Threads, Fasteners, and Springs
Examples of Screws

<table>
<thead>
<tr>
<th>Fastener Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wood Screws</strong></td>
</tr>
<tr>
<td>Screws with a smooth</td>
</tr>
<tr>
<td>shank and tapered point</td>
</tr>
<tr>
<td>for use in wood.</td>
</tr>
<tr>
<td>Abbreviated WS</td>
</tr>
<tr>
<td><strong>Machine Screws</strong></td>
</tr>
<tr>
<td>Screws with threads</td>
</tr>
<tr>
<td>for use with a nut</td>
</tr>
<tr>
<td>or tapped hole.</td>
</tr>
<tr>
<td>Abbreviated MS</td>
</tr>
<tr>
<td><strong>Sheet Metal Screws</strong></td>
</tr>
<tr>
<td>Fully threaded screws</td>
</tr>
<tr>
<td>with a point for use in</td>
</tr>
<tr>
<td>sheet metal.</td>
</tr>
<tr>
<td>Abbreviated SMS</td>
</tr>
<tr>
<td><strong>Self Drilling SMS</strong></td>
</tr>
<tr>
<td>A Sheet metal screw with</td>
</tr>
<tr>
<td>a self drilling point.</td>
</tr>
<tr>
<td><strong>Hex Bolts</strong></td>
</tr>
<tr>
<td>Bolts with a hexagonal</td>
</tr>
<tr>
<td>head with threads for use</td>
</tr>
<tr>
<td>with a nut or tapped hole.</td>
</tr>
<tr>
<td>Abbreviated HHMB or HXBT</td>
</tr>
<tr>
<td><strong>Carriage Bolts</strong></td>
</tr>
<tr>
<td>Bolts with a smooth</td>
</tr>
<tr>
<td>rounded head that has</td>
</tr>
<tr>
<td>a small square section</td>
</tr>
<tr>
<td>underneath.</td>
</tr>
<tr>
<td><strong>Lag Bolts</strong></td>
</tr>
<tr>
<td>Bolts with a wood thread</td>
</tr>
<tr>
<td>and pointed tip.</td>
</tr>
<tr>
<td>Abbreviated Lag</td>
</tr>
<tr>
<td><strong>Set Screws</strong></td>
</tr>
<tr>
<td>Machine screws with no</td>
</tr>
<tr>
<td>head for screwing all</td>
</tr>
<tr>
<td>the way into threaded</td>
</tr>
<tr>
<td>holes.</td>
</tr>
</tbody>
</table>
# Head Styles

<table>
<thead>
<tr>
<th>Head Styles</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>A countersunk head with a flat top. Abbreviated FH</td>
</tr>
<tr>
<td>Oval</td>
<td>A countersunk head with a rounded top. Abbreviated OH or OV</td>
</tr>
<tr>
<td>Pan</td>
<td>A slightly rounded head with short vertical sides. Abbreviated PN</td>
</tr>
<tr>
<td>Truss</td>
<td>An extra wide head with a rounded top. Abbreviated Truss</td>
</tr>
<tr>
<td>Round</td>
<td>A domed head. Abbreviated RH</td>
</tr>
<tr>
<td>Hex</td>
<td>A hexagonal Head. Abbreviated HH or HX</td>
</tr>
<tr>
<td>Hex Washer</td>
<td>A hex head with built in washer.</td>
</tr>
<tr>
<td>Slotted Hex Washer</td>
<td>A hex head with built in washer and a slot.</td>
</tr>
</tbody>
</table>
## Drive Types

<table>
<thead>
<tr>
<th>Drive Types</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phillips and Frearson</strong></td>
<td>An X shaped drive. Abbreviated PH</td>
</tr>
<tr>
<td><strong>Slotted</strong></td>
<td>A slot in the head. Abbreviated SL</td>
</tr>
<tr>
<td><strong>Combination</strong></td>
<td>A combination of slotted and Phillips drives. Abbreviated Combo</td>
</tr>
<tr>
<td><strong>Socket or Allen</strong></td>
<td>A hexagonal hole for use with and Allen wrench.</td>
</tr>
</tbody>
</table>
Nut Types

**Hex**
A six sided nut. Also referred to as a finished hex nut.

**Nylon Insert Lock**
A nut with a nylon insert to prevent backing off. Also referred to as a Nylock.

**Jam**
A hex nut with a reduced height.

**Nylon Insert Jam Lock**
A nylock nut with a reduced height.

**Wing**
A nut with 'wings' for hand tightening.

**Cap or Acorn**
A nut with a domed top over the end of the fastener.

**Flange**
A nut with a built in washer like flange.

**Kep**
A nut with a built in external tooth lock washer, used to speed up assembly.

**Tee**
A nut designed to be driven into wood to create a threaded hole.

**Square**
A four sided nut.

**Prevailing torque lock**
A non-reversible nut used for high temperature applications.
# Washer Types

<table>
<thead>
<tr>
<th>Washer Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flat</strong></td>
<td>A flat washer used to distribute load, available in SAE, USS, and other patterns.</td>
</tr>
<tr>
<td><strong>Fender</strong></td>
<td>An oversize flat washer used to further distribute load especially on soft materials.</td>
</tr>
<tr>
<td><strong>Finishing</strong></td>
<td>A washer used to obtain a 'finished' look. Usually used with oval head screws.</td>
</tr>
<tr>
<td><strong>Split Lock</strong></td>
<td>The most common style of washer used to prevent nuts and bolts from backing out.</td>
</tr>
<tr>
<td><strong>External Tooth Lock</strong></td>
<td>A washer with external 'teeth' Used to prevent nuts and bolts from backing out.</td>
</tr>
<tr>
<td><strong>Internal Tooth Lock</strong></td>
<td>A washer with internal 'teeth' Used to prevent nuts and bolts from backing out.</td>
</tr>
<tr>
<td><strong>Square</strong></td>
<td>A square shaped washer.</td>
</tr>
</tbody>
</table>
SCREW THREAD - A ridge of uniform section in the form of a helix on the external or internal surface of a cylinder.
EXTERNAL THREAD - A thread on the outside of a member, as on a shaft.
INTERNAL THREAD - A thread on the inside of a member, as in a hole.
MAJOR DIAMETER - The largest diameter of a screw thread (for both internal and external threads).
MINOR DIAMETER - The smallest diameter of a screw thread (for both internal and external threads).
PITCH - The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis. The pitch (P) is equal to 1 divided by the number of threads per inch.
PITCH DIAMETER - The diameter of an imaginary cylinder passing through threads where the widths of the threads and the widths of the spaces would be equal.
LEAD - The distance a screw thread advances axially in one turn.
ANGLE OF THREAD - The angle between the sides of the thread measured in a plane through the axis of the screw.
CREST - The top surface joining the two sides of a thread.
ROOT - The bottom surface joining the sides of two adjacent threads.
SIDE - The surface of the thread that connects the crest with the root.
AXIS OF SCREW - The longitudinal centerline through the screw.
DEPTH OF THREAD - The distance between the crest and the root of the thread measured normal to the axis.
FORM OF THREAD - The cross section of thread cut by a plane containing the axis.
SERIES OF THREAD - Standard number of threads per inch for various diameters.
12.3. Screw Thread Forms

The thread form is basically the shape of the thread. Various forms of threads are used for different purposes. The main uses for threads are to hold parts together, to adjust parts with reference to each other, and to transmit power. The following shows some of the typical thread forms.
Sharp-V thread (60 degrees) is useful for certain adjustments because of the increased friction resulting from the full thread face. It is also used on brass pipe work.

American national thread, with flattened roots and crests, is a stronger thread. This form replaced the sharp-V thread for general use.

Unified thread is the standard thread agreed upon by the United States, Canada, and Great Britain in 1948 and has replaced the American national form. The 11 series are the coarse thread series (UNC or NC), recommended for general use: the fine thread series (UNF or NF). The unified extra fine thread series (UNEF) has many more threads per inch for given diameters than any series of the American national or unified.

Metric thread is the standard screw thread agreed upon for international screw thread fasteners.

Square thread is theoretically the ideal thread for power transmission, since its face is nearly at right angles to the axis, but due to the difficulty of cutting it with dies and because of other inherent disadvantages, square thread has been displaced to a large extent by the acme thread.
Acme thread is a modification of the square thread and has largely replaced it. It is stronger than the square thread, is easier to cut, and has the advantage (is easy disengagement from a split a itt, as on the lead screw of a lathe.

Standard worm thread (not shown) is similar to the acme thread but is deeper. It is used on shafts to carry power to worm wheels.

Whitworth thread was the British standard and has been replaced by the unified thread.

Knuckle thread is usually rolled from sheet metal but is sometimes cast. Buttress thread is designed to transmit power in one direction only. It is commonly used in large guns, in jacks, and in other mechanisms that have high-strength requirements.

A number of different thread forms are defined in various ASME standards. For example:
<table>
<thead>
<tr>
<th>Thread</th>
<th>Series Description</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACME G</td>
<td>General purpose acme thread</td>
<td>B1.5</td>
</tr>
<tr>
<td>NPT</td>
<td>Tapered pipe thread for general use</td>
<td>B1.20.1</td>
</tr>
<tr>
<td>STI</td>
<td>Helical coil inserts</td>
<td>B18.29.1</td>
</tr>
<tr>
<td>UN</td>
<td>Straight Unified inch thread</td>
<td>B1.1</td>
</tr>
<tr>
<td>UNJ</td>
<td>Straight Unified inch thread with mandatory radius root on external thread</td>
<td>B1.15</td>
</tr>
</tbody>
</table>

The old N thread series has been superseded by the UN series.
UNJ and MJ Threads

UNJ and MJ threads, often referred to as “J” threads, are predominately used in the aerospace industry and other applications requiring high fatigue strength, including some automotive applications. The “UNJ” designation is used for inch screw threads and “MJ” for metric threads. “J” threads are similar to standard Unified or metric threads except they have a large radius in the root or minor diameter of the external thread. This radius eliminates sharp corners in the minor diameter of the bolt to increase the stripping strength. This technique is based upon the principle of using filets or radii in sharp corners on parts to strengthen stress points were cracking or failure may occur due to changes in temperature, vibration, or heavy loads. All other dimensions, such as pitch diameter and major diameter, are the same as standard threads. Since the radius on the external thread increases the minor diameter of the bolt, the internal thread or nut must be modified to allow it to assemble. The minor diameter of the internal thread must be enlarged to clear the radius. This is the only change to the internal thread. All other dimensions are the same as standard Unified and metric threads.

What type of tools are used to produce “J” threads? For the internal threads, since the only change is the minor diameter size, only the tap drill size will need to be changed. The same tap used to produce standard threads is used to produce “J” threads. All tooling for external threads, such as dies, thread rolls, and chasers, must be made to produce a radius at the minor diameter. In addition, all run-out or incomplete threads must also have a radius. In other words, the chamfered teeth on dies and chasers must have rounded crests. Unfortunately, rounded chamfered teeth are difficult to produce, and therefore, not readily available on dies and chasers. In order to use these tools to produce “J” threads on a part, an undercut or clearance must be incorporated beyond the full thread requirement to accommodate the chamfer.
12-4 Thread Series

The thread series is the detail of the shape and number of threads per inch comprising different groups of fasteners. Five series of threads were used in the old ANSI standards:

1. **Coarse thread** - general-purpose thread used for holding. Designated NC (national coarse).
2. **Fine thread** - greater number of threads per inch: used extensively in automotive and aircraft construction. Designated NF (national fine).
3. **8-pitch thread** - All diameters have eight threads per inch. Used on bolts for high-pressure pipe flanges, cylinder-head studs, and similar fasteners. Designated 8N (national form, 8 threads per inch).
4. **12-pitch thread** - All diameters have 12 threads per inch: used in boiler work and for thin nuts on shafts and sleeves in machine construction. Designated 12N (national form, 12 threads per inch).
5. **16-pitch thread** - All diameters have 16 threads per inch; used where necessary to have a fine thread regardless of diameter, as on adjusting collars and bearing retaining nuts. Designated 16N (national form, 16 threads per inch).
12-5 Thread Notes

**Metric Threads:**
1. MJ10 x 1.5 LH
2. MJ10 x 1.5-6H / 6g-N-LH
3. 1-1/2-6 (2 STARTS) UNC

A **tap drill** is sized to form a hole that will leave enough material for thread to be cut using a tap in order to form a threaded hole.

**Unified Threads**
1. 1-20 (3 STARTS) UNC-2A
2. 1-18 UNF-2B (internal)
3. 1-16 UN-2A (external)
(g) INTERNAL THREAD - METRIC

(h) EXTERNAL THREAD - METRIC

(i) INTERNAL THREAD Unified

(j) EXTERNAL THREAD Unified

**FIGURE 12.3** Thread Notes.
**METRIC THREAD -- Aerospace threads MJ**

![Diagram of a metric thread](image)

**BOLT** Figure 1

<table>
<thead>
<tr>
<th>Thread designation</th>
<th>d</th>
<th>Td</th>
<th>d2</th>
<th>Td2</th>
<th>d3</th>
<th>Td3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MJ1.6 x 0.35-4h6h</td>
<td>1.600</td>
<td>1.515</td>
<td>0.095</td>
<td>1.373</td>
<td>1.333</td>
<td>0.04</td>
</tr>
<tr>
<td>MJ2 x 0.4-4h6h</td>
<td>2.000</td>
<td>1.905</td>
<td>0.095</td>
<td>1.740</td>
<td>1.698</td>
<td>0.042</td>
</tr>
<tr>
<td>MJ2.5 x 0.45-4h6h</td>
<td>2.5</td>
<td>2.4</td>
<td>0.1</td>
<td>2.208</td>
<td>2.163</td>
<td>0.045</td>
</tr>
<tr>
<td>MJ3 x 0.5-4h6h</td>
<td>3.000</td>
<td>2.894</td>
<td>0.106</td>
<td>2.675</td>
<td>2.627</td>
<td>0.048</td>
</tr>
<tr>
<td>MJ3.5 x 0.6-4h6h</td>
<td>3.500</td>
<td>3.375</td>
<td>0.125</td>
<td>3.110</td>
<td>3.057</td>
<td>0.053</td>
</tr>
</tbody>
</table>

Dimensions in millimetres
12.8 Thread Pitch

**FIGURE 12.4** Pitch of Threads.

- **(a)** 4 THREADS PER IN.
- **(b)** METRIC THREADS
- **(c)** 8 THREADS PER IN.
- **(d)** 8 THDS PER IN.
- **(e)** 3 THDS PER IN.
- **(f)** 3 THDS PER IN.

**FIGURE 12.5** Right-Hand and Left-Hand Threads.

- **(a)** RIGHT-HAND THREAD
- **(b)** LEFT-HAND THREAD
12.10 Single and Multiple Threads

**FIGURE 12.6** Multiple Threads.

**FIGURE 12.7** Detailed Metric, American National, and Unified Threads.
12.12-13 External/Internal Thread Symbols

**FIGURE 12.8** External Thread Symbols.

**FIGURE 12.9** Internal Thread Symbols.
Any three axis mill that is capable of helical interpolation can be used for thread milling. Helical interpolation involves three axes moving simultaneously. Two axes, 'X' and 'Y', move in a circular motion while the 'Z' axis moves in a linear motion.
Thread Rolling

A die, which is a hardened tool with the thread profile, is pressed on to a rotating workpiece. As the force is gradually increased, the thread profile is transferred to the workpiece. This process produces screws with greater strength than machined threads due to the cold working, as well as better material yield.

Axial, radial and tangential thread rolling systems
A partial profile insert can produce a range of threads by penetrating to different depths. How fine a pitch the insert can machine is determined by the size of a small nose radius (not represented by this diagram). How coarse a pitch the insert can machine is determined by the strength of this radius.

Multi-tooth inserts feature multiple teeth in series. Threading efficiency may improve, but cutting forces are high.
The term **bolt** is generally used to denote a through bolt that has a head on one end, is passed through clearance holes in two or more aligned parts, and is threaded on the other end to receive a nut to tighten and hold the parts together, as shown in Figure 12.20a.

A **hexagon-head cap screw**, shown in Figure 12.20b, is similar to a bolt except it often has greater threaded length. It is often used when one of the pans being held together is threaded to act as a nut. The cap screw is screwed on with a wrench. Cap screws are not screwed into thin materials if strength is desired.

A **stud**, shown in Figure 12.20c, is a steel rod threaded on one or both ends. If threaded on both ends, it is screwed into place with a pipe wrench or with a stud driver. If threaded on one end, it is force fitted into place. As a rule, a stud is passed through a clearance hole in one member, is screwed into another member, and uses a nut on the free end, as shown.

A **machine screw** is similar to a slotted-head cap screw but usually smaller. It may be used with or without a nut. Figure 12.21 shows different screw head types.
Figure 12.20: Bolt, Cap Screw, and Stud.

(a) Bolt  (b) Cap Screw  (c) Stud
FIGURE 12.21  Types of Screwheads.
12.20 Tapped Holes

**FIGURE 12.22** Drilled and Tapped Holes.

- **(a) Twist Drill**
- **(b) Drilled (Section)**
- **(c) Drilled and Tapped (Section)**
- **(d) Drilled and Tapped (Elevation)**
- **(e) Drilled and Bottom Tapped (Section)**
- **(f) Relief**
Some of hand taps (cutting tool used to make internal threads) and two tapping tools used to turn the tap and form the threads, the T-handle and the Tap Wrenches, that are often used with drill press shown below.
12.21 Standard Bolts and Nuts

![Diagram of standard bolts and nuts with dimensions labeled]

**FIGURE 12.24** Bolt Proportions (Regular).
12.23 Specifications for Bolts and Nuts

In specifying bolts in parts lists, in correspondence, or elsewhere, the following information must be covered in order:

1. Nominal size of bolt body
2. Thread specification or thread note
3. Length of bolt
4. Finish of bolt
5. Style of head
6. Name

EXAMPLE (COMPLETE DECIMAL-INCH)

.75-10 UNC-2A x 2.50 HEXAGON CAP SCREW

EXAMPLE (Abbreviated Decimal-INCH)

.75 x 2.50 HEXCAP SCR

EXAMPLE (METRIC)

M8 x 1.25-40, HEXCAP SCR
Nuts may be specified as follows:

EXAMPLE (Complete)
5/8-11 UNC-2B SQUARE NUT

EXAMPLE (Abbreviated)
5/8 SQ NUT

EXAMPLE (Metric)
M8 x 1.25 HEX NUT
12.24 Locknuts and Locking Devices

FIGURE 12.26  Locknuts and Locking Devices.
12.25 Standard Cap Screws
12.29 Miscellaneous Fasteners

FIGURE 12.31 Miscellaneous Bolts and Screws.
12.30 Keys

Keys are used to prevent movement between shafts and wheels, couplings, cranks, and similar machine parts attached to or supported by shafts, as shown in Figure 12.32. A **keyseat** is in a shaft; a **keyway** is in the hub or surrounding part.
12.31 Machine Pins

**FIGURE 12.33** Woodruff Keys and Key-Slot Cutter.

(a) WOODRUFF KEY-SLOT CUTTER

(b)

(c)

**FIGURE 12.34** Taper Pin.

L (MAX)

TAPER .25 PER FT
12.32 Rivets

Rivets are permanent fastenings as distinguished from removable fastenings, such as bolts and screws. Rivets are generally used to hold sheet metal or rolled steel shapes together and are made of wrought iron, carbon steel, copper, or occasionally other metals.
**FIGURE 12.35** Standard Large Rivets.

(a) BUTTON HEAD
(b) HIGH BUTTON HEAD (ACORN)
(c) CONE HEAD
(d) PAN HEAD
(e) FLAT TOP COUNTERSUNK HD
(f) ROUND TOP COUNTERSUNK HD

**FIGURE 12.36** Common Riveted Joints.

(a) SINGLE RIVETED LAP JOINT
(b) DOUBLE RIVETED LAP JOINT
(c) SINGLE RIVETED BUTT JOINT
(d) DOUBLE RIVETED BUTT JOINT
**FIGURE 12.37** Conventional Rivet Symbols.
Close Up of an Airplane A10

Click here for more details.
Collapsed Bridge in Minnesota, 2007

Click here for more details.
12.33 Springs

A spring is a mechanical device that stores energy when deflected and return the same amount of energy when released.
Welding is a method for the permanent assembly of metal parts.

Welding can be divided into at least three classes: arc welding, gas welding, and resistance welding.

1. Arc welding: Heat is generated by an electric arc and the parts are simply fused together and became one. In some cases electrod is used that provides a filler material.

2. Gas welding: The burning gas (oxygen and acetylene) raises the temperature of the part to be joined and a welding rod provides filler material.

3. Resistance welding: The parts that are to be welded, while being forced together by mechanical pressure, are raised to the temperature of fusion by the passage of a heavy electrical current through the junction. (Filler materials are not used. One form is "spot welding")
Welded Joints

Types of welded joints.

- BUTT
- LAP
- TEE
- CORNER
- EDGE 0-30°
Welded Groove Shapes

- SQUARE GROOVE
- V-GROOVE
- BEVEL-GROOVE
- FILLET
- U-GROOVE
- J-GROOVE
- FLARE-V
- SEAM
- FLARE-BEVEL
- EDGE FLANGE
- CORNER FLANGE
- PLUG
- SLOT
- RESISTANCE
- ELECTRON BEAM
A spring is a mechanical device that stores energy when deflected and return the same amount of energy when released.
A typical welded joints, sections, and symbols is shown below.
Comparison of detail drawings of a casting and welding