# 18 Threads and Fastening Devices

## Learning Objectives

After studying this chapter, you will be able to:

- Identify and explain common terms used to describe screw threads.
- Describe the standard methods used to represent threads on drawings.
- Identify different types of bolts, screws, and nuts and explain how they are drawn.
- Explain the purpose of washers and retaining rings.
- List applications for rivets, pin fasteners, and keys.

## Technical Terms

Angle of thread
Backlash
Blind rivet
Bolt
Cap nuts
Cap screw
Captive nuts
Common nuts
Crest
Detailed representation
Double-threaded screw
Drive screws
External thread
Fastener
Finished nuts
Finishing washers
Flat washers
Free-spinning nuts
Heavy nuts
Internal thread
Jam nuts
Keys
Knurled nuts
Lead
Lead angle
Left-hand thread
Locknuts
Lock washers
Machine screw
Major diameter
Metric Screw Thread Series
Minor diameter
Nut
Pins
Pitch
Pitch diameter
Prevailing-torque locknuts
Retaining rings
Right-hand thread
Root
Schematic representation
Self-retaining nuts
Setscrew
Simplified representation
Single-thread engaging nuts
Single-threaded screw
Slotted nuts
Special nuts
Spring-action locknuts
Springs
Standard rivet
Straight pipe threads
Stud
Tapered pipe threads
Thread class
Thread-cutting screws
Thread form
Thread-forming screws
Thread series
Triple-threaded screw
Unified Coarse (UNC)
Unified Constant Pitch (UN)
Unified Extra Fine (UNEF)
Unified Fine (UNF)
Unified Screw Thread Series
Wing nuts
Wood screws

The types of hardware and methods required by industry to join components makes fastening one of the most dynamic and fastest-growing technologies. A ***fastener*** is any mechanical device used to attach two or more pieces or parts together in a fixed position. To a nontechnical person, fasteners may appear quite simple. Many fasteners are simple. However, in high-volume assembly work, the speed of assembly, holding capabilities, and reliability of fasteners call for many special types of fasteners, **Figure 18-1**. Many different industries use fasteners. Some of these industries include the aerospace, appliance, automotive, and electrical industries.

Threads and threaded fasteners are used on most machine assemblies produced in industry. Standard methods of specifying and representing screw threads are presented in this chapter.

**Figure 18-1**. Many industrial assemblies require fasteners. The types of fasteners selected must suit the needs of a particular manufacturing or construction application.

Considerable progress has been made jointly by the United States, Canada, and England in standardizing screw threads. The result of this cooperative effort is the ***Unified Screw Thread Series***. This is now the American standard for screw thread forms.

Unified threads and the former standard series, American National threads, have essentially the same thread form. These threads are mechanically interchangeable. The chief difference in the two types of threads is in the application of allowances, tolerances, pitch diameter, and specification.

# Thread Terminology

It is important to understand the general terminology associated with thread forms. The following list includes the more important thread terms, **Figure 18-2**.

- ***Major diameter***. The largest diameter on an external or internal screw thread.
- ***Minor diameter***. The smallest diameter on an external or internal screw thread.
- ***Pitch diameter***. The diameter of an imaginary cylinder passing through the thread profiles at the point where the widths of the thread and groove are equal.
- ***Pitch***. The distance from a point on one screw thread to a corresponding point on the next thread, measured parallel to the axis. The pitch for a particular thread may

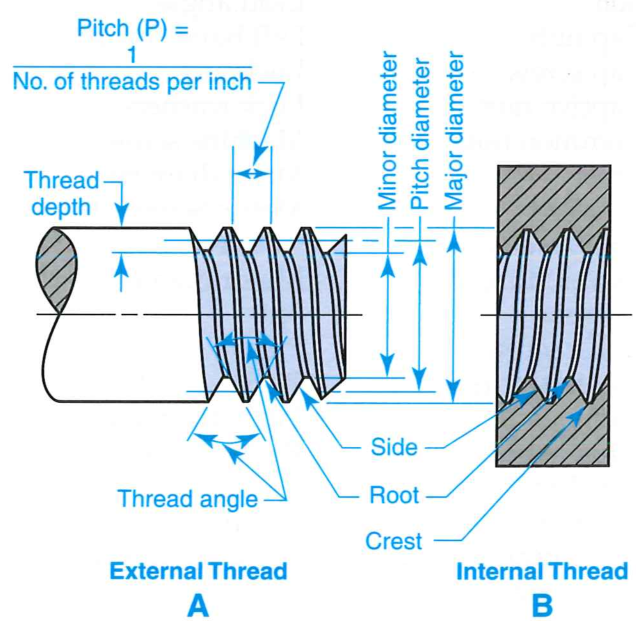


**Figure 18-2**. Specific terms associated with thread forms.

be calculated mathematically by dividing one inch by the number of threads per inch. Example:

$$\text{Pitch} = \frac{1''}{10 \text{ threads/inch}} = .10''$$

- *Crest*. The top surface of a thread joining two sides (or flanks).
- *Root*. The bottom surface of a thread joining two sides (or flanks).
- *Angle of thread*. The included angle between the sides, or flanks, of the thread measured in an axial plane.
- *External thread*. The thread on the outside of a cylinder, such as a machine bolt.
- *Internal thread*. The thread on the inside of a cylinder, such as a nut.
- *Thread form*. The profile of the thread as viewed on the axial plane.
- *Thread series*. The groups of diameter-pitch combinations distinguished from each other by the number of threads per inch applied to a specific diameter.
- *Thread class*. Designation describing the fit between two mating thread parts with respect to the amount of clearance or interference present when they are assembled. Class 1 represents a loose fit and Class 3 a tight fit.
- *Right-hand thread*. A thread, when viewed in the end view, that winds clockwise to assemble. A thread is considered to be right-hand thread (RH) unless otherwise stated.
- *Left-hand thread*. A thread, when viewed in the end view, that winds counterclockwise to assemble. Left-hand (LH) threads are indicated as such.

## Thread Forms

A thread form is the profile of the thread. There are a number of standard thread forms, **Figure 18-3**. However, the Unified screw thread form has been recognized by the United States, Canada, and Great Britain as the standard for fasteners such as bolts, machine screws, and nuts. The Unified form is a combination of the American National and British Whitworth forms. The Unified form has almost completely replaced the American National form due to fewer difficulties encountered in producing the flat crest and root of the thread.

While the Unified form is used for fasteners, other thread forms are used for specific applications. The Square, Acme, Buttress, and Worm thread forms are used to transmit motion and power. This is due to the thread profile of each form. The profiles of these thread forms are more vertical with their axes. Examples of motion and power transmission include steering gears (worm threads) and lead screws (square and Acme threads) on machine lathes. The Sharp V thread form is used where friction is desired, such as setscrews. The Knuckle thread form is used for fast assembly of parts, such as lightbulbs and bottle caps.

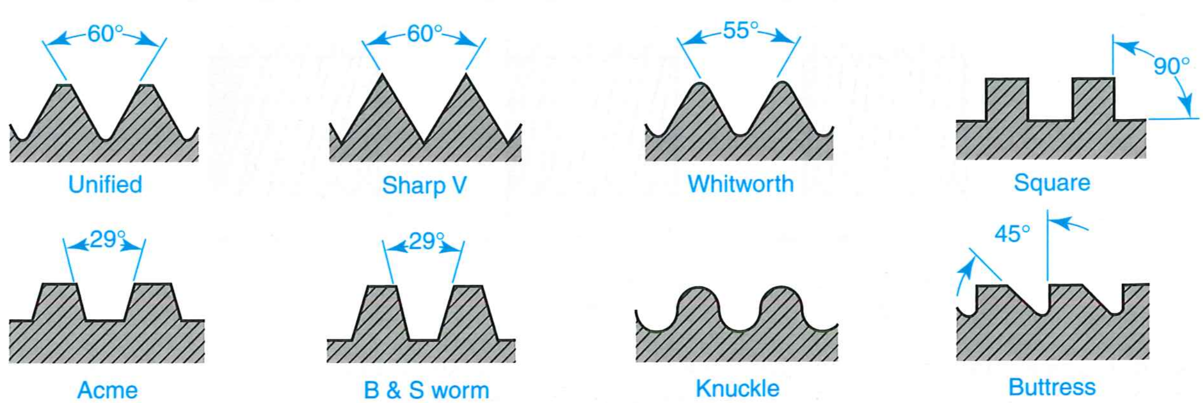


**Figure 18-3**. Thread forms designate the profile of the thread.

## Thread Series

A thread series designates the form of thread for a particular application. There are four standard series of Unified screw threads: coarse, fine, extra fine, and constant pitch.

The ***Unified Coarse (UNC)*** series is used for general applications. This series is used for bolts, screws, nuts, and threads in cast iron, soft metals, or plastic where fast assembly or disassembly is required.

The ***Unified Fine (UNF)*** series is used for bolts, screws, and nuts where a higher tightening force between parts is required. The Unified Fine series is also used where the length of the thread engagement is short and where a small lead angle is desired. The ***lead angle*** is the angle between the helix of the thread at the pitch diameter and a plane perpendicular to the axis.

The ***Unified Extra Fine (UNEF)*** series is used for even shorter lengths of thread engagements. It is also used for thin-wall tubes, nuts, ferrules, and couplings, and in applications requiring high stress resistance.

The ***Unified Constant Pitch (UN)*** series is designated *UN*. The number of threads per inch precedes the designation. For example, "8UN" specifies a Unified Constant Pitch thread with eight threads per inch. This series of threads is for special purposes, such as high-pressure applications. This series is also used for large diameters where other thread series do not meet the requirements.

The 8-thread series, 12-thread series, and 16-thread series fall within the Constant Pitch classifications. The 8-thread series (8UN) is also used as a substitute for the Unified Coarse series for diameters larger than 1". The 12-thread series (12UN) is used as a continuation of the Fine Thread series for diameters larger than 1 1/2". The 16-thread series (16UN) is used as a continuation of the Extra Fine series for diameters larger than 1 11/16". Dimensions for the Unified series of thread are given in the Reference Section of this book.

## Thread Classes

The classes of fit for external and internal threads of mating parts are distinguished from each other by the amount of tolerance and allowance permitted for each class. Classes 1A, 2A, and 3A indicate external threads. Classes 1B, 2B, and 3B indicate internal threads.

Class 1 fits are used for applications requiring minimum binding to permit frequent and quick assembly or disassembly. A Class 2 fit is for bolts, screws, nuts, and similar fasteners for normal applications in mass production. A Class 3 fit is for applications requiring closer tolerances than the other classes for a fit to withstand greater stress and vibration.

## Single and Multiple Threads

A screw or other threaded machine part may contain single or multiple threads, **Figure 18-4**. A ***single-threaded screw*** will move forward into its mating part a distance equal to its pitch in one complete revolution (360°). In the case of a

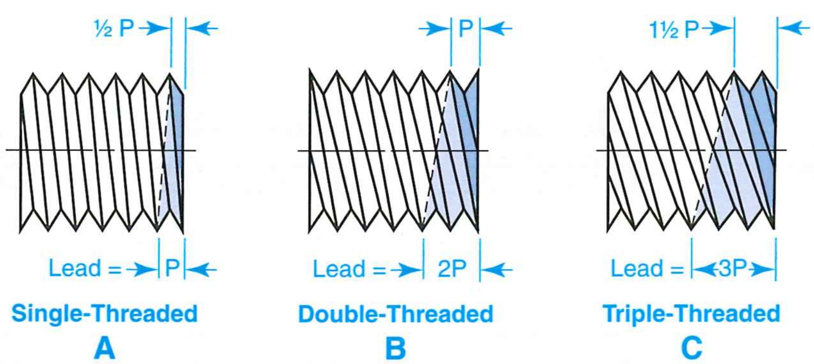


**Figure 18-4.** Single-threaded and multiple-threaded screws. A—A single thread moves into the part a distance equal to the pitch in one revolution. B—A double thread moves into the part a distance equal to twice its pitch in one revolution. C—A triple thread moves into the part a distance equal to three times its pitch in one revolution.

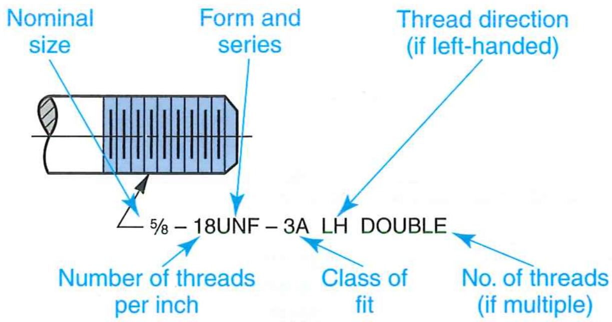


**Figure 18-5**. A note specifying threads should list the nominal size (major diameter), the number of threads per inch, the thread form and series, and the thread class, in that order. The thread is assumed to be right-handed unless noted. If the thread is anything other than a single thread, the indication should follow the thread class and direction (if required).

single-threaded screw, the pitch (P) is equal to the lead. The *lead* is the axial advance of the thread in one revolution. Notice that the crest line is offset a distance of 1/2P since a single view shows only a one-half revolution of a thread.

A ***double-threaded screw*** has two threads side by side and moves forward into its mating part a distance equal to its lead, or 2P. The crest line of a double-threaded screw is offset a distance of P in a single view.

A ***triple-threaded screw*** has three individual threads. A triple-threaded screw moves forward a distance equal to its lead, or 3P.

Single threads are used where considerable pressure or power is to be exerted in the movement of mating parts. A nut and bolt, or a machinist vise screw and its jaws, are two examples where single threads are used. Multiple threads are used where rapid movement between mating parts is desired. The mating parts of a ballpoint pen, or water faucet valves, are examples where multiple threads are used.

# Thread Specifications

Screw threads are specified on drawings by thread notes, **Figure 18-5**. A thread note provides the following information in a standard sequential order: The nominal size (major diameter or screw number), the number of threads per inch, the thread form (UN) and series (F) grouped together (UNF), and the class of fit (3A). A thread is assumed to be a right-hand, single thread unless noted otherwise. A left-hand thread is indicated by the letters "LH" and multiple threads are indicated by the specification "DOUBLE" or "TRIPLE."

Thread specifications must be included on all threaded parts by a note or by direct dimensions. A thread note for external thread is shown in **Figure 18-5**. For internal thread, threads are specified as shown in **Figure 18-6**. The note may be connected to a leader in the circular view, **Figure 18-6A**. The length or depth of the threaded part is given as the last item in the specification. The length may also be dimensioned directly on the part, **Figure 18-6B**. Standard size bolts and nuts may be called out by a letter on the drawing and specified in the materials list. A thread note indicating the number of holes to be threaded, the thread specification, the tap drill size, the thread depth, and countersinking is shown in **Figure 18-7**.

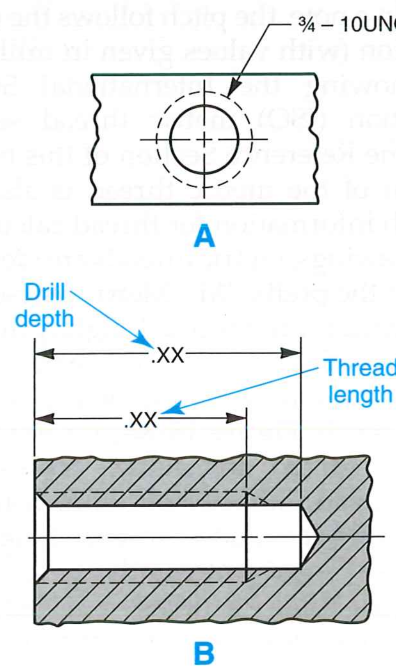


**Figure 18-6**. Internal thread specifications on drawings. A—An internal thread can be specified with a callout to the circular view. B—An internal thread can also be specified by dimensions in a section view. (Bottom: American Society of Mechanical Engineers)

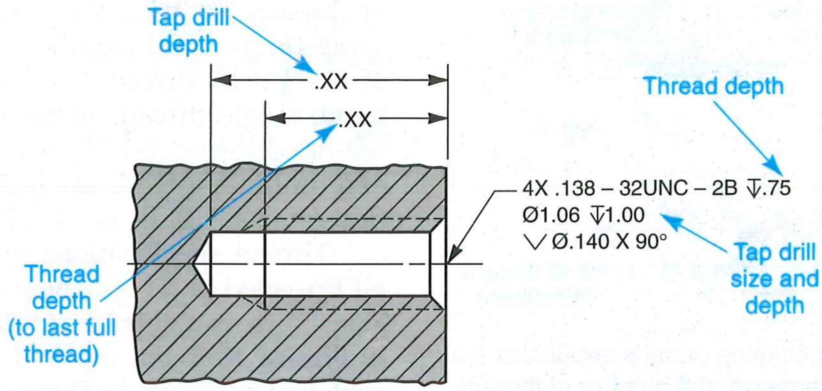


**Figure 18-7.** Thread notes may provide additional information such as the tap drill size, the drill depth, and the thread depth. (American Society of Mechanical Engineers)

## Metric Thread Specifications

Metric thread specifications are similar to Unified thread specifications, but there are some slight variations. In the Unified series, the designation of the thread pitch is given as the number of threads per inch (for example, the note "3/4–10UNC" specifies a pitch of 1/10"). In the ***Metric Screw Thread Series,*** the specification given for the pitch is the actual pitch. When required in a note, the pitch follows the diameter specification (with values given in millimeters). Tables showing the International Standards Organization (ISO) metric thread series are given in the Reference Section of this book. The basic form of the metric thread is also shown along with information for thread calculations.

On drawings, metric threads are identified in notes with the prefix "M." Metric coarse threads and fine threads are specified slightly differently. Metric coarse threads are most common and are designated by simply giving the prefix "M" and the diameter. In **Figure 18-8A**, for example, M8 is a coarse thread designation representing a nominal thread diameter of 8 mm with a pitch of 1.25 mm understood (a thread designation is for a coarse thread unless otherwise noted). A coarse metric thread generally falls between the coarse and fine series of Unified thread measurements for a comparable diameter.

Metric fine threads are designated by listing the pitch as a suffix, **Figure 18-8B**. A fine thread for a part specified as "M8 × 1.0" would indicate an 8 mm diameter with a pitch of 1.0 mm.

The tolerance and class of fit are designated for metric threads by combining numbers and letters and adding them in a certain sequence to the callout. The thread designation in **Figure 18-9** calls for a fine thread of 6 mm diameter and 0.75 mm pitch (no pitch is given in the designation for a coarse thread). Also given are the pitch diameter tolerance (grade 6) and allowance (h) and the major diameter tolerance (grade 6) and allowance (g).

# Thread Representations

There are three conventional methods of representing threads on drawings. Threads may be represented using a ***detailed representation,*** a ***schematic representation,*** or a ***simplified representation,*** **Figure 18-10**. The detailed convention is a closer representation of the actual thread. It is sometimes used to show the geometry of a thread form as an enlarged detail.

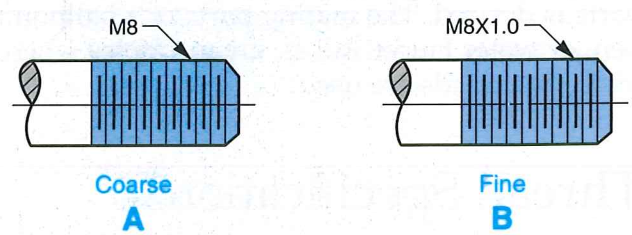


**Figure 18-8.** Metric thread designations. A—A metric coarse thread designation gives only the diameter (the pitch is understood). B—The fine thread designation gives the pitch following the diameter.

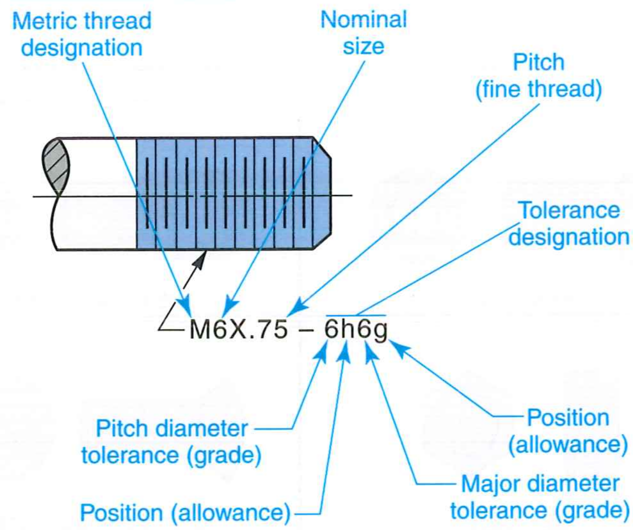


**Figure 18-9.** A complete designation for a metric thread will provide all of the information to fully describe the thread.

However, the schematic and simplified conventions are more commonly used. They save drafting time and, in many instances, produce a clearer drawing.

In manual drafting, there are standard drawing procedures used to lay out and draw representations of threads. These procedures are discussed in the following sections. In CAD drafting, it is more common to generate threads and threaded parts (such as fasteners) by inserting predrawn symbols. Symbols for use on CAD drawings are called *blocks*. Many CAD programs provide symbols for fasteners, such as bolts and screws, as blocks. Often, blocks are stored with other blocks in collections known as *symbol libraries*. See **Figure 18-11**. Symbol libraries make it easy to access a specific type of fastener for a given application. In more advanced CAD programs, threaded fasteners can be created as solid models by entering thread specifications

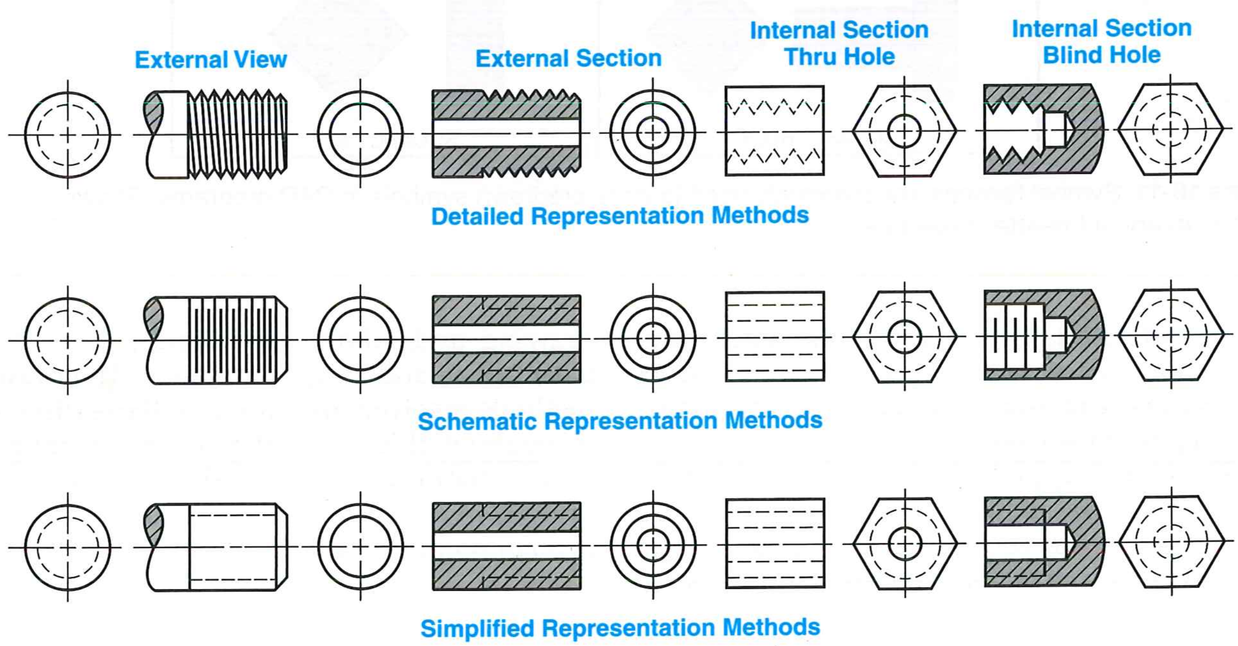


**Figure 18-10.** Conventional representations of screw threads.

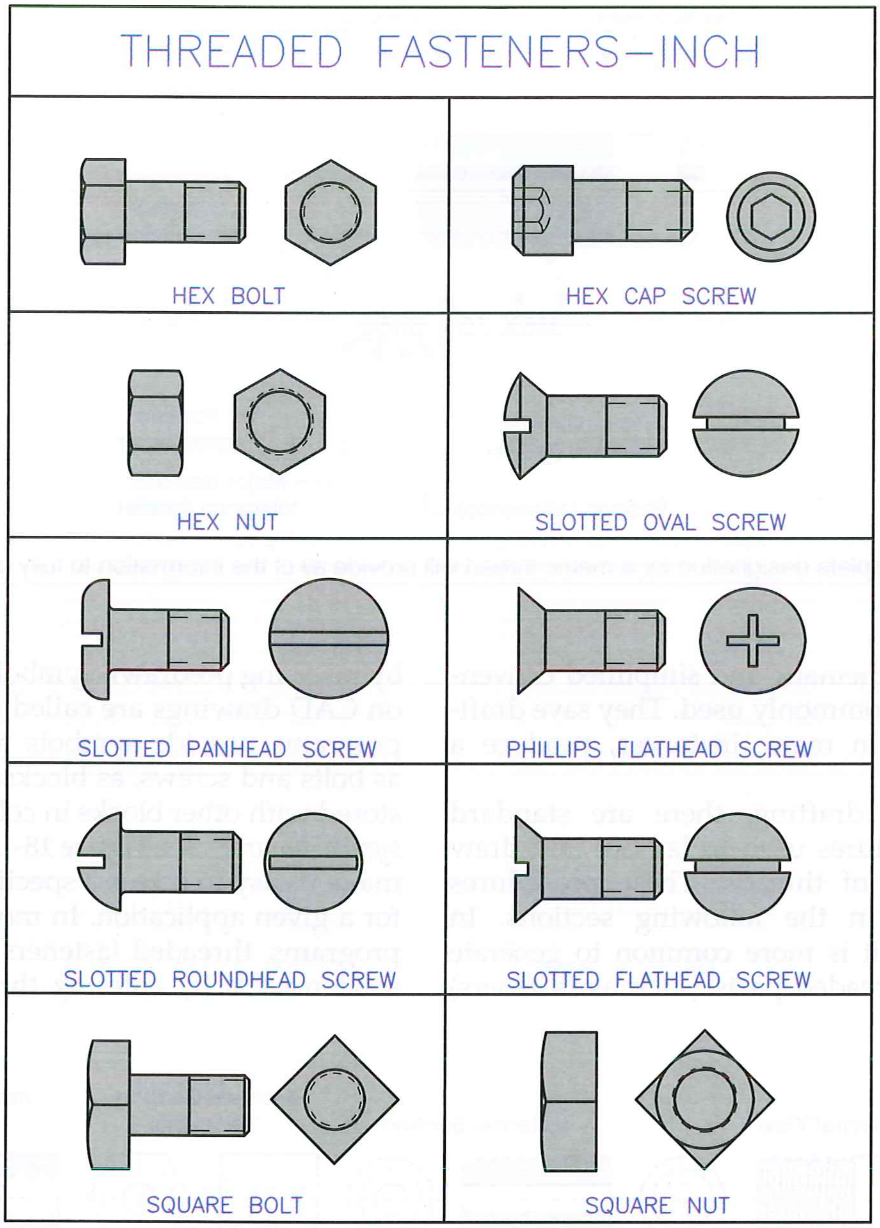


**Figure 18-11.** Symbol libraries are commonly used to store predrawn symbols in CAD programs. Shown is a symbol library of threaded fasteners.

or parameters related to a given manufacturing application. These CAD-based methods save considerable drawing time and provide many advantages to the drafter.

The drawing procedures presented in this chapter are best suited for manual drawing applications, but if you are using a CAD system, you can construct thread representations using drawing and editing commands, such as the **Line**, **Offset**, and **Copy** commands. The drawing methods involved are similar to those discussed throughout this book. If you are creating the representations from original geometry, you can save them as blocks and incorporate them into symbol libraries for later use.

## Construct a Detailed Representation of Sharp V Threads

The construction of the Sharp V thread form with a detailed thread representation is shown in **Figure 18-12**. The pitch of the thread can be used to lay out the thread spacing, **Figure 18-12A**. The thread pitch is equal to *1/number of threads per inch*. However, the conventional practice, especially on small machine parts, is to approximate the pitch spacing for the thread crests so that they appear natural and are in proportion with the size of the part. Proceed as follows to draw a detailed thread representation.

1. Lay out the lines for the major diameter and the centerline axis. Lay off measurements for the crest lines, **Figure 18-12A**. Start the spacing with a half space, since the first thread crest represents only a 1/2 revolution, or 180°. Continue the spacing along the bottom edge of the threaded part.
2. Draw the crest lines by adjusting a triangle along a straightedge to the correct slope, **Figure 18-12B**. Actually, the crest and root lines are helix curves, but they are drawn as straight lines.
3. Draw lines inclined at 60° to construct the sides for the thread form, **Figure 18-12C**. Join the bottom of these threads to form the root lines. Notice that the root lines are not parallel to the crest lines in this representation. This is due to the difference in diameters.
4. Complete the representation by drawing a chamfer on the end of the thread at the minor diameter, **Figure 18-12D**. Add the callout (thread note) to provide the thread specification.

Notice that the slope for a right-hand thread is shown in **Figure 18-12**. The thread advances into its mating part when turned clockwise on its axis. The slope for a left-hand thread would be the opposite.

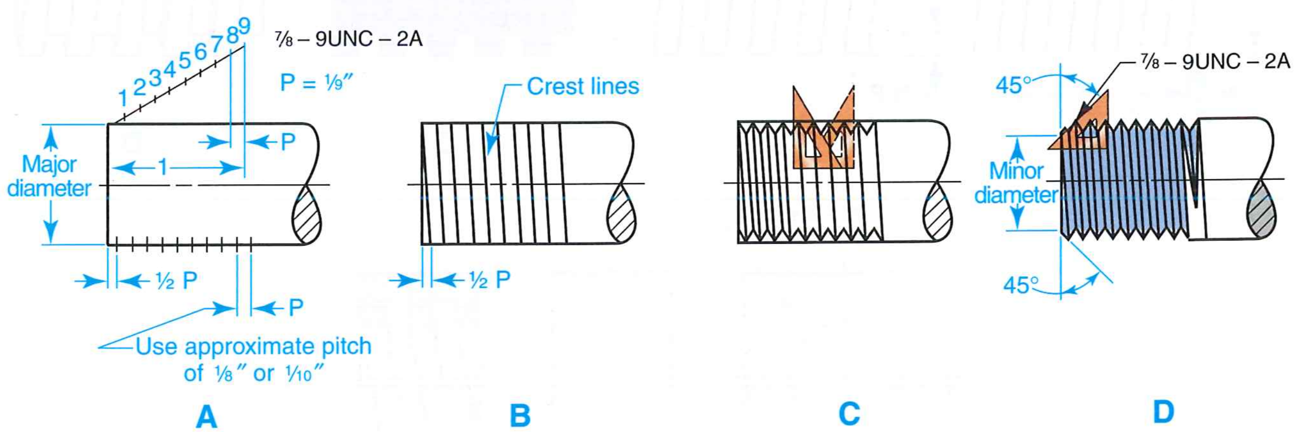


**Figure 18-12**. Constructing a detailed representation of the Sharp V thread form.

## Construct a Detailed Representation of Square Threads

The construction of the square thread form with a detailed thread representation is shown in **Figure 18-13**. This is an approximation of the thread since the thread would appear as a helix curve rather than a straight line. Proceed as follows to draw a detailed thread representation.

1. Construct the major diameter. Draw crest lines 1/2P apart for single threads, **Figure 18-13A**. The pitch of the square threads in **Figure 18-13** is equal to 1/4".
2. Draw the lines for the top of the threads, **Figure 18-13B**.
3. Draw light lines representing the minor diameter a distance of 1/2P from the major diameter.
4. Draw diagonal construction lines connecting the tops of the thread to represent the portion of the thread on the back side that is visible. Darken the visible thread line outside the minor diameter, **Figure 18-13C**.
5. Draw a light construction line between the inside crest lines to locate points on the minor diameter where the root lines meet the minor diameter, **Figure 18-13D**.
6. Connect these points with the points where the adjacent crest line crosses the centerline to form the root lines of the thread.
7. Add a note to provide the thread specification.

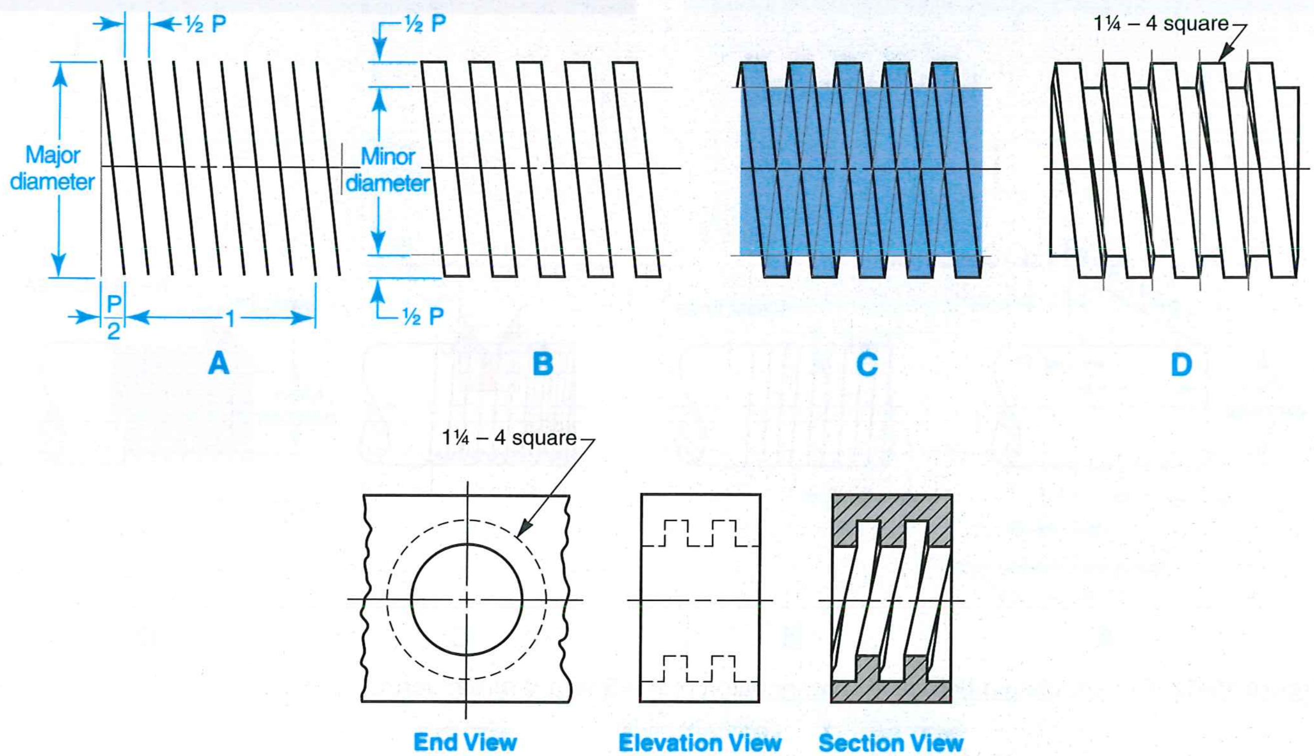


**Figure 18-13**. Constructing detailed representations of the square thread form. Shown are constructions for an external square thread (top) and an internal square thread (bottom).

# Construct a Detailed Representation of Acme Threads

The Acme thread form is similar to the square thread form, except the sides of the Acme form are drawn to provide an included angle of 30° (actually 29°) for the groove and 30° for the thread, **Figure 18-14**. Proceed as follows to draw a detailed thread representation.

1. Draw a centerline and lay off the length and the major diameter, **Figure 18-14A**.
2. Determine the thread pitch (the thread pitch in **Figure 18-14** is equal to 1/4"). Draw the minor diameter 1/2P from the major diameter.
3. Draw the pitch diameter halfway between the major and minor diameters, **Figure 18-14B**. Lay off the thread pitch along one pitch diameter line by measuring a series of divisions 1/2P (for the thread and groove) and projecting these divisions to the opposite pitch diameter line.
4. Construct the sides of the threads by drawing lines inclined at 15° to the vertical division lines and through the points marked on the pitch diameter, **Figure 18-14C**. Draw the crest and root diameter lines of the thread.
5. Connect the thread crests with lines sloping downward 1/2P to the right for right-hand threads (or to the left for left-hand threads).
6. Draw the root lines to complete the thread, **Figure 18-14D**.
7. Add a note to provide the thread specification.

There are two general classifications for Acme threads: General Purpose threads and Centralizing threads. The General Purpose

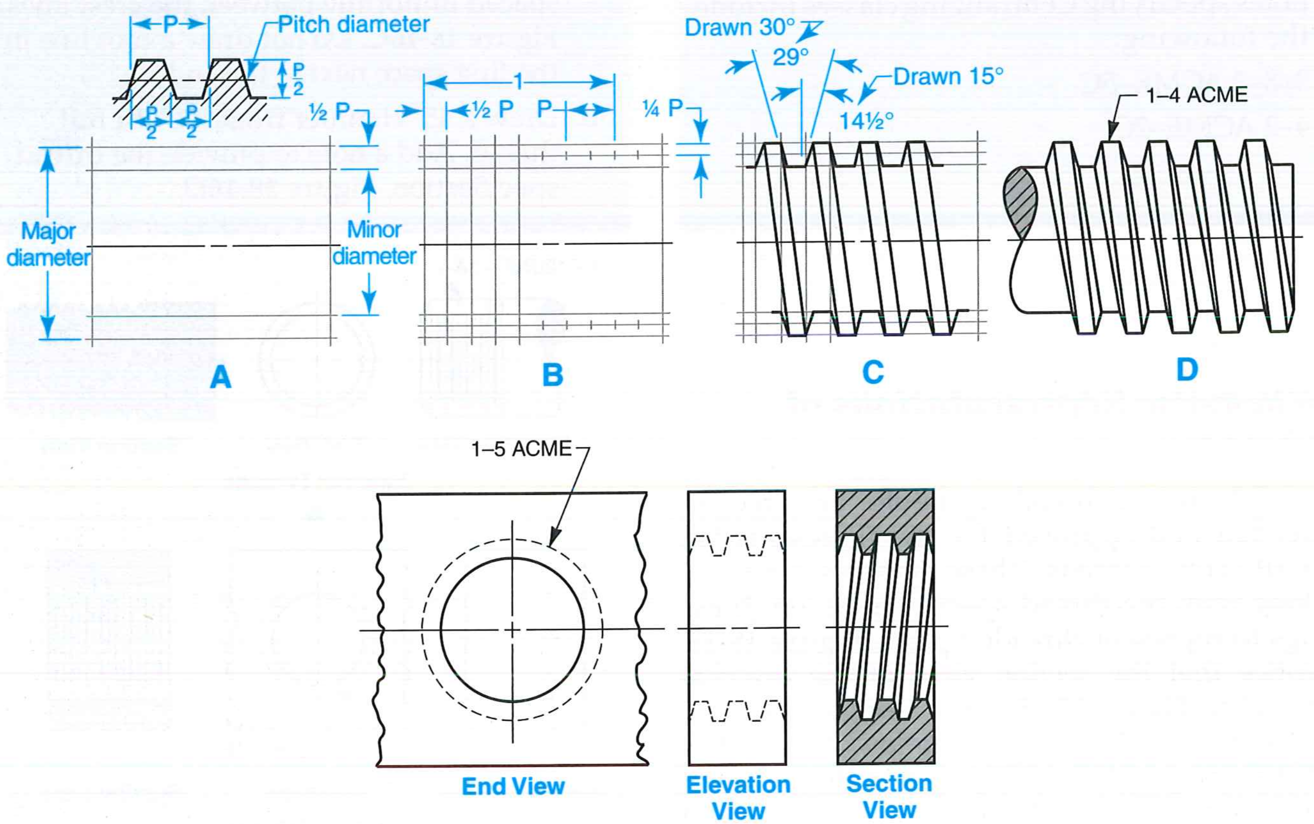


**Figure 18-14**. Constructing detailed representations of the Acme thread form. Shown are constructions for an external thread (top) and an internal thread (bottom).

classes (Classes 2G, 3G, and 4G) provide clearances on all diameters for free movement. The variation in classes has to do with the amount of backlash in the threads. ***Backlash*** is the play (lost motion) between moving parts, such as a threaded shaft and nut, or the teeth of meshing gears. Class 2G is the preferred choice for General Purpose threads. If less backlash is desired, Classes 3G and 4G are provided.

Examples of Acme thread notes specifying General Purpose threads include the following:

1/2–10 ACME–2G

2–4 ACME–4G

The Centralizing classes of Acme threads (Classes 2C to 6C) have limited clearances at the major diameters of internal and external threads. This permits a bearing to maintain approximate alignment of the threads and prevents wedging. A Class 6C Acme thread is a closer fit than a Class 2C thread. Examples of Acme thread notes specifying Centralizing classes include the following:

3/8–2 ACME–5C

4–2 ACME–2C

## Schematic Representations of Threads

Schematic thread symbols are recommended and approved for the representation of all screw threads. These symbols are used, along with the thread specifications, on drawings to represent threaded parts, **Figure 18-15**. Notice that the section view of the external thread in **Figure 18-15** is not a schematic symbol but a detailed representation. Also notice that the internal thread symbol in the elevation view is the same symbol used for the simplified representation of internal threads in the elevation view.

## Construct a Schematic Representation of Threads

The construction of the schematic thread symbol is as follows. See **Figure 18-16**.

1. Lay out a centerline and the major diameter of the thread, **Figure 18-16A**.
2. Lay off the pitch of the thread. The pitch does not need to be true, and can be estimated if laid off uniformly.
3. Draw thin lines across the major diameter to represent the crest lines of the thread.
4. To construct the minor diameter, lay off a 60° "V" between the crest lines. Draw a light construction line along the threaded length of the part, **Figure 18-16B**. Repeat this on the opposite side of the piece.
5. Use a heavy line for the root lines. The root lines are drawn between the lines marking the minor diameter and are spaced uniformly between the crest lines, **Figure 18-16C**. Do not draw a root line in the first space next to the end.
6. Draw a 45° chamfer from the last full thread. Add a note to provide the thread specification, **Figure 18-16D**.

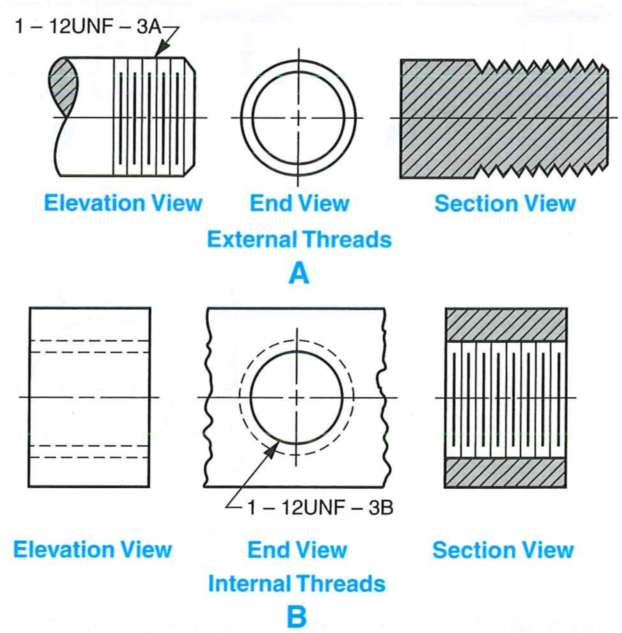


**Figure 18-15**. Schematic representations of threads.

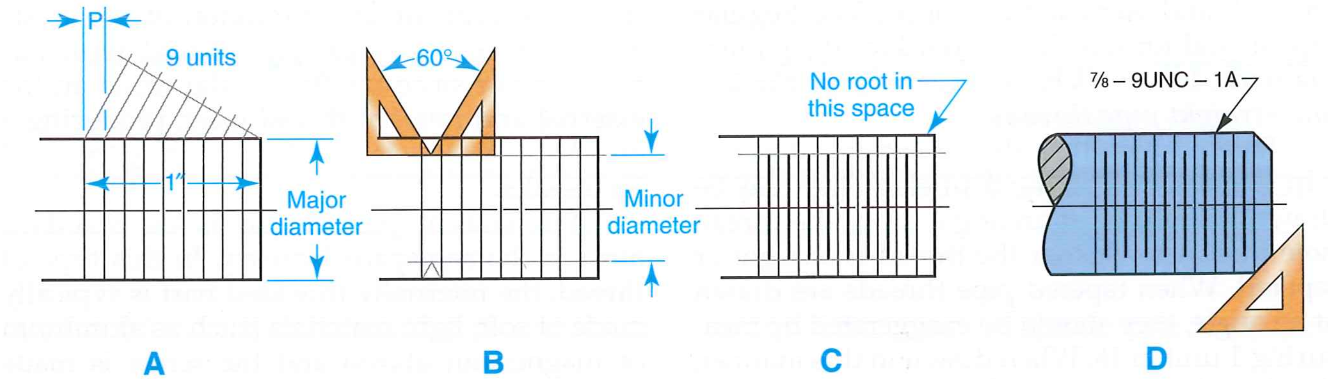


**Figure 18-16.** Constructing a schematic representation of an external thread.

## *Simplified Representations of Threads*

The use of simplified thread symbols is the fastest way to represent screw threads on a drawing, **Figure 18-17**. The major diameter is laid out by direct measurement. The minor diameter is laid out by using the 60° "V" method, or estimated measurements.

## *Representations of Small Threads*

A threaded part of a small diameter is difficult to draw to true or reduced scale dimensions. The small screw pitch will crowd the crest and root lines when using the schematic method, **Figure 18-18**. In the simplified method, the clarity of the symbol would be impaired by a crowding of the major and minor diameters. The conventional practice is to exaggerate the space between crests and roots, and major and minor diameters, since accuracy is not as important as clarity of the symbol. The note specifying the thread controls the actual thread characteristics.

## *Pipe Threads*

Pipe thread forms are classified by their intended use. Three approved forms for pipe threads include the American Standard Regular,

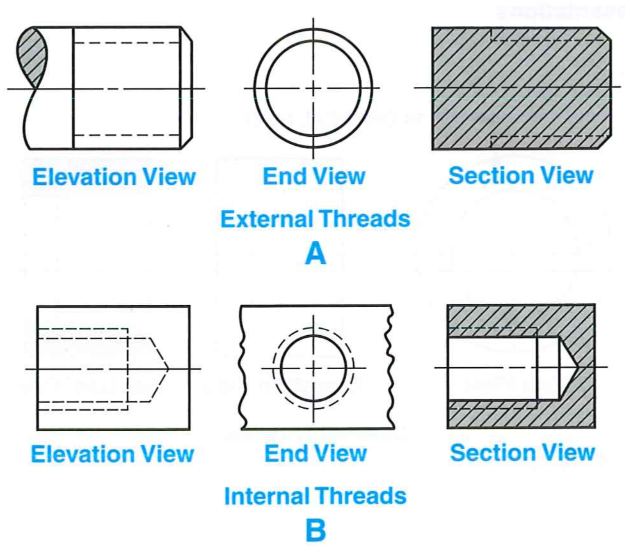


**Figure 18-17.** Simplified representations of threads can provide clarity to the drawing. These should be used when specific details of the thread do not need to be seen.

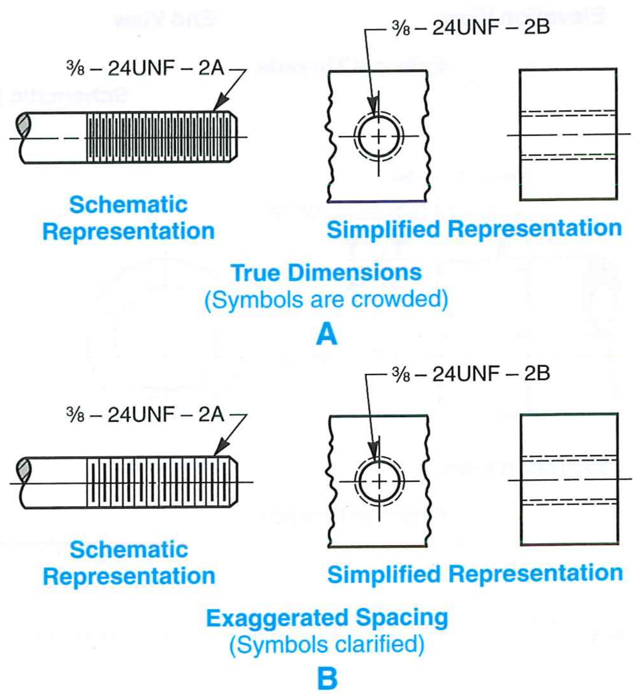


**Figure 18-18.** Exaggerated spacing clarifies thread representations on small thread drawings.

Dryseal, and Aeronautical forms. The Regular pipe thread form is the standard for the plumbing trade. It is available in ***tapered pipe threads*** and ***straight pipe threads***.

Tapered pipe threads are cut on a taper of 1 in 16 measured on the diameter. They may be drawn straight or at an angle, since the thread note indicates whether the thread is straight or tapered. When tapered pipe threads are drawn at an angle, they should be exaggerated by measuring 1 unit in 16. When drawn in this manner, the threads are measured on the radius (rather than the diameter). This produces an angle of approximately 3°, **Figure 18-19**.

Dryseal pipe threads are standard for automotive, refrigeration, and hydraulic tube and pipe fittings. The general forms and dimensions of these threads are the same as regular pipe threads except for the truncation of the crests and roots. The Dryseal pipe thread form has no clearance since the flats of the crests on the external and internal thread meet, producing a metal-to-metal contact and eliminating the need for a sealer.

Aeronautical pipe thread is the standard form in the aerospace industry. In this type of thread, the internally threaded part is typically made of soft, light materials (such as aluminum or magnesium alloys) and the screw is made from high-strength steel. An insert, usually of phosphor bronze, is used as the bearing part of the internal thread, preventing wear on the light alloy thread, **Figure 18-20**.

The Regular and Aeronautical pipe thread forms require a sealer to prevent leakage in the joint. The Dryseal form requires no seal.

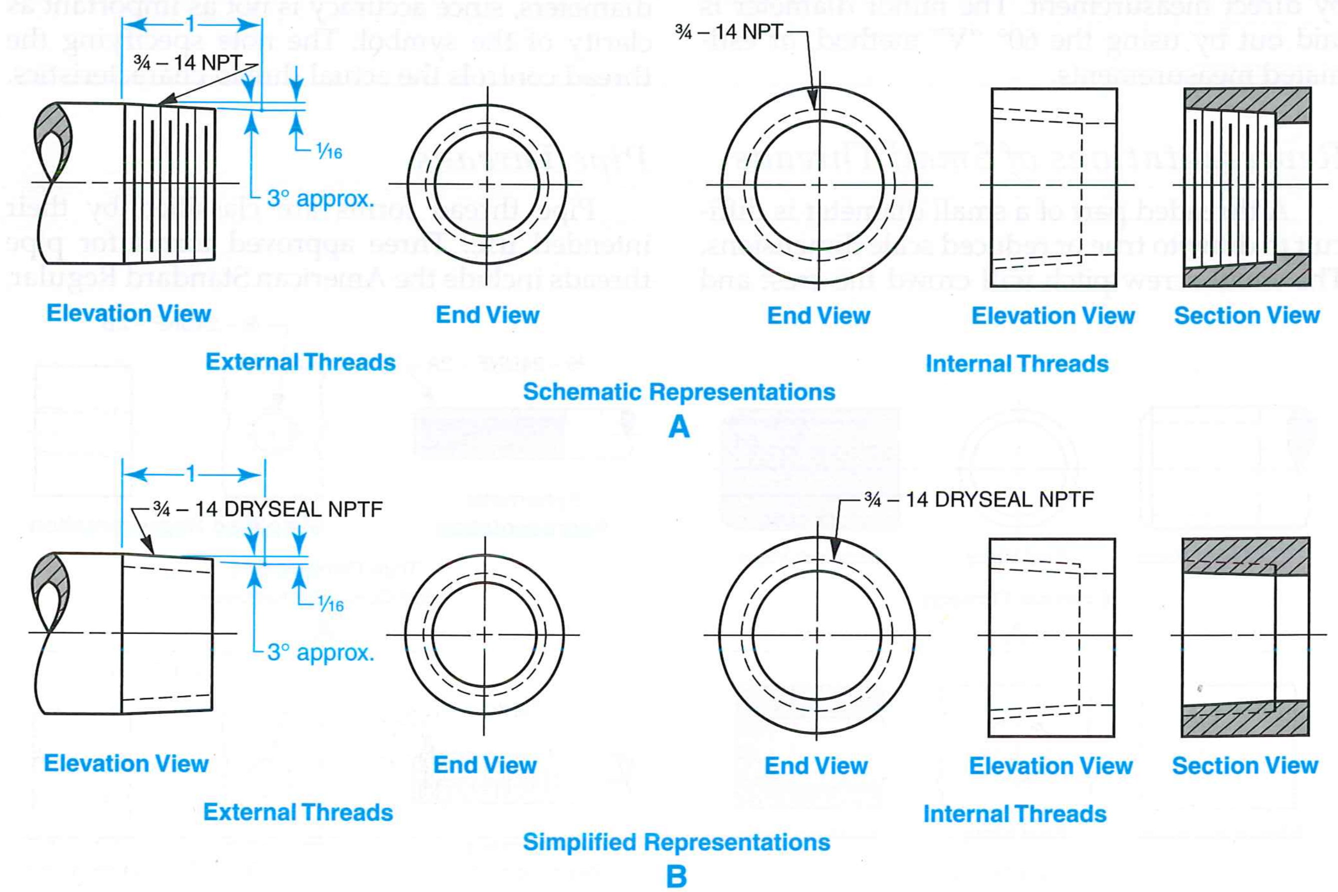


**Figure 18-19**. Tapered pipe threads can be represented in schematic and simplified forms.

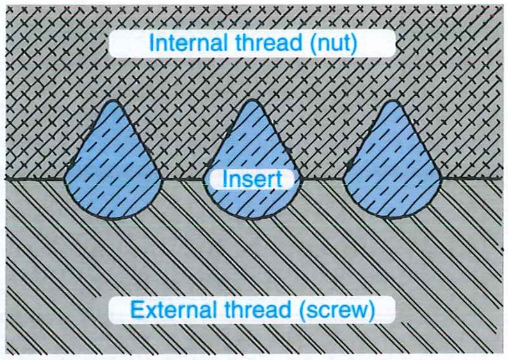


**Figure 18-20.** Aeronautical pipe threads have an insert that will bear the load. These threads are used when one of the thread materials is soft and the other is hard.

The specifications for American Standard pipe threads are listed in sequence in the following order: the nominal size, the number of threads per inch, and the symbols for the series and form. An example of a typical specification is 1/2-14 NPT.

The following symbols are used to designate the more common American Standard pipe thread forms:

- NPT—American Standard Taper Pipe Thread
- NPTR—American Standard Taper Pipe for Railing Joints
- NPTF—Dryseal American Standard Taper Pipe Thread
- NPSF—Dryseal American Standard Fuel Internal Straight Pipe Thread
- NPSI—Dryseal American Standard Intermediate Internal Straight Pipe Thread

# Bolts and Screws

There are many varieties and sizes of bolts, nuts, and screws for all kinds of industrial applications. There are five general types of threaded fasteners that the drafter should be familiar with. See **Figure 18-21**.

A ***bolt*** has a head on one end and is threaded on the other end to receive a nut. It is inserted through clearance holes to hold two or more parts together, **Figure 18-21A**.

A ***cap screw*** is similar to a bolt with a head on one end, but it usually has a greater length of thread on the other. It is screwed into a part with mating internal threads for greater strength and rigidity, **Figure 18-21B**.

A ***stud*** is a rod threaded on both ends to be screwed into a part with mating internal threads. A ***nut*** is used on the other end to secure two or more parts together, **Figure 18-21C**.

A ***machine screw*** is similar to a cap screw, except it is smaller and has a slotted head, **Figure 18-21D**.

A ***setscrew*** is used to prevent motion between two parts, such as rotation of a collar on a shaft, **Figure 18-21E**.

The ranges of sizes and exact dimensions for various types of threaded fasteners are given in the Reference Section of this book.

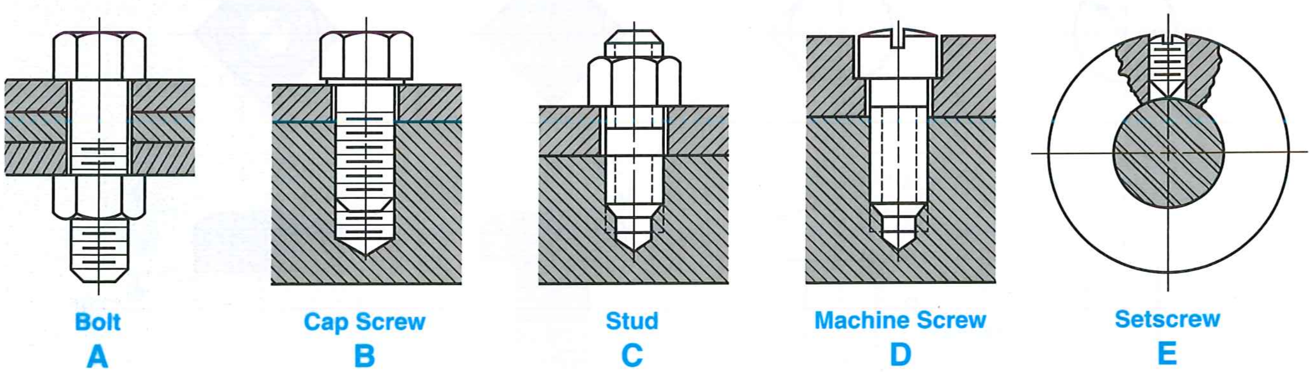


**Figure 18-21.** There are five general types of bolts and screws.

## Construct Square Bolt Heads and Nuts

The drawing of square bolt heads is identical to the drawing of square nuts, except the nut is usually thicker than the bolt head. The method illustrated in **Figure 18-22** is based on the bolt diameter and is an approximation of the actual projection.

The drawing of bolt heads and nuts across their corners is the best representation. This method should be used when a choice is available. This method is shown first.

1. Draw the bolt diameter (nominal size), **Figure 18-22A**.
2. Draw the bolt head thickness and diameter.
3. Draw the square head around the diameter at 45° and project it to the front view, **Figure 18-22B**.
4. Locate the centers for the chamfer arcs in the front view by projecting lines at 60° to horizontal down from the center and outside of the corners of the top surface.
5. Complete the square bolt head by drawing 30° chamfer lines at the outside corners in the front view, **Figure 18-22C**.

The regular square head nut shown in **Figure 18-22D** is 7/8D in thickness (where *D* = the bolt diameter). The thickness of a heavy duty nut equals the diameter of the bolt it matches. The hidden lines in the front view that represent threads are not normally shown, especially in bolt and nut assemblies. Refer to **Figure 18-21**.

## Construct Hexagonal Bolt Heads and Nuts

Hexagonal bolt heads and nuts are also best represented when drawn across their corners. For this method, shown in **Figure 18-23**, proceed as follows. Two alternate procedures for drawing square and hexagonal head nuts across their flats are shown following this procedure in **Figure 18-24**.

1. Draw the bolt diameter (nominal size), **Figure 18-23A**.

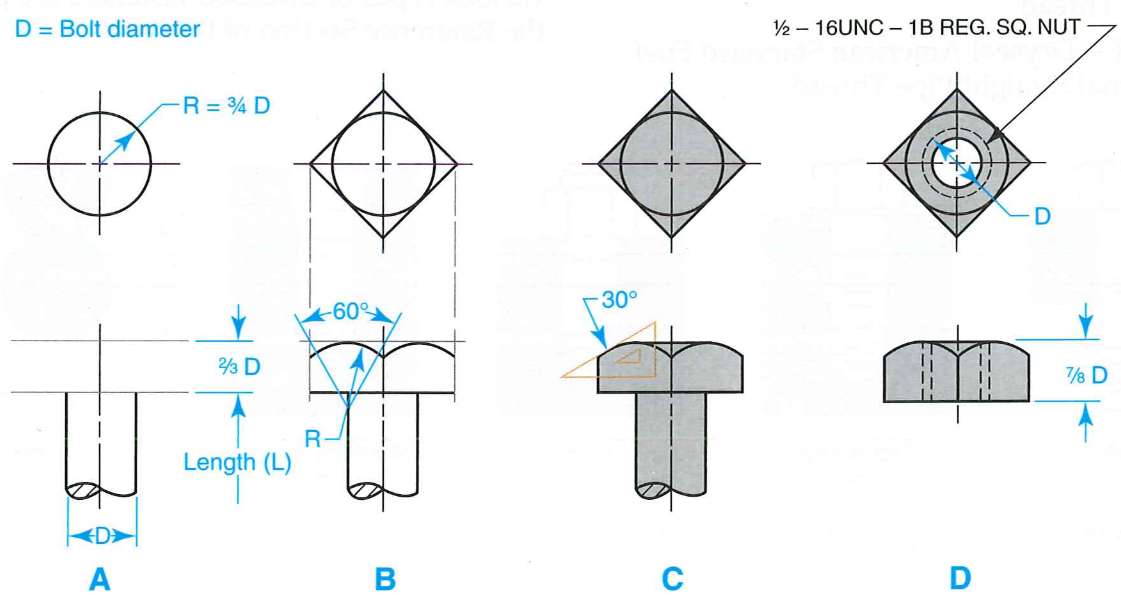


**Figure 18-22.** Drawing square bolt heads and nuts across their corners gives a close approximation of the true projection.

2. Draw the bolt head thickness and diameter.
3. Lay out the hexagonal head around the diameter at 60° to horizontal. Project the head to the front view, **Figure 18-23B**.
4. Locate the center for the center chamfer arc in the front view by projecting lines at 60° to horizontal and down from the outside corners of the top surface.
5. Locate the centers for the chamfer arcs at the ends by projecting 60° lines down from the two inside corners to meet the other 60° lines.
6. Complete the hexagonal bolt head by drawing 30° chamfer lines at the outside corners in the front view, **Figure 18-23C**.

The construction of a hexagonal nut is shown in **Figure 18-23D**. A regular nut is drawn 7/8D in thickness and a heavy duty nut is drawn 1D in thickness. Hidden lines may be omitted unless needed for clarity.

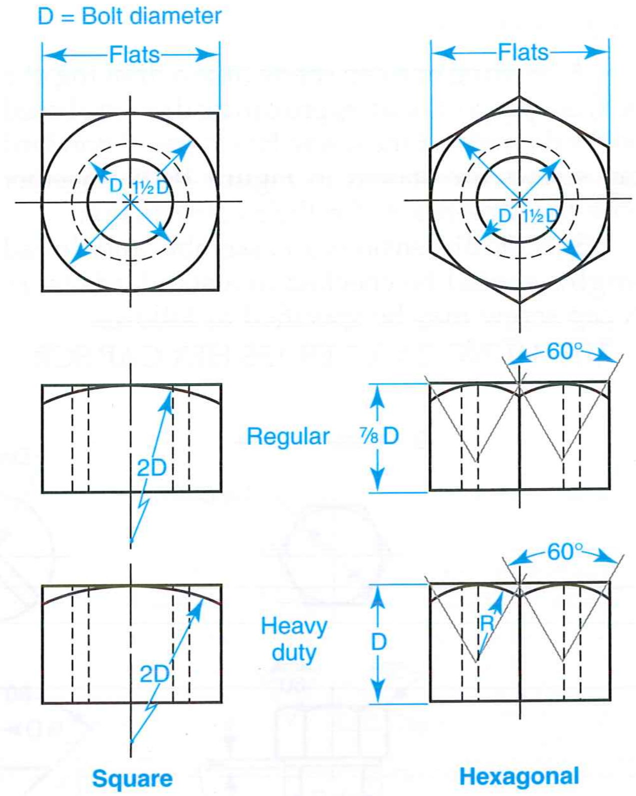


**Figure 18-24**. Drawing square and hexagonal nuts across the flats does not produce a good representation. These representations should be avoided whenever possible.

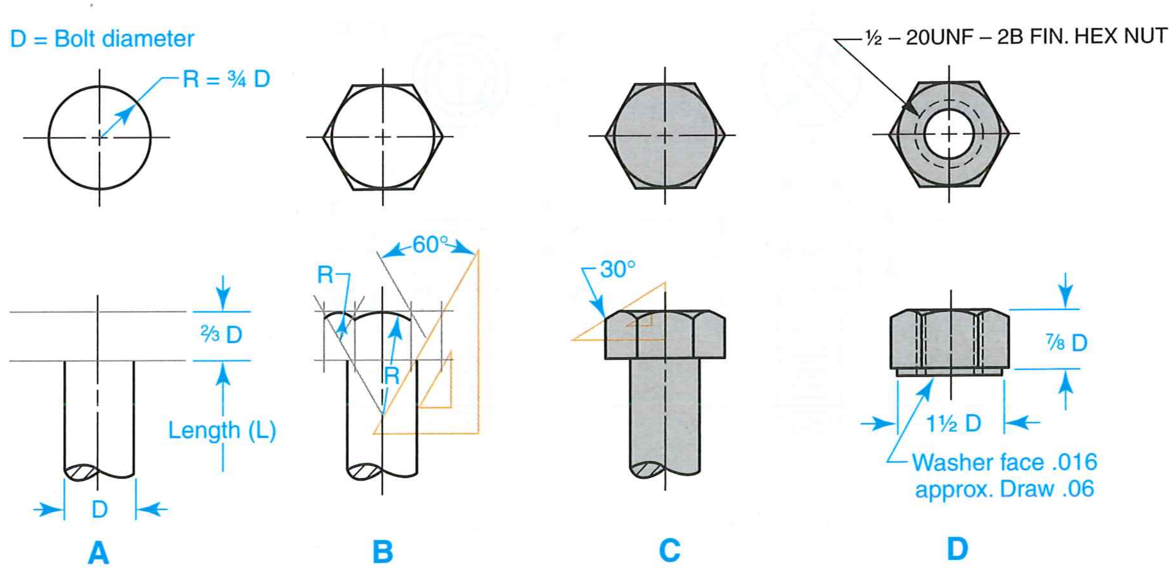


**Figure 18-23**. Drawing hexagonal bolt heads and nuts across the corners.

## Cap Screws

A drawing of a cap screw (like a drawing of a bolt) is a proportional, approximate drawing based on the diameter of the screw. Five types of standard cap screws are shown in **Figure 18-25**, together with the dimensions for their construction.

Specific dimensions for assembly and thread lengths should be checked in a standards table. A cap screw may be specified as follows:

7/16–14UNC–2A X 2 BRASS HEX CAP SCR

If the cap screw is made of steel, the material term is omitted.

## Machine Screws

Four common types of machine screws and their approximate dimensions for construction are shown in **Figure 18-26**. Machine screws are similar to cap screws, but usually smaller in diameter.

The threads on most machine screws are either Unified Coarse (UNC) or Unified Fine (UNF),

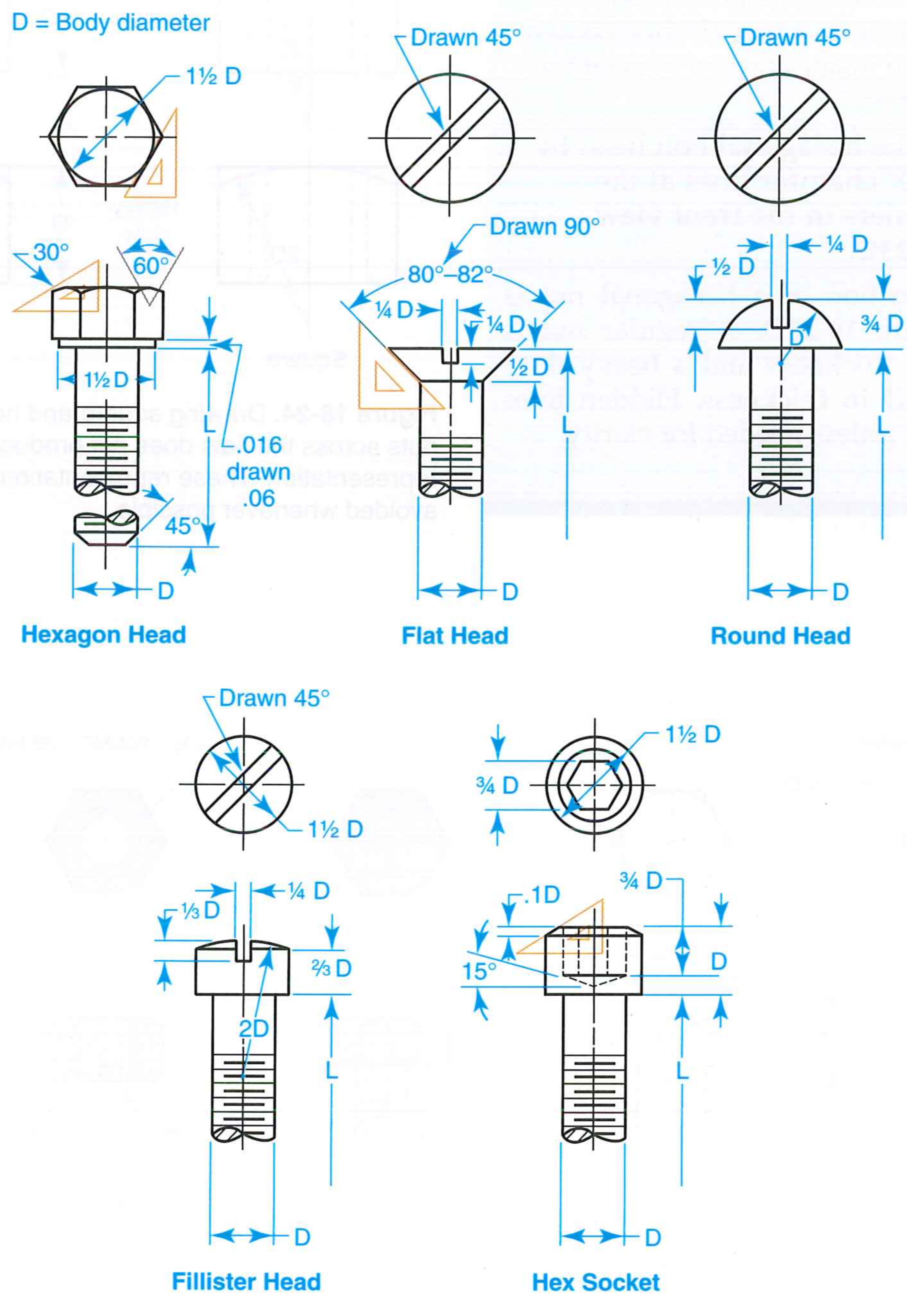


**Figure 18-25**. Drawing conventions for standard cap screws. Approximate dimensions are shown.

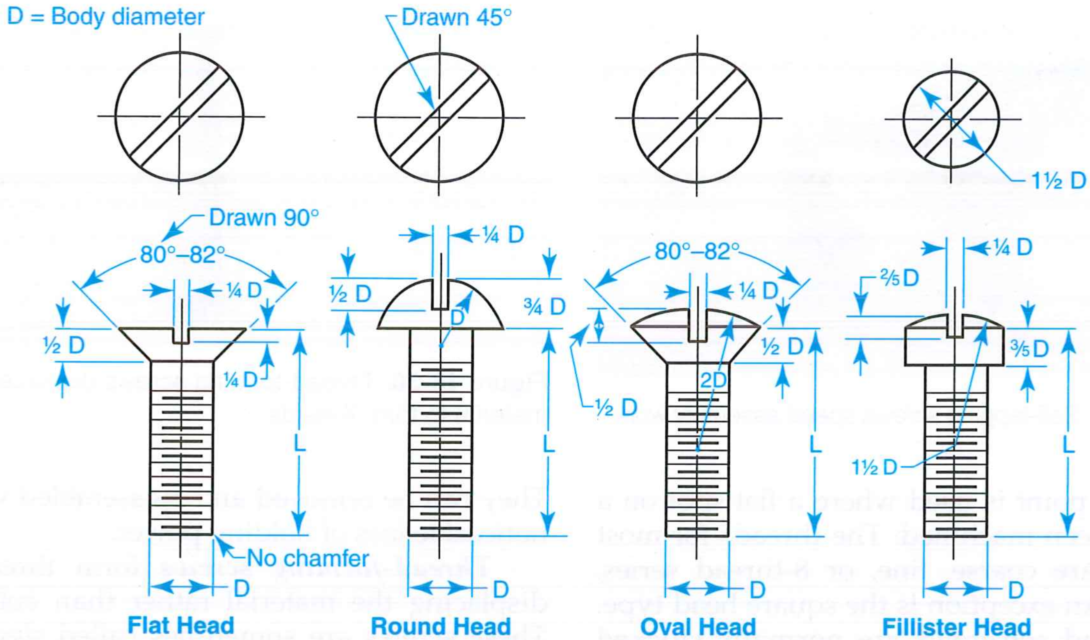


**Figure 18-26**. Drawing conventions for standard machine screws. Approximate dimensions are shown.

Class 2A. Screws that are 2″ in length or less are threaded to within two threads of the bearing surface. The thread length on screws longer than 2″ is a minimum of 1 3/4″. A machine screw may be specified as follows:

8–24UNF–2A X 1 OVAL HD MACH SCR

## Setscrews

Setscrews are of the standard square head type as well as several headless types, **Figure 18-27**. Several styles of points are also available with each type. When a setscrew is used against a round shaft, a cup point is likely to hold best. A

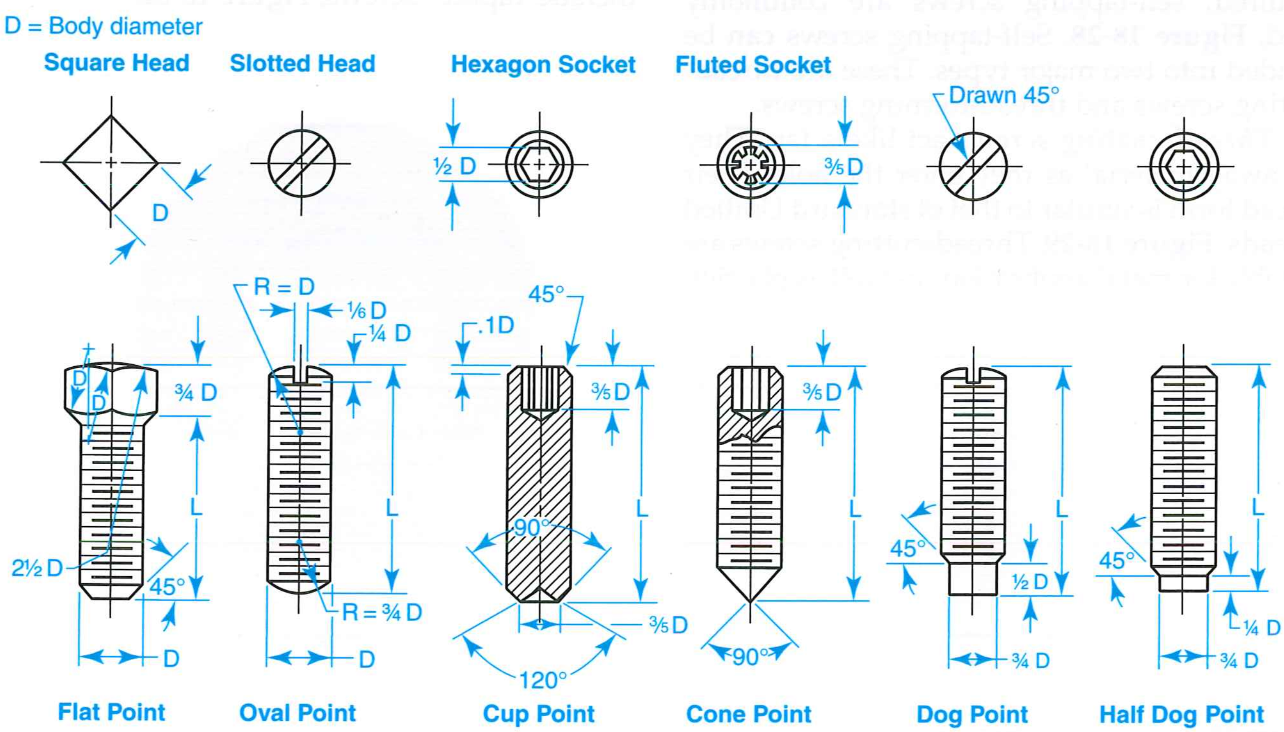


**Figure 18-27**. Drawing conventions for standard setscrews. Approximate dimensions are shown.

**Figure 18-28**. Self-tapping screws speed assembly work.

flat or dog point is used where a flat spot on a shaft has been machined. The threads for most setscrews are coarse, fine, or 8-thread series, Class 2A. An exception is the square head type. Square head setscrews are normally stocked in the coarse series and size 1/4″ or larger. A setscrew may be specified as follows:

1/4–28UNF–2A X 5/8 HEX SOCK CUP PT SET SCR

## Self-Tapping Screws

Time in assembly work is of great importance in many industrial applications. To meet this condition where threaded fasteners are required, self-tapping screws are commonly used, **Figure 18-28**. Self-tapping screws can be divided into two major types. These are thread-cutting screws and thread-forming screws.

***Thread-cutting screws*** act like a tap. They cut away material as they enter the hole. Their thread form is similar to that of standard Unified threads, **Figure 18-29**. Thread-cutting screws are suitable for metal applications as well as plastics.

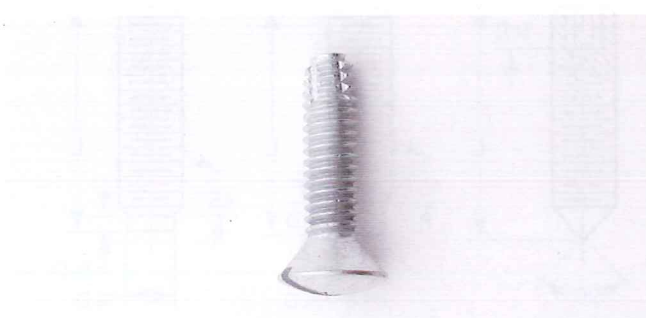

**Figure 18-29**. Thread-cutting screws actually cut threads as they are inserted.

**Figure 18-30**. Thread-forming screws displace the material to form threads.

They can be removed and reassembled without noticeable loss of holding power.

***Thread-forming screws*** form threads by displacing the material rather than cutting it. These screws are sometimes called *sheet metal screws*. They are especially suited for thin-gage sheet metal up to .375″ in thickness, as well as any soft material such as wood or plastic, **Figure 18-30**. The thread form on thread-forming screws is a narrow, sharp crest. No chips or waste material are formed in their application. A number of patented thread-forming screws have a special shape to displace the metal and form a tight-fitting thread. These types of screws include Taptite® screws, **Figure 18-31**.

**Figure 18-31**. Taptite® screws have special forms to provide a more secure thread engagement. (REMINC)

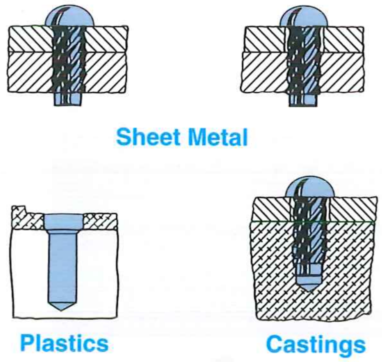


**Figure 18-32**. Drive screws are designed for permanent assembly.

## *Drive Screws*

Some industrial applications call for permanent fasteners. These fasteners are not expected to be disassembled. ***Drive screws*** are designed for this use, **Figure 18-32**. They have multiple threads with a large lead angle. They are driven by a force in line with their axis, rather than torque. (Torque is a circular force, or force through a radius.)

Once seated, drive screws cannot be removed and reinserted easily. Economy is one of the main reasons for using these types of screws where circumstances permit. Safety is another reason. Sometimes it is necessary to assemble components so that they cannot be disassembled without special tools. Drive screws are available for use with a variety of materials. They are typically used with wood, plastic, or metal.

## *Wood Screws*

***Wood screws*** are standardized with three head types: flat, oval, and round, **Figure 18-33**. These are available in slotted or Phillips head drives. The Phillips head is used in most commercially manufactured products where time in assembly is important.

Wood screws range in diameter from .060" to .372". A typical specification in a note or in the materials list is specified as follows:

NO. 9 × 1 1/2 OVAL HD WOOD SCR

## *Drawing Templates for Threaded Fasteners*

A variety of templates are available for drawing threads, bolts, screws, nuts, and fastener head types, **Figure 18-34**. Templates are used in manual drafting to speed drafting time and to produce more uniform representations of threaded fasteners.

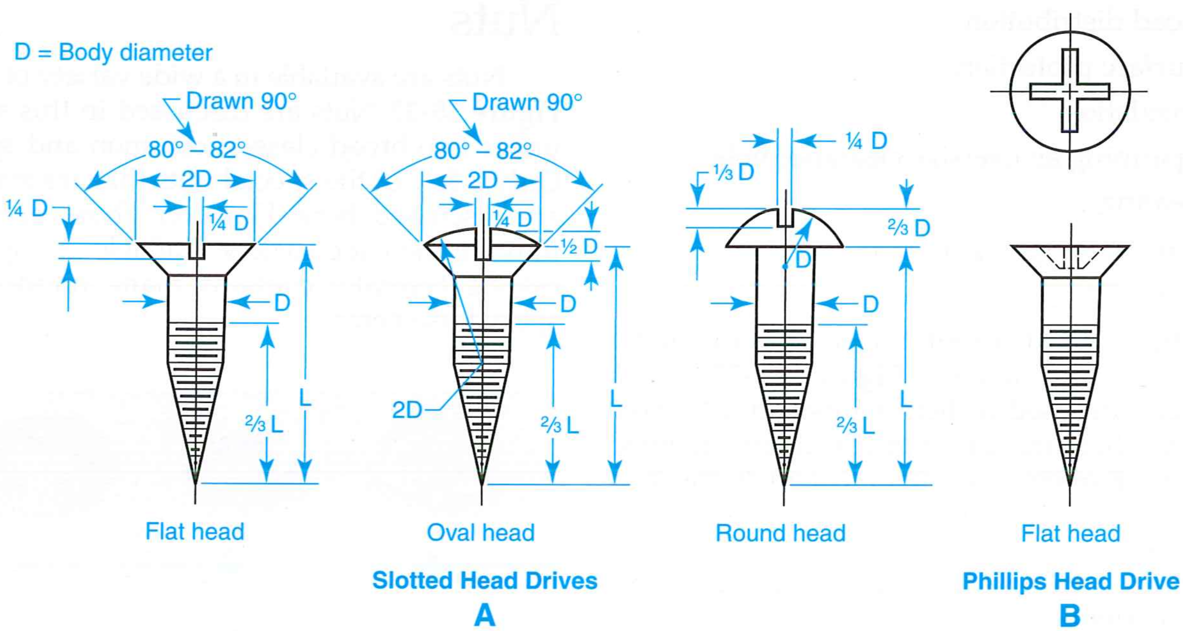


**Figure 18-33**. Standard types of wood screws. A—The three standard head types are flat, oval, and round. Shown are slotted head drives. B—The Phillips head drive is common in industrial work.

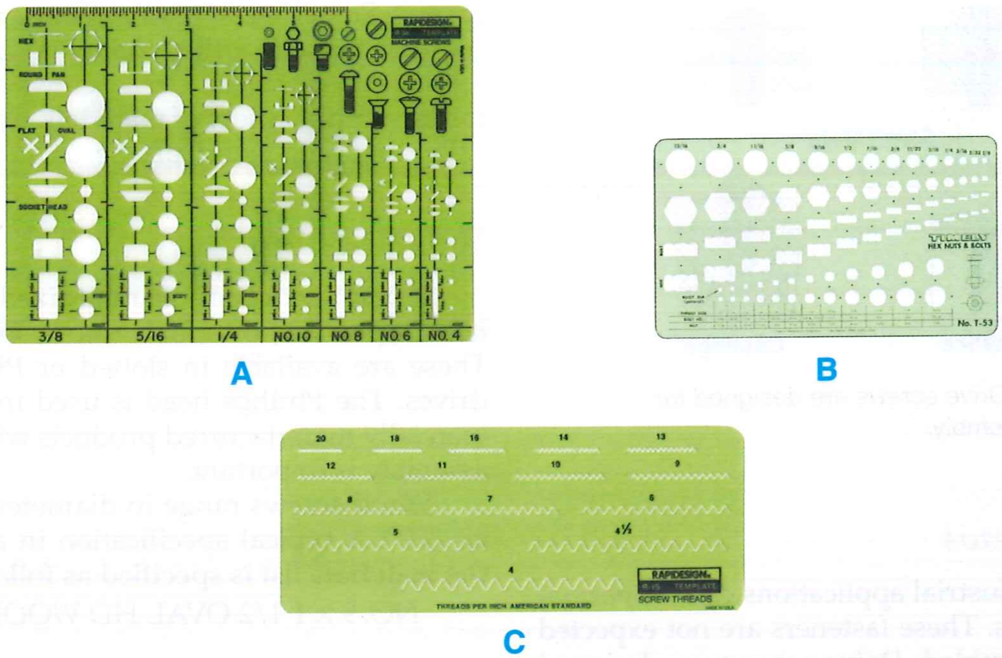


**Figure 18-34.** Templates should be used when available to speed the drawing of threads and fasteners. A—Drawing template for machine screws. B—Drawing template for hexagonal head fasteners. C—Drawing template for screw threads. (Alvin & Co.)

## Washers and Retaining Rings

Washers are added to screw assemblies for several different reasons. The following is a list of the more common reasons for using washers:

- Load distribution
- Surface protection
- Insulation
- Spanning an oversize clearance hole
- Sealing
- Taking up spring tension
- Locking

There are different types of washers for fastening applications, **Figure 18-35**. ***Lock washers*** are used to help withstand vibration. Lock washers include split-spring and toothed washers. ***Finishing washers*** distribute the load and eliminate the need for a countersunk hole. They are used extensively for attaching fabric coverings. ***Flat washers*** are used primarily for load distribution.

***Retaining rings*** are inexpensive devices used to provide a shoulder for holding, locking, or positioning components on shafts, pins, studs, or in bores, **Figure 18-36**. They are available in a wide variety of designs. They almost always slip or snap into grooves and are sometimes called "snap" rings.

## Nuts

Nuts are available in a wide variety of types, **Figure 18-37**. Nuts are discussed in this section under two broad classes: common and special. Only a few of the special nuts that are available are discussed here. However, those presented indicate the wide variety available. A supplier's catalog typically contains many hundreds of special-use items.


**Figure 18-35.** Common types of washers used in mechanical assemblies. A—Finishing washer. B—Lock washer. C—Flat washer.

**Figure 18-36**. Retaining rings are inexpensive fasteners. They can be quickly assembled or removed.

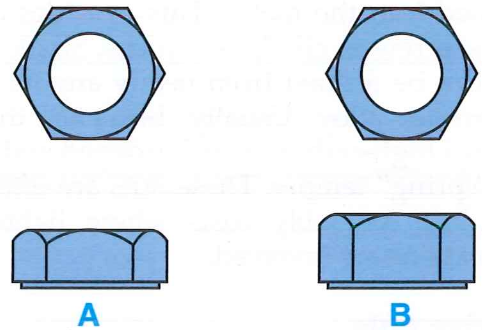


**Figure 18-38**. Common nuts are used for bolts on assemblies and are generally of two types. A—Finished. B—Heavy.

## Common Nuts

Nuts used on bolts for assemblies are known as ***common nuts***. Common nuts are generally divided into two classifications: finished and heavy, **Figure 18-38**. ***Finished nuts*** are used for close tolerances. ***Heavy nuts*** are used for a looser fit, for large-clearance holes, and for high loads.

## Special Nuts

There are a number of types of special nuts available. ***Special nuts*** are used where an application requires features not found on common nuts. Cap nuts, single-thread engaging nuts, captive or self-retaining nuts, and locknuts are all types of special nuts.

### Cap, wing, and knurled nuts

***Cap nuts*** are used in cases where appearance is important, **Figure 18-39A**. Cap nuts are sometimes called *acorn nuts*. ***Wing nuts*** and ***knurled nuts*** allow for hand tightening, **Figure 18-39B** and **Figure 18-39C**.

### Single-thread engaging nuts

Nuts formed by stamping a thread-engaging impression in a flat piece of metal are called ***single-thread engaging nuts***. An example of a single-thread engaging nut is shown in **Figure 18-40**. The nut shown has helical prongs that engage and lock on the screw thread root diameter. A protruding truncated cone nut is

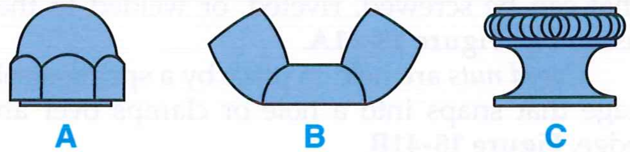


**Figure 18-39**. Cap nuts, wing nuts, and knurled nuts are special nuts.

**Figure 18-37**. The variety of nuts used in industry is seemingly limitless.

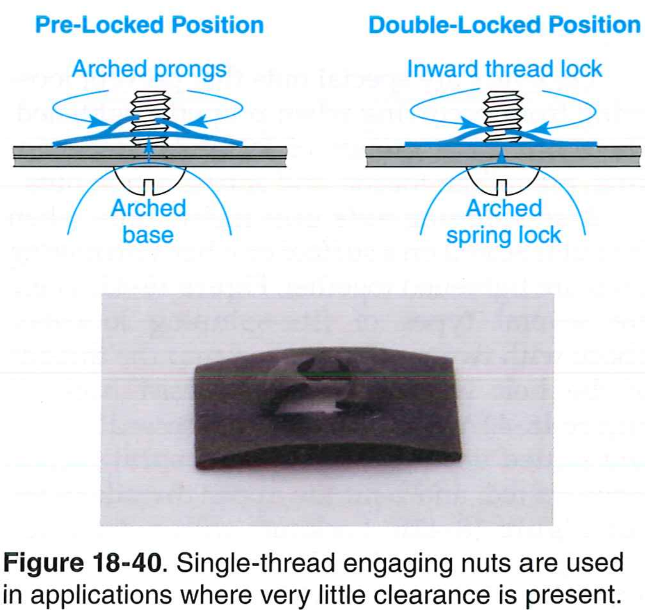


**Figure 18-40**. Single-thread engaging nuts are used in applications where very little clearance is present.

stamped into the metal. This provides a ramp for the screw to climb as it turns. Single-thread nuts can be formed from nearly any ferrous or nonferrous alloy. Usually, however, they are made of high-carbon steel, hardened and drawn to a "spring" temper. These nuts are often used to reduce assembly costs where lighter-duty applications are involved.

## Captive nuts

***Captive nuts***, also known as ***self-retaining nuts***, are multiple-threaded nuts that are held in place by a clamp or binding device of light gage metal. They are used for applications involving thin materials. These nuts are also used where threaded fasteners are needed at inaccessible or blind locations. Assemblies that require repeated assembly and disassembly often use these nuts as well.

Self-retaining nuts may be grouped according to four means of attachment. These groupings include plate (or anchor) nuts, caged nuts, clinch nuts, and self-piercing nuts.

*Plate nuts* or *anchor nuts* have mounting lugs that can be screwed, riveted, or welded to the assembly, **Figure 18-41A**.

*Caged nuts* are held in place by a spring-steel cage that snaps into a hole or clamps over an edge, **Figure 18-41B**.

*Clinch nuts* are designed with a pilot collar clinched or staked into a parent part through a precut hole, **Figure 18-41C**.

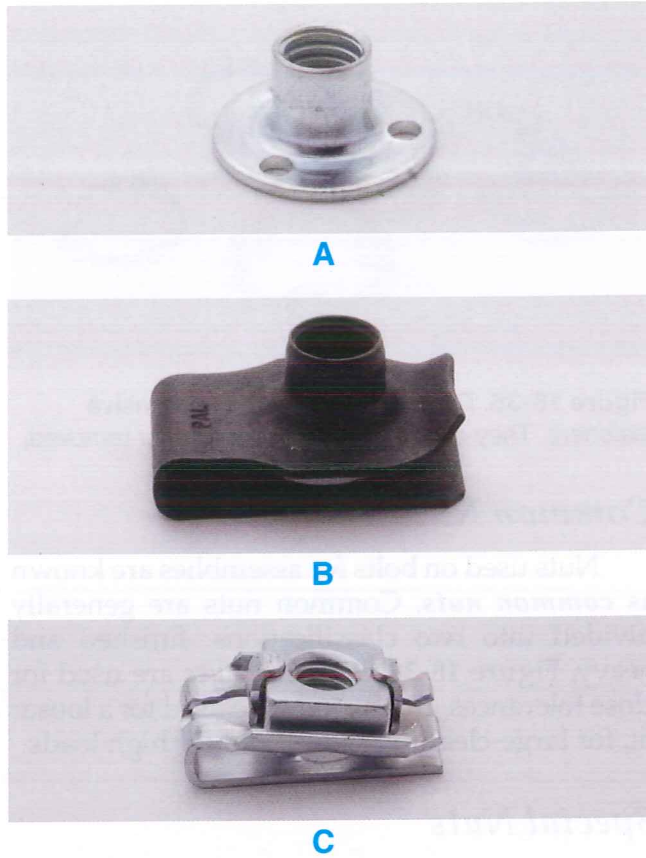


**Figure 18-41.** Captive (or self-retaining) nuts are held in place by a clamping or binding device and are classified according to the attachment method. A—Plate nut. B—Caged nut. C—Clinch nut.

## Locknuts

***Locknuts*** are special nuts that prevent loosening from occurring when properly tightened. There are three groups of locknuts: free-spinning, prevailing-torque, and spring-action nuts.

***Free-spinning nuts*** grip tightly only when the nut is seated on a surface or when two mating parts are tightened together, **Figure 18-42**. There are several types of free-spinning locknuts. Those with two mating parts clamp the threads of the bolt when seated and resist back-off, **Figure 18-42A**. Locknuts with a recessed bottom and slotted upper portion cause a spring action when seated, and bind the upper threads of the nut, **Figure 18-42B**. Locknuts with a deformed bearing surface tend to dig in and remain tight when seated, **Figure 18-42C**.

Some free-spinning locknuts have a lock washer secured to the main nut, **Figure 18-42D**. Others have inserts, **Figure 18-42E**. The insert tends to flow around the threads when seated, forming a tight lock and seal. ***Jam nuts*** are thin nuts used under common nuts, **Figure 18-42F**. When seated under pressure, the threads of the jam nut and bolt are elastically deformed. This causes considerable resistance against loosening. ***Slotted nuts*** have slots to receive a cotter pin or wire, **Figure 18-42G**. The pin or wire passes through a drilled hole in the bolt, locking the nut in place. These nuts look very similar to the "spring-action" nuts described previously. Refer to **Figure 18-42B**.

***Prevailing-torque locknuts*** start freely, and then must be wrench-tightened to the final position. This is due to a deformation of the threads or insert in the center or upper portion of the nut. These nuts maintain a constant load against loosening whether seated or not.

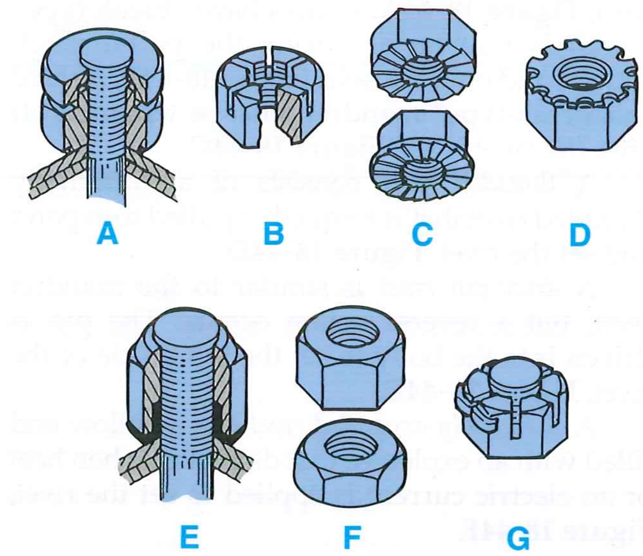


**Figure 18-42.** There are many types of free-spinning locknuts. A—Mating type. B—Slotted locknut with recessed bottom. C—Locknut with deformed bearing surface. D—Locknut with lock washer. E—Locknut with insert. F—Jam nut. G—Slotted locknut.

***Spring-action locknuts*** are single-thread nuts, usually stamped from spring steel. They lock in place when driven up against a surface. Refer to **Figure 18-40**. These nuts are sometimes classified as free-spinning locknuts, but they can be jammed onto a thread without spinning. Frequently in mass production situations, these nuts are jammed onto a thread. (Note that these locknuts are also single-thread engaging nuts.)

# Rivets

The manufacture of many assembled products requires a permanent type of fastener. In these cases, rivets often are the answer. Rivets are typically used for aircraft, small appliances, and jewelry. Rivet sizes are indicated by the diameter of the shank and by the length of the shank, if it is an unusual length. Rivets are available in a variety of head styles and are grouped into two general types: standard and blind.

## Standard Rivets

A ***standard rivet*** is inserted into a clearance hole in two mating parts and formed on both ends to provide a permanent fastener. Standard rivets come in several styles, depending on strength, methods of application, and other design requirements, **Figure 18-43**.

The *semitubular rivet* is the most widely used standard rivet, **Figure 18-43A**. This type of rivet becomes essentially a solid rivet when properly specified and set. Semitubular rivets can be used to pierce very thin light metals, although they are not classified as self-piercing rivets.

A *full tubular rivet* has a deeper shank hole. This type of rivet can also punch its own hole in fabric, some plastics, and other soft materials, **Figure 18-43B**. The shear strength of full tubular rivets is less than that of semitubular rivets.

A *bifurcated rivet* (or *split rivet*) is punched or sawed to form prongs that enable it to punch its own holes in fiber, wood, plastic, or metal, **Figure 18-43C**. This type of rivet is also called a *self-piercing rivet*.

A *compression rivet* consists of two parts: a deep-drilled tubular part and a solid part designed for an interference fit when set, **Figure 18-43D**. This type of rivet is used when both sides of a workpiece must have a finished appearance, such as the handle of a kitchen knife.

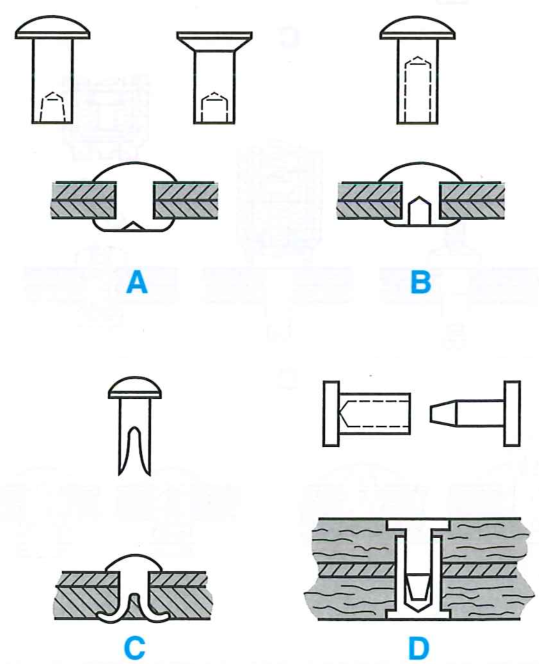


**Figure 18-43.** Standard rivets come in a variety of different types. A—Semitubular. B—Full tubular. C—Bifurcated (split). D—Compression.

## Blind Rivets

A ***blind rivet*** is installed in a joint that is accessible from only one side. However, blind rivets can also be used in applications where both sides of the joint are accessible to simplify assembly, reduce cost, and to improve appearance. Blind rivets are classified by the methods used in setting, **Figure 18-44**. They are also available in a variety of head styles.

A *pull-mandrel rivet* is set by inserting the rivet in the joint and pulling a mandrel to upset the blind end of the rivet. This type of rivet is sometimes called a *pop rivet*. Some rivets have mandrels that pull through, leaving a hole in the rivet, **Figure 18-44A**. Others have "break-type" mandrels that break during the pull-through process and plug the hole, **Figure 18-44B**. A third "nonbreak-type" mandrel must be trimmed off after the rivet is set, **Figure 18-44C**.

A *threaded rivet* consists of an internally threaded rivet that is torqued or pulled to expand and set the rivet, **Figure 18-44D**.

A *drive-pin rivet* is similar to the mandrel rivet, but a reverse action occurs. The pin is driven into the body to set the blind side of the rivet, **Figure 18-44E**.

A *chemically expanded rivet* has a hollow end filled with an explosive that detonates when heat or an electric current is applied to set the rivet, **Figure 18-44F**.

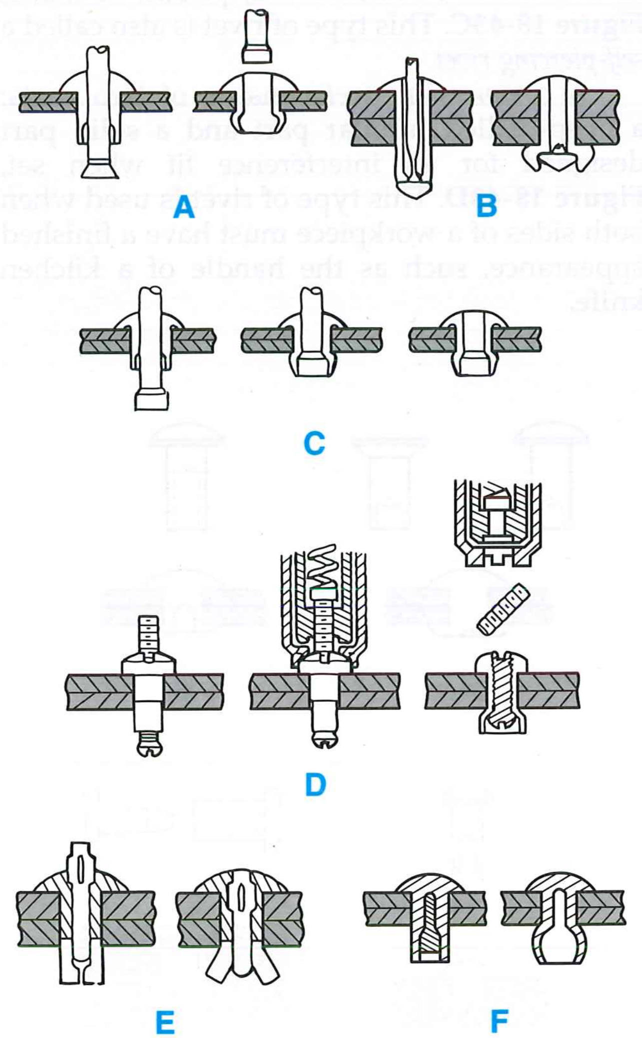


**Figure 18-44**. Common types of blind rivets. A—Pull-through mandrel. B—Break mandrel. C—Nonbreak mandrel. D—Threaded. E—Drive-pin. F—Chemically expanded.

# Pin Fasteners, Keys, and Springs

Keys and pin fasteners provide two other ways of joining parts. Each device has an application that it is best suited for. Springs are presented here because their graphic representation is very similar to threads.

## Pin Fasteners

Where the load is "primarily" shear, ***pins*** can be an inexpensive and effective means of fastening, **Figure 18-45**. The method of representing

**Figure 18-45**. Pin fasteners.

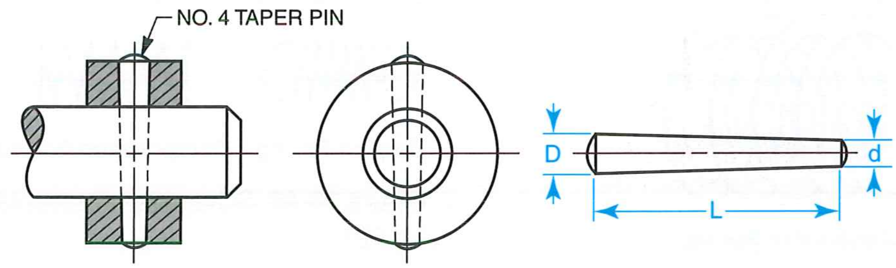


**Figure 18-46.** Conventional method for representing pin fasteners on drawings.

pins on a drawing is shown in **Figure 18-46.** Some of the different types of pins include the following.

- Hardened dowel
- Ground dowel
- Hardened taper
- Ground taper
- Grooved surface
- Spring (or tubular)
- Clevis
- Cotter

## Keys

***Keys*** are used to prevent rotation between a shaft and a machine part. Some parts that typically use keys are gears and pulleys. The four most common types of keys are square, gib head, Pratt and Whitney, and Woodruff. These are shown in **Figure 18-47** along with the methods of dimensioning them.

## Springs

***Springs*** are used to store and release mechanical energy by yielding to a force and recovering shape when the force is removed. Springs are designed for a variety of mechanical applications. On drawings, coil springs are represented using conventions similar to those used for screw threads. A detailed representation of a coil spring from a check valve is shown in **Figure 18-48**. Schematic representations of various types of coil springs are shown in **Figure 18-49**.

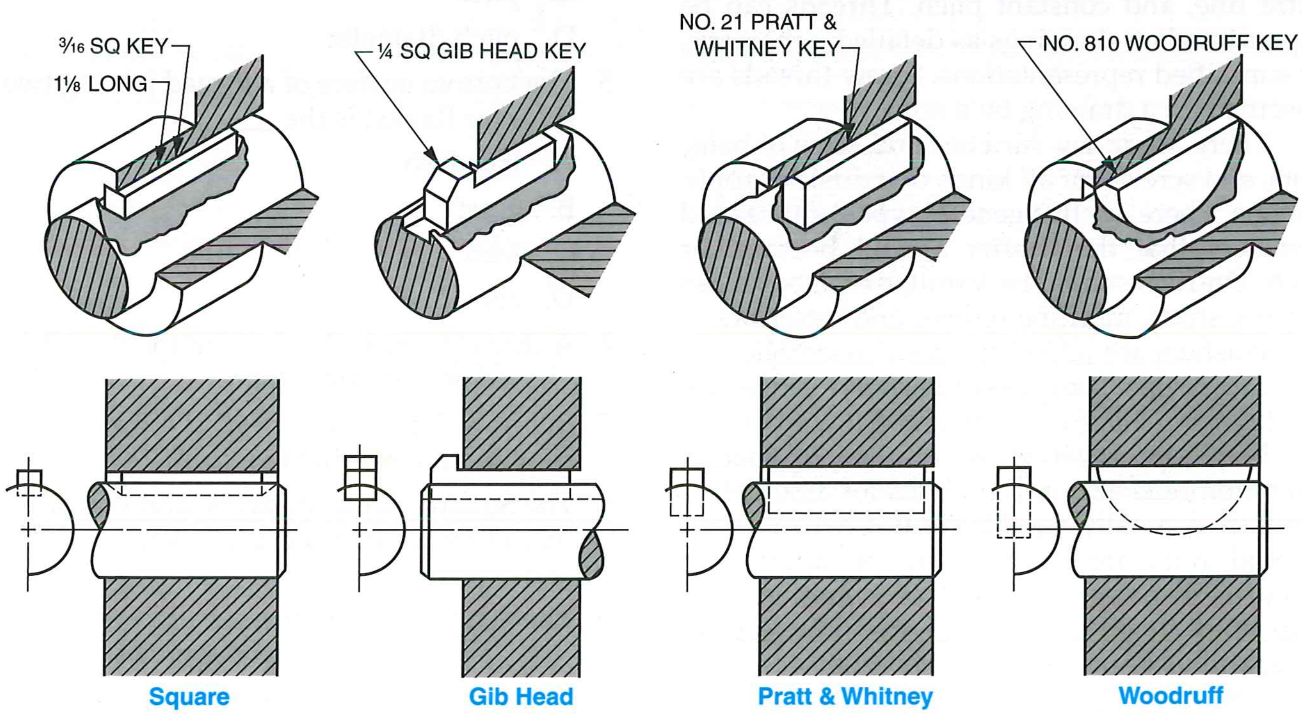


**Figure 18-47.** Common types of keys.

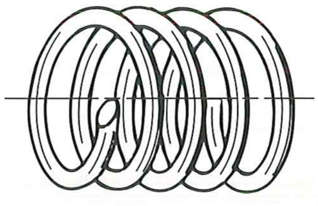


**Figure 18-48.** A detailed representation of coil springs.

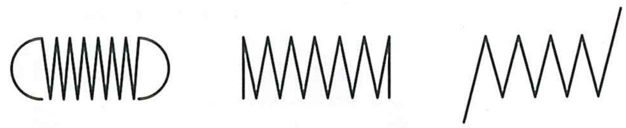


**Figure 18-49.** Schematic representations of coil springs.

To lay out a coil spring, mark off the pitch distance along the diameter of the coil. Give the coils a slope of one-half the pitch for closely wound springs. Note the difference in the representation of tension and compression springs and how the different types of ends are drawn in each case. To avoid a repetitious series of coils, phantom lines may be used to represent repeated detail between spring ends.

## Chapter Summary

Many different types of fasteners are used in industry. A fastener is any mechanical device used to attach two or more pieces or parts together in a fixed position.

The Unified Screw Thread Series is the American standard for screw threads. There are four series of Unified screw threads: coarse, fine, extra fine, and constant pitch. Threads can be represented on drawings as detailed, schematic, or simplified representations. Screw threads are specified on a drawing by a note.

There are many varieties and sizes of bolts, nuts, and screws for all kinds of industrial applications. There are five general types of threaded fasteners that the drafter should be familiar with. Drafters should be familiar with bolts, cap screws, studs, machine screws, and setscrews.

Washers are added to screw assemblies for several reasons. The types of washers include lock washers, finishing washers, and flat washers.

Nuts are classified as common or special. Common nuts are used on bolts for assemblies. They are generally classified as finished or heavy. Special nuts are used where an application requires features not found on common nuts. Cap nuts, single-thread engaging nuts, captive nuts, and locknuts are all special nuts.

Some assembled products require permanent types of fasteners. Rivets are often the answer. Many special types of rivets are produced for specialized purposes.

Keys and pin fasteners provide two other ways of joining parts.

## Review Questions

1. Define the term *fastener.*
2. What is the American standard for screw thread forms?
3. The largest diameter on an external or internal screw thread is the _____.
4. The distance from a point on one screw thread to a corresponding point on the next thread, measured parallel to the axis, is the _____.
   A. angle of thread
   B. minor diameter
   C. pitch
   D. pitch diameter
5. The bottom surface of a thread joining two sides (or flanks) is the _____.
   A. backlash
   B. crest
   C. lead
   D. root
6. A thread form is the _____ of the thread as viewed on the axial plane.
7. In screw threads, the Unified form is a combination of what two forms?
8. The Square, Acme, Buttress, and Worm thread forms are used to transmit _____ and _____.
9. The Sharp V thread form is used where _____ is desired, such as setscrews.
10. Name the four standard series of Unified screw threads.