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RULES FOR THE USE OF SI UNITS APPLICABLE TO METRIC MECHANICAL FASTENERS

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FOREWORD

The International System of Units (SI) is a rationalized and coherent system of measurement units based on the metric system. SI was developed by the General Conference of Weights and Measures. It was officially adopted by the Conference in 1960, and has since been accepted by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). SI is in a continuing state of review and refinement, with the General Conference on Weights and Measures meeting at least once every six years. At the present time, SI consists of seven base units, two supplementary units, a series of derived units consistent with the base and supplementary units, and a series of prefixes for the formation of multiples and submultiples of the various units. Complete details of SI can be found in ISO 1000, NIST Special Publication 330, or ASTM E380.

This Recommended Practice was prepared to give guidance in the units, prefixes, and editorial style to be used in the preparation of engineering documents on metric fasteners. All standards presented in this book conform to this Recommended Practice.

1. Scope

1.1 This Recommended Practice abstracts from the International System of Units (SI) the units for those quantities most commonly used to define the characteristics, dimensions, and properties of mechanical fasteners. This document also outlines editorial style rules to be followed when using SI units.

1.2 Appendix A to this Recommended Practice gives information on conversion of U.S. customary units to SI units. Also, as an assist to familiarize fastener producers and users with relationships between SI units and customary units, the Appendix presents several approximate equivalencies.

2. Reference Documents

The material presented in this Recommended Practice is abstracted from the following sources:

ISO 1000 — Rules for the Use of Units of the International System of Units and a Selection of the Decimal Multiples and Submultiples of the SI Units.

NIST Special Publication 330 — The International System of Units (SI), published by U.S. Department of Commerce, National Institute of Standards and Technology.

ASTM E380 — Standard for Metric Practice, published by the American Society for Testing and Materials.

SAE Rules for the Use of SI [Metric] Units in SAE Reports, published by the Society of Automotive Engineers.

3. Quantities

3.1 Length. The SI base unit for length is meter (m).

All linear dimensional characteristics of fasteners (diameters, heights, thicknesses,

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lengths, thread dimensions, etc.) should be expressed in millimeters (mm). Tolerances should be given in millimeters (mm), and surface roughness in micrometers (μm).

3.2 **Mass.** The SI base unit for mass is kilogram (kg).

The mass (commonly referred to as weight) of a fastener and masses related to fastener manufacturing and marketing should be expressed in kilograms (kg). Alternatively, grams (g) may be used to express a small mass, and megagrams (Mg), which equals 1000 kg, may be used when expressing a large mass.

NOTE: Considerable confusion exists in use of the terms mass and weight. Mass is a property of matter to which it owes its inertia. If a body or particle of matter at rest is released from the forces holding it at rest, it will experience the acceleration of free fall (acceleration of gravity). The force required to restrain it against free fall is commonly called weight. This force is proportional to the mass of the body and is often expressed in mass units (kg); but as it is a force, it should be expressed in force units (N). The acceleration of free fall varies in time and space; weight (which is proportional to it) does too, although mass does not. In common parlance the term "weight," as a container of bolts, is used where the technically correct term is mass. Since this nontechnical usage of the term "weight" is common, the term should be avoided in technical usage.

3.3 **Density.** The SI unit for density is kilogram per cubic meter (kg/m³) and should be used when expressing densities related to fasteners.

3.4 **Time.** The SI base unit for time is second (s). When expressing time the following units are acceptable: second (s), minute (min), hour (h), day (d), week and year.

3.5 **Temperature.** The SI base unit for temperature is kelvin (K).

Because of the wide usage of the degree Celsius, particularly in engineering and nonscientific areas, the Celsius scale (formerly called the centigrade scale) should be used when expressing temperature as related to fastener manufacturing processes and to fastener application practices. The Celsius scale is related directly to the kelvin scale as follows:

one degree Celsius (1°C) equals one degree kelvin (1K), exactly

and

a Celsius temperature (t) is related to a kelvin temperature (T), as follows:

$$T = 273.15 + t, \text{ exactly}$$

3.6 **Plane Angle.** The SI unit for plane angle is radian (rad), and is equal to $180°/\pi$ (57.296°).

For fasteners, plane angles should be expressed in degrees (°) with decimal subdivisions instead of minutes and seconds.

3.7 **Area.** The SI unit for area is square meter (m^2).

For fasteners, the recommended unit for expressing area is square millimeter (mm^2).

3.8 **Volume.** The SI unit for volume is cubic meter (m^3).

For fasteners, the recommended unit for expressing volume is cubic millimeter (mm^3).

3.9 **Force.** The SI unit for force is newton (N).

For fasteners, forces (loads) should be expressed in newtons (N), kilonewtons (kN) or meganewtons (MN).

3.10 **Stress.** The SI unit for pressure or stress is pascal (Pa), and equals one newton per square meter (N/m^2).

For fasteners, stresses should be expressed in megapascals (MPa).

3.11 **Torque.** The SI unit for torque is newton-meter (N·m) and should be used for fasteners.

3.12 **Multiple and Submultiple Prefixes.** The multiple and submultiple prefixes used to

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quantify SI units as used for fasteners shall be as follows:

Multiplication Factor	Prefix	SI Symbol
$1\,000\,000 = 10^6$	mega	M
$1\,000 = 10^3$	kilo	k
$0.001 = 10^{-3}$	milli	m
$0.000001 = 10^{-6}$	micro	μ

4. Rules for Style and Usage

4.1 General. The units as noted for their applicability for fasteners in Section 3 should be used.

4.2 Application of Prefixes. The prefixes given in 3.12 should be used to indicate orders of magnitude, thus eliminating insignificant digits and decimals, and providing a convenient substitute for writing powers of 10 as generally preferred in computation. For example —

2 N × 10^3 or 2000 N becomes 2 kN
7.2 mm × 10^{-3} or 0.0072 mm becomes 7.2 μm

Prefixes should be applied to the numerator of compound units, except when using kilogram (kg) in the denominator. Since kilogram is a base unit of SI, this particular multiple is not a violation and should be used in preference to the gram.

With SI units of higher order such as m^2 or m^3, the prefix is also raised to the same order; for example, mm^2 is $10^{-6}m^2$ not $10^{-2}m^2$.

4.3 Selection of Prefix. When expressing a quantity by a numerical value and a unit, a prefix should be chosen so that the numerical value preferably lies between 0.1 and 1000, except where certain multiples and submultiples have been agreed for particular use, for example, MPa. The same unit, multiple, or submultiple should be used in tables even though the series may exceed the preferred range of 0.1 to 1000.

The decimal point shall be used to indicate decimal parts of a quantity. Whenever a numerical value is less than one, a zero should precede the decimal point.

4.4 Capitalization. Symbols for SI units are only capitalized when the unit is derived from a proper name; for example, N for Isaac Newton. Unabbreviated units are not capitalized, for example, kelvin and newton. Numerical prefixes given in 3.12 and their symbols are not capitalized; except for the symbol M (mega).

4.5 Plurals. Unabbreviated SI units form their plurals in the usual manner. SI symbols are always written in singular form. For example,

50 newtons or 50 N
25 millimeters or 25 mm

4.6 Punctuation. Periods are not used after any SI unit symbol, except at the end of a sentence.

4.7 Number Grouping. It is the practice in many metric countries to use a comma (instead of a decimal point) to indicate decimal parts of a quantity. Consequently, to avoid confusion, commas to separate multi-digit numbers into groupings of three should be omitted, and digits should be placed without spaces or other separators both to left and right of the decimal point. To facilitate convenient reading, effort should be made, through selection of appropriate prefixes, to limit the number of digits to the left of a decimal point to four or less.

4.8 Derived Units. In symbols for derived units, a center dot is used to indicate multiplication (for example, N·m), and a slash to indicate division (for example, kg/m^3). Symbols to the left of the slash are in the numerator, and symbols to the right are in the denominator.

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Appendix A — SI Units and Conversions for Quantities Commonly Used in Defining Characteristics and Properties of Mechanical Fasteners

Quantity	Unit	Symbol	Conversions From Customary Units (1)			Approximate Equivalencies Between SI and U.S. Customary Units (2)
			To Convert From	To	Multiply By	
length	meter millimeter micrometer	m mm µm	inch foot foot	mm mm m	2.540000* E + 01 3.048000* E + 02 3.048000* E – 01	25 mm = 1 in. 300 mm = 1 ft 25 µm = .001 in.
mass	kilogram gram megagram	kg g Mg	ounce pound ton (2000 lb) ton (2000 lb)	g kg kg Mg	2.834952 E + 01 4.535924 E – 01 9.071847 E + 02 9.071847 E – 01	28 g = 1 oz 1 kg = 35 oz 1 kg = 2.2 lbs 1 Mg = 2200 lbs
density	kilogram per cubic meter	kg/m³	pounds per cubic foot	kg/m³	1.601846 E + 01	16 kg/m³ = 1 lb/ft³
temperature	degree Celsius	°C	degrees Fahrenheit	°C	°C = 5/9 (°F – 32)*	0°C = 32°F (exact) 20°C = 68°F (exact) 100°C = 212°F (exact) 480°C = 900°F
area	square meter square millimeter	m² mm²	square inch square foot	mm² m²	6.451600* E + 02 9.290304* E – 02	645 mm² = 1 in.² 1 m² = 11 ft²
volume	cubic meter cubic millimeter	m³ mm³	cubic inch cubic foot cubic yard	mm³ m³ m³	1.638706 E + 04 2.831685 E – 02 7.645549 E – 01	16400 mm³ = 1 in.³ 1 m³ = 35 ft³ 1 m³ = 1.3 yd³
force	newton kilonewton meganewton	N kN MN	ounce-force pound-force pound-force kip (1000 lbf) kip	N N kN kN MN	2.780139 E – 01 4.448222 E + 00 4.448222 E – 03 4.448222 E + 00 4.448222 E – 03	1 N = 3.6 oz 4.4 N = 1 lbf 1 kN = 225 lbf 1 MN = 225 kips
stress	megapascal	MPa	pound-force/inch² (psi) kips/inch² (ksi)	MPa MPa	6.894757 E – 03 6.894757 E + 00	1MPa = 145 psi 7 MPa = 1000 psi 7 MPa = 1 ksi
torque	newton-meter	N·m	inch ounce inch pound foot pound	N·m N·m N·m	7.061552 E – 03 1.129848 E – 01 1.355818 E + 00	1 N·m = 140 in. oz 1 N·m = 9 in. lb 1.4 N·m = 1 ft. lb 1 N·m = .75 ft. lb

NOTES:

1. Conversion factors that are exact are followed by a *. Other conversion factors have been rounded in accordance with accepted rules, and conversions will be accurate only to the sixth decimal place.

   Conversion factors are presented for ready adaption to computer read-out and electronic data transmission. The factors are written as a number greater than one and less than ten with six decimal places. This number is followed by the letter E (for exponent), a plus or minus symbol, and two digits which indicate the power of 10 by which the number must be multiplied to obtain the correct conversion. For example: 6.894757 E – 03 is 0.006894757. Similarly, 1.638706 E + 04 is 16387.06.

2. The relationships given in this column are not exact, except for those noted. All others are rounded equivalencies and are presented strictly to give a quick appreciation of the magnitude of SI quantities in comparison with those expressed in U.S. customary units. None of these relationships should be used when making a conversion to SI units.

WHAT IS A SCREW? WHAT IS A BOLT?

One of the questions most frequently asked about fasteners during the past decades has been: *"What's the difference between a screw and a bolt?"* A seemingly innocent question, it is nevertheless one that until 1965 did not lend itself to a positive clear-cut answer. Every "expert" had an answer, usually different from others, and no matter how logical or persuasive it was, it seemed that the criteria employed to differentiate screws from bolts permitted far more exceptions to the rule than compliance with it.

While many engineers looked upon this question as an interesting exercise in semantics, it created for the fastener manufacturer and his customer an increasingly troublesome variety of problems. By the early 60's, it became quite clear that the need to establish a pattern of consistency in the nomenclature of threaded fasteners could no longer be ignored.

It just so happened that Subcommittee 2 of Standards Committee B18 of the American National Standards Institute was studying the possibility of simplifying the standards for square and hexagon bolts, screws, and nuts. Recognizing that conflicts in product terminology existed just within the few products under its own technical responsibility, the Subcommittee volunteered to prepare definitions, together with an identification procedure, which would permit the positive classification of any externally headed and threaded fastener as a bolt or a screw.

In accepting this assignment, the Subcommittee was aware that certain basic factors of fastener life were inviolable. They realized that most of the product names being currently used had long histories of acceptance commercially, and that massive changes, regardless upon what logic they might be based, would not be welcomed. They also appreciated that any new definition for a bolt and a screw should reflect to the maximum degree possible generic understandings of what these products really are. Further, they knew that any procedure designed to differentiate screws from bolts must be simple, quickly performed, primarily visual, and independent of an intimate knowledge of product design and manufacturing methods. Moreover, the conclusion yielded by the investigation should be reproducible.

Finding the Solution

The first step, of course, was a study of encyclopedia and dictionary definitions. Previous efforts within this country to identify such products were reviewed, and also the basis of differentiation recognized in other countries of the world were considered. The one common thread that seemed to wind its way through the many principles examined was that **screws are used in tapped holes; bolts are used with nuts.**

This one generally accepted generic difference set the stage for solution of the riddle. By introducing a small, yet novel, twist in this concept, suddenly, for the first time, black and white definitions materialized, and the gray area of overlap disappeared.

Once the Subcommittee had accepted this new concept, it was a logical continuation to analyze the principal engineering features of a threaded fastener which give it the capability of being used in a tapped hole. As soon as this work was completed, a specification was drafted, presenting the new definitions and outlining a step-by-step procedure for determining whether a headed and threaded product should be properly identified as a bolt or as a screw. The specification was circulated and following further refinement, was given final endorsement by the Subcommittee and approval by ASME Standards Committee B18. "Specifications for Identification of Bolts and Screws" was

WHAT IS A SCREW? WHAT IS A BOLT?

published for the first time as an Appendix of the newly issued "American National Standard Square and Hex Bolts and Screws", ANSI B18.2.1-1965.

The new subtlety involved simply modifying the intent of the criterion, "screws are used in tapped holes," to be: "screws have the capability of being used in tapped holes." This change led to an extremely simple and yet surprisingly pure set of criteria for distinguishing a bolt from a screw. **The basic premise is that if a fastener is so designed as to permit it to be properly assembled into a tapped hole, it is a screw.** If, on the other hand, the design of the fastener indicates that it is not suited for use in a tapped hole and should be assembled with a nut, it is a bolt. Thus, the difference is based on the design capability of the fastener, and not on actual service application. This new approach effectively removes the doubt from those fasteners which are used sometimes in tapped holes and sometimes with nuts.

How It Works

To see how the system works, consider some of the more familiar types of threaded fasteners and how they fit the definitions and identification procedure. Many are immediately obvious, by the application of the primary criteria of ASME B18.2.1 Appendix B. Wood screws, lag screws, and most types of tapping screws do not have thread forms which can accommodate standard nuts; therefore, these products are automatically classified as screws. Plow, carriage, track, elevator, and step bolts have head configurations which prevent their being tightened by turning the head during assembly. Consequently, this makes their use in a tapped hole impractical, and automatically classifies these products as bolts.

This screening out still leaves a number of externally threaded fasteners, such as square bolts, hex cap screws, hex bolts, machine screws, and socket head cap screws, which have an indicated dual ability to be turned into a tapped hole, or to be assembled with a nut. However, in accordance with the ASME B18.2.1 Appendix, if the majority of the design characteristics assist the proper use in a tapped or other preformed hole, the product is a screw regardless of its installed service application. The supplementary criteria are then applied to determine if its primary characteristics contribute to its function as a screw. These supplementary criteria include the following elements:

— Bearing Surface
— Head Angularity
— Body Control
— Shank Straightness
— Thread Concentricity
— Thread Length
— Point
— Length Tolerance

Applying these criteria, the majority being present would define a product in question as a screw.

The criteria established are non-dimensional and apply equally to either inch or metric fasteners. The complete information may be found in Appendix B of ASME B18.2.1: Specifications for Identification of Bolts and Screws.

Interestingly, of all of the many standard types of fasteners now covered by American National Standards, only in one or two isolated instances was a change in nomenclature from screw to bolt, or bolt to screw, necessary to provide a complete pattern of consistency. These changes were completed in the late 1960's. Importantly, as new products are designed and introduced into American National Standards and/or ASME standards, they can be assigned correct nomenclature at the outset.

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IFI ENGINEERING COMMITTEE RECOMMENDED HOLE SIZES – METRIC TYPES D, F, G, T TAPPING SCREWS

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IFI NOTE:

The Engineering Committee of the IFI's Division I - Industrial Products recognized the need to develop hole size recommendations for users of metric Types D, F, G and T tapping screws. In early 1996, effort was undertaken to develop the following information not yet incorporated into ASME B18.6.5M. It is presented here for guidance purposes. It should be noted, however, that because conditions and considerations having a bearing upon screw applications differ widely, it may be necessary or desirable to vary the hole from the suggested size to best suit a given application. Users should consult with manufacturers concerning specific applications.

Recommended Hole Sizes - Metric Types D, F, G, T

Size	Material Thickness	Steel Hole Size	Drill Size	Aluminum Hole Size	Drill Size	Cast Iron Hole Size	Drill Size	Die Cast - Zinc or Alum	
								Hole Size	Drill Size
M2 - 0.4	1.27	1.69	51	1.61	52	1.74	1.75 mm	1.69	51
	1.52	1.69	51	1.69	51	1.74	1.75 mm	1.69	51
	2.11	1.69	51	1.69	51	1.74	1.75 mm	1.76	1.75 mm
	2.77	1.69	51	1.69	51	1.81	1.81 mm	1.76	1.75 mm
	3.18	1.74	1.75 mm	1.69	51	1.81	1.81 mm	1.76	1.75 mm
	3.56	1.74	1.75 mm	1.69	51	1.81	1.81 mm	1.76	1.75 mm
M2.5 - 0.45	1.27	2.09	45	2.04	2.05 mm	2.26	43	2.12	2.10 mm
	1.52	2.09	45	2.09	45	2.26	43	2.12	2.10 mm
	2.11	2.12	2.10 mm	2.12	2.10 mm	2.26	43	2.20	2.20 mm
	2.77	2.20	2.20 mm	2.12	2.10 mm	2.26	43	2.26	43
	3.18	2.20	2.20 mm	2.12	2.10 mm	2.26	43	2.26	43
	3.56	2.20	2.20 mm	2.20	2.20 mm	2.31	2.30 mm	2.26	43
	4.78	2.26	43	2.20	2.20 mm	2.31	2.30 mm	2.26	43
M3 - 0.5	1.27	2.52	39	2.52	39	2.73	2.75 mm	2.64	37
	1.52	2.52	39	2.52	39	2.73	2.75 mm	2.64	37
	2.11	2.61	2.60 mm	2.52	39	2.77	35	2.64	37
	2.77	2.64	37	2.61	2.60 mm	2.77	35	2.64	37
	3.18	2.70	2.70 mm	2.61	2.60 mm	2.77	35	2.73	2.75 mm
	3.56	2.70	2.70 mm	2.61	2.60 mm	2.77	35	2.73	2.75 mm
	4.78	2.77	35	2.70	2.70 mm	2.80	2.80 mm	2.73	2.75 mm
M3.5 - 0.6	1.27	2.93	32	2.93	32	3.15	3.20 mm	3.04	31
	1.52	3.00	3.00 mm	2.93	32	3.15	3.20 mm	3.15	3.20 mm
	2.11	3.04	31	2.96	32	3.22	3.20 mm	3.15	3.20 mm
	2.77	3.04	31	3.00	3.00 mm	3.22	3.20 mm	3.15	3.20 mm
	3.18	3.04	31	3.04	31	3.22	3.20 mm	3.15	3.20 mm
	3.56	3.15	3.20 mm	3.04	31	3.22	3.20 mm	3.15	3.20 mm
	4.78	3.22	3.20 mm	3.15	3.20 mm	3.26	30	3.15	3.20 mm
	6.35	3.22	3.20 mm	3.22	3.20 mm	3.26	30	3.15	3.20 mm

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IFI ENGINEERING COMMITTEE RECOMMENDED HOLE SIZES – METRIC TYPES D, F, G, T TAPPING SCREWS

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Recommended Hole Sizes - Metric Types D, F, G, T (Continued)

Size	Material Thickness	Steel Hole Size	Drill Size	Aluminum Hole Size	Drill Size	Cast Iron Hole Size	Drill Size	Die Cast - Zinc or Alum	
								Hole Size	Drill Size
M4 - 0.7	1.27	3.33	3.30 mm	3.33	3.30 mm	3.59	3.60 mm	3.46	29
	1.52	3.38	3.40 mm	3.33	3.30 mm	3.68	3.70 mm	3.51	3.50 mm
	2.11	3.42	29	3.33	3.30 mm	3.68	3.70 mm	3.51	3.50 mm
	2.77	3.51	3.50 mm	3.42	29	3.68	3.70 mm	3.51	3.50 mm
	3.18	3.51	3.50 mm	3.42	29	3.68	3.70 mm	3.59	3.60 mm
	3.56	3.59	3.60 mm	3.51	3.50 mm	3.68	3.70 mm	3.59	3.60 mm
	4.78	3.68	3.70 mm	3.59	3.60 mm	3.68	3.70 mm	3.59	3.60 mm
	6.35	3.68	3.70 mm	3.68	3.70 mm	3.72	26	3.68	3.70 mm
	7.92	3.68	3.70 mm	3.68	3.70 mm	3.72	26	3.68	3.70 mm
M5 - 0.8	1.27	4.24	4.25 mm	4.19	4.20 mm	4.58	15	4.44	4.40 mm
	1.52	4.29	4.30 mm	4.24	4.25 mm	4.58	15	4.53	4.50 mm
	2.11	4.44	4.40 mm	4.29	4.30 mm	4.63	14	4.53	4.50 mm
	2.77	4.44	4.40 mm	4.34	18	4.63	14	4.53	4.50 mm
	3.18	4.53	4.50 mm	4.39	17	4.63	14	4.53	4.50 mm
	3.56	4.58	15	4.44	4.40 mm	4.63	14	4.53	4.50 mm
	4.78	4.63	14	4.53	4.50 mm	4.68	13	4.58	15
	6.35	4.63	14	4.63	14	4.68	13	4.58	15
	7.92	4.63	14	4.63	14	4.68	13	4.63	14
	9.52	4.63	14	4.63	14	4.68	13	4.63	14
M6 - 1.0	2.11	5.24	5.25 mm	5.12	7	5.54	5.50 mm	5.36	5.40 mm
	2.77	5.36	5.40 mm	5.18	6	5.54	5.50 mm	5.36	5.40 mm
	3.18	5.36	5.40 mm	5.24	5.25 mm	5.54	5.50 mm	5.36	5.40 mm
	3.56	5.36	5.40 mm	5.24	5.25 mm	5.54	5.50 mm	5.36	5.40 mm
	4.78	5.54	5.50 mm	5.36	5.40 mm	5.61	2	5.36	5.40 mm
	6.35	5.54	5.50 mm	5.54	5.50 mm	5.61	2	5.54	5.50 mm
	7.92	5.54	5.50 mm	5.54	5.50 mm	5.61	2	5.54	5.50 mm
	9.52	5.54	5.50 mm	5.54	5.50 mm	5.61	2	5.54	5.50 mm
	12.70	5.54	5.50 mm	5.54	5.50 mm	5.61	2	5.54	5.50 mm
M8 - 1.25	2.77	7.13	K	6.90	6.90 mm	7.44	7.40 mm	7.13	K
	3.18	7.13	K	7.05	J	7.44	7.40 mm	7.28	7.30 mm
	3.56	7.28	7.30 mm	7.05	J	7.44	7.40 mm	7.28	7.30 mm
	4.78	7.44	7.40 mm	7.28	7.30 mm	7.51	7.50 mm	7.28	7.30 mm
	6.35	7.44	7.40 mm	7.44	7.40 mm	7.51	7.50 mm	7.28	7.30 mm
	7.92	7.44	7.40 mm	7.44	7.40 mm	7.51	7.50 mm	7.44	7.40 mm
	9.52	7.44	7.40 mm	7.44	7.40 mm	7.51	7.50 mm	7.44	7.40 mm
	12.70	7.44	7.40 mm	7.44	7.40 mm	7.51	7.50 mm	7.44	7.40 mm
M10 - 1.5	3.18	9.14	9.10 mm	8.86	9.00 mm	9.32	9.30 mm	9.14	9.10 mm
	3.56	9.14	9.10 mm	8.96	9.00 mm	9.32	9.30 mm	9.14	9.10 mm
	4.78	9.32	9.30 mm	9.14	9.10 mm	9.32	9.30 mm	9.14	9.10 mm
	6.35	9.42	9.40 mm	9.32	9.30 mm	9.32	9.30 mm	9.23	9.25 mm
	7.92	9.42	9.40 mm	9.32	9.30 mm	9.32	9.30 mm	9.23	9.25 mm
	9.52	9.42	9.40 mm	9.32	9.30 mm	9.32	9.30 mm	9.32	9.30 mm
	12.70	9.42	9.40 mm	9.32	9.30 mm	9.32	9.30 mm	9.32	9.30 mm

NOTES:

1. Because conditions differ widely, it may be necessary to vary the hole size to best suit a particular application. Refer to text on first page of Appendix VI of B18.6.5M, page K–9 and the IFI Note page K–16.
2. The drill sizes listed are closest approximate size to the hole diameters shown.

ISO SYSTEM OF LIMITS AND FITS

INTRODUCTION

The ISO System of Limits and Fits relates to tolerances on parts and components and to the fits corresponding to their assembly.

The system is based on a series of arithmetically related magnitudes and placements of tolerances graded to suit all classes of precision from the finest to the coarsest. The system was originally structured on the relationship of circular shafts and holes, however, it is broadly applicable to the tolerancing of the external and internal dimensions of all types of component parts, including mechanical fasteners.

In the development of the ISO standards for fasteners, the ISO System for Limits and Fits was used extensively in the determination of suitable product tolerances. Consequently, the following brief introduction may be helpful not only in understanding the derivation of the tolerances specified for many of the fastener products presented in this book, but also as a possible guide in the selection of appropriate tolerances for specially designed fasteners and other headed and formed parts.

Due to inherent and unavoidable inaccuracies of manufacturing methods, no part can be made precisely to exact dimensions. To meet functional requirements it is customary engineering practice to establish a zone or envelope (limits of size) within which the actual product as manufactured must lie. The arithmetic difference between the limits permitted for each dimension is its tolerance. Additionally, it is normal practice to specify a basic size for each dimension with the placement of each of the two limits of size being located relative to this basic size. The magnitude and sign of the placement, known as the deviation, are obtained by subtracting the basic size from the applicable limit. Fig. 1 illustrates these relationships.

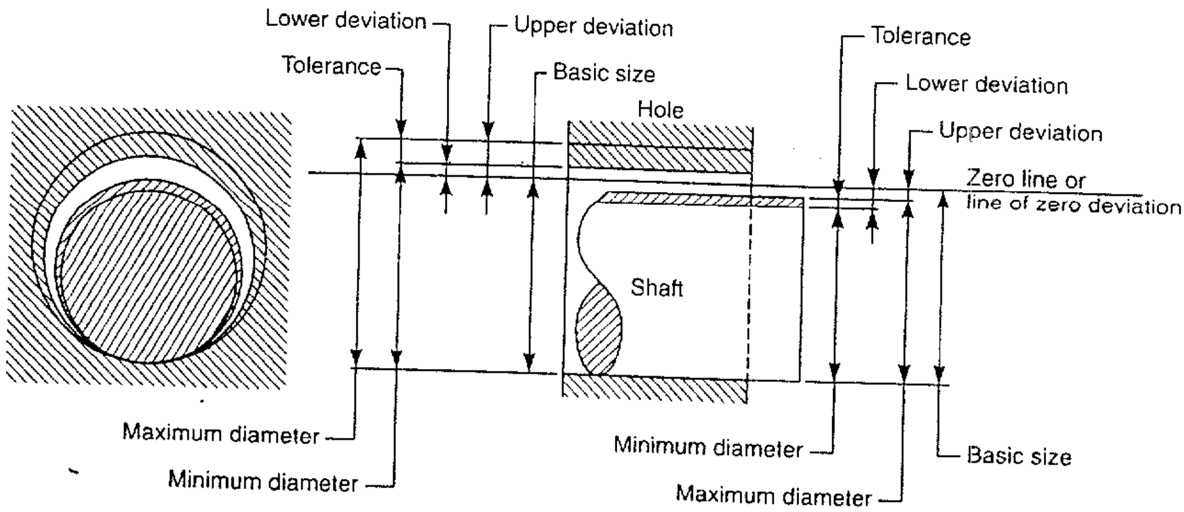

Fig. 1 Diagrammatic Illustration of Definitions

ISO SYSTEM OF LIMITS AND FITS

Table 1 Standard Tolerances for ISO Tolerance Grades

Nominal Dimension mm		ISO Tolerance Grade								
over	to	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16	IT17
—	3	0.025	0.040	0.060	0.10	0.14	0.25	0.40	0.60	1.00
3	6	0.030	0.048	0.075	0.12	0.18	0.30	0.48	0.75	1.20
6	10	0.036	0.058	0.090	0.15	0.22	0.36	0.58	0.90	1.50
10	18	0.043	0.070	0.11	0.18	0.27	0.43	0.70	1.10	1.80
18	30	0.052	0.084	0.13	0.21	0.33	0.52	0.84	1.30	2.10
30	50	0.062	0.100	0.16	0.25	0.39	0.62	1.00	1.60	2.50
50	80	0.074	0.120	0.19	0.30	0.46	0.74	1.20	1.90	3.00
80	120	0.087	0.140	0.22	0.35	0.54	0.87	1.40	2.20	3.50
120	180	0.100	0.160	0.25	0.40	0.63	1.00	1.60	2.50	4.00
180	250	0.115	0.185	0.29	0.46	0.72	1.15	1.85	2.90	4.60
250	315	0.130	0.210	0.32	0.52	0.81	1.30	2.10	3.20	5.20
315	400	0.140	0.230	0.36	0.57	0.89	1.40	2.30	3.60	5.70
400	500	0.155	0.250	0.40	0.63	0.97	1.55	2.50	4.00	6.30

All tolerances are in millimeters.

DEFINITIONS

Size — a number expressing in a particular unit the numerical value of a feature.

Actual size — the size of the feature as obtained by measurement.

Basic size — the size by reference to which the limits of size are fixed. The basic size (frequently called the nominal size) is the same for both members of a fit.

Limits of size — the maximum and minimum sizes permitted for a feature.

Deviation — the algebraic difference between a size (actual, maximum, etc.) and the corresponding basic size.

Upper deviation — the algebraic difference between the maximum limit of size and the corresponding basic size.

Lower deviation — the algebraic difference between the minimum limit of size and the corresponding basic size.

Fundamental deviation — that one of the two deviations, nearest to the zero line, which is conventionally chosen to define the position of the tolerance zone in relation to the zero line.

Zero line — in a graphical representation of limits and fits, the straight line to which deviations are referred. The zero line is the line of zero deviation and represents the basic size.

Tolerance — the difference between the maximum limit of size and the minimum limit of size (or in other words the algebraic difference between the upper deviation and the lower deviation). Tolerance is an absolute value without sign.

Tolerance zone — in a graphical representation of tolerances, this is the area between the

TECHNICAL DATA

ISO SYSTEM OF LIMITS AND FITS

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Table 2 Limits of Tolerances— Upper and Lower Deviations

Nominal Dimension over	Nominal Dimension to	h10	h11	h12	h13	h14	h15	h16	h17	js13	js14	js15	js16	js17	H13	H14	H15
		Fundamental Deviations															
—	3	0 −0.040	0 −0.060	0 −0.10	0 −0.14	0 −0.25	0 −0.40	0 −0.60	0 −1.00	±0.07	±0.125	±0.20	±0.30	±0.50	+0.14 0	+0.25 0	+0.40 0
3	6	0 −0.048	0 −0.075	0 −0.12	0 −0.18	0 −0.30	0 −0.48	0 −0.75	0 −1.20	±0.09	±0.15	±0.24	±0.375	±0.60	+0.18 0	+0.30 0	+0.48 0
6	10	0 −0.058	0 −0.090	0 −0.15	0 −0.22	0 −0.36	0 −0.58	0 −0.90	0 −1.50	±0.11	±0.18	±0.29	±0.45	±0.75	+0.22 0	+0.36 0	+0.58 0
10	18	0 −0.070	0 −0.11	0 −0.18	0 −0.27	0 −0.43	0 −0.70	0 −1.10	0 −1.80	±0.135	±0.215	±0.35	±0.55	±0.90	+0.27 0	+0.43 0	+0.70 0
18	30	0 −0.084	0 −0.13	0 −0.21	0 −0.33	0 −0.52	0 −0.84	0 −1.30	0 −2.10	±0.165	±0.26	±0.42	±0.65	±1.05	+0.33 0	+0.52 0	+0.84 0
30	50	0 −0.100	0 −0.16	0 −0.25	0 −0.39	0 −0.62	0 −1.00	0 −1.60	0 −2.50	±0.185	±0.31	±0.50	±0.80	±1.25	+0.39 0	+0.62 0	+1.00 0
50	80	0 −0.120	0 −0.19	0 −0.30	0 −0.46	0 −0.74	0 −1.20	0 −1.90	0 −3.00	±0.23	±0.37	±0.60	±0.95	±1.50	+0.46 0	+0.74 0	+1.20 0
80	120	0 −0.140	0 −0.22	0 −0.35	0 −0.54	0 −0.87	0 −1.40	0 −2.20	0 −3.50	±0.27	±0.435	±0.70	±1.10	±1.75	+0.54 0	+0.87 0	+1.40 0
120	180	0 −0.160	0 −0.25	0 −0.40	0 −0.63	0 −1.00	0 −1.60	0 −2.50	0 −4.00	±0.315	±0.50	±0.80	±1.25	±2.00	+0.63 0	+1.00 0	+1.60 0
180	250	0 −0.185	0 −0.29	0 −0.46	0 −0.72	0 −1.15	0 −1.85	0 −2.90	0 −4.60	±0.36	±0.575	±0.925	±1.45	±2.30	+0.72 0	+1.15 0	+1.85 0
250	315	0 −0.210	0 −0.32	0 −0.52	0 −0.81	0 −1.30	0 −2.10	0 −3.20	0 −5.20	±0.405	±0.65	±1.05	±1.60	±2.60	+0.81 0	+1.30 0	+2.10 0
315	400	0 −0.230	0 −0.36	0 −0.57	0 −0.89	0 −1.40	0 −2.30	0 −3.60	0 −5.70	±0.445	±0.70	±1.15	±1.80	±2.85	+0.89 0	+1.40 0	+2.30 0
400	500	0 −0.250	0 −0.40	0 −0.63	0 −0.97	0 −1.55	0 −2.50	0 −4.00	0 −6.30	±0.485	±0.775	±1.25	±2.00	±3.15	+0.97 0	+1.55 0	+2.50 0

All values are in millimeters.

two lines representing the limits of tolerance and is defined by its magnitude (tolerance) and by its position in relation to the zero line.

Tolerance grade — in a standardized system of limits and fits, a group of tolerances considered to correspond to the same level of accuracy for all basic sizes.

Unilateral tolerance — a tolerance placed entirely to one side of the basic size.

Bilateral tolerance — a tolerance placed partially to one side of the basic size with the remainder placed to the other.

Shaft — a term used by convention to designate all external features of a part, including parts which are not cylindrical.

Hole — a term used by convention to designate all internal features of a part, including parts which are not cylindrical.

Fit — the relationship resulting from the difference, before assembly, between the sizes of two parts which are to be assembled.

Clearance — the difference between the external size and the internal size, before assembly, when this difference is positive.

Interference — the difference between the external size and the internal size, before assembly, when this difference is negative.

THE SYSTEM

The ISO System of Limits and Fits is based on a series of tolerances and deviations. The In-

ISO SYSTEM OF LIMITS AND FITS

ternational Tolerance Grades (IT) are given in Table 1. Grades are designated by numerals, with ascending order signifying larger tolerances. The specified tolerances for each grade are approximately 60 percent larger than those of the next lower grade. Every fifth grade the tolerance values repeat, but at a multiple of 10. Each tolerance applies to a range of sizes. For example, tolerance grade IT13 specifies the same tolerance of 0.33 mm for all features with a basic size (nominal dimension) of 18 up to and including 30 mm.

Fundamental deviations are designated by one or two letters. In the full ISO system there are 27 fundamental deviations (placement of the tolerance of a feature relative to its basic size); however, only a very few have frequent use in the tolerancing of fasteners, specifically *h*, *js*, and *H*. Fundamental deviations designated using lower case letters apply to external dimensions (such as head widths, diameters and heights, body diameters, nut thicknesses, product lengths, etc.) and those using a capital letter apply to internal dimensions (such as hole diameters, socket widths, clearance holes, etc.). Fundamental deviation *h* signifies application of the tolerance unilaterally negative, thus the basic size is the maximum size. Fundamental deviation *js* signifies application of the tolerance bilaterally divided equally plus and minus from the basic size. Fundamental deviation *H* signifies application of the tolerance unilaterally positive, thus the basic size is the minimum size. Table 2 details the upper and lower deviations for the most commonly specified tolerances for the various features of fasteners.

Examples:

ISO 4759/I specifies h13 tolerances for width across flats of hex nuts. ASME B18.2.4.1, page D–3, specifies that M14 nuts have a basic width across flats equal to 21 mm. Referring to Table 2, the h13 tolerance for this nominal dimension is plus 0, minus 0.33 mm. Consequently, the width across flats for M14 nuts is 21.00/20.67 mm.

ISO 4759/I specifies that hex bolts have a body diameter tolerance equal to ±IT15. According to Table 1, for a nominal dimension of 20 mm, the IT15 tolerance is 0.84 mm. Consequently, the body diameter limits for hex structural bolts, ANSI B18.2.3.7M, page F–11, are 20.84/19.16 mm.

DOCUMENTS

ISO 286 — The ISO System of Limits and Fits

ANSI B4.2-1978 (R 1994) — Preferred Metric Limits and Fits

ISO 4759/I — Tolerances for Fasteners, Part I: Bolts, Screws and Nuts with Thread Diameters ≥ 1.6 and ≤ 150 mm and Product Grades A, B and C

ISO 4759/II — Tolerances for Fasteners, Part II: Bolts, Screws and Nuts with Thread Diameters from 1 up to 3 mm and Product Grade F, for Fine Mechanics

ISO 4759/III — Tolerances for Fasteners, Part III: Washers for Metric Bolts, Screws and Nuts with Thread Diameters from 1 up to and including 150 mm, Product Grades A and C

ISO standards are available from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036. ANSI B4.2 is available from either ANSI or the American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, U.S.A.

WEIGHTS OF METRIC FASTENERS

IFI NOTES:

1. *The weights given in Tables 2, 3 and 4 are for steel fasteners based on the dimensions given in the applicable ANSI or ASME standard. All weights are in kilograms (1 kg = 2.205 lbs).*

2. *To obtain the weight of fasteners made of materials other than steel, multiply the weight of the steel fastener by the conversion factor for the corresponding material as given in Table 1.*

Table 1 Weight Conversion Table for Materials

Common Fastener Materials	Grams per cm^3	Conversion Factor[1]
Carbon and Low Alloy Steels Type 304 Stainless Steel Type 410 Stainless Steel	7.833 7.920 7.747	1.000 1.011 0.989
Leaded Brass (Free Cutting Brass) Cold Heading Brass (Yellow Brass) Naval Brass	8.499 8.476 8.413	1.085 1.082 1.074
Low Silicon Bronze High Silicon Bronze Muntz Metal	8.750 8.523 8.382	1.117 1.088 1.070
Phosphor Bronze Manganese Bronze Aluminum Bronze	8.805 8.358 8.162	1.124 1.067 1.042
Copper Cupro Nickel Monel Metal	8.969 8.938 8.828	1.145 1.141 1.127
"K" Monel Inconel Aluminum – 17-S	8.476 8.499 2.797	1.082 1.085 0.357
Aluminum – 24-S Titanium Alloy (4 Al, 4 Mn) Beryllium	2.765 4.512 1.825	0.353 0.576 0.233

NOTE:
1. Carbon steel at 7.833 g/cm^3

WEIGHTS OF METRIC FASTENERS

Table 2 Weights of Metric Hex Cap Screws — ASME B18.2.3.1M
Approximate weight of 100 steel screws in kilograms

Screw Length \ Screw Size	M5 × 0.8	M6 × 1	M8 × 1.25	M10 × 1.5 (16)	M10 × 1.5 (15)	M12 × 1.75	M14 × 2	M16 × 2	M20 × 2.5	M24 × 3
8	0.237	—	—	—	—	—	—	—	—	—
10	0.261	0.425	—	—	—	—	—	—	—	—
12	0.285	0.459	0.939	—	—	—	—	—	—	—
14	0.308	0.493	1.00	1.74	1.61	—	—	—	—	—
16	0.332	0.527	1.06	1.84	1.71	2.71	4.07	—	—	—
20	0.385	0.595	1.19	2.03	1.90	2.99	4.46	—	—	—
25	0.459	0.699	1.34	2.28	2.15	3.35	4.94	7.00	—	—
30	0.533	0.806	1.53	2.52	2.39	3.70	5.44	7.66	13.3	—
35	0.608	0.914	1.72	2.82	2.69	4.06	5.92	8.31	14.4	22.7
40	0.681	1.02	1.91	3.12	2.99	4.90	6.41	8.96	15.4	24.2
45	0.756	1.13	2.10	3.42	3.29	5.33	7.00	9.64	16.4	25.7
50	0.830	1.24	2.29	3.72	3.59	5.77	7.59	10.4	17.4	27.1
55	—	1.34	2.49	4.02	3.89	6.20	8.18	11.2	18.5	28.6
60	—	1.45	2.68	4.32	4.19	6.63	8.78	12.0	19.7	30.1
65	—	—	2.85	4.63	4.50	7.07	9.37	12.7	20.9	31.7
70	—	—	3.06	4.93	4.80	7.50	9.96	13.5	22.1	33.4
75	—	—	3.25	5.23	5.10	7.93	10.5	14.3	23.4	35.2
80	—	—	3.44	5.53	5.40	8.36	11.1	15.1	24.6	36.9
85	—	—	—	5.83	5.70	8.80	11.7	15.8	25.8	38.7
90	—	—	—	6.13	6.00	9.23	12.3	16.6	27.0	40.4
100	—	—	—	6.73	6.60	10.1	13.5	18.2	29.4	43.9
110	—	—	—	—	—	11.0	14.7	19.7	31.8	47.4
120	—	—	—	—	—	11.8	15.9	21.3	34.2	50.9
130	—	—	—	—	—	—	16.9	22.7	36.4	54.1
140	—	—	—	—	—	—	18.1	24.2	38.9	57.6
150	—	—	—	—	—	—	—	25.8	41.3	61.1
160	—	—	—	—	—	—	—	27.3	43.7	64.6
170	—	—	—	—	—	—	—	—	46.1	68.1
180	—	—	—	—	—	—	—	—	48.5	71.6
190	—	—	—	—	—	—	—	—	51.0	75.1
200	—	—	—	—	—	—	—	—	52.9	77.8
220	—	—	—	—	—	—	—	—	—	84.8
240	—	—	—	—	—	—	—	—	—	91.8

NOTE: Dimensions of ASME B18.2.3.1M metric cap screws are given on page C-1.

(Table continued on page K-34)

WEIGHTS OF METRIC FASTENERS

Table 2 Weights of Metric Hex Cap Screws — ASME B18.2.3.1M (Continued)
Approximate weight of 100 steel screws in kilograms

Screw Length \ Screw Size	M30 × 3.5	M36 × 4	M42 × 4.5	M48 × 5	M56 × 5.5	M64 × 6	M72 × 6	M80 × 6	M90 × 6	M100 × 6
40	44.2	—	—	—	—	—	—	—	—	—
45	46.5	74.5	—	—	—	—	—	—	—	—
50	48.9	77.9	117	—	—	—	—	—	—	—
55	51.2	81.3	121	—	—	—	—	—	—	—
60	53.6	84.7	126	181	—	—	—	—	—	—
65	55.9	88.1	131	187	—	—	—	—	—	—
70	58.2	91.5	135	193	246	—	—	—	—	—
75	60.6	94.8	140	200	263	—	—	—	—	—
80	63.2	98.2	145	206	279	408	—	—	—	—
85	65.9	102	149	212	296	419	—	—	—	—
90	68.7	105	154	218	313	430	572	—	—	—
100	74.1	113	163	230	330	452	601	776	—	—
110	79.6	121	173	242	347	474	629	812	—	—
120	85.1	129	182	255	363	496	657	847	1150	1510
130	90.1	136	194	268	380	518	686	883	1190	1570
140	95.6	144	205	282	397	540	714	918	1240	1620
150	101	152	215	296	416	562	742	953	1290	1680
160	107	160	226	310	435	584	771	989	1330	1740
170	112	167	237	324	454	609	799	1020	1380	1790
180	117	175	247	338	473	634	827	1060	1420	1850
190	123	183	258	352	492	659	856	1090	1470	1910
200	127	190	267	364	508	680	888	1130	1510	1960
220	138	206	288	392	546	730	951	1210	1600	2080
240	149	221	310	420	584	780	1010	1290	1700	2190
260	160	237	331	448	622	830	1080	1360	1800	2310
280	171	253	353	476	660	880	1140	1440	1900	2430
300	182	269	374	504	699	930	1200	1520	2000	2560
340	—	300	417	560	775	1029	1330	1680	2190	2800
380	—	332	460	616	851	1129	1460	1830	2390	3040
420	—	—	502	672	927	1229	1580	1990	2590	3290
460	—	—	—	727	1000	1328	1710	2140	2790	3530
500	—	—	—	783	1080	1428	1840	2300	2980	3780
600	—	—	—	—	1270	1677	2150	2690	3480	4390
700	—	—	—	—	—	1926	2470	3080	3970	5000
800	—	—	—	—	—	—	—	3470	4460	5610
900	—	—	—	—	—	—	—	—	4960	6220
1000	—	—	—	—	—	—	—	—	—	6820

NOTE: Dimensions of ASME B18.2.3.1M metric cap screws are given on page C–1.

WEIGHTS OF METRIC FASTENERS

Table 3 Weights of Metric High Strength Structural Bolts — ANSI B18.2.3.7M
Approximate weight of 100 steel bolts in kilograms

Bolt Length \ Bolt Size	M16 × 2	M20 × 2.5	M22 × 2.5	M24 × 3	M27 × 3	M30 × 3.5	M36 × 4
45	10.8	—	—	—	—	—	—
50	11.6	19.8	—	—	—	—	—
55	12.3	21.0	26.0	—	—	—	—
60	13.1	22.3	27.5	35.4	—	—	—
65	13.9	23.5	29.0	37.1	50.5	—	—
70	14.7	24.7	30.5	38.9	52.7	64.0	—
75	15.5	26.0	32.0	40.7	55.0	66.8	—
80	16.3	27.2	33.5	42.4	57.2	69.6	108
85	17.1	28.4	34.9	44.2	59.5	72.4	112
90	17.9	29.7	36.4	46.0	61.7	75.1	116
95	18.6	30.9	37.9	47.8	63.9	77.9	120
100	19.4	32.1	39.4	49.5	66.2	80.1	124
110	20.8	34.3	42.1	52.7	70.4	85.6	132
120	22.4	36.8	45.0	56.2	74.9	91.1	140
130	24.0	39.2	48.0	59.7	79.4	96.7	148
140	25.6	41.7	51.0	63.3	83.9	102	155
150	27.1	44.1	54.0	66.8	88.4	108	163
160	28.7	46.6	57.0	70.4	92.8	113	171
170	30.3	49.1	59.9	73.9	97.3	119	179
180	31.8	51.5	62.9	77.5	102	124	187
190	33.4	54.0	65.9	81.0	106	130	195
200	35.0	56.4	68.9	84.6	111	135	203
210	36.6	58.9	71.8	88.1	115	141	211
220	38.2	61.4	74.8	91.6	120	146	219
230	39.7	63.8	77.8	95.2	124	152	227
240	41.3	66.2	80.8	98.7	129	158	235
250	42.9	68.7	83.8	102	133	163	243
260	44.5	71.2	86.7	106	138	169	251
270	46.0	73.7	89.7	109	142	174	259
280	47.6	76.1	92.7	113	147	180	267
290	49.2	78.6	95.7	116	151	185	275
300	50.8	81.1	98.6	120	156	191	283

NOTE: Dimensions of ANSI B18.2.3.7M bolts are given on page F–9.

WEIGHTS OF METRIC FASTENERS

Table 4 Weights of Metric Hex Nuts
Approximate weight of 1000 tapped steel nuts in kilograms

Nom Nut Size	Type of Nut		
	Hex, Style 1 ASME B18.2.4.1M	Hex, Style 2 ANSI B18.2.4.2M	Heavy Hex ANSI B18.2.4.6M
M1.6 × 0.35	0.053	—	—
M2 × 0.4	0.109	—	—
M2.5 × 0.45	0.224	—	—
M3 × 0.5	0.317	0.392	—
M3.5 × 0.6	0.429	0.515	—
M4 × 0.7	0.677	0.820	—
M5 × 0.8	1.22	1.34	—
M6 × 1	2.27	2.51	—
M8 × 1.25	4.94	5.50	—
M10 × 1.5 (16)	9.26	10.3	—
M10 × 1.5 (15)	7.58	8.46	—
M12 × 1.75	14.5	16.2	24.7
M14 × 2	22.8	25.3	36.9
M16 × 2	34.4	38.4	55.4
M20 × 2.5	63.6	72.3	106
M22 × 2.5	—	—	132
M24 × 3	108	122	183
M27 × 3	—	—	263
M30 × 3.5	219	246	340
M36 × 4	377	426	586
M42 × 4.5	—	—	900
M48 × 5	—	—	1350
M56 × 5.5	—	—	1910
M64 × 6	—	—	2620
M72 × 6	—	—	3460
M80 × 6	—	—	4450
M90 × 6	—	—	6330
M100 × 6	—	—	8610

NOTE: Dimensions of ASME B18.2.4.1M nuts are given on page D–3; those of B18.2.4.2M nuts on page D–8; and those of B18.2.4.6M nuts on page D–29.

FASTENER TERMINOLOGY

IFI NOTE:

Terminology for mechanical fasteners is the key for a common understanding of the products, characteristics, processes and installation. There are three basic documents which provide fastener terminology including:

ASME B18.12 – Glossary of Terms for Mechanical Fasteners
ASTM F1789 – Standard Terminology for F-16 Mechanical Fasteners
IFI Glossary of Terms Relating to Aerospace Fasteners

This section contains some of the basic terms used in this book. These terms are frequently used in fastener descriptions and discussion, but are by no means all of the terms used. The reader is encouraged to obtain copies of the above complete documents from their respective publishers, which include many more of the terms which are widely used. The addresses for these sources are found beginning on page K-41.

1. General

Mechanical fasteners are produced by forming which is a scrapless process. Parts are produced at high speeds often exceeding 500 pieces per minute. The speed of production is a variable with size and material as major criteria. Some fasteners may be produced by screw machining which is significantly slower and involves metal removal.

Thread rolling, heat treatment, and plating are some of the numerous secondary operations which may be used to develop a given fastener.

2. Basic Product Terminology

2.1 **Blank** A fastener in some intermediate stage of manufacture.

2.2 **Bolt** A headed and externally threaded mechanical device designed for insertion through holes in assembled parts to mate with a nut and is normally intended to be tightened or released by turning that nut (see page K-5).

2.3 **Fastener** A mechanical device designed specifically to hold, join, couple, assemble, or maintain equilibrium of single or multiple components. The resulting assembly may function dynamically or statically as a primary or secondary component of a mechanism or structure. Based on application intended, a fastener receives varying degrees of built-in precision and engineering capability, insuring adequate, sound service under planned, preestablished environmental conditions.

2.3.1 **Standard Fastener** A fastener which can be referenced from nationally recognized standards and may be produced by any interested party.

2.3.2 **Nonstandard Fastener** One which deviates in some degree from a standard fastener and is often referred to as a **special** fastener.

2.4 **Nut** A perforated block (usually of metal) possessing an internal screw thread, intended for use on an external screw thread such as a bolt or stud for the purpose of tightening or holding two or more bodies in definite relative positions.

2.5 **Pin** A straight cylindrical or tapered fastener, with or without a head, designed to perform a semi-permanent attaching or locating function.

2.6 Retaining Ring A precision-engineered fastener designed to provide an accurately located shoulder for positioning and securing components in an assembly.

2.7 Rivet A headed and unthreaded mechanical device used to assemble two or more components by an applied force which deforms the plain rivet end to develop a completed mechanical joint.

2.8 Screw A headed and externally threaded mechanical device possessing capabilities which permit it to be inserted into holes in assembled parts, of mating with a preformed internal thread or forming its own thread, and of being tightened or released by torquing its head (see page K–5).

2.9 Stud A headless cylindrical fastener, externally threaded on either one or both ends or over its entire length, designed for insertion through holes in assembled parts to either mate with a nut or into a preformed threaded hole or into a hole to form its own thread. Ball studs are not fasteners.

2.10 Threaded Insert An internally threaded bushing designed to be assembled with soft or brittle materials to provide a threaded hole having greater strength, hardness, and wear resistance.

2.11 Washer A thin cylinder having a centrally located hole or partial slot and is used as a component with other fasteners as a spacer, a load distribution element, or to increase resistance to loosening in a fastened joint.

3. Basic Manufacturing Terminology

3.1 Age Hardening is a term which describes the process of increasing the hardness of an alloy through a time-temperature medium. Most often related to those alloys whose hardening mechanisms act through the precipitation of carbides or other interstitials from an unstable solid solution state to form a different and stable matrix, with resultant hardening of the alloy in the optimum aged condition. (Over-aging by an increase of temperature or time, or both, usually results in softening of the alloy, but does not make it unstable.)

3.2 Annealing is a process involving heating and cooling which usually is applied to induce softening. Also used for treatments intended to alter mechanical or physical properties, produce a definite microstructure or remove gases. Stress relieving is a form of annealing applied for the sole purpose of reducing stresses.

3.3 Boltmaker A specialized type of transfer header which forms the head on a blank, may trim the head to a required shape, may point the end and roll a thread.

3.4 Case Hardened A fastener which is case hardened is made of ferrous material which has a surface made harder than the core.

3.5 A Cold Header is a horizontal machine which is supplied with wire or rod at room temperatures and in a continuous manner produces parts by applying machine pressure to cause the metal to flow and form a given configuration.

3.6 Cold Heading is a process at room temperature which includes heading, upsetting, extrusion and forging in a cold header.

3.7 Decarburization is when a fastener has a surface carbon content lower than the carbon content of its core. (See page K–22.)

3.8 Electrodeposition is the deposition of a substance upon an electrode by passing electric current through an electrolyte. In electroplating, the process is used to plate metallic coatings to components suspended in a solution containing the plate metal.

FASTENER TERMINOLOGY

3.9 Electroplating is the electrodepositing of metal in an adherent form upon an object serving as a cathode.

3.10 Flash Plate is a very thin film of electrodeposited plate, usually less than 2.5 μm in thickness. Used in manufacture to facilitate hot and cold forming by increasing lubricity, for protection of the base metal during carburizing, nitriding and other heat treatments or as a preplate to improve bonding of subsequent electroplating. (Copper is much used in flash plating.)

3.11 Heat Treatment is the heating and cooling of a solid metal or alloy in such a way as to obtain desired conditions or properties with as little change as possible to the original shape, size or surface finish of the part being treated. The new properties obtained as the result of heat treatment are achieved by the changes in the nature, form, size or distribution of the structural constituents. Fundamental heat treatments include hardening (ferrous alloys), solution treatment (precipitation and age hardening alloys), and annealing.

3.12 Hot-Dip Galvanizing is the coating of a metal part or object such as a fastener with zinc by immersion in a bath of molten zinc followed by removal of excess zinc in a centrifuge or brushing of threads.

3.13 Hot Heading is an operation associated with bolt making involving the hot forging of heads on large diameter stock or on stock which cannot be successfully cold headed because of the material characteristics or the head complexity. While production rates are lower than cold heading, advantages include better flow lines, a more refined and homogeneous grain structure and a low strain-inducing process.

3.14 Mechanical Plating is a plating process in which metal powders are peened onto the work surface by tumbling or other means.

3.15 Passivating is a process of dissolving ferrous particles and surface impurities from stainless steel by chemical means (usually a nitric acid dip) to produce a passive film on the surface to inhibit corrosion.

3.16 Quench Crack is a fracture produced from thermal stresses induced during rapid cooling or quenching of a metal or alloy.

3.17 Quenching is a rapid cooling heat treatment in which the quenching medium may be air, elementary gas, water, spray, fog, oil or salt bath. Used on various materials to obtain entirely different effects. Because of the variables involved, the term quenching means very little to the metallurgist unless the material and quenching medium are known.

3.18 Slotting is a process of forming or cutting the slot on the head of a fastener during either the primary or secondary operation. (Slots may be sawed or struck.)

3.19 Spheroidizing in heat treatment is the heating and cooling of an alloy steel to produce a spherical or globular form of carbide, the heating being a type of soaking treatment and the cooling rate very slow and controlled. Frequently applied to severely cold worked material prior to further cold working.

3.20 Thread Rolling is a process which produces external threads by applying a squeezing pressure while rolling a cylindrical workpiece between grooved dies.

4. Basic Mechanical Property Terminology

4.1 Ductility is the ability of a material to deform before it fractures.

4.2 Fatigue Strength is the maximum dynamic load a fastener can withstand for a specified number of repeated applications prior to its failure.

4.3 Hardness is a measure of a material's ability to resist abrasion and indentation.

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4.4 **Mechanical Properties** are those properties which involve a relationship between strain and stress. Properties such as tensile and yield strengths, hardness and ductility, are all subject to change dependent on the choice of manufacturing methods and metallurgical treatments. Only rarely are the final mechanical properties those of the raw material from which it is made.

4.5 **Proof Load** is a tension-applied load that the fastener must support without evidence of permanent deformation. Proof load is an absolute value, not a maximum or minimum.

4.6 **Shear Strength** is the maximum load applied normal to a fastener's axis that can be supported prior to fracture. Single shear is load occurring in one transverse plane while double shear is load applied in two planes.

4.7 **Tensile Strength** is the maximum tension-applied load a fastener can support prior to or coincident with its fracture.

4.8 **Torsional Strength** is a load, usually expressed in terms of applied torque, at which a fastener fails by being twisted off about its axis.

4.9 **Toughness** is a material's ability to accept punishment in the form of impact and shock loading and its measure is defined as impact strength.

4.10 **Yield Strength** is the tension-applied load at which a fastener experiences a specified amount of permanent deformation.

5. Basic Assembly, Tolerance, and Geometric Feature Terminology

5.1 **Fillet** of a fastener is the concave junction between the shank diameter and bearing surface of the bolt or screw head.

5.2 **Fit** is the general term used to signify the range of tightness which may result from the application of a single combination of allowances and tolerances in the design of mating parts.

5.3 **Full Indicator Movement (FIM)** is the total indicator movement observed with the dial indicator in contact with the part feature surface during one full revolution of the part about its datum axis. In the United States, the terms Full Indicator Reading (FIR) and Total Indicator Reading (TIR) are used.

5.4 **Fundamental Deviation** is an ISO term which is called **allowance** in North America and is the prescribed difference between the design (maximum material) and the basic size which is that size from which the limits of size are derived by the application of allowances and tolerances.

5.5 **The Grip** of a fastener is generally the thickness of material or parts which the fastener is designed to secure when assembled.

5.6 **Recess** in a fastener is a manufactured groove, slot, depression or other geometric form, usually in the head of a screw through which torque is applied by the use of a mating driver.

5.7 **Shank** is that portion of a headed fastener which lies between the head and the extreme point.

5.8 **Thread Lap** is a surface defect appearing as a seam, caused by folding over the surface of metal during the thread rolling operation.

5.9 **Thread Runout** the area at the terminating end of a thread section containing incomplete threads (usually incompletely formed crests).

5.10 **Torque-Tension** is the relationship between the assembly torque and the axial load it induces in the bolt or screw.

5.11 **Washer Face** is the machined or formed surface visible under the head of screw or structural bolt which provides a bearing surface appearing as a thin integral washer.

IFI NOTES:

There are three private-sector standards writing bodies — ASTM, ASME, SAE — which administer comprehensive programs to develop and publish engineering standards relating to metric series mechanical fasteners. Documents released by these three organizations are viewed as national standards. Additionally, and as necessary, Industrial Fasteners Institute issues fastener standards to supplement those of the three private-sector groups.

The U.S. Government, principally its Department of Defense, Department of Commerce and General Services Administration, publishes engineering standards on fasteners. While intended primarily for use by the Federal Services, several have gained private-sector acceptance and are frequently referenced in national standards.

Several large OEM corporations write their own standards for fasteners. Most are patterned on national standards, but each contains some differences, additions and extensions which the OEM feels necessary to satisfy its own unique and special requirements.

The following listings detail the principal fastener and fastener-support standards issued by ASTM, ASME, SAE and IFI. It would be impractical to list the documents of the Federal Government or those of any of the several OEMs.

ASTM Standards

ASTM (the American Society for Testing and Materials), founded in 1898, is a scientific and technical organization formed for "the development of standards on characteristics and performance of materials, products, systems, and services; and the promotion of related knowledge." ASTM is the world's largest source of voluntary consensus standards.

ASTM operates through technical committees with each functioning within well defined and monitored procedures which ensure balanced representation among producers, users and general interest participants. Committee F-16 on Fasteners has technical responsibility for most of the ASTM standards relating to fastener materials and fastener products. Most of those standards relating to metric series fasteners are abstracted in this book. These standards, as well as all those relating to metric series fasteners, together with a number of support standards, are published in Volume 15.08 of the Annual Book of ASTM Standards. Copies of Vol. 15.08 (or any of the other several dozen volumes comprising the Book of Standards) are available for purchase from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, U.S.A.

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IFI acknowledges its appreciation to ASTM for its permission to publish abstracts of ASTM standards dealing with metric series fasteners. A list of these standards and all other ASTM standards referenced in this book follows:

F837M Stainless Steel Socket Head Cap Screws [Metric] (see page H–91).

F871M Electrodeposited Coatings on Threaded Components [Metric] (see page B–144).

F879M Stainless Steel Socket Button and Flat Countersunk Head Cap Screws [Metric] (see page H–78).

F880M Stainless Steel Socket Set Screws [Metric] (see page H–73).

F912M Alloy Steel Socket Set Screws [Metric] (see page H–67).

F959M Compressible-Washer-Type Direct Tension Indicators for Use With Structural Fasteners [Metric] (see page F–25).

F1135 Cadmium or Zinc Chromate Organic Corrosion Protective Coatings for Fasteners (see page B–194).

F1136 Chromium/Zinc Corrosion Protective Coatings for Fasteners (see page B–191).

F1137 Phosphate/Oil and Phosphate/Organic Corrosion Protective Coatings for Fasteners (see page B–197).

F1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection (see page L–82).

ASME Standards

The American Society of Mechanical Engineers, founded in 1880, is an educational, technical and professional society of mechanical engineers and other qualifying individuals. ASME has many objectives with one of its more important being "developing industry's mechanical standards, codes, safety procedures, and operating principles."

ASME is an internationally recognized voluntary standards setting organization. There are currently about 1,300 ASME codes and standards developed or maintained annually, in addition to many related accreditation activities. These are widely accepted throughout industry and government as the authoritative guidelines for promoting safety, reliability, productivity, and efficiency in practically every industry that relies on mechanical engineering components or equipment.

Two of the technical committees functioning under ASME operation procedures are Standards Committee B1 on Screw Threads and Standards Committee B18 on Mechanical Fasteners. The standards developed by these committees, as well as most other ASME standards committees, are submitted to the American National Standards Institute to be channelled through its procedures for adoption as American National Standards.

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Prior to 1982, such standards were designated "ANSI". Since then new issues have either been designated "ANSI/ASME", "ASME/ANSI," or "ASME". As standards are revised, the current trend is to designate them as "ASME" standards. This is why various designations are included in this book.

Most of the standards developed by ASME Standards Committee B1 and B18 are included in this book, either abstracted or in full. Complete copies of each are available for purchase from either The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990 or from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

A listing of the included and referenced ASME standards in this book follows:

B1.3M	Screw Thread Gaging Systems for Dimensional Acceptability (see page A–46).
B1.7M	Nomenclature, Definitions, and Letter Symbols for Screw Threads and Related Features (see page A–11).
B1.13M	Metric Screw Threads – M Profile (see page A–20).
B1.16M	Gages and Gaging for Metric M Screw Threads (see page A–55).
B18.1.3M	Metric Small Solid Rivets (see page I–57).
B18.2.3.1M	Metric Hex Cap Screws (see page C–1).
B18.2.3.2M	Metric Formed Hex Screws (see page C–19).
B18.2.3.3M	Metric Heavy Hex Screws (see page C–30).
B18.2.3.4M	Metric Hex Flange Screws (see page C–38).
B18.2.3.5M	Metric Hex Bolts (see page C–52).
B18.2.3.6M	Metric Heavy Hex Bolts (see page C–60).
B18.2.3.7M	Metric Heavy Hex Structural Bolts (see page F–9).
B18.2.3.8M	Metric Hex Lag Screws (see page C–66).
B18.2.3.9M	Metric Heavy Hex Flange Screws (see page C–71).
B18.2.3.10M	Square Head Bolts [Metric Series] (see page C–86).
B18.2.4.1M	Metric Hex Nuts, Style 1 (see page D–3).

B18.2.4.2M	Metric Hex Nuts, Style 2 (see page D–8).
B18.2.4.3M	Metric Slotted Hex Nuts (see page D–13).
B18.2.4.4M	Metric Hex Flange Nuts (see page D–19).
B18.2.4.5M	Metric Hex Jam Nuts (see page D–24).
B18.2.4.6M	Metric Heavy Hex Nuts (see page D–29).
B18.2.7.1M	Metric 12-Spline Flange Screws (see page C–126).
B18.3.1M	Metric Socket Head Cap Screws (see page H–1).
B18.3.2M	Metric Hexagon Keys and Bits (see page H–55).
B18.3.3M	Metric Hexagon Socket Head Shoulder Screws (see page H–18).
B18.3.4M	Metric Hexagon Socket Button Head Cap Screws (see page H–28).
B18.3.5M	Metric Hexagon Socket Flat Countersunk Head Cap Screws (see page H–35).
B18.3.6M	Metric Socket Set Screws (see page H–45).
B18.5.2.1M	Metric Round Head Short Square Neck Bolts (see page C–99).
B18.5.2.2M	Metric Round Head Square Neck Bolts (see page C–107).
B18.5.2.3M	Round Head Square Neck Bolts With Large Head [Metric Series] (see page C–119).
B18.6.5M	Metric Thread Forming and Thread Cutting Tapping Screws (see page G–37).
B18.6.7M	Metric Machine Screws (see page G–12).
B18.7.1M	Metric General Purpose Semi-Tubular Rivets (see page I–68).
B18.8.3M	Metric Spring Pins, Coiled (see page J–2).
B18.8.4M	Metric Spring Pins, Slotted (see page J–8).
B18.8.5M	Metric Machine Dowel Pins – Hardened Ground (see page J–16).
B18.8.6M	Cotter Pins [Metric Series] (see page J–22).
B18.8.7M	Headless Clevis Pins [Metric Series] (see page J–26).

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B18.8.8M Headed Clevis Pins [Metric Series] (see page J–32).

B18.13.1M Screw and Washer Assemblies - SEMS (see page G–102).

B18.16.1M Mechanical and Performance Requirements for Prevailing-Torque Type Steel Metric Hex Nuts and Hex Flange Nuts (see page E–21).

B18.16.2M Torque-Tension Test Requirements for Prevailing-Torque Type Steel Metric Hex Nuts and Hex Flange Nuts (see page E–30).

B18.16.3M Dimensional Requirements for Prevailing-Torque Type Steel Metric Hex Nuts and Hex Flange Nuts (see page E–15).

B18.18.1M Inspection and Quality Assurance for General Purpose Fasteners (see page L–5).

B18.18.2M Inspection and Quality Assurance for High-Volume Machine Assembly Fasteners (see page L–10).

B18.18.3M Inspection and Quality Assurance for Special Purpose Fasteners (see page L–18).

B18.18.4M Inspection and Quality Assurance for Fasteners for Highly Specialized Engineered Applications (see page L–31).

B18.18.5M Inspection and Quality Assurance Plan Requiring In-Process Inspection and Controls (see page L–39).

B18.18.6M Quality Assurance Plan for Fasteners Produced in a Third Party Accreditation System (see page L–50).

B18.18.7M Quality Assurance Plan for Fasteners Produced in a Customer Approved Control Plan (see page L–53).

B18.21.2M Metric Lock Washers (see page J–49).

B18.22M Metric Plain Washers (see page J–38).

FAP-1 Quality Assurance Program Requirements for Fastener Manufacturers, Distributors, and Testing Laboratories (see page L–55).

SAE Standards

The Society of Automotive Engineers (SAE) is a professional engineering society which promotes the arts, sciences, standards and engineering practices connected with the design, construction and utilization of self-propelled mechanisms, prime movers, their components and related equipment. SAE engineering standards, technical reports and recommended practices are developed through technical committees which coordinate and utilize the knowledge, experience and skills of engineers and other individuals qualified to address the technical problems falling within the committee's scope of responsibility.

SAE currently publishes annually a three-volume handbook which contains all of its standards, recommended practices and information reports. Each surface vehicle standard, recommended practice, or information report has a designation consisting of the letter "J" combined with a number. Fastener standards are published in Volume 1.

Copies of the Annual SAE Handbook are available from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096-0001, U.S.A.

J121M Decarburization in Hardened and Tempered Metric Threaded Fasteners (see page K–22).

J174M Torque-Tension Test Procedure for Steel Threaded Fasteners – Metric Series

J417 Hardness Tests and Hardness Number Conversions

J423 Methods of Measuring Case Depth

J891 Spring Nuts

J892M Push-On Spring Nuts Metric Series – General Specifications

J1053M Steel Stamped Nuts of One Pitch Thread Design – Metric Series

J1102M Mechanical and Material Requirements for Metric Wheel Bolts

J1199 Mechanical and Material Requirements for Metric Externally Threaded Steel Fasteners

J1200 Blind Rivets – Break Mandrel Type

J1216 Test Methods for Metric Threaded Fasteners

J1237 Metric Thread Rolling Screws (see page G–80).

J1648 Protective Coatings for Fasteners

J1701M Torque-Tension Tightening for Metric Series Fasteners

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IFI Standards

Industrial Fasteners Institute (IFI) is the trade association of the North American fastener manufacturing industry. Since its founding in 1931, IFI has been a strong supporter of standardization, participates actively in the standards development work of ASTM, ASME, SAE, and ISO, and cooperates with government and private-sector groups interested in standardization efforts relating to mechanical fasteners.

It has been the continuing policy of IFI to assist the fastener standards writing activities of other organizations, both through representation on their technical committees and as individually requested. IFI does not issue standards in competition with any other group. However, IFI does prepare and issue fastener standards under its own name when needed to satisfy either of two circumstances — when a need is identified that does not fall within the scope of responsibility of one of the national standardization bodies and when there is an urgency to release a working document immediately. In the latter instance IFI procedures permit an accelerated preparation, approval and publication of a needed standard. Once released it serves as an interim document for use until a national standard, usually based on the IFI issue, can be written and channelled through the broader and more encompassing approval procedures of the appropriate national body. At that time IFI withdraws its standard and supports the new national standard.

IFI standards relating to metric series fasteners are designated with "500" series numbers, (those of inch with "100" series numbers). To date, IFI has issued over 40 metric standards. Many of these metric standards have been withdrawn since they have been incorporated into ASTM, ASME and SAE standards. Copies of IFI publications are available from the Industrial Fasteners Institute, 1717 East Ninth Street, Suite 1105, Cleveland, Ohio 44114-2879.

IFI metric fastener standards which have been issued and subsequently withdrawn or maintained include the following:

IFI Number	Superseded by (S) or Maintained (M)	Standard
142	M	Hydrogen Embrittlement Risk Management, page K-26
500	S	ANSI B1.18M and B1.19M
501	S	ASTM F568M, page B-56
502	S	ASME B18.6.5M, page G-37
503	S	SAE J1237, page G-80
504	M	Metric Self-Drilling Tapping Screws, page G-92
505	M	Metric Break Mandrel Blind Rivets, page I-8

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IFI Number	Superseded by (S) or Maintained (M)	Standard
506	S	ASME B18.2.3.1M, page C–1 ASME B18.2.3.5M, page C–52
507	S	ASME B18.2.4.1M, page D–3 ASME B18.2.4.2M, page D–8 ASME B18.2.4.3M, page D–13 ASME B18.2.4.4M, page D–19 ASME B18.2.4.6M, page D–29
508	S	ASTM A563M, page B–68
509	M	Metric Break Mandrel Closed End Blind Rivets, page I–15
510	M	Dimensional Requirements of Duplex Face and Single Face Flat Thread Rolling Dies – Inch and Metric, available as a separate
511	S	ASME B18.2.7.1M, page C–126
512-C	S	ASME B18.8.3M, page J–2
512-S	S	ASME B18.8.4M, page J–8
513	S	ASME B18.6.7M, page G–12
514	S	ASME B18.16.1M, page E–21 ASME B18.16.3M, page E–15
515	S	ASME B18.5.2.2M, page C–107
516	S	ASTM F738M, page B–79
517	S	ASTM F836M, page B–91
518	S	ASTM F468M, page B–99
519	S	ASTM F467M, page B–109
520	M	Metric Pull Through Mandrel Blind Rivets, page I–21
522	M	Mechanical Testing of Metric Blind Rivets, page I–27

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IFI Number	Superseded by (S) or Maintained (M)	Standard
523	S	ASTM F606M, page B–130
524	M	Metric Nonmetallic Resistant Element Prevailing-Torque Screws, page E–7
525	M	Metric Chemical Coated Prevailing-Torque Screws, page E–12
526	S	ASME B18.2.3.7M, page F–9 ASME B18.2.4.6M, page D–29 ASTM F436M, page J–42
527	M	Clearance Holes for Metric Threaded Fasteners, page K–7
528	M	Metric Double End Studs, Continuous Thread Studs, and Bent Bolts, page C–94
529	S	ASTM F788/F788M, page B–115
530	M	Metric Structural Splitting Self-Plugging Pull Mandrel Blind Rivets, page I–32
531	S	ASME B18.13.1M, page G–102
532	S	ASME B18.21.2M, page J–49
533	S	ASTM F812/F812M, page B–123
534	M	Metric Beveled Washers, page J–48
535	S	ASME B18.3.5M, page H–35
536	S	ASME B18.2.3.4M, page C–38
537	cancelled	Identification Requirements ¼ Kegs
538	S	ASME B18.2.3.9M, page C–71
539	cancelled	Boundary Profiles for Gaging
540	S	ASME B1.3M, page A–46

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IFI Number	Superseded by (S) or Maintained (M)	Standard
541	cancelled	Metric Hex Transmission Tower Bolts
542	S	ASTM F436M, page J–42
543	M	Test for Evaluating the Torque-Tension Relationship on Both External and Internal Metric Threaded Fasteners, page E–31
544	M	Metric Round Head Ribbed Neck Bolts, page C–114
110/550	M	Glossary of Terms Related to Blind Rivets, page I–3
551	M	Metric Structural Flush Break Pull Mandrel Self-Plugging Blind Rivets, page I–38
552	M	Metric Multi-Grip Flush Break Pull Mandrel Self-Plugging Blind Rivets, page I–46
553	M	Metric Drive Pin Blind Rivets, page I–51

:CHNICAL DATA

IN-PROCESS SAMPLING FREQUENCY

IFI

A METHOD OF CALCULATION PROVIDES A NOMOGRAPH ALTERNATIVE

ASME B18.18.3M includes a nomograph, page L–23, Fig. 2, which facilitates the determination of the required sampling frequency (nondestructive) based on a given production rate, lot size and inspection level of a fastener characteristic.

To assist users, a study of this nomograph was carried out by an IFI staff engineer. It was determined that a set of equations could be written which would yield similar results to those obtained using the nomograph. These equations may then be used to computerize the establishment of a sampling frequency based on a given lot size, production rate, and inspection level.

Let: LS = lot size
SR = frequency of sampling rate
PR = production rate
e = base of natural logarithms
= 2.71828. . .
h_1 = height on production rate scale
h_2 = height on lot size scale
h_3 = height on reference line scale
h_4 = height on inspection level scale:

Inspection Level	h_4
A	4.30
B	3.78
C	3.31
D	2.77

h_5 = height on frequency of sampling scale

$$SR = 0.102\ e^{(1.042)h_5}$$

$$h_5 = 2\ (h_4 - h_2) + h_1$$

$$h_1 = 0.956\ \ln (PR) - 4.408$$

$$h_2 = 1.098\ (LS)^{0.124}\ e^{-16{,}408{,}000 \times LS}$$

Example:

PR = 4,000 pieces/hr.
LS = 40,000 pieces
B = Inspection level of characteristic

$\therefore h_1 = 0.956 \ln (4{,}000) - 4.408$
$h_1 = 3.521$

$h_2 = 1.098\ (40{,}000)^{0.124}\ e^{-16{,}408{,}000 \times 40{,}000}$
$h_2 = 4.059$

$h_4 = 3.78$ @ B level

$\therefore h_5 = 2\ (3.78 - 4.059) + 3.521$
$h_5 = 3.003$

$\therefore SR = 0.102e^{(1.042)3.003}$
$= 2.331 \ \therefore$ 3 pieces/hour

From nomograph 2.4 pieces/hour → 3 pieces/hr.