmatrix}$

When writing tolerance deviations single spaced, the more positive deviation is shown first. If the upper and lower deviations are equal, the deviation is shown only once preceded by the ± symbol.

Examples:	53.4 +0.2 -0.4	not: 53.4 -0.4 +0.2
	84.5 ± 0.3	not: 84.5 +0.3 -0.3

SECTION VIII

DRAWING GUIDELINES

8.1 GENERAL DRAWING GUIDELINES

General drawing practices shall be performed in accordance with GP-435. Details particular to metric drawings shall be as specified in this section.

8.2 DRAWING SCALES

All drawings should have an indication of scale displayed somewhere on each sheet whether the drawing is 1/8"=1'-0", NOT TO SCALE, or another appropriate scale. As more designs are done in metric units, it is critical that the scale and units used be clearly displayed on the drawing.

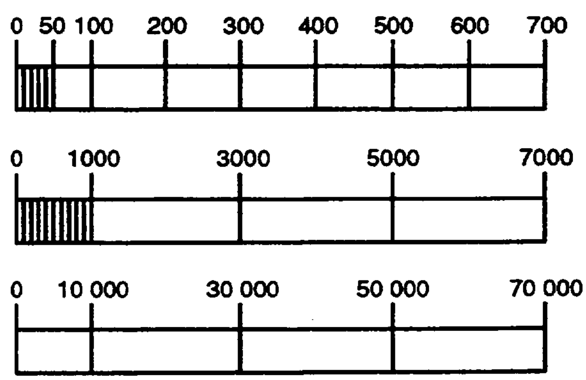
Most inch-pound scales are not exact conversions of metric scales. Table 8-1 lists common inch-pound scales and the preferred metric scales which are in multiples of 1, 2, 5, and 10 (following the 1-2-5 series). Use of the scales listed in the OTHER column should be limited to special applications. When converting a drawing from inch-pound units to metric, the drawing may need to be resized to the appropriate metric scale. Use a reasonable metric scale for new drawings. On drawings, the scale is expressed as a nondimensional entity as shown in the following example. Note that drawings of scale ratios greater than 1:200 should be dimensioned in meters. Otherwise, use millimeters as the primary dimensional unit. The units used are defined by adding appropriate notes according to 8.5. Refer to section XI for information on specific metric scales for construction work.

Examples:

1:10

1:100

1:1000



8.3 DIMENSIONING

Drawings for all new designs shall use SI units, except for drawings for those programs or projects for which a waiver against using SI units has been approved. If an inch-pound item is approved for use on a metric project, the dimensions of that item should be soft converted to metric. If the inch-pound item is used in a hybrid project, then the dimensions of that item may remain in inch-pound units except for where it interfaces with metric items in which case the interfaces should be soft converted to metric (or dual dimensioned, in limited situations).

Table 8-1. Drawing Scales

Inch-Pound		Metric Scales	
Size	Ratio	Preferred	Other
FULL	1:1	1:1	
HALF	1:2		1:2
4" = 1′-0" 3" = 1′-0"	1:3 1:4	1:5	
2" = 1′-0" 1-1/2" = 1′-0" 1" = 1′-0"	1:6 1:8 1:12	1:10	
3/4" = 1′-0" 1/2" = 1′-0"	1:16 1:24	1:20	1:25
3/8" = 1′-0" 1/4" = 1′-0" 1" = 5′-0" 3/16" = 1′-0"	1:32 1:48 1:60 1:64	1:50	
1/8" = 1′-0" 1" = 10′-0" 3/32" = 1′-0"	1:96 1:120 1:128	1:100	
1/16" = 1′-0"	1:192	1:200	
1" = 20′-0"	1:240		1:250
1" = 30′-0" 1/32" = 1′-0" 1" = 40′-0"	1:360 1:384 1:480	1:500	
1" = 50′-0" 1" = 60′-0" 1/64" = 1′-0" 1" = 1 chain 1" = 80′-0"	1:600 1:720 1:768 1:792 1:960	1:1000	
LOCATION OR SURVEY	1:2500	1:2000	

8.3.1 READING METRIC SCALES

Metric scales must be used to measure metric measurements. Metric measures cannot be read off of an inch-pound scale because the scales are not equivalent. For example, a metric scale ratio of 1:200 is not the same for measuring feet and inches. Table 8.2 shows examples of reading metric scales. Larger scales may be read off of a smaller scale by adding zeros to the values read (see table 8-3).

Table 8-2. Examples of Metric Scale Measurements

Scale (mm)	Line Measures (mm)	Calculate	Read
1:1	60	1 x 60 = 60 mm	60 mm
1:10	60	10 x 60 = 600 mm	600 mm
1:100	60	100 x 60 = 6000 mm	6 m
1:100	52	100 x 52 = 5200 mm	5.2 m
1:20	50	20 x 50 - 1000 mm	1 m
1:50	80	50 x 80 = 4000 mm	4 m

Table 8-3. Reading Larger Scales From Smaller Scales

Scale (mm)	Desired Scale (mm)	Line Measures	Calculate	Read
1:5	1:5	50	5 x 50 = 250 mm	250 mm
	1:50	50	50 x 50 = 2500 mm	2.5 m
	1:500	50	500 x 50 = 25 000 mm	25 m
1:2	1:2	40	2 x 40 = 80 mm	80 mm
	1:20	40	20 x 40 = 800 mm	800 mm
	1:200	40	200 x 40 = 8000 mm	8 m

8.3.2 INTERFACES OF DIFFERENT MEASUREMENT UNITS. Unless required to define an interface, dimensions of components shall be shown only in the measurement units used for the original design. If dimensions from the alternate measurement system are required for reference purposes, they should be given in supporting notes or a table but not as part of the dimension lines (see 8.3.7.3).

8.3.3 INTERFACES OF HYBRID MEASUREMENT UNITS. When inch-pound items interface with SI items, dimensions of the interface on drawings and in associated interface control documents shall be expressed in dual units. The measurement units used for the original design of a component are shown first. The alternate units are obtained by mathematical conversion shown by any of the methods described in 8.3.7.

8.3.4 DIMENSIONING IN SHARED COORDINATE SYSTEMS. When the use of inch-pound and SI coordinate systems is required, both coordinate systems should have the same origin, and the direction of the axes should be parallel. The origin of the alternate coordinate system may be at convenient integer values in the primary system.

8.3.5 UNIT DESIGNATIONS. Only one unit should be used for each quantity (e.g., length) shown on the drawing. Measurements may end up in magnitudes greater than 1000 (e.g., 250 000 mm), which is common and acceptable. Dimensional units need not be specified on each dimension unless it differs from the primary unit used on the drawing and noted in accordance with 8.5.

8.3.6 NUMERICAL VALUES. All numerical values shown on drawings and specifications shall be expressed in the decimal format. Values shown as fractions are not permitted, particularly for inch-pound units. Fractions commonly used in inch-pound measurements must be converted to their decimal equivalents. For example, the fraction 1/8 must be represented by the decimal 0.125 or another round equivalent (e.g., 0.13) reflecting a reasonable accuracy.

For lengths, the smallest unit used should be the whole millimeter (e.g., 143 mm). Drawings should never show decimal millimeters (e.g., 142.3 mm) except when detailing a high precision part or product thickness.

When sizing objects or placing objects with respect to other objects, use preferred numbers and metric modules whenever possible. See section VII for information on preferred sizes and 11.1.7 for discussion on metric modules.

8.3.7 DUAL DIMENSIONING METHODS. Dual dimensioning is a procedure for showing values in units from two different measurement systems (e.g., metric and inch-pounds) or the same drawing. Dual dimensioning is a duplication of effort, hinders the learning process, clutters a drawing, and provides opportunities for confusion and errors in reading drawings. Dual dimensions shall not be used on metric projects except to describe interfaces with new nonmetric items or existing facilities, systems, or equipment, as authorized by the responsible design organization. The method used to dual dimension a drawing shall be either the position method, the bracket method, or by using a dual-unit table as described in this section.

8.3.7.1 Position Method. The position method shows the value in the primary measurement units (primary value) separated by a line from the value in the secondary measurement units (secondary value). When this method is used, a note shall be provided on the drawing explaining how the primary and secondary dimensions are identified. An example of the note is shown below. See figure 8-1 for a sample drawing that uses the position method.

Example: NOTE: $\frac{\text{MILLIMETER}}{\text{INCH}}$; MILLIMETER/INCH

8.3.7.2 Bracket Method. The bracket method shows the primary value followed by the secondary value in brackets. When this method is used, a note shall be provided on the drawing explaining how the primary and secondary dimensions are identified. An example note is shown below. See figure 8-2 for a sample drawing that uses the bracket method.

Example: NOTE: DIMENSIONS IN [ ] ARE MILLIMETERS.

8.3.7.3 Dual-Unit Tables. Dual dimensions may be shown in a table where a dimension is identified on the drawing by a letter. The letter is referenced on a table with the quantity listed in two applicable measurement units. This method is most practical when used on a drawing with limited space for dimensions. See figure 8-3 for a sample drawing using conversion tables.

8.4 TOLERANCE

Tolerances used shall be according to the ANSI version of the ISO system of limits and fits, as summarized in section VII and supplemented by appendix H.

8.5 NOTES

A general note should be included on the drawing stating that the drawing is metric and identifying the magnitude of the primary unit used. The magnitude of the unit is shown as the base unit with the proper prefix attached (e.g., millimeters). Then, no units are required on individual dimensions unless it is different from the primary unit defined in the note. Examples of general notes are shown below.

Examples: This is a metric drawing. All dimensions are in millimeters except as noted.

All units in this drawing are metric. All dimensions are in millimeters.

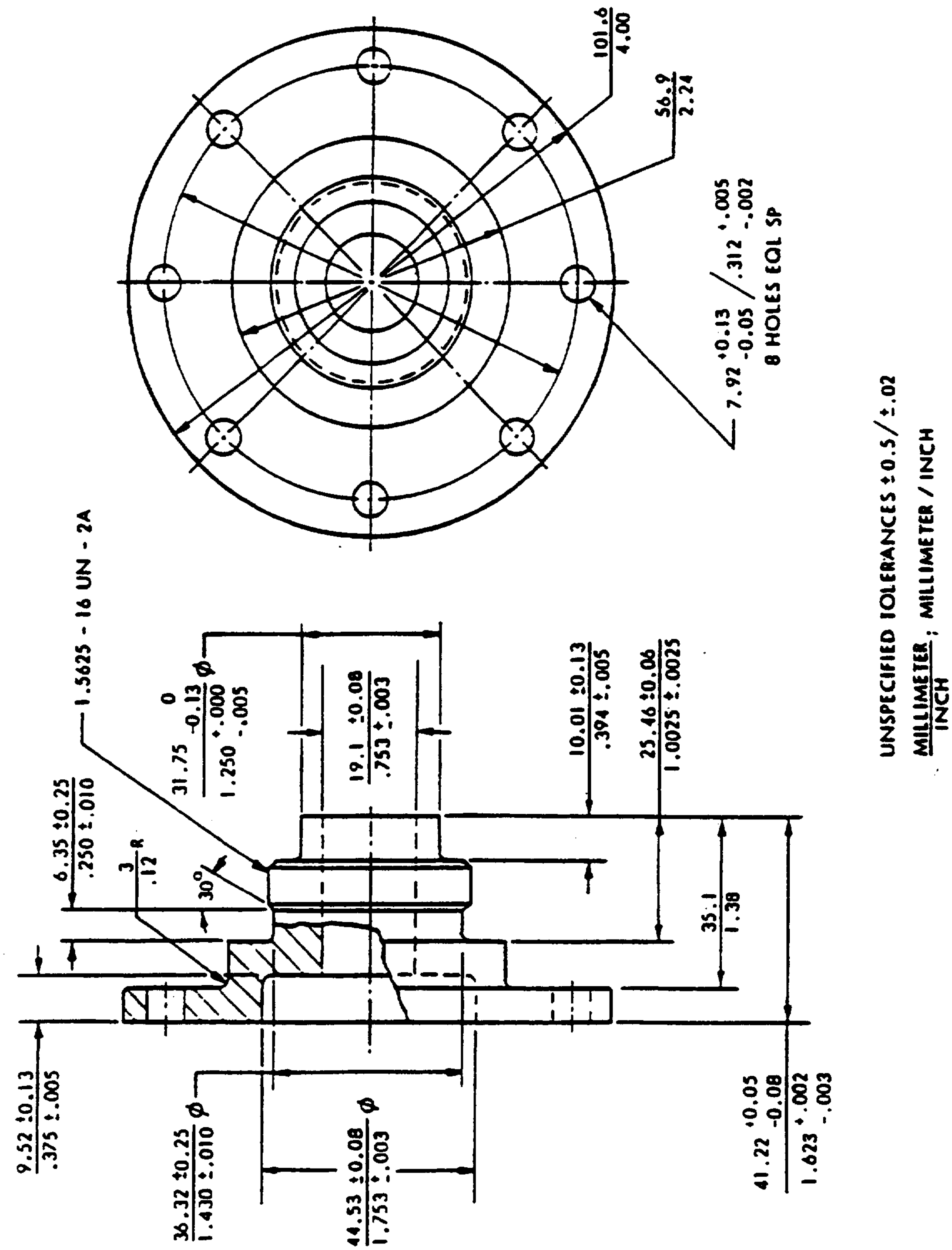
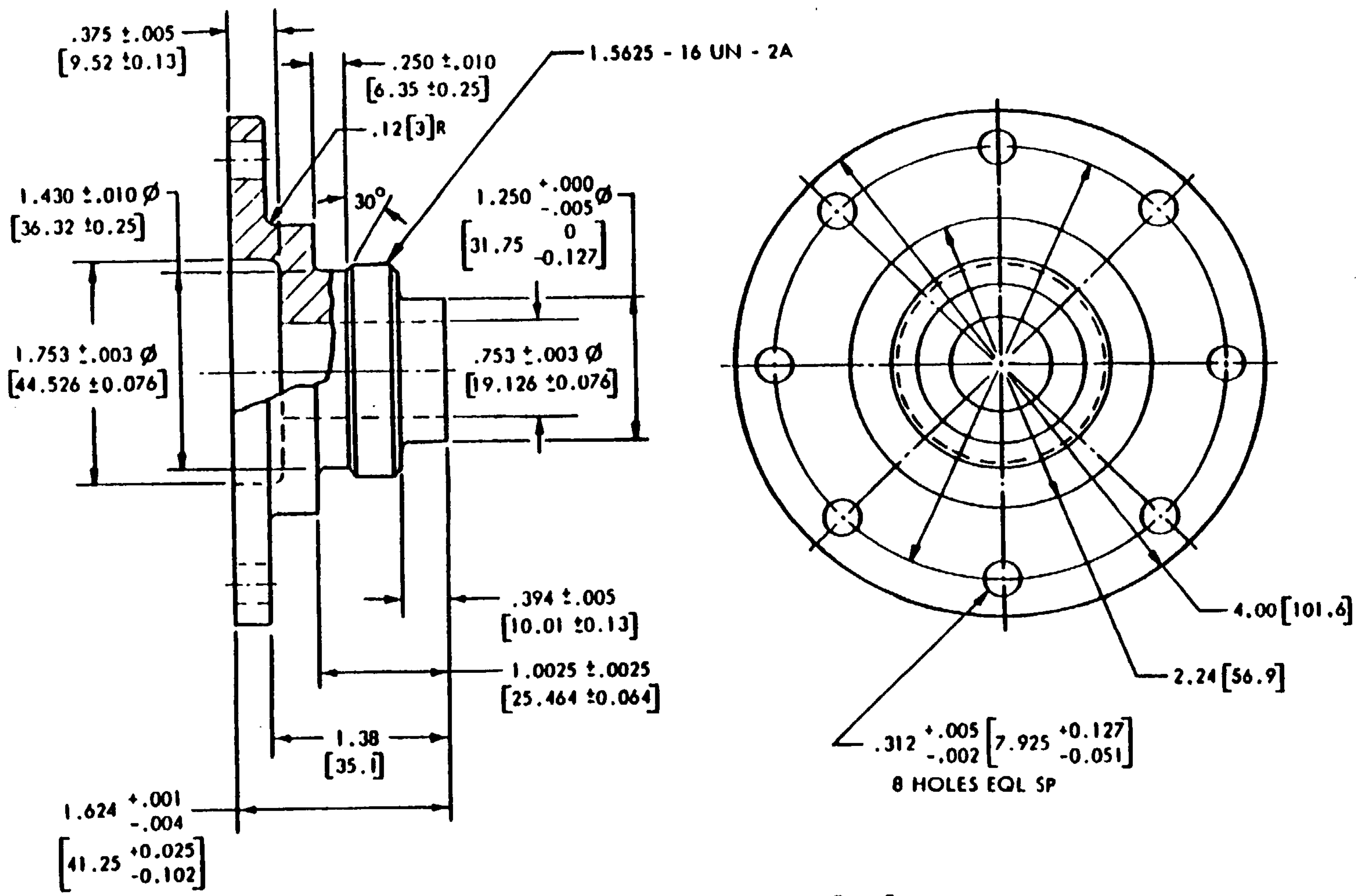
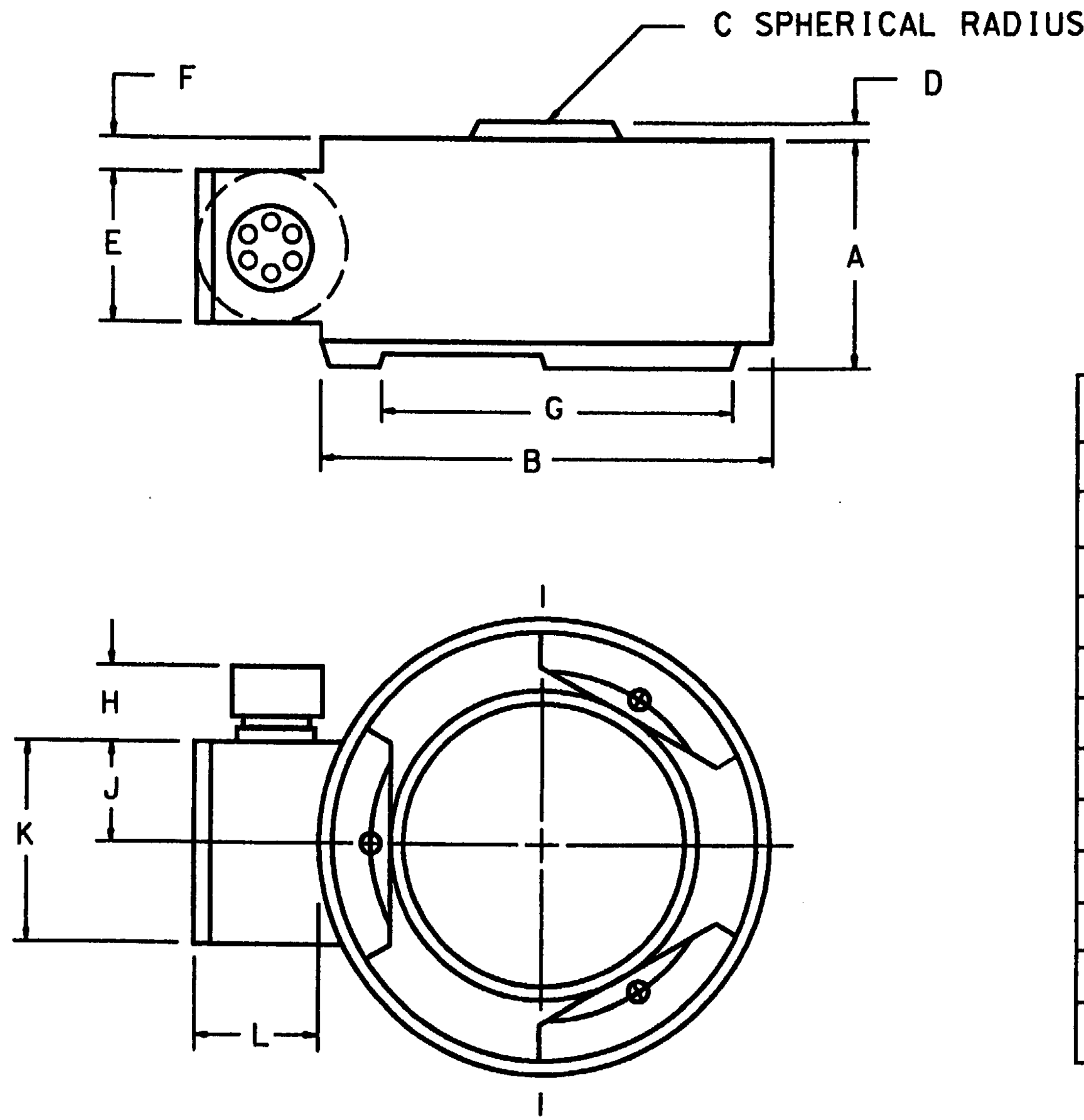


Figure 8-1. Position Method



UNSPECIFIED TOLERANCES ±.02[0.51]
DIMENSIONS IN [ ] ARE MILLIMETERS

Figure 8-2. Bracket Method



DIMENSIONAL DATA		
	IN	mm
A	0.68	17.3
B	1.35	34.3
C	2.00	50.8
D	0.05	1.3
E	0.45	11.4
F	0.10	2.5
G	1.06	26.9
H	0.23	5.8
J	0.30	7.6
K	0.60	15.2
L	0.38	9.7

Figure 8-3. Dual Dimensioning Using a Conversion Table

Notes identifying units used shall be added to each sheet of a drawing for clarity. The note may be part of the specific notes list or placed in a noticeable location.

Example: NOTE: ALL DIMENSIONS ARE IN MILLIMETERS (mm) UNLESS OTHERWISE NOTED.

8.6 COMPUTER-AIDED DRAFTING AND DESIGN (CADD) FILES

CADD drawing files should be set up using units of resolution compatible for both inch-pound and metric increments to facilitate conversion between the two measurement systems. For example, a resolution using 320 positional units per millimeter equates evenly to 8128 positional units per inch (no fractional or decimal units involved).

8.7 DRAWING FORMATS AND SHEET SIZES

Drawing formats shall remain in accordance with GP-435. The placement of all format features are soft conversions of the inch-pound dimensions. These format sizes produce net drawing areas that are within the sheet sizes of both standards, so drawings may satisfactorily be reproduced on either inch-pound or international standard sheet sizes (A series) by contact printing and microfilm projection methods until the supply of international standard paper sizes becomes more readily available. Table 8-4 lists both inch-pound and international format sizes in millimeters.

Table 8-4. Comparison of Standard Format Sizes

International			Inch-Pound		
Size	Width (mm)	Length (mm)	Size	Width (mm)	Length (mm)
A4	210	297	A	215.9	279.4
A3	297	420	B	279.4	431.8
A2	420	594	C	431.8	558.8
A1	594	841	D	558.8	863.6
A0	841	1189	E	863.6	1117.6
			F	711.2	1016.0

8.8 DRAWING PACKAGES

8.8.1 COVER SHEET. The cover sheet of the drawing should be labeled "SI METRIC" in large letters in a conspicuous location. In addition, each sheet shall identify the units used in accordance with 8.5.

8.8.2 CONVERSION CHARTS. To avoid confusion during the metric transition period, the first sheet of a drawing may include a conversion chart. The chart should include conversions for only the units included in the drawing. See figure 8-4 for an example of a drawing cover sheet with a conversion chart. Conversion charts are particularly beneficial when reference drawings are not in the same measurement system of units.

8.8.3 LIST OF ABBREVIATIONS. For metric drawings, the list of abbreviations shall not include any inch-pound unit abbreviations. Inch-pound unit abbreviations should only be listed in applicable conversion charts for hybrid systems or when existing inch-pound items are called out.

8.8.4 REFERENCE DRAWINGS. Reference drawings should be in the same measurement units and scale as the primary drawing if the reference drawing is created for the metric project. If it is not feasible or possible to rescale and dimension the reference drawing, include a conversion chart on the first sheet of the primary drawing.

8.8.5 SPECIFICATIONS. All specifications shall reflect the measurement system used on the drawings. All criteria listed in this document for drawings applies to associated specifications.

8.8.6 SELECTING PRIMARY UNITS. Drawings for each discipline (e.g., structural, mechanical, electrical, etc.) have standard magnitudes for units. For example, the primary dimensional unit for mechanical design is millimeters. See section XI for units to be used for each discipline.

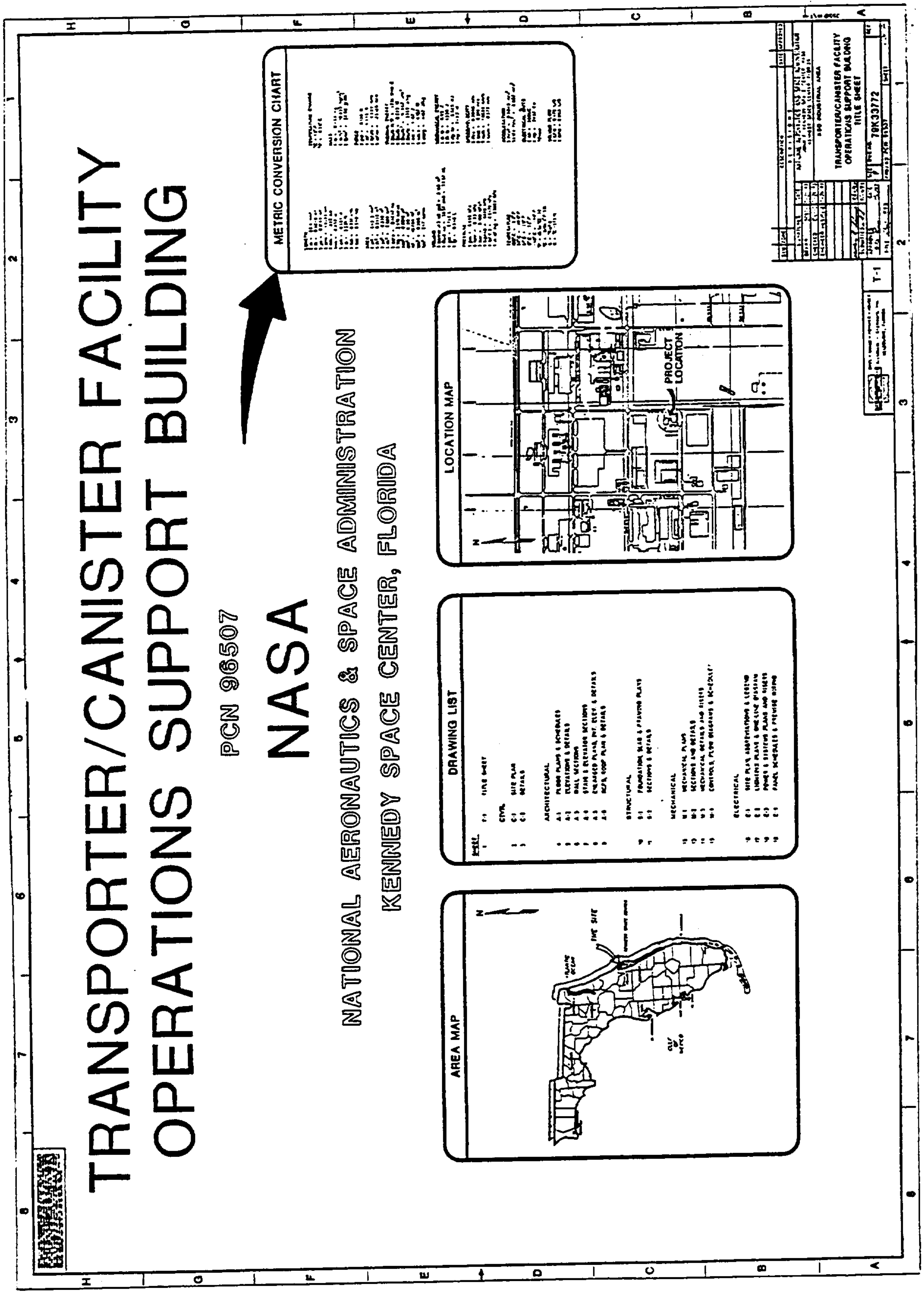


Figure 8-4. Example of a Metric Drawing Cover Sheet

SECTION IX

PRESENTATIONS AND TECHNICAL DOCUMENTATION

9.1 INTRODUCTION

This section provides recommendations on including measurements in technical writing situations such as presentations, reports, manuals, data packages, standards, specifications, and other official publications and documentation.

9.2 DEFINITIONS

a. Document, Hybrid - A hybrid document is one in which some requirements are given in rounded, rational metric units, and others are given in rounded rational inch-pound units. Hybrid documents may be required for use in new designs that use existing nonmetric components interfacing with metric components.

b. Document, Inch-Pound - Inch-pound documents have requirements given in rounded, rational, inch-pound units only, usually as a result of being originally developed using the inch-pound system. Inch-pound documents are developed for items to interface or operate with other inch-pound items.

c. Document, Metric - Metric documents have requirements given in rounded, rational, metric units only, usually as a result of being originally developed in metric. Documents containing units that are the same in both the metric and inch-pound systems (e.g., volt, ampere, ohm) are classified as metric documents. Documents containing dimensional interfaces must have these interfaces in metric sizes to be classified as metric documents. Metric documents are developed for items to interface or operate with other metric items.

d. Document, Not-Measurement-Sensitive - A not-measurement-sensitive document is one in which application of the requirements does not depend substantially on measured quantities. This type of document can be used with either a metric system or an inch-pound system.

9.3 PRESENTATIONS AND MEETINGS

Presentations should be written giving numbers in the measurement system used for the design requirements of the program or project. Information presented that is not program/project oriented should use SI units. Soft conversions of inch-pound units to SI units are acceptable and encouraged in management presentations. For metric design programs, it is recommended that in presentations dual units (inch-pound units in parentheses) be used as required for clarity at the discretion of the program office. Likewise, for inch-pound programs, it is recommended that SI units be displayed in parentheses following the inch-pound units.

Measurements in reports, data packages, standards, technical interchange meetings, and reviews of new systems are to be in SI, unless waived in accordance with NMI 8010.2. Summaries may be reported in dual units with the values of the primary measurement system being written first followed immediately by the values of the secondary measurement system given in parentheses. It is not necessary to convert existing information.

9.4 TECHNICAL DOCUMENTATION

There are several approaches to including SI units into new and existing documents, standards, specifications, and other technical documentation: (1) creating a parallel document; (2) adding a metric appendix; (3) inserting metric notes and equivalent values; or (4) incorporating metric information into other official documents. The system of units used in the document should be identified on the cover page of the document. This is accomplished by adding a "logo" to the cover page that identifies the units used. It is placed in the upper left corner of the cover page opposite the document number. The logos used and the corresponding document number indicators should be as described in the following paragraphs for documents that contain both SI and inch-pound units, documents containing only metric units, documents that have separate SI and inch-pound versions, and documents that are not measurement sensitive. If a document contains only inch-pound units and is not a document written solely for use by a metric-exempted program (e.g., Shuttle, Space Station, etc.), the document should be revised to include SI units. Documents written using only SI units shall not be revised to include inch-pound units. The following paragraphs describe each approach mentioned above and explain the method of identifying the measurement system used in the document.

9.4.1 PARALLEL DOCUMENT. For very complex documents filled with many conversions, the logical method is to issue a separate SI document. Great care should be used to ensure that the new document is hard metric and that equivalents are carefully selected. After that, the basic document and the metric document would be revised concurrently until such time as the inch-pound version is no longer required and is cancelled. Documents that have separate, standalone versions, where each contains units of only one measurement system, have different designations on the cover page of each version. The cover of the SI version shows the METRIC logo in the upper left corner of the page. The document number contains a lower case m in parentheses immediately following the document number and before any applicable revision letters, as shown in the example.

Example:

METRIC

KSC-STD-164(m)B

The cover of the inch-pound version does not show a logo and the document number does not contain any indicator of the units used.

Example:

KSC-STD-164B

9.4.2 METRIC APPENDIX. For less complex documents, or for very complex documents where retention of the original document number is considered necessary, a metric appendix may be prepared. The basic document would remain in inch-pound units with reference to the appendix for metric information. The appendix would refer to the basic document for technical features and cite only the metric equivalents, exercising care to ensure that equivalents are carefully selected. A standard or specification that contains both SI and inch-pound unit references exhibits a METRIC/INCH-POUND logo on the cover of the document and carries either a basic number or, if it is a revision, is raised to the next revision letter. The logo is placed on the upper left corner of the page opposite the document number. Writing of the SI units in the text shall follow the rules for units, symbols, style, and usage as described in sections II through IV.

Example:

METRIC/INCH-POUND

KSC-STD-164B

9.4.3 METRIC NOTES AND EQUIVALENT VALUES. For relatively simple documents with only a few measurement units, the secondary measurement system units may be added in parentheses directly after the primary measurement system units in the text. Another way of adding the alternate units is to add an appropriate note or footnote. This is the preferred method for documentation in international business. See 9.5 for specific information on incorporating dual units in text. The document measurement system logo would be as described in 9.4.2.

9.4.4 METRIC INFORMATION IN OTHER DOCUMENTATION. Other documents may be used in lieu of developing separate metric specifications or standards for a project. Metric requirements may be inserted into contracts or other official documentation which may be a convenient avenue for conveying the information.

No special logo or other identification is required on other documentation used to define metric requirements. Identification of the measurement system used should be noted, though, in an appropriate introductory section of the document.

9.4.5 DOCUMENTS CONTAINING SI UNITS ONLY. A standard or specification that contains only SI units exhibits a METRIC logo and document number according to the format identified in 9.4.1. Usage of the SI units in the text shall follow the rules for units, symbols, style, and usage as were described in sections II through IV. Also, see 9.4.1 for additional information.

Example:

METRIC

KSC-STD-6(m)C

9.4.6 NOT-MEASUREMENT-SENSITIVE DOCUMENTS. Documents that do not contain information dependent on any particular measurement system are considered to be not measurement sensitive and are labeled as such on the cover. No changes to the document number are required.

Example:

NOT MEASUREMENT SENSITIVE

KSC-STD-164B

9.5 WRITING TEXT CONTAINING MEASUREMENT UNITS

All rules for style and usage shall apply as described in sections II through IV of this handbook when writing a document that references SI values. In documentation, it is preferred that numbers be used with unit symbols. For example, "6.5 m/s" is preferred over "6.5 meters per second."

9.5.1 TEXT CONTAINING ONLY SI VALUES. Where it has been standard practice to cite metric units alone, such as citing temperatures only in degrees Celsius, the inch-pound equivalents may be omitted. The following example is a paragraph written using only SI units.

Example: The average rate of fall shall be 6.5 m/s with a 12-m minimum fall to reach the terminal velocity. In those cases where wind speed is to be included in the test, the following values shall be used: steady state of 5.1 m/s and gusts to 15.4 m/s lasting 2 min and applied every 15 min.

9.5.2 TEXT CONTAINING BOTH SI AND INCH-POUND VALUES. The primary measurement system units shall be shown first with the units of the secondary measurement system shown in parentheses immediately following the primary reference. Since the Executive Order 12770 mandates the use of SI for the Federal government, SI is considered the primary measurement system of units. If the documentation is written for an exempted program (see 1.4), the primary measurement system of units shall be the system the program uses for design of hardware.

Examples: In the free field at distances less than 3 m (10 ft) from the boundary of the plumes, the distribution of pressure amplitudes ....

The air velocity flowing across the wet bulb shall not be less than 4.6 m/s (15 ft/s). Provisions shall be made for controlling the flow of air throughout the internal test chamber area where the velocity of air shall be maintained between 0.5 m/s to 2 m/s (1.6 ft/s to 6.6 ft/s). Distilled or deionized water having a pH value between 6.5 and 7.5 at 25 °C (77 °F) shall be used to obtain the specified humidity.

When a value is referenced in two measurement units and is repeated several times throughout a paragraph, the reference for the secondary unit does not have to be repeated again in the same paragraph.

Example: Ball valves shall conform to requirements specified herein. Valves shall be rated for service at a gage pressure not less than 1.2 MPa (175 psi) at 93 °C (200 °F). Valve bodies in sizes 50 mm (2 in) and smaller shall be screwed-end connection-type constructed of Class A copper alloy. Valve bodies in sizes 65 mm (2.5 in) and larger shall be flanged-end connection type, constructed of Class D material. Balls and stems of valves 50 mm and smaller shall be manufacturer's standard with hard chrome plating finish. Balls and stems of valves 65 mm and larger shall be manufacturer's standard Class C corrosion-resistant steel alloy with hard chrome plating ....

9.5.3 TEXT CONTAINING NOMINAL VALUES. When nominal inch-pound values are used in text, use nominal metric size equivalents if known. Otherwise, soft convert the actual inch-pound dimensions to SI units. Refer to the soft-converted values first and then show the nominal value in parentheses to provide a reference for clarity.

Examples: Partitions shall be framed with 38 mm by 90 mm (2 by 4 nominal) wood studs spaced 400 mm on center.

Sheathing shall be 20 mm by 190 mm (1 by 8 nominal) boards, installed at 90 degrees to the bearing surface with at least two 3-mm (8-penny) nails at each bearing.

The pipe size used is 50-mm (2-in) nominal.

9.6 TABLES USING TWO MEASUREMENT SYSTEMS

9.6.1 TWO MEASUREMENT SYSTEMS, ONE COLUMN. Two sets of units may be shown in the same column of a table. As in writing text, values of the primary measurement system are written first followed immediately by the value of the secondary measurement system. The unit symbols may appear with the respective value or shown at the column heading as shown in the following two examples.

Example:

Summer Test		Winter Test	
Before	During	Before	During
3 °C (90 °F)	24 °C (75 °F)	13 °C (55 °F)	10 °C (50 °F)

or:

Summer Test		Winter Test	
Before °C (°F)	During °C (°F)	Before °C (°F)	During °C (°F)
3 (90)	24 (75)	13 (55)	10 (50)

9.6.2 TWO MEASUREMENT SYSTEMS, TWO COLUMNS. If space permits, each value of each measurement system may be shown in its own column. The heading of each column shall clearly indicate the units for the values shown in that column.

Example:

Period (min)	Rate (mm/h)	Rate (in/h)
10	13	0.5
3	221	8.7
5	89	3.5
42	13	0.51

9.7 FIGURES USING TWO MEASUREMENT SYSTEMS

The use of both SI and inch-pound measurements on a drawing or other pictorial illustrations to be used in a standardized document should be avoided. It is preferred that tables be used to translate specific inch-pound units to metric units. See 8.3.7.3 for proper methods of using tables in drawings.

SECTION X

COMPUTER AND KEYBOARD APPLICATIONS

This section describes accepted symbols of SI units and prefixes to be used with data interchange (computer) systems with limited types and numbers of keyboard characters (also called limited character sets) primarily in systems where computers communicate with other computers and require no communication with humans. Some of these symbols are also used in electrical work. These character representations are not to be used if all the characters and symbols for the international symbols, as described in sections II and III, are available. The symbols described in this section shall not be used for transfer of information to the public or for publications. Instead, the full names of units and proper SI symbols shall be used. Refer to ANSI X3.50 and IEEE Std 260 for additional information.

10.1 SINGLE- AND DOUBLE-CASE SYSTEMS

Single- and double-case systems are those keyboard-controlled systems primarily composed of letters, numbers, and punctuation symbols. These systems probably are not capable of producing the Greek letters µ and Ω, the degree sign (°), and superscript functions. Each system is described in the following paragraphs. In several cases, a letter represents two different units or prefixes. The context of the information presented should not lead to confusion over the meaning. If so, the units should be spelled out to avoid ambiguity. Examples of representations with two definitions are M for milli and meter, N for newton and nano, H for hecto and hour, S for second and siemens, T for tesla and metric ton, and A for ampere and atto. Table 10-1 shows the accepted representations for SI units for both single-case and double-case systems. Prefixes for both systems are shown in table 10-2.

10.1.1 SINGLE-CASE SYSTEMS. Single-case systems are those systems that are capable of using only upper-case letters or only lower-case letters, numbers, and the characters hyphen (-), period (.), and slant (/).

10.1.2 DOUBLE-CASE SYSTEMS. Double-case systems are those systems that are capable of using both upper-case and lower-case letters, numbers, and the characters apostrophe ('), quotation marks ("), hyphen (-), period (.), and slant (/). All capitalized letters remain so even with the prefix attached.

Example: MOhm (for megohm) not: Mohm

Table 10-1. Single- and Double-Case Representations of SI Units

Name of Unit	International (Common Use) Symbol	Single Case Representations		Double Case Representations
		Lower	Upper	
Base SI Units:				
meter (metre)	m	m	M	m
kilogram	kg	kg	KG	kg
second	s	s	S	s
ampere	A	A	A	A
kelvin	K	K	K	K
mole	mol	mol	MOL	mol
candela	cd	cd	CD	cd
Supplementary units:				
radian	rad	rad	RAD	rad
steradian	sr	sr	SR	sr
Derived SI units:				
hertz	Hz	hz	HZ	Hz
newton	N	n	N	N
pascal	Pa	pa	PA	Pa
joule	J	j	J	J
watt	W	w	W	W
coulomb	C	c	C	C
volt	V	v	V	V
farad	F	f	F	F
ohm	Ω	ohm	OHM	Ohm
siemens	S	s	SIE	S
weber	Wb	wb	WB	Wb
degree Celsius	°C	cel or c	CEL or C	Cel or C
tesla	T	t	T	T
henry	H	h	H	H
lumen	lm	lm	LM	lm
lux	lx	lx	LX	lx
becquerel	Bq	bq	BQ	Bq
gray	Gy	gy	GY	Gy
sievert	Sv	sv	SV	Sv
Other units:				
grade (angle)	g(s)*	gon	GON	gon
degree (angle)	°(s)*	deg	DEG	deg
minute (angle)	′(s)*	min	MIN	′(s)* or min
second (angle)	″(s)*	sec	SEC	″(s)* or sec
liter (litre)	l	l	L	l
are	a	a	ARE	a
minute (time)	min	min	MIN	min
hour	h	h	HR	h
day	d	d	D	d
year**	a	a	ANN	a
gram	g	g	G	g
bar	bar	bar	BAR	bar
electronvolt	eV	eV	EV	eV
atomic mass unit	u	u	U	u

* (s) indicates symbol is used in the right superscript position (like an exponent).

** This representation is most suitable for international exchange. The use of the designations yr and YR are acceptable for U.S. interchange.

Table 10-2. Single- and Double-Case Representations of SI Prefixes

Prefix	Factor by Which Unit is Multiplied	International (Common Use) Symbol	Single Case Representations		Double Case Representations
			Lower	Upper	
exa	10^{18}	E	ex	EX	E
peta	10^{15}	P	pe	PE	P
tera	10^{12}	T	t	T	T
giga	10^{9}	G	g	G	G
mega	10^{6}	M	ma	MA	M
kilo	10^{3}	k	k	K	k
hecto	10^{2}	h	h	H	h
deka (deca)	10^{1}	da	da	DA	da
deci	10^{-1}	d	d	D	d
centi	10^{-2}	c	c	C	c
milli	10^{-3}	m	m	M	m
micro	10^{-6}	µ	u*	U*	u*
nano	10^{-9}	n	n	N	n
pico	10^{-12}	p	p	P	p
femto	10^{-15}	f	f	F	f
atto	10^{-18}	a	a	A	a

* When used in documentation that will be reproduced or printed, add a "tail" by hand to the letter to create the µ letter.

10.2 SPACING

In free text or narrative situations, a space should be used between the value and the unit, as described in 4.5. A space between a value and unit symbol is optional for formatted data since the particular format is defined in the computer program.

10.3 PRODUCTS OF UNITS

Multiplication of two or more units is represented by a period between the unit symbols, instead of the raised dot as described in 4.3.1.

Example: Pa.s (for pascal second)

10.4 DIVISION OF UNITS (RATIOS)

Division and ratios of units are indicated by a slant (/). Denominators may also be expressed with negative exponents (see 10.5).

Example: m/s (for meters per second)

10.5 POWERS

If superscript capabilities are not available, an exponent is written immediately following the unit symbols as shown in the following paragraphs.

10.5.1 POSITIVE EXPONENTS. Positive exponents are represented by the exponent value (without a sign) placed immediately following the unit symbol.

Examples: M3 (for cubic meter)
mm2 (for mm^2)

10.5.2 NEGATIVE EXPONENTS. Negative exponents are represented by the negative sign and the exponent value immediately following the unit symbol.

Examples: M-3 (for $1/m^3$ or m^{-3})
W.m-2 or W/m2 (for W/m^2)

10.6 PREFIXES

Adding a prefix to unit symbols follows the same rules expressed in section III, particularly that no space or other symbol is used between the prefix and the unit symbol. A prefix never stands alone or with any other prefix (i.e., no compound prefixes).

SECTION XI

SCIENCE, ENGINEERING, AND CONSTRUCTION

This section discusses the units used in general, science, engineering, and construction applications. The units identified in the following paragraphs may need to be modified to show the proper prefixes when magnitudes of values warrant that change following the rules in the previous sections. Refer to appendix G for applicable conversion factors.

11.1 PROJECT CONSIDERATIONS

A project is "metric" when drawings, specifications, and procedures show only SI units; construction, fabrication, or implementation takes place in only SI units; and inspection occurs in only SI units. This does not imply that every item used in the project is originally designed in metric units. It does imply that all the information describing and defining components and materials that are identified in drawings, specifications, and product literature be in metric units, a process that involves soft conversion.

The decision on whether to use hard metric or soft metric conversion must be based on knowledge, experience, and common sense. Consideration should include product and material availability and impact to the project schedule and cost. Hard metric products should be selected when procurement lead times are within the schedule and when costs are reasonable and do not become a significant percent of the budget. See 11.1.8 for additional discussion on acquiring metric products and materials.

The following paragraphs describe metric usage and conversion in various types of projects, drawings, and specifications. Also provided are recommended wording for advertisements, announcements, and project definition (e.g., statements of work).

11.1.1 TYPES OF PROJECTS.

11.1.1.1 <u>New Construction and Fabrication</u>. New facilities, systems, and equipment shall be specified in metric, whether hard metric or soft converted (see 11.1.3), in accordance with program or project requirements (see 1.4).

11.1.1.2 <u>Renovation</u>. The use of CADD has simplified the execution of metric modification and renovation projects. These projects include refurbishment, remodeling, and replacement of systems, equipment, or facilities. Major modification makes it feasible to install entire systems and components in metric sizes. Examples include installing a new ceiling system using 600- by 600-mm components is practical even though the original ceiling was made of a different modular size; or installing a new air-handling system specified in metric. In small projects, consideration should be given to the cost of metric products and lead times to determine the practicality of installing new metric items.

When converting portions of a system to metric, consider converting the entire system's operational controls for safety and maintainability reasons. For example, it would be unsafe to control HVAC in a new part of a building using the Celsius temperature scale and the preexisting part using the Fahrenheit scale. It is not as important that some portions of the HVAC system's physical components are metric and some are not, as long as all of the system's monitoring controls are in the same system.

11.1.1.3 Demolition. Some projects may involve complete or partial demolition of existing facilities, systems, or equipment. Some items may be disposed of or saved for storage, reinstallation, or refurbishment. When storage or complete demolition and disposal are specified, there would be no need to convert any part of the project to metric; often times, portions of old drawings are used only to identify areas to be dismantled. If items are to be saved for reinstallation or refurbishment, it may be required that those items be soft converted to metric.

11.1.2 DRAWINGS. Notations on drawings shall follow the guidelines outlined in section VIII except as noted in this section. Shop drawings should use the same dimensions as on contract documents to avoid errors in translation.

In building design, the following scale ratios shall not be used: 1:25, 1:75, 1:80, and 1:125. See section VIII for the table of preferred scales. Generally, dimensional units for scale ratios from 1:1 up to 1:200 should be in millimeters exclusively. Scales with ratios greater than 1:200 should be in meters.

Each sheet of the drawing should have a note identifying the primary dimensional unit (e.g., "ALL DIMENSIONS ARE MILLIMETERS (mm) UNLESS OTHERWISE NOTED."). Then, it is unnecessary to include units on each dimension. Round to whole millimeters unless greater precision is required; SI drawings should almost never show decimal millimeters unless for a high precision part or a product thickness being detailed.

Dual dimensions should not be used except as specified in 1.5 and 8.3.7. Wherever dual units are employed, the design unit precedes the equivalent unit with the unit employed for verification of tolerance identified with an asterisk (*). For example, if a space vehicle is designed in the inch-pound system of units, dual units at a payload interface would be shown as millimeters*(inches) [e.g., 255.0* mm (10.04 in)].

11.1.3 SPECIFICATIONS.

11.1.3.1 Units. All measurements in specifications must be stated in metric units, whether they are hard metric or soft converted. Specifications should use the same measurement units as the drawing. For example, if the drawing uses millimeters, then the specifications should use millimeters. If two sets of units are used for hybrid/interface systems, the specifications should also reflect the dual units for the appropriate items. The policy of the National Institute of Building Sciences (NIBS) is that "wherever the use of an inch-pound measure serves to clarify an otherwise familiar metric measure, the inch-pound unit may be placed in parentheses after the metric measure," (e.g., 38 mm by 80 mm [2 by 4 nominal)].

The millimeter is the length unit used for almost all measurements and is consistent with dimensions in major codes, such as the National Fire Protection Association's (NFPA's) National Electrical Code and Building Officials and Code Administrators' (BOCA's) National Building Code (NBC). Use of the millimeter provides dimensions for products and buildings that are integers, thus eliminating decimals. It is acceptable to use large numbers of millimeters, often with five and six digits (e.g., 150 000 mm, 45 600 mm). Meters may be used for very large, rounded sizes, as applicable. Centimeters are never used in construction.
In some instances, it may be less confusing to describe dimensions in terms of more basic units, such as for areas in terms of the linear dimensions defining the space (e.g., area 5 m by 20 m for storage of materials).

11.1.3.2 Products. Refer to metric or dual unit codes and standards, check product availability, and specify metric products. Modular products will be available in sizes based on multiples of 10, 100, or other metric modules or preferred sizes. Most products will be relabeled in metric units resulting in no difference between the physical size of the metric products and inch-pound products. Nominal designations based on inch-pound sizes will be replaced with new metric-based names. See 11.1.8 for additional information on metric products and materials.

11.1.3.3 Conversion. Use professional rounding to 100-mm modules when preferred sizes (e.g., 200, 500, 1000, etc.) are not practical. In each case, the user must determine the acceptable choice, aiming for clean, rounded metric dimensions as alternatives. Simple mathematically converted dimensions should not be used. It is not recommended that metric measurements be converted to inch-pound units for manufacture or construction and then converted back to metric. This "round-trip" conversion (see 6.3.4) can cause mistakes in the translation where parts out of tolerance and incorrect quantities of materials are delivered. Contractors are cautioned at preconstruction meeting not to do round-trip conversions as such errors are at their expense. See 6.5 for additional information on conversion practices using professional rounding.

11.1.3.4 <u>Construction Specifications</u>. Terminology similar to the following paragraphs should be included in Division One of construction specifications.

> "During the prebid conference, a session will be specifically devoted to metric. The 95-percent rule will be explained, showing that most products specified are the same products contractors are currently using, only specified in metric dimensions. All hard metric products used on the project will be identified and discussed. Contractors will be cautioned that they should ask suppliers about delivery schedules on hard metric products and not assume they are the same as inch-dimensioned ones.
>
> "All correspondence must use SI metric units exclusively. All cost data submitted by the contractor in a proposal or any other submission must be in metric units. All shop drawings, catalog cuts, and other submittals must be submitted with metric units and dimensions that clearly demonstrate conformance with the metric units given in the drawings and specifications. Metric supplements to existing product literature or data will be accepted on bond paper.
>
> "All operation and maintenance (O&M) material must be submitted with metric units and dimensions that clearly demonstrate conformance with the metric units given in the drawings and specifications. Metric supplements to existing O&M material will be accepted on bond paper.
>
> "All meetings and presentations which involve discussion of measurements or units must be conducted in SI units."

11.1.4 STATEMENTS OF WORK. The following information shall be added to the appropriate parts of the statements of work to direct architectural and engineering firms (A&E's) to do the project in metric.

> "2.0 INTERNATIONAL SYSTEM OF UNITS
>
> "This facility [or project] shall be designed using the International System of Units (SI). With the exception of a conversion table on the cover sheet of the design drawings, all dimensioning shall be exclusively in metric units. This shall also hold true for the project specifications, cost estimates, test reports, data manual, and any other submissions.

"Where possible and economically practical, specified materials shall be American-made hard-metric products. The A&E shall provide a justification for any nonmetric materials specified, which must then be approved by the Contracting Officer's representative. Documentation of this "justification" shall be included in the data manual."

"4.2.2 SPECIFICATIONS

"The A&E shall be responsible for modifying any specification sections used that have not already been converted to the International System of Units. The lead design engineer shall confer with the SPECSINTACT office (BOC-263) (407-853-2292) for a copy of existing metric specifications.

"First Submittal	Each section shall be modified, as required, to reflect the SI system of measurement. Newly modified individual sections shall be left in their generic formats; i.e., editing notes shall not be deleted and no red-lines should be made. The intent is to create a boilerplate metric specification for future use at KSC. A copy of the project diskettes shall be included in this submittal."

11.1.5 A&E AND CONSTRUCTION MANAGEMENT SCOPE. The following terminology is recommended for insertion into each A&E scope of work:

"Metric Measurement.

"Measurements and units of any type, on all submissions of this project, shall be shown in SI metric units exclusively. Non-SI measurements shall not appear in reports, drawings, specifications, or any other submissions. A&E firms must strive to utilize as many hard-metric products as possible.

"All cost estimating should be submitted in metric units only. All correspondence should be written in SI units exclusively. All shop drawings, catalog cuts, and other construction phase material shall be submitted in metric units. Submit all operations and maintenance manuals in metric units."

11.1.6 ANNOUNCEMENTS AND ADVERTISEMENTS.

11.1.6.1 Commerce Business Daily (CBD). Advertisements in the CBD for A&E or construction management (CM) solicitations should state the area of the project in square meters only (e.g., "The new building will be approximately 15 000 square meters of occupiable office and storage space."). Each announcement should state: "This project will be designed and built entirely in metric units."

11.1.6.1.1 A&E Firm Announcements. A&E firm announcements, including term contract announcements, should include the following sentence as an evaluation factor: "Familiarity with the metric system and ability to design in metric units." Metric experience should not yet be mandated. Although many firms have substantial metric experience, many excellent design firms have not yet had an opportunity to perform metric design work.

11.1.6.1.2 Construction Management Announcements. Construction management announcements, including term construction management announcements, should include the following sentence as an evaluation factor: "Familiarity with the metric system and ability to perform required services in metric units."

11.1.6.1.3 Construction Advertisement. The following phrases should be used for each CBD advertisement for construction projects designed in metric. The area of the project should be shown in metric dimensions only [e.g., This project involves the renovation of a 24 000 gross square meter (GSM) building.]. Then, state: "This project has been designed completely in metric units. All testing will use metric units. Shop drawings and product literature must be submitted with metric dimensions. Supplements to existing product literature will be accepted on bond paper."

11.1.6.2 Request for Proposal (RFP). Each RFP shall require a summary of the firm's metric experience, its experience with the metric system, and its ability to perform required services in metric units.

11.1.7 METRIC MODULES. Metric modules are basic sizes reflecting even or rounded numbers of units. The basic metric module is 100 mm. Table 11-1 shows the basic metric module, submodules, and multimodules and their approximate inch equivalents. The multimodules and submodules, in preferred order, are 6000, 3000, 1200, 600, 300, 100, 50, 25, 20, and 10.

Table 11-1. Metric Modules

	Millimeters	Close to
Basic module	100	4 inches
Submodule	50 25 20 10 5	2 inches 1 inch - - -
Multimodules	300 600 1200 3000 6000	1 foot 2 feet 4 feet 10 feet 20 feet

11.1.8 PRODUCTS AND MATERIALS. Over 95 percent of the products used in building construction today will undergo no physical changes at all during the metric transition. All that will occur is that the dimensions of the product will be identified in drawings, specifications, and on product literature in metric units, a process of soft conversion. Most standard products will not change physical dimensions but will be soft converted. Custom products may be specified in metric dimensions since their manufacture is performed using computer-controlled machinery (e.g., wood doors, glass and windows, metal ductwork, interior stonework, and precast facade systems). Determining whether to select only hard metric products and materials should be based upon whether there is a significant impact to the schedule for longer lead-time items or budget. Some hard metric products may have minimum order quantities which may limit their use to larger projects. Most products, however, are the same dimensions in both measurement systems and can easily be used on any project.

11.1.8.1 Modular Products. Products that will change physically to be hard metric are those that are modular in nature. These products include air diffusers and grilles (lay-in type), brick and concrete masonry units (at the option of the contractor), drywall, fluorescent lighting fixtures (lay-in type), raised access flooring, and suspended ceiling tiles and grids.

11.1.8.2 Tolerance. Tolerances should be in accordance with section VII except in the situations when established tolerances are not feasible while soft converting to metric. Use professional judgment in converting the tolerances. If possible, add or select tolerances so that materials in either metric and inch-pound sizes fit the specifications, thus increasing the number of products available from which to select. This concept is illustrated in the following example.

Example: Select a tolerance for thickness of 14-gage steel plate.

The preferred metric specification for thickness of 14-gage plate in metric is 1.9 mm. The actual thickness is 1.9939 mm (0.0785 in). The plate may be specified to be a minimum thickness of 1.9 mm. This allows for the thicker inch-dimensioned material without violating the size specification. An alternate method of specifying the thickness is to write a particular tolerance, such as 1.9 +0.095 0.000 mm.

11.1.9 TOOLS. All metric work shall be performed using tools and other necessary equipment that measures in proper metric units. It is not important whether the tools are designed in metric as long as it properly measures in metric units. To prevent errors in construction and fabrication, it is recommended that no tools measuring in nonmetric units be permitted in the immediate work area. Experience, though, has shown that it has been helpful for dual metric/inch-pound tape measures to be used initially to help employees become accustomed to the new measurement units.

Many tools are available from the General Services Administration (GSA) and can be ordered from the Standardization and Control of Industrial-Quality Tools catalog.

11.1.10 TRAINING. As briefly discussed in 1.7, training should be performed as close to the beginning of a new metric project as is possible. This training time would be different for each type of job. For example, on a facilities project, architects and engineers would need to be trained prior to the design phases of the project; tradespeople would need training just before construction. It may also be beneficial to conduct short training sessions periodically throughout the project phases to ensure proper understanding of SI measurements, usage, and implementation using metric tools.

11.1.11 INSPECTION. Proper inspection is critical to the success of a metric project, particularly during the transition period when many employees are unfamiliar with the SI measurement system. It is imperative that inspectors have a thorough understanding of SI and of the metric requirements for the project. Improper inspection leads to rework, schedule delays, and cost overruns.

Inspections shall be performed using metric gages, tools, and other inspection equipment whenever practicable. This is particularly important when verifying fine tolerances. Using metric inspection devices on metric-defined parts and dimensions prevents the loss of tolerance and errors as a result of conversion.

11.2 GENERAL SCIENCE AND ENGINEERING

11.2.1 LENGTH/LINEAR MEASUREMENTS. The primary linear measure for most engineering work is the millimeter. The meter is used in major dimensions in calculations and on drawings. Use of the millimeter and meter improves clarity and saves space and time in drawing, typing, and computer applications. Other units may be used in special circumstances, such as using meters and kilometers for long distances and micrometers for precision measurements. Millimeters provide integer measurements within tolerances with millimeters, thus eliminating decimals and fractional units. The centimeter shall be avoided because it is not a consistent submultiple of 1000 based on the meter; it can be confused easily with millimeters with only a factor of 10 difference. When centimeters are shown in documents for such things as snow depth, body dimensions, or carpet sizes, etc., convert them to either millimeters or meters.

When writing length measurements, whole numbers always indicate millimeters (e.g., 3600, 300, 25). Lengths up to 3 ft 3-5/16 in (998.54 mm) can be represented in whole millimeters to three digits; up to 32 ft 9 in (9982.2 mm) can be represented by whole millimeters to four digits; and up to 328 ft (99 974.4 mm) can be written in whole millimeters to five digits. Decimalized expressions to three places indicate meters (e.g., 3.600, 0.300, 0.025); although, meters may also be carried to one and two decimal places. When required for purposes of accuracy, show three decimal places.

The following list shows the applications to use for various length units.

a. meter (m)	boundary and cadastral surveys; survey plans; heights, geodetic surveys, and contours; spans, levels, overall dimensions, column heights, etc.; trench, curb, fence, pipe, conduit, and channel lengths; lumber and length measurements related to other building materials; depth of storage tanks and reservoirs; height of potentiometric head, hydraulic head, piezometric head; sound wavelengths
b. kilometer (km)	distances for transportation purposes; geographical or statistical applications in surveying; long pipe and channel lengths

c. millimeter (mm) — spans; building dimensions; depth and width of sections; displacement settlement, deflection, elongation; radius of gyration; eccentricity; detailed dimensions; lumber cross sections, thicknesses, diameters, sheet metal gages, fasteners, most building product dimensions and length measurements; pipe diameters; radii of ground water wells, height of capillary rise, precipitation (rainfall), evaporation; slump of concrete, size of aggregate; sound wavelengths

d. micrometers (µm) — thickness of coatings (paint, galvanizing, etc.), thin materials thickness, size of fine aggregate

11.2.2 AREA. The preferred unit of area is the square meter. Square kilometers are used for large areas and square millimeters are used for small areas. The term hectare is used only for land and water measurements, where

$$1 \text{ ha} = (100)^2 \text{ m}^2 = 10\,000 \text{ m}^2 = 10^4 \text{ m}^2 = 10^{-2} \text{ km}^2$$

Avoid square centimeters due to possible confusion with square millimeters; use square millimeters (mm^2), where 1 cm^2 equals 100 mm^2, or square meters (m^2) instead. The exponential form of square meters is also acceptable (e.g., 1.5×10^6 m^2).

It may be more practical to use dimensions to describe area rather than the computed area. Always put the width measurement first, then put the height.

Examples:	40 mm x 90 mm	not:	3600 mm^2
	300 mm x 600 mm	not:	180 000 mm^2

The following list shows the applications to use for various area units.

a. square meter (m^2) — general areas; plots, plans, deeds, small land areas, areas of cross section of earthworks, channels, and larger pipes; surface areas of tanks and small reservoirs; site clearing; floor areas; paving, masonry construction, roofing, wall and floor finishes, plastering, paintwork, glass areas, membranes, lining materials, insulation, reinforcing mesh, and formwork; areas of all

		building components; surface areas for room absorption of sound
b.	square kilometer (km^2)	areas of counties and states, large catchment areas or other large land areas
c.	hectare (ha)	land and water measurements, farms and public lands, irrigation areas, drainage areas; areas on boundary and other survey plans
d.	square millimeter (mm^2)	small areas in general; areas of cross section for structural and other sections, bars, pipes, rolled and pressed shapes, etc.

11.2.3 VOLUME, FLUID CAPACITY, AND VOLUMETRIC FLOW. The cubic meter is the preferred volume unit for engineering purposes and is used for large volume quantities. The cubic millimeter is used primarily for volumes and capacity in small quantities. Most applications in construction use the cubic meter. Cubic decimeters and cubic centimeters are acceptable since they are multiples of 1000 in volume, but limit the usage. The liter and milliliter are used for fluid (liquid and gas) volumes and capacity of containers for fluids only.

$$1 \text{ L} = 1/1000 \text{ m}^3 = 1 \text{ dm}^3 = 10^{-3} \text{ m}^3$$
$$1 \text{ m}^3 = 1000 \text{ L}$$

Volumetric flow rates are measured in terms of cubic meter per second, liter per second, or cubic meter per hour. The use of minutes shall be avoided, as in units such as cubic meters per minute or liter per minute.

Examples:	$1 \text{ m}^3/\text{s}$ or 1000 L/s	not:	$60 \text{ m}^3/\text{min}$
	1 L/s or $3.6 \text{ m}^3/\text{h}$	not:	60 L/min
	$1 \text{ m}^3/\text{h}$ or 1000 L/h	not:	16.67 L/min

The following list shows the applications to use for various volume units.

a.	cubic meter (m^3)	large volumes; volume of earthworks, excavation, filling, and waste removal; concrete, mortar, sand, timber, all bulk materials supplied by volume; large volumes of fluids as in water distribution, irrigation, diversions, sewage, storage capacity, and underground basins

b.	liter (L)	volumes of fluids and fluid capacity of containers; liquid materials, domestic water supply, consumption, volume/capacity of full tanks; capacity of plumbing systems
c.	milliliter (mL)	same as liter but for smaller quantities
d.	cubic meter per second (m^3/s)	volumetric flow in general; flow in pipes, ducts, channels, rivers, irrigation spray demand
e.	liter per second (L/s)	volumetric flow of fluids

11.2.4 MASS. The kilogram is used for the amount of material or mass in general. The metric ton (1000 kg) is used for larger quantities of materials and ratings of lifting equipment. The gram is used primarily for samples of materials for testing. The following list shows specific applications for mass units.

a.	kilogram (kg)	calculations and specifications for mass of materials in general; mass of structural elements and machinery; ratings of lower capacity support and lifting equipment
b.	metric ton (t)	ratings of support and lifting equipment (e.g., trucks, bridges, cranes, etc.); mass greater than 10 000 kg for large quantities of materials, such as structural steel, reinforcement, aggregates, concrete, etc.; large items (e.g., calculating mass of large precast concrete units for estimating transport costs)
c.	gram (g)	samples of materials for testing
d.	milligram (mg), µg, or ng	mass of moisture vapor
e.	kilogram per meter (kg/m)	linear density of sections, bars, similar materials of uniform cross section
f.	gram per meter (g/m)	linear density of wire and similar materials of uniform cross section

g.	kilogram per square meter (kg/m^2)	mass per area for slabs, plates, similar items of uniform thickness or depth; rating for load-carrying capacities of floors (for display on notices, not in calculations)
h.	grams per square meter (g/m^2)	thin sheet materials, coatings, etc.
i.	kilogram per cubic meter (kg/m^3)	mass density of materials in general, mass per volume in concrete mix; evaluation of masses of structures and materials; concentration
j.	gram per cubic meter (g/m^3) or $\mu g/m^3$	concentration, as in pollution control
k.	kilogram per second (kg/s) or t/h	rate of transport of materials on conveyors and other material handling equipment

11.2.5 STRUCTURAL SECTION PROPERTIES. Geometric cross-sectional properties use multiples of units raised to certain powers, such as cubic millimeters, millimeters to the fourth power, and millimeters to the sixth power, as described in the following paragraphs.

11.2.5.1 Modulus of Section. The modulus of section (Z) is in units of cubic millimeters (mm^3) or cubic meters (m^3), where 1 mm^3 is equal to 10^{-9} m^3. Examples of these moduli include plastic section modulus and elastic section modulus.

Example: $Z_x = 1.835 \times 10^6$ mm^3 or 1.835×10^{-3} m^3

11.2.5.2 Second Moment of Area or Torsional Constant. The second moment of area (I) (moment of inertia) or torsional constant is in units of millimeters or meters to the fourth power (e.g., mm^4, m^4), where 1 mm^4 is equal to 10^{-12} m^4.

Example: $I_{xx} = 0.371 \times 10^9$ mm^4 or 0.371×10^{-3} m^4

11.2.5.3 Warping Constant. The warping constant (C_w) and the torsional constant (J) are in units of millimeters or meters to the sixth power (e.g., m^6, mm^6), where mm^6 is equal to 10^{-18} m^6.

Examples: $J = 0.691 \times 10^6$ mm^6 or 0.691×10^{-12} m^6
$C_w = 0.924 \times 10^{12}$ mm^6 or 0.924×10^{-6} m^6

11.2.6 PLANE ANGLES. The SI unit for plane angle is the radian (rad), which is used primarily for calculations. The degree (of arc), minute, and second are used in limited applications. The degree (of arc) and decimal degrees are used in engineering and construction applications. Slopes and gradients may be expressed as a ratio or as a percentage. For example, 26.57 degrees, the ratio 1:2, 50 percent, and 0.4637 rad all describe the same slope angle. See 11.3.1.3 for specific information on slopes related to construction. The following list summarizes the applications using each plane angle unit.

a.	radian (rad)	calculations, slopes
b.	degree (°), minute (′), second (″)	cartography and surveying; bearings shown on boundaries and cadastral survey plans; geodetic surveying
c.	degree (°), decimal degree	engineering and construction; general angular measurement; angle of rotation, torsion, shear resistance, friction, and internal friction; slopes

11.2.7 TIME INTERVAL. The SI unit for time interval is the second. The units day and hour are acceptable alternatives. Minutes shall be avoided to reduce the number of units used. Therefore, the time unit in flow rates is the second or the hour. Also, avoid using the term month unless a specific calendar month is referenced. Calendar year refers to 365 days (31 536 000 s). The following list summarizes the use of acceptable time units.

a.	second (s)	time used in test methods; all calculations involving derived units with a time component (e.g., velocity, acceleration, flow rates, etc.); period or periodic time; reverberation time, duration of sound
b.	hour (h), day (d), year [annum (a)]	time used in test methods, all calculations involving labor time, plant hire, maintenance periods, etc.

11.2.8 TEMPERATURE. Kelvin is the SI term for thermodynamic temperature and temperature interval. In kelvin, there are no negative temperatures. Degree Celsius (°C) is acceptable in calculations involving temperature interval since the degree Celsius is equal in magnitude to the kelvin, but the difference in values between the scale is 273.15 degrees, where °C = K - 273.15. Actual temperature measurements should normally be measured in degrees Celsius. The following list shows applications for each temperature unit.

a.	kelvin (K)	thermodynamic temperature; calculations involving units of temperature; calculations using temperature intervals in heat transfer, thermal expansion, test methods, etc., particularly when compound units are recommended
b.	degree Celsius (°C)	meteorology and general applications; ambient temperature values; calculations using temperature intervals in heat transfer calculations, temperature intervals in test methods, etc., but not when compound units are recommended
c.	1/K or 1/°C (coefficient of linear thermal expansion)	expansion of materials subject to a change in temperature

11.2.9 LINEAR DYNAMICS. The newton is an absolute derived unit of force. It is a practical unit that extends through to units for pressure and stress, energy, work, quantity of heat, power, and electrical units.

Avoid the term "weight" to eliminate confusion whether meaning force of gravity or mass. Weight has generally meant "mass" in commercial and everyday use; "force of gravity," a particular force, usually refers to gravitational acceleration, which varies on the earth's surface. Be clear when specifying mass or force. In dynamic calculations, use the equation $F = m{\cdot}a$ instead of $W = m{\cdot}g$. Use the equation $F_g = m{\cdot}g$ only to determine the force due to gravity. For engineering design purposes, ASTM E621 recommends that g equal 9.8 m/s (International Standard value is 9.806 65 m/s) because: (a) 9.8 m/s^2 provides accuracy in nearly all instances; (b) fewer decimal places result as compared to using 9.81 m/s or 9.806 65 m/s; and (c) it provides a more accurate product than using a factor of 10 since it causes a greater error. Do not use kilogram-force (kg_f); it is inconsistent with SI. The following list summarizes applications for dynamics units.

a.	meters per second (m/s)	calculations involving rectilinear motion, velocity and speed in general; wind velocity; velocity of fluids; pipe flow velocity
b.	kilometers per hour (km/h)	wind speed; speed used in transportation, and speed limits
c.	millimeters per hour (mm/h)	rainfall intensity

d. kilogram meter per second (kg·m/s)	momentum in applied mechanics; evaluation of impact and dynamic forces

11.2.10 ROTATIONAL DYNAMICS.

11.2.10.1 Angle, Angular Velocity, and Angular Acceleration. The SI units for angle, angular velocity, and angular acceleration are the radian (rad), radian per second (rad/s), and radian per second squared (rad/s^2), respectively. When appropriate, use the dimensionless units of 1, 1/s, and 1/s^2. Use radian per second for calculations involving rotational motion. Use meters per second squared for kinematics and calculation of dynamic forces. The recommended value of acceleration due to gravity (*g*) for use in the U.S. is 9.8 m/s^2.

11.2.10.2 Rotation. For rotational speed, the unit hertz is used instead of cycles per second (cps). The rotational frequency or speed of rotation is in revolutions per second (r/s). This is widely used in the specification of rotational speed of machinery. Use revolution per minute (r/min) only for slow-moving equipment.

11.2.10.3 Moment of Force (Torque, Bending Moment). The unit for torque is the newton meter. Note that the joule, also defined as a newton meter, should never be used for torque. Torque is a vector quantity and the joule represents the scalar quantity of work. In calculations, use newton meter per radian (N·m/rad) for torque. The newton meter, kilonewton meter, and meganewton meter are used for bending moment, torsional moment, overturning moment, tightening tension for high-strength bolts, and torque in engine drive shafts, axles, and other similar applications.

11.2.10.4 Moment of Inertia. The moment of inertia (I) is the mass distribution of a body about an axis, where I is equal to the sum of each mass (m) times the square of its distance (r) from the axis of rotation (Σmr^2). The SI unit for I is the kilogram meter per radian squared (kg·m^2/rad^2). The use of radian in the unit provides for dimensional consistency.

11.2.10.5 Angular Momentum. The angular momentum or moment of momentum is the linear momentum (kg·m/s) times the moment arm, in meters. The SI unit for angular momentum is the kilogram square meter per radian second [kg·m^2/(rad·s)]. For a rotating body, the angular momentum is equal to the moment of inertia (kg·m^2/rad^2) times the angular velocity ω in either rad/s or 1/s.

11.2.10.6 Rotational Kinetic Energy and Work. The joule is the unit used for rotational kinetic energy, which is equal to one half of the moment of inertia times the square of the angular velocity ($\frac{1}{2}I\omega^2$). Rotational work is also in terms of joules. The work is equal to the torque (in newton meters) times the angular rotation (in radians), which is the unit of newton meter radian (N·m·rad).

11.2.10.7 Torsional Stiffness. The torsional stiffness, or torsion constant, is the applied torque, in newton meters, divided by the angle of twist in radians, resulting in newton meter per radian (N·m/rad).

11.2.10.8 Centripetal Force and Acceleration. Centripetal acceleration is either v^2/r or $\omega^2 r$, where v is tangential linear velocity in meters per second, r is the radius in meters, and ω is the angular velocity (rad/s), measured in meters per second squared. Centripetal force is measured in newtons and is equal to the mass times the centripetal acceleration.

11.2.11 PRESSURE, STRESS, AND ELASTIC MODULUS. The SI unit for pressure, stress, and elastic modulus is the pascal. Except where noted elsewhere in this section, use megapascal (MPa) instead of meganewton per square meter (MN/m^2) or newton per square millimeter (N/mm^2) (1 MPa = 1 N/mm^2 = 1 MN/m^2) and use kilopascal instead of kilonewton per square meter (kN/m^2). Avoid using the units bar and millibar. Gage pressure is equal to the absolute pressure minus the ambient pressure, where the ambient pressure is usually atmospheric pressure. Absolute pressure is never negative. Gage pressure is positive if it is above the ambient pressure and negative if it is below (vacuum). For a vacuum, the designation should clarify whether negative gage pressure or absolute pressure is meant. For nameplates, graphs, and gages, units of pressure are designated as "kPa (gage)" or "kPa (absolute)," not kPag or kPaa, respectively. See 4.3.6 for additional information. The following list shows the various applications related to pressure.

a. pascal (Pa)	calculations; low differential pressure in fluids, duct pressure in air conditioning, heating, and ventilating systems; sound pressure as in instantaneous or peak sound pressure (previously expressed as a root-mean-square value); vapor pressure, vapor pressure difference, and vapor pressure drop
b. kilopascal (kPa)	uniformly distributed pressure (loads) on floors or under footings; soil bearing pressure; wind pressure (loads); snow loads, dead and live loads; pressure in fluids; fluid flow resistance in closed systems; differential pressure in high-pressure ventilation systems; lower pressure fluids. Where wind pressure, snow loads, dead and live loads are shown in kN/m^2, change units to kPa.

c.	megapascal (MPa)	as required for modulus of elasticity; higher pressure fluids; stress (ultimate, proof, yield, permissible, calculated, etc.) in structural materials; concrete and steel strength grade.
d.	gigapascal (GPa)	modulus of elasticity in high-strength materials
e.	micropascal (µPa)	sound pressure (20 µPa is the reference quantity for sound pressure level)
f.	square meter per newton (m^2/N, or Pa^{-1}) or m^2/kN (or kPa^{-1})	compressibility for settlement analysis, coefficient of compressibility, and bulk compressibility
g.	pascal second (Pa·s) or mPa·s	dynamic viscosity (shear stresses in fluids)
h.	square meter per second (m^2/s) or mm^2/s	kinematic viscosity in the computation of Reynold's number and settlement analysis (coefficient of consolidation)

11.2.12 FORCE. The unit for force is usually the newton or kilonewton. Applications for each force unit are listed below.

a.	newton (N)	calculations
b.	kilonewton (kN)	columns, piles, ties, prestressing tendons, etc.; concentrated forces, axial forces; reactions; shear force, and gravitational force (load)
c.	newton per meter (N/m)	force-per-length calculations
d.	kilonewton per meter (kN/m)	traverse force (load) per length on a beam, column, etc.; force distributed in a linear direction

11.2.13 ENERGY, WORK, QUANTITY OF HEAT. The unit of energy and work is the joule, which is equal to a newton meter (N·m) and a watt second (W·s). The joule replaces the British thermal unit (Btu), therm, calorie, kilocalorie, foot-pound force ($ft\text{-}lb_f$), and other energy and work units. Listed below are the energy and work units for particular applications.

a.	joule (J), kJ, or MJ	new electrical applications and new electrical systems; impact energy (work required to break a standard specimen); thermal energy calculations; enthalphy, latent heat, sensible heat
b.	kilowatthour (kWh)	electrical applications using existing meters for electrical consumption
c.	joule per square meter (J/m^2)	impact strength and impact ductility
d.	joule per kilogram (J/kg) or kJ/kg or MJ/kg	specific energy, specific latent heat, or combustion heat (mass basis) for heat of transition; specific sensible heat and specific heat in psychrometric calculations; heat and energy contained in materials; combustion heat per mass; calorific value of fuels (mass basis)
e.	joule per cubic meter (J/m^3) or kJ/m^3	energy density; sound energy density; combustion heat per volume
f.	megajoule per cubic meter (MJ/m^3)	calorific value of fuels (volume basis)
g.	joule per kelvin (J/K) or kJ/K	heat capacity and entropy, particularly in the thermal behavior of materials; heat transmission calculations
h.	joule per kilogram kelvin [J/(kg·K)] or kJ/(kg·K)	thermal behavior of materials; heat transmission calculations

11.2.14 POWER AND HEAT FLOW RATE. The watt replaces such units as horsepower (electric, boiler) and foot pound-force per hour ($ft\text{-}lb_f/h$) (per minute or per second) for general power, and the Btu per hour (Btu/h), calorie (or kilocalorie) per minute or per second, and the ton of refrigeration. The following list identifies applications used with the various power units.

a.	watt (W) or kW	power in general (mechanical, electrical, thermal); input/output rating, etc., of motors, engines, heating and ventilating plants, and other equipment in general; heat flow through walls, windows, etc.; heat

demand; active power (or useful power) of an electrical circuit; sound energy flux, particularly for sound power and rate of flow of sound energy

b. megawatt (MW) — power input/output rating, etc., of heavy power plants

c. picowatt (pW) — sound power level (1 pW is the reference quantity for sound power level)

d. watt per square meter (W/m^2) — power density, heat flux density, and irradiance through walls and other heat transfer surfaces; heat transmission calculations; sound intensity

e. watt per cubic meter (W/m^3) or kW/m^3 — heat release rate, particularly for rate of heat release per volume over time (for gases and fluids)

f. watt per meter kelvin [$W/(m{\cdot}K)$] or $W/(m{\cdot}°C)$ — thermal conductivity, estimation of thermal behavior of homogeneous materials and systems; heat transmission calculations; thermal conductivity of structural and building materials in fire-resistance testing, insulation, etc.

g. watt per square meter kelvin [$W/(m^2{\cdot}K)$] or $W/(m^2{\cdot}°C)$ — thermal conductance in heat transfer calculations for buildings, building components and equipment; transmittance of construction elements; calculation of coefficients of heat transfer

h. meter kelvin per watt ($m{\cdot}K/W$) or $m{\cdot}°C/W$ — thermal resistivity for heat transmission calculations for materials and building elements (reciprocal of thermal conductivity)

i. square meter kelvin per watt ($m^2{\cdot}K/W$) or $m^2{\cdot}°C/W$ — thermal resistance for heat transmission calculations; rating of thermal insulating materials (thermal resistances are additive) - the "R" value

11.2.15 MOISTURE MOVEMENT IN BUILDINGS. The unit "perm" is a specification of performance and is converted to the SI unit of kilogram per pascal second square meter [kg/(Pa·s·m^2)]. The lower the value, the greater the retardation of moisture movement. Do not use "metric perm" (g/24 h·m^2·mmHg); it is not in SI units.

Resistance to moisture movement is termed vapor resistance and vapor resistivity. Resistivity is additive, so the higher the value, the better the resistance to moisture movement. Always mention the word "vapor" to distinguish it from applications related to permeance and permeability as used with electromagnetic fields. The following list itemizes other units used in moisture movement.

a.	microgram per pascal second square meter [µg/(Pa·s·m^2)] or ng/(Pa·s·m^2)	vapor permeance for transmission of moisture vapor through building elements (roofs, walls, floors), surface coefficient of vapor transfer in still or moving air. In some international situations, the area is cancelled out and the unit is kilogram per newton second [kg/(N·s)].
b.	microgram per pascal second meter [µg/(Pa·s·m)] or ng/(Pa·s·m)	vapor permeability, particularly for transmission of moisture vapor through a specified thickness of a homogeneous material or construction. In some international situations, the unit is in terms of kilogram meter per newton second [kg·m/(N·s)].
c.	pascal second square meter per kilogram (Pa·s·m^2/kg)	vapor resistance
d.	megapascal second square meter per kilogram (MPa·s·m^2/kg) or GPa·s·m^2/kg	resistance to moisture vapor transmission by building elements; surface vapor resistance in still or moving air
e.	pascal second meter per kilogram (Pa·s·m/kg)	vapor resistivity
f.	megapascal second meter per kilogram (MPa·s·m/kg) or GPa·s·m/kg	resitivity to moisture vapor transmission by a specific thickness of a homogeneous material or construction

11.2.16 SURFACE TREATMENT. Units for surface texture and coating is designated in micrometers, which is the correct SI name for the micron. Measurements in mils are to be converted to micrometers.

11.2.17 FREQUENCY. Hertz is the primary unit for frequency of sound, frequency bands or ranges, vibration, and shock, replacing the unit of cycles per second. Frequency of electromagnetic waves, power frequency for electric motors, and radio frequencies are in terms of hertz, kilohertz, or megahertz, as applicable.

11.2.18 ELECTRICAL AND MAGNETIC UNITS. The following list summarizes the applications for the various electrical units.

a.	ampere (A)	maintenance rating of an electrical installation and leakage current, magnetomotive force, magnetic potential difference, and in other calculations involving magnetic circuits
b.	ampere per meter (A/m) or kA/m	magnetic field strength in calculations of magnetic circuitry such as transformers, magnetic amplifiers, and general cores
c.	ampere per square meter (A/m^2) or kA/m^2 or A/mm^2	current density, particularly in the design of cross-sectional area of an electrical conductor
d.	coulomb (C)	voltage of a unit with capacitive-type characteristics related to the amount of charge present (for example, electrostatic precipitators) and for storage battery capacities
e.	volt (V)	electric potential, potential difference, and electromotive force
f.	volt per meter (V/m)	electric field strength resulting in a potential gradient; electrical parameters such as dielectric strength
g.	volt ampere (V·A)	apparent power in an electrical circuit
h.	farad (F)	capacitance in electronic components, electrical design and performance calculators

i.	ohm (Ω)	resistance in electrical devices such as motors, generators, heaters, electrical distribution systems, etc.
j.	ohm meter (Ω·m)	resistivity
k.	siemens (S)	conductance, admittance, susceptance
l.	siemens per meter (S/m)	electrical conductivity
m.	weber (Wb)	magnetic flux, flux of magnetic induction
n.	weber per meter (Wb/m)	magnetic vector potential
o.	tesla (T)	magnetic flux density, magnetic induction
p.	henry (H)	self-inductance, mutual inductance, permeance; calculations involving transformers
q.	henry per meter (H/m)	permeability (the relationship between the magnetic flux density and the magnetic fluid strength)
r.	1/henry (1/H)	reluctance of motors and generators

11.2.19 LIGHTING. The following list summarizes the applications for the various lighting units.

a.	candela (cd)	luminous intensity
b.	candela per square meter (cd/m^2) or cd/mm^2	luminance for the assessment of surface brightness; luminance; of light sources, lamps and light bulbs; calculation of glare in lighting layouts
c.	lumen (lm)	luminous flux of light sources, lamps, and light bulbs
d.	lumen seconds (lm·s); lm·h	quantity of light
e.	lux (lx)	illuminance as the luminous flux per area used in determination of illumination levels and design/evaluation of interior lighting

		layouts (outdoor daylight illumination on a horizontal plane ranges up to 100 klx)
f.	lumen per square meter (lm/m^2)	luminous exitance
g.	lux second (lx·s)	light exposure
h.	lumens per watt (lm/W)	luminous efficacy as in the rating of luminous efficacy of artificial light sources

11.2.20 ACOUSTICS. The standard reference value for sound pressure is 20 µPa. Do not use dyne for sound pressure. Sound pressure levels are generally shown in the nondimensional logarithmic unit decibel (dB) signifying the ratio of actual pressure to reference pressure. Sound pressure level is equal to the following equation:

$$L_p = 20 \log_{10} \frac{\text{actual pressure (Pa)}}{20 \times 10^{-6} \text{ (Pa)}}$$

The standard reference value for sound power is 1 pW. The sound power level is equal to the following:

$$L = 10 \log_{10} \frac{\text{actual pressure (W)}}{20 \times 10^{-12} \text{ (W)}}$$

Picowatt per square meter is the unit used for sound intensity level. The standard reference value for sound intensity is 1 pW/m^2. Sound intensity is defined by the following equation.

$$L_i = 10 \log_{10} \frac{\text{actual intensity (W/m}^2\text{)}}{10^{-12} \text{ (W/m}^2\text{)}}$$

Specific acoustic impedance is in terms of pascal second per meter (Pa·s/m). Acoustic impedance and acoustic resistance is in pascal second per cubic meter ($Pa \cdot s/m^3$).

11.3 CONSTRUCTION

The following paragraphs discuss details particular to construction which are not already addressed in 11.2. Many types of products and materials are listed according to the respective engineering discipline. For additional information on construction products and materials, refer to the GSA's Metric Design Guide.

11.3.1 CIVIL.

11.3.1.1 Products. Civil products that are unchanged in metric include caisson forms and reinforced concrete pipe. See 11.3.4.2 for discussion on pipe.

11.3.1.2 Survey Measurements. When converting distances (in feet) and areas (in square feet) to SI, use the U.S. survey foot conversion. The U.S. survey foot is based on the definition where 1 foot equals 1200/3937 or 0.304 800 6 m. The geodetic surveys within the U.S. were originally performed using the old standard definition. In 1959 the definition for foot was changed so that 1 foot equals 0.3048 m exactly for all applications except surveying. See 11.2.1 and 11.2.2 for units used in surveying. Survey stations are equal to 1 km.

The National Geodetic Survey (NGS) and the U.S. Geological Survey (USGS) have complete data bases of U.S. survey information in metric units available for all survey and mapping required for metric design and construction in the U.S.

11.3.1.3 Slopes. Slopes are shown as nondimensional ratios. The vertical component is shown first, then the horizontal component is shown. For example, a rise of 1 m in 4 m is expressed as 1:4. Always compare like units, meters to meters, millimeters to millimeters, etc. For slopes less than 45°, the vertical component is unitary (e.g., 1:20). For slopes greater than 45°, the horizontal component is unitary (e.g., 5:1).

11.3.1.4 Contour and Elevation. Contour intervals are usually 1000-mm, 500-mm, or 250-mm intervals, depending on the slope. Elevation is in millimeters. Soft convert benchmark elevations to millimeters. Some international drawings show contours in 0.5-m increments.

11.3.1.5 Excavation. See 11.2.1 and 11.2.3 for units used in excavation applications.

11.3.1.6 Paving. See 11.2.1 and 11.2.2 for units used in paving applications.

11.3.1.7 Concrete. Concrete strength designation changes are in megapascals (MPa) to the nearest 5-MPa increment, replacing the pound-per-square-inch (psi) designation. The strength requirements are identical in both metric and inch-pound systems, just labeled in different units. General purpose concrete for metric use is offered in four strengths, as compared to six available strengths for nonmetric applications. Table 11-2 shows equivalent values for concrete strength.

Table 11-2. Concrete Strength

Previous (psi)	Exact Conversion MPa	Specify MPa
2500	17.23	20
3000	20.67	20 or 25 *
3500	24.12	25
4000	27.56	30
4500	31.01	35
5000	34.45	35

* If code requires 3000 psi, then 25 MPa must be used; otherwise, it is a professional judgment whether to use 20 MPa or 25 MPa.

11.2.1.8 Reinforcing Bar. Bar sizes are identified in accordance with ASTM A615M, ASTM A616M, ASTM A617M, ASTM A706M, or ASTM A775M. Reinforcing bar is offered in certain grades (e.g., A615M bar is grade 300 or 400), which corresponds to the yield strength in megapascals. For example, grade 300 has a yield strength of 300 MPa. General purpose rebar in metric is designated in eight bar sizes, reduced from the eleven nonmetric sizes. The nominal size reflects the size of the bar in millimeters (e.g., Number 20 bar is a nominal 20-mm size). Table 11-3 shows the nominal sizes of reinforcing bar for metric use.

Table 11-3. Reinforcing Bar Sizes

Nominal Diameter (mm)	Actual Diameter (mm)	Cross-Sectional Area (mm^2)
10	11.3	100
15	16.0	200
20	19.5	300
25	25.2	500
30	29.9	700
35	35.7	1000
45	43.7	1500
55	56.4	2500

11.3.2 ARCHITECTURAL.

11.3.2.1 Products. Architectural products that will remain unchanged physically in metric units include the following items: door hardware, elevators and escalators, filing and shelving units, kitchen equipment, landscaping products, lavatory units, toilets and toilet partitions, paint products, resilient base, revolving entrance doors, roofing members, systems furniture, and vertical blinds. The architectural planning module is 600 mm, which is the closest to the 24-inch size previously used.

11.3.2.2 Lumber. Physical sizes of most lumber products are identical in both metric and inch-pound units. Nominal size designations, not yet determined for metric usage, will reflect the measurement system used. Plywood and other wood-based panels may be available in hard metric sizes (e.g., 1200-mm or 2400-mm widths).

11.3.2.3 Carpentry. Lengths are measured in meters and millimeters.

11.3.2.4 Insulation. Batt insulation is sized to 400 mm and 600 mm, replacing the nominal sizes of 16 and 24 inches, respectively. The thickness of the insulation will not change. A friction fit may result when the metric-sized insulation is used because of the slight changes in stud spacing.

11.3.2.5 Doors and Windows. Standard metric doors heights are either 2050 mm or 2100 mm for 80-inch doors and 2100 mm for 84-inch doors. Door widths vary as listed in table 11-4. The thickness of the doors, the material, and hardware items are identical for metric- and inch-dimensioned doors. A common door size is 900 mm by 2100 mm.

Table 11-4. Door Widths

inch-pound	metric (mm)
2′-6"	750
2′-8"	800
2′-10"	850
3′-0"	900 or 950
3′-4"	1000

Dimensions for window glass are measured in millimeters. Glass thickness designations already represent the thickness of the glass in millimeters; therefore, there is no difference in identifying glass thickness in SI units.

11.3.2.6 Drywall. Drywall is resized for metric to be 1200 mm wide by either 2400 mm or 3000 mm, replacing the 8- and 10-foot sizes, respectively. The thickness of the drywall remains the same physical size but is relabeled in millimeters to prevent recalculation of fire, acoustic, and thermal ratings. Specify only the sheet length and width in hard metric. Thicknesses will remain 12.7 mm and 15.9 mm. Minimum orders may be as high as 2400 sheets drywall measuring 1200 mm by 2400 mm. If hard metric size drywall can not be obtained, select an inch-dimensioned drywall and cut it to fit the metric stud spacing.

11.3.2.7 Stud Spacing. Stud spacing is either 400 mm, which replaces the 16-inch spacing, or 600 mm for the previously used 24-inch spacing. Other spacing of even multiples may be used to fit the sheet size.

11.3.2.8 Sheet Metal. Sheet metal thickness should be identified in millimeters, not gage. The physical thickness of the metal is identical in both inch-pound and metric units, only the name is different. For clarity, the gage designation should be followed by the minimum millimeter size in parentheses in specifications. See table 11-5 for gage size equivalents for sheet metal used in metric design. Table 11.6 provides a more complete table of metal gage conversions.

Table 11-5. Metric Sheet Metal Sizes

Gage	Inch	Exact mm	Specify Less Than Exact mm	Percent Thinner
32	0.0134	0.3404	0.34	0.1
30	0.0157	0.3988	0.39	2.2
28	0.0187	0.4750	0.47	1.1
26	0.0217	0.5512	0.55	0.2
24	0.0276	0.7010	0.7	0.1
22	0.0336	0.8534	0.85	0.4
20	0.0396	1.0058	1	0.6
18	0.0516	1.3106	1.3	0.8
16	0.0635	1.6129	1.6	0.8
14	0.0785	1.9939	1.9	4.7
12	0.1084	2.7534	2.7	1.9
10	0.1382	3.5103	3.5	0.3
8	0.1681	4.2697	4.2	1.6

Table 11-6. Sheet Metal Gage Conversions

Name Of Gage	American Or Browne & Sharpe		United States Standard		Manufacturers Standard*			
Abbreviation	B&S		U.S. Std.		—			
Principal Use	Aluminum Nonferrous Sheet, Wire, Rod		Steel Sheet And Plate [7700 kg/m³ (480 lb/ft³)]		Ferrous Sheet			
					Uncoated		Galvanized	
Number	Inch	Millimeter	Inch	Millimeter	Inch	Millimeter	Inch	Millimeter
7/0's	—	—	0.5	12.7	—	—	—	—
6/0's	0.5800	14.732	0.46875	11.90625	—	—	—	—
5/0's	0.5165	13.119	0.4375	11.1125	—	—	—	—
4/0's	0.4600	11.684	0.40625	10.31875	—	—	—	—
3/0's	0.4096	10.404	0.375	9.525	—	—	—	—
2/0's	0.3648	9.266	0.34375	8.73125	—	—	—	—
0	0.3249	8.252	0.3125	7.9375	—	—	—	—
1	0.2893	7.348	0.28125	7.14375	—	—	—	—
2	0.2576	6.543	0.265625	6.746875	—	—	—	—
3	0.2294	5.827	0.25	6.35	0.2391	6.073	—	—
4	0.2043	5.189	0.234375	5.953125	0.2242	5.695	—	—
5	0.1819	4.620	0.21875	5.55625	0.2092	5.314	—	—
6	0.1620	4.115	0.203125	5.159375	0.1943	4.935	—	—
7	0.1443	3.665	0.1875	4.7625	0.1793	4.554	—	—
8	0.1285	3.264	0.171875	4.365625	0.1644	4.176	0.1681	4.270
9	0.1144	2.906	0.15625	3.96875	0.1495	3.797	0.1532	3.891
10	0.1019	2.588	0.140625	3.571875	0.1345	3.416	0.1382	3.510
11	0.09074	2.3048	0.125	3.175	0.1196	3.038	0.1233	3.132
12	0.08081	2.0526	0.109375	2.778125	0.1046	2.657	0.1084	2.753
13	0.07196	1.8278	0.09375	2.38125	0.0897	2.278	0.0934	2.372
14	0.06408	1.6276	0.078125	1.984375	0.0747	1.897	0.0785	1.994
15	0.05707	1.4496	0.0703125	1.7859375	0.0673	1.709	0.0710	1.803
16	0.05082	1.2908	0.0625	1.5875	0.0598	1.519	0.0635	1.613
17	0.04526	1.1496	0.05625	1.42875	0.0538	1.367	0.0575	1.461
18	0.04030	1.0236	0.05	1.27	0.0478	1.214	0.0516	1.311
19	0.03589	0.9116	0.04375	1.11125	0.0418	1.062	0.0456	1.158
20	0.03196	0.8118	0.0375	0.9525	0.0359	0.912	0.0396	1.006
21	0.02846	0.7229	0.034375	0.873125	0.0329	0.836	0.0366	0.930
22	0.02535	0.6439	0.03125	0.79375	0.0299	0.759	0.0336	0.853
23	0.02257	0.5733	0.028125	0.714375	0.0269	0.683	0.0306	0.777
24	0.02010	0.5105	0.025	0.635	0.0239	0.607	0.0276	0.701
25	0.01790	0.4547	0.021875	0.555625	0.0209	0.531	0.0247	0.627
26	0.01594	0.4049	0.01875	0.47625	0.0179	0.455	0.0217	0.551
27	0.01420	0.3607	0.0171875	0.4365625	0.0164	0.417	0.0202	0.513
28	0.01264	0.3211	0.015625	0.396875	0.0149	0.378	0.0187	0.475
29	0.01126	0.2860	0.0140625	0.3571875	0.0135	0.343	0.0172	0.437
30	0.01003	0.2548	0.0125	0.3175	0.0120	0.305	0.0157	0.399
31	0.008928	0.22677	0.0109375	0.2778125	0.0105	0.267	—	—
32	0.007950	0.20193	0.01015625	0.25796875	0.0097	0.246	—	—
33	0.007080	0.17983	0.009375	0.238125	0.0090	0.229	—	—
34	0.006305	0.16015	0.00859375	0.21828125	0.0082	0.208	—	—
35	0.005615	0.14262	0.0078125	0.1984375	0.0075	0.191	—	—
36	0.005000	0.12700	0.00703125	0.17859375	0.0067	0.170	—	—
37	0.004453	0.11311	0.006640625	0.16867188	0.0064	0.163	—	—
38	0.003965	0.10071	0.00625	0.15875	0.0060	0.152	—	—
39	0.003531	0.08969	—	—	—	—	—	—
40	0.003145	0.07988	—	—	—	—	—	—

* For uncoated sheets, use manufacturers' standard gage number; for galvanized sheets, use galvanized sheet gage number. The equivalent thickness for galvanized sheet includes both the base metal and the coating on both surfaces. All listed values are based on a coating thickness of 0.094 mm (0.0037 in.), which is for the coating designation of G210.

11.3.2.9 Brick and Concrete Masonry Units. The standard metric brick is 90 mm by 57 mm by 190 mm. Mortar joints are 10 mm instead of the 3/8- and 1/2-in joints. The brick module is 600 mm by 600 mm replacing the 2- by 2-ft module. The material composition of bricks is identical in both SI and inch-pound systems. American modular brick is 92 mm by 57 mm by 194 mm (3-5/8 by 2-1/4 by 7-5/8 in) with a 3/8-in joint, and 89 mm by 56 mm by 190 mm (3-1/2 by 2-3/16 by 7-1/2 in) with a 1/2-in joint. Three courses with 10-mm joints are equal to 201 mm, which is rounded to 200 mm.

Metric concrete masonry units (CMU) are 190 mm by 190 mm by 390 mm (7-1/2 by 7-1/2 by 15-3/8 in). Standard metric joints are 10 mm rather than 1/2 in. The metric CMU module is 600 mm by 600 mm. The material composition of CMU's is identical in both metric and inch-pound units. American modular block is 194 mm by 194 mm by 397 mm. Stacking nonmortar-joint block is 203 mm by 203 mm by 406 mm.

Masonry walls shall remain the same in thickness, for reasons of fire resistance and compressive strength. The height and length of the units are important only for appearance, ability to accommodate metric doors and windows, even courses for ties, round dimensions between openings to facilitate construction, and for the weight of the unit for lifting by hand. In accordance with ASTM E621, specify masonry construction by wall area and thickness, rather than by specifying individual block sizes.

11.3.2.10 Floors. For raised floors, the grids and lay-in tile are 600 mm by 600 mm. Grid profiles, tile thickness, and support systems are identical in both metric and inch-pound units.

11.3.2.11 Ceilings. Metric ceiling grids, lay-in ceiling tile, air diffusers, and fixtures are sized to a standard 600 mm by 600 mm. A larger size option is 600 mm by 1200 mm. Metric and inch-pound grid profiles, tile thicknesses, air diffuser capacities, fluorescent tubes, and means of suspension are unchanged for metric usage.

11.3.2.12 Paint and Plaster. Lengths are measured in meters or millimeters. Areas are measured in square meters. Water capacity is in liters for plaster applications and in liters or milliliters for painting. The unit for coverage is liters per square meter.

11.3.2.13 Roofing. Dimensions are measured in meters or millimeters, areas are measured in square meters, and slope is measured in millimeters per meter (mm/m).

11.3.3 STRUCTURAL.

11.3.3.1 Structural Steel Sections and Decking. See 11.2 for the units used for length, mass, cross section, and other geometric properties of structural steel sections. Stress is in newtons per square millimeter (N/mm^2) or megapascals (MPa). Joules are used to describe energy absorption as in requirements for impact tests. Moments are in newton millimeters (N·mm).

There are no physical differences between metric and inch-pound cross sections, only the names reflect different measurement systems. The American Institute of Steel Construction (AISC) recommends using currently used steel shapes in metric dimensions according to ASTM A6/A6M with all calculations performed in metric to facilitate review.

Steel decking will remain unchanged physically. Table 11-7 shows the yield stresses of certain ASTM steel designations.

Table 11-7. Yield Stresses of Steel

ASTM Designation	Yield Stress (N/mm^2)	Yield Stress [kip/in^2 (approx.)]
A36M	250	36
A572 Gr 345	345	50
A588M	345	50
A582M	485	70
A514M	690	100

11.3.3.2 Structural Bolts. Structural bolts have metric-sized diameters and threads in accordance with ASTM A325M and ASTM A490M. Standard metric bolt sizes in millimeters are shown in table 11-8.

Table 11-8. Standard Metric Bolt Sizes

Metric Designation	Diameter (mm)	Diameter (in)
M16	16	0.63
M20	20	0.79
M24	24	0.94
M27	27	1.06
M30	30	1.18
M36	36	1.42

11.3.3.3 Floor Loading. Units for floor loading are either kilograms per square meter (kg/m^2) or kilopascals (kPa), depending on whether the application is in terms of mass or force. These units replace the unit of pounds per square foot (psf or lb/ft^2). Structural calculations are in kilonewtons per square meter (kN/m^2) or kilopascals (kPa). Table 11-9 shows equivalent floor loadings.

Table 11-9. Floor Loading

Previous (psf)	New (kPa)	Percent Stronger
50	2.5	4.4
80	4	1.8
100	5	4.4
120	6	4.4
150	7.5	4.4
200	10	4.4
250	12	0.2
300	15	4.4
350	17	1.4
400	20	4.4
450	22	2.1
500	24	0.2

11.3.4 MECHANICAL.

11.3.4.1 Products. No physical changes are planned for the following mechanical items: air handling units; boilers; chillers; fan coil units; pumps of any type; heating, ventilating, and air-conditioning (HVAC) control systems; pipe; plumbing fixtures; pumps; and valves. Units used should be in accordance with the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) handbooks.

11.3.4.2 Pipe and Tubing. Piping and tubing previously identified by nominal pipe sizes (NPS's) in inches are identified by diameter nominal (DN) designations in metric. Thread sizes reflect metric thread designations. The cross sections of piping and tubing are identical in metric and inch-pound units. Steel and copper tubing will remain unchanged until further notice. Hard metric copper tube sizes are given in ASTM B88M, but this tubing may not yet be available in sufficient quantities for widespread use. Schedule designations (e.g., schedule 40, type K, L, M) remain unchanged. During the metric transition, put the following note and table on the cover sheet of mechanical drawings.

"ALL SIZES ARE INDUSTRY STANDARD ASTM A53 PIPE AND ASTM B88 TUBE DESIGNATED BY THEIR NOMINAL MILLIMETER (mm) DIAMETER EQUIVALENT. SEE CHART BELOW."

Nominal Size	
Inch	mm
1/2	15
3/4	20
1	25
1-1/4	32
1-1/2	40
2	50
2-1/2	65
3	80
3-1/2	90
4	100
5	125
6	150
8	200
10	250
12	300

Table 11-10 shows additional nominal pipe sizes and some metric equivalents for inside and outside diameters and volumes for piping and conduit. The nominal sizes listed in the table apply to all plumbing, natural gas, heating oil, drainage, and miscellaneous piping used in most fluids applications. To identify pipe or tubing for metric use, write "DN" followed by the nominal millimeter size. For example, DN40 is a nominal 40-mm (1-1/2 inches NPS) pipe or tube.

The designation of the National Standard Pipe Taper (NPT) pipe thread is also used with the DN pipe size. For example, 3/4-inch NPT is DN20 NPT.

Table 11-10. Pipe, Tubing, and Conduit Sizes *

U.S. NPS (inch)	ISO DN (mm)	Inside Diameter (mm)	Outside Diameter (mm)	Volume (L/m)
1/8	6	6.8	10.3	0.0363
3/16	7	-	-	-
1/4	8	9.2	13.7	0.0665
3/8	10	12.5	17.1	0.123
1/2	15	15.8	21.3	0.196
5/8	18	-	-	-
3/4	20	20.9	26.7	0.343
1	25	26.6	33.4	0.556
1-1/4	32	35.1	42.2	0.968
1-1/2	40	40.9	48.3	1.31
2	50	52.5	60.3	2.16
2-1/2	65	62.7	73.0	3.09
3	80	77.9	88.9	4.77
3-1/2	90	90.1	101.6	6.38
4	100	102.3	114.3	8.22
4-1/2	115	-	-	-
5	125	128.2	141.3	12.9
6	150	154.1	168.3	18.6
8	200	202.7	219.1	32.3
10	250	253.2	273.1	50.4
12	300	304.8	373.9	73.0
14	350	-	-	-
16	400	-	-	-
18	450	-	-	-
20	500	-	-	-
24	600	-	-	-
28	700	-	-	-
30	750	-	-	-
32	800	-	-	-
36	900	-	-	-
40	1000	-	-	-
44	1100	-	-	-
48	1200	-	-	-
52	1300	-	-	-
56	1400	-	-	-
60	1500	-	-	-

* For pipe over 60 in, use 1 in equals 25 mm.

11.3.4.3 Heating, Ventilating, and Air Conditioning. The temperature unit for HVAC systems is degrees Celsius, not degrees Fahrenheit. All other controls are identical in both metric and inch-pound units. Existing HVAC systems may retain the Fahrenheit temperature designations if only part of the system is being renovated. All major manufacturers offer products in terms of Celsius temperatures. See 11.2 for units used in general HVAC applications. Other units used in HVAC systems are to be used according to ASHRAE standards.

Diffusers and registers are hard metric to fit the metric ceiling grid systems. Ductwork is a custom product and is available in hard metric sizes (e.g., 300 mm by 600 mm). Round, flexible ductwork should be soft converted to metric.

11.3.4.4 Plumbing. See 11.2 for units used in plumbing.

11.3.4.5 Drainage. See 11.2 for units used in drainage applications. Slope is in millimeters per meter (mm/m).

11.3.5 ELECTRICAL.

11.3.5.1 Products. Electric products that will retain the same physical dimensions in metric include cable trays, conduit, fiber optic cables, fire alarm systems and components, junction boxes, motors, panelboards, receptacles, switches, switchgear, transformers, underfloor duct systems, and uninterruptable power supply (UPS) systems. Metric sizes of copper wire may eventually be used. See 11.2 for units used in particular electrical applications.

11.3.5.2 Lighting Fixtures. Hard metric lighting fixtures are available for lay-in type systems in 600-mm by 600-mm and 600-mm by 1200-mm sizes. It is recommended that the 600-mm by 600-mm size be used with sockets on only one end of the fixture with a compact tube or T-8 U-tube for higher efficiency.

11.3.5.3 Electrical Wire, Cable, and Conduit. Electrical conduit is designated in a nominal millimeter size instead of in nominal inches. The physical size or cross section of the conduit is identical in both metric and inch-pound units. See table 11-10. for the inside and outside diameters for nominal sizes of conduit. During transition to metric, the cover sheet of the electrical drawings should include the following note and table.

> "ALL CONDUIT SIZES ARE INDUSTRY STANDARD ENGLISH SIZE CONDUIT DESIGNATED BY THEIR ROUNDED NOMINAL MILLIMETER (mm) DIAMETER EQUIVALENT. SEE CHART BELOW."

Nominal Size	
Inch	mm
1/2	15
3/4	20
1	25
1-1/4	32
1-1/2	40
2	50
2-1/2	65
3	80
3-1/2	90
4	100
5	125
6	150

Electrical wire is identified with the American Wire Gage (AWG) sizes and designations and is not anticipated to change to metric nominal sizes until ASTM B682 is available in metric. In the event that metric equivalence is necessary, possibly for international work, refer to table 11-11 for recommended wire gage conversions. Reference to the cross-sectional area of wire and cable shall be shown in kcmil, not MCM, for thousands of circular mils since the letters M and C represent other quantities in SI.

Table 11-11. Recommended Wire Gage Equivalents (Brown & Sharpe or American)*

Gage No.	Equivalent Diameter (mm)	** First Choice Sizes (mm)	Second Choice Sizes (mm)
28	0.305	0.315	0.300 or 0.335
26	0.381	0.355 or 0.400	0.375
24	0.508	0.500	0.475 or 0.530
22	0.635	0.630	0.600 or 0.670
20	0.813	0.850	0.800 or 0.900
18	1.02	1.000	0.950 or 1.06
16	1.27	1.25	1.18 or 1.32
14	1.63	1.60	1.50 or 1.70
12	2.03	2.00	1.90 or 2.12
10	2.57	2.50	2.36 or 2.65
8	3.25	3.15	3.00 or 3.35

* All metric size diameters conform to the Renard series of preferred numbers.
** Sizes recommended by the International Electrotechnical Commission (IEC).

APPENDIX A

LEGISLATION

Federal Register / Vol. 56, No. 145 / Monday, July 29, 1991 / Presidential Documents 35801

Presidential Documents

Executive Order 12770 of July 25, 1991

Metric Usage in Federal Government Programs

By the authority vested in me as President by the Constitution and the laws of the United States of America, including the Metric Conversion Act of 1975, Public Law 94-168 (15 U.S.C. 205a *et seq.*) ("the Metric Conversion Act"), as amended by section 5164 of the Omnibus Trade and Competitiveness Act of 1988, Public Law 100-418 ("the Trade and Competitiveness Act"), and in order to implement the congressional designation of the metric system of measurement as the preferred system of weights and measures for United States trade and commerce, it is hereby ordered as follows:

Section 1. *Coordination by the Department of Commerce.* (a) The Secretary of Commerce ("Secretary") is designated to direct and coordinate efforts by Federal departments and agencies to implement Government metric usage in accordance with section 3 of the Metric Conversion Act (15 U.S.C. 205b), as amended by section 5164(b) of the Trade and Competitiveness Act.

(b) In furtherance of his duties under this order, the Secretary is authorized:

(1) to charter an Interagency Council on Metric Policy ("ICMP"), which will assist the Secretary in coordinating Federal Government-wide implementation of this order. Conflicts and questions regarding implementation of this order shall be resolved by the ICMP. The Secretary may establish such subcommittees and subchairs within this Council as may be necessary to carry out the purposes of this order.

(2) to form such advisory committees representing other interests, including State and local governments and the business community, as may be necessary to achieve the maximum beneficial effects of this order; and

(3) to issue guidelines, to promulgate rules and regulations, and to take such actions as may be necessary to carry out the purposes of this order. Regulations promulgated by the Secretary shall function as policy guidelines for other agencies and departments.

(c) The Secretary shall report to the President annually regarding the progress made in implementing this order. The report shall include:

(1) an assessment of progress made by individual Federal agencies towards implementing the purposes underlying this order;

(2) an assessment of the effect that this order has had on achieving the national goal of establishing the metric system as the preferred system of weights and measures for United States trade and commerce; and

(3) on October 1, 1992, any recommendations which the Secretary may have for additional measures, including proposed legislation, needed to achieve the full economic benefits of metric usage.

Sec. 2. *Department and Agency Responsibilities.* All executive branch departments and agencies of the United States Government are directed to take all appropriate measures within their authority to carry out the provisions of this order. Consistent with this mission, the head of each executive department and agency shall:

(a) use, to the extent economically feasible by September 30, 1992, or by such other date or dates established by the department or agency in consultation with the Secretary of Commerce, the metric system of measurement in Federal Government procurements, grants, and other business-related activities. Other business-related activities include all use of measurement units in agency programs and functions related to trade, industry, and commerce.

(1) Metric usage shall not be required to the extent that such use is impractical or is likely to cause significant inefficiencies or loss of markets to United States firms.

(2) Heads of departments and agencies shall establish an effective process for a policy-level and program-level review of proposed exceptions to metric usage. Appropriate information about exceptions granted shall be included in the agency annual report along with recommendations for actions to enable future metric usage.

(b) seek out ways to increase understanding of the metric system of measurement through educational information and guidance and in Government publications. The transition to use of metric units in Government publications should be made as publications are revised on normal schedules or new publications are developed, or as metric publications are required in support of metric usage pursuant to paragraph (a) of this section.

(c) seek the appropriate aid, assistance, and cooperation of other affected parties, including other Federal, State, and local agencies and the private sector, in implementing this order. Appropriate use shall be made of governmental, trade, professional, and private sector metric coordinating groups to secure the maximum benefits of this order through proper communication among affected sectors.

(d) formulate metric transition plans for the department or agency which shall incorporate the requirements of the Metric Conversion Act and this order, and which shall be approved by the department or agency head and be in effect by November 30, 1991. Copies of approved plans shall be forwarded to the Secretary of Commerce. Such metric transition plans shall specify, among other things:

(1) the total scope of the metric transition task for that department or agency, including firm dates for all metric accomplishment milestones for the current and subsequent fiscal year;

(2) plans of the department or agency for specific initiatives to enhance cooperation with industry, especially small business, as it voluntarily converts to the metric system, and with all affected parties in undertaking the requirements of paragraph (a) of this section; and

(3) specific steps and associated schedules through which the department or agency will seek to increase understanding of the metric system through educational information and guidance, and in department or agency publications.

(e) designate a senior-level official as the Metric Executive for the department or agency to assist the head of each executive department or agency in implementing this order. The responsibilities of the Metric Executive shall include, but not be limited to:

(1) acting as the department's or agency's policy-level representative to the ICMP and as a liaison with other government agencies and private sector groups:'

(2) management oversight of department or agency outreach and response to inquiries and questions from affected parties during the transition to metric system usage; and

(3) management oversight of preparation of the department's or agency's metric transition plans and progress reports, including the Annual Metric Report required by 15 U.S.C. 205j and OMB Circular A-11.

(4) preparation by June 30, 1992, of an assessment of agency progress and problems, together with recommendations for steps to assure successful implementation of the Metric Conversion Act. The assessment and recommendations shall be approved by the head of the department or agency and provided

Federal Register / Vol. 56, No. 145 / Monday, July 29, 1991 / Presidential Documents 35803

to the Secretary by June 30, 1992, for inclusion in the Secretary's October 1, 1992, report on implementation of this order.

Sec. 3. *Application of Resources.* The head of each executive department and agency shall be responsible for implementing and applying the necessary resources to accomplish the goals set forth in the Metric Conversion Act and this order.

Sec. 4. *Judicial Review.* This order is intended only to improve the internal management of the executive branch and is not intended to create any right or benefit, substantive or procedural, enforceable at law by a party against the United States, its agencies, its officers, or any other person.

THE WHITE HOUSE,
July 25, 1991.

[FR Doc. 91-18028
Filed 7-25-91; 3:08 pm]
Billing code 3195-01-M

APPENDIX B

HISTORY OF SI

APPENDIX B

HISTORY OF SI

This appendix provides brief summaries of events that occurred in the development of SI and of biographical data for persons whose names are used for SI unit names.

B.1 CHRONOLOGICAL EVENTS

1790's The National Assembly of France requested the French Academy of Sciences to "deduce an invariable standard for all the measures and all the weights" to replace poorly related measurement units then used. The Commission appointed by the Academy assigned the name metre (meter) (derived from the Greek word metron, meaning "a measure") to the unit of length. The metric unit of mass, a gram, was defined as the mass of one cubic centimeter of water at its temperature of maximum density. The metric unit of fluid was the cubic decimeter.

Thomas Jefferson described England's weights and measures standards to Congress and outlined a decimal system of weights and measures of his own conception.

1821 John Quincy Adams recommended to Congress that it act to bring about uniformity in weights and measures and described France's metric system as praiseworthy.

1840 France made the metric system compulsory.

1866 By an Act of Congress (Kassen Act), it was made "lawful throughout the United States of America to employ the weights and measures of the metric system in all contracts, dealings or court proceedings."

1875 The "Treaty of the Meter" set up well-defined metric standards for length and mass. Known as the Metre Convention (International Metric Convention), it established the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures) (CGPM) and the International Bureau of Weights and Measures (IBWM), its administrative arm based in Sevres, France, near Paris. The Metre Convention determined base units for length, area, volume, capacity, and mass (based on centimeter, gram, and second - thus the cgs system). This treaty was signed by 17 countries, including the United States.

1893 All standard U.S. measures were defined in terms of the metric units.

1900 A total of 35 nations, including the major nations of continental Europe and most of South America, had officially accepted the metric system. Units began to be based on meter, kilogram, and second - thus the MKS system.

1902 Congressional legislation requiring the Federal government to use metric exclusively was defeated by one vote.

1935 The International Electrotechnical Commission formally adopted the MKS (meter-kilogram-second) system and included the ampere as the base unit of electrical current (MKSA system).

1948 The CGPM instructed the International Committee on Weights and Measures (Comité International des Poids et Mesures) (CIPM) to "study establishment of complete set of rules for units of measurement...to find out for this purpose, by official inquiry, the opinion prevailing in scientific, technical, and educational circles in all countries;" and "to make recommendations on the establishment of a practical system of units of measurement suitable for adoption by all signatories to the Meter Convention."

1950's The CGPM initiated the adoption of seven base units: length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity. A committee of the Organization of American States proposed that the Metric System be adopted throughout the Western Hemisphere. Later, Australia, Canada, New Zealand, South Africa, the United Kingdom, and the United States adopted common standards for the inch-pound system in metric terms. One inch was made equivalent to 2.54 centimeter and 1 pound was made equivalent to 0.453 592 37 kilogram.

1960's The CGPM adopted the name International System of Units (SI) and laid down rules for prefixes, derived and supplementary units, etc.; meanwhile, Japan converted to the metric system of measurement and the British Board of Trade announced that the government consider it desirable to adopt metric units in the United Kingdom, with a target date of 10 years. New Zealand began an 8-year conversion to metric units. In the U.S., an Act providing for a 3-year program to determine the impact of increasing the use of the metric system was passed by Congress and signed into law by the President.

1970's Australia announced plans for a 10-year change over to SI metric measurement, and Canada announced a commitment to the metric conversion.

The comprehensive report on the U.S. Metric study titled *A Metric America: A Decision Whose Time Has Come* was released. The U.S. Senate by voice vote passed the Pell Bill dealing with metric conversion; but, the House did not act on the legislation. The American National Standards Institute established the American National Metric Council with offices in Washington, D.C. Congress passed the first official legislation concerning conversion to the metric system as part of Public Law 93-380, to extend and amend the Elementary and Secondary Education Act of 1965. Under Section 403 of this Act, it states "the metric system of measurement will have increased use in the United States, and as such, the metric system will become the dominant system of weights and measures in the United States." Later, the Metric Conversion Act of 1975 encouraged the use of the metric system in business and industrial applications.

1980's The Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418) amended the Metric Conversion Act of 1975 and established the modern metric system (SI) as the preferred system of measurement in the U.S.

1991 Executive Order 12770 signed by President George Bush mandated the use of SI by the Federal government.

B.2 BIOGRAPHICAL INFORMATION

B.2.1 AMPÈRE, ANDRÉ MARIE (1775-1836). French physicist and mathematician. Ampère demonstrated experimentally that currents exert magnetic forces on each other and established that a magnet is equivalent to a distribution of currents. He derived Ampère's law and the equation for the force exerted by a magnetic field on a current element.

B.2.2 BECQUEREL, ANTOINE-HENRI (1852-1908). French physicist. Becquerel discovered radioactivity in uranium.

B.2.3 CELSIUS, ANDERS (1701-1744). Swedish astronomer. Celsius constructed the thermometer, originally setting 0 °C as the boiling point of water and 100 °C as the freezing point of water. Later, the scale was reversed to set the freezing point and boiling point at 0 °C and 100 °C, respectively.

B.2.4 COULOMB, CHARLES AUGUSTIN DE (1736-1806). French physicist. He invented the torsion balance and established that the electric force between small charged balls obeys an inverse-square law.

B.2.5 FARADAY, MICHAEL (1791-1867). English physicist and chemist. Faraday introduced the concept of field lines and recognized that electric and magnetic fields are physical entities.

B.2.6 HENRY, JOSEPH (1797-1878). American experimental physicist. Henry made important improvements in electromagnets by winding coils of insulated wire around iron pole pieces and invented an electromagnetic motor and a new, efficient telegraph. He discovered self-induction and investigated how currents in one circuit induce currents in another.

B.2.7 HERTZ, HEINRICH RUDOLPH (1857-1894). German physicist. Hertz supplied the first experimental evidence for the electromagnetic waves predicted by Maxwell's theory, generated these waves by means of an electric spark, measured their speed and wavelength, and established their similarity to light waves in the phenomena of reflection, refraction, and polarization.

B.2.8 JOULE, JAMES PRESCOTT (1818-1889). English physicist. Joule established experimentally that heat is a form of mechanical energy and made the first direct measurement of the mechanical equivalent of heat. Joule also provided empirical proof of the general law of conservation of energy.

B.2.9 KELVIN, LORD WILLIAM THOMSON (1824-1907). British physicist and engineer. Besides inventing the absolute temperature scale, he was the first to state the principle of dissipation of energy incorporated in the Second Law of Thermodynamics.

B.2.10 NEWTON, SIR ISAAC (1642-1727). English mathematician and physicist. Newton identified the laws of motion and the law of universal gravitation and demonstrated that planets in the sky as well as bodies on the Earth obey the same mathematical equations. He shares the credit for discovering the calculus method.

B.2.11 OHM, GEORG SIMON (1787-1854). German physicist. Ohm was lead to his law by an analogy between the conduction of electricity and the conduction of heat: the electric field is analogous to the temperature gradient and the electric current is analogous to the heat flow.

B.2.12 PASCAL, BLAISE (1623-1662). French scientist. Pascal is regarded as the founder of modern probability theory. In physics, he performed experiments on atmospheric pressure and on the equilibrium of fluids.

B.2.13 SIEMENS, ERNST WERNER VON (1816-1892). German electrical engineer and inventor. Siemens developed telegraphy and the self-acting dynamo.

B.2.14 TESLA, NIKOLA (1856-1943). American electrical engineer and inventor. Tesla made contributions in high-voltage technology, ranging from new motors and generators to transformers and a system for radio transmission. Tesla designed the power-generating station at Niagara Falls.

B.2.15 VOLTA, CONTE ALESSANDRO (1745-1827). Italian physicist. Volta developed the first "voltaic pile," or battery, consisting of a large stack of moist discs of cardboard (electrolyte) sandwiched between discs of metal (electrodes).

B.2.16 WATT, JAMES (1736-1819). Scottish inventor and engineer. Watt modified and improved an earlier steam engine design and introduced horsepower as a unit of mechanical power.

B.2.17 WEBER, WILHELM EDUARD (1804-1891). German physicist. Weber worked on problems in magnetism and devised a system of units for electric and magnetic quantities.

APPENDIX C

METRIC DOCUMENTATION

APPENDIX C

METRIC DOCUMENTATION

The documents listed in this appendix are Government and nongovernment (industry) publications that contain guidelines for using SI.

C.1 GOVERNMENTAL

John F. Kennedy Space Center (KSC), NASA

NMI 8010.2	Use of the Metric System of Measurement in NASA Programs
KMI 8010.2	Use of the Metric System of Measurement in KSC Facilities, Systems, and Equipment
KHB 8010.2	KSC Metric Transition Plan
DE-MI 8010.2	Metric System

Federal Standard (FED-STD)

FED-STD-376A	Preferred Metric Units for General Use by the Federal Government

National Institute of Standards and Technology (NIST)

NIST LC 1120	Guidelines for the Use of the Modernized Metric System
NIST Special Publication 304	The Modernized Metric System - International System of Units
NIST Special Publication 330	International System of Units (SI)
NIST Special Publication 811	Guide for the Use of the International System of Units
NIST Special Publication 814	Interpretation of the SI for the United States and Metric Conversion Policy for Federal Agencies

(Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.)

Publication SP-7012

Publication SP-7012, NASA, 1973, E.A. Mechtly	The International System of Units - Physical Constants and Conversion Factors

U.S. Department of Defense

MIL-STD-1476	Metric System Application in New Design
SD-10	Guide for Identification and Development of Metric Standards

(Available from Standardization Documents Order Desk, Bldg. 40, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

U.S. General Services Administration (GSA)

	Metric Design Guide
	National Stock Number Guide to Commonly Used Metric Tools
	Standardization and Control of Industrial-Quality Tools

(Available from Federal Supply Service, Washington, DC 20406)

U.S. Government Printing Office

Metric Conversion Policy for Federal Agencies; Rule	15 CFR Part 19, Subpart B. Federal Register, January 2, 1991
Metric System of Measurement: Interpretation of the International System of Units for the United States; Notice	Federal Register, December 20, 1990

(Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.)

C.2 NONGOVERNMENTAL

Aerospace Industries Association of America, Inc./National Aerospace Standards

NAS 10000-77	NA Documents Preparation and Maintenance on SI (Metric) Units. A style guide to prepare National Aerospace Standards Using SI.
NAS 10001-85	Preferred Metric Units for Aerospace. A listing of preferred SI units for many quantities used in aerospace work, their conversion factors, and style rules.

(Available from the Aerospace Industries Association of America, Inc., 1250 Eye Street, N.W., Washington, DC 20005)

American Association of State Highway and Transportation Officials (AASHTO)

AASHTO R 1-77	Standard Metric Practice Guide
	Guide to Metric Conversion
	Standard Specifications for Transportation Materials

(Available from AASHTO, 444 N. Capitol Street, N.W., Washington, DC 20001.)

American Concrete Institute (ACI)

ACI 318M-89/318RM-89	Building Code Requirements for Reinforced Concrete and Commentary
ACI 318.1M-89/ 318.1RM-89	Building Code Requirements for Metric Structural Plain Concrete and Commentary

(Available from ACI, P.O. Box 19150, Detroit, MI 48219.)

American Congress on Surveying and Mapping

	Metric Practice Guide for Surveying and Mapping

(Available from American Congress on Surveying and Mapping, 5410 Grosvenor Lane, Suite 100, Bethesda, MD 20814.)

American Forest and Paper Association (formerly National Forest Products Association)

Lumber and Wood Products Metric Planning Package

(Available from American Forest and Paper Association, 1250 Connecticut Ave., N.W., Washington, DC 20036.)

American Institute of Architects (AIA)

AIA MASTERSPEC. Available in 1993. Contains dual units.

AIA Pocket Metric Guide. Available in June 1993.

The Architect's Studio Companion: Technical Guidelines for Preliminary Design. By Edward Allen and Joseph Iano. Includes dual units.

Architectural Detailing: Function, Constructability, and Aesthetics. By Edward Allen. Includes dual units. Available with Architect's Studio Companion.

Architectural Graphic Standards. A metric edition is not due for several years, but current editions include a comprehensive section on metric conversion.

Fundamentals of Building Construction: Materials and Methods. By Edward Allen. Includes dual units.

Neufert Architect's Data. By Ernst Neufert. Second International (metric) Edition (Germany).

Wiley Engineer's Desk Reference. By S.I. Heisler. Includes dual units.

(Available from AIA Bookstore, 1735 New York Avenue, N.W., Washington, DC 20006. All but the AIA Pocket Metric Guide are published by John Wiley & Sons, Professional Reference and Trade Group, 605 Third Ave., New York, NY 10158.)

American Institute of Steel Construction

Manual of Steel Construction, Metric Edition. To be published in 1994.

Metric Conversion: Load and Resistance Factor Design Specification for Structural Steel Buildings

Metric Properties of Structural Shapes with Dimensions According to ASTM A6M. Metric version of Part I of the Manual of Steel Construction.

(Available from Metric Publications, 1 East Wacker Dr., Suite 3100, Chicago, IL 60601-2001.)

American National Metric Council (ANMC)

ANMC Metric Editorial Guide

Managing Metrication in Business and Industry

Metric Guide for Educational Materials

SI Metric Training Guide

(Available from ANMC, 1735 N. Lynn St., Suite 950, Arlington, VA 22209.)

American National Standards Institute (ANSI)

ANSI B4.2-78	Preferred Metric Limits and Fits
ANSI B4.3-78	Metric Dimensioned Products, General Tolerances for

ANSI X3.50	Representations for U.S. Customary, SI, and Other Units To Be Used in Systems with Limited Character Sets
ANSI Y14.6aM	Metric Supplement (to ANSI Y14.6, Screw Thread Representation)

(Available from ANSI, 11 West 42nd Street, New York, NY 10036.)

American Society for Testing and Materials (ASTM)

ASTM C899	Use of Metric Units of Measure for Reporting Properties of Refractory Materials, Practice for (Committee C-8 Supplement to E380)
ASTM E380	Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)
ASTM E577	Guide for Dimensional Coordination of Rectilinear Building Parts and Systems
ASTM E621	Standard Practice for the Use of Metric (SI) Units in Building Design and Construction (Committee E-6 Supplement to E380)
ASTM E713	Standard Guide for Selection of Scales for Metric Building Drawings
ASTM E835	Guide for Dimensional Coordination of Structural Clay Units, Concrete Masonry Units, and Clay Flue Linings
ASTM STP 565	Evolution of the International Practical Temperature Scale of 1968

See the Annual Book of ASTM Standards for the following ASTM-related material references:

	Abbreviated Metric Practice Guide for the Roofing Industry (Volume 04.04)

Condensed Metric Practice Guide for Corrosion (Volume 03.02)

Guidelines for Metrication in the Field of Electrodeposition and Related Processes (Volume 02.05)

Guidelines for SI Conversion of Units in the Field of Flexible Barrier Materials (Volume 15.09)

Metric Practice Guide for Cement (Volume 04.01)

Metric Practice Guide for Concrete and Concrete Aggregates (Volume 04.02)

Suggested SI Units for Textile (Volume 07.01, Volume 07.02)

(Available from ASTM, 1916 Race Street, Philadelphia, PA 19103.)

American Society of Agricultural Engineers (ASAE)

ASAE EP285.7-90	Use of SI (Metric) Units

(Available from ASAE, 2950 Niles Road, St. Joseph, MI 49085.)

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)

ASHRAE CH37-85	Units and Conversion (ASHRAE Handbook - Fundamentals of SI)
	Psychrometric Charts SI (Charts 1 through 7)
	SI for HVAC&R
	1988 Handbook -- Equipment (Includes dual units)
	1989 Handbook -- Fundamentals (SI edition)

	1990 Refrigeration Handbook (SI edition)
	1991 Handbook -- HVAC Applications (SI edition)
	1992 Handbook -- HVAC Systems and Equipment (SI edition)

(Available from ASHRAE, 1791 Tullie Circle, N.E., Atlanta, GA 30329. All ASHRAE standards are published in metric or with dual units. ASHRAE plans to discontinue the use of inch-pound units by the year 2000.)

American Society of Mechanical Engineers (ASME)

ASME SI-1-82	Orientation and Guide for Use of SI (Metric) Units
ASME SI-2-76	SI Units in Strength of Materials
ASME SI-3-76	SI Units in Dynamics
ASME SI-4-76	SI Units in Thermodynamics
ASME SI-5-76	SI Units in Fluid Mechanics
ASME SI-6-76	SI Units in Kinematics
ASME SI-7-77	SI Units in Heat Transfer
ASME SI-8-76	SI Units in Vibration
ASME SI-9-81	Guide for Metrication of Codes and Standards Using SI (Metric) Units
ASME SI-10-76	Steam Charts, SI (Metric) and U.S. Customary Units
	ASME Steam Tables in SI (Metric) Units for Instructional Use

(Available from ASME, 345 East 47th Street, New York, NY 10017 or from 22 Law Drive, Fairfield, NJ 07007. All other ASME standards, except the Boiler and Pressure Vessel Code, are published either in separate SI editions or with dual units.)

American Welding Society (AWS)

AWS A1.1	Metric Practice Guide for the Welding Industry

(Available from AWS, 550 N.W. Lejeune Road, P.O. Box 351040, Miami, FL 33135. All AWS standards include dual units.)

BPS Professional Books, Oxford, U.K.

Neufert Architect's Data. By Ernst Neufert, 2d International (metric) Edition

(Available from the AIA Bookstore, 1735 New York Avenue, Washington, DC 20006.)

Building Officials and Code Administrators (BOCA) International

BOCA National Building, Fire Prevention, Mechanical, and Plumbing Codes

(Available from BOCA, 4051 W. Flossmoor Rd., Country Club Hills, IL 60477-5795.)

Construction Specifications Institute (CSI)

CSI SPECTEXT. Contains dual units. All other CSI publications contain dual units or are being converted.

(Available from CSI, 601 Madison St., Alexandria, VA 22314-1791.)

For Good Measure

By William D. Johnstone, a complete compendium of international weights and measures.

(Available from Holt, Rinehart and Winston, New York.)

Hardwood Plywood Manufacturers Association

Interim Voluntary Standard for Hardwood and Decorative Plywood. Includes dual units.

(Available from Hardwood Plywood Manufacturers Association, Box 2789, Reston, VA 22090-2789.)

Industrial Fasteners Institute

Metric Fastener Standards

(Available from Industrial Fasteners Institute, 1105 East Ohio Building, 1717 E. 9th St., Cleveland, OH 44114.)

Institute of Electrical and Electronics Engineers (IEEE)

IEEE 260	Standard Letter Symbols for Units of Measurement (SI Units, Customary Inch-Pound Units, and Certain Other Units)
ANSI/IEEE STD 268	American National Standard for Metric Practice
IEEE 945-84	Recommended Practice for Preferred Metric Units for Use in Electrical and Electronics Science and Technology
	Units and Conversion Charts, by Theodore Wildi

(Available from IEEE, 345 E. 47th Street, New York, NY 10017 or from 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.)

International Conference of Building Officials

Uniform Building, Fire, Mechanical, and Plumbing Codes. The 1994 editions will be published with dual units.

(Available from International Conference of Building Officials, 5360 South Workman Mill Rd., Whittier, CA 90601.)

International Organization for Standardization (ISO)

ISO 1000	SI Units and Recommendations for the Use of Their Multiples and Certain Other Units
ISO 2955	Information Processing - Representation of SI and Other Units for Use in Systems with Limited Character Sets
ISO 31/O-1974	General Introduction to ISO 31 - General Principles Concerning Quantities, Units and Symbols
ISO 31/I-1978	Quantities and Units of Space and Time
ISO 31/II-1978	Quantities and Units of Periodic and Related Phenomena
ISO 31/III-1978	Quantities and Units of Mechanics
ISO 31-IV-1978	Quantities and Units of Heat
R31-Part V-1965	Quantities and Units of Electricity and Magnetism
ISO 31/VI-1973	Quantities and Units of Light and Related Electro-Magnetic Radiations
ISO 31/VII-1978	Quantities and Units of Acoustics
ISO 31/VIII-1973	Quantities and Units of Physical Chemistry and Molecular Physics
ISO 31/IX-1973	Quantities and Units of Atomic and Nuclear Physics
ISO 31/X-1973	Quantities and Units of Nuclear Reactions and Ionizing Radiations
ISO 31/XI-1978	Mathematical Signs and Symbols for Use in the Physical Sciences and Technology
ISO 31/XII-1975	Dimensionless Parameters

ISO 31/XIII-1975	Quantities and Units of Solid State Physics
ISO 370-1975	Conversion of Toleranced Dimensions from Inches into Millimetres and Vice Versa

[Available in the United States from American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036.]

National Environmental Balancing Bureau

Fundamentals, Air Systems, and Hydronic Systems guides. Available in metric editions:

Environmental Systems Technology (20 chapters) Chapter 2-84, Fundamentals; Chapter 6-84, Air Distribution Systems; and Chapter 7-84, Hydronic Systems

Procedural Standards for Measuring Sound and Vibration (27 sections)

Testing, Adjusting, Balancing Manual for Technicians (14 chapters)

Sound and Vibration in Environmental Systems (8 chapters)

Procedural Standards for Testing, Adjusting, Balancing of Environmental Systems (11 sections)

(Available from National Environmental Balancing Bureau, 1385 Piccard Dr., Rockville, MD 20850.)

National Fire Protection Association (NFPA)

NFPA 13	Installation of Sprinkler Systems
NFPA 70	National Electrical Code
NFPA 101	Life Safety Code

(Available from NFPA, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.)

National Institute of Building Sciences (NIBS)

NIBS	Metric Guide for Federal Construction
NIBS	Metric in Construction (a bimonthly newsletter)

(Available from NIBS, 1201 L Street, N.W., Suite 400, Washington, DC 20005.)

National Particleboard Association and National Hardboard Association

	Metric units currently are being added to the NPA and NHA/ANSI standards for particleboard and medium-density fiberboard.

(Available from National Particleboard Association, 18928 Premiere Ct., Gaithersburg, MD 20879 and American Hardboard Association, 520 North Hicks Road, Palatine, IL 60067.)

National Technical Information Service

NBS Special Publication 530	Metrication in Building Design, Production, and Construction -- A Compendium of 10 Papers
NBS Technical Note 990	The Selection of Preferred Metric Values for Design and Construction
PB 89-226922	Metric Handbook for Federal Officials (includes Federal Standard No. 376A of May 5, 1983, Preferred Metric Units for General Use by the Federal Government)

(Available from National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161.)

R.S. Means Company

	Means Building Construction Cost Data, Metric Edition

(Available from R.S. Means Company, Box 800, Kingston, MA 02364.)

Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)

	All SMACNA publications are being converted to dual units.

(Available from SMACNA, 4201 Lafayette Center Dr., Chantilly, VA 22021.)

SI Metric Handbook

	By John L. Feirer, The Metric Company

(Available from Charles Scribner's Sons, New York.)

Society of Automotive Engineers (SAE)

SAE AIR 1657-81	Handbook of Hydraulic Metric Calculations
SAE AIR 1758-82	Limits and Fits - International Metric Tolerance Systems
SAE J916-91	Rules for SAE Use of SI (Metric) Units, Recommended Practice

(Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.)

Society of Manufacturing Engineers (SME)

	Metrication for Engineers
	The Metric System: A Review of Industrial Applications

(Available from SME, 1 SME Drive, Box 930, Dearborn, MI 48121.)

Southern Building Code Congress International, Inc.

	Standard Building Code

(Available from Southern Building Code Congress International, Inc., 900 Montclair Road, Birmingham, AL 35213-1206.)

The Association for Manufacturing Technology

Guidelines for Metric Conversion in Machine Tool and Related Industries

(Available from The Association for Manufacturing Technology, 7901 Westpark Dr., McLean, VA 22102-4269.)

The Wall Street Journal Guide to the Metric System

(Available from Dow Jones Books, P.O. Box 300, Princeton, NJ 08540.)

By Jerry E. Bishop

Underwriters Laboratories Inc. (UL)

Virtually all UL standards contain dual units.

(Available from UL, 333 Pfingsten Rd., Northbrook, IL 60062.)

U.S. Metric Association

Freeman Training/Education Metric Materials List

Guidance for Companies Considering Converting their Operations to Using the Metric System. Available free to company members.

Metric Units of Measure and Style Guide

(Available from U.S. Metric Association, 10245 Andasol Avenue, Northridge, CA 91325.)

Water Environment Federation

Manual of Practice No. 6, Units of Expression for Wastewater Treatment Management

(Available from Water Environment Federation, 601 Wythe St., Alexandria, VA 22314.)

Water Pollution Control Federation

MO6	Units of Expression for Wastewater Treatment Management

(Available from Water Pollution Control Federation, 601 Wythe St., Alexandria, VA 22314.)

John Wiley and Sons

	The Architect's Studio Companion: Technical Guidelines for Preliminary Design. By Edward Allen and Joseph Iano (includes dual units)
	Wiley Engineer's Desk Reference. By S.I. Heisler (includes dual units)

(Available from Professional Reference and Trade Group, 605 Third Avenue, New York, NY.)

APPENDIX D

SIGNIFICANT DIGITS AND ROUNDING

APPENDIX D

SIGNIFICANT DIGITS AND ROUNDING

D.1 SIGNIFICANT DIGITS

When converting values from one unit to another, implied or required precision of the value converted must be considered. The converted value must carry the same number of significant digits to maintain the accuracy of the original value. As defined in 6.2, a significant digit is any digit necessary to define the specific value. Determining the number of significant digits requires knowledge of how the original value was obtained. If the original value was measured to the nearest whole unit increment (e.g., 10 feet), then there are two significant digits. If the original value was measured to the nearest tenth of a unit (e.g., 10.4 feet), then there are three significant digits.

Zeros may be either significant digits or merely indicate the order of magnitude of a number. The number 873 248 709 contains nine significant digits, including the zero. If this number is rounded to 873 249 000, the first six digits are significant and the three zeros indicate the magnitude of the number rounded to the nearest thousand.

When converting inch-pound values to metric, take into consideration the specific digits making up the number. After multiplying the original inch-pound value by the conversion factor, round to the same number of significant digits as the original number if the first digit of the metric number is greater than or equal to the first significant digit of the original number. In the examples shown, both original values have two significant digits and both answers are rounded to the same number of significant digits.

Example: Convert 11 miles to kilometers.

11 mi x 1.609 km/mi = 17.669 km, which rounds to 18 km

Example: Convert 61 miles to kilometers.

61 mi x 1.609 km/mi = 98.149 km, which rounds to 98 km

Round the metric values to one more significant digit than the original inch-pound value if the first digit of the metric number is smaller than the first significant digit of the original value. In the following examples, the original values have two significant digits and both answers are rounded to one more significant digit than the original value - three significant digits.

Example: Convert 66 miles to kilometers.

66 mi x 1.609 km/mi = 106.194 km, which rounds to 106 km

Example: Convert 81 feet to meters.

81 ft x 0.3048 m/ft = 24.6888 m, which rounds to 24.7 m

There are situations when the previous guidelines may not produce the most reasonable results. Judgment should be used to determine when the guidelines given above apply. The following example illustrates a case when judgment should be used. The rule described in the previous paragraph shows that 179.27 kPa should be rounded to three significant digits, but rounding it to two significant digits may be an acceptable degree of accuracy for the particular situation.

Example: Convert 26 pounds per square inch to kilopascals.

26 psi x 6.895 kPa/psi = 179.27 kPa, which rounds to 179 kPa, but use 180 kPa

D.2 ARITHMETIC OPERATIONS

D.2.1 ADDITION AND SUBTRACTION. When adding and subtracting, the answer shall contain no more significant digits farther to the right than occurs in the least precise number as described in the following steps and shown in the example.

1. Determine the least precise number and in which place the last significant digit lies (e.g., hundreds place, thousands place, etc.).

2. Round each number to one digit to the right of that place. For example, if the last significant digit lies in the thousands place, round each number to the hundreds place.

3. Perform the addition or subtraction and round the answer to the number of significant digits determined in step 1.

Example: Add the numbers 163 000 000, 217 885 000, and 96 432 768.

The least precise number is 163 000 000 with three significant digits with the last significant digit in the millions place. Round each number to the hundred-thousands place (one place to the right of the last significant digit's place): 163 000 000, 217 900 000, 96 400 000

Add: 163 000 000
217 900 000
+96 400 000
477 300 000

Round the answer to three significant digits (the number of significant digits in the least precise number): 477 000 000

Example: Subtract 0.356 68 from 111.794.

Even though 0.356 68 has only five significant digits, 111.794 is less precise with the last significant digit in the thousandths place. Round 0.356 68 to the ten-thousandths place (one place to the right of the thousandths place) and add a zero to 111.794, and then subtract.

111.7940
\- 0.3567
111.4373

Round the answer to six significant digits (the number of significant digits in the least precise number): 111.437

D.2.2 MULTIPLICATION AND DIVISION. When multiplying and dividing, the product or quotient shall contain only the number of significant digits in the number with the fewest significant digits used in the operation. Note that this process depends on the total number of significant digits in the numbers multiplied or divided as compared to the addition and subtraction process which depends on the precision of the numbers used.

Example: Multiply 846.46 by 1.4.

The number with the fewest significant digits is 1.4 with two.
846.46 x 1.4 = 1185.044
Round the answer to two significant digits: 1200

D.2.3 INTEGERS. Number that are exact counts are not rounded prior to performing an arithmetic operation. When the count is used in computation with a measurement, the number of significant digits in the answer is the same as the number of significant digits in the measurement. If, however, the count is an estimate, then the rules apply as described in D.2.1 and D.2.2.

D.3 ROUNDING

When the first digit to be discarded is less than 5, the last digit retained is not changed.

Example: Round 4.684 25 to four digits.

Answer: 4.684

When the first digit discarded is greater than 5, or if it is a 5 followed by at least one digit other than 0, the last digit retained is increased by one unit.

Example: Round 8.376 52 to four digits.

Answer: 8.377

Example: Round 8.376 52 to three digits.

Answer: 8.38

When the first digit discarded is exactly 5, followed only by zeros, the last digit retained should be rounded upward if it is an odd number, but no adjustment is made if it is an even number.

Example: Round 4.365 to three digits.

Answer: 4.36

Example: Round 4.355 to three digits.

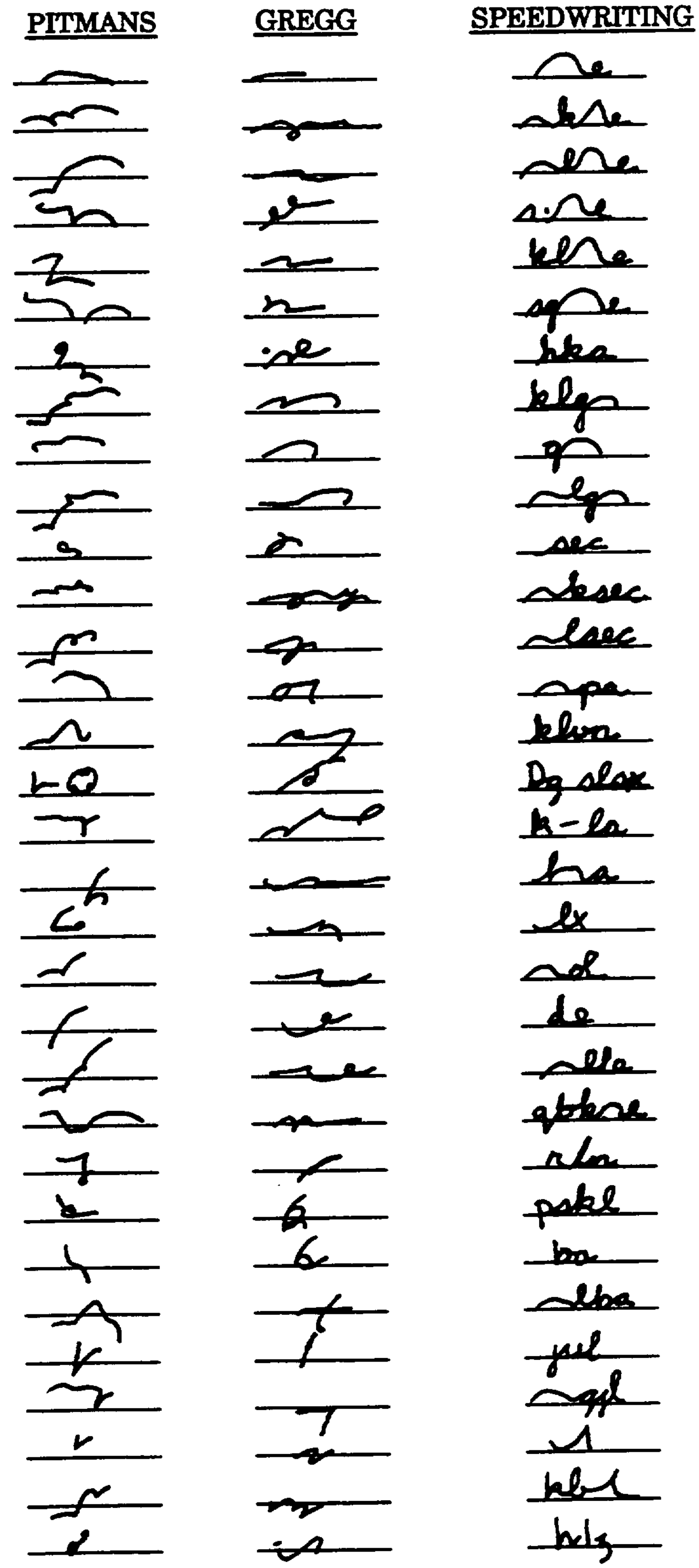
Answer: 4.36

APPENDIX E

EXAMPLES OF SI (METRIC) SHORTHAND FORMS

EXAMPLES OF SI (METRIC) SHORTHAND FORMS

WORD	SI SYMBOL
meter	m
micrometer	µm
millimeter	mm
centimeter	cm
kilometer	km
square meter	m^2
hectare	ha
kilogram	kg
gram	g
milligram	mg
second	s
microsecond	µs
millisecond	ms
ampere	A
kelvin	K
degree Celsius	°C
candela	cd
lumen	lm
lux	lx
mole	mol
liter	L or l
millimeter	mL or ml
cubic meter	m^3
newton	N
pascal	Pa
bar	bar
millibar	mbar
joule	J
megajoule	MJ
watt	W
kilowatt	kW
hertz	Hz



APPENDIX F

PHYSICAL CONSTANTS

APPENDIX F
PHYSICAL CONSTANTS

Quantity	Symbol	Value	Units
Electron charge	e	1.602×10^{-19}	C
Electron mass	m_e	9.109×10^{-31}	kg
Unified atomic mass constant	m_u	1.660×10^{-27}	kg
Proton mass	m_p	1.672×10^{-27}	kg
Neutron mass	m_n	1.674×10^{-27}	kg
Mass of hydrogen	m_H	1.673×10^{-27}	kg
Planck constant	h	6.625×10^{-34}	J·s
Boltzmann constant	k	1.380×10^{-23}	J/kg
Avogadro's number	N_o	$6.022\ 169 \times 10^{23}$	molecules per mole
Gas constant for air	R_a	8.314 34	J/(K·mol)
		287.045	J/(kg·K)
Gas constant for water vapor	R_v	461.52	J/(kg·K)
Velocity of sound in air (at P_o, 20 °C, 50% relative humidity)	M	344.0	m/s
Velocity of light in vacuum	c_o	2.998×10^{8}	m/s
Gravitational constant	G	6.673×10^{-11}	N·m²/kg
Specific heat (heat capacity) of air at 15 °C			
- at constant pressure	c_p	1.004 76	kJ/(kg·K)
- at constant volume	c_v	717.986	J/(kg·K)
Absolute (zero) temperature	T	0.0	K
		-273.15	°C
Standard atmosphere at sea level			
Pressure	P_o	101.325	kPa
Temperature	T_o	288.15	K
		15.0	°C
Specific volume of ideal gas (at STP)	V_o	22.41	m³/mol
Acceleration due to gravity	g	9.806 65	m/s²
Specific weight	$g_o\rho_o$	1.225 0	kg/m³
Density	ρ_o	0.124 92	kg/m³
Kinematic viscosity	ν_o	$1.460\ 7 \times 10^{-5}$	m²/s
Absolute viscosity	μ_o	$1.789\ 4 \times 10^{-5}$	kg/(m·s)

APPENDIX G

CONVERSION TABLES

Table G-1. Conversion Factors (Alphabetical Listing)

NOTES:

1. The "E" notation indicates that the value shown is multiplied by 10 raised to the power of the number that follows the E (e.g., 2.044 175 E+04 means 2.044 175 x 10^4)
2. Numbers shown with an asterisk (*) denote exact values.

Multiply	By		To Obtain
abampere	1.000 000*	E+01	ampere (A)
abcoulomb	1.000 000*	E+01	coulomb (C)
abfarad	1.000 000*	E+09	farad (F)
abhenry	1.000 000*	E-09	henry (H)
abmho	1.000 000*	E+09	siemens (S)
abohm	1.000 000*	E-09	ohm (Ω)
abvolt	1.000 000*	E-08	volt (V)
acre foot	1.233 489	E+03	cubic meter (m^3)
acre	4.046 873	E+03	square meter (m^2)
ampere hour (Ah)	3.600 000*	E+03	coulomb (C)
angstrom	1.000 000*	E-10	meter (m)
are	1.000 000*	E+02	square meter (m^2)
astronomical unit (AU)	1.495 979	E+11	meter (m)
atmosphere, standard (atm)	1.013 250*	E+05	pascal (Pa)
atmosphere, technical (= 1 kg_f/cm^2)	9.806 650*	E+04	pascal (Pa)
atomic mass unit (amu)	1.660 566	E-27	kilogram (kg)
bar	1.000 000*	E+05	pascal (Pa)
barn	1.000 000*	E-28	square meter (m^2)
barrel (for petroleum, 42 gal)	1.589 873	E-01	cubic meter (m^3)
biot	1.000 000*	E+01	ampere (A)
board foot	2.359 737	E-03	cubic meter (m^3)
British thermal unit (Btu) †			

† In these expressions, kelvin (K) indicates a temperature interval. Therefore, K may be replaced by degree Celsius (°C) if desired without changing the value or affecting the conversion factor. For example, in thermal conductivity, 1 W/(m·K) = 1 W/(m·°C).

Table G-1. Conversion Factors (Alphabetical Listing) (cont)

Multiply	By		To Obtain
- mean	1.055 87	E+03	joule (J)
- 39 °F	1.059 67	E+03	joule (J)
- 59 °F	1.054 80	E+03	joule (J)
- 60 °F	1.054 68	E+03	joule (J)
- International Table	1.055 056	E+03	joule (J)
- - Btu/h	2.930 711	E-01	watt (W)
- - Btu/s	1.055 056	E+03	watt (W)
- - Btu/ft^2	1.135 653	E+04	joule per square meter (J/m^2)
- - Btu/(ft^2·s)	1.135 653	E+04	watt per square meter (W/m^2)
- - Btu/(ft^2·h)	3.154 591	E+00	watt per square meter (W/m^2)
- - Btu/lb	2.326 000*	E+03	joule per kilogram (J/kg)
- - Btu/ft^3	3.725 895	E+04	joule per cubic meter (J/m^3)
- - Btu·ft/(h·ft^2·°F)	1.730 735	E+00	watt per meter kelvin [W/(m·K)]
- - Btu·in/(h·ft^2·°F)	1.442 279	E-01	watt per meter kelvin [W/(m·K)]
- - Btu·in/(s·ft^2·°F)	5.192 204	E+02	watt per meter kelvin [W/(m·K)]
- - Btu/(h·ft^2·°F)	5.678 263	E+00	watt per square meter kelvin [W/(m^2·K)]
- - Btu/(s·ft^2·°F)	2.044 175	E+04	watt per square meter kelvin [W/(m^2·K)]
- - Btu/°F	1.899 108	E+03	joule per kelvin (J/K)
- - Btu/(lb·°F)	4.186 800*	E+03	joule per kilogram kelvin [J/(kg·K)]
- - °F·h·ft^2/Btu	1.761 102	E-01	kelvin square meter per watt (K·m^2/W)
- - °F·h·ft^2/(Btu·in)	6.933 471	E+00	kelvin meter per watt (K·m/W)
- thermochemical	1.054 350	E+03	joule (J)
- - Btu/h	2.928 751	E-01	watt (W)
- - Btu/min	1.757 250	E+01	watt (W)
- - Btu/s	1.054 350	E+03	watt (W)
- - Btu/ft^2	1.134 893	E+04	joule per square meter (J/m^2)
- - Btu/(ft^2·s)	1.134 893	E+04	watt per square meter (W/m^2)
- - Btu/(ft^2·min)	1.891 489	E+02	watt per square meter (W/m^2)
- - Btu/(ft^2·h)	3.152 481	E+00	watt per square meter (W/m^2)
- - Btu/(in^2·s)	1.634 246	E+06	watt per square meter (W/m^2)
- - Btu/lb	2.324 444	E+03	joule per kilogram (J/kg)
- - Btu/ft^3	3.723 402	E+04	joule per cubic meter (J/m^3)

Table G-1. Conversion Factors (Alphabetical Listing) (cont)

Multiply	By		To Obtain
- Btu·ft/(h·ft²·°F)	1.729 577	E+00	watt per meter kelvin [W/(m·K)]
- Btu·in/(h·ft²·°F)	1.441 314	E-01	watt per meter kelvin [W/(m·K)]
- Btu·in/(s·ft²·°F)	5.188 732	E+02	watt per meter kelvin [W/(m·K)]
- Btu/(h·ft²·°F)	5.674 466	E+00	watt per square meter kelvin [W/(m²·K)]
- Btu/(s·ft²·°F)	2.042 808	E+04	watt per square meter kelvin [W/(m²·K)]
- Btu/°F	1.897 831	E+03	joule per kelvin (J/K)
- Btu/(lb·°F)	4.184 000*	E+03	joule per kilogram kelvin [J/(kg·K)]
- °F·h·ft²/Btu	1.762 280	E-01	kelvin square meter per watt (K·m²/W)
- °F·h·ft²/(Btu·in)	6.938 113	E+00	kelvin meter per watt (K·m/W)
bushel (U.S.) (bu)	3.523 907	E-02	cubic meter (m³)
calorie (cal) †			
- International Table	4.186 800*	E+00	joule (J)
- cal/g	4.186 800*	E+03	joule per kilogram (J/kg)
- cal/(g·°C)	4.186 800*	E+03	joule per kilogram kelvin [J/(kg·K)]
- mean	4.190 02	E+00	joule (J)
- thermochemical (cal_{th})	4.184 000*	E+00	joule (J)
- cal/cm²	4.184 000*	E+04	joule per square meter (J/m²)
- cal/g	4.184 000*	E+03	joule per kilogram (J/kg)
- cal/(g·°C)	4.184 000*	E+03	joule per kilogram kelvin [J/(kg·K)]
- cal/min	6.973 333	E-02	watt (W)
- cal/s	4.184 000*	E+00	watt (W)
- cal/(cm²·s)	4.184 000*	E+04	watt per square meter (W/m²)
- cal/(cm²·min)	6.973 333	E+02	watt per square meter (W/m²)
- cal/(cm·s·°C)	4.184 000*	E+02	watt per meter kelvin [W/(m·K)]
- 15 °C	4.185 80	E+00	joule (J)
- 20 °C	4.181 90	E+00	joule (J)
- kilogram, International Table	4.186 800*	E+03	joule (J)

† In these expressions, kelvin (K) indicates a temperature interval. Therefore, K may be replaced by degree Celsius (°C) if desired without changing the value or affecting the conversion factor. For example, in thermal conductivity, 1 W/(m·K) = 1 W/(m·°C).

Table G-1. Conversion Factors (Alphabetical Listing) (cont)

Multiply	By		To Obtain
- kilogram, mean	4.190 02	E+03	joule (J)
- kilogram, thermochemical	4.184 000	E+03	joule (J)
candela per square inch (cd/in^2)	1.550 003	E+03	candela per square meter (cd/m^2)
candle	1.000 000	E+00	candela (cd)
candlepower	1.000 000	E+00	candela (cd)
carat (metric)	2.000 000*	E-04	kilogram (kg)
centimeter of mercury (0 °C) (cmHg)	1.333 22	E+03	pascal (Pa)
centimeter of water (4 °C) (cmH_2O)	9.806 38	E+01	pascal (Pa)
centipoise (dynamic viscosity) (cP)	1.000 000*	E-03	pascal second (Pa·s)
centistokes (kinematic viscosity) (cSt)	1.000 000*	E-06	square meter per second (m^2/s)
chain (survey)	2.011 684	E+01	meter (m)
circular mil	5.067 075	E-10	square meter (m^2)
clo †	1.55	E-01	kelvin square meter per watt ($K{\cdot}m^2/W$)
cord	3.624 720	E+01	square meter (m^2)
cup (c)	2.365 882	E-04	cubic meter (m^3)
curie (Ci)	3.700 000*	E+10	becquerel (Bq)
darcy	9.869 233	E-13	square meter (m^2)
day	8.640 000*	E+04	second (s)
day (sidereal)	8.616 409	E+04	second (s)
degree (angle) (°)	1.745 329	E-02	radian (rad)
degree			
- degree Celsius (°C)	$T_K = t_{°C} + 273.15$		kelvin (K)
- degree centigrade	1.000 000	E+00	degree Celsius (°C)
- degree Fahrenheit (°F)	$t_{°C} = (t_{°F} - 32)/1.8$		degree Celsius (°C)
- degree Fahrenheit (°F)	$T_K = (t_{°F} + 459.67)/1.8$		degree Celsius (°C)
- degree Rankine (°R)	$T_K = T_{°R}/1.8$		kelvin (K)
denier	1.111 111	E-07	kilogram per meter (kg/m)

† In these expressions, kelvin (K) indicates a temperature interval. Therefore, K may be replaced by degree Celsius (°C) if desired without changing the value or affecting the conversion factor. For example, in thermal conductivity, 1 W/(m·K) = 1 W/(m·°C).

Table G-1. Conversion Factors (Alphabetical Listing) (cont)

Multiply	By		To Obtain
dram			
- avoirdupois	1.771 845	E-03	kilogram (kg)
- liquid	3.696 588	E-06	cubic meter (m^3)
- troy or apothocary	3.887 935	E-03	kilogram (kg)
drop	6.485 240	E-08	cubic meter (m^3)
dyne			
- dyne (force)	1.000 000*	E-05	newton (N)
- dyne (troy)	6.609 490	E-08	kilogram (kg)
- dyne·cm	1.000 000*	E-07	newton meter (N·m)
- dyne/cm^2	1.000 000*	E-01	pascal (Pa)
electronvolt (eV)	1.602 193	E-19	joule (J)
EMU (electromagnetic unit)			
- of capacitance	1.000 000*	E+09	farad (F)
- of current	1.000 000*	E+01	ampere (A)
- of electric potential	1.000 000*	E-08	volt (V)
- of inductance	1.000 000*	E-09	henry (H)
- of resistance	1.000 000*	E-09	ohm (Ω)
ESU (electrostatic unit)			
- of capacitance	1.112 650	E-12	farad (F)
- of current	3.335 6	E-10	ampere (A)
- of electric potential	2.997 9	E+02	volt (V)
- of inductance	8.987 554	E+11	henry (H)
- of resistance	8.987 554	E+11	ohm (Ω)
erg	1.000 000*	E-07	joule (J)
- erg/(cm^2·s)	1.000 000*	E-03	watt per square meter (W/m^2)
- erg/s	1.000 000*	E-07	watt (W)
faraday			
- faraday (based on carbon-12)	9.648 70	E+04	coulomb (C)
- faraday (chemical)	9.649 57	E+04	coulomb (C)
- faraday (physical)	9.652 19	E+04	coulomb (C)
fathom	1.828 804	E+00	meter (m)
fermi (femtometer)	1.000 000*	E-15	meter (m)

Table G-1. Conversion Factors (Alphabetical Listing) (cont)

Multiply	By		To Obtain
fluid ounce (see ounce)			
foot (ft)	3.048 000*	E-01	meter (m)
- U.S. survey	3.048 006	E-01	meter (m)
- ft H_2O (39.2 °F)	2.988 98	E+03	pascal (Pa)
- ft^2	9.290 304*	E-02	square meter (m^2)
- ft^2/h (thermal diffusivity)	2.580 640*	E-05	square meter per second (m^2/s)
- ft^2/s	9.290 304*	E-02	square meter per second (m^2/s)
- ft^3 (volume; section modulus)	2.831 685	E-02	cubic meter (m^3)
- ft^3/min	4.719 474	E-04	cubic meter per second (m^3/s)
- ft^3/s	2.831 685	E-02	cubic meter per second (m^3/s)
- ft^4 (second moment of area)	8.630 975	E-03	meter to the fourth power (m^4)
- ft/h	8.466 667	E-05	meter per second (m/s)
- ft/min	5.080 000*	E-03	meter per second (m/s)
- ft/s	3.048 000*	E-01	meter per second (m/s)
- ft/s^2	3.048 000*	E-01	meter per second squared (m/s^2)
footcandle (fc)	1.076 391	E+01	lux (lx)
footlambert (fL)	3.426 259	E+00	candela per square meter (cd/m^2)
foot pound ($ft{\cdot}lb_f$)	1.355 818	E+00	joule (J)
- $ft{\cdot}lb_f/h$	3.766 161	E-04	watt (W)
- $ft{\cdot}lb_f/min$	2.259 697	E-02	watt (W)
- $ft{\cdot}lb_f/s$	1.355 818	E+00	watt (W)
foot-poundal	4.214 011	E-02	joule (J)
furlong	2.011 684	E+02	meter (m)
g, standard free fall	9.806 650*	E+00	meter per second squared (m/s^2)
gal	1.000 000*	E-02	meter per second squared (m/s^2)
gallon (gal)			
- Canadian liquid	4.546 090	E-03	cubic meter (m^3)
- U.K. liquid	4.546 092	E-03	cubic meter (m^3)
- U.S. dry	4.404 884	E-03	cubic meter (m^3)
- U.S. liquid	3.785 412	E-03	cubic meter (m^3)

Table G-1. Conversion Factors (Alphabetical Listing) (cont)

Multiply	By		To Obtain
- gallon/day	4.381 264	E-08	cubic meter per second (m^3/s)
- gallon/minute	6.309 020	E-05	cubic meter per second(m^3/s)
- gallon/hp·h (SFC, specific fuel consumption)	1.410 089	E-09	cubic meter per joule (m^3/J)
gamma	1.000 000*	E-09	tesla (T)
gauss	1.000 000*	E-04	tesla (T)
gilbert	7.957 747	E-01	ampere (A)
gill (U.K.)	1.420 653	E-04	cubic meter (m^3)
gill (U.S.)	1.182 941	E-04	cubic meter (m^3)
grade			
- grade	9.000 000*	E-01	degree (angular)
- grade	1.570 796	E-02	radian (rad)
- grade	$\pi/200$*		radian (rad)
grain	6.479 891*	E-05	kilogram (kg)
grain/gallon (U.S. liquid)	1.711 806	E-02	kilogram per cubic meter (kg/m^3)
gram	1.000 000*	E-03	kilogram (kg)
g/cm^3	1.000 000*	E+03	kilogram per cubic meter (kg/m^3)
g_f/cm^2	9.806 650*	E+01	pascal (Pa)
hectare (ha)	1.000 000*	E+04	square meter (m^2)
horsepower (hp)			
- 550 $ft \cdot lb_f/s$	7.456 999	E+02	watt (W)
- boiler	9.809 50	E+03	watt (W)
- electric	7.460 000*	E+02	watt (W)
- horsepower hour (hp·h)	2.684 520	E+06	joule (J)
- metric	7.354 99	E+02	watt (W)
- water	7.460 43	E+02	watt (W)
- U.K.	7.457 0	E+02	watt (W)
hour	3.600 000*	E+03	second (s)
hour (sidereal)	3.590 170	E+03	second (s)
hundredweight (long)	5.080 235	E+01	kilogram (kg)
hundredweight (short)	4.535 924	E+01	kilogram (kg)
inch (in)	2.540 000*	E-02	meter (m)

Table G-1. Conversion Factors (Alphabetical Listing) (cont)

Multiply	By		To Obtain
- in Hg (32 °F)	3.386 38	E+03	pascal (Pa)
- in Hg (60 °F)	3.376 85	E+03	pascal (Pa)
- in H_2O (39.2 °F)	2.490 82	E+02	pascal (Pa)
- in H_2O (60 °F)	2.488 4	E+02	pascal (Pa)
- in^2	6.451 600*	E-04	square meter (m^2)
- in^3 (volume)	1.638 706	E-05	cubic meter (m^3)
- in^3 (section modulus)	1.638 706	E-05	meter cubed (m^3)
- in^3/min	2.731 177	E-07	cubic meter per second (m^3/s)
- in^4 (second moment of area)	4.162 314	E-07	meter to the fourth power (m^4)
- in/s	2.540 000*	E-02	meter per second (m/s)
- in/s^2	2.540 000*	E-02	meter per second squared (m/s^2)
kayser	1.000 000*	E+02	1 per meter (1/m)
kelvin (K)	$t_{°C} = T_K - 273.15$		degree Celsius (°C)
kilocalorie (kcal)			
- International Table	4.186 800*	E+03	joule (J)
- mean	4.190 02	E+03	joule (J)
- thermochemical	4.184 000*	E+03	joule (J)
- - kilocalorie/min	6.973 333	E+01	watt (W)
- - kilocalorie/s	4.184 000*	E+03	watt (W)
kilogram-force (kg_f)	9.806 650*	E+00	newton (N)
- $kg_f \cdot m$	9.806 650*	E+00	newton meter (N·m)
- $kg_f \cdot s^2/m$ (mass)	9.806 650*	E+00	kilogram (kg)
- kg_f/cm^2	9.806 650*	E+04	pascal (Pa)
- kg_f/m^2	9.806 650*	E+00	pascal (Pa)
- kg_f/mm^2	9.806 650*	E+06	pascal (Pa)
kilometer per hour (km/h)	2.777 778	E-01	meter per second (m/s)
kilopond (1 kp = 1 kg_f)	9.806 650*	E+00	newton (N)
kW·h	3.600 000*	E+06	joule (J)
kip (1000 lb_f)	4.448 222	E+03	newton (N)
kip/in^2 (ksi)	6.894 757	E+06	pascal (Pa)

Table G-1. Conversion Factors (Alphabetical Listing) (cont)

Multiply	By		To Obtain
knot (international) (kn)	5.144 444	E-01	meter per second (m/s)
lambert (L)	1/π*	E+04	candela per square meter (cd/m²)
lambert	3.183 099	E+03	candela per square meter (cd/m²)
langley (= 1 cal/cm²)	4.184 000*	E+04	joule per square meter (J/m²)
light year	9.460 55	E+15	meter (m)
link (survey)	2.011 684	E-01	meter (m)
liter (L)	1.000 000*	E-03	cubic meter (m³)
lumen per square feet (lm/ft²)	1.076 391	E+01	lumen per square meter (lm/m²)
maxwell	1.000 000*	E-08	weber (Wb)
mho	1.000 000*	E+00	siemens (S)
mho per centimeter	1.000 000*	E+00	siemens per meter (S/m)
microinch (μin)	2.540 000*	E-08	meter (m)
micron	1.000 000*	E-06	meter (m)
mil	2.540 000*	E-05	meter (m)
mile (mi)			
- International	1.609 344*	E+03	meter (m)
- U.S. statute	1.609 347	E+03	meter (m)
- international nautical	1.852 000*	E+03	meter (m)
- U.S. nautical	1.852 000*	E+03	meter (m)
- mi² (international)	2.589 988	E+06	square meter (m²)
- mi² (U.S. statute)	2.589 998	E+06	square meter (m²)
- mi/gal	4.251 437	E-01	kilometer per liter (km/L)
- mi/h (international)	4.470 400*	E-01	meter per second (m/s)
- mi/h (international)	1.609 344*	E+00	kilometer per hour (km/h)
- mi/min (international)	2.682 240*	E+01	meter per second (m/s)
- mi/s (international)	1.609 344*	E+03	meter per second (m/s)
millibar	1.000 000*	E+02	pascal (Pa)
millimeter of mercury (0 °C) (mmHg)	1.333 22	E+02	pascal (Pa)
millimeter of water (4 °C) (mmH₂O)	9.806 38	E+00	pascal (Pa)
millimicron	1.000 000*	E-09	meter (m)
minim	6.161 152	E-08	cubic meter (m³)
minute (angle) (′)	2.908 882	E-04	radian (rad)

Table G-1. Conversion Factors (Alphabetical Listing) (cont)

Multiply	By		To Obtain
minute (min)	6.000 000*	E+01	second (s)
minute (sidereal)	5.983 617	E+01	second (s)
oersted	7.957 747	E+01	ampere per meter (A/m)
ohm centimeter	1.000 000*	E-02	ohm meter (Ω·m)
ohm circular-mil per foot	1.662 426	E-09	ohm meter (Ω·m)
ounce (oz)			
- avoirdupois	2.834 952	E-02	kilogram (kg)
- oz/gal (U.K. liquid)	6.236 023	E+00	kilogram per cubic meter (kg/m^3)
- oz/gal (U.S. liquid)	7.489 152	E+00	kilogram per cubic meter (kg/m^3)
- oz/in^3	1.729 994	E+03	kilogram per cubic meter (kg/m^3)
- oz/ft^2	3.051 517	E-01	kilogram per square meter (kg/m^2)
- oz/yd^2	3.390 575	E-02	kilogram per square meter (kg/m^2)
- troy or apothecary	3.110 348	E-02	kilogram (kg)
- U.K. fluid	2.841 306	E-05	cubic meter (m^3)
- U.S. fluid	2.957 353	E-05	cubic meter (m^3)
- ounce-force (oz_f)	2.780 139	E-01	newton (N)
- $oz_f \cdot in$	7.061 552	E-03	newton meter (N·m)
parsec	3.085 678	E+16	meter (m)
peck (U.S.)	8.809 768	E-03	cubic meter (m^3)
pennyweight	1.555 174	E-03	kilogram (kg)
perm			
- perm (0 °C)	5.721 35	E-11	kilogram per pascal second square meter [$kg/(Pa \cdot s \cdot m^2)$]
- perm (23 °C)	5.745 25	E-11	kilogram per pascal second square meter [$kg/(Pa \cdot s \cdot m^2)$]
- perm·in (0 °C)	1.453 22	E-12	kilogram per pascal second meter [$kg/(Pa \cdot s \cdot m)$]
- perm·in (23 °C)	1.459 29	E-12	kilogram per pascal second meter [$kg/(Pa \cdot s \cdot m)$]
phot	1.000 000*	E+04	lumen per square meter (lm/m^2)
pica (printer's)	4.217 518	E-03	meter (m)

Table G-1. Conversion Factors (Alphabetical Listing) (cont)

Multiply	By		To Obtain
pint (U.S. dry) (pt)	5.506 105	E-04	cubic meter (m^3)
pint (U.S. liquid) (pt)	4.731 765	E-04	cubic meter (m^3)
point (printer's)	3.514 598*	E-04	meter (m)
poise (absolute viscosity)	1.000 000*	E-01	pascal second (Pa·s)
pond	4.999 438	E-01	kilogram (kg)
pound (lb)			
- avoirdupois	4.535 924	E-01	kilogram (kg)
- pound (troy or apothecary)	3.732 417	E-01	kilogram (kg)
- lb·ft	1.382 550	E-01	kilogram meter (kg·m)
- lb·ft^2 (moment of inertia)	4.214 011	E-02	kilogram square meter (kg·m^2
- lb·in^2 (moment of inertia)	2.926 397	E-04	kilogram square meter (kg·m^2)
- lb/ft·h	4.133 789	E-04	pascal second (Pa·s)
- lb/ft·s	1.488 164	E+00	pascal second (Pa·s)
- lb/ft^2	4.882 428	E+00	kilogram per square meter (kg/m^2)
- lb/ft^3	1.601 846	E+01	kilogram per cubic meter (kg/m^3)
- lb/gal (U.K. liquid)	9.977 637	E+01	kilogram per cubic meter (kg/m^3)
- lb/gal (U.S. liquid)	1.198 264	E+02	kilogram per cubic meter (kg/m^3)
- lb/h	1.259 979	E-04	kilogram per second (kg/s)
- lb/hp·h (SFC, specific fuel consumption)	1.689 659	E-07	kilogram per joule (kg/J)
- lb/in^3	2.767 990	E+04	kilogram per cubic meter (kg/m^3)
- lb/min	7.559 873	E-03	kilogram per second (kg/s)
- lb/s	4.535 924	E-01	kilogram per second (kg/s)
- lb/yd^3	5.932 764	E-01	kilogram per cubic meter (kg/m^3)
poundal (mass)	1.410 000	E-02	kilogram (kg)
poundal (force)	1.382 550	E-01	newton (N)
- poundal/ft^2	1.488 164	E+00	pascal (Pa)
- poundal·s/ft^2	1.488 164	E+00	pascal second (Pa·s)
pound-force (lb_f)	4.448 222	E+00	newton (n)
- lb_f ·ft	1.355 818	E+00	newton meter (N·m)
- lb_f ·ft/in	5.337 866	E+01	newton meter per meter (N·m/m)

Table G-1. Conversion Factors (Alphabetical Listing) (cont)

Multiply	By		To Obtain
- $lb_f \cdot in$	1.129 848	E-01	newton meter (N·m)
- $lb_f \cdot in/in$	4.448 222	E+00	newton meter per meter (N·m/m)
- $lb_f \cdot s/ft^2$	4.788 026	E+01	pascal second (Pa·s)
- $lb_f \cdot s/in^2$	6.894 757	E+03	pascal second (Pa·s)
- lb_f /ft	1.459 390	E+01	newton per meter (N/m)
- lb_f /ft^2	4.788 026	E+01	pascal (Pa)
- lb_f /in	1.751 268	E+02	newton per meter (N/m)
- lb_f /in^2 (psi)	6.894 757	E+03	pascal (Pa)
- lb_f /lb (thrust/weight ratio) (Note: weight ratio refers to mass ratio.)	9.806 650	E+00	newton per kilogram (N/kg)
quart (U.S. dry) (qt)	1.101 221	E-03	cubic meter (m^3)
quart (U.S. liquid) (qt)	9.463 529	E-04	cubic meter (m^3)
rad (absorbed dose)	1.000 000*	E-02	gray (Gy)
rem (dose equivalent)	1.000 000*	E-02	sievert (Sv)
rhe	1.000 000*	E+01	1 per pascal second [1/(Pa·s)]
rod	5.029 210	E+00	meter (m)
roentgen	2.580 000*	E-04	coulomb per kilogram (C/kg)
rpm (r/min)	1.047 198	E-01	radian per second (rad/s)
scruple (apothocary)	1.295 978	E-03	kilogram (kg)
scruple (liquid)	1.183 872	E-06	cubic meter (m^3)
second (angle) (")	4.848 137	E-06	radian (rad)
second (sidereal)	9.972 696	E-01	second (s)
shake	1.000 000*	E-08	second (s)
slug	1.459 390	E+01	kilogram (kg)
- slug/ft·s	4.788 026	E+01	pascal second (Pa·s)
- slug/ft^3	5.153 788	E+02	kilogram per cubic meter (kg/m^3)
statampere	3.335 640	E-10	ampere (A)
statcoulomb	3.335 640	E-10	coulomb (C)
statfarad	1.112 650	E-12	farad (F)
stathenry	8.987 554	E+11	henry (H)
statmho	1.112 650	E-12	siemens (S)
statohm	8.987 554	E+11	ohm (Ω)

Table G-1. Conversion Factors (Alphabetical Listing) (cont)

Multiply	By		To Obtain
statvolt	2.997 925	E+02	volt (V)
stere	1.000 000*	E+00	cubic meter (m^3)
stilb	1.000 000*	E+04	candela per square meter (cd/m^2)
stokes (kinematic viscosity) (st)	1.000 000*	E-04	square meter per second (m^2/s)
tablespoon	1.478 676	E-05	cubic meter (m^3)
teaspoon	4.928 922	E-06	cubic meter (m^3)
tex	1.000 000*	E-06	kilogram per meter (kg/m)
therm (European Community)	1.055 06	E+08	joule (J)
therm (U.S.)	1.054 804*	E+08	joule (J)
ton			
- assay	2.916 667	E-02	kilogram (kg)
- British shipping (42 ft^3)	1.189 308	E+00	cubic meter (m^3)
- long, 2240 lb	1.016 047	E+03	kilogram (kg)
- metric (t)	1.000 000*	E+03	kilogram (kg)
- nuclear equivalent of TNT	4.184	E+09	joule (J)
- of refrigeration (= 12 000 Btu/h)	3.516 8	E+03	watt (W)
- register (100 ft^3)	2.831 685	E+00	cubic meter (m^3)
- short, 2000 lb	9.071 847	E+02	kilogram (kg)
- ton (long)/yd^3	1.328 939	E+03	kilogram per cubic meter (kg/m^3)
- ton (short)/yd^3	1.186 553	E+03	kilogram per cubic meter (kg/m^3)
- ton (short)/h	2.519 958	E-01	kilogram per second (kg/s)
- ton-force (2000 lb_f)	8.896 443	E+03	newton (N)
- U.S. shipping (40 ft^3)	1.132 674	E+00	cubic meter (m^3)
tonne	1.000 000*	E+03	kilogram (kg)
torr (mmHg, 0 °C)	1.333 22	E+02	pascal (Pa)
unit pole	1.256 637	E-07	weber (Wb)
watt (W)			
- W·h	3.600 000*	E+03	joule (J)
- W·s	1.000 000*	E+00	joule (J)
- W/cm^2	1.000 000*	E+04	watt per square meter (W/m^2)

Table G-1. Conversion Factors (Alphabetical Listing) (cont)

Multiply	By		To Obtain
- W/in^2	1.550 003	E+03	watt per square meter (W/m^2)
yard (yd)	9.144 000*	E-01	meter (m)
- yd^2	8.361 274	E-01	square meter (m^2)
- yd^3	7.645 549	E-01	cubic meter (m^3)
- yd^3/min	1.274 258	E-02	cubic meter per second (m^3/s)
year (yr)			
- year (365 days)	3.153 600*	E+07	second (s)
- year (sidereal)	3.155 815	E+07	second (s)
- year (tropical)	3.155 693	E+07	second (s)
γ	1.000 000*	E-09	kilogram (kg)
λ	1.000 000*	E-09	cubic meter (m^3)

a.3.

Table G-2. Conversion Factors (Classified Listing)

ACCELERATION
1 ft/s^2 = 0.304 8 m/s^2 *
1 g = 9.806 650 m/s^2 *
1 in/s^2 = 0.025 4 m/s^2 *

ANGLE
1° = 0.017 453 29 rad
1′ = 2.908 88 x 10^{-4} rad
1" = 0.016 667°
1" = 4.848 137 x 10^{-6} rad
1" = 2.777 78 x 10^{-4} degree
grade = 0.015 707 96 rad

ANGULAR VELOCITY (see VELOCITY)

AREA
1 acre = 0.404 69 ha
1 acre = 4 046.9 m^2
1 are = 100.000 m^2 *
1 barn = 1.000 x 10^{-28} m^2 *
1 circular mil = 506.707 5 mm^2
1 darcy = 9.869 233 x 10^{-13} m^2
1 ft^2 = 0.092 903 04 m^2 *
1 ha = 10 000.0 m^2 *
1 in^2 = 645.16 mm^2 *
1 in^2 = 6.451 6 cm^2 *
1 mi^2 (international) = 2.589 988 x 10^6 m^2
1 mi^2 (U.S. statute) = 2.589 988 km^2
1 yd^2 = 0.836 127 4 m^2

BENDING MOMENT OR TORQUE
dyne·cm = 1.000 x 10^{-7} N·m *
kg$_f$·m = 9.806 650 N·m *
oz$_f$·in = 7.061 552 x 10^{-3} N·m
lb$_f$·in = 0.112 984 8 N·m
lb$_f$·ft = 1.355 818 N·m

BENDING MOMENT OR TORQUE PER UNIT LENGTH
1 lb$_f$·ft/in = 53.378 66 N·m/m
1 lb$_f$·in/in = 4.448 222 N·m/m

CAPACITY (see VOLUME)

DENSITY (see MASS PER UNIT VOLUME)

ELECTRICITY AND MAGNETISM
1 abampere = 10.00 A *
1 abcoulomb = 10.00 C *
1 abfarad = 1.000 x 10^9 F *
1 abhenry = 1.000 x 10^{-9} H *
1 abmho = 1.000 x 10^9 S *
1 abohm = 1.000 x 10^{-9} Ω *
1 abvolt = 1.000 x 10^{-8} V *
1 Ah = 3 600.000 C *
1 faraday (based on Carbon-12) = 96 487.0 C
1 faraday (chemical) = 96 495.7 C
1 faraday (physical) = 96 521.9 C
1 gamma = 1.000 x 10^{-9} T *
1 oersted = 79.577 47 A/m
1 gauss = 100.000 000 µT *
1 maxwell = 10.000 000 nWb *
1 mho = 1.000 000 S *
1 Ω·CM/ft = 1.662 426 nΩ·m
1 mho/cm = 100.000 S/m *
1 statampere = 3.335 640 x 10^{-10} A
1 statcoulomb = 3.335 640 x 10^{-10} C
1 statfarad = 1.112 650 x 10^{-12} F
1 stathenry = 8.987 554 x 10^{11} H
1 statmho = 1.112 650 x 10^{-12} S
1 statohm = 8.987 554 x 10^{11} Ω
1 statvolt = 29 979.25 V
1 unit pole = 1.256 637 x 10^{-7} Wb

ENERGY (includes WORK)
1 kW·h = 3.600 MJ *
1 W·h = 3.600 kJ *
1 W·s = 1.000 J *
1 cal$_{th}$ = 4.184 000 J *

* Exact
** See table G-1 for additional conversions for this unit.

Table G-2. Conversion Factors (Classified Listing) (cont)

1 Btu** = 1.055 056 kJ *
1 hp·h = 2.684 520 MJ
1 ft·lb_f = 1.355 818 J
1 eV = 1.602 19 x 10^{-19} J

ENERGY PER UNIT AREA TIME
1 Btu (International Table)/(ft^2·s)** = 11 356.53 W/m^2
1 Btu (thermochemical)/(ft^2·s)** = 11 348.93 W/m^2
1 cal_{th}/(cm^2·min)** = 697.333 3 W/m^2
1 W/in^2 = 1.550 003 kW/m^2

FUEL EFFICIENCY
1 mi/gal (mpg) = 0.425 143 7 km/L

FLOW (see MASS PER UNIT TIME or VOLUME PER UNIT TIME)

FORCE
1 dyne = 1.000 x 10^{-5} N *
1 kip = 4.448 222 kN
1 lb_f = 4.448 222 N
1 lb_f/lb [thrust/weight(mass) ratio] = 9.806 650 N/kg
1 oz_f = 0.278 013 9 N
1 pdl = 0.138 255 0 N
1 ton-force (2000 lb_f) = 8.896 443 kN

FORCE PER UNIT AREA (see PRESSURE)

FORCE PER UNIT LENGTH
1 lb_f/ft = 14.593 90 N/m
1 lb_f/in = 175.126 8 N/m

FREQUENCY (includes ROTATIONAL FREQUENCY)
1 cycles per second = 1.000 000 Hz *
1 rps = 1.000 000 r/s *
1 rpm = 1.000 000 r/min *

HEAT
1 Btu/s = 1.055 056 kW
1 Btu/h = 0.293 071 1 W
1 Btu (International Table)·in/(ft^2·h·°F)** = 0.144 227 9 W/(m·°C)
1 Btu (International Table)/(ft^2·h·°F)** = 5.678 263 W/(m^2·°C)
1 Btu/°F = 1.899 108 kJ/°C
1 Btu/°F = 1.899 108 kJ/K
1 Btu/(lb·°F) = 4.186 8 kJ/(kg·°C) *
1 Btu/lb = 2.326 kJ/kg *
1 cal_{th}/(cm·s·°C)** = 418.400 W/(m·K) *
1 °F·h·ft^2/Btu (International Table)** = 0.176 110 2 K·m^2/W
1 ft^2/h = 2.580 640 x 10^{-5} m^2/s *

LENGTH
1 nmi = 1.852 km *
1 mi = 1.609 3 km
1 yd = 0.914 4 m
1 ft (U.S. survey) = 0.304 800 6 m
1 ft = 0.304 8 m *
1 in = 25.4 mm *
1 in = 2.54 cm *
1 mil = 25.4 µm *
1 micron = 1.000 µm *
1 µin = 0.025 4 µm *
1 Å = 0.100 nm *
1 astronomical unit = 1.495 979 x 10^{11} m
1 chain = 20.116 84 m
1 fathom = 1.828 804 m
1 light year = 9.460 55 x 10^{15} m
1 mi (U.S. statute)** = 1.609 347 km

* Exact
** See table G-1 for additional conversions for this unit.

Table G-2. Conversion Factors (Classified Listing) (cont)

LIGHT (including ELECTROMAGNETIC RADIATION)
1 Å = 0.100 nm *
1 L = 3 183.099 cd/m²
1 cd/in² = 1 550.003 cd/m²
1 fL = 3.426 259 cd/m²
1 lm/ft² = 10.763 91 lm/m²
1 fc = 10.763 91 lx

MASS
1 ton (long) ** = 1.016 047 t * [1 t = 1000 kg)
1 ton (short) = 0.907 184 74 t *
1 slug = 14.593 90 kg
1 lb (avdp) = 0.453 592 37 kg *
1 oz (troy) = 31.103 48 g
1 oz (avdp) = 28.349 52 g
1 grain = 64.798 91 mg *
1 tonne = 1 000.000 kg *

MASS PER UNIT AREA
1 oz/ft² = 0.305 157 1 kg/m²
1 oz/yd² = 0.033 905 75 kg/m²
1 lb/ft² = 4.882 428 kg/m²

MASS PER UNIT CAPACITY (see MASS PER UNIT VOLUME)

MASS PER UNIT LENGTH
1 lb/ft = 1.111 111 x 10^{-7} kg/m
1 lb/in = 1.488 164 kg/m
1 lb/yd = 0.496 054 681 kg/m

MASS PER UNIT TIME (includes FLOW)
1 perm (0 °C)** = 5.721 35 x 10^{-11} kg/(Pa·s·m²)
1 perm·in (0 °C)** = 1.453 22 x 10^{-12} kg/(Pa·s·m)
1 lb/h = 1.259 979 x 10^{-4} kg/s
1 lb/min = 7.559 873 x 10^{-3} kg/s
1 lb/s = 0.453 592 4 kg/s
1 lb/(hp·h) = 1.689 659 x 10^{-7} kg/J
1 ton (short)/h = 0.251 995 8 kg/s

MASS PER UNIT VOLUME (includes DENSITY, MASS CAPACITY, and CONCENTRATION)
1 ton (short)/yd³ = 1.186 553 t/m³
1 lb/ft³ = 16.018 46 kg/m³
1 lb/gal (U.S. liquid) = 119.826 4 g/L
1 oz/gal (U.S. liquid) = 7.489 152 g/L
1 g/cm³ = 1 000.0 kg/m³ *
1 slug/ft³ = 515.378 8 kg/m³
1 lb/in³ = 27 679.90 kg/m³

MECHANICS
1 lb·ft = 0.128 255 0 kg·m
1 lb·ft/s = 0.138 255 0 kg·m/s
1 lb·ft²/s = 0.042 140 11 kg·m²/s
1 lb·ft² = 0.042 140 11 kg·m²
1 lb_f/ft = 14.593 90 N/m

POWER
1 ton (refrigeration) ** 3.516 800 kW
1 Btu/s = 1.055 056 kW
1 hp (550 ft·lb_f/s) ** = 0.745 699 9 kW
1 hp (electric)** = 0.746 000 kW *
1 Btu/h = 0.293 071 1 W
1 ft·lb_f/h = 3.766 161 x 10^{-4} W
1 ft·lb_f/min = 0.022 593 97 mW
1 ft·lb_f/s = 1.355 818 W

PRESSURE or STRESS (FORCE PER UNIT AREA)
1 atm (std) = 101.325 kPa *
1 bar = 100.00 kPa *
1 dyne/cm² = 0.100 Pa *
1 lb_f/in² (psi) = 6.894 757 kPa
1 inHg (32 °F) ** = 3.386 38 kPa
1 inH_2O (60 °F) ** = 0.248 84 kPa

* Exact
** See table G-1 for additional conversions for this unit.

Table G-2. Conversion Factors (Classified Listing) (cont)

1 cmH_2O (4 °C) = 98.063 8 Pa
1 torr [mm Hg (0 °C)] = 0.133 322 kPa
1 millibar (mbar) = 0.100 kPa *
1 kip/in² (ksi) = 6.894 757 GPa
1 lb_f/in^2 (psi) = 6.894 757 MPa
1 lb_f/ft^2 = 0.047 880 26 kPa

RADIATION UNITS (including NUCLEAR REACTION and IONIZATION)
1 Ci = 37.000 GBq *
1 rad = 10.000 mGy *
1 rem = 10.000 mSv *
1 roentgen (R) = 0.000 258 C/kg

SPEED (see VELOCITY)

STRESS (see PRESSURE)

TEMPERATURE
1 °R, where $T_K = t_R/1.8$
1 °F, where $t_C = (t_F - 32)/1.8$
1 °C, where $T_K = t_C + 273.15$

TEMPERATURE INTERVAL
1 °R = 0.56 K
1 °F = 0.56 K
1 °C = 1 K

TIME
1 yr ** = 1.000 a

TORQUE (see BENDING MOMENT)

VELOCITY (includes SPEED and ANGULAR VELOCITY)
1 rad/s = 1.000 rad/s *
1 knot (kn) = 1.853 2 km/h
1 knot (kn) = 0.514 444 4 m/s
1 mi/h (mph) = 1.609 3 km/h
1 ft/s = 0.304 8 m/s
1 km/h = 0.277 777 8 m/s
1 r/min (rpm) = 0.104 719 8 rad/s

VISCOSITY
1 centipoise = 1.000 mPa·s *
1 centistoke = 1.000 mm²/s *
1 ft²/s = 0.092 903 04 m²/s
1 lb/(ft·h) = 4.133 789 x 10^{-4} Pa·s
1 lb/(ft·s) = 1.488 164 Pa·s
1 $lb_f \cdot s/ft^2$ = 47.880 26 Pa·s
1 $lb_f \cdot s/in^2$ = 6.894 757 kPa·s
1 slug/(ft·s) = 47.880 26 Pa·s

VOLUME (includes CAPACITY)
1 acre foot = 1 233.5 m³
1 yd³ = 0.764 554 9 m³
1 bbl (42 U.S. gal) = 0.158 987 3 m³
1 ft³ = 0.028 316 85 m³
1 ft³ (fluid) = 28.316 85 L
1 board foot = 0.002 359 737 m³
1 bushel (U.S.) = 0.035 239 07 m³
1 gal (U.S. fluid) = 3.785 412 L
1 qt (U.S. fluid) = 0.946 352 9 L
1 pt (U.S. fluid) = 0.473 176 5 L
1 oz (U.S. fluid) = 29.573 53 mL
1 in³ = 16.387 06 cm³
1 cup (fluid) = 236.588 2 mL
1 tablespoon (fluid) = 14.786 76 mL
1 teaspoon (fluid) = 4.928 922 mL
1 L = 0.0010 m³ *
1 ton (register) = 2.831 685 m³

VOLUME PER UNIT TIME (includes FLOW)
1 ft³/min = 4.719 474 x 10^{-4} m³/s
1 ft³/min (fluid) = 0.471 947 4 L/s
1 ft³/s = 0.028 316 85 m³/s
1 ft³/s (fluid) = 28.316 85 L/s
1 gal/(hp·h) [SFC] = 1.410 089 x 10^{-9} m³/J
1 in³/min = 2.731 177 x 10^{-7} m³/s
1 in³/min = 0.273 117 7 mL/s

* Exact
** See table G-1 for additional conversions for this unit.

Table G-2. Conversion Factors (Classified Listing) (cont)

1 gal [U.S. liquid]/min =
$6.309\ 020 \times 10^{-5}$ m^3/s
1 gal [U.S. liquid]/min = 0.063 090 2 L/s

WORK (see ENERGY)

* Exact
** See table G-1 for additional conversions for this unit.

Table G-3. Decimal-to-Millimeter Equivalents

FRACTION (INCH)	DECIMAL (INCH)	MILLIMETERS
1/64	0.015625	0.397
1/32	0.03125	0.794
3/64	0.046875	1.191
1/16	0.0625	1.588
5/64	0.078125	1.984
3/32	0.09375	2.381
7/64	0.109375	2.778
1/8	0.1250	3.175
9/64	0.140625	3.572
5/32	0.15625	3.969
11/64	0.171875	4.366
3/16	0.1875	4.763
13/64	0.203125	5.159
7/32	0.21875	5.556
15/64	0.234375	5.953
1/4	0.2500	6.350
17/64	0.265625	6.747
9/32	0.28125	7.144
19/64	0.296875	7.541
5/16	0.3125	7.938
21/64	0.328125	8.334
11/32	0.34375	8.731
23/64	0.359375	9.128
3/8	0.3750	9.525
25/64	0.390625	9.922
13/32	0.40625	10.319
27/64	0.421875	10.716
7/16	0.4375	11.113
29/64	0.453125	11.509
15/32	0.46875	11.906
31/64	0.484375	12.303
1/2	0.5000	12.700

FRACTION (INCH)	DECIMAL (INCH)	MILLIMETERS
33/64	0.515625	13.907
17/32	0.53125	13.494
35/64	0.546875	13.891
9/16	0.5625	14.288
37/64	0.578125	14.684
19/32	0.59375	15.081
39/64	0.609375	15.478
5/8	0.6250	15.875
41/64	0.640625	16.272
21/32	0.65625	16.669
43/64	0.671875	17.066
11/16	0.6875	17.463
45/64	0.703125	17.859
23/32	0.71875	18.256
47/64	0.734375	18.653
3/4	0.7500	19.050
49/64	0.765625	19.447
25/32	0.78125	19.844
51/64	0.796875	20.241
13/16	0.8125	20.638
53/64	0.828125	21.034
27/32	0.84375	21.431
55/64	0.859375	21.828
7/8	0.8750	22.225
57/64	0.890625	22.622
29/32	0.90625	23.019
59/64	0.921875	23.416
15/16	0.9375	23.813
61/64	0.953125	24.209
31/32	0.96875	24.606
63/64	0.984375	25.003
1	1.000	25.400

Table G-4. Millimeter-to-Inch Equivalents

MILLIMETER	INCH	MILLIMETER	INCH	MILLIMETER	INCH	MILLIMETER	INCH
0.1	0.0039	22	0.8661	52	2.0472	82	3.2283
0.2	0.0079	23	0.9055	53	2.0866	83	3.2677
0.3	0.0118	24	0.9449	54	2.1260	84	3.3071
0.4	0.0157	25	0.9843	55	2.1654	85	3.3465
0.5	0.0197	26	1.0236	56	2.2047	86	3.3858
0.6	0.0236	27	1.0630	57	2.2441	87	3.4252
0.7	0.0276	28	1.1024	58	2.2835	88	3.4646
0.8	0.0315	29	1.1417	59	2.3228	89	3.5039
0.9	0.0354	30	1.1811	60	2.3622	90	3.5433
1	0.0394	31	1.2205	61	2.4016	91	3.5827
2	0.0787	32	1.2598	62	2.4409	92	3.6220
3	0.1181	33	1.2992	63	2.4803	93	3.6614
4	0.1575	34	1.3386	64	2.5197	94	3.7008
5	0.1969	35	1.3780	65	2.5591	95	3.7402
6	0.2362	36	1.4173	66	2.5984	96	3.7795
7	0.2756	37	1.4567	67	2.6378	97	3.8189
8	0.3150	38	1.4961	68	2.6772	98	3.8583
9	0.3543	39	1.5354	69	2.7165	99	3.8976
10	0.3937	40	1.5748	70	2.7559	100	3.9370
11	0.4331	41	1.6142	71	2.7953	125	4.9213
12	0.4724	42	1.6535	72	2.8346	150	5.9055
13	0.5118	43	1.6929	73	2.8740	175	6.8898
14	0.5512	44	1.7323	74	2.9134	200	7.8740
15	0.5906	45	1.7717	75	2.9528	225	8.8583
16	0.6299	46	1.8110	76	2.9921	250	9.8425
17	0.6693	47	1.8504	77	3.0315	275	10.8268
18	0.7087	48	1.8898	78	3.0709	300	11.8110
19	0.7480	49	1.9291	79	3.1102	325	12.7953
20	0.7874	50	1.9685	80	3.1496	350	13.7795
21	0.8268	51	2.0079	81	3.1890	375	14.7638

APPENDIX H

TOLERANCES AND FITS

TABLE H-1. INTERNATIONAL TOLERANCE GRADES

TABLE H-2. FUNDAMENTAL DEVIATIONS FOR INTERNAL (HOLE) DIMENSIONS

TABLE H-3. FUNDAMENTAL DEVIATIONS FOR EXTERNAL (SHAFT) DIMENSIONS

TABLE H-4. PREFERRED TOLERANCE ZONES FOR INTERNAL (HOLE) DIMENSIONS (DIMENSIONS IN MILLIMETERS)

TABLE H-5. PREFERRED TOLERANCE ZONES FOR EXTERNAL (SHAFT) DIMENSIONS (DIMENSIONS IN MILLIMETERS)

TABLE H-6. PREFERRED HOLE BASIS CLEARANCE FITS (DIMENSIONS IN MILLIMETERS)

TABLE H-7. PREFERRED SHAFT BASIS CLEARANCE FITS (DIMENSIONS IN MILLIMETERS)

APPENDIX H

TOLERANCES AND FITS

This appendix gives instructions on determining specific tolerance limits with the assistance of tables and examples. The tables in this appendix are listed below. More complete tables and additional information may be found in ANSI B4.2.

H.1 INTERNAL DIMENSION TOLERANCE

For tolerance zone letters A through JS, the lower deviation is the fundamental deviation and the upper deviation is equal to the lower deviation plus the tolerance grade value for the appropriate basic size.

$$\textit{Upper Deviation} = \textit{Lower Deviation} + \textit{Tolerance Grade}$$

Example: Internal Dimension 10C9

Basic dimension = 10 millimeters
IT9 at 10 mm (table H-1) = 0.036
Lower deviation for C at 10 mm (table H-2) = +0.080
Upper deviation = (+0.080) + (+0.036) = +0.116

$$10C9 = 10.000 \begin{pmatrix} +0.116 \\ +0.080 \end{pmatrix}$$

Example: Internal Dimension 50H7

Basic dimension = 50 millimeters
IT7 at 50 mm (table H-1) = 0.025

Lower deviation for H at 50 mm (table H-2) = 0.000
Upper deviation = 0.000 + 0.025 = +0.025

$$50H7 = 50.000 \begin{pmatrix} +0.025 \\ 0.000 \end{pmatrix}$$

For tolerance zone letters J through ZC, the upper deviation is the fundamental deviation, and the lower deviation is equal to the upper deviation minus the tolerance grade value for the appropriate basic size.

Lower Deviation = Upper Deviation - Tolerance Grade

Example: Internal Dimension 300M10

Basic dimension = 300 millimeters
IT10 at 300 mm (table H-1) = 0.210
Upper deviation for M at 300 mm (table H-2) = -0.020
Lower deviation = (-0.020) - (+0.210) = -0.230

$$300M15 = 300.000 \begin{pmatrix} -0.020 \\ -0.230 \end{pmatrix}$$

Example: Internal Dimension 75Z20

Basic dimension = 75 millimeters
IT20 at 75 mm (table H-1) = IT15 x 0.10 = 1.200 x 0.10 = 12.000
Upper deviation for Z at 75 mm (table H-2) = -0.210
Lower deviation = (-0.210) - (+12.000) = -12.210

$$75Z20 = 75.000 \begin{pmatrix} -0.210 \\ -12.210 \end{pmatrix}$$

H.2 EXTERNAL DIMENSION TOLERANCE

For tolerance zone letters a through js, the upper deviation is the fundamental deviation and the lower deviation is equal to the upper deviation minus the tolerance grade value for the appropriate basic size.

Lower Deviation = Upper Deviation - Tolerance Grade

Example: External Dimension 315c11

Basic dimension = 315 millimeters

IT11 at 315 mm (table H-1) = 0.320
Upper deviation for c at 315 mm (table H-3) = -0.330
Lower deviation = (-0.330) - (+0.320) = -0.650

$$315c11 = 315.000 \begin{pmatrix} -0.330 \\ -0.650 \end{pmatrix}$$

Example: External Dimension 800h13

Basic dimension = 800 millimeters
IT13 at 800 mm (table H-1) = 1.250
Upper deviation for h at 800 mm (table H-3) = 0.000
Lower deviation = (0.000) - (+1.250) = -1.250

$$800h13 = 800.000 \begin{pmatrix} 0.000 \\ -1.250 \end{pmatrix}$$

Example: External Dimension 25js8

Basic dimension = 25 millimeters
IT8 at 25 mm (table H-1) = 0.033
Upper deviation for js at 25 mm (table H-3) = +IT/2 = 0.033/2 = 0.016
Lower deviation = (0.016) - (+0.033) = -0.016

$$25js8 = 25.000 \begin{pmatrix} +0.016 \\ -0.016 \end{pmatrix}$$

For tolerance zone letters j through zc, the lower deviation is the fundamental deviation and the upper deviation is equal to the lower deviation plus the tolerance grade value for the appropriate basic size.

Upper Deviation = Lower Deviation + Tolerance Grade

Example: External Dimension 65n14

Basic dimension = 65 millimeters
IT14 at 65 mm (table H-1) = 0.740
Lower deviation for n at 65 mm (table H-3) = +0.020
Upper deviation = (+0.020) + (+0.740) = +0.760

$$65n14 = 65.000 \begin{pmatrix} +0.760 \\ +0.020 \end{pmatrix}$$

Example: External Dimension 85zc5

Basic dimension = 85 millimeters
IT5 at 85 mm (table H-1) = 0.015
Lower deviation for zc at 85 mm (table H-3) = +0.585
Upper deviation = (+0.585) + (+0.015) = +0.600

$$85zc5 = 85.000 \begin{pmatrix} +0.600 \\ +0.585 \end{pmatrix}$$

H.4 HOLE-BASIS VERSUS SHAFT-BASIS FIT

It may sometimes be more practical to change a hole-basis fit to a shaft-basis fit without changing the total tolerance and fit condition. To do this, the fundamental deviations between the shaft and hole are reversed and the IT grade remains unchanged. In other words, the IT grade number stays the same for the individual parts and the tolerance zone letters are switched. For example, the clearance fit C10/f10 converts to F10/c10; transition fit K8/n7 converts to N8/k7, and so on. The following example shows that during this conversion, the total tolerance remains the same as the original fit.

Example: Convert fit 50H7/p6 to 50P6/h7.

Hole dimension 50H7 = $\begin{pmatrix} 60.030 \\ 60.000 \end{pmatrix}$ Shaft dimension 50p6 = $\begin{pmatrix} 60.051 \\ 60.032 \end{pmatrix}$

Total tolerance = $\begin{pmatrix} -0.002 \\ -0.051 \end{pmatrix}$

Keep the size and IT grade number the same. Switch the letters from H to P and p to h.

Hole dimension 50P7 = $\begin{pmatrix} 59.979 \\ 59.949 \end{pmatrix}$ Shaft dimension 50h6 = $\begin{pmatrix} 60.000 \\ 59.981 \end{pmatrix}$

Total tolerance = $\begin{pmatrix} -0.002 \\ -0.051 \end{pmatrix}$

Table H-1. International Tolerance Grades

BASIC SIZE		TOLERANCE GRADES *																	
OVER (mm)	TO (mm)	IT01	IT0	IT1	IT2	IT3	IT4	IT5	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16
0	3	0.0003	0.0005	0.0008	0.0012	0.002	0.003	0.004	0.006	0.010	0.014	0.025	0.040	0.060	0.100	0.140	0.250	0.400	0.600
3	6	0.0004	0.0006	0.001	0.0015	0.0025	0.004	0.005	0.008	0.012	0.018	0.030	0.048	0.075	0.120	0.180	0.300	0.480	0.750
6	10	0.0004	0.0006	0.001	0.0015	0.0025	0.004	0.006	0.009	0.015	0.022	0.036	0.058	0.090	0.150	0.220	0.360	0.580	0.900
10	18	0.0005	0.0008	0.0012	0.002	0.003	0.005	0.008	0.011	0.018	0.027	0.043	0.070	0.110	0.180	0.270	0.430	0.700	1.100
18	30	0.0006	0.001	0.0015	0.0025	0.004	0.006	0.009	0.013	0.021	0.033	0.052	0.084	0.130	0.210	0.330	0.520	0.840	1.300
30	50	0.0006	0.001	0.0015	0.0025	0.004	0.007	0.011	0.016	0.025	0.039	0.062	0.100	0.160	0.250	0.390	0.620	1.000	1.600
50	80	0.0008	0.0012	0.002	0.003	0.005	0.008	0.013	0.019	0.030	0.046	0.074	0.120	0.190	0.300	0.460	0.740	1.200	1.900
80	120	0.001	0.0015	0.0025	0.004	0.006	0.010	0.015	0.022	0.035	0.054	0.087	0.140	0.220	0.350	0.540	0.870	1.400	2.200
120	180	0.0012	0.002	0.0035	0.005	0.008	0.012	0.018	0.025	0.040	0.063	0.100	0.160	0.250	0.400	0.630	1.000	1.600	2.500
180	250	0.002	0.003	0.0045	0.007	0.010	0.014	0.020	0.029	0.046	0.072	0.115	0.185	0.290	0.460	0.720	1.150	1.850	2.900
250	315	0.0025	0.004	0.006	0.008	0.012	0.016	0.023	0.032	0.052	0.081	0.130	0.210	0.320	0.520	0.810	1.300	2.100	3.200
315	400	0.003	0.005	0.007	0.009	0.013	0.018	0.025	0.036	0.057	0.089	0.140	0.230	0.360	0.570	0.890	1.400	2.300	3.600
400	500	0.004	0.006	0.008	0.010	0.015	0.020	0.027	0.040	0.063	0.097	0.155	0.250	0.400	0.630	0.970	1.550	2.500	4.000
500	630	0.0045	0.006	0.009	0.011	0.016	0.022	0.030	0.044	0.070	0.110	0.175	0.280	0.440	0.700	1.100	1.750	2.800	4.400
630	800	0.005	0.007	0.010	0.013	0.018	0.025	0.035	0.050	0.080	0.125	0.200	0.320	0.500	0.800	1.250	2.000	3.200	5.000
800	1000	0.0055	0.008	0.011	0.015	0.021	0.029	0.040	0.056	0.090	0.140	0.230	0.360	0.560	0.900	1.400	2.300	3.600	5.600
1000	1250	0.0065	0.009	0.013	0.018	0.024	0.034	0.046	0.066	0.105	0.165	0.260	0.420	0.660	1.050	1.650	2.600	4.200	6.600
1250	1600	0.008	0.011	0.015	0.021	0.029	0.040	0.054	0.078	0.125	0.195	0.310	0.500	0.780	1.250	1.950	3.100	5.000	7.800
1600	2000	0.009	0.013	0.018	0.025	0.035	0.048	0.065	0.092	0.150	0.230	0.370	0.600	0.920	1.500	2.300	3.700	6.000	9.200
2000	2500	0.011	0.015	0.022	0.030	0.041	0.057	0.077	0.110	0.175	0.260	0.440	0.700	1.100	1.750	2.800	4.400	7.000	11.000
2500	3150	0.013	0.018	0.026	0.036	0.050	0.069	0.093	0.136	0.210	0.330	0.540	0.860	1.350	2.100	3.300	5.400	8.600	13.500

* Values for tolerance grades larger than IT16 are calculated by using the following formula: IT17 = IT12 x 10; IT18 = IT13 x 10; etc.

Table H-2. Fundamental Deviations for Internal (Hole) Dimensions

Fundamental Deviation		Lower Deviation								
Letter		A	B	C	D	E	F	G	H	JS[1]
IT Grade		01 to 16								
Basic Size (in millimeters)										
Over	Up to and Including									
0	3	+0.270	+0.140	+0.060	+0.020	+0.014	+0.006	+0.002	0.000	
3	6	+0.270	+0.140	+0.070	+0.030	+0.020	+0.010	+0.004	0.000	
6	10	+0.280	+0.150	+0.080	+0.040	+0.025	+0.013	+0.005	0.000	
10	14	+0.290	+0.150	+0.095	+0.050	+0.032	+0.016	+0.006	0.000	
14	18	+0.290	+0.150	+0.095	+0.050	+0.032	+0.016	+0.006	0.000	
18	24	+0.300	+0.160	+0.110	+0.065	+0.040	+0.020	+0.007	0.000	
24	30	+0.300	+0.160	+0.110	+0.065	+0.040	+0.020	+0.007	0.000	
30	40	+0.310	+0.170	+0.120	+0.080	+0.050	+0.025	+0.009	0.000	
40	50	+0.320	+0.180	+0.130	+0.080	+0.050	+0.025	+0.009	0.000	
50	65	+0.340	+0.190	+0.140	+0.100	+0.060	+0.030	+0.010	0.000	
65	80	+0.360	+0.200	+0.150	+0.100	+0.060	+0.030	+0.010	0.000	
80	100	+0.380	+0.220	+0.170	+0.120	+0.072	+0.036	+0.012	0.000	
100	120	+0.410	+0.240	+0.180	+0.120	+0.072	+0.036	+0.012	0.000	−IT/2
120	140	+0.460	+0.260	+0.200	+0.145	+0.085	+0.043	+0.014	0.000	
140	160	+0.520	+0.280	+0.210	+0.145	+0.085	+0.043	+0.014	0.000	
160	180	+0.580	+0.310	+0.230	+0.145	+0.085	+0.043	+0.014	0.000	
180	200	+0.660	+0.340	+0.240	+0.170	+0.100	+0.050	+0.015	0.000	
200	225	+0.740	+0.380	+0.260	+0.170	+0.100	+0.050	+0.015	0.000	
225	250	+0.820	+0.420	+0.280	+0.170	+0.100	+0.050	+0.015	0.000	
250	280	+0.920	+0.480	+0.300	+0.190	+0.110	+0.056	+0.017	0.000	
280	315	+1.050	+0.540	+0.330	+0.190	+0.110	+0.056	+0.017	0.000	
315	355	+1.200	+0.600	+0.360	+0.210	+0.125	+0.062	+0.018	0.000	
355	400	+1.350	+0.680	+0.400	+0.210	+0.125	+0.062	+0.018	0.000	
400	450	+1.500	+0.760	+0.440	+0.230	+0.135	+0.068	+0.020	0.000	
450	500	+1.650	+0.840	+0.480	+0.230	+0.135	+0.068	+0.020	0.000	
IT Grade		6 to 16								
500	630	—	—	—	+0.260	+0.145	+0.076	+0.022	0.000	
630	800	—	—	—	+0.290	+0.160	+0.080	+0.024	0.000	
800	1000	—	—	—	+0.320	+0.170	+0.086	+0.026	0.000	
1000	1250	—	—	—	+0.350	+0.195	+0.098	+0.028	0.000	+IT/2
1250	1600	—	—	—	+0.390	+0.220	+0.110	+0.030	0.000	
1600	2000	—	—	—	+0.430	+0.240	+0.120	+0.032	0.000	
2000	2500	—	—	—	+0.480	+0.260	+0.130	+0.034	0.000	
2500	3150	—	—	—	+0.520	+0.290	+0.145	+0.038	0.000	

Fundamental Deviation		Lower Deviation		
Letter		CD	EF	FG
IT Grade		01 to 16		
Basic Size (in millimeters)				
Over	Up to and Including			
0	3	+0.034	+0.010	+0.004
3	6	+0.046	+0.014	+0.006
6	10	+0.056	+0.018	+0.008

[1] JS deviations in the grades 7 to 11 should be rounded off to 1/2 (IT-0.001) when the IT value is odd.

Table H-2. Fundamental Deviations for Internal (Hole) Dimensions (cont)

Fundamental Deviation		Upper Deviation								
Letter		J			K [3]		M [3]		N [3]	
IT Grade		6	7	8	<8	>8	<8 [2]	>8	<8	>8
Basic Size (in millimeters) Over	Up to and Including									
0	3	+0.002	+0.004	+0.006	0.000	0.000	-0.002	-0.002	-0.004	-0.004
3	**6**	**+0.005**	**+0.006**	**+0.010**	**-0.001+Δ**	—	**-0.004+Δ**	**-0.004**	**-0.008+Δ**	**0.000**
6	10	+0.005	+0.008	+0.012	-0.001+Δ	—	-0.006+Δ	-0.006	-0.010+Δ	0.000
10	**14**	**+0.006**	**+0.010**	**+0.015**	**-0.001+Δ**	—	**-0.007+Δ**	**-0.007**	**-0.012+Δ**	**0.000**
14	18	+0.006	+0.010	+0.015	-0.001+Δ	—	-0.007+Δ	-0.007	-0.012+Δ	0.000
18	**24**	**+0.008**	**+0.012**	**+0.020**	**-0.002+Δ**	—	**-0.008+Δ**	**-0.008**	**-0.015+Δ**	**0.000**
24	30	+0.008	+0.012	+0.020	-0.002+Δ	—	-0.008+Δ	-0.008	-0.015+Δ	0.000
30	**40**	**+0.010**	**+0.014**	**+0.024**	**-0.002+Δ**	—	**-0.009+Δ**	**-0.009**	**-0.017+Δ**	**0.000**
40	50	+0.010	+0.014	+0.024	-0.002+Δ	—	-0.009+Δ	-0.009	-0.017+Δ	0.000
50	**65**	**+0.013**	**+0.018**	**+0.028**	**-0.002+Δ**	—	**-0.011+Δ**	**-0.011**	**-0.020+Δ**	**0.000**
65	80	+0.013	+0.018	+0.028	-0.002+Δ	—	-0.011+Δ	-0.011	-0.020+Δ	0.000
80	**100**	**+0.016**	**+0.022**	**+0.034**	**-0.003+Δ**	—	**-0.013+Δ**	**-0.013**	**-0.023+Δ**	**0.000**
100	120	+0.016	+0.022	+0.034	-0.003+Δ	—	-0.013+Δ	-0.013	-0.023+Δ	0.000
120	**140**	**+0.018**	**+0.026**	**+0.041**	**-0.003+Δ**	—	**-0.015+Δ**	**-0.015**	**-0.027+Δ**	**0.000**
140	160	+0.018	+0.026	+0.041	-0.003+Δ	—	-0.015+Δ	-0.015	-0.027+Δ	0.000
160	**180**	**+0.018**	**+0.026**	**+0.041**	**-0.003+Δ**	—	**-0.015+Δ**	**-0.015**	**-0.027+Δ**	**0.000**
180	200	+0.022	+0.030	+0.047	-0.004+Δ	—	-0.017+Δ	-0.017	-0.031+Δ	0.000
200	**225**	**+0.022**	**+0.030**	**+0.047**	**-0.004+Δ**	—	**-0.017+Δ**	**-0.017**	**-0.031+Δ**	**0.000**
225	250	+0.022	+0.030	+0.047	-0.004+Δ	—	-0.017+Δ	-0.017	-0.031+Δ	0.000
250	**280**	**+0.025**	**+0.036**	**+0.055**	**-0.004+Δ**	—	**-0.020+Δ**	**-0.020**	**-0.034+Δ**	**0.000**
280	315	+0.025	+0.036	+0.055	-0.004+Δ	—	-0.020+Δ	-0.020	-0.034+Δ	0.000
315	**355**	**+0.029**	**+0.039**	**+0.060**	**-0.004+Δ**	—	**-0.021+Δ**	**-0.021**	**-0.037+Δ**	**0.000**
355	400	+0.029	+0.039	+0.060	-0.004+Δ	—	-0.021+Δ	-0.021	-0.037+Δ	0.000
400	**450**	**+0.033**	**+0.043**	**+0.066**	**-0.005+Δ**	—	**-0.023+Δ**	**-0.023**	**-0.040+Δ**	**0.000**
450	500	+0.033	+0.043	+0.066	-0.005+Δ	—	-0.023+Δ	-0.023	-0.040+Δ	0.000
IT Grade		6 to 16								
500	**560**	—	—	—	**0.000**	**0.000**	**-0.026**	**-0.026**	**-0.044**	**-0.044**
560	630	—	—	—	0.000	0.000	-0.026	-0.026	-0.044	-0.044
630	**710**	—	—	—	**0.000**	**0.000**	**-0.030**	**-0.030**	**-0.050**	**-0.050**
710	800	—	—	—	0.000	0.000	-0.030	-0.030	-0.050	-0.050
800	**900**	—	—	—	**0.000**	**0.000**	**-0.034**	**-0.034**	**-0.056**	**-0.056**
900	1000	—	—	—	0.000	0.000	-0.034	-0.034	-0.056	-0.056
1000	**1120**	—	—	—	**0.000**	**0.000**	**-0.040**	**-0.040**	**-0.066**	**-0.066**
1120	1250	—	—	—	0.000	0.000	-0.040	-0.040	-0.066	-0.066
1250	**1400**	—	—	—	**0.000**	**0.000**	**-0.048**	**-0.048**	**-0.078**	**-0.078**
1400	1600	—	—	—	0.000	0.000	-0.048	-0.048	-0.078	-0.078
1600	**1800**	—	—	—	**0.000**	**0.000**	**-0.058**	**-0.058**	**-0.092**	**-0.092**
1800	2000	—	—	—	0.000	0.000	-0.058	-0.058	-0.092	-0.092
2000	**2240**	—	—	—	**0.000**	**0.000**	**-0.068**	**-0.068**	**-0.110**	**-0.110**
2240	2500	—	—	—	0.000	0.000	-0.068	-0.068	-0.110	-0.110
2500	**2800**	—	—	—	**0.000**	**0.000**	**-0.076**	**-0.076**	**-0.135**	**-0.135**
2800	3150	—	—	—	0.000	0.000	-0.076	-0.076	-0.135	-0.135

[2] Special Case: for M6 from 250 to 315, upper deviation = -0.009 (instead of -0.011)

[3] Refer to the last columns of this table for values of Δ.

Table H-2. Fundamental Deviations for Internal (Hole) Dimensions (cont)

Fundamental Deviation		Upper Deviation								
Letter		P	R	S	T	U	V	X	Y	Z
IT Grade		Above 7 [4]								
Basic Size (in millimeters)										
Over	Up to and Including									
0	3	–0.006	–0.010	–0.014	—	–0.018	—	–0.020	—	–0.026
3	6	–0.012	–0.015	–0.019	—	–0.023	—	–0.028	—	–0.035
6	10	–0.015	–0.019	–0.023	—	–0.028	—	–0.034	—	–0.042
10	14	–0.018	–0.023	–0.028	—	–0.033	—	–0.040	—	–0.050
14	18	–0.018	–0.023	–0.028	—	–0.033	–0.039	–0.045	—	–0.060
18	24	–0.022	–0.028	–0.035	—	–0.041	–0.047	–0.054	–0.063	–0.073
24	30	–0.022	–0.028	–0.035	–0.041	–0.048	–0.055	–0.064	–0.075	–0.088
30	40	–0.026	–0.034	–0.043	–0.048	–0.060	–0.068	–0.080	–0.094	–0.112
40	50	–0.026	–0.034	–0.043	–0.054	–0.070	–0.081	–0.097	–0.114	–0.136
50	65	–0.032	–0.041	–0.053	–0.066	–0.087	–0.102	–0.122	–0.144	–0.172
65	80	–0.032	–0.043	–0.059	–0.075	–0.102	–0.120	–0.146	–0.174	–0.210
80	100	–0.037	–0.051	–0.071	–0.091	–0.124	–0.146	–0.178	–0.214	–0.258
100	120	–0.037	–0.054	–0.079	–0.104	–0.144	–0.172	–0.210	–0.254	–0.310
120	140	–0.043	–0.063	–0.092	–0.122	–0.170	–0.202	–0.248	–0.300	–0.365
140	160	–0.043	–0.065	–0.100	–0.134	–0.190	–0.228	–0.280	–0.340	–0.415
160	180	–0.043	–0.068	–0.108	–0.146	–0.210	–0.252	–0.310	–0.380	–0.465
180	200	–0.050	–0.077	–0.122	–0.166	–0.236	–0.284	–0.350	–0.425	–0.520
200	225	–0.050	–0.080	–0.130	–0.180	–0.258	–0.310	–0.385	–0.470	–0.575
225	250	–0.050	–0.084	–0.140	–0.196	–0.284	–0.340	–0.425	–0.520	–0.640
250	280	–0.056	–0.094	–0.158	–0.218	–0.315	–0.385	–0.475	–0.580	–0.710
280	315	–0.056	–0.098	–0.170	–0.240	–0.350	–0.425	–0.525	–0.650	–0.790
315	355	–0.062	–0.108	–0.190	–0.268	–0.390	–0.475	–0.590	–0.730	–0.900
355	400	–0.062	–0.114	–0.208	–0.294	–0.436	–0.530	–0.660	–0.820	–1.000
400	450	–0.068	–0.126	–0.232	–0.330	–0.490	–0.595	–0.740	–0.920	–1.100
450	500	–0.068	–0.132	–0.252	–0.380	–0.540	–0.660	–0.820	–1.000	–1.250
IT Grade		6 to 16								
500	560	–0.078	–0.150	–0.280	–0.400	–0.600	—	—	—	—
560	630	–0.078	–0.155	–0.310	–0.450	–0.660	—	—	—	—
630	710	–0.088	–0.175	–0.340	–0.500	–0.740	—	—	—	—
710	800	–0.088	–0.185	–0.380	–0.560	–0.840	—	—	—	—
800	900	–0.100	–0.210	–0.430	–0.620	–0.940	—	—	—	—
900	1000	–0.100	–0.220	–0.470	–0.680	–1.050	—	—	—	—
1000	1120	–0.120	–0.250	–0.520	–0.780	–1.150	—	—	—	—
1120	1250	–0.120	–0.260	–0.580	–0.840	–1.300	—	—	—	—
1250	1400	–0.140	–0.300	–0.640	–0.960	–1.450	—	—	—	—
1400	1600	–0.140	–0.330	–0.720	–1.050	–1.600	—	—	—	—
1600	1800	–0.170	–0.370	–0.820	–1.200	–1.850	—	—	—	—
1800	2000	–0.170	–0.400	–0.920	–1.350	–2.000	—	—	—	—
2000	2240	–0.195	–0.440	–1.000	–1.500	–2.300	—	—	—	—
2240	2500	–0.195	–0.460	–1.100	–1.650	–2.500	—	—	—	—
2500	2800	–0.240	–0.550	–1.250	–1.900	–2.900	—	—	—	—
2800	3150	–0.240	–0.580	–1.400	–2.100	–3.200	—	—	—	—

[4] To determine P to ZC for IT grades below 7, use the same deviations as for grades above 7 increased by Δ.

Table H-2. Fundamental Deviations for Internal (Hole) Dimensions (cont)

Fundamental Deviation		Upper Deviation			Values for Δ [5]					
Letter		ZA	ZB	ZC						
IT Grade		Above 7			3	4	5	6	7	8
Basic Size (in millimeters)										
Over	Up to and Including									
0	3	–0.032	–0.040	–0.060	0.000	0.000	0.000	0.000	0.000	0.000
3	6	–0.042	–0.050	–0.080	0.001	0.0015	0.001	0.003	0.004	0.006
6	10	–0.052	–0.067	–0.097	0.001	0.0015	0.002	0.003	0.006	0.007
10	14	–0.064	–0.090	–0.130	0.001	0.002	0.003	0.003	0.007	0.009
14	18	–0.077	–0.108	–0.150	0.001	0.002	0.003	0.003	0.007	0.009
18	24	–0.098	–0.136	–0.188	0.0015	0.002	0.003	0.004	0.008	0.012
24	30	–0.118	–0.160	–0.218	0.0015	0.002	0.003	0.004	0.008	0.012
30	40	–0.148	–0.200	–0.274	0.0015	0.003	0.004	0.005	0.009	0.014
40	50	–0.180	–0.242	–0.325	0.0015	0.003	0.004	0.005	0.009	0.014
50	65	–0.226	–0.300	–0.405	0.002	0.003	0.005	0.006	0.011	0.016
65	80	–0.274	–0.360	–0.480	0.002	0.003	0.005	0.006	0.011	0.016
80	100	–0.335	–0.445	–0.585	0.002	0.004	0.005	0.007	0.013	0.019
100	120	–0.400	–0.525	–0.690	0.002	0.004	0.005	0.007	0.013	0.019
120	140	–0.470	–0.620	–0.800	0.003	0.004	0.006	0.007	0.015	0.023
140	160	–0.535	–0.700	–0.900	0.003	0.004	0.006	0.007	0.015	0.023
160	180	–0.600	–0.780	–1.000	0.003	0.004	0.006	0.007	0.015	0.023
180	200	–0.670	–0.880	–1.150	0.003	0.004	0.006	0.009	0.017	0.026
200	225	–0.740	–0.960	–1.250	0.003	0.004	0.006	0.009	0.017	0.026
225	250	–0.820	–1.050	–1.350	0.003	0.004	0.006	0.009	0.017	0.026
250	280	–0.920	–1.200	–1.560	0.004	0.004	0.007	0.009	0.020	0.029
280	315	–1.000	–1.300	–1.700	0.004	0.004	0.007	0.009	0.020	0.029
315	355	–1.150	–1.500	–1.900	0.004	0.005	0.007	0.011	0.021	0.032
355	400	–1.300	–1.650	–2.100	0.004	0.005	0.007	0.011	0.021	0.032
400	450	–1.450	–1.850	–2.400	0.005	0.005	0.007	0.013	0.023	0.034
450	500	–1.600	–2.100	–2.600	0.005	0.005	0.007	0.013	0.023	0.034
IT Grade		6 to 16								
500	3150	—	—	—	—	—	—	—	—	—

[5] In determining K, M, and N up to IT grade 8 and P to ZC up to IT grade 7, add the Δ value appropriate to the IT grade as indicated. For example, for P7 from 18 to 30, Δ = -0.008 ∴ upper deviation = -0.014.

Table H-3. Fundamental Deviations for External (Shaft) Dimensions

Fundamental Deviation		Upper Deviation								
Letter		a	b	c	d	e	f	g	h	js [6]
IT Grade		01 to 16								
Basic Size (in millimeters)										
Over	Up to and Including									
0	3	–0.270	–0.140	–0.060	–0.020	–0.014	–0.006	–0.002	0.000	
3	6	–0.270	–0.140	–0.070	–0.030	–0.020	–0.010	–0.004	0.000	
6	10	–0.280	–0.150	–0.080	–0.040	–0.025	–0.013	–0.005	0.000	
10	14	–0.290	–0.150	–0.095	–0.050	–0.032	–0.016	–0.006	0.000	
14	18	–0.290	–0.150	–0.095	–0.050	–0.032	–0.016	–0.006	0.000	
18	24	–0.300	–0.160	–0.110	–0.065	–0.040	–0.020	–0.007	0.000	
24	30	–0.300	–0.160	–0.110	–0.065	–0.040	–0.020	–0.007	0.000	
30	40	–0.310	–0.170	–0.120	–0.080	–0.050	–0.025	–0.009	0.000	
40	50	–0.320	–0.180	–0.130	–0.080	–0.050	–0.025	–0.009	0.000	
50	65	–0.340	–0.190	–0.140	–0.100	–0.060	–0.030	–0.010	0.000	
65	80	–0.360	–0.200	–0.150	–0.100	–0.060	–0.030	–0.010	0.000	
80	100	–0.380	–0.220	–0.170	–0.120	–0.072	–0.036	–0.012	0.000	
100	120	–0.410	–0.240	–0.180	–0.120	–0.072	–0.036	–0.012	0.000	+IT/2
120	140	–0.460	–0.260	–0.200	–0.145	–0.085	–0.043	–0.014	0.000	
140	160	–0.520	–0.280	–0.210	–0.145	–0.085	–0.043	–0.014	0.000	
160	180	–0.580	–0.310	–0.230	–0.145	–0.085	–0.043	–0.014	0.000	
180	200	–0.660	–0.340	–0.240	–0.170	–0.100	–0.050	–0.015	0.000	
200	225	–0.740	–0.380	–0.260	–0.170	–0.100	–0.050	–0.015	0.000	
225	250	–0.820	–0.420	–0.280	–0.170	–0.100	–0.050	–0.015	0.000	
250	280	–0.920	–0.480	–0.300	–0.190	–0.110	–0.056	–0.017	0.000	
280	315	–1.050	–0.540	–0.330	–0.190	–0.110	–0.056	–0.017	0.000	
315	355	–1.200	–0.600	–0.360	–0.210	–0.125	–0.062	–0.018	0.000	
355	400	–1.350	–0.680	–0.400	–0.210	–0.125	–0.062	–0.018	0.000	
400	450	–1.500	–0.760	–0.440	–0.230	–0.135	–0.068	–0.020	0.000	
450	500	–1.650	–0.840	–0.480	–0.230	–0.135	–0.068	–0.020	0.000	
IT Grade		6 to 16								
500	630	—	—	—	–0.260	–0.145	–0.076	–0.022	0.000	
630	800	—	—	—	–0.290	–0.160	–0.080	–0.024	0.000	
800	1000	—	—	—	–0.320	–0.170	–0.086	–0.026	0.000	
1000	1250	—	—	—	–0.350	–0.195	–0.098	–0.028	0.000	+IT/2
1250	1600	—	—	—	–0.390	–0.220	–0.110	–0.030	0.000	
1600	2000	—	—	—	–0.430	–0.240	–0.120	–0.032	0.000	
2000	2500	—	—	—	–0.480	–0.260	–0.130	–0.034	0.000	
2500	3150	—	—	—	–0.520	–0.290	–0.145	–0.038	0.000	

Fundamental Deviation		Lower Deviation		
Letter		cd	ef	fg
IT Grade		01 to 16		
Basic Size (in millimeters)				
Over	Up to and Including			
0	3	–0.034	–0.010	–0.004
3	6	–0.046	–0.014	–0.006
6	10	–0.056	–0.018	–0.008

[6] js deviations in the grades 7 to 11 should be rounded off to 1/2 (IT-0.001) when the IT value is odd.

Table H-3. Fundamental Deviations for External (Shaft) Dimensions (cont)

Fundamental Deviation		Lower Deviation								
Letter		j			k		m	n	p	r
IT Grade		5 - 6	7	8	4 - 7	≤3, >7	01 to 16			
Basic Size (in millimeters)										
Over	Up to and Including									
0	3	–0.002	–0.004	–0.006	0.000	0.000	+0.002	+0.004	+0.006	+0.010
3	6	–0.002	–0.004	—	+0.001	0.000	+0.004	+0.008	+0.012	+0.015
6	10	–0.002	–0.005	—	+0.001	0.000	+0.006	+0.010	+0.015	+0.019
10	14	–0.003	–0.006	—	+0.001	0.000	+0.007	+0.012	+0.018	+0.023
14	18	–0.003	–0.006	—	+0.001	0.000	+0.007	+0.012	+0.018	+0.023
18	24	–0.004	–0.008	—	+0.002	0.000	+0.008	+0.015	+0.022	+0.028
24	30	–0.004	–0.008	—	+0.002	0.000	+0.008	+0.015	+0.022	+0.028
30	40	–0.005	–0.010	—	+0.002	0.000	+0.009	+0.017	+0.026	+0.034
40	50	–0.005	–0.010	—	+0.002	0.000	+0.009	+0.017	+0.026	+0.034
50	65	–0.007	–0.012	—	+0.002	0.000	+0.011	+0.020	+0.032	+0.041
65	80	–0.007	–0.012	—	+0.002	0.000	+0.011	+0.020	+0.032	+0.043
80	100	–0.009	–0.015	—	+0.003	0.000	+0.013	+0.023	+0.037	+0.051
100	120	–0.009	–0.015	—	+0.003	0.000	+0.013	+0.023	+0.037	+0.054
120	140	–0.011	–0.018	—	+0.003	0.000	+0.015	+0.027	+0.043	+0.063
140	160	–0.011	–0.018	—	+0.003	0.000	+0.015	+0.027	+0.043	+0.065
160	180	–0.011	–0.018	—	+0.003	0.000	+0.015	+0.027	+0.043	+0.068
180	200	–0.013	–0.021	—	+0.004	0.000	+0.017	+0.031	+0.050	+0.077
200	225	–0.013	–0.021	—	+0.004	0.000	+0.017	+0.031	+0.050	+0.080
225	250	–0.013	–0.021	—	+0.004	0.000	+0.017	+0.031	+0.050	+0.084
250	280	–0.016	–0.026	—	+0.004	0.000	+0.020	+0.034	+0.056	+0.094
280	315	–0.016	–0.026	—	+0.004	0.000	+0.020	+0.034	+0.056	+0.098
315	355	–0.018	–0.028	—	+0.004	0.000	+0.021	+0.037	+0.062	+0.108
355	400	–0.018	–0.028	—	+0.004	0.000	+0.021	+0.037	+0.062	+0.114
400	450	–0.020	–0.032	—	+0.005	0.000	+0.023	+0.040	+0.068	+0.126
450	500	–0.020	–0.032	—	+0.005	0.000	+0.023	+0.040	+0.068	+0.132
IT Grade		6 to 16								
500	560	—	—	—	0.000	0.000	+0.026	+0.044	+0.078	+0.150
560	630	—	—	—	0.000	0.000	+0.026	+0.044	+0.078	+0.155
630	710	—	—	—	0.000	0.000	+0.030	+0.050	+0.088	+0.175
710	800	—	—	—	0.000	0.000	+0.030	+0.050	+0.088	+0.185
800	900	—	—	—	0.000	0.000	+0.034	+0.056	+0.100	+0.210
900	1000	—	—	—	0.000	0.000	+0.034	+0.056	+0.100	+0.220
1000	1120	—	—	—	0.000	0.000	+0.040	+0.066	+0.120	+0.250
1120	1250	—	—	—	0.000	0.000	+0.040	+0.066	+0.120	+0.260
1250	1400	—	—	—	0.000	0.000	+0.048	+0.078	+0.140	+0.300
1400	1600	—	—	—	0.000	0.000	+0.048	+0.078	+0.140	+0.330
1600	1800	—	—	—	0.000	0.000	+0.058	+0.092	+0.170	+0.370
1800	2000	—	—	—	0.000	0.000	+0.058	+0.092	+0.170	+0.400
2000	2240	—	—	—	0.000	0.000	+0.068	+0.110	+0.195	+0.440
2240	2500	—	—	—	0.000	0.000	+0.068	+0.110	+0.195	+0.460
2500	2800	—	—	—	0.000	0.000	+0.076	+0.135	+0.240	+0.550
2800	3150	—	—	—	0.000	0.000	+0.076	+0.135	+0.240	+0.580

Table H-3. Fundamental Deviations for External (Shaft) Dimensions (cont)

Fundamental Deviation		Upper Deviation									
Letter		s	t	u	v	x	y	z	za	zb	zc
IT Grade		01 to 16									
Basic Size (in millimeters) Over	Up to and Including										
0	3	+0.014	—	+0.018	—	+0.020	—	+0.026	+0.032	+0.040	+0.060
3	6	+0.019	—	+0.023	—	+0.028	—	+0.035	+0.042	+0.050	+0.080
6	10	+0.023	—	+0.028	—	+0.034	—	+0.042	+0.052	+0.067	+0.097
10	14	+0.028	—	+0.033	—	+0.040	—	+0.050	+0.064	+0.090	+0.130
14	18	+0.028	—	+0.033	+0.039	+0.045	—	+0.060	+0.077	+0.108	+0.150
18	24	+0.035	—	+0.041	+0.047	+0.054	+0.063	+0.073	+0.098	+0.136	+0.188
24	30	+0.035	+0.041	+0.048	+0.055	+0.064	+0.075	+0.088	+0.118	+0.160	+0.218
30	40	+0.043	+0.048	+0.060	+0.068	+0.080	+0.094	+0.112	+0.148	+0.200	+0.274
40	50	+0.043	+0.054	+0.070	+0.081	+0.097	+0.114	+0.136	+0.180	+0.242	+0.325
50	65	+0.053	+0.066	+0.087	+0.102	+0.122	+0.144	+0.172	+0.226	+0.300	+0.405
65	80	+0.059	+0.075	+0.102	+0.120	+0.146	+0.174	+0.210	+0.274	+0.360	+0.480
80	100	+0.071	+0.091	+0.124	+0.146	+0.178	+0.214	+0.258	+0.335	+0.445	+0.585
100	120	+0.079	+0.104	+0.144	+0.172	+0.210	+0.254	+0.310	+0.400	+0.525	+0.690
120	140	+0.092	+0.122	+0.170	+0.202	+0.248	+0.300	+0.365	+0.470	+0.620	+0.800
140	160	+0.100	+0.134	+0.190	+0.228	+0.280	+0.340	+0.415	+0.535	+0.700	+0.900
160	180	+0.108	+0.146	+0.210	+0.252	+0.310	+0.380	+0.465	+0.600	+0.780	+1.000
180	200	+0.122	+0.166	+0.236	+0.284	+0.350	+0.425	+0.520	+0.670	+0.880	+1.150
200	225	+0.130	+0.180	+0.258	+0.310	+0.385	+0.470	+0.575	+0.740	+0.960	+1.250
225	250	+0.140	+0.196	+0.284	+0.340	+0.425	+0.520	+0.640	+0.820	+1.050	+1.350
250	280	+0.158	+0.218	+0.315	+0.385	+0.475	+0.580	+0.710	+0.920	+1.200	+1.550
280	315	+0.170	+0.240	+0.350	+0.425	+0.525	+0.650	+0.790	+1.000	+1.300	+1.700
315	355	+0.190	+0.268	+0.390	+0.475	+0.590	+0.730	+0.900	+1.150	+1.500	+1.900
355	400	+0.208	+0.294	+0.435	+0.530	+0.660	+0.820	+1.000	+1.300	+1.650	+2.100
400	450	+0.232	+0.330	+0.490	+0.595	+0.740	+0.920	+1.100	+1.450	+1.850	+2.400
450	500	+0.252	+0.360	+0.540	+0.660	+0.820	+1.000	+1.250	+1.600	+2.100	+2.600
IT Grade		6 to 16									
500	560	+0.280	+0.400	+0.600	—	—	—	—	—	—	—
560	630	+0.310	+0.450	+0.660	—	—	—	—	—	—	—
630	710	+0.340	+0.500	+0.740	—	—	—	—	—	—	—
710	800	+0.380	+0.560	+0.840	—	—	—	—	—	—	—
800	900	+0.430	+0.620	+0.940	—	—	—	—	—	—	—
900	1000	+0.470	+0.680	+1.050	—	—	—	—	—	—	—
1000	1120	+0.520	+0.780	+1.150	—	—	—	—	—	—	—
1120	1250	+0.580	+0.840	+1.300	—	—	—	—	—	—	—
1250	1400	+0.640	+0.960	+1.450	—	—	—	—	—	—	—
1400	1600	+0.720	+1.050	+1.600	—	—	—	—	—	—	—
1600	1800	+0.820	+1.200	+1.850	—	—	—	—	—	—	—
1800	2000	+0.920	+1.350	+2.000	—	—	—	—	—	—	—
2000	2240	+1.000	+1.500	+2.300	—	—	—	—	—	—	—
2240	2500	+1.100	+1.650	+2.500	—	—	—	—	—	—	—
2500	2800	+1.250	+1.900	+2.900	—	—	—	—	—	—	—
2800	3150	+1.400	+2.100	+3.200	—	—	—	—	—	—	—

Table H-4. Preferred Tolerance Zones for Internal (Hole) Dimensions (Dimensions in Millimeters)

Basic Size		A11	B11	C11	D9	D10	D11	E8	E9	E10	F7	F8
OVER	0	+0.330	+0.200	+0.120	+0.045	+0.060	+0.080	+0.028	+0.039	+0.054	+0.016	+0.020
TO	3	+0.270	+0.140	+0.060	+0.020	+0.020	+0.020	+0.014	+0.014	+0.014	+0.006	+0.006
OVER	**3**	**+0.345**	**+0.215**	**+0.145**	**+0.060**	**+0.078**	**+0.105**	**+0.038**	**+0.050**	**+0.068**	**+0.022**	**+0.028**
TO	**6**	**+0.270**	**+0.140**	**+0.070**	**+0.030**	**+0.030**	**+0.030**	**+0.020**	**+0.020**	**+0.020**	**+0.010**	**+0.010**
OVER	6	+0.370	+0.240	+0.170	+0.076	+0.098	+0.130	+0.047	+0.061	+0.083	+0.028	+0.035
TO	10	+0.280	+0.150	+0.080	+0.040	+0.040	+0.040	+0.025	+0.025	+0.025	+0.013	+0.013
OVER	**10**	**+0.400**	**+0.260**	**+0.205**	**+0.093**	**+0.120**	**+0.160**	**+0.059**	**+0.075**	**+0.102**	**+0.034**	**+0.043**
TO	**14**	**+0.290**	**+0.150**	**+0.095**	**+0.050**	**+0.050**	**+0.050**	**+0.032**	**+0.032**	**+0.032**	**+0.016**	**+0.016**
OVER	14	+0.400	+0.260	+0.205	+0.093	+0.120	+0.160	+0.059	+0.075	+0.102	+0.034	+0.043
TO	18	+0.290	+0.150	+0.095	+0.050	+0.050	+0.050	+0.032	+0.032	+0.032	+0.016	+0.016
OVER	**18**	**+0.430**	**+0.290**	**+0.240**	**+0.117**	**+0.149**	**+0.195**	**+0.073**	**+0.092**	**+0.124**	**+0.041**	**+0.053**
TO	**24**	**+0.300**	**+0.160**	**+0.110**	**+0.065**	**+0.065**	**+0.065**	**+0.040**	**+0.040**	**+0.040**	**+0.020**	**+0.020**
OVER	24	+0.430	+0.290	+0.240	+0.117	+0.149	+0.195	+0.073	+0.092	+0.124	+0.041	+0.053
TO	30	+0.300	+0.160	+0.110	+0.065	+0.065	+0.065	+0.040	+0.040	+0.040	+0.020	+0.020
OVER	**30**	**+0.470**	**+0.330**	**+0.280**	**+0.142**	**+0.180**	**+0.240**	**+0.089**	**+0.112**	**+0.150**	**+0.050**	**+0.064**
TO	**40**	**+0.310**	**+0.170**	**+0.120**	**+0.080**	**+0.080**	**+0.080**	**+0.050**	**+0.050**	**+0.050**	**+0.025**	**+0.025**
OVER	40	+0.480	+0.340	+0.290	+0.142	+0.180	+0.240	+0.089	+0.112	+0.150	+0.050	+0.064
TO	50	+0.320	+0.180	+0.130	+0.080	+0.080	+0.080	+0.050	+0.050	+0.050	+0.025	+0.025
OVER	**50**	**+0.530**	**+0.380**	**+0.330**	**+0.174**	**+0.220**	**+0.290**	**+0.106**	**+0.134**	**+0.180**	**+0.060**	**+0.076**
TO	**65**	**+0.340**	**+0.190**	**+0.140**	**+0.100**	**+0.100**	**+0.100**	**+0.060**	**+0.060**	**+0.060**	**+0.030**	**+0.030**
OVER	65	+0.550	+0.390	+0.340	+0.174	+0.220	+0.290	+0.106	+0.134	+0.180	+0.060	+0.076
TO	80	+0.360	+0.200	+0.150	+0.100	+0.100	+0.100	+0.060	+0.060	+0.060	+0.030	+0.030
OVER	**80**	**+0.600**	**+0.440**	**+0.390**	**+0.207**	**+0.260**	**+0.340**	**+0.126**	**+0.159**	**+0.212**	**+0.071**	**+0.090**
TO	**100**	**+0.380**	**+0.220**	**+0.170**	**+0.120**	**+0.120**	**+0.120**	**+0.072**	**+0.072**	**+0.072**	**+0.036**	**+0.036**
OVER	100	+0.630	+0.460	+0.400	+0.207	+0.260	+0.340	+0.126	+0.159	+0.212	+0.071	+0.090
TO	120	+0.410	+0.240	+0.180	+0.120	+0.120	+0.120	+0.072	+0.072	+0.072	+0.036	+0.036
OVER	**120**	**+0.710**	**+0.510**	**+0.450**	**+0.245**	**+0.305**	**+0.395**	**+0.148**	**+0.185**	**+0.245**	**+0.083**	**+0.106**
TO	**140**	**+0.460**	**+0.260**	**+0.200**	**+0.145**	**+0.145**	**+0.145**	**+0.085**	**+0.085**	**+0.085**	**+0.043**	**+0.043**
OVER	140	+0.770	+0.530	+0.460	+0.245	+0.305	+0.395	+0.148	+0.185	+0.245	+0.083	+0.106
TO	160	+0.520	+0.280	+0.210	+0.145	+0.145	+0.145	+0.085	+0.085	+0.085	+0.043	+0.043
OVER	**160**	**+0.830**	**+0.560**	**+0.480**	**+0.245**	**+0.305**	**+0.395**	**+0.148**	**+0.185**	**+0.245**	**+0.083**	**+0.106**
TO	**180**	**+0.580**	**+0.310**	**+0.230**	**+0.145**	**+0.145**	**+0.145**	**+0.085**	**+0.085**	**+0.085**	**+0.043**	**+0.043**
OVER	180	+0.950	+0.630	+0.530	+0.285	+0.355	+0.460	+0.172	+0.215	+0.285	+0.096	+0.122
TO	200	+0.660	+0.340	+0.240	+0.170	+0.170	+0.170	+0.100	+0.100	+0.100	+0.050	+0.050
OVER	**200**	**+1.030**	**+0.670**	**+0.550**	**+0.285**	**+0.355**	**+0.460**	**+0.172**	**+0.215**	**+0.285**	**+0.096**	**+0.122**
TO	**225**	**+0.740**	**+0.380**	**+0.260**	**+0.170**	**+0.170**	**+0.170**	**+0.100**	**+0.100**	**+0.100**	**+0.050**	**+0.050**
OVER	225	+1.110	+0.710	+0.570	+0.285	+0.355	+0.460	+0.172	+0.215	+0.285	+0.096	+0.122
TO	250	+0.820	+0.420	+0.280	+0.170	+0.170	+0.170	+0.100	+0.100	+0.100	+0.050	+0.050
OVER	**250**	**+1.240**	**+0.800**	**+0.620**	**+0.320**	**+0.400**	**+0.510**	**+0.191**	**+0.240**	**+0.320**	**+0.108**	**+0.137**
TO	**280**	**+0.920**	**+0.480**	**+0.300**	**+0.190**	**+0.190**	**+0.190**	**+0.110**	**+0.110**	**+0.110**	**+0.056**	**+0.056**
OVER	280	+1.370	+0.860	+0.650	+0.320	+0.400	+0.510	+0.191	+0.240	+0.320	+0.108	+0.137
TO	315	+1.050	+0.540	+0.330	+0.190	+0.190	+0.190	+0.110	+0.110	+0.110	+0.056	+0.056
OVER	**315**	**+1.560**	**+0.960**	**+0.720**	**+0.350**	**+0.440**	**+0.570**	**+0.214**	**+0.265**	**+0.355**	**+0.119**	**+0.151**
TO	**355**	**+1.200**	**+0.600**	**+0.360**	**+0.210**	**+0.210**	**+0.210**	**+0.125**	**+0.125**	**+0.125**	**+0.062**	**+0.062**
OVER	355	+1.710	+1.040	+0.760	+0.350	+0.440	+0.570	+0.214	+0.265	+0.355	+0.119	+0.151
TO	400	+1.350	+0.680	+0.400	+0.210	+0.210	+0.210	+0.125	+0.125	+0.125	+0.062	+0.062
OVER	**400**	**+1.900**	**+1.160**	**+0.840**	**+0.385**	**+0.480**	**+0.630**	**+0.232**	**+0.290**	**+0.385**	**+0.131**	**+0.165**
TO	**450**	**+1.500**	**+0.760**	**+0.440**	**+0.230**	**+0.230**	**+.0.230**	**+0.135**	**+0.135**	**+0.135**	**+0.068**	**+0.068**
OVER	450	+2.050	+1.240	+0.880	+0.385	+0.480	+0.630	+0.232	+0.290	+0.385	+0.131	+0.165
TO	500	+1.650	+0.840	+0.480	+0.230	+0.230	+0.230	+0.135	+0.135	+0.135	+0.068	+0.068

Table H-4. Preferred Tolerance Zones for Internal (Hole) Dimensions (Dimensions in Millimeters) (cont)

Basic Size		F9	G6	G7	H6	H7	H8	H9	H10	H11	JS6	JS7
OVER	0	+0.031	+0.008	+0.012	+0.006	+0.010	+0.014	+0.025	+0.040	+0.060	+0.003	+0.005
TO	3	+0.006	+0.002	+0.002	0.000	0.000	0.000	0.000	0.000	0.000	–0.003	–0.005
OVER	**3**	**+0.040**	**+0.012**	**+0.016**	**+0.008**	**+0.012**	**+0.018**	**+0.030**	**+0.048**	**+0.075**	**+0.004**	**+0.006**
TO	**6**	**+0.010**	**+0.004**	**+0.004**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**–0.004**	**–0.006**
OVER	6	+0.049	+0.014	+0.020	+0.009	+0.015	+0.022	+0.036	+0.058	+0.090	+0.0045	+0.007
TO	10	+0.013	+0.005	+0.005	0.000	0.000	0.000	0.000	0.000	0.000	–0.0045	–0.007
OVER	**10**	**+0.059**	**+0.017**	**+0.024**	**+0.011**	**+0.018**	**+0.027**	**+0.043**	**+0.070**	**+0.110**	**+0.0055**	**+0.009**
TO	**14**	**+0.016**	**+0.006**	**+0.006**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**–0.0055**	**–0.009**
OVER	14	+0.059	+0.017	+0.024	+0.011	+0.018	+0.027	+0.043	+0.070	+0.110	+0.0055	+0.009
TO	18	+0.016	+0.006	+0.006	0.000	0.000	0.000	0.000	0.000	0.000	–0.0055	–0.009
OVER	**18**	**+0.072**	**+0.020**	**+0.028**	**+0.013**	**+0.021**	**+0.033**	**+0.052**	**+0.084**	**+0.130**	**+0.0065**	**+0.010**
TO	**24**	**+0.020**	**+0.007**	**+0.007**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**–0.0065**	**–0.010**
OVER	24	+0.072	+0.020	+0.028	+0.013	+0.021	+0.033	+0.052	+0.084	+0.130	+0.0065	+0.010
TO	30	+0.020	+0.007	+0.007	0.000	0.000	0.000	0.000	0.000	0.000	–0.0065	–0.010
OVER	**30**	**+0.087**	**+0.025**	**+0.034**	**+0.016**	**+0.025**	**+0.039**	**+0.062**	**+0.100**	**+0.160**	**+0.008**	**+0.012**
TO	**40**	**+0.025**	**+0.009**	**+0.009**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**–0.008**	**–0.012**
OVER	40	+0.087	+0.025	+0.034	+0.016	+0.025	+0.039	+0.062	+0.100	+0.160	+0.008	+0.012
TO	50	+0.025	+0.009	+0.009	0.000	0.000	0.000	0.000	0.000	0.000	–0.008	–0.012
OVER	**50**	**+0.104**	**+0.029**	**+0.040**	**+0.019**	**+0.030**	**+0.046**	**+0.074**	**+0.120**	**+0.190**	**+0.0095**	**+0.015**
TO	**65**	**+0.030**	**+0.010**	**+0.010**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**–0.0095**	**–0.015**
OVER	65	+0.104	+0.029	+0.040	+0.019	+0.030	+0.046	+0.074	+0.120	+0.190	+0.0095	+0.015
TO	80	+0.030	+0.010	+0.010	0.000	0.000	0.000	0.000	0.000	0.000	–0.0095	–0.015
OVER	**80**	**+0.123**	**+0.034**	**+0.047**	**+0.022**	**+0.035**	**+0.054**	**+0.087**	**+0.140**	**+0.220**	**+0.011**	**+0.017**
TO	**100**	**+0.036**	**+0.012**	**+0.012**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**–0.011**	**–0.017**
OVER	100	+0.123	+0.034	+0.047	+0.022	+0.035	+0.054	+0.087	+0.140	+0.220	+0.011	+0.017
TO	120	+0.036	+0.012	+0.012	0.000	0.000	0.000	0.000	0.000	0.000	–0.011	–0.017
OVER	**120**	**+0.143**	**+0.039**	**+0.054**	**+0.025**	**+0.040**	**+0.063**	**+0.100**	**+0.160**	**+0.250**	**+0.0125**	**+0.020**
TO	**140**	**+0.043**	**+0.014**	**+0.014**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**–0.0125**	**–0.020**
OVER	140	+0.143	+0.039	+0.054	+0.025	+0.040	+0.063	+0.100	+0.160	+0.250	+0.0125	+0.020
TO	160	+0.043	+0.014	+0.014	0.000	0.000	0.000	0.000	0.000	0.000	–0.0125	–0.020
OVER	**160**	**+0.143**	**+0.039**	**+0.054**	**+0.025**	**+0.040**	**+0.063**	**+0.100**	**+0.160**	**+0.250**	**+0.0125**	**+0.020**
TO	**180**	**+0.043**	**+0.014**	**+0.014**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**–0.0125**	**–0.020**
OVER	180	+0.165	+0.044	+0.061	+0.029	+0.046	+0.072	+0.115	+0.185	+0.290	+0.0145	+0.023
TO	200	+0.050	+0.015	+0.015	0.000	0.000	0.000	0.000	0.000	0.000	–0.0145	–0.023
OVER	**200**	**+0.165**	**+0.044**	**+0.061**	**+0.029**	**+0.046**	**+0.072**	**+0.115**	**+0.185**	**+0.290**	**+0.0145**	**+0.023**
TO	**225**	**+0.050**	**+0.015**	**+0.015**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**–0.0145**	**–0.023**
OVER	225	+0.165	+0.044	+0.061	+0.029	+0.046	+0.072	+0.115	+0.185	+0.290	+0.0145	+0.023
TO	250	+0.050	+0.015	+0.015	0.000	0.000	0.000	0.000	0.000	0.000	–0.0145	–0.023
OVER	**250**	**+0.186**	**+0.049**	**+0.069**	**+0.032**	**+0.052**	**+0.081**	**+0.130**	**+0.210**	**+0.320**	**+0.016**	**+0.026**
TO	**280**	**+0.056**	**+0.017**	**+0.017**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**–0.016**	**–0.026**
OVER	280	+0.186	+0.049	+0.069	+0.032	+0.052	+0.081	+0.130	+0.210	+0.320	+0.016	+0.026
TO	315	+0.056	+0.017	+0.017	0.000	0.000	0.000	0.000	0.000	0.000	–0.016	–0.026
OVER	**315**	**+0.202**	**+0.054**	**+0.075**	**+0.036**	**+0.057**	**+0.089**	**+0.140**	**+0.230**	**+0.360**	**+0.018**	**+0.028**
TO	**355**	**+0.062**	**+0.018**	**+0.018**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**–0.018**	**–0.028**
OVER	355	+0.202	+0.054	+0.075	+0.036	+0.057	+0.089	+0.140	+0.230	+0.360	+0.018	+0.028
TO	400	+0.062	+0.018	+0.018	0.000	0.000	0.000	0.000	0.000	0.000	–0.018	–0.028
OVER	**400**	**+0.223**	**+0.060**	**+0.083**	**+0.040**	**+0.063**	**+0.097**	**+0.155**	**+0.250**	**+0.400**	**+0.020**	**+0.031**
TO	**450**	**+0.068**	**+0.020**	**+0.020**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**–0.020**	**–0.031**
OVER	450	+0.223	+0.060	+0.083	+0.040	+0.063	+0.097	+0.155	+0.250	+0.400	+0.020	+0.031
TO	500	+0.068	+0.020	+0.020	0.000	0.000	0.000	0.000	0.000	0.000	–0.020	–0.031

Table H-4. Preferred Tolerance Zones for Internal (Hole) Dimensions (Dimensions in Millimeters) (cont)

Basic Size	JS8	K6	K7	K8	M6	M7	M8	N6	N7	N8	P6
OVER 0	+0.007	0.000	0.000	0.000	−0.002	−0.002	−0.002	−0.004	−0.004	−0.004	−0.006
TO 3	−0.007	−0.006	−0.010	−0.014	−0.008	−0.012	−0.016	−0.010	−0.014	−0.018	−0.012
OVER 3	**+0.009**	**+0.002**	**+0.003**	**+0.005**	**−0.001**	**0.000**	**+0.002**	**−0.005**	**−0.004**	**−0.002**	**−0.009**
TO 6	**−0.009**	**−0.006**	**−0.009**	**−0.013**	**−0.009**	**−0.012**	**−0.016**	**−0.013**	**−0.016**	**−0.020**	**−0.017**
OVER 6	+0.011	+0.002	+0.005	+0.004	−0.003	0.000	+0.001	−0.007	−0.004	−0.003	−0.012
TO 10	−0.011	−0.007	−0.010	−0.016	−0.012	−0.015	−0.021	−0.016	−0.019	−0.025	−0.021
OVER 10	**+0.013**	**+0.002**	**+0.006**	**+0.008**	**−0.004**	**0.000**	**+0.002**	**−0.009**	**−0.005**	**−0.003**	**−0.015**
TO 14	**−0.013**	**−0.009**	**−0.012**	**−0.019**	**−0.015**	**−0.018**	**−0.025**	**−0.020**	**−0.023**	**−0.030**	**−0.026**
OVER 14	+0.013	+0.002	+0.006	+0.008	−0.004	0.000	+0.002	−0.009	−0.005	−0.003	−0.015
TO 18	−0.013	−0.009	−0.012	−0.019	−0.015	−0.018	−0.025	−0.020	−0.023	−0.030	−0.026
OVER 18	**+0.016**	**+0.002**	**+0.006**	**+0.010**	**−0.004**	**0.000**	**+0.004**	**−0.011**	**−0.007**	**−0.003**	**−0.018**
TO 24	**−0.016**	**−0.011**	**−0.015**	**−0.023**	**−0.017**	**−0.021**	**−0.029**	**−0.024**	**−0.028**	**−0.036**	**−0.031**
OVER 24	+0.016	+0.002	+0.006	+0.010	−0.004	0.000	+0.004	−0.011	−0.007	−0.003	−0.018
TO 30	−0.016	−0.011	−0.015	−0.023	−0.017	−0.021	−0.029	−0.024	−0.028	−0.036	−0.031
OVER 30	**+0.019**	**+0.003**	**+0.007**	**+0.012**	**−0.004**	**0.000**	**+0.005**	**−0.012**	**−0.008**	**−0.003**	**−0.021**
TO 40	**−0.019**	**−0.013**	**−0.018**	**−0.027**	**−0.020**	**−0.025**	**−0.034**	**−0.028**	**−0.033**	**−0.042**	**−0.037**
OVER 40	+0.019	+0.003	+0.007	+0.012	−0.004	0.000	+0.005	−0.012	−0.008	−0.003	−0.021
TO 50	−0.019	−0.013	−0.018	−0.027	−0.020	−0.025	−0.034	−0.028	−0.033	−0.042	−0.037
OVER 50	**+0.023**	**+0.004**	**+0.009**	**+0.014**	**−0.005**	**0.000**	**+0.005**	**−0.014**	**−0.009**	**−0.004**	**−0.026**
TO 65	**−0.023**	**−0.015**	**−0.021**	**−0.032**	**−0.024**	**−0.030**	**−0.041**	**−0.033**	**−0.039**	**−0.050**	**−0.045**
OVER 65	+0.023	+0.004	+0.009	+0.014	−0.005	0.000	+0.005	−0.014	−0.009	−0.004	−0.026
TO 80	−0.023	−0.015	−0.021	−0.032	−0.024	−0.030	−0.041	−0.033	−0.039	−0.050	−0.045
OVER 80	**+0.027**	**+0.004**	**+0.010**	**+0.016**	**−0.006**	**0.000**	**+0.006**	**−0.016**	**−0.010**	**−0.004**	**−0.030**
TO 100	**−0.027**	**−0.018**	**−0.025**	**−0.038**	**−0.028**	**−0.035**	**−0.048**	**−0.038**	**−0.045**	**−0.058**	**−0.052**
OVER 100	+0.027	+0.004	+0.010	+0.016	−0.006	0.000	+0.006	−0.016	−0.010	−0.004	−0.030
TO 120	−0.027	−0.018	−0.025	−0.038	−0.028	−0.035	−0.048	−0.038	−0.045	−0.058	−0.052
OVER 120	**+0.031**	**+0.004**	**+0.012**	**+0.020**	**−0.008**	**0.000**	**+0.008**	**−0.020**	**−0.012**	**−0.004**	**−0.036**
TO 140	**−0.031**	**−0.021**	**−0.028**	**−0.043**	**−0.033**	**−0.040**	**−0.055**	**−0.045**	**−0.052**	**−0.067**	**−0.061**
OVER 140	+0.031	+0.004	+0.012	+0.020	−0.008	0.000	+0.008	−0.020	−0.012	−0.004	−0.036
TO 160	−0.031	−0.021	−0.028	−0.043	−0.033	−0.040	−0.055	−0.045	−0.052	−0.067	−0.061
OVER 160	**+0.031**	**+0.004**	**+0.012**	**+0.020**	**−0.008**	**0.000**	**+0.008**	**−0.020**	**−0.012**	**−0.004**	**−0.036**
TO 180	**−0.031**	**−0.021**	**−0.028**	**−0.043**	**−0.033**	**−0.040**	**−0.055**	**−0.045**	**−0.052**	**−0.067**	**−0.061**
OVER 180	+0.036	+0.005	+0.013	+0.022	−0.008	0.000	+0.009	−0.022	−0.014	−0.005	−0.041
TO 200	−0.036	−0.024	−0.033	−0.050	−0.037	−0.046	−0.063	−0.051	−0.060	−0.077	−0.070
OVER 200	**+0.036**	**+0.005**	**+0.013**	**+0.022**	**−0.008**	**0.000**	**+0.009**	**−0.022**	**−0.014**	**−0.005**	**−0.041**
TO 225	**−0.036**	**−0.024**	**−0.033**	**−0.050**	**−0.037**	**−0.046**	**−0.063**	**−0.051**	**−0.060**	**−0.077**	**−0.070**
OVER 225	+0.036	+0.005	+0.013	+0.022	−0.008	0.000	+0.009	−0.022	−0.014	−0.005	−0.041
TO 250	−0.036	−0.024	−0.033	−0.050	−0.037	−0.046	−0.063	−0.051	−0.060	−0.077	−0.070
OVER 250	**+0.040**	**+0.005**	**+0.016**	**+0.025**	**−0.009**	**0.000**	**+0.009**	**−0.025**	**−0.014**	**−0.005**	**−0.047**
TO 280	**−0.040**	**−0.027**	**−0.036**	**−0.056**	**−0.041**	**−0.052**	**−0.072**	**−0.057**	**−0.066**	**−0.086**	**−0.079**
OVER 280	+0.040	+0.005	+0.016	+0.025	−0.009	0.000	+0.009	−0.025	−0.014	−0.005	−0.047
TO 315	−0.040	−0.027	−0.036	−0.056	−0.041	−0.052	−0.072	−0.057	−0.066	−0.086	−0.079
OVER 315	**+0.044**	**+0.007**	**+0.017**	**+0.028**	**−0.010**	**0.000**	**+0.011**	**−0.026**	**−0.016**	**−0.005**	**−0.051**
TO 355	**−0.044**	**−0.029**	**−0.040**	**−0.061**	**−0.046**	**−0.057**	**−0.078**	**−0.062**	**−0.073**	**−0.094**	**−0.087**
OVER 355	+0.044	+0.007	+0.017	+0.028	−0.010	0.000	+0.011	−0.026	−0.016	−0.005	−0.051
TO 400	−0.044	−0.029	−0.040	−0.061	−0.046	−0.057	−0.078	−0.062	−0.073	−0.094	−0.087
OVER 400	**+0.048**	**+0.008**	**+0.018**	**+0.029**	**−0.010**	**0.000**	**+0.011**	**−0.027**	**−0.017**	**−0.006**	**−0.055**
TO 450	**−0.048**	**−0.032**	**−0.045**	**−0.068**	**−0.050**	**−0.063**	**−0.086**	**−0.067**	**−0.080**	**−0.103**	**−0.095**
OVER 450	+0.048	+0.008	+0.018	+0.029	−0.010	0.000	+0.011	−0.027	−0.017	−0.006	−0.055
TO 500	−0.048	−0.032	−0.045	−0.068	−0.050	−0.063	−0.086	−0.067	−0.080	−0.103	−0.095

Table H-4. Preferred Tolerance Zones for Internal (Hole) Dimensions (Dimensions in Millimeters) (cont)

Basic Size	P7	P8	R6	R7	R8	S6	S7	T6	T7	U7
OVER 0 TO 3	–0.006 –0.016	–0.006 –0.020	–0.010 –0.016	–0.010 –0.020	–0.010 –0.024	–0.014 –0.020	–0.014 –0.024	not defined		–0.018 –0.028
OVER 3 TO 6	**–0.008 –0.020**	**–0.012 –0.030**	**–0.012 –0.020**	**–0.011 –0.023**	**–0.015 –0.033**	**–0.016 –0.024**	**–0.015 –0.027**	**not defined**		**–0.019 –0.031**
OVER 6 TO 10	–0.009 –0.024	–0.015 –0.037	–0.016 –0.025	–0.013 –0.028	–0.019 –0.041	–0.020 –0.029	–0.017 –0.032	not defined		–0.022 –0.037
OVER 10 TO 14	**–0.011 –0.029**	**–0.018 –0.045**	**–0.020 –0.031**	**–0.016 –0.034**	**–0.023 –0.050**	**–0.025 –0.036**	**–0.021 –0.039**	**not defined**		**–0.026 –0.044**
OVER 14 TO 18	–0.011 –0.029	–0.018 –0.045	–0.020 –0.031	–0.016 –0.034	–0.023 –0.050	–0.025 –0.036	–0.021 –0.039	not defined		–0.026 –0.044
OVER 18 TO 24	**–0.014 –0.035**	**–0.022 –0.055**	**–0.024 –0.037**	**–0.020 –0.041**	**–0.028 –0.061**	**–0.031 –0.044**	**–0.027 –0.048**	**not defined**		**–0.033 –0.054**
OVER 24 TO 30	–0.014 –0.035	–0.022 –0.055	–0.024 –0.037	–0.020 –0.041	–0.028 –0.061	–0.031 –0.044	–0.027 –0.048	–0.037 –0.050	–0.033 –0.054	–0.040 –0.061
OVER 30 TO 40	**–0.017 –0.042**	**–0.026 –0.065**	**–0.029 –0.045**	**–0.025 –0.050**	**–0.034 –0.073**	**–0.038 –0.054**	**–0.034 –0.059**	**–0.043 –0.059**	**–0.039 –0.064**	**–0.051 –0.076**
OVER 40 TO 50	–0.017 –0.042	–0.026 –0.065	–0.029 –0.045	–0.025 –0.050	–0.034 –0.073	–0.038 –0.054	–0.034 –0.059	–0.049 –0.065	–0.045 –0.070	–0.061 –0.086
OVER 50 TO 65	**–0.021 –0.051**	**–0.032 –0.078**	**–0.035 –0.054**	**–0.030 –0.060**	**–0.041 –0.087**	**–0.047 –0.066**	**–0.042 –0.072**	**–0.060 –0.079**	**–0.055 –0.085**	**–0.076 –0.106**
OVER 65 TO 80	–0.021 –0.051	–0.032 –0.078	–0.037 –0.056	–0.032 –0.062	–0.043 –0.089	–0.053 –0.072	–0.048 –0.078	–0.069 –0.088	–0.064 –0.094	–0.091 –0.121
OVER 80 TO 100	**–0.024 –0.059**	**–0.037 –0.091**	**–0.044 –0.066**	**–0.038 –0.073**	**–0.051 –0.105**	**–0.064 –0.086**	**–0.058 –0.093**	**–0.084 –0.106**	**–0.078 –0.113**	**–0.111 –0.146**
OVER 100 TO 120	–0.024 –0.059	–0.037 –0.091	–0.047 –0.069	–0.041 –0.076	–0.054 –0.108	–0.072 –0.094	–0.066 –0.101	–0.097 –0.119	–0.091 –0.126	–0.131 –0.166
OVER 120 TO 140	**–0.028 –0.068**	**–0.043 –0.106**	**–0.056 –0.081**	**–0.048 –0.088**	**–0.063 –0.126**	**–0.085 –0.110**	**–0.077 –0.117**	**–0.115 –0.140**	**–0.107 –0.147**	**–0.155 –0.195**
OVER 140 TO 160	–0.028 –0.068	–0.043 –0.106	–0.058 –0.083	–0.050 –0.090	–0.065 –0.128	–0.093 –0.118	–0.085 –0.125	–0.127 –0.152	–0.119 –0.159	–0.175 –0.215
OVER 160 TO 180	**–0.028 –0.068**	**–0.043 –0.106**	**–0.061 –0.086**	**–0.053 –0.093**	**–0.068 –0.131**	**–0.101 –0.126**	**–0.093 –0.133**	**–0.139 –0.164**	**–0.131 –0.171**	**–0.195 –0.235**
OVER 180 TO 200	–0.033 –0.079	–0.050 –0.122	–0.068 –0.097	–0.060 –0.106	–0.077 –0.149	–0.113 –0.142	–0.105 –0.151	–0.157 –0.186	–0.149 –0.195	–0.219 –0.265
OVER 200 TO 225	**–0.033 –0.079**	**–0.050 –0.122**	**–0.071 –0.100**	**–0.063 –0.109**	**–0.080 –0.152**	**–0.121 –0.150**	**–0.113 –0.159**	**–0.171 –0.200**	**–0.163 –0.209**	**–0.241 –0.287**
OVER 225 TO 250	–0.033 –0.079	–0.050 –0.122	–0.075 –0.104	–0.067 –0.113	–0.084 –0.156	–0.131 –0.160	–0.123 –0.169	–0.187 –0.216	–0.179 –0.225	–0.267 –0.313
OVER 250 TO 280	**–0.036 –0.088**	**–0.056 –0.137**	**–0.085 –0.117**	**–0.074 –0.126**	**–0.094 –0.175**	**–0.149 –0.181**	**–0.138 –0.190**	**–0.209 –0.241**	**–0.198 –0.250**	**–0.295 –0.347**
OVER 280 TO 315	–0.036 –0.088	–0.056 –0.137	–0.089 –0.121	–0.078 –0.130	–0.098 –0.179	–0.161 –0.193	–0.150 –0.202	–0.231 –0.263	–0.220 –0.272	–0.330 –0.382
OVER 315 TO 355	**–0.041 –0.098**	**–0.062 –0.151**	**–0.097 –0.133**	**–0.087 –0.144**	**–0.108 –0.197**	**–0.179 –0.215**	**–0.169 –0.226**	**–0.257 –0.293**	**–0.247 –0.304**	**–0.369 –0.426**
OVER 355 TO 400	–0.041 –0.098	–0.062 –0.151	–0.103 –0.139	–0.093 –0.150	–0.114 –0.203	–0.197 –0.233	–0.187 –0.244	–0.283 –0.319	–0.273 –0.330	–0.414 –0.471
OVER 400 TO 450	**–0.045 –0.108**	**–0.068 –0.165**	**–0.113 –0.153**	**–0.103 –0.166**	**–0.126 –0.223**	**–0.219 –0.259**	**–0.209 –0.272**	**–0.317 –0.357**	**–0.307 –0.370**	**–0.467 –0.530**
OVER 450 TO 500	–0.045 –0.108	–0.068 –0.165	–0.119 –0.159	–0.109 –0.172	–0.132 –0.229	–0.239 –0.279	–0.229 –0.292	–0.347 –0.387	–0.337 –0.400	–0.517 –0.580

Table H-5. Preferred Tolerance Zones for External (Shaft) Dimensions (Dimensions in Millimeters)

Basic Size	a11	b11	c11	d8	d9	d10	e7	e8	e9	f6	f7
OVER 0	-0.270	-0.140	-0.060	-0.020	-0.020	-0.020	-0.014	-0.014	-0.014	-0.006	-0.006
TO 3	-0.330	-0.200	-0.120	-0.034	-0.045	-0.060	-0.024	-0.028	-0.039	-0.012	-0.016
OVER 3	**-0.270**	**-0.140**	**-0.070**	**-0.030**	**-0.030**	**-0.030**	**-0.020**	**-0.020**	**-0.020**	**-0.010**	**-0.010**
TO 6	**-0.345**	**-0.215**	**-0.145**	**-0.048**	**-0.060**	**-0.078**	**-0.032**	**-0.038**	**-0.050**	**-0.018**	**-0.022**
OVER 6	-0.280	-0.150	-0.080	-0.040	-0.040	-0.040	-0.025	-0.025	-0.025	-0.013	-0.013
TO 10	-0.370	-0.240	-0.170	-0.062	-0.076	-0.098	-0.040	-0.047	-0.061	-0.022	-0.028
OVER 10	**-0.290**	**-0.150**	**-0.095**	**-0.050**	**-0.050**	**-0.050**	**-0.032**	**-0.032**	**-0.032**	**-0.016**	**-0.016**
TO 14	**-0.400**	**-0.260**	**-0.205**	**-0.077**	**-0.093**	**-0.120**	**-0.050**	**-0.059**	**-0.075**	**-0.027**	**-0.034**
OVER 14	-0.290	-0.150	-0.095	-0.050	-0.050	-0.050	-0.032	-0.032	-0.032	-0.016	-0.016
TO 18	-0.400	-0.260	-0.205	-0.077	-0.093	-0.120	-0.050	-0.059	-0.075	-0.027	-0.034
OVER 18	**-0.300**	**-0.160**	**-0.110**	**-0.065**	**-0.065**	**-0.065**	**-0.040**	**-0.040**	**-0.040**	**-0.020**	**-0.020**
TO 24	**-0.430**	**-0.290**	**-0.240**	**-0.098**	**-0.117**	**-0.149**	**-0.061**	**-0.073**	**-0.092**	**-0.033**	**-0.041**
OVER 24	-0.300	-0.160	-0.110	-0.065	-0.065	-0.065	-0.040	-0.040	-0.040	-0.020	-0.020
TO 30	-0.430	-0.290	-0.240	-0.098	-0.117	-0.149	-0.061	-0.073	-0.092	-0.033	-0.041
OVER 30	**-0.310**	**-0.170**	**-0.120**	**-0.080**	**-0.080**	**-0.080**	**-0.050**	**-0.050**	**-0.050**	**-0.025**	**-0.025**
TO 40	**-0.470**	**-0.330**	**-0.280**	**-0.119**	**-0.142**	**-0.180**	**-0.075**	**-0.089**	**-0.112**	**-0.041**	**-0.050**
OVER 40	-0.320	-0.180	-0.130	-0.080	-0.080	-0.080	-0.050	-0.050	-0.050	-0.025	-0.025
TO 50	-0.480	-0.340	-0.290	-0.119	-0.142	-0.180	-0.075	-0.089	-0.112	-0.041	-0.050
OVER 50	**-0.340**	**-0.190**	**-0.140**	**-0.100**	**-0.100**	**-0.100**	**-0.060**	**-0.060**	**-0.060**	**-0.030**	**-0.030**
TO 65	**-0.530**	**-0.380**	**-0.330**	**-0.146**	**-0.174**	**-0.220**	**-0.090**	**-0.106**	**-0.134**	**-0.049**	**-0.060**
OVER 65	-0.360	-0.200	-0.150	-0.100	-0.100	-0.100	-0.060	-0.060	-0.060	-0.030	-0.030
TO 80	-0.550	-0.390	-0.340	-0.146	-0.174	-0.220	-0.090	-0.106	-0.134	-0.049	-0.060
OVER 80	**-0.380**	**-0.220**	**-0.170**	**-0.120**	**-0.120**	**-0.120**	**-0.072**	**-0.072**	**-0.072**	**-0.036**	**-0.036**
TO 100	**-0.600**	**-0.440**	**-0.390**	**-0.174**	**-0.207**	**-0.260**	**-0.107**	**-0.126**	**-0.159**	**-0.058**	**-0.071**
OVER 100	-0.410	-0.240	-0.180	-0.120	-0.120	-0.120	-0.072	-0.072	-0.072	-0.036	-0.036
TO 120	-0.630	-0.460	-0.400	-0.174	-0.207	-0.260	-0.107	-0.126	-0.159	-0.058	-0.071
OVER 120	**-0.460**	**-0.260**	**-0.200**	**-0.145**	**-0.145**	**-0.145**	**-0.085**	**-0.085**	**-0.085**	**-0.043**	**-0.043**
TO 140	**-0.710**	**-0.510**	**-0.450**	**-0.208**	**-0.245**	**-0.305**	**-0.125**	**-0.148**	**-0.185**	**-0.068**	**-0.083**
OVER 140	-0.520	-0.280	-0.210	-0.145	-0.145	-0.145	-0.085	-0.085	-0.085	-0.043	-0.043
TO 160	-0.770	-0.530	-0.460	-0.208	-0.245	-0.305	-0.125	-0.148	-0.185	-0.068	-0.083
OVER 160	**-0.580**	**-0.310**	**-0.230**	**-0.145**	**-0.145**	**-0.145**	**-0.085**	**-0.085**	**-0.085**	**-0.043**	**-0.043**
TO 180	**-0.830**	**-0.560**	**-0.480**	**-0.208**	**-0.245**	**-0.305**	**-0.125**	**-0.148**	**-0.185**	**-0.068**	**-0.083**
OVER 180	-0.660	-0.340	-0.240	-0.170	-0.170	-0.170	-0.100	-0.100	-0.100	-0.050	-0.050
TO 200	-0.950	-0.630	-0.530	-0.242	-0.285	-0.355	-0.146	-0.172	-0.215	-0.079	-0.096
OVER 200	**-0.740**	**-0.380**	**-0.260**	**-0.170**	**-0.170**	**-0.170**	**-0.100**	**-0.100**	**-0.100**	**-0.050**	**-0.050**
TO 225	**-1.030**	**-0.670**	**-0.550**	**-0.242**	**-0.285**	**-0.355**	**-0.146**	**-0.172**	**-0.215**	**-0.079**	**-0.096**
OVER 225	-0.820	-0.420	-0.280	-0.170	-0.170	-0.170	-0.100	-0.100	-0.100	-0.050	-0.050
TO 250	-1.110	-0.710	-0.570	-0.242	-0.285	-0.355	-0.146	-0.172	-0.215	-0.079	-0.096
OVER 250	**-0.920**	**-0.480**	**-0.300**	**-0.190**	**-0.190**	**-0.190**	**-0.110**	**-0.110**	**-0.110**	**-0.056**	**-0.056**
TO 280	**-1.240**	**-0.800**	**-0.620**	**-0.271**	**-0.320**	**-0.400**	**-0.162**	**-0.191**	**-0.240**	**-0.088**	**-0.108**
OVER 280	-1.050	-0.540	-0.330	-0.190	-0.190	-0.190	-0.110	-0.110	-0.110	-0.056	-0.056
TO 315	-1.370	-0.860	-0.650	-0.271	-0.320	-0.400	-0.162	-0.191	-0.240	-0.088	-0.108
OVER 315	**-1.200**	**-0.600**	**-0.360**	**-0.210**	**-0.210**	**-0.210**	**-0.125**	**-0.125**	**-0.125**	**-0.062**	**-0.062**
TO 355	**-1.560**	**-0.960**	**-0.720**	**-0.299**	**-0.350**	**-0.440**	**-0.182**	**-0.214**	**-0.265**	**-0.098**	**-0.119**
OVER 355	-1.350	-0.680	-0.400	-0.210	-0.210	-0.210	-0.125	-0.125	-0.125	-0.062	-0.062
TO 400	-1.710	-1.040	-0.760	-0.299	-0.350	-0.440	-0.182	-0.214	-0.265	-0.098	-0.119
OVER 400	**-1.500**	**-0.760**	**-0.440**	**-0.230**	**-0.230**	**-0.230**	**-0.135**	**-0.135**	**-0.135**	**-0.068**	**-0.068**
TO 450	**-1.900**	**-1.160**	**-0.840**	**-0.327**	**-0.385**	**-0.480**	**-0.198**	**-0.232**	**-0.290**	**-0.108**	**-0.131**
OVER 450	-1.650	-0.840	-0.480	-0.230	-0.230	-0.230	-0.135	-0.135	-0.135	-0.068	-0.068
TO 500	-2.050	-1.240	-0.880	-0.327	-0.385	-0.480	-0.198	-0.232	-0.290	-0.108	-0.131

Table H-5. Preferred Tolerance Zones for External (Shaft) Dimensions (Dimensions in Millimeters) (cont)

Basic Size		f8	g5	g6	h5	h6	h7	h8	h9	h11	js5	js6
OVER	0	–0.006	–0.002	–0.002	0.000	0.000	0.000	0.000	0.000	0.000	+0.002	+0.003
TO	3	–0.020	–0.006	–0.008	–0.004	–0.006	–0.010	–0.014	–0.025	–0.060	–0.002	–0.003
OVER	3	–0.010	–0.004	–0.004	0.000	0.000	0.000	0.000	0.000	0.000	+0.0025	+0.004
TO	6	–0.028	–0.009	–0.012	–0.005	–0.008	–0.012	–0.018	–0.030	–0.075	–0.0025	–0.004
OVER	6	–0.013	–0.005	–0.005	0.000	0.000	0.000	0.000	0.000	0.000	+0.003	+0.0045
TO	10	–0.035	–0.011	–0.014	–0.006	–0.009	–0.015	–0.022	–0.036	–0.090	–0.003	–0.0045
OVER	10	–0.016	–0.006	–0.006	0.000	0.000	0.000	0.000	0.000	0.000	+0.004	+0.0055
TO	14	–0.043	–0.014	–0.017	–0.008	–0.011	–0.018	–0.027	–0.043	–0.110	–0.004	–0.0055
OVER	14	–0.016	–0.006	–0.006	0.000	0.000	0.000	0.000	0.000	0.000	+0.004	+0.0055
TO	18	–0.043	–0.014	–0.017	–0.008	–0.011	–0.018	–0.027	–0.043	–0.110	–0.004	–0.0055
OVER	18	–0.020	–0.007	–0.007	0.000	0.000	0.000	0.000	0.000	0.000	+0.0045	+0.0065
TO	24	–0.053	–0.016	–0.020	–0.009	–0.013	–0.021	–0.033	–0.052	–0.130	–0.0045	–0.0065
OVER	24	–0.020	–0.007	–0.007	0.000	0.000	0.000	0.000	0.000	0.000	+0.0045	+0.0065
TO	30	–0.053	–0.016	–0.020	–0.009	–0.013	–0.021	–0.033	–0.052	–0.130	–0.0045	–0.0065
OVER	30	–0.025	–0.009	–0.009	0.000	0.000	0.000	0.000	0.000	0.000	+0.0055	+0.008
TO	40	–0.064	–0.020	–0.025	–0.011	–0.016	–0.025	–0.039	–0.062	–0.160	–0.0055	–0.008
OVER	40	–0.025	–0.009	–0.009	0.000	0.000	0.000	0.000	0.000	0.000	+0.0055	+0.008
TO	50	–0.064	–0.020	–0.025	–0.011	–0.016	–0.025	–0.039	–0.062	–0.160	–0.0055	–0.008
OVER	50	–0.030	–0.010	–0.010	0.000	0.000	0.000	0.000	0.000	0.000	+0.0065	+0.0095
TO	65	–0.076	–0.023	–0.029	–0.013	–0.019	–0.030	–0.046	–0.074	–0.190	–0.0065	–0.0095
OVER	65	–0.030	–0.010	–0.010	0.000	0.000	0.000	0.000	0.000	0.000	+0.0065	+0.0095
TO	80	–0.076	–0.023	–0.029	–0.013	–0.019	–0.030	–0.046	–0.074	–0.190	–0.0065	–0.0095
OVER	80	–0.036	–0.012	–0.012	0.000	0.000	0.000	0.000	0.000	0.000	+0.0075	+0.011
TO	100	–0.090	–0.027	–0.034	–0.015	–0.022	–0.035	–0.054	–0.087	–0.220	–0.0075	–0.011
OVER	100	–0.036	–0.012	–0.012	0.000	0.000	0.000	0.000	0.000	0.000	+0.0075	+0.011
TO	120	–0.090	–0.027	–0.034	–0.015	–0.022	–0.035	–0.054	–0.087	–0.220	–0.0075	–0.011
OVER	120	–0.043	–0.014	–0.014	0.000	0.000	0.000	0.000	0.000	0.000	+0.009	+0.0125
TO	140	–0.106	–0.032	–0.039	–0.018	–0.025	–0.040	–0.063	–0.100	–0.250	–0.009	–0.0125
OVER	140	–0.043	–0.014	–0.014	0.000	0.000	0.000	0.000	0.000	0.000	+0.009	+0.0125
TO	160	–0.106	–0.032	–0.039	–0.018	–0.025	–0.040	–0.063	–0.100	–0.250	–0.009	–0.0125
OVER	160	–0.043	–0.014	–0.014	0.000	0.000	0.000	0.000	0.000	0.000	+0.009	+0.0125
TO	180	–0.106	–0.032	–0.039	–0.018	–0.025	–0.040	–0.063	–0.100	–0.250	–0.009	–0.0125
OVER	180	–0.050	–0.015	–0.015	0.000	0.000	0.000	0.000	0.000	0.000	+0.010	+0.0145
TO	200	–0.122	–0.035	–0.044	–0.020	–0.029	–0.046	–0.072	–0.115	–0.290	–0.010	–0.0145
OVER	200	–0.050	–0.015	–0.015	0.000	0.000	0.000	0.000	0.000	0.000	+0.010	+0.0145
TO	225	–0.122	–0.035	–0.044	–0.020	–0.029	–0.046	–0.072	–0.115	–0.290	–0.010	–0.0145
OVER	225	–0.050	–0.015	–0.015	0.000	0.000	0.000	0.000	0.000	0.000	+0.010	+0.0145
TO	250	–0.122	–0.035	–0.044	–0.020	–0.029	–0.046	–0.072	–0.115	–0.290	–0.010	–0.0145
OVER	250	–0.056	–0.017	–0.017	0.000	0.000	0.000	0.000	0.000	0.000	+0.0115	+0.016
TO	280	–0.137	–0.040	–0.049	–0.023	–0.032	–0.052	–0.081	–0.130	–0.320	–0.0115	–0.016
OVER	280	–0.056	–0.017	–0.017	0.000	0.000	0.000	0.000	0.000	0.000	+0.0115	+0.016
TO	315	–0.137	–0.040	–0.049	–0.023	–0.032	–0.052	–0.081	–0.130	–0.320	–0.0115	–0.016
OVER	315	–0.062	–0.018	–0.018	0.000	0.000	0.000	0.000	0.000	0.000	+0.0125	+0.018
TO	355	–0.151	–0.043	–0.054	–0.025	–0.036	–0.057	–0.089	–0.140	–0.360	–0.0125	–0.018
OVER	355	–0.062	–0.018	–0.018	0.000	0.000	0.000	0.000	0.000	0.000	+0.0125	+0.018
TO	400	–0.151	–0.043	–0.054	–0.025	–0.036	–0.057	–0.089	–0.140	–0.360	–0.0125	–0.018
OVER	400	–0.068	–0.020	–0.020	0.000	0.000	0.000	0.000	0.000	0.000	+0.0135	+0.020
TO	450	–0.165	–0.047	–0.060	–0.027	–0.040	–0.063	–0.097	–0.155	–0.400	–0.0135	–0.020
OVER	450	–0.068	–0.020	–0.020	0.000	0.000	0.000	0.000	0.000	0.000	+0.0135	+0.020
TO	500	–0.165	–0.047	–0.060	–0.027	–0.040	–0.063	–0.097	–0.155	–0.400	–0.0135	–0.020

Table H-5. Preferred Tolerance Zones for External (Shaft) Dimensions (Dimensions in Millimeters) (cont)

Basic Size	js7	k5	k6	k7	m5	m6	m7	n5	n6	n7	p5
OVER 0	+0.005	+0.004	+0.006	+0.010	+0.006	+0.008	+0.012	+0.008	+0.010	+0.014	+0.010
TO 3	-0.005	0.000	0.000	0.000	+0.002	+0.002	+0.002	+0.004	+0.004	+0.004	+0.006
OVER 3	**+0.006**	**+0.006**	**+0.009**	**+0.013**	**+0.009**	**+0.012**	**+0.016**	**+0.013**	**+0.016**	**+0.020**	**+0.017**
TO 6	**-0.006**	**+0.001**	**+0.001**	**+0.001**	**+0.004**	**+0.004**	**+0.004**	**+0.008**	**+0.008**	**+0.008**	**+0.012**
OVER 6	+0.007	+0.007	+0.010	+0.016	+0.012	+0.015	+0.021	+0.016	+0.019	+0.025	+0.021
TO 10	-0.007	+0.001	+0.001	+0.001	+0.006	+0.006	+0.006	+0.010	+0.010	+0.010	+0.015
OVER 10	**+0.009**	**+0.009**	**+0.012**	**+0.019**	**+0.015**	**+0.018**	**+0.025**	**+0.020**	**+0.023**	**+0.030**	**+0.026**
TO 14	**-0.009**	**+0.001**	**+0.001**	**+0.001**	**+0.007**	**+0.007**	**+0.007**	**+0.012**	**+0.012**	**+0.012**	**+0.018**
OVER 14	+0.009	+0.009	+0.012	+0.019	+0.015	+0.018	+0.025	+0.020	+0.023	+0.030	+0.026
TO 18	-0.009	+0.001	+0.001	+0.001	+0.007	+0.007	+0.007	+0.012	+0.012	+0.012	+0.018
OVER 18	**+0.010**	**+0.011**	**+0.015**	**+0.023**	**+0.017**	**+0.021**	**+0.029**	**+0.024**	**+0.028**	**+0.036**	**+0.031**
TO 24	**-0.010**	**+0.002**	**+0.002**	**+0.002**	**+0.008**	**+0.008**	**+0.008**	**+0.015**	**+0.015**	**+0.015**	**+0.022**
OVER 24	+0.010	+0.011	+0.015	+0.023	+0.017	+0.021	+0.029	+0.024	+0.028	+0.036	+0.031
TO 30	-0.010	+0.002	+0.002	+0.002	+0.008	+0.008	+0.008	+0.015	+0.015	+0.015	+0.022
OVER 30	**+0.012**	**+0.013**	**+0.018**	**+0.027**	**+0.020**	**+0.025**	**+0.034**	**+0.028**	**+0.033**	**+0.042**	**+0.037**
TO 40	**-0.012**	**+0.002**	**+0.002**	**+0.002**	**+0.009**	**+0.009**	**+0.009**	**+0.017**	**+0.017**	**+0.017**	**+0.026**
OVER 40	+0.012	+0.013	+0.018	+0.027	+0.020	+0.025	+0.034	+0.028	+0.033	+0.042	+0.037
TO 50	-0.012	+0.002	+0.002	+0.002	+0.009	+0.009	+0.009	+0.017	+0.017	+0.017	+0.026
OVER 50	**+0.015**	**+0.015**	**+0.021**	**+0.032**	**+0.024**	**+0.030**	**+0.041**	**+0.033**	**+0.039**	**+0.050**	**+0.045**
TO 65	**-0.015**	**+0.002**	**+0.002**	**+0.002**	**+0.011**	**+0.011**	**+0.011**	**+0.020**	**+0.020**	**+0.020**	**+0.032**
OVER 65	+0.015	+0.015	+0.021	+0.032	+0.024	+0.030	+0.041	+0.033	+0.039	+0.050	+0.045
TO 80	-0.015	+0.002	+0.002	+0.002	+0.011	+0.011	+0.011	+0.020	+0.020	+0.020	+0.032
OVER 80	**+0.017**	**+0.018**	**+0.025**	**+0.038**	**+0.028**	**+0.035**	**+0.048**	**+0.038**	**+0.045**	**+0.058**	**+0.052**
TO 100	**-0.017**	**+0.003**	**+0.003**	**+0.003**	**+0.013**	**+0.013**	**+0.013**	**+0.023**	**+0.023**	**+0.023**	**+0.037**
OVER 100	+0.017	+0.018	+0.025	+0.038	+0.028	+0.035	+0.048	+0.038	+0.045	+0.058	+0.052
TO 120	-0.017	+0.003	+0.003	+0.003	+0.013	+0.013	+0.013	+0.023	+0.023	+0.023	+0.037
OVER 120	**+0.020**	**+0.021**	**+0.028**	**+0.043**	**+0.033**	**+0.040**	**+0.055**	**+0.045**	**+0.052**	**+0.067**	**+0.061**
TO 140	**-0.020**	**+0.003**	**+0.003**	**+0.003**	**+0.015**	**+0.015**	**+0.015**	**+0.027**	**+0.027**	**+0.027**	**+0.043**
OVER 140	+0.020	+0.021	+0.028	+0.043	+0.033	+0.040	+0.055	+0.045	+0.052	+0.067	+0.061
TO 160	-0.020	+0.003	+0.003	+0.003	+0.015	+0.015	+0.015	+0.027	+0.027	+0.027	+0.043
OVER 160	**+0.020**	**+0.021**	**+0.028**	**+0.043**	**+0.033**	**+0.040**	**+0.055**	**+0.045**	**+0.052**	**+0.067**	**+0.061**
TO 180	**-0.020**	**+0.003**	**+0.003**	**+0.003**	**+0.015**	**+0.015**	**+0.015**	**+0.027**	**+0.027**	**+0.027**	**+0.043**
OVER 180	+0.023	+0.024	+0.033	+0.050	+0.037	+0.046	+0.063	+0.051	+0.060	+0.077	+0.070
TO 200	-0.023	+0.004	+0.004	+0.004	+0.017	+0.017	+0.017	+0.031	+0.031	+0.031	+0.050
OVER 200	**+0.023**	**+0.024**	**+0.033**	**+0.050**	**+0.037**	**+0.046**	**+0.063**	**+0.051**	**+0.060**	**+0.077**	**+0.070**
TO 225	**-0.023**	**+0.004**	**+0.004**	**+0.004**	**+0.017**	**+0.017**	**+0.017**	**+0.031**	**+0.031**	**+0.031**	**+0.050**
OVER 225	+0.023	+0.024	+0.033	+0.050	+0.037	+0.046	+0.063	+0.051	+0.060	+0.077	+0.070
TO 250	-0.023	+0.004	+0.004	+0.004	+0.017	+0.017	+0.017	+0.031	+0.031	+0.031	+0.050
OVER 250	**+0.026**	**+0.027**	**+0.036**	**+0.056**	**+0.043**	**+0.052**	**+0.072**	**+0.057**	**+0.066**	**+0.086**	**+0.079**
TO 280	**-0.026**	**+0.004**	**+0.004**	**+0.004**	**+0.020**	**+0.020**	**+0.020**	**+0.034**	**+0.034**	**+0.034**	**+0.056**
OVER 280	+0.026	+0.027	+0.036	+0.056	+0.043	+0.052	+0.072	+0.057	+0.066	+0.086	+0.079
TO 315	-0.026	+0.004	+0.004	+0.004	+0.020	+0.020	+0.020	+0.034	+0.034	+0.034	+0.056
OVER 315	**+0.028**	**+0.029**	**+0.040**	**+0.061**	**+0.046**	**+0.057**	**+0.078**	**+0.062**	**+0.073**	**+0.094**	**+0.087**
TO 355	**-0.028**	**+0.004**	**+0.004**	**+0.004**	**+0.021**	**+0.021**	**+0.021**	**+0.037**	**+0.037**	**+0.037**	**+0.062**
OVER 355	+0.028	+0.029	+0.040	+0.061	+0.046	+0.057	+0.078	+0.062	+0.073	+0.094	+0.087
TO 400	-0.028	+0.004	+0.004	+0.004	+0.021	+0.021	+0.021	+0.037	+0.037	+0.037	+0.062
OVER 400	**+0.031**	**+0.032**	**+0.045**	**+0.068**	**+0.050**	**+0.063**	**+0.086**	**+0.067**	**+0.080**	**+0.103**	**+0.095**
TO 450	**-0.031**	**+0.005**	**+0.005**	**+0.005**	**+0.023**	**+0.023**	**+0.023**	**+0.040**	**+0.040**	**+0.040**	**+0.068**
OVER 450	+0.031	+0.032	+0.045	+0.068	+0.050	+0.063	+0.086	+0.067	+0.080	+0.103	+0.095
TO 500	-0.031	+0.005	+0.005	+0.005	+0.023	+0.023	+0.023	+0.040	+0.040	+0.040	+0.068

Table H-5. Preferred Tolerance Zones for External (Shaft) Dimensions (Dimensions in Millimeters) (cont)

Basic Size		p6	p7	r5	r6	r7	s5	s6	s7	t5	t6	t7
OVER	0	+0.012	+0.016	+0.014	+0.016	+0.020	+0.018	+0.020	+0.024	not defined		
TO	3	+0.006	+0.006	+0.010	+0.010	+0.010	+0.014	+0.014	+0.014			
OVER	**3**	**+0.020**	**+0.024**	**+0.020**	**+0.023**	**+0.027**	**+0.024**	**+0.027**	**+0.031**	**not defined**		
TO	**6**	**+0.012**	**+0.012**	**+0.015**	**+0.015**	**+0.015**	**+0.019**	**+0.019**	**+0.019**			
OVER	6	+0.024	+0.030	+0.025	+0.028	+0.034	+0.029	+0.032	+0.038	not defined		
TO	10	+0.015	+0.015	+0.019	+0.019	+0.019	+0.023	+0.023	+0.023			
OVER	**10**	**+0.029**	**+0.036**	**+0.031**	**+0.034**	**+0.041**	**+0.036**	**+0.039**	**+0.046**	**not defined**		
TO	**14**	**+0.018**	**+0.018**	**+0.023**	**+0.023**	**+0.023**	**+0.028**	**+0.028**	**+0.028**			
OVER	14	+0.029	+0.036	+0.031	+0.034	+0.041	+0.036	+0.039	+0.046	not defined		
TO	18	+0.018	+0.018	+0.023	+0.023	+0.023	+0.028	+0.028	+0.028			
OVER	**18**	**+0.035**	**+0.043**	**+0.037**	**+0.041**	**+0.049**	**+0.044**	**+0.048**	**+0.056**	**not defined**		
TO	**24**	**+0.022**	**+0.022**	**+0.028**	**+0.028**	**+0.028**	**+0.035**	**+0.035**	**+0.035**			
OVER	24	+0.035	+0.043	+0.037	+0.041	+0.049	+0.044	+0.048	+0.056	+0.050	+0.054	+0.062
TO	30	+0.022	+0.022	+0.028	+0.028	+0.028	+0.035	+0.035	+0.035	+0.041	+0.041	+0.041
OVER	**30**	**+0.042**	**+0.051**	**+0.045**	**+0.050**	**+0.059**	**+0.054**	**+0.059**	**+0.068**	**+0.059**	**+0.064**	**+0.073**
TO	**40**	**+0.026**	**+0.026**	**+0.034**	**+0.034**	**+0.034**	**+0.043**	**+0.043**	**+0.043**	**+0.048**	**+0.048**	**+0.048**
OVER	40	+0.042	+0.051	+0.045	+0.050	+0.059	+0.054	+0.059	+0.068	+0.065	+0.070	+0.079
TO	50	+0.026	+0.026	+0.034	+0.034	+0.034	+0.043	+0.043	+0.043	+0.054	+0.054	+0.054
OVER	**50**	**+0.051**	**+0.062**	**+0.054**	**+0.060**	**+0.071**	**+0.066**	**+0.072**	**+0.083**	**+0.079**	**+0.085**	**+0.096**
TO	**65**	**+0.032**	**+0.032**	**+0.041**	**+0.041**	**+0.041**	**+0.053**	**+0.053**	**+0.053**	**+0.066**	**+0.066**	**+0.066**
OVER	65	+0.051	+0.062	+0.056	+0.062	+0.073	+0.072	+0.078	+0.089	+0.088	+0.094	+0.105
TO	80	+0.032	+0.032	+0.043	+0.043	+0.043	+0.059	+0.059	+0.059	+0.075	+0.075	+0.075
OVER	**80**	**+0.059**	**+0.072**	**+0.066**	**+0.073**	**+0.086**	**+0.086**	**+0.093**	**+0.106**	**+0.106**	**+0.113**	**+0.126**
TO	**100**	**+0.037**	**+0.037**	**+0.051**	**+0.051**	**+0.051**	**+0.071**	**+0.071**	**+0.071**	**+0.091**	**+0.091**	**+0.091**
OVER	100	+0.059	+0.072	+0.069	+0.076	+0.089	+0.094	+0.101	+0.114	+0.119	+0.126	+0.139
TO	120	+0.037	+0.037	+0.054	+0.054	+0.054	+0.079	+0.079	+0.079	+0.104	+0.104	+0.104
OVER	**120**	**+0.068**	**+0.083**	**+0.081**	**+0.088**	**+0.103**	**+0.110**	**+0.117**	**+0.132**	**+0.140**	**+0.147**	**+0.162**
TO	**140**	**+0.043**	**+0.043**	**+0.063**	**+0.063**	**+0.063**	**+0.092**	**+0.092**	**+0.092**	**+0.122**	**+0.122**	**+0.122**
OVER	140	+0.068	+0.083	+0.083	+0.090	+0.105	+0.118	+0.125	+0.140	+0.152	+0.159	+0.174
TO	160	+0.043	+0.043	+0.065	+0.065	+0.065	+0.100	+0.100	+0.100	+0.134	+0.134	+0.134
OVER	**160**	**+0.068**	**+0.083**	**+0.086**	**+0.093**	**+0.108**	**+0.126**	**+0.133**	**+0.148**	**+0.164**	**+0.171**	**+0.186**
TO	**180**	**+0.043**	**+0.043**	**+0.068**	**+0.068**	**+0.068**	**+0.108**	**+0.108**	**+0.108**	**+0.146**	**+0.146**	**+0.146**
OVER	180	+0.079	+0.096	+0.097	+0.106	+0.123	+0.142	+0.151	+0.168	+0.186	+0.195	+0.212
TO	200	+0.050	+0.050	+0.077	+0.077	+0.077	+0.122	+0.122	+0.122	+0.166	+0.166	+0.166
OVER	**200**	**+0.079**	**+0.096**	**+0.100**	**+0.109**	**+0.126**	**+0.150**	**+0.159**	**+0.176**	**+0.200**	**+0.209**	**+0.226**
TO	**225**	**+0.050**	**+0.050**	**+0.080**	**+0.080**	**+0.080**	**+0.130**	**+0.130**	**+0.130**	**+0.180**	**+0.180**	**+0.180**
OVER	225	+0.079	+0.096	+0.104	+0.113	+0.130	+0.160	+0.169	+0.186	+0.216	+0.225	+0.242
TO	250	+0.050	+0.050	+0.084	+0.084	+0.084	+0.140	+0.140	+0.140	+0.196	+0.196	+0.196
OVER	**250**	**+0.088**	**+0.108**	**+0.117**	**+0.126**	**+0.146**	**+0.181**	**+0.190**	**+0.210**	**+0.241**	**+0.250**	**+0.270**
TO	**280**	**+0.056**	**+0.056**	**+0.094**	**+0.094**	**+0.094**	**+0.158**	**+0.158**	**+0.158**	**+0.218**	**+0.218**	**+0.218**
OVER	280	+0.088	+0.108	+0.121	+0.130	+0.150	+0.193	+0.202	+0.222	+0.263	+0.272	+0.292
TO	315	+0.056	+0.056	+0.098	+0.098	+0.098	+0.170	+0.170	+0.170	+0.240	+0.240	+0.240
OVER	**315**	**+0.098**	**+0.119**	**+0.133**	**+0.144**	**+0.165**	**+0.215**	**+0.226**	**+0.247**	**+0.293**	**+0.304**	**+0.325**
TO	**355**	**+0.062**	**+0.062**	**+0.108**	**+0.108**	**+0.108**	**+0.190**	**+0.190**	**+0.190**	**+0.268**	**+0.268**	**+0.268**
OVER	355	+0.098	+0.119	+0.139	+0.150	+0.171	+0.233	+0.244	+0.265	+0.319	+0.330	+0.351
TO	400	+0.062	+0.062	+0.114	+0.114	+0.114	+0.208	+0.208	+0.208	+0.294	+0.294	+0.294
OVER	**400**	**+0.108**	**+0.131**	**+0.153**	**+0.166**	**+0.189**	**+0.259**	**+0.272**	**+0.295**	**+0.357**	**+0.370**	**+0.393**
TO	**450**	**+0.068**	**+0.068**	**+0.126**	**+0.126**	**+0.126**	**+0.232**	**+0.232**	**+0.232**	**+0.330**	**+0.330**	**+0.330**
OVER	450	+0.108	+0.131	+0.159	+0.172	+0.195	+0.279	+0.292	+0.315	+0.387	+0.400	+0.423
TO	500	+0.068	+0.068	+0.132	+0.132	+0.132	+0.252	+0.252	+0.252	+0.360	+0.360	+0.360

Table H-5. Preferred Tolerance Zones for External (Shaft) Dimensions (Dimensions in Millimeters) (cont)

Basic Size	u6	u7
OVER 0 TO 3	+0.024 +0.018	+0.028 +0.018
OVER 3 TO 6	+0.031 +0.023	+0.035 +0.023
OVER 6 TO 10	+0.037 +0.028	+0.043 +0.028
OVER 10 TO 14	+0.044 +0.033	+0.051 +0.033
OVER 14 TO 18	+0.044 +0.033	+0.051 +0.033
OVER 18 TO 24	+0.054 +0.041	+0.062 +0.041
OVER 24 TO 30	+0.061 +0.048	+0.069 +0.048
OVER 30 TO 40	+0.076 +0.060	+0.085 +0.060
OVER 40 TO 50	+0.086 +0.070	+0.095 +0.070
OVER 50 TO 65	+0.106 +0.087	+0.117 +0.087
OVER 65 TO 80	+0.121 +0.102	+0.132 +0.102
OVER 80 TO 100	+0.146 +0.124	+0.159 +0.124
OVER 100 TO 120	+0.166 +0.144	+0.179 +0.144
OVER 120 TO 140	+0.195 +0.170	+0.210 +0.170
OVER 140 TO 160	+0.215 +0.190	+0.230 +0.190
OVER 160 TO 180	+0.235 +0.210	+0.250 +0.210
OVER 180 TO 200	+0.265 +0.236	+0.282 +0.236
OVER 200 TO 225	+0.287 +0.258	+0.304 +0.258
OVER 225 TO 250	+0.313 +0.284	+0.330 +0.284
OVER 250 TO 280	+0.347 +0.315	+0.367 +0.315
OVER 280 TO 315	+0.382 +0.350	+0.402 +0.350
OVER 315 TO 355	+0.426 +0.390	+0.447 +0.390
OVER 355 TO 400	+0.471 +0.435	+0.492 +0.435
OVER 400 TO 450	+0.530 +0.490	+0.553 +0.490
OVER 450 TO 500	+0.580 +0.540	+0.603 +0.540

Table H-6. Preferred Hole Basis Clearance Fits (Dimensions in Millimeters)

Basic Size		Loose Running			Free Running			Close Running	
	Hole H11	Shaft c11	Fit	Hole H9	Shaft d9	Fit	Hole H8	Shaft f7	Fit
1 Max	1.060	0.940	0.180	1.025	0.980	0.070	1.014	0.994	0.030
Min	1.000	0.880	0.060	1.000	0.955	0.020	1.000	0.984	0.006
1.2 Max	1.260	1.140	0.180	1.225	1.180	0.070	1.214	1.194	0.030
Min	1.200	1.080	0.060	1.200	1.155	0.020	1.200	1.184	0.006
1.6 Max	1.660	1.540	0.180	1.625	1.580	0.070	1.614	1.594	0.030
Min	1.600	1.480	0.060	1.600	1.555	0.020	1.600	1.584	0.006
2 Max	2.060	1.940	0.180	2.025	1.980	0.070	2.014	1.994	0.030
Min	2.000	1.880	0.060	2.000	1.955	0.020	2.000	1.984	0.006
2.5 Max	2.560	2.440	0.180	2.525	2.480	0.070	2.514	2.494	0.030
Min	2.500	2.380	0.060	2.500	2.455	0.020	2.500	2.484	0.006
3 Max	3.060	2.940	0.180	3.025	2.980	0.070	3.014	2.994	0.030
Min	3.000	2.880	0.060	3.000	2.955	0.020	3.000	2.984	0.006
4 Max	4.075	3.930	0.220	4.030	3.970	0.090	4.018	3.990	0.040
Min	4.000	3.855	0.070	4.000	3.940	0.030	4.000	3.978	0.010
5 Max	5.075	4.930	0.220	5.030	4.970	0.090	5.018	4.990	0.040
Min	5.000	4.855	0.070	5.000	4.940	0.030	5.000	4.978	0.010
6 Max	6.075	5.930	0.220	6.030	5.970	0.090	6.018	5.990	0.040
Min	6.000	5.855	0.070	6.000	5.940	0.030	6.000	5.978	0.010
8 Max	8.090	7.920	0.260	8.036	7.960	0.112	8.022	7.987	0.050
Min	8.000	7.830	0.080	8.000	7.924	0.040	8.000	7.972	0.013
10 Max	10.090	9.920	0.260	10.036	9.960	0.112	10.022	9.987	0.050
Min	10.000	9.830	0.080	10.000	9.924	0.040	10.000	9.972	0.013
12 Max	12.110	11.905	0.315	12.043	11.950	0.136	12.027	11.984	0.061
Min	12.000	11.795	0.095	12.000	11.907	0.050	12.000	11.966	0.016
16 Max	16.110	15.905	0.315	16.043	15.950	0.136	16.027	15.984	0.061
Min	16.000	15.795	0.095	16.000	15.907	0.050	16.000	15.966	0.016
20 Max	20.130	19.890	0.370	20.052	19.935	0.169	20.033	19.980	0.074
Min	20.000	19.760	0.110	20.000	19.883	0.065	20.000	19.959	0.020
25 Max	25.130	24.890	0.370	25.052	24.935	0.169	25.033	24.980	0.074
Min	25.000	24.760	0.110	25.000	24.883	0.065	25.000	24.959	0.020
30 Max	30.130	29.890	0.370	30.052	29.935	0.169	30.033	29.980	0.074
Min	30.000	29.760	0.110	30.000	29.883	0.065	30.000	29.959	0.020
40 Max	40.160	39.880	0.440	40.062	39.920	0.204	40.039	39.975	0.089
Min	40.000	39.720	0.120	40.000	39.858	0.080	40.000	39.950	0.025
50 Max	50.160	49.870	0.450	50.062	49.920	0.204	50.039	49.975	0.089
Min	50.000	49.710	0.130	50.000	49.858	0.080	50.000	49.950	0.025
60 Max	60.190	59.860	0.520	60.074	59.900	0.248	60.046	59.970	0.106
Min	60.000	59.670	0.140	60.000	59.826	0.100	60.000	59.940	0.030
80 Max	80.190	79.850	0.530	80.074	79.900	0.248	80.046	79.970	0.106
Min	80.000	79.660	0.150	80.000	79.826	0.100	80.000	79.940	0.030
100 Max	100.220	99.830	0.610	100.087	99.880	0.294	100.054	99.964	0.125
Min	100.000	99.610	0.170	100.000	99.793	0.120	100.000	99.929	0.036
120 Max	120.220	119.820	0.620	120.087	119.880	0.294	120.054	119.964	0.125
Min	120.000	119.600	0.180	120.000	119.793	0.120	120.000	119.929	0.036
160 Max	160.250	159.790	0.710	160.100	159.855	0.345	160.063	159.957	0.146
Min	160.000	159.540	0.210	160.000	159.755	0.145	160.000	159.917	0.043
200 Max	200.290	199.760	0.820	200.115	199.830	0.400	200.072	199.950	0.168
Min	200.000	199.470	0.240	200.000	199.715	0.170	200.000	199.904	0.050
250 Max	250.290	249.720	0.860	250.115	249.830	0.400	250.072	249.950	0.168
Min	250.000	249.430	0.280	250.000	249.715	0.170	250.000	249.904	0.050
300 Max	300.320	299.670	0.970	300.130	299.810	0.450	300.081	299.944	0.189
Min	300.000	299.350	0.330	300.000	299.680	0.190	300.000	299.892	0.056
400 Max	400.360	399.600	1.120	400.140	399.790	0.490	400.089	399.938	0.208
Min	400.000	399.240	0.400	400.000	399.650	0.210	400.000	399.881	0.062
500 Max	500.400	499.520	1.280	500.155	499.770	0.540	500.097	499.932	0.228
Min	500.000	499.120	0.480	500.000	499.615	0.230	500.000	499.869	0.068

Table H-6. Preferred Hole Basis Clearance Fits (Dimensions in Millimeters) (cont)

Basic Size	Sliding Hole H7	Sliding Shaft g6	Sliding Fit	Locational Clearance Hole H7	Locational Clearance Shaft h6	Locational Clearance Fit	Locational Transition Hole H7	Locational Transition Shaft k6	Locational Transition Fit
1 Max	1.010	0.998	0.018	1.010	1.000	0.016	1.010	1.006	0.010
Min	1.000	0.992	0.002	1.000	0.994	0.000	1.000	1.000	-0.006
1.2 Max	1.210	1.198	0.018	1.210	1.200	0.016	1.210	1.206	0.010
Min	1.200	1.192	0.002	1.200	1.194	0.000	1.200	1.200	-0.006
1.6 Max	1.610	1.598	0.018	1.610	1.600	0.016	1.610	1.606	0.010
Min	1.600	1.592	0.002	1.600	1.594	0.000	1.600	1.600	-0.006
2 Max	2.010	1.998	0.018	2.010	2.000	0.016	2.010	2.006	0.010
Min	2.000	1.992	0.002	2.000	1.994	0.000	2.000	2.000	-0.006
2.5 Max	2.510	2.498	0.018	2.510	2.500	0.016	2.510	2.506	0.010
Min	2.500	2.492	0.002	2.500	2.494	0.000	2.500	2.500	-0.006
3 Max	3.010	2.998	0.018	3.010	3.000	0.016	3.010	3.006	0.010
Min	3.000	2.992	0.002	3.000	2.994	0.000	3.000	3.000	-0.006
4 Max	4.012	3.996	0.024	4.012	3.000	0.020	4.012	4.009	0.011
Min	4.000	3.988	0.004	4.000	3.992	0.000	4.000	4.001	-0.009
5 Max	5.012	4.996	0.024	5.012	5.000	0.020	5.012	5.009	0.011
Min	5.000	4.988	0.004	5.000	4.992	0.000	5.000	5.001	-0.009
6 Max	6.012	5.996	0.024	6.012	6.000	0.020	6.012	6.009	0.011
Min	6.000	5.988	0.004	6.000	5.992	0.000	6.000	6.001	-0.009
8 Max	8.015	7.995	0.029	8.015	8.000	0.024	8.015	8.010	0.014
Min	8.000	7.986	0.005	8.000	7.991	0.000	8.000	8.001	-0.010
10 Max	10.015	9.995	0.029	10.015	10.000	0.024	10.015	10.010	0.014
Min	10.000	9.986	0.005	10.000	9.991	0.000	10.000	10.001	-0.010
12 Max	12.018	11.994	0.035	12.018	12.000	0.029	12.018	12.012	0.017
Min	12.000	11.983	0.006	12.000	11.989	0.000	12.000	12.001	-0.012
16 Max	16.018	15.994	0.035	16.018	16.000	0.029	16.018	16.012	0.017
Min	16.000	15.983	0.006	16.000	15.989	0.000	16.000	16.001	-0.012
20 Max	20.021	19.993	0.041	20.021	20.000	0.034	20.021	20.015	0.019
Min	20.000	19.980	0.007	20.000	19.897	0.000	20.000	20.002	-0.015
25 Max	25.021	24.993	0.041	25.021	25.000	0.034	25.021	25.015	0.019
Min	25.000	24.980	0.007	25.000	24.987	0.000	25.000	25.002	-0.015
30 Max	30.021	29.893	0.041	30.021	30.000	0.034	30.021	30.015	0.019
Min	30.000	29.980	0.007	30.000	29.987	0.000	30.000	30.002	-0.015
40 Max	40.025	39.991	0.050	40.025	40.000	0.041	40.025	40.018	0.023
Min	40.000	39.975	0.009	40.000	39.984	0.000	40.000	40.002	-0.018
50 Max	50.025	49.991	0.050	50.025	50.000	0.041	50.025	50.018	0.023
Min	50.000	49.975	0.009	50.000	49.984	0.000	50.000	50.002	-0.018
60 Max	60.030	59.990	0.059	60.030	60.000	0.049	60.030	60.021	0.028
Min	60.000	59.971	0.010	60.000	59.981	0.000	60.000	60.002	-0.021
80 Max	80.030	79.990	0.059	80.030	80.000	0.049	80.030	80.021	0.028
Min	80.000	79.971	0.010	80.000	79.981	0.000	80.000	80.002	-0.021
100 Max	100.035	99.988	0.069	100.035	100.000	0.057	100.035	100.025	0.032
Min	100.000	99.966	0.012	100.000	99.978	0.000	100.000	100.003	-0.025
120 Max	120.035	119.988	0.069	120.035	120.000	0.057	120.035	120.025	0.032
Min	120.000	119.966	0.012	120.000	119.978	0.000	120.000	120.003	-0.025
160 Max	160.040	159.986	0.079	160.040	160.000	0.065	160.040	160.028	0.037
Min	160.000	159.961	0.014	160.000	159.975	0.000	160.000	160.003	-0.028
200 Max	200.046	199.985	0.090	200.046	200.000	0.075	200.046	200.033	0.042
Min	200.000	199.956	0.015	200.000	199.971	0.000	200.000	200.004	-0.033
250 Max	250.046	249.985	0.090	250.046	250.000	0.075	250.046	250.033	0.042
Min	250.000	249.956	0.015	250.000	249.971	0.000	250.000	250.004	-0.033
300 Max	300.052	299.983	0.101	300.052	300.000	0.084	300.052	300.036	0.048
Min	300.000	299.951	0.017	300.000	299.968	0.000	300.000	300.004	-0.036
400 Max	400.057	399.982	0.111	400.057	400.000	0.093	400.057	400.040	0.053
Min	400.000	399.946	0.018	400.000	399.964	0.000	400.000	400.004	-0.040
500 Max	500.063	499.980	0.123	500.063	500.000	0.103	500.063	500.045	0.058
Min	500.000	499.940	0.020	500.000	499.960	0.000	500.000	500.005	-0.045

Table H-6. Preferred Hole Basis Clearance Fits (Dimensions in Millimeters) (cont)

Basic Size	Locational Transition			Locational Interference			Medium Drive		
	Hole H7	Shaft n6	Fit	Hole H7	Shaft p6	Fit	Hole H7	Shaft s6	Fit
1 Max	1.010	1.010	0.006	1.010	1.012	0.004	1.010	1.020	–0.004
Min	1.000	1.004	–0.010	1.000	1.006	–0.012	1.000	1.014	–0.020
1.2 Max	1.210	1.210	0.006	1.210	1.212	0.004	1.210	1.220	–0.004
Min	1.200	1.204	–0.010	1.200	1.206	–0.012	1.200	1.214	–0.020
1.6 Max	1.610	1.610	0.006	1.610	1.612	0.004	1.610	1.620	–0.004
Min	1.600	1.604	–0.010	1.600	1.606	–0.012	1.600	1.614	–0.020
2 Max	2.010	2.010	0.006	2.010	2.012	0.004	2.010	2.020	–0.004
Min	2.000	2.004	–0.010	2.000	2.006	–0.012	2.000	2.014	–0.020
2.5 Max	2.510	2.510	0.006	2.510	2.512	0.004	2.510	2.520	–0.004
Min	2.500	2.504	–0.010	2.500	2.506	–0.012	2.500	2.514	–0.020
3 Max	3.010	3.010	0.006	3.010	3.012	0.004	3.010	3.020	–0.004
Min	3.000	3.004	–0.010	3.000	3.006	–0.012	3.000	3.014	–0.020
4 Max	4.012	4.016	0.004	4.012	4.020	0.000	4.012	4.027	–0.007
Min	4.000	4.008	–0.016	4.000	4.012	–0.020	4.000	4.019	–0.027
5 Max	5.012	5.016	0.004	5.012	5.020	0.000	5.012	5.027	–0.007
Min	5.000	5.008	–0.016	5.000	5.012	–0.020	5.000	5.019	–0.027
6 Max	6.012	6.016	0.004	6.012	6.020	0.000	6.012	6.027	–0.007
Min	6.000	6.008	–0.016	6.000	6.012	–0.020	6.000	6.019	–0.027
8 Max	8.015	8.019	0.005	8.015	8.024	0.000	8.015	8.032	–0.008
Min	8.000	8.010	–0.019	8.000	8.015	–0.024	8.000	8.023	–0.032
10 Max	10.015	10.019	0.005	10.015	10.024	0.000	10.015	10.032	–0.008
Min	10.000	10.010	–0.019	10.000	10.015	–0.024	10.000	10.023	–0.032
12 Max	12.018	12.023	0.006	12.018	12.029	0.000	12.018	12.039	–0.010
Min	12.000	12.012	–0.023	12.000	12.018	–0.029	12.000	12.028	–0.039
16 Max	16.018	16.023	0.006	16.018	16.029	0.000	16.018	16.039	–0.010
Min	16.000	16.012	–0.023	16.000	16.018	–0.029	16.000	16.028	–0.039
20 Max	20.021	20.028	0.006	20.021	20.035	–0.001	20.021	20.048	–0.014
Min	20.000	20.015	–0.028	20.000	20.022	–0.035	20.000	20.035	–0.048
25 Max	25.021	25.028	0.006	25.021	25.035	–0.001	25.021	25.048	–0.014
Min	25.000	25.015	–0.028	25.000	25.022	–0.035	25.000	25.035	–0.048
30 Max	30.021	30.028	0.006	30.021	30.035	–0.001	30.021	30.048	–0.014
Min	30.000	30.015	–0.028	30.000	30.022	–0.035	30.000	30.035	–0.048
40 Max	40.025	40.033	0.008	40.025	40.042	–0.001	40.025	40.059	–0.018
Min	40.000	40.017	–0.033	40.000	40.026	–0.042	40.000	40.043	–0.059
50 Max	50.025	50.033	0.008	50.025	50.042	–0.001	50.025	50.059	–0.018
Min	50.000	50.017	–0.033	50.000	50.026	–0.042	50.000	50.043	–0.059
60 Max	60.030	60.039	0.010	60.030	60.051	–0.002	60.030	60.072	–0.023
Min	60.000	60.020	–0.039	60.000	60.032	–0.051	60.000	60.053	–0.072
80 Max	80.030	80.039	0.010	80.030	80.051	–0.002	80.030	80.078	–0.029
Min	80.000	80.020	–0.039	80.000	80.032	–0.051	80.000	80.059	–0.078
100 Max	100.035	100.045	0.012	100.035	100.059	–0.002	100.035	100.093	–0.036
Min	100.000	100.023	–0.045	100.000	100.037	–0.059	100.000	100.071	–0.093
120 Max	120.035	120.045	0.012	120.035	120.059	–0.002	120.035	120.101	–0.044
Min	120.000	120.023	–0.045	120.000	120.037	–0.059	120.000	120.079	–0.101
160 Max	160.040	160.052	0.013	160.040	160.068	–0.003	160.040	160.125	–0.060
Min	160.000	160.027	–0.052	160.000	160.043	–0.068	160.000	160.100	–0.125
200 Max	200.046	200.060	0.015	200.046	200.079	–0.004	200.046	200.151	–0.076
Min	200.000	200.031	–0.060	200.000	200.050	–0.079	200.000	200.122	–0.151
250 Max	250.046	250.060	0.015	250.046	250.079	–0.004	250.046	250.169	–0.094
Min	250.000	250.031	–0.060	250.000	250.050	–0.079	250.000	250.140	–0.169
300 Max	300.052	300.066	0.018	300.052	300.088	–0.004	300.052	300.202	–0.118
Min	300.000	300.034	–0.066	300.000	300.056	–0.088	300.000	300.170	–0.202
400 Max	400.057	400.073	0.020	400.057	400.098	–0.005	400.057	400.244	–0.151
Min	400.000	400.037	–0.073	400.000	400.062	–0.098	400.000	400.208	–0.244
500 Max	500.063	500.080	0.023	500.063	500.108	–0.005	500.063	500.292	–0.189
Min	500.000	500.040	–0.080	500.000	500.068	–0.108	500.000	500.252	–0.292

Table H-6. Preferred Hole Basis Clearance Fits (Dimensions in Millimeters) (cont)

Basic Size		Force	
	Hole H7	Shaft u6	Fit
1 Max	1.010	1.024	-0.008
Min	1.000	1.018	-0.024
1.2 Max	1.210	1.224	-0.008
Min	1.200	1.218	-0.024
1.6 Max	1.610	1.624	-0.008
Min	1.600	1.618	-0.024
2 Max	2.010	2.024	-0.008
Min	2.000	2.018	-0.024
2.5 Max	2.510	2.524	-0.008
Min	2.500	2.518	-0.024
3 Max	3.010	3.024	-0.008
Min	3.000	3.018	-0.024
4 Max	4.012	4.031	-0.011
Min	4.000	4.023	-0.031
5 Max	5.012	5.031	-0.011
Min	5.000	5.023	-0.031
6 Max	6.012	6.031	-0.011
Min	6.000	6.023	-0.031
8 Max	8.015	8.037	-0.013
Min	8.000	8.028	-0.037
10 Max	10.015	10.037	-0.013
Min	10.000	10.028	-0.037
12 Max	12.018	12.044	-0.015
Min	12.000	12.033	-0.044
16 Max	16.018	16.044	-0.015
Min	16.000	16.033	-0.044
20 Max	20.021	20.054	-0.020
Min	20.000	20.041	-0.054
25 Max	25.021	25.061	-0.027
Min	25.000	25.048	-0.061
30 Max	30.021	30.061	-0.027
Min	30.000	30.048	-0.061
40 Max	40.025	40.076	-0.035
Min	40.000	40.060	-0.076
50 Max	50.025	50.086	-0.045
Min	50.000	50.070	-0.086
60 Max	60.030	60.106	-0.057
Min	60.000	60.087	-0.106
80 Max	80.030	80.121	-0.072
Min	80.000	80.102	-0.121
100 Max	100.035	100.146	-0.089
Min	100.000	100.124	-0.146
120 Max	120.035	120.166	-0.109
Min	120.000	120.144	-0.166
160 Max	160.040	160.215	-0.150
Min	160.000	160.190	-0.215
200 Max	200.046	200.265	-0.190
Min	200.000	200.236	-0.265
250 Max	250.046	250.313	-0.238
Min	250.000	250.284	-0.313
300 Max	300.052	300.382	-0.298
Min	300.000	300.350	-0.382
400 Max	400.057	400.471	-0.378
Min	400.000	400.435	-0.471
500 Max	500.063	500.580	-0.477
Min	500.000	500.540	-0.580

Table H-7. Preferred Shaft Basis Clearance Fits (Dimensions in Millimeters)

Basic Size	Loose Running Hole C11	Loose Running Shaft h11	Loose Running Fit	Free Running Hole D9	Free Running Shaft h9	Free Running Fit	Close Running Hole F8	Close Running Shaft h7	Close Running Fit
1 Max	1.120	1.000	0.180	1.045	1.000	0.070	1.020	1.000	0.030
Min	1.060	0.940	0.060	1.020	0.975	0.020	1.006	0.990	0.006
1.2 Max	**1.320**	**1.200**	**0.180**	**1.245**	**1.200**	**0.070**	**1.220**	**1.200**	**0.030**
Min	**1.260**	**1.140**	**0.060**	**1.220**	**1.175**	**0.020**	**1.206**	**1.190**	**0.006**
1.6 Max	1.720	1.600	0.180	1.645	1.600	0.070	1.620	1.600	0.030
Min	1.660	1.540	0.060	1.620	1.575	0.020	1.606	1.590	0.006
2 Max	**2.120**	**2.000**	**0.180**	**2.045**	**2.000**	**0.070**	**2.020**	**2.000**	**0.030**
Min	**2.060**	**1.940**	**0.060**	**2.020**	**1.975**	**0.020**	**2.006**	**1.990**	**0.006**
2.5 Max	2.620	2.500	0.180	2.545	2.500	0.070	2.520	2.500	0.030
Min	2.560	2.440	0.060	2.520	2.475	0.020	2.506	2.490	0.006
3 Max	**3.120**	**3.000**	**0.180**	**3.045**	**3.000**	**0.070**	**3.020**	**3.000**	**0.030**
Min	**3.060**	**2.940**	**0.060**	**3.020**	**2.975**	**0.020**	**3.006**	**2.990**	**0.006**
4 Max	4.145	4.000	0.220	4.060	4.000	0.090	4.028	4.000	0.040
Min	4.070	3.925	0.070	4.030	3.970	0.030	4.010	3.988	0.010
5 Max	**5.145**	**5.000**	**0.220**	**5.060**	**5.000**	**0.090**	**5.028**	**5.000**	**0.040**
Min	**5.070**	**4.925**	**0.070**	**5.030**	**4.970**	**0.030**	**5.010**	**4.988**	**0.010**
6 Max	6.145	6.000	0.220	6.060	6.000	0.090	6.028	6.000	0.040
Min	6.070	5.925	0.070	6.030	5.970	0.030	6.010	5.988	0.010
8 Max	**8.170**	**8.000**	**0.260**	**8.076**	**8.000**	**0.112**	**8.035**	**8.000**	**0.050**
Min	**8.080**	**7.910**	**0.080**	**8.040**	**7.964**	**0.040**	**8.013**	**7.985**	**0.013**
10 Max	10.170	10.000	0.260	10.076	10.000	0.112	10.035	10.000	0.050
Min	10.080	9.910	0.080	10.040	9.964	0.040	10.013	9.985	0.013
12 Max	**12.205**	**12.000**	**0.315**	**12.093**	**12.000**	**0.136**	**12.043**	**12.000**	**0.061**
Min	**12.095**	**11.890**	**0.095**	**12.050**	**11.957**	**0.050**	**12.016**	**11.982**	**0.016**
16 Max	16.205	16.000	0.315	16.093	16.000	0.136	16.043	16.000	0.061
Min	16.095	15.890	0.095	16.050	15.957	0.050	16.016	15.982	0.016
20 Max	**20.240**	**20.000**	**0.370**	**20.117**	**20.000**	**0.169**	**20.053**	**20.000**	**0.074**
Min	**20.110**	**19.870**	**0.110**	**20.065**	**19.948**	**0.065**	**20.020**	**19.979**	**0.020**
25 Max	25.240	25.000	0.370	25.117	25.000	0.169	25.053	25.000	0.074
Min	25.110	24.870	0.110	25.065	24.948	0.065	25.020	24.979	0.020
30 Max	**30.240**	**30.000**	**0.370**	**30.117**	**30.000**	**0.169**	**30.053**	**30.000**	**0.074**
Min	**30.110**	**29.870**	**0.110**	**30.065**	**29.948**	**0.065**	**30.020**	**29.979**	**0.020**
40 Max	40.280	40.000	0.440	40.142	40.000	0.204	40.064	40.000	0.089
Min	40.120	39.840	0.120	40.080	39.938	0.080	40.025	39.975	0.025
50 Max	**50.290**	**50.000**	**0.450**	**50.142**	**50.000**	**0.204**	**50.064**	**50.000**	**0.089**
Min	**50.130**	**49.840**	**0.130**	**50.080**	**49.938**	**0.080**	**50.025**	**49.975**	**0.025**
60 Max	60.330	60.000	0.520	60.174	60.000	0.248	60.076	60.000	0.106
Min	60.140	59.810	0.140	60.100	59.926	0.100	60.030	59.970	0.030
80 Max	**80.340**	**80.000**	**0.530**	**80.174**	**80.000**	**0.248**	**80.076**	**80.000**	**0.106**
Min	**80.150**	**79.810**	**0.150**	**80.100**	**79.926**	**0.100**	**80.030**	**79.970**	**0.030**
100 Max	100.390	100.000	0.610	100.207	100.000	0.294	100.090	100.000	0.125
Min	100.170	99.780	0.170	100.120	99.913	0.120	100.036	99.965	0.036
120 Max	**120.400**	**120.000**	**0.620**	**120.207**	**120.000**	**0.294**	**120.090**	**120.000**	**0.125**
Min	**120.180**	**119.780**	**0.180**	**120.120**	**119.913**	**0.120**	**120.036**	**119.965**	**0.036**
160 Max	160.460	160.000	0.710	160.245	160.000	0.345	160.106	160.000	0.146
Min	160.210	159.750	0.210	160.145	159.900	0.145	160.043	159.960	0.043
200 Max	**200.530**	**200.000**	**0.820**	**200.285**	**200.000**	**0.400**	**200.122**	**200.000**	**0.168**
Min	**200.240**	**199.710**	**0.240**	**200.170**	**199.885**	**0.170**	**200.050**	**199.954**	**0.050**
250 Max	250.570	250.000	0.860	250.285	250.000	0.400	250.122	250.000	0.168
Min	250.280	249.710	0.280	250.170	249.885	0.170	250.050	249.954	0.050
300 Max	**300.650**	**300.000**	**0.970**	**300.320**	**300.000**	**0.450**	**300.137**	**300.000**	**0.189**
Min	**300.330**	**299.680**	**0.330**	**300.190**	**299.870**	**0.190**	**300.056**	**299.948**	**0.056**
400 Max	400.760	400.000	1.120	400.350	400.000	0.490	400.151	400.000	0.208
Min	400.400	399.640	0.400	400.210	399.860	0.210	400.062	399.943	0.062
500 Max	**500.880**	**500.000**	**1.280**	**500.385**	**500.000**	**0.540**	**500.165**	**500.000**	**0.228**
Min	**500.480**	**499.600**	**0.480**	**500.230**	**499.845**	**0.230**	**500.068**	**499.937**	**0.068**

Table H-7. Preferred Shaft Basis Clearance Fits (Dimensions in Millimeters) (cont)

Basic Size	Sliding Hole G7	Sliding Shaft h6	Sliding Fit	Locational Clearance Hole H7	Locational Clearance Shaft h6	Locational Clearance Fit	Locational Transition Hole K7	Locational Transition Shaft h6	Locational Transition Fit
1 Max	1.012	1.000	0.018	1.010	1.000	0.016	1.000	1.000	0.006
Min	1.002	0.994	0.002	1.000	0.994	0.000	0.990	0.994	–0.010
1.2 Max	**1.212**	**1.200**	**0.018**	**1.210**	**1.200**	**0.016**	**1.200**	**1.200**	**0.006**
Min	**1.202**	**1.194**	**0.002**	**1.200**	**1.194**	**0.000**	**1.190**	**1.194**	**–0.010**
1.6 Max	1.612	1.600	0.018	1.610	1.600	0.016	1.600	1.600	0.006
Min	1.602	1.594	0.002	1.600	1.594	0.000	1.590	1.594	–0.010
2 Max	**2.012**	**2.000**	**0.018**	**2.010**	**2.000**	**0.016**	**2.000**	**2.000**	**0.006**
Min	**2.002**	**1.994**	**0.002**	**2.000**	**1.994**	**0.000**	**1.990**	**1.994**	**–0.010**
2.5 Max	2.512	2.500	0.018	2.510	2.500	0.016	2.500	2.500	0.006
Min	2.502	2.494	0.002	2.500	2.494	0.000	2.490	2.494	–0.010
3 Max	**3.012**	**3.000**	**0.018**	**3.010**	**3.000**	**0.016**	**3.000**	**3.000**	**0.006**
Min	**3.002**	**2.994**	**0.002**	**3.000**	**2.994**	**0.000**	**2.990**	**2.994**	**–0.010**
4 Max	4.016	4.000	0.024	4.012	3.000	0.020	4.003	3.000	0.011
Min	4.004	3.992	0.004	4.000	3.992	0.000	3.991	3.992	–0.009
5 Max	**5.016**	**5.000**	**0.024**	**5.012**	**5.000**	**0.020**	**5.003**	**5.000**	**0.011**
Min	**5.004**	**4.992**	**0.004**	**5.000**	**4.992**	**0.000**	**4.991**	**4.992**	**–0.009**
6 Max	6.016	6.000	0.024	6.012	6.000	0.020	6.003	6.000	0.011
Min	6.004	5.992	0.004	6.000	5.992	0.000	5.991	5.992	–0.009
8 Max	**8.020**	**8.000**	**0.029**	**8.015**	**8.000**	**0.024**	**8.005**	**8.000**	**0.014**
Min	**8.005**	**7.991**	**0.005**	**8.000**	**7.991**	**0.000**	**7.990**	**7.991**	**–0.010**
10 Max	10.020	10.000	0.029	10.015	10.000	0.024	10.005	10.000	0.014
Min	10.005	9.991	0.005	10.000	9.991	0.000	9.990	9.991	–0.010
12 Max	**12.024**	**12.000**	**0.035**	**12.018**	**12.000**	**0.029**	**12.006**	**12.000**	**0.017**
Min	**12.006**	**11.989**	**0.006**	**12.000**	**11.989**	**0.000**	**11.988**	**11.989**	**–0.012**
16 Max	16.024	16.000	0.035	16.018	16.000	0.029	16.006	16.000	0.017
Min	16.006	15.989	0.006	16.000	15.989	0.000	15.988	15.989	–0.012
20 Max	**20.028**	**20.000**	**0.041**	**20.021**	**20.000**	**0.034**	**20.006**	**20.000**	**0.019**
Min	**20.007**	**19.987**	**0.007**	**20.000**	**19.897**	**0.000**	**19.985**	**19.897**	**–0.015**
25 Max	25.028	25.000	0.041	25.021	25.000	0.034	25.006	25.000	0.019
Min	25.007	24.987	0.007	25.000	24.987	0.000	24.985	24.987	–0.015
30 Max	**30.028**	**30.000**	**0.041**	**30.021**	**30.000**	**0.034**	**30.006**	**30.000**	**0.019**
Min	**30.007**	**29.987**	**0.007**	**30.000**	**29.987**	**0.000**	**29.985**	**29.987**	**–0.015**
40 Max	40.034	40.000	0.050	40.025	40.000	0.041	40.007	40.000	0.023
Min	40.009	39.984	0.009	40.000	39.984	0.000	39.982	39.984	–0.018
50 Max	**50.034**	**50.000**	**0.050**	**50.025**	**50.000**	**0.041**	**50.007**	**50.000**	**0.023**
Min	**50.009**	**49.984**	**0.009**	**50.000**	**49.984**	**0.000**	**49.982**	**49.984**	**–0.018**
60 Max	60.040	60.000	0.059	60.030	60.000	0.049	60.009	60.000	0.028
Min	60.010	59.981	0.010	60.000	59.981	0.000	59.979	59.981	–0.021
80 Max	**80.040**	**80.000**	**0.059**	**80.030**	**80.000**	**0.049**	**80.009**	**80.000**	**0.028**
Min	**80.010**	**79.981**	**0.010**	**80.000**	**79.981**	**0.000**	**79.979**	**79.981**	**–0.021**
100 Max	100.047	100.000	0.069	100.035	100.000	0.057	100.010	100.000	0.032
Min	100.012	99.978	0.012	100.000	99.978	0.000	99.975	99.978	–0.025
120 Max	**120.047**	**120.000**	**0.069**	**120.035**	**120.000**	**0.057**	**120.010**	**120.000**	**0.032**
Min	**120.012**	**119.978**	**0.012**	**120.000**	**119.978**	**0.000**	**119.975**	**119.978**	**–0.025**
160 Max	160.054	160.000	0.079	160.040	160.000	0.065	160.012	160.000	0.037
Min	160.014	159.975	0.014	160.000	159.975	0.000	159.972	159.975	–0.028
200 Max	**200.061**	**200.000**	**0.090**	**200.046**	**200.000**	**0.075**	**200.013**	**200.000**	**0.042**
Min	**200.015**	**199.971**	**0.015**	**200.000**	**199.971**	**0.000**	**199.967**	**199.971**	**–0.033**
250 Max	250.061	250.000	0.090	250.046	250.000	0.075	250.013	250.000	0.042
Min	250.015	249.971	0.015	250.046	249.971	0.000	249.967	249.971	–0.033
300 Max	**300.069**	**300.000**	**0.101**	**300.052**	**300.000**	**0.084**	**300.016**	**300.000**	**0.048**
Min	**300.017**	**299.968**	**0.017**	**300.000**	**299.968**	**0.000**	**299.964**	**299.968**	**–0.036**
400 Max	400.075	400.000	0.111	400.057	400.000	0.093	400.017	400.000	0.053
Min	400.018	399.964	0.018	400.000	399.964	0.000	399.960	399.964	–0.040
500 Max	**500.083**	**500.000**	**0.123**	**500.063**	**500.000**	**0.103**	**500.018**	**500.000**	**0.058**
Min	**500.020**	**499.960**	**0.020**	**500.000**	**499.960**	**0.000**	**499.955**	**499.960**	**–0.045**

Table H-7. Preferred Shaft Basis Clearance Fits (Dimensions in Millimeters) (cont)

Basic Size	Locational Transition			Locational Interference			Medium Drive		
	Hole N7	Shaft h6	Fit	Hole P7	Shaft h6	Fit	Hole S7	Shaft h6	Fit
1 Max	0.996	1.000	0.002	0.994	1.000	0.000	0.986	1.000	–0.008
Min	0.986	0.994	–0.014	0.984	0.994	–0.016	0.976	0.994	–0.024
1.2 Max	1.196	1.200	0.002	1.194	1.200	0.000	1.186	1.200	–0.008
Min	1.186	1.194	–0.014	1.184	1.194	–0.016	1.176	1.194	–0.024
1.6 Max	1.596	1.600	0.002	1.594	1.600	0.000	1.586	1.600	–0.008
Min	1.586	1.594	–0.014	1.584	1.594	–0.016	1.576	1.594	–0.024
2 Max	1.996	2.000	0.002	1.994	2.000	0.000	1.986	2.000	–0.008
Min	1.986	1.994	–0.014	1.984	1.994	–0.016	1.976	1.994	–0.024
2.5 Max	2.496	2.500	0.002	2.494	2.500	0.000	2.486	2.500	–0.008
Min	2.486	2.494	–0.014	2.484	2.494	–0.016	2.476	2.494	–0.024
3 Max	2.996	3.000	0.002	2.994	3.000	0.000	2.986	3.000	–0.008
Min	2.986	2.994	–0.014	2.984	2.994	–0.016	2.976	2.994	–0.024
4 Max	3.996	3.000	0.004	3.992	3.000	0.000	3.985	3.000	–0.007
Min	3.984	3.992	–0.016	3.980	3.992	–0.020	3.973	3.992	–0.027
5 Max	4.996	5.000	0.004	4.992	5.000	0.000	4.985	5.000	–0.007
Min	4.984	4.992	–0.016	4.980	4.992	–0.020	4.973	4.992	–0.027
6 Max	5.996	6.000	0.004	5.992	6.000	0.000	5.985	6.000	–0.007
Min	5.984	5.992	–0.016	5.980	5.992	–0.020	5.973	5.992	–0.027
8 Max	7.996	8.000	0.005	7.991	8.000	0.000	7.983	8.000	–0.008
Min	7.981	7.991	–0.019	7.976	7.991	–0.024	7.968	7.991	–0.032
10 Max	9.996	10.000	0.005	9.991	10.000	0.000	9.983	10.000	–0.008
Min	9.981	9.991	–0.019	9.976	9.991	–0.024	9.968	9.991	–0.032
12 Max	11.995	12.000	0.006	11.989	12.000	0.000	11.979	12.000	–0.010
Min	11.977	11.989	–0.023	11.971	11.989	–0.029	11.961	11.989	–0.039
16 Max	15.995	16.000	0.006	15.989	16.000	0.000	15.979	16.000	–0.010
Min	15.977	15.989	–0.023	15.971	15.989	–0.029	15.961	15.989	–0.039
20 Max	19.993	20.000	0.006	19.986	20.000	–0.001	19.973	20.000	–0.014
Min	19.972	19.897	–0.026	19.965	19.897	–0.035	19.952	19.897	–0.048
25 Max	24.993	25.000	0.006	24.986	25.000	–0.001	24.973	25.000	–0.014
Min	24.972	24.987	–0.028	24.965	24.987	–0.035	24.952	24.987	–0.048
30 Max	29.993	30.000	0.006	29.986	30.000	–0.001	29.973	30.000	–0.014
Min	29.972	29.987	–0.028	29.965	29.987	–0.035	29.952	29.987	–0.048
40 Max	39.992	40.000	0.008	39.983	40.000	–0.001	39.996	40.000	–0.018
Min	39.967	39.984	–0.033	39.958	39.984	–0.042	39.941	39.984	–0.059
50 Max	49.992	50.000	0.008	49.983	50.000	–0.001	49.966	50.000	–0.018
Min	49.967	49.984	–0.033	49.958	49.984	–0.042	49.941	49.984	–0.059
60 Max	59.991	60.000	0.010	59.979	60.000	–0.002	59.958	60.000	–0.023
Min	59.961	59.981	–0.039	59.949	59.981	–0.051	59.928	59.981	–0.072
80 Max	79.991	80.000	0.010	79.979	80.000	–0.002	79.952	80.000	–0.029
Min	79.961	79.981	–0.039	79.949	79.981	–0.051	79.922	79.981	–0.078
100 Max	99.990	100.000	0.012	99.976	100.000	–0.002	99.942	100.000	–0.036
Min	99.955	99.978	–0.045	99.941	99.978	–0.059	99.907	99.978	–0.093
120 Max	119.990	120.000	0.012	119.976	120.000	–0.002	119.934	120.000	–0.044
Min	119.955	119.978	–0.045	119.941	119.978	–0.059	119.899	119.978	–0.101
160 Max	159.988	160.000	0.013	159.972	160.000	–0.003	159.915	160.000	–0.060
Min	159.948	159.975	–0.052	159.932	159.975	–0.068	159.875	159.975	–0.125
200 Max	199.986	200.000	0.015	199.967	200.000	–0.004	199.895	200.000	–0.076
Min	199.940	199.971	–0.060	199.921	199.971	–0.079	199.849	199.971	–0.151
250 Max	249.986	250.000	0.015	249.967	250.000	–0.004	249.877	250.000	–0.094
Min	249.940	249.971	–0.060	249.921	249.971	–0.079	249.831	249.971	–0.169
300 Max	299.986	300.000	0.018	299.964	300.000	–0.004	299.850	300.000	–0.118
Min	299.934	299.968	–0.066	299.912	299.968	–0.088	299.798	299.968	–0.202
400 Max	399.984	400.000	0.020	399.959	400.000	–0.005	399.813	400.000	–0.151
Min	399.927	399.964	–0.073	399.902	399.964	–0.098	399.756	399.964	–0.244
500 Max	499.983	500.000	0.023	499.955	500.000	–0.005	499.771	500.000	–0.189
Min	499.920	499.960	–0.080	499.892	499.960	–0.108	499.708	499.960	–0.292

Table H-7. Preferred Shaft Basis Clearance Fits (Dimensions in Millimeters) (cont)

Basic Size		Force Hole U7	Force Shaft h6	Force Fit
1	Max	0.982	1.000	-0.012
	Min	0.972	0.994	-0.028
1.2	Max	1.182	1.200	-0.012
	Min	1.172	1.194	-0.028
1.6	Max	1.582	1.600	-0.012
	Min	1.572	1.594	-0.028
2	Max	1.982	2.000	-0.012
	Min	1.972	1.994	-0.028
2.5	Max	2.482	2.500	-0.012
	Min	2.472	2.494	-0.028
3	Max	2.982	3.000	-0.012
	Min	2.972	2.994	-0.028
4	Max	3.981	3.000	-0.011
	Min	3.969	3.992	-0.031
5	Max	4.981	5.000	-0.011
	Min	4.969	4.992	-0.031
6	Max	5.981	6.000	-0.011
	Min	5.969	5.992	-0.031
8	Max	7.978	8.000	-0.013
	Min	7.963	7.991	-0.037
10	Max	9.978	10.000	-0.013
	Min	9.963	9.991	-0.037
12	Max	11.974	12.000	-0.015
	Min	11.956	11.989	-0.044
16	Max	15.974	16.000	-0.015
	Min	15.956	15.989	-0.044
20	Max	19.967	20.000	-0.020
	Min	19.946	19.897	-0.054
25	Max	24.960	25.000	-0.027
	Min	24.939	24.987	-0.061
30	Max	29.960	30.000	-0.027
	Min	29.939	29.987	-0.061
40	Max	39.949	40.000	-0.035
	Min	39.924	39.984	-0.076
50	Max	49.939	50.000	-0.045
	Min	49.914	49.984	-0.086
60	Max	59.924	60.000	-0.057
	Min	59.894	59.981	-0.106
80	Max	79.909	80.000	-0.072
	Min	79.879	79.981	-0.121
100	Max	99.889	100.000	-0.089
	Min	99.854	99.978	-0.146
120	Max	119.869	120.000	-0.109
	Min	119.834	119.978	-0.166
160	Max	159.825	160.000	-0.150
	Min	159.785	159.975	-0.215
200	Max	199.781	200.000	-0.190
	Min	199.735	199.971	-0.265
250	Max	249.733	250.000	-0.238
	Min	249.687	249.971	-0.313
300	Max	299.670	300.000	-0.298
	Min	299.618	299.968	-0.382
400	Max	399.586	400.000	-0.378
	Min	399.529	399.964	-0.471
500	Max	499.483	500.000	-0.477
	Min	499.420	499.960	-0.580

APPENDIX I

UNIT INDEX

UNIT INDEX

UNIT INDEX (cont)

UNIT INDEX (cont)

UNIT INDEX (cont)

APPENDIX J

REFERENCES

APPENDIX J

REFERENCES

ANSI B4.2, *Preferred Metric Limits and Fits*, American National Standards Institute, Inc., New York, 1978

ANSI X3.50, *Representations for U.S. Customary, SI, and Other Units To Be Used in Systems With Limited Character Sets*, American National Standards Institute, Inc., New York, June 1986

ANSI/IEEE Std 268, *American National Standard for Metric Practice*, Institute of Electrical and Electronics Engineers, Inc., New York, October 1992

ASTM E380, *Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)*, American Society of Testing and Materials, Philadelphia, December 1991

ASTM E621, *Standard Practice for the Use of Metric (SI) Units in Building Design and Construction (Committee E-6 Supplement to E380)*, American Society of Testing and Materials, Philadelphia, 1984, reapproved 1991

Federal Standard 376, *Preferred Metric Units for General Use by the Federal Government*, Metric Practice Subcommittee of the Metrication Operating Committee of the Interagency Council on Metric Policy, Washington, D.C., 1992

For Good Measure, Johnstone, William D., Holt, Rinehart and Winston, New York, 1975

General Bulletin #1908, American Institute of Steel Construction, Inc., January 13, 1992

IEEE Std 260, *IEEE Standard Letter Symbols for SI Units and for Certain Other Units of Measure*, The Institute of Electrical and Electronics Engineers, Inc., New York, 1977

ISO 1000, *SI Units and Recommendations for the Use of Their Multiples and of Certain Other Units*, International Organization for Standardization, second edition, New York, 1981

Metric Design Guide, U.S. General Services Administration, Public Buildings Service, Washington, DC, July 1993

Metric Guide for Federal Construction, National Institute of Building Sciences, The Construction Subcommittee of the Metrication Operating Committee of the Interagency Council on Metric Policy, First Edition, Washington, D.C., 1991

Metric Guide for Office and General Use, U.S. Metric Association, Northridge, CA

Metric in Construction, newsletter of the Construction Metrication Council of the National Institute of Building Sciences, Washington, D.C., Volume 1, 1992, and Volume 2, 1993

Metric (SI) Guide, NASA Lewis Research Center, Engineering Technology Branch, Engineering Support Division, Engineering Directorate, Cleveland, Ohio, July 1992

NASA Metric Transition Plan, NASA, Washington, D.C., 1992

NIST Special Publication 330, *The International System of Units (SI)*, United States Department of Commerce, National Institute of Standards and Technology, Washington, D.C., August 1991

NIST Special Publication 814, *Interpretation of the SI for the United States and Metric Conversion Policy for Federal Agencies*, United States Department of Commerce, National Institute of Standards and Technology, Washington, D.C., October 1991

Office of Space Flight Metric Transition Plan, Office of Space Flight, NASA, Washington, DC, April 1991

SAS 33, *Aluminum Construction Manual, Section 3, Engineering Data for Aluminum Structures*, Aluminum Association, Washington, D.C., December, 1986, p.97

SD-10, *Guide for Identification and Development of Metric Standards*, Office of the Assistant Secretary of Defense for Production and Logistics, Washington, D.C., March 1990

SI Metric Handbook, John L. Feirer, The Metric Company, Charles Scribner's Sons, New York, 1977

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
November 1993

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
SI (Metric) Handbook

5. FUNDING NUMBERS

6. AUTHOR(S)
Elisa A. Artusa

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Launch Structures Section
Mechanical Engineering Division
NASA, Kennedy Space Center, FL

8. PERFORMING ORGANIZATION REPORT NUMBER
KSC-DM-3673

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
John F. Kennedy Space Center
National Aeronautics and Space Administration
Kennedy Space Center, FL 32899

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
TM-109197

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This guide provides information for an understanding of SI units, symbols, and prefixes; style and usage in documentation in both the United States and in international business; conversion techniques; limits, fits, and tolerance data; and drawing and technical writing guidelines. Also provided is information on SI usage for specialized applications like data processing and computer programming, science, engineering, and construction. Related information in the appendixes include legislative documents, historical and biographical data, a list of metric documentation, rules for determining significant digits and rounding, conversion factors, shorthand notation, and a unit index.

14. SUBJECT TERMS
Metric, Metric System, International System of Units, SI, Units, Measurement Units, Measurement System, Measures

15. NUMBER OF PAGES
266

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL