Fastener Handout

Introduction: Engineering Design Representation

Despite advances, 2D mechanical drawings are still the most popular format for design documentation. Automated extraction techniques allow mechanical drawings to be developed directly from 3D geometric models, simplifying the process. However, some elements of design representation not easily conveyed through the model database and therefore not as easily extracted to 2D drawings. Many of these elements are notational in nature. Some examples include thread specifications, surface finishes, surface quality, and dimension tolerances.

This handout will focus on the standards of annotation for fasteners, and hole callouts (local notes). Annotation standardization is provided by the ASME Y14 series of standards. These standards call for the expanded use of symbology in annotation. This is due to the international understandability of symbols. The table at right shows the current standard symbols commonly used in mechanical drawings along with the out-dated "abbreviation" form. We will discuss this topic further when covering Geometric Dimensioning and Tolerance.

GENERAL DIMENSIONING SYMBOLS		
CURRENT PRACTICE	ABBREVIATION IN NOTES	PARAMETER
Ø	DIA	DIAMETER
SØ	SPHER DIA	SPHERICAL DIAMETER
R	R	RADIUS
CR	CR	CONTROLLED RADIUS
SR	SR	SPHERICAL RADIUS
⌴	CBORE or SFACE	COUNTERBORE SPOTFACE
⌵	CSK	COUNTERSINK
↧	DP	DEEP
○	—	DIMENSION ORIGIN
□	SQ	SQUARE
( )	REF	REFERENCE
X	PL	PLACES, TIMES
⌒	—	ARC LENGTH
⌳	—	SLOPE
⌲	—	CONICAL TAPER

Threads

Screw threads serve three basic functions in mechanical systems; 1) to provide a clamping force 2) to restrict or control motion, and 3) to transmit power. Geometrically, a screw thread is a helical incline plane. A helix is the curve defined by moving a point with uniform angular and linear velocity around an axis. The distance the point moves linear (parallel to the axis) in one revolution is referred to as pitch or lead. The term *internal threads* refers to threads cut into the sidewall of an existing hole. *External threads* refers to threads cut or rolled into the external cylindrical surface of a fastener or stud. The size most commonly associated with screw threads is the ***nominal diameter***. Nominal diameter is a more of a label than a size. For example, a bolt and nut may be described as being ½" diameter. But neither the external threads of the bolt nor the internal threads of the nut are exactly .500 in diameter. In fact, the bolt diameter is a little smaller and the nut diameter a little larger. But it is easier to specify the components by a single size designation since the bolt and nut are mating components.

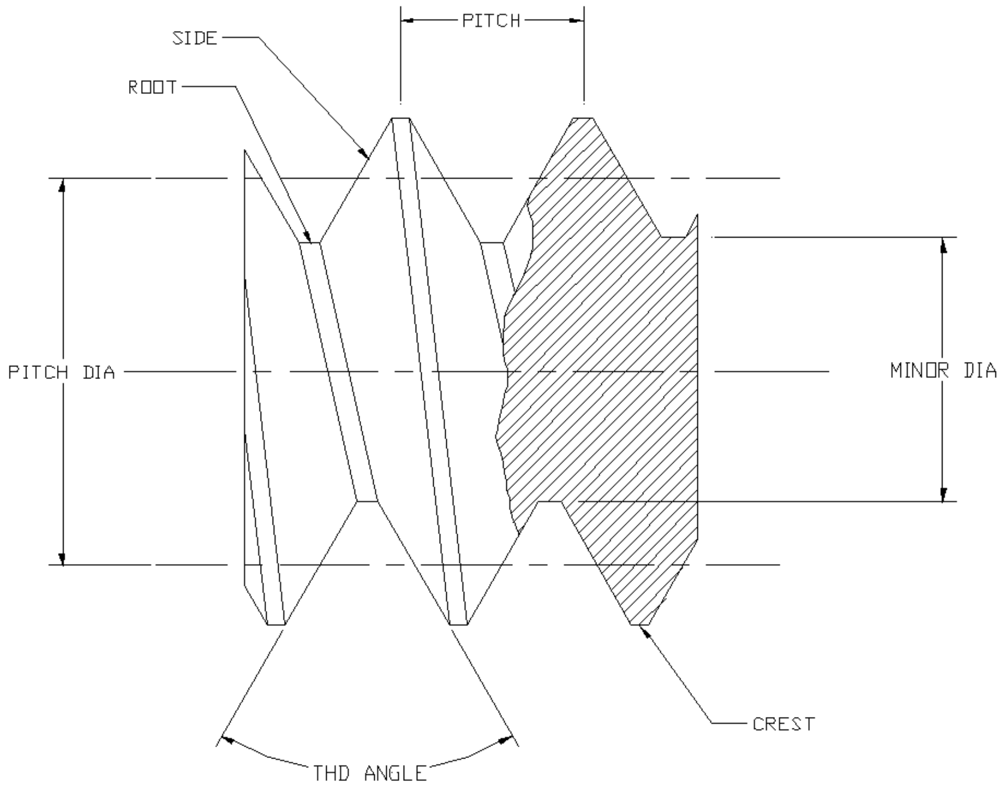


Fig. 1 Thread Profile (External)

Crest – the peak of the thread for external threads, the valley of the thread for internal threads
Major Diameter - The largest diameter of the thread
Minor Diameter - The smallest diameter of the thread
Pitch Diameter – nominally the mean of the major and minor diameters
Thread Angle – The included angle between two adjacent thread walls.

Effect of thread angle on strength:

The lower the value of the thread angle, the greater the load carrying capability of the thread.

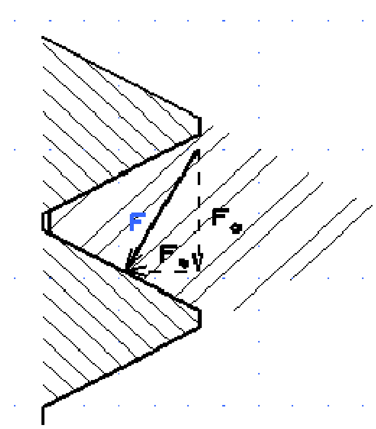


Fig. 2 Thread Forces

The force of mating threads is normal to the surface of the thread. This is shown in the figure as F. The components of the force F transverse and parallel to the axis are shown as F_t and F_a. The component of force typically responsible for failure is that applied transverse to the axis of the thread. It is this load that can cause cracking in internal threads, especially under cyclic loads. Internal threads are more susceptible since they are typically cut and cutting operations in metals produce surface irregularities that can contribute to crack growth. External threads are typically rolled onto a fastener and therefore lack the surface flaws of cut threads. As the thread angle decreases, the component F_t gets smaller. This is why square and buttress threads are usually used for power transfer applications.

Standardization of Threads: (Standard Inch Units)

To facilitate their use, screw threads have been standardized. In 1948, the United States, Great Britain and Canada established the current system for standard inch dimension threads. This is the Unified thread series and consists of specifications for Unified Coarse (UNC) Unified Fine (UNF) and Unified Extra Fine (UNEF) threads. Metric threads are also standardized. Metric thread specification is given through ISO standards. Thread information is available in tabular form from many sources including Mechanical Drawing texts and Machine Design handbooks.

Thread form:

Thread form is a classification based upon the cross-sectional profile of the thread. The standard thread form for inch unit threads in U.S. is the *Unified* (UN) thread form. This thread form is characterized by a 60 degree thread angle and a flat crest and rounded root.

Thread series:

Thread series is a standard based upon the number of threads/inch for a specific nominal diameter. Standards for standard inch units are: *Coarse* (C), *Fine* (F), *Extra-Fine* (EF). The figure at right shows fine and coarse thread fasteners. The designation is based upon the number of threads per unit length. A short discussion of each thread series is given below.

Fig. 3 Course, Fine Threads

Threads per Inch:

Literally a measure of the number of crests per unit of length measured along the axis of the thread. The number of threads/inch for a thread series is given by standard and may be found in thread tables. The Tap Chart shown later in this document gives the number of threads/inch based upon threads series and nominal diameter.

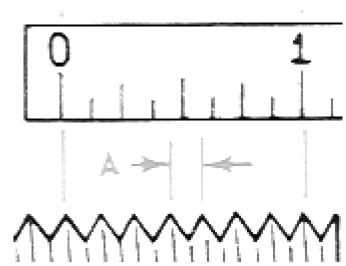


Fig. 4 Threads per Inch

Descriptions of the Thread Series:

Unified Coarse. UNC is the most commonly used thread on general-purpose fasteners. Coarse threads are deeper than fine threads and are easier to assemble without cross threading. UNC threads are normally easier to remove when corroded, owing to their sloppy fit. A UNC fastener can be procured with a class 3 (tighter) fit if needed (fit classes covered below).

Unified Fine. UNF thread has a larger minor diameter than UNC thread, which gives UNF fasteners slightly higher load-carrying (in shear) and better torque-locking capabilities than UNC fasteners of the same material and outside diameter. The fine threads have tighter manufacturing tolerances than UNC threads, and the smaller lead angle allows for finer tension adjustment. UNF threads are frequently used in cases where thread engagement is minimized due to thinner wall thickness.

Unified national extra fine. UNEF is a thread finer than UNF and is common to the aerospace field. This thread is particularly advantageous for tapped holes in hard materials as well as for tapped holes in thin materials where engagement is at a minimum.

Class fit:

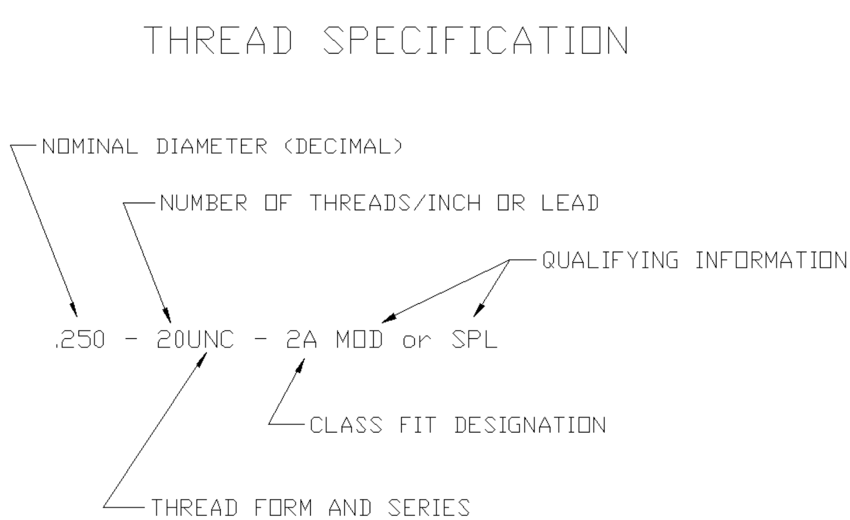
Class fit is a specification of how tightly mating external and internal threads will mesh. It is based upon the difference in the values of the respective pitch diameters. These differences are in the thousandths of an inch. For the Unified thread form, the classes of fit are:

Class 1: Loose fit. Threads may be assembled easily by hand. Used in cases where frequent assembly/disassembly required. Typically require use of locking devices such as lock washers, locking nuts, jam nuts, etc. Class 1 fits are common for bolts and nuts.

Class 2: Standard fit. Threads may be assembled partly by hand. Most common fit in use. Used in semi-permanent assemblies.

Class 3: Tight fit. Can be started by hand, but requires assistance (tools) to advance threads. Common for set screws. Used in permanent assemblies.

An additional designation is made for external (A) versus internal (B) threads and is included as a postscript to the numerical designation.



Standard inch unit thread specification examples

.4375 - 20UNF - 2A, LH

.500 - 13UNC – 1A

.375 - 24UNEF - 2B

Specification of Metric Threads:

Metric threads are defined in the standards document ISO 965-1. Metric thread specifications always begin with thread series designation (for example M or MJ), followed by the fastener's nominal diameter and thread pitch (both in units of millimeters) separated by the symbol "x".

Metric thread specification examples

MJ6 x 1 - 4H5H

M8 x 1.25 - 4h6h LH

M10 x 1.5 - 4h5h

Metric thread series:

There exist multiple metric thread series used for special applications. The standard is the M series. The MJ series is one of the most common of the special application threads.

M Series: Standard metric thread profile
MJ Series: Modified series in which crest and root radii are specified

Metric thread fits:

A fit between metric threads is indicated by internal thread class fit followed by external thread tolerance class separated by a slash; e.g., M10 x 1.5-6H/6g. The class fit is specified by tolerance grade (numeral) and by tolerance position (letter).

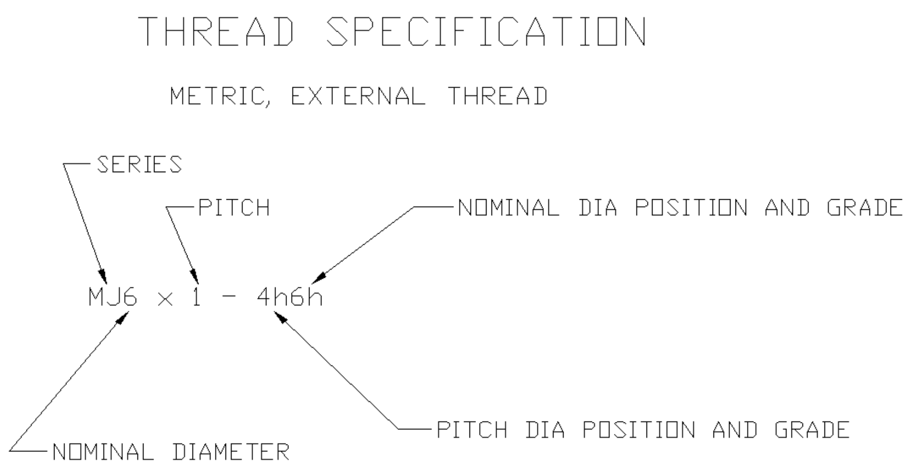
General purpose fit
6g (external) 6H (internal)
Close fit
5g6g (external) 6H (internal)

If thread fit designation (e.g., "-6g") is omitted (e.g., M10 x 1.5), it specifies a "medium" fit, which is 6H/6g. The 6H/6g fit is the standard ISO tolerance class for general use.

English unit internal and external thread class fit 2B/2A is essentially equivalent to ISO thread class fit 6H/6g. English unit class fit 3B/3A is approximately equivalent to ISO class fit 4H5H/4h6h.

Default metric fastener thread pitch. If metric thread pitch designation (e.g., " x 1.5") is omitted, it specifies coarse pitch threads. For example, M10 or M10-6g, by default, specifies M10 x 1.5. The standard metric fastener thread series for general purpose threaded components is the M thread profile and the coarse pitch thread series.

Metric fastener thread series compatibility. Metric fastener thread series M is the common thread profile. Thread series MJ designates the *external* thread has an increased root radius (shallower root relative to external M thread profile), thereby having higher fatigue strength (due to reduced stress concentrations), but requires the truncated crest height of the MJ internal thread to prevent interference at the external MJ thread root. M external threads are compatible with both M *and* MJ internal threads.



M10 x 1.5-6g means metric fastener thread series M, fastener nominal size (nominal major diameter) 10 mm, thread pitch 1.5 mm, *external* thread class fit 6g. If referring to *internal* thread tolerance, the "g" would be uppercase.

Left Hand Threads:

Unless otherwise specified, screw threads are assumed to be right-handed. This means that the direction of the thread helix is such that a clockwise rotation of the thread will cause it to advance along its axis. Left-handed threads advance when rotated counter clockwise. Left-handed threads are often used in situations where rotation loads would cause right-hand threads to loosen during service. A common example is the bicycle. The pedals of a bicycle are attached to the crank arm using screw threads. The pedal on one side of the bicycle uses right-hand threads and the other uses left-hand. This prevents the motion of pedals and crank from unscrewing the pedal and having it fall off during use. Left-hand threads must be indicated in the thread specification. This is accomplished by appending "LH" to the end of the specification.

Local Notes

Local notes, also referred to as callouts, are included on a drawing to specify information for a specific feature of a component or assembly. The feature being referenced is indicated through the use of a leader line. The leader line points to the feature in question and terminates at the note. One common example of a local note is the specification of the size dimension of a hole feature.

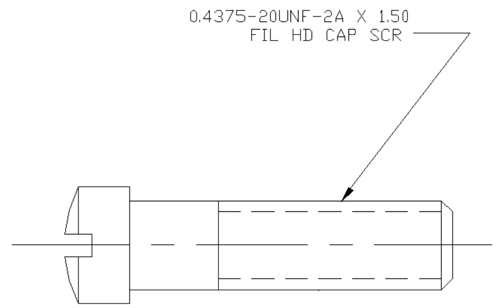


Fig. 5 Callout Examples

When a callout is made to a hole feature, the leader line should reference the circular view of hole with line pointing toward the center of the circle. The note should be written in the order of operations performed. (e.g. drill then thread) and the leader arrowhead should touch the representation of the last operation performed.

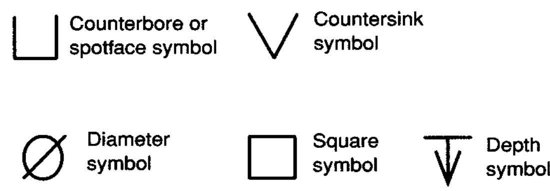


Fig. 6 Common Callout Symbols

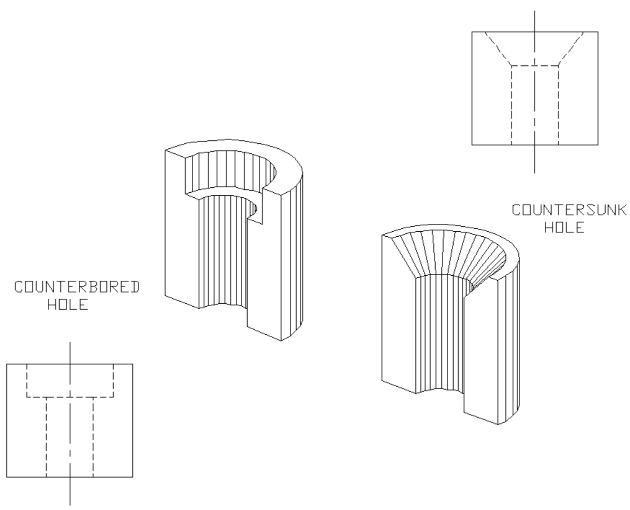


Fig. 7 Counterbored and Countersunk Holes

The two examples of callouts below reference counterbored and countersunk holes. In case you have forgotten, counterboring and countersinking are secondary machining operations used to create cylindrical and conical (respectively) enlargements of a hole, usually for the purpose of recessing a fastener head.

In the examples shown at right the pilot hole is specified first then the counterbore or countersink is specified. Notice that no specification of operation is given for the pilot hole. Operation specifications such as “DRILL” or “BORE” are no longer included in notes and callouts. Rather only the feature sizes (and tolerances, if applicable) are included.

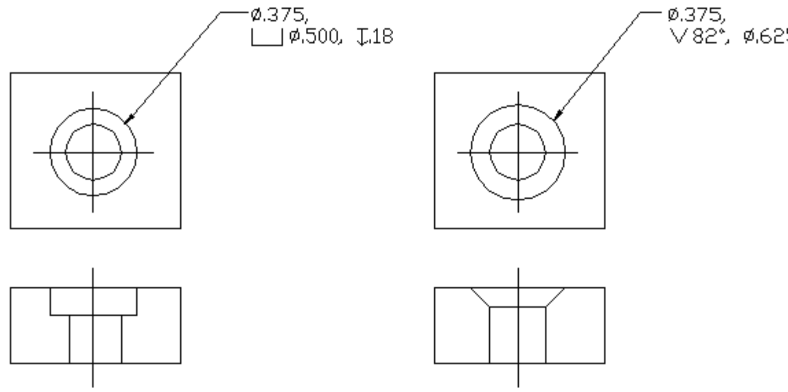


Fig. 8 Counterbore and Countersink Callouts

Counterbore specification:

Include the diameter of the counterbore, which is based upon fastener head diameter with a clearance value added. (Refer to Head Dimension Tables, Appendix A for this information)

Include the depth of the counterbore, which is based upon head profile height. (Refer to Head Dimension Tables, Appendix A for this information)

Countersink specification:

Include the angle of countersink and <u>either</u>;

1) depth of countersink

or

2) diameter of maximum opening (based upon fastener head diameter plus 1/64 typ. or equivalent)

Examples of metric notes for counterbored, countersunk and spot-faced holes are given at right.

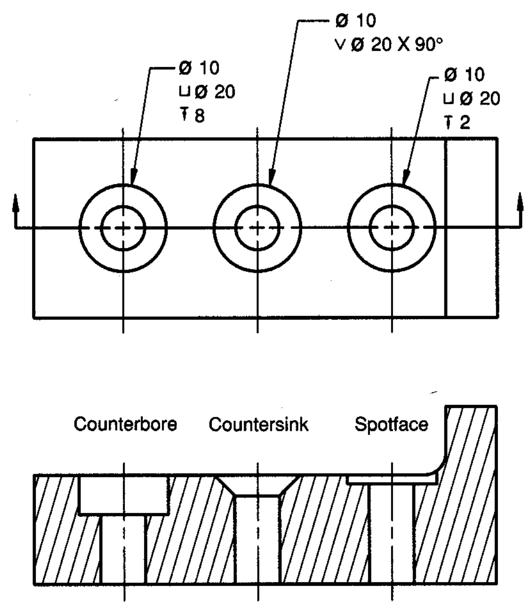


Fig. 9 Metric Notes for Counterbored, Countersunk and Spotfaced Holes.

The depth of a machined hole is categorized as being either thru or blind. A thru hole begins at the penetrating surface and terminates at another surface. Therefore the “depth” of the hole is based upon the distance between the two surfaces. Because of this, the thru hole requires no specification of depth in the note. The word “THRU” should not be included with the note. If no depth is specified, a hole is by default a thru feature. This is demonstrated in the notes for the countersunk and counterbored holes shown in Figures 8 and 9.

A blind hole is machined to a specified depth. This depth specification must be included in the note for a blind hole. The depth value refers to the cylindrical (useable) portion of the hole (see Figure 10). The tip angle in not included in the value of hole depth.

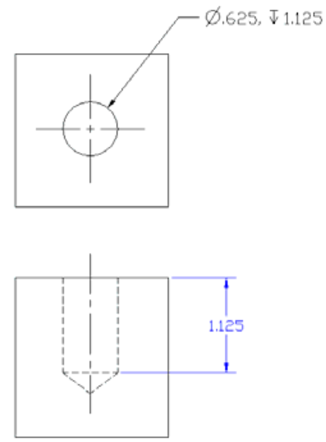


Fig. 10 Hole Depth

When multiple occurrences of the same hole specification exist in a single component, it is not necessary to write a callout to each hole in the pattern. Rather, the preferred procedure is to write the note to one hole, and then include within that note a reference to the total number of identical features in the pattern. The proper form for these notes is given below and in the figure at right.

4 x ϕ.375

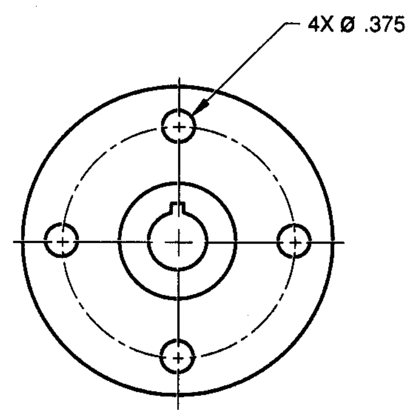


Fig. 11 Multiple Occurances

Writing notes for threaded holes:

The note for a threaded hole is a specification of all information required for the creation of the hole. This includes; 1) the diameter (and depth if blind) of the pilot hole drilled prior to thread creation. 2) the specification of the internal threads for the hole. Again a depth is given if the hole is blind.

The creation of the internal threads is a metal cutting process referred to as “tapping”. It should be apparent that in order to cut metal, the diameter of the pilot hole must be smaller than the major diameter of the threads. This difference in diameters is very important. If the pilot hole diameter is too small, too much material will have to be cut and the thread cutting tool (tap), being very hard (and therefore brittle) will break. If the pilot hole diameter is too large, the thread height will be too small and load carrying capability of threads will be compromised. In practice, the diameter of the pilot hole will set the minor diameter of the internal threads. Typically the thread height for internal threads is approximately 75% of the mating external threads (it may be as low as 50% for materials such as steel). This means a gap will exist between the crest of the external thread and the root of the internal. For this reason, threads may not be considered a seal in and of themselves.

The diameter of the pilot hole is specific for each thread series and form. This unique diameter is determined by referencing the thread series and form within a standard table. Typically this value is referred to in the table as the "tap drill diameter". (although in the table below it is given as "Drill Size") The following table also provides the values of *Threads per Inch* for specific nominal diameters and thread series.

Tap Chart - UNC/UNF Threads

Tap size	NF/NC UNF/UNC	Threads per inch	Basic major dia (inches)	Basic effective dia (inches)	Basic minor dia of ext. threads (inches)	Basic minor dia of int. threads (inches)	Drill size
1/4-20	UNC	20	.2500	.2175	.1887	.1959	#7
1/4-28	UNF	28	.2500	.2268	.2062	.2113	#3
5/16-18	UNC	18	.3125	.2764	.2443	.2524	F
5/16-24	UNF	24	.3125	.2854	.2614	.2674	I
3/8-16	UNC	16	.3750	.3344	.2983	.3073	5/16
3/8-24	UNF	24	.3750	.3479	.3239	.3299	Q
7/16-14	UNC	14	.4375	.3911	.3499	.3602	U
7/16-20	UNF	20	.4375	.4050	.3762	.3834	25/64
1/2-13	UNC	13	.5000	.4500	.4056	.4167	27/64
1/2-20	UNF	20	.5000	.4675	.4387	.4459	29/64
9/16-12	UNC	12	.5625	.5084	.4603	.4723	31/64
9/16-18	UNF	18	.5625	.5264	.4943	.5024	33/64
5/8-11	UNC	11	.6250	.5660	.5135	.5266	17/32
5/8-18	UNF	18	.6250	.5869	.5568	.5649	37/64
3/4-10	UNC	10	.7500	.6650	.6273	.6417	21/32
3/4-16	UNF	16	.7500	.7094	.6733	.6823	11/16
7/8-9	UNC	9	.8750	.8028	.7387	.7547	49/64
7/8-14	UNF	14	.8750	.8286	.7874	.7977	13/16
1-8	UNC	8	1.000	.9188	.8466	.8647	7/8
1-14	UNF	14	1.000	.9459	.8978	.9098	15/16

Notice that in the table shown above, the tap drill diameter is given in fractions, letters, and numbers. These are all drill sizes, just designated in different ways. When including these diameters in the annotation, use the following.

Diameter from table a fraction:	write as exact decimal equivalent or fraction
Diameter from table a letter:	write letter and give decimal equivalent* as reference (in parentheses)
Diameter from table a number:	write number and give decimal equivalent* as reference

* these values may be obtained from Number and Letter Drill Size decimal equivalence tables, see Appendix D

The note for the threaded hole is then written in order of operation. That is, the specification of the pilot hole, then the specification of the threads being cut, and depth (if required)

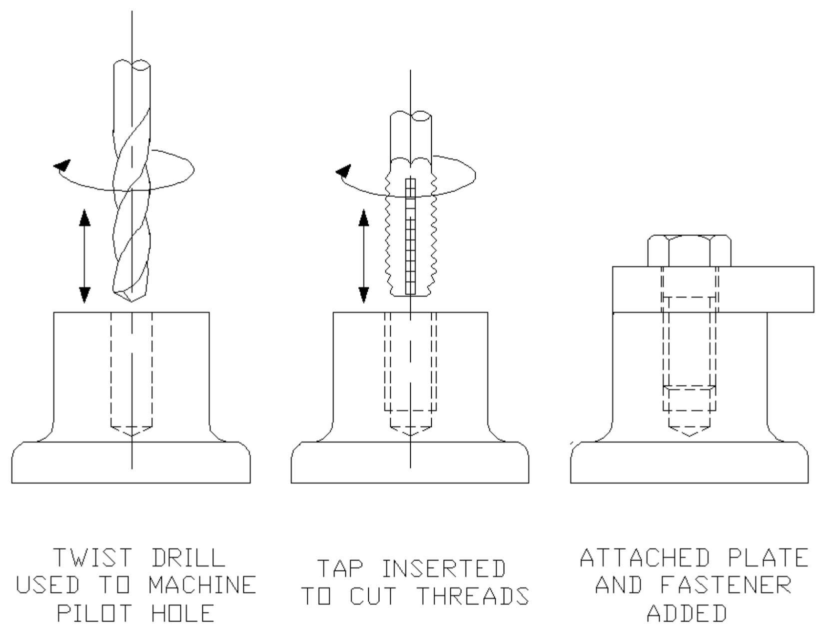
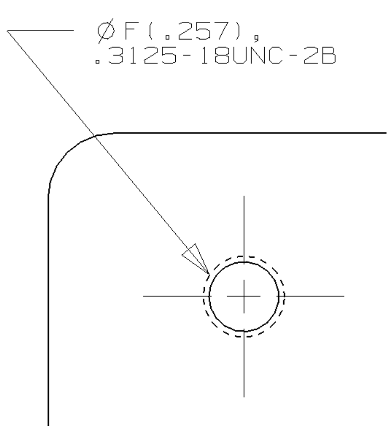
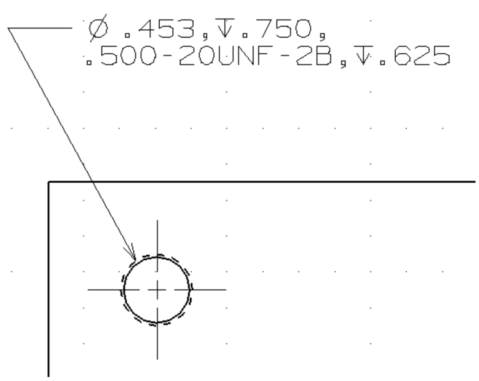


Fig. 12 Machining a Threaded Hole

Examples of notes for threaded holes.





Threaded Mechanical Fasteners

In order to fully understand engineering prints and to provide adequate information when ordering components, one should be able to both create and read complete mechanical fastener specifications. This will give you the ability to write accurate specification of desired fastener and to associate a given specification with the respective fastener.

The specification of a fastener includes the following:

A Complete Thread Specification
Head type
Fastener type
Fastener length

It also may include a specification of material and grade (strength). See Appendix C for hex head cap screw grades.

Examples of fastener specification for the various fastener types are given later in this document.

There exist many different head types for mechanical fasteners. Some are very specialized such as castellated and tamper proof heads. We will only consider six basic head types. These six basic types are listed below along with the standard abbreviation for each.

Hexagonal head (HEX HD)

Fillister head (FIL HD

Flat head (FLAT HD)

Oval head (OVAL HD)

Round head (RND HD)

Hexagonal socket head (SOC HD)

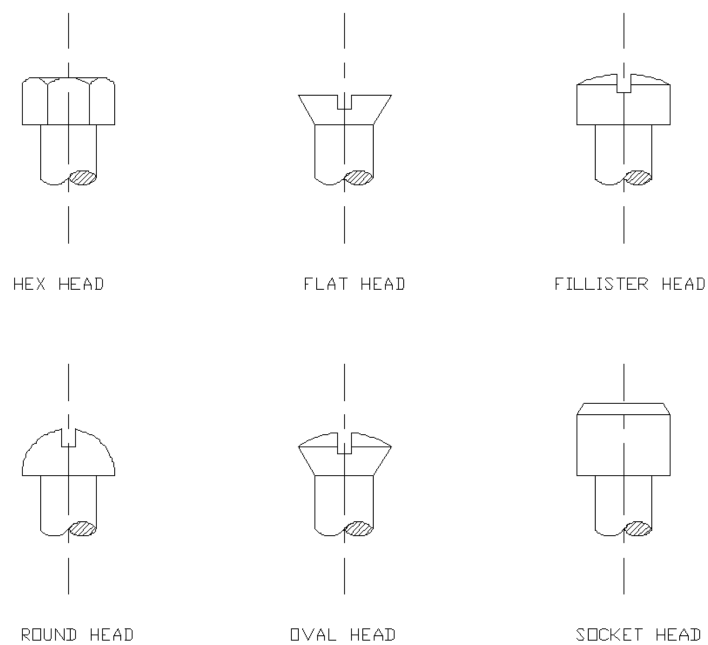


Fig. 13 Common Head Types

Note: The fillister, flat, oval and round head types are commonly available with slot or Phillips drive. Other drive types (such as hex socket) are also available, but less common.

Mechanical Fasteners:

There are three basic types of mechanical fastener. They are the Cap Screw (CAP SCR), Machine Screw (MACH SCR), and the Set Screw (SET SCR).

Cap screws and machine screws are very similar. Both are available with the same type of head. They are both used in conjunction with internally threaded holes for the purpose of clamping components together. There are however, difference between cap and machine screws.

Clamping Force:

When a cap or machine screw is used to attach to components to one another, the fastener is inserted through a clearance hole in one component and onto a threaded hole in another (see Fig 14). An alternative assembly would be to pass the fastener through two clearance holes and use a nut for clamping. (Fig. 15)

Clamping force is applied through contact between the bottom face of head and the contact between the internal and external threads.

When these methods are used, the fastener is inserted into the internally threaded component (either the threaded hole or the nut) and advanced by rotating the fastener. When the head of the fastener make contact with surface of the component being attached, the head can advance no further. However, some additional rotation of the fastener can be made, usually by means of some fashion or tool (a wrench for example). Since the threads will advance during this rotation but the head cannot a tensile load is generated in the shank of the fastener. This tensile load is proportional to the force used to rotate the fastener. The rotational force is referred to as “seating torque” and the tensile force is referred to as “pre-load”.

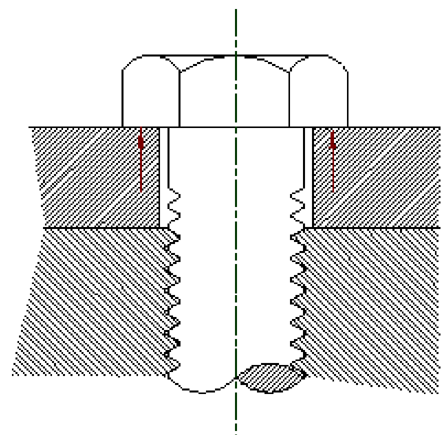


Fig. 14 Force on Fastener Head

Cap Screws (CAP SCR)

Cap screws tend toward larger diameters. The threaded end of a cap screw is chamfered. The minimum thread length is a function fastener nominal diameter. For most cap screws, the minimum length of thread equals 2 * DIA + 0.25. For socket head cap screws, the minimum thread length equals 2 * DIA + 0.50. A cap screw specified with a nut is referred to as a bolt.

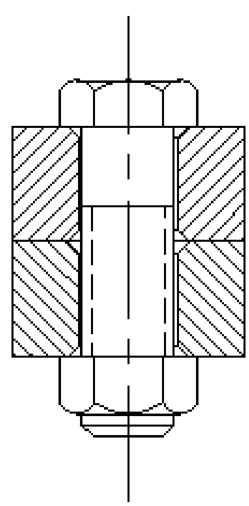


Fig. 15 Bolt and Nut

Machine Screws (MACH SCR)

Machine screws are only available in smaller diameters. The threaded end of the fastener not chamfered but rather simply sheared. The minimum thread length is a function of fastener length as follows:

if fastener length > 2, then min. thread length = 1.75

if fastener length < 2, then min. thread length = fastener length

Examples of Cap and Machine Screw Fastener Descriptions

The following example is the specification for a 1.50 long cap screw with a hexagonal head and using 7/16 nominal diameter Unified fine threads of a standard fit.

1.50 X .4375 – 20UNF –2A

HEX HD, CAP SCR

Set Screws (SET SCR)

The function of set screws is to restrict or control motion.. They are commonly used in conjunction with collars, pulleys, or gears on shafts. With the exception of the antiquated square head, set screws are headless fasteners and therefore threaded for their entire length.   Lacking heads, set screws are categorized by drive type (similar to head type) and point style. Most set screws use Class 3 fit threads. This is to provide resistance to the set screw “backing out” of its threaded hole during service.

In addition, set screws have a specified point type. The point is used to provide various amounts of holding power when used. Holding power concerns will be discussed below. The available point types for set screws are the Cone, Cup, Flat, Oval, and Dog (full or half) points. Profiles of these point type are shown in figure 17.

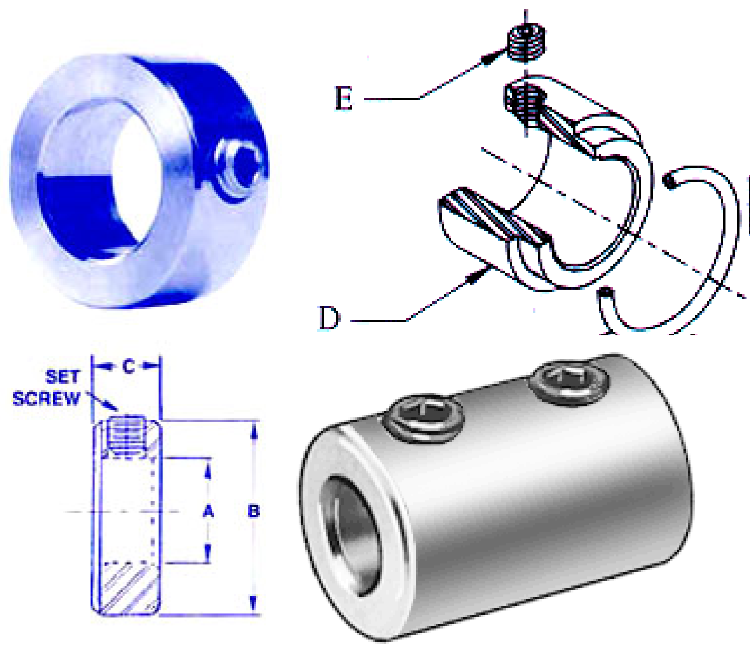
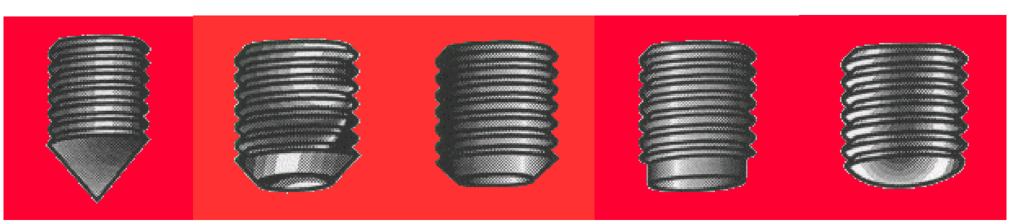


Fig. 16 Examples of Set Screw Usage



Cone　**Cup**　**Flat**　**Dog**　**Oval**

Fig. 17 Set Screw Point Types

Set Screw Holding Power:

In many applications, set screws are used to prevent the rotational and axial movement of parts such as collars, couplings, and pulley sheaves mounted to shafts. Failure of the set screw in these cases is relative motion of .01 inch between components.

An important consideration in setscrew selection is the holding power provided by the contact between the setscrew point and attachment surface (typically a cylindrical shaft). Holding power is generally specified as the tangential force in pounds. Axial holding power is assumed to be equal to the torsional holding power. Some additional resistance to rotation is contributed by penetration of the set screw point into the attachment surface. In cases where point penetration is desired, the set screw should have a material hardness at least 10 points higher on the Rockwell scale than that of the attachment material. Cup-point set screws cut into the shaft material. Cone-point setscrews also penetrate the attachment surface and may be used with a spotting hole to enhance this penetration. Oval-point and flat-point setscrews do not penetrate the surface and hence have less holding power.

Set screw selection often begins with the common axiom stating that set screw diameter should be equal to approximately one-half shaft diameter. This rule of thumb often gives satisfactory results, but its usefulness may be limited. Manufacturers' data or data supplied by standard machine design texts will give more reliable results.

Seating torque: Torsional holding power is almost directly proportional to the seating torque of cup, flat, and oval-point setscrews.

Point style: Setscrew point penetration contributes as much as 15% to the total holding power. When the cone-point setscrew is used, it requires the greatest installation torque because of its deeper penetration. Oval point, which has the smallest contact area, yields the smallest increase in holding power.

Relative hardness: Hardness becomes a significant factor when the difference between setscrew point and shafting is less than 10 Rockwell C scale points. Lack of point penetration reduces holding power.

Flatted shafting: About 6% more torsional holding power can be expected when a screw seats on a flat surface. Flatting, however, does little to prevent the 0.01-in. relative movement usually considered as a criterion of failure. Axial holding power is the same.

Length of thread engagement: The length of thread engagement does not have a noticeable effect on axial and torsional holding power, provided there is sufficient engagement to prevent thread stripping during tightening. In general, the minimum recommended length of engagement is 1 to 1.5 times the major diameter of the setscrew for threading in brass, cast iron, and aluminum; and 0.75 to 1 times the diameter for use in steel and other materials of comparable hardness. Be aware that the lengths of engagement specified are for full threads engaged, not overall screw length.

Thread type: A negligible difference exists in the performance of coarse and fine threads of the same class of fit. Most set screws are class 3A fit.

Drive type: Most set screws use socket (either hex or fluted) drive or a slot drive. The type of drive affects the seating torque that can be attained because it determines how much torque can be transmitted to the screw. Less torque can be transmitted through a slot drive than a socket drive. Therefore, holding power of the slotted screw is about 45% less.

Number of setscrews: Two setscrews give more holding power than one, but not necessarily twice as much. Holding power is approximately doubled when the second screw is installed in an axial line with the first but is only about 30% greater when the screws are diametrically opposed. Where design dictates that the two screws be installed on the same circumferential line, displacement of 60° is recommended as the best compromise between maximum holding power and minimum metal between tapped holes. This displacement gives 1.75 times the holding power of one screw.

Torque force: The compressive force developed at the point depends on lubrication, finish, and material.

Setscrews and keyways: When a setscrew is used in combination with a key, the screw diameter should be equal to the width of the key. In this combination, the setscrew holds the parts in an axial direction only. The key, keyseat and keyway assembly carries the torsional load on the parts.

The key should be tight fitting so that no motion is transmitted to the screw. Under high reversing or alternating loads, a poorly fitted key will cause the screw to back out and lose its clamping force.

Examples of Set Screw Fastener Descriptions

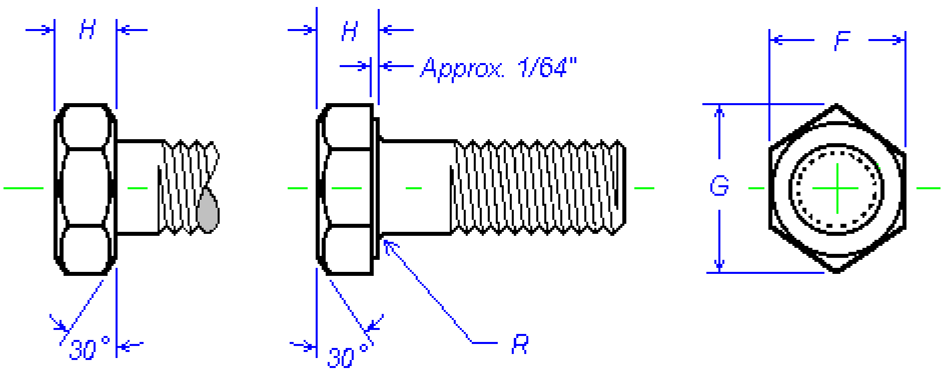
The following example is the specification for a 1.00 long set screw with a hexagonal socket drive, a cup point, a 1/4 nominal diameter, Unified fine threads and a class 3 fit.

1.00 X .250 – 28UNF – 3A
SOC HD, CUP PT, SET SCR

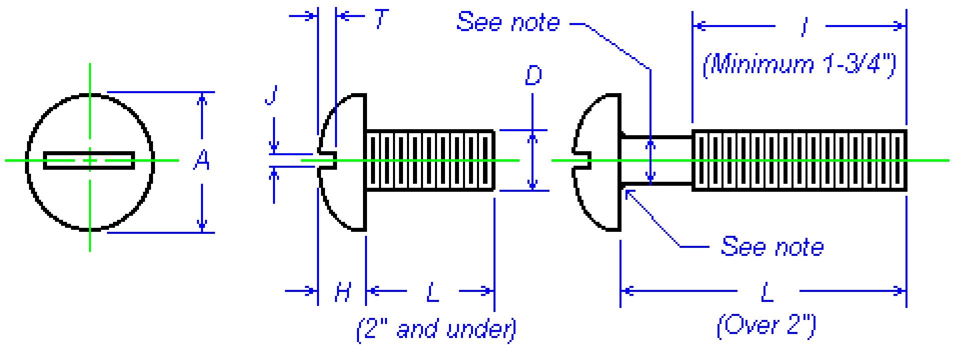
Appendix A

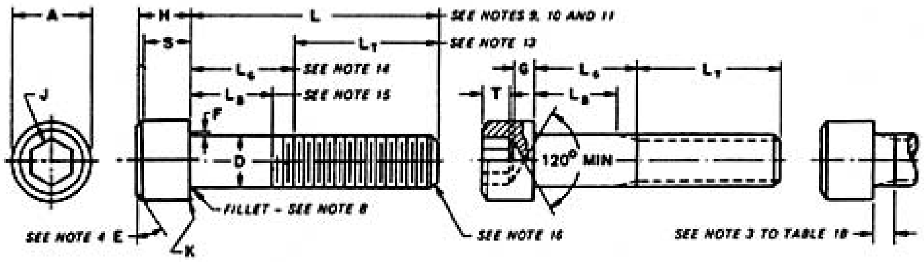
Fastener Head Dimension Tables

The following tables given the head dimensions for various types of machine and cap screws. They are helpful in specifying counterbore and countersink sizes for callouts. More complete tables may be found in Mechanical Design Handbooks and Mechanical drawing texts.



Nominal Diameter	F (across flats)	G (across points)	H (head height)	R (fillet radius)
1/4 (0.2500)	.4375		5/32	
5/16 (0.3125)	.5000		13/64	
3/8 (0.3750)	.5625		15/64	
7/16 (0.4375)	.6875		9/32	
1/2 (0.5000)	.7500		5/16	
9/16 (0.5625)	.8125		23/64	
5/8 (0.6250)	.9375		25/64	
3/4 (0.7500)	1.1250		15/32	
7/8 (0.8750)	1.3125		35/64	
1 (1.0000)	1.5000		39/64	
1 1/8 (1.1250)	1.6875		11/16	
1 1/4 (1.2500)	1.8750		25/32	
1 3/8 (1.3750)	2.0625		27/32	
1 1/2 (1.5000)	2.2500		15/16	


T
See note
I
(Minimum 1-3/4")
D
J
A
See note
H
L
(2" and under)
L
(Over 2")



• Table 1 •

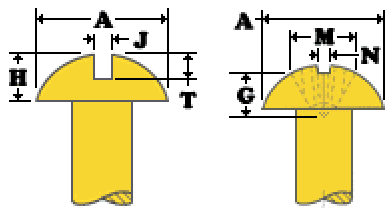
Dimensions of Hexagon and Spline Socket Head Cap Screws (1960 Series)

Nominal Size or Basic Screw Diameter		D Body Diameter		A Head Diameter		H Head Height		S Head Side Height	J Hex Socket Size		T Key Engagmt	G Wall Thkns	K Chamfer or Radius
		Max	Min	Max	Min	Max	Min	Max	Nominal		Min	Min	Max
0	0.0600	0.0600	0.0568	0.096	0.091	0.060	0.057	0.054		0.050	0.025	0.020	0.003
1	0.0730	0.0730	0.0695	0.118	0.112	0.073	0.070	0.066	1/16	0.062	0.031	0.025	0.003
2	0.0860	0.0860	0.0822	0.140	0.134	0.086	0.083	0.077	5/64	0.078	0.038	0.029	0.003
3	0.0990	0.0990	0.0949	0.161	0.154	0.099	0.095	0.089	5/64	0.078	0.044	0.034	0.003
4	0.1120	0.1120	0.1075	0.183	0.176	0.112	0.108	0.101	3/32	0.094	0.051	0.038	0.005
5	0.1250	0.1250	0.1202	0.205	0.198	0.125	0.121	0.112	3/32	0.094	0.057	0.043	0.005
6	0.1380	0.1380	0.1329	0.226	0.218	0.138	0.134	0.124	7/64	0.109	0.064	0.047	0.005
8	0.1640	0.1640	0.1585	0.270	0.262	0.164	0.159	0.148	9/64	0.141	0.077	0.056	0.005
10	0.1900	0.1900	0.1840	0.312	0.303	0.190	0.185	0.171	5/32	0.156	0.090	0.065	0.005
1/4	0.2500	0.2500	0.2435	0.375	0.365	0.250	0.244	0.225	3/16	0.188	0.120	0.095	0.008
5/16	0.3125	0.3125	0.3053	0.469	0.457	0.312	0.306	0.281	1/4	0.250	0.151	0.119	0.008
3/8	0.3750	0.3750	0.3678	0.562	0.550	0.375	0.368	0.337	5/16	0.312	0.182	0.143	0.008
7/16	0.4375	0.4375	0.4294	0.656	0.642	0.438	0.430	0.394	3/8	0.375	0.213	0.166	0.010
1/2	0.5000	0.5000	0.4919	0.750	0.735	0.500	0.492	0.450	3/8	0.375	0.245	0.190	0.010
5/8	0.6250	0.6250	0.6163	0.938	0.921	0.625	0.616	0.562	1/2	0.500	0.307	0.238	0.010
3/4	0.7500	0.7500	0.7406	1.125	1.107	0.750	0.740	0.675	5/8	0.625	0.370	0.285	0.010
7/8	0.8750	0.8750	0.8647	1.312	1.293	0.875	0.864	0.787	3/4	0.750	0.432	0.333	0.015
1	1.0000	1.0000	0.9886	1.500	1.479	1.000	0.988	0.900	3/4	0.750	0.495	0.380	0.015
See Notes	1	2,15		3				4	21				6

Machine Screws Head Dimensions

Head Dimension Tables Courtesy of Smith Fastener
www.smithfast.com

Round Head Machine Screws

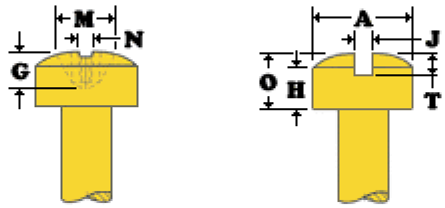


Slotted **Phillips**

Head Dimensions for Round Head Machine Screws - ANSI B18.6.3

Nominal Size	A		H		J		T		M		G	N	Phillips Driver Size
	Head Diameter		Height of Head		Slot Width		Slot Depth		Dimensions of Recess				
									Diameter		Depth	Width	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	
2	.162	.146	.069	.059	.031	.023	.048	.037	.100	.087	.053	.017	1
3	.187	.169	.078	.067	.035	.027	.053	.040	.109	.096	.062	.018	1
4	.211	.193	.086	.075	.039	.031	.058	.044	.118	.105	.072	.019	1
5	.236	.217	.095	.083	.043	.035	.063	.047	.154	.141	.074	.027	2
6	.260	.240	.103	.091	.048	.039	.068	.051	.162	.149	.084	.027	2
8	.309	.287	.120	.107	.054	.045	.077	.058	.178	.165	.101	.030	2
10	.359	.334	.137	.123	.060	.050	.087	.065	.195	.182	.119	.031	2
12	.408	.382	.153	.139	.067	.056	.096	.073	.249	.236	.125	.032	3
1/4	.472	.443	.175	.160	.075	.064	.109	.082	.268	.255	.147	.034	3
5/16	.590	.557	.216	.198	.084	.072	.132	.099	.308	.295	.187	.040	3
3/8	.708	.670	.256	.237	.094	.081	.155	.117	.387	.374	.228	.064	4
1/2	.813	.766	.355	.332	.106	.091	.211	.159	.416	.403	.256	.068	4

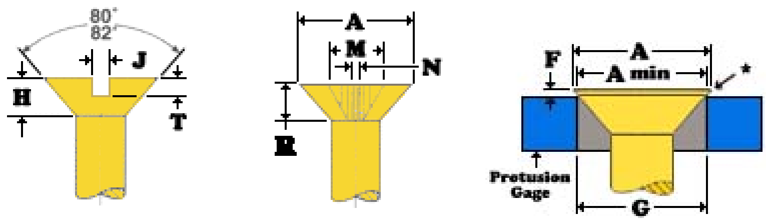
Fillister Head Machine Screws



	A		H		O		J		T		M		G	N	
Nominal Size	Head Diameter		Head Height				Slot Width		Slot Depth		Dimensions of Recess				Phillips Driver Size
			Side Height		Total Height						Diameter		Depth	Width	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	
0	.096	.083	.043	.038	.055	.047	.023	.016	.025	.015	.067	.054	.039	.013	0
2	.140	.124	.062	.053	.083	.066	.031	.023	.037	.025	.104	.091	.059	.017	
3	.161	.145	.070	.061	.095	.077	.035	.027	.043	.030	.112	.099	.068	.019	1
4	.183	.166	.079	.069	.107	.088	.039	.031	.048	.035	.122	.109	.078	.019	1
5	.205	.187	.088	.078	.120	.100	.043	.035	.054	.040	.143	.130	.067	.027	2
6	.226	.208	.096	.086	.132	.111	.048	.039	.060	.045	.166	.153	.091	.028	2
8	.270	.250	.113	.102	.156	.133	.054	.045	.071	.054	.182	.169	.108	.030	2
10	.313	.292	.130	.118	.180	.156	.060	.050	.083	.064	.199	.186	.124	.031	2
12	.357	.334	.148	.134	.205	.178	.067	.056	.094	.074	.259	.246	.141	.034	3
1/4	.414	.389	.170	.155	.237	.207	.075	.064	.109	.087	.281	.268	.161	.036	3
5/16	.518	.490	.211	.194	.295	.262	.084	.072	.137	.110	.322	.309	.203	.042	3
3/8	.622	.590	.253	.233	.355	.315	.094	.081	.164	.133	.389	.376	.233	.065	4

Table: Head Dimensions for Fillister Head Machine Screws - ANSI B18.6.3

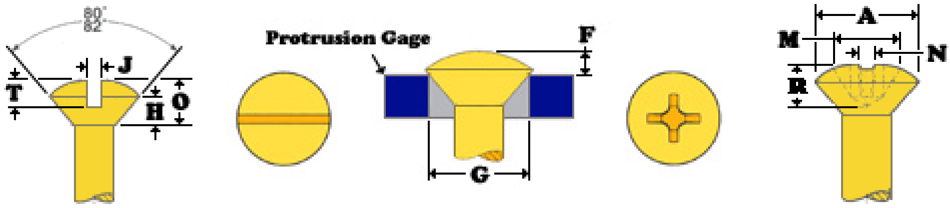
Flat Head Machine Screws



Head Dimensions for 82° Flat Head Machine Screws - ANSI B18.6.3 - 1998

Nominal Size	A		H		J		T		M	R	N	F		G	Phillips Driver Size
	Head Dimensions *				Slot Dimensions				Recess Dimensions			Protrusion Above Gaging Diameter		Gaging Diameter	
	Diameter		Height		Width		Depth		Dia	Depth	Width				
	Max	Min	Max	Min	Max	Min	Max	Min	Ref	Ref	Ref	Max	Min		
0	.112	.096	.035	.026	.023	.016	.015	.010	.062	.035	.014	.026	.016	.078	0
1	.137	.120	.043	.033	.026	.019	.019	.012	.070	.043	.015	.028	.016	.101	0
2	.162	.144	.051	.040	.031	.023	.023	.015	.096	.055	.017	.029	.017	.124	1
3	.187	.167	.059	.047	.035	.027	.027	.017	.100	.060	.018	.031	.018	.148	1
4	.212	.191	.067	.055	.039	.031	.030	.020	.122	.081	.018	.032	.019	.172	1
5	.237	.215	.075	.062	.043	.035	.034	.022	.148	.074	.027	.034	.020	.196	2
6	.262	.238	.083	.069	.048	.039	.038	.024	.168	.094	.029	.036	.021	.220	2
8	.312	.285	.100	.084	.054	.045	.045	.029	.182	.110	.030	.039	.023	.267	2
10	.362	.333	.116	.098	.060	.050	.053	.034	.198	.124	.032	.042	.025	.313	2
12	.412	.380	.132	.112	.067	.056	.060	.039	.262	.144	.035	.045	.027	.362	3
1/4	.477	.442	.153	.131	.075	.064	.070	.046	.276	.160	.036	.050	.029	.424	3
5/16	.597	.556	.191	.165	.084	.072	.088	.058	.358	.205	.061	.057	.0345	.539	4
3/8	.717	.670	.230	.200	.094	.081	.106	.070	.386	.234	.065	.065	.039	.653	4
1/2	.815	.765	.223	.186	.106	.091	.103	.065	.418	.265	.069	.081	.049	.739	4
* Edge of head may be rounded or flat.															

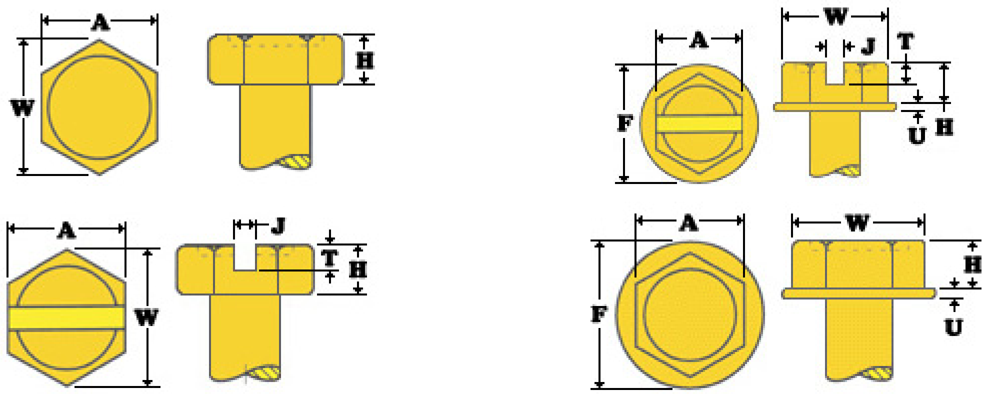
Oval Head Machine Screws



Head Dimensions for Oval Head Machine Screws - ANSI B18.6.3

Nominal Size	A		H	O	J		T		M	R	N	F		G	Phillips Driver Size
	Head Diameter		Head Height		Slot Dimensions				Recess Dimensions			Protrusion Above Gaging Diameter		Gaging Diameter	
			Side	Total	Width		Depth		Dia	Depth	Width				
	Max	Min	Max	Max	Max	Min	Max	Min	Rew	Ref	Ref	Max	Min		
0	.112	.096	.035	.056	.023	.016	.030	.025	.068	.036	.014	.047	.031	.078	0
1	.137	.120	.043	.068	.026	.019	.038	.031	.070	.039	.015	.053	.035	.101	0
2	.162	.144	.051	.080	.031	.023	.045	.037	.106	.060	.018	.058	.039	.124	1
3	.187	.167	.059	.092	.035	.027	.052	.043	.118	.072	.019	.064	.044	.148	1
4	.212	.191	.067	.104	.039	.031	.059	.049	.130	.086	.019	.069	.048	.172	1
5	.237	.215	.075	.116	.043	.035	.067	.055	.152	.073	.028	.075	.053	.196	2
6	.262	.238	.083	.128	.048	.039	.074	.060	.172	.092	.030	.080	.057	.220	2
8	.312	.285	.100	.152	.054	.045	.088	.072	.186	.107	.031	.091	.066	.267	2
10	.362	.333	.116	.176	.060	.050	.103	.084	.202	.125	.033	.102	.075	.313	2
12	.412	.380	.132	.200	.067	.056	.117	.096	.264	.140	.038	.113	.084	.362	3
1/4	.477	.442	.153	.232	.075	.064	.136	.112	.284	.160	.040	.129	.095	.424	3
5/16	.597	.556	.191	.290	.084	.072	.171	.141	.384	.226	.065	.155	.117	.539	4
3/8	.717	.670	.230	.347	.094	.081	.206	.170	.404	.245	.068	.182	.139	.653	4
7/16	.760	.715	.223	.345	.094	.081	.210	.174	.416	.257	.070	.195	.150	.690	4
1/2	.815	.765	.223	.354	.106	.091	.216	.176	.430	.271	.071	.212	.163	.739	4

Hex Head Machine Screws



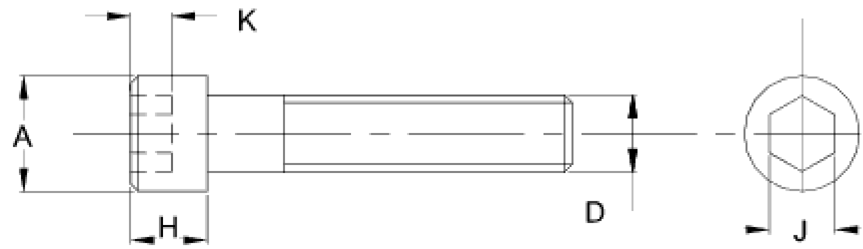
Head Dimensions
Hex Head and Hex Washer Head Machine Screws - ANSI B18.6.3 - 1998

Nominal Size	A		W	H		F		U		J		T	
	Width Across Flats		Width Across Corners	Head Height		Washer Diameter		Washer Thickness		Slot Width		Slot Depth	
	Max	Min	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
2	.125	.120	.134	.050	.040	.166	.154	.016	.010	-	-	-	-
4	.188	.181	.202	.060	.049	.243	.225	.019	.011	.039	.031	.042	.025
5	.188	.181	.202	.070	.058	.260	.240	.025	.015	.043	.035	.049	.030
6	.250	.244	.272	.093	.080	.328	.302	.025	.015	.048	.039	.053	.033
8	.250	.244	.272	.110	.096	.348	.322	.031	.019	.054	.045	.074	.052
10	.312	.305	.340	.120	.105	.414	.384	.031	.019	.060	.050	.080	.057
12	.312	.305	.340	.155	.139	.432	.398	.039	.022	.067	.056	.103	.077
1/4	.375	.367	.409	.190	.172	.520	.480	.050	.030	.075	.064	.111	.083
5/16	.500	.489	.545	.230	.208	.676	.624	.055	.035	.084	.072	.134	.100
3/8	.562	.551	.614	.295	.270	.780	.720	.063	.037	.094	.081	.168	.131
1/2	.750	.735	.820	.400	.367	1.040	.960	.085	.050	-	-	-	-

Metric Cap Screws

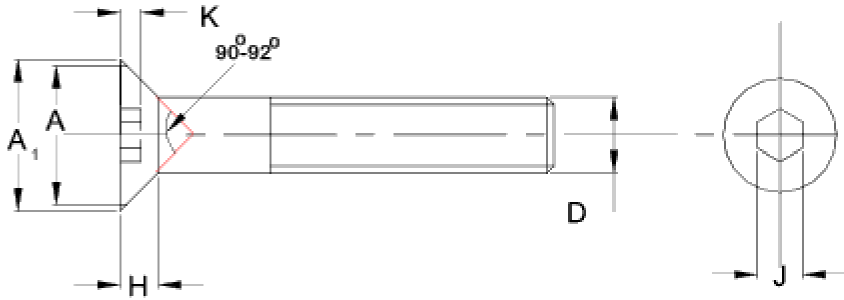
Notes:
All linear dimensions in millimeters
The dimensions are generally in accordance with BS EN ISO 4762 BS 3643- 2 & BS 4168

Socket Head Cap Screws (Metric)



Nominal	Thread.	Hex Socket Size	Body diameter and Head height		Head Dia		Soc. length
Size	Pitch		Max	Min	Max	Min	
M3	0.5	2.50	3.00	2.86	5.50	5.20	1.3
M4	0.70	3.00	4.00	3.82	7.00	6.64	2.00
M5	0.8	4.00	5.00	4.82	8.50	8.14	2.70
M6	1.0	5.00	6.00	5.82	10.00	9.64	3.30
M8	1.25	6.00	8.00	7.78	13.00	12.57	4.3
M10	1.5	8.00	10.00	9.78	16.00	15.57	5.50
M12	1.75	10.00	12.00	11.73	18.00	17.57	6.60
M16	2.0	14.00	16.00	15.73	24.00	23.48	8.80
M20	2.5	17.00	20.00	19.67	30.00	29.48	10.70
M24	3.0	19.00	24.00	23.67	36.00	35.38	12.90

Flat Head Cap Screws (Metric)



Nominal size	Thread Pitch	Hex Socket Size	Max Cone Dia	Head Dia		Head Height	Soc. length
D		J	A_1	A_max	A_Min	H	K
M3	0.5	2,0	6,72	6,00	5,82	1,86	1,05
M4	0.70	2,5	8,96	8,00	7,78	2,48	1,49
M5	0.8	3,0	11,2	10,00	9,78	3,1	1,86
M6	1.0	4,0	13,44	12,00	11,75	3,72	2,16
M8	1.25	5,0	17,92	16,00	15,73	4,96	2,85
M10	1.5	6,0	22,4	20,00	19,67	6,2	3,60
M12	1.75	8,0	26,88	24,00	23,67	7,44	4,35
M16	2.0	10,0	33,6	32,00	29,67	8,8	4,89
M20	2.5	10,0	40,32	40,00	35,61	10,16	5,49

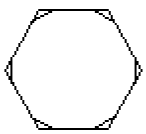
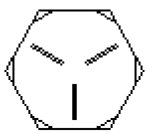
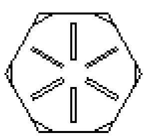
Appendix B

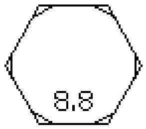
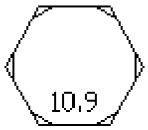
Recommended Fastener Torques (from www.boltdepot.com)

Size	Recommended Torque									
	Grade 5		**Grade 8**		**18-8 S/S**		**Bronze**		**Brass**	
	Coarse	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**
#4*	-	-	-	-	5.2	-	4.8	-	4.3	-
#6*	-	-	-	-	9.6	-	8.9	-	7.9	-
#8*	-	-	-	-	19.8	-	18.4	-	16.2	-
#10*	-	-	-	-	22.8	31.7	21.2	29.3	18.6	25.9
1/4	8	10	12	14	6.3	7.8	5.7	7.3	5.1	6.4
5/16	17	19	24	27	11	11.8	10.3	10.9	8.9	9.7
3/8	31	35	44	49	20	22	18	20	16	18
7/16	49	55	70	78	31	33	29	31	26	27
1/2	75	85	105	120	43	45	40	42	35	37
9/16	110	120	155	170	57	63	53	58	47	51
5/8	150	170	284	323	93	104	86	96	76	85
3/4	270	295	510	568	128	124	104	102	118	115
7/8	395	435	813	902	194	193	178	178	159	158
1	590	660	905	1030	287	289	265	240	235	212
* Sizes from 4 to 10 are in in.-lbs. Sizes from 1/4 up are in Ft. -lbs.										

Appendix C

Bolt Grade Markings and Strength Chart (Table from www.boltdepot.com)

Head Markings	Grade or Class	Material	Nominal Size Range (Inches)	Mechanical Properties: Proof Load (psi)	Mechanical Properties: Minimum Yield Strength (psi)	Mechanical Properties: Minimum Tensile Strength (psi)
American						
 No Markings	**Grade 2**	Low or Medium Carbon Steel	1/4 thru 3/4	55,000	57,000	74,000
			Over 3/4 thru 1-1/2	33,000	36,000	60,000
 3 Radial Lines	**Grade 5**	Medium Carbon Steel, Quenched and Tempered	1/4 thru 1	85,000	92,000	120,000
			Over 1 thru 1-1/2	74,000	81,000	105,000
 6 Radial Lines	**Grade 8**	Medium Carbon Alloy Steel, Quenched and Tempered	1/4 thru 1-1/2	120,000	130,000	150,000
Stainless markings vary. Most stainless is non-magnetic	**18-8 Stainless**	Steel alloy with 17-19% Chromium and 8-13% Nickel	1/4 thru 5/8		80,000 – 90,000	100,000 – 125,000
			3/4 thru 1		45,000 – 70,000	100,000
			Above 1			80,000 – 90,000
Metric						

 8.8	**Class 8.8**	Medium Carbon Steel, Quenched and Tempered	All Sizes thru 1-1/2	85,000	92,000	120,000
 10.9	**Class 10.9**	Alloy Steel, Quenched and Tempered	All Sizes thru 1-1/2	120,000	130,000	150,000
Stainless markings vary. Most stainless is non-magnetic	**A-2 Stainless**	Steel alloy with 17-19% Chromium and 8-13% Nickel	1/4 thru 5/8		80,000 – 90,000	100,000 – 125,000
			3/4 thru 1		45,000 – 70,000	100,000
			Above 1			80,000 – 90,000
Tensile Strength: The maximum load in tension (pulling apart) which a material can withstand before breaking or fracturing. **Yield Strength:** The maximum load at which a material exhibits a specific permanent deformation **Proof Load:** An axial tensile load which the product must withstand without evidence of any permanent set.						

ISO metric fastener material strength property classes (grades). ISO metric fastener material property classes (grades) should be used. For example, fastener material ISO property class 5.8 means nominal (minimum) tensile ultimate strength 500 MPa and nominal (minimum) tensile yield strength 0.8 times tensile ultimate strength or 0.8(500) = 400 MPa. (In a few cases, the actual tensile ultimate strength may be approximately 20 MPa higher than nominal tensile ultimate strength indicated via the nominal property class code. Consult Table 10, below, for exact values.) Many anchor bolts (L, J, and U bolts, and threaded rod) are made from low carbon steel grades, such as ISO classes 4.6, 4.8, and 5.8.

Appendix D

Letter and Number Decimal Equivalents

NUMBER DRILL SIZES							
No.	Size of No. in Decimals	No.	Size of No. in Decimals	No.	Size of No. in Decimals	No.	Size of No. in Decimals
1	0.2280	21	0.1590	41	0.0960	61	0.0390
2	0.2210	22	0.1570	42	0.0935	62	0.0380
3	0.2130	23	0.1540	43	0.0890	63	0.0370
4	0.2090	24	0.1520	44	0.0860	64	0.0360
5	0.2055	25	0.1495	45	0.0820	65	0.0350
6	0.2040	26	0.1470	46	0.0810	66	0.0330
7	0.2010	27	0.1440	47	0.0785	67	0.0320
8	0.1990	28	0.1405	48	0.0760	68	0.0310
9	0.1960	29	0.1360	49	0.0730	69	0.02925
10	0.1935	30	0.1285	50	0.0700	70	0.0280
11	0.1910	31	0.1200	51	0.0670	71	0.0260
12	0.1890	32	0.1160	52	0.0635	72	0.0250
13	0.1850	33	0.1130	53	0.0595	73	0.0240
14	0.1820	34	0.1110	54	0.0550	74	0.0225
15	0.1800	35	0.1100	55	0.0520	75	0.0210
16	0.1770	36	0.1065	56	0.0465	76	0.0200
17	0.1730	37	0.1040	57	0.0430	77	0.0180
18	0.1695	38	0.1015	58	0.0420	78	0.0160
19	0.1660	39	0.0995	59	0.0410	79	0.0145
20	0.1610	40	0.0980	60	0.0400	80	0.0135

LETTER DRILL SIZE			
A	0.234	N	0.302
B	0.238	O	0.316
C	0.242	P	0.323
D	0.246	Q	0.332
E	0.250	R	0.339
F	0.257	S	0.348
G	0.261	T	0.358
H	0.266	U	0.368
I	0.272	V	0.377
J	0.277	W	0.386
K	0.281	X	0.397
L	0.290	Y	0.404
M	0.295	Z	0.413