The Student Engineer's Companion

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Preface

This book has been compiled with the intention of providing all those interested in engineering, whether as a profession or as a hobby, with easily understood and clearly illustrated descriptions of a large number of basic machine elements, tools, processes and materials.

With an increasing number of pupils studying technology and engineering drawing and design at school, there is a need for a single inexpensive volume containing a comprehensive range of the 'hardware' of engineering. I hope that this book will satisfy that need and incidentally yield much good material for engineering drawing exercises. It should also prove to be invaluable to students embarking upon engineering courses many of whom will have had little or no practical experience, and especially to students outside the United Kingdom who are studying engineering in the English language, wherever they may be, and have difficulty with the often archaic and confusing terminology. The book should also find a place in the drawing office and workshop as well as the layman's library.

The Student Engineer's Companion describes about 800 concepts presented in four sections, Basic Engineering Components, Power Transmission Elements, Workshop Equipment, and Engineering Materials, which are accompanied by nearly 550 illustrations. Most of these are in the form of engineering drawings, often with two views in third angle projection, and a comprehensive index allows easy cross-reference. As far as possible the alternative American terminology has been given.

The first section describes about 450 basic components including, for example, 90 under the heading of Fasteners such as bolts, nuts, and rivets. In the second section a wide range of power transmission elements is given including, brakes, clutches, shaft couplings and cams. The most commonly used hand and machine tools, together with metal joining and forming equipment, appear in the third section. The final section deals with the more important metals and their alloys, plastics and other materials used in engineering.

I would like to thank my colleagues at Newcastle-upon-Tyne Polytechnic and friends at Thornhill Comprehensive School, Sunderland, for checking the drawings and scripts and for their constructive suggestions. Finally, I would like to thank my wife, Anne, for her patience and assistance in producing this book.

J.C.

1. Basic Engineering Components

1.1 FASTENERS

BOLTS

The bolt is widely used in engineering to fasten machine parts together, often in conjunction with a nut, to form a non-permanent connection between the parts. It has a head (usually hexagonal but which may also be square or round) and a shank of circular cross-section which is screwed with a V thread for part of its length. When the shank is screwed for its whole length it is often called a *screw* or *machine screw*.

Bolts are available in a wide range of shank diameters and lengths with various thread pitches.

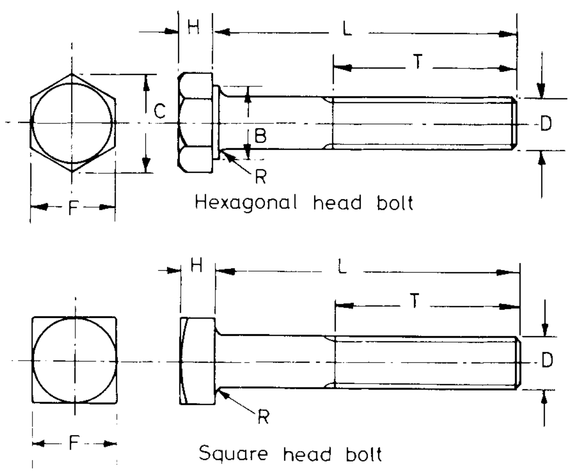


Figure 1.1 *Types of bolt*

Materials Most bolts are made of low or medium carbon steel by forging or machining, and the threads may be cut or rolled. Forged bolts are termed 'black' and machined bolts 'bright'. They are also made in high tensile steel (HT bolts), alloy steel, stainless steel, brass and other non-ferrous metals and alloys. In some cases they are protected from corrosion by galvanising or plating.

Types of thread In Britain metric bolts (ISOM) have largely replaced Whitworth (BSW) and British Standard Fine (BSF). For small sizes British Association (BA) threads are used. In the U.S.A. the most common threads are 'unified fine' (UNF) and 'unified coarse' (UNC).

Dimensions and proportions British and U.S. bolts have fractional inch sizes, e.g. ¼ in., ½ in., 1 in., with standard lengths, e.g. 1 in., 2½ in., etc., and metric bolts are made with diameters of integral numbers of mm, as shown in Table 1.1.

Table 1.1
EXTRACT FROM TABLE OF METRIC BOLT SIZES (mm)

Nominal Size	*D*	*H*	*F*	*Thread pitch* Coarse	*Thread pitch* Fine
M10	10	7	17	1.5	1.25
M12	12	8	19	1.75	1.25
M16	16	10	24	2.0	1.5
M20	20	13	30	2.5	1.5

D = Outside or major diameter of thread
L = Length of shank
T = Length of thread
H = Height of head
F = Distance across flats
C = Distance across corners
R = Radius of fillet under head
B = Bearing diameter

The main dimensions of bolts are: outside or major diameter of thread, length of shank, length of thread, height of head, hexagon size across flats and across corners. In addition, the pitch of the threads is given and sometimes the diameter at the bottom of the threads. The expression 'length of bolt' refers to the shank length.

Loading The total load on a bolt is the sum of the initial tightening load and the load imposed by the machine parts fastened by the bolt. The tightening load is often controlled by the stipulation of a limiting tightening torque and special torque spanners are available for this purpose.

Bolted joint A bolt may be used with a nut and washer to fasten parts together. The washer prevents damage to the surface of the part adjacent to the nut when the nut is tightened. In this case the bolt is referred to as a *through bolt.*

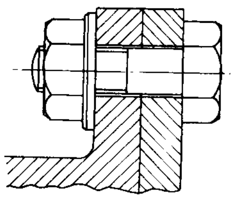


Figure 1.2 *Bolted joint (through bolt) application*

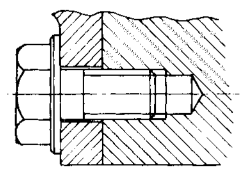


Figure 1.3 *Tap bolt application*

Tap bolt In circumstances where a nut cannot be accommodated it may be replaced by a threaded hole in one of the machine parts connected by the bolt. Passing through a clearance hole in the first part, the bolt is screwed into the threaded hole in the second part. Closer spacing of the bolts is achieved by the use of socket-head screws which are described later.

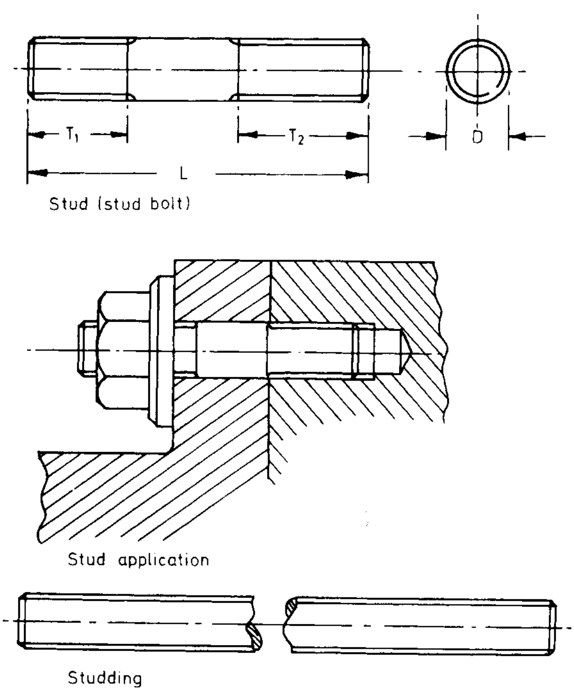


Figure 1.4 *Stud and application*

Stud (stud bolt) In cases where a tap bolt may have to be removed and replaced at frequent intervals, damage to the thread in the hole may occur. In such situations it is advisable to use a stud or stud bolt.

A stud consists of a piece of round bar threaded at each end with a plain middle section. The threads may have different pitches or be of opposite hands, i.e. one right hand and the other left hand. One end of the stud is screwed into the threaded part using two nuts or a special *stud box*, and the other part fastened by means of a nut and washer. The stud is left in place when the parts are dismantled.

Lengths of screwed rod known as *studding* are available for use as studs.

Uniform strength bolt Bolts under high impulsive load have a tendency to break at the bottom of the threads where the cross sectional area is smallest, and the V shape tends to produce cracks.

In a uniform strength bolt part of the shank is reduced in diameter to that at the bottom of the thread. Under high shock loads this part stretches and relieves the stress in the threads.

Alternatively, the shank may be drilled to reduce the area of cross section.

Uniform strength bolts are used for big-ends of connecting-rods in petrol and diesel engines.

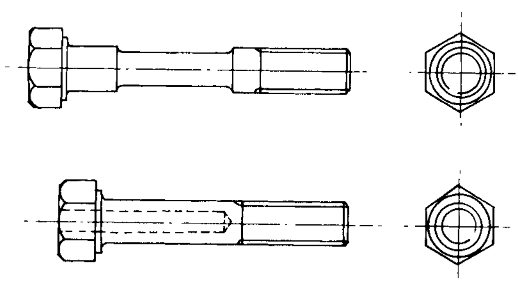


Figure 1.5 *Uniform strength bolts*

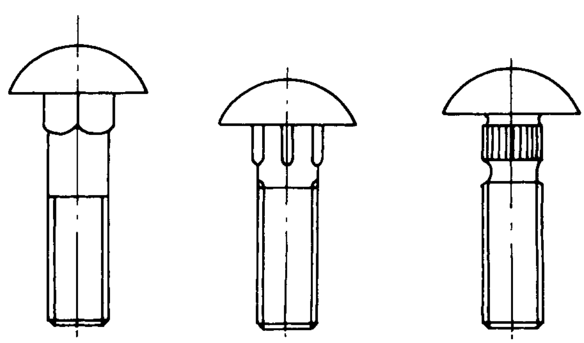


Figure 1.6 *Coach bolts (carriage bolts)*

Coach bolt (carriage bolt) Coach bolts, or carriage bolts, usually have round heads and are black bolts made of low carbon steel with coarse threads. They are used to fasten metal parts to wood. Ribs, fins or a square on the neck under the head act as locking devices. Square nuts are used with coach bolts.

Hexagon socket head screw (or bolt) A wide variety of screws (or bolts) are available which have a hexagonal recess or socket in a circular head requiring a special key or wrench for tightening. The head has many forms: cap, countersunk and button. These screws are invariably made of high tensile steel and have a coating of black oxide due to heat-treatment.

Socket screws are mostly used as tap bolts and the heads are often located in a recess for a neat appearance.

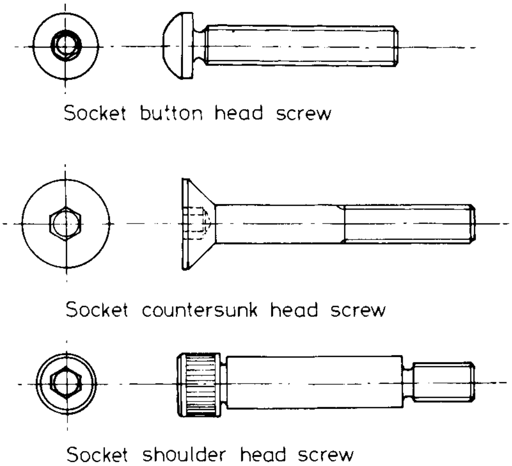
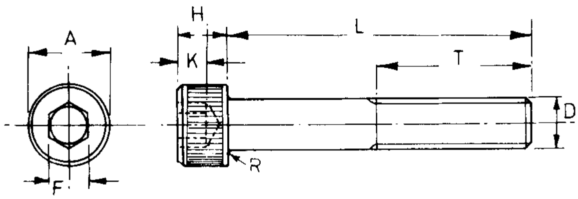


Figure 1.10 *Types of socket head screws*



Typical metric sizes (mm)

D = 10.0	R = 0.6
A = 16.0	F = 8.0
H = 10.0	K = 5.5

L/T according to application

Figure 1.7 *Hexagon socket head screw*

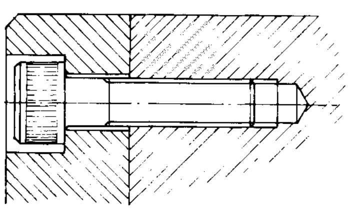


Figure 1.8 *Hexagon socket head screw application*

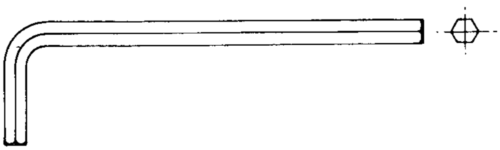


Figure 1.9 *Hexagon socket wrench (Allen key)*

T bolt The T bolt has a specially-shaped head which suits the T slots in bedplates and machine-tool tables and allows the bolt to slide in the slot without rotating.

It is used extensively for holding down work to be machined and is available in mild steel and high tensile steel.

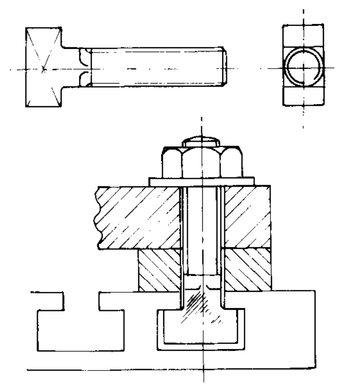


Figure 1.11 *T bolt and application*

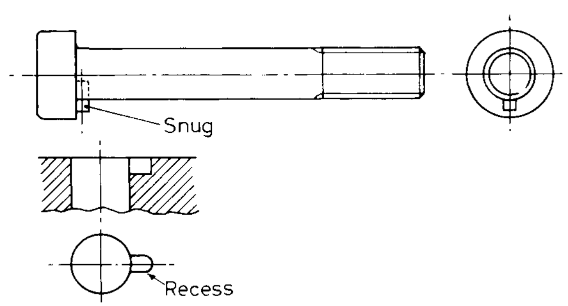


Figure 1.12 *Cheese head bolt*

Cheese head bolt Large bolts are often made with a circular head known as a *cheese head.* This shape eliminates the necessity for a hexagon. To prevent rotation of the bolt when being tightened, a pin or *snug* driven or screwed into the shank, just below the head, engages with a recess in the face of the adjacent part.

Rag bolt (foundation bolt) Rag bolts, or foundation bolts, are used for attaching machinery etc. to concrete or masonry.

Made of steel or iron, the rag bolt has a flat, tapered and roughened head which ensures a good bond when grouted into concrete.

The *indented foundation bolt* has a round body with indentations.

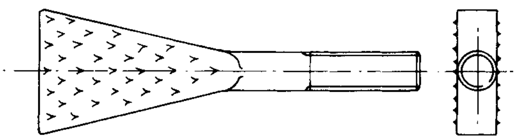


Figure 1.13 *Rag bolt*

Figure 1.14 *Indented foundation bolt*

Rawlbolt (anchor bolt) A proprietary bolt for anchoring machinery to a floor or wall. A hole is drilled and the bolt inserted. When tightened, the segmented shell is expanded by a cone on the screw to give the bolt a tight fit in the hole.

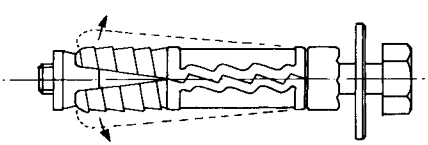


Figure 1.15 *Rawlbolt*

Eye bolt An eye bolt consists of a steel ring to which a screwed shank is attached, and it is usually permanently fitted to heavy machinery to provide an anchorage point for a rope, chain or hook used for lifting purposes.

The proportions and material used are controlled by strict standards.

Fitted bolt In most cases through bolts are fitted into holes slightly larger than the bolt diameter which are known as 'clearance' holes. Sometimes, however,

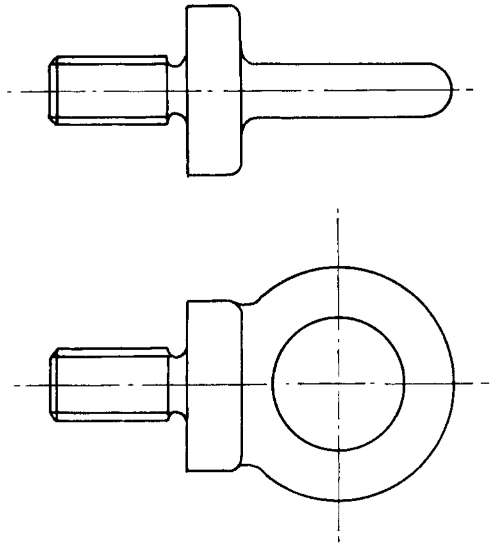


Figure 1.16 *Eye bolt*

the shank of the bolt is accurately machined and fitted into a reamed or bored hole with a very small clearance and this results in an exact location of the parts bolted together. Fitted bolts are often used in solid bolted and flanged shaft couplings, e.g. for a ship's propeller shaft. An alternative method of location is to use dowels in conjunction with bolts.

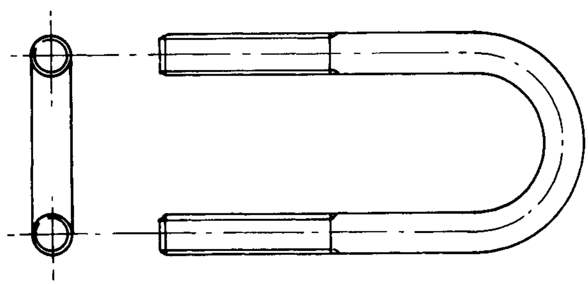


Figure 1.17 *U bolt*

U bolt This consists of a piece of circular bar bent in the form of a U and with the ends threaded. It is used for fastening round, or half round, objects such as pipes and shafts to flat surfaces.

SCREWS

This name is given to a wide variety of threaded fasteners with various types of head used with metal, wood, plastics, etc.

The name is sometimes used instead of bolt, as in the case of socket screws, but usually refers to small screwed fasteners used for light assemblies.

Most screws employed in engineering are made of steel or brass, sometimes plated, using British, metric or American threads. For small screws ranging in size from about 1.5mm to 6mm British Association and metric threads are used.

Special threads are employed for wood screws and self-tapping screws.

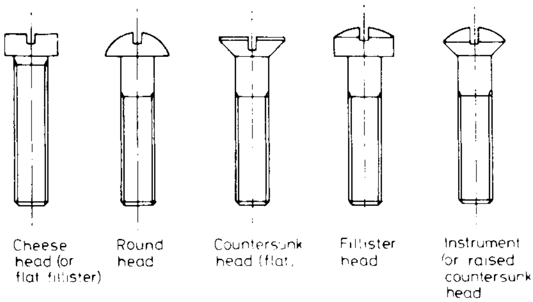


Figure 1.18 *Slotted head machine screws*

Slotted head machine screw This has a rectangular-section slot cut in the head to suit a screwdriver. There are many types of head, including round, cheese (flat fillister), fillister and countersunk or flat.

They are available in various threads and in both steel and brass which may be either cadmium or chromium plated.

Set screw Set screws are used to prevent relative motion between machine parts and often they take the place of keys on shafts where the transmitted torque is small. Most set screws do not have heads but have either a slot or a hexagon socket, and these types are known as *grub screws*.

Hardened steel is used in most cases and a variety of points is available.

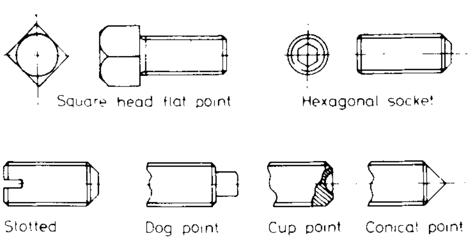


Figure 1.19 *Set screws*

Self-tapping screw (thread-forming and cutting screw) Self-tapping screws have a coarse screw thread on a tapered shank and are made of hardened steel.

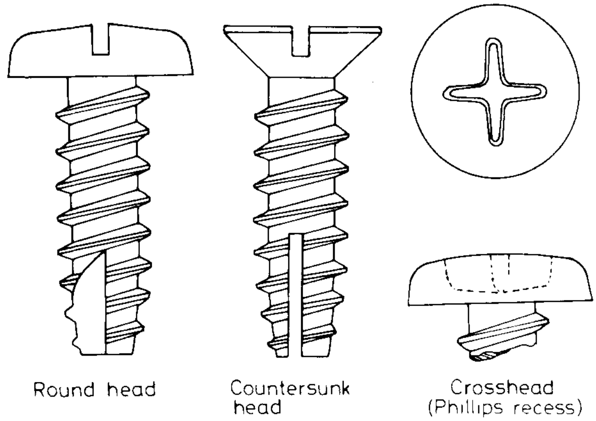


Figure 1.20 *Self-tapping screws*

They eliminate the necessity for a threaded hole or nut by cutting a thread in the material into which they are driven.

The shank may have either a blunt or a pointed end and it sometimes has longitudinal grooves which help to cut the thread in the manner of a screw tap. The heads are round, button or countersunk and have either slots or cross-shaped recesses, the latter requiring the use of a cross-head screwdriver.

These screws are used extensively for the assembly of sheet metal parts, soft castings and plastics.

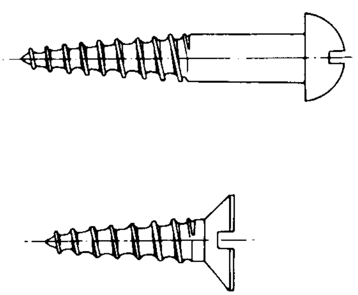


Figure 1.21 *Wood screws*

Wood screw This type is often used in engineering to attach sheet metal to wood. Wood screws are made of steel, brass, gunmetal and copper, and may be painted or electroplated. The heads are round or countersunk with either slots or star recesses.

Wood screws are available in a wide range of diameters from 2–10mm and in many lengths.

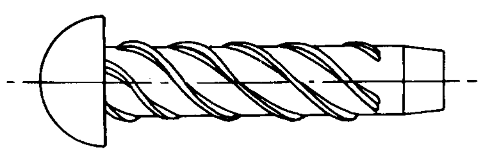


Figure 1.22 *Drive screw*

Table 1.2
ISO METRIC PRECISION HEXAGON NUTS AND THIN NUTS (mm)

Nominal size and diameter	*Thread pitch (coarse)*	*Width across flats*	*Width across corners*	*Thickness of nut Normal*	*Thin*
d	p	s	c	m	t
M5	0.8	8.0	9.20	4.0	–
M6	1.0	10.0	11.50	5.0	–
M8	1.25	13.0	15.00	6.5	5.0
M10	1.5	17.0	19.60	8.0	6.0
M12	1.75	19.0	21.90	10.0	7.0
M16	2.0	24.0	27.70	13.0	8.0

Drive screw Drive screws are hardened steel pins with very coarse pitch multistart screw threads. They are hammered or pressed into unthreaded holes in which they rotate to form a mating thread.

They are used for the rapid attachment of parts such as nameplates to castings, clips, etc. (Figure 1.22).

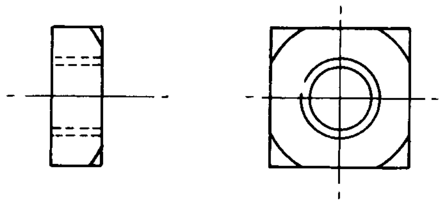


Figure 1.24 *Square nut*

NUTS

A nut is a collar, usually made of metal, with a threaded hole into which is fitted a bolt, stud or screwed bar. Together with a bolt it provides the most widely used means of fastening parts together.

Nuts may be hexagonal, square or round in shape. Steel nuts are available in either black or bright condition and may be forged or machined. Black nuts may be machined on one or both faces and bright nuts have one or both faces chamfered.

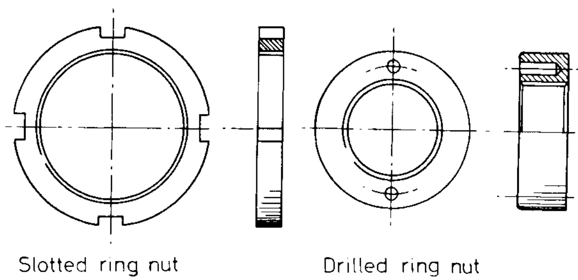


Figure 1.25 *Ring nuts*

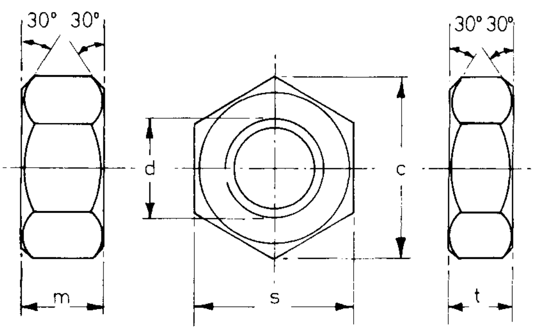


Figure 1.23 *ISO metric precision hexagon nut and thin nut*

Cap nut (crown nut, dome nut) In these one end of the threaded hole is closed and rounded to protect the end of the bolt or stud and give a neat appearance. They are made in steel or brass and are usually chromium plated.

Wing nut These nuts have wing-like projections for hand tightening. They are made in steel and brass and are used where frequent removal and replacement of parts is required.

Square nut Square nuts are usually obtained in the black, or unmachined, state and provide a cheap alternative to hexagon nuts.

Round nut (ring nut) These are often used for attaching parts to shafts and have slots or holes so that they may be tightened by using a special key.

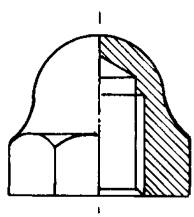


Figure 1.26 *Cap nut (crown nut, dome nut)*

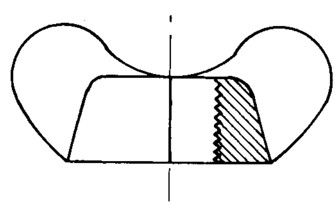


Figure 1.27 *Wing nut*

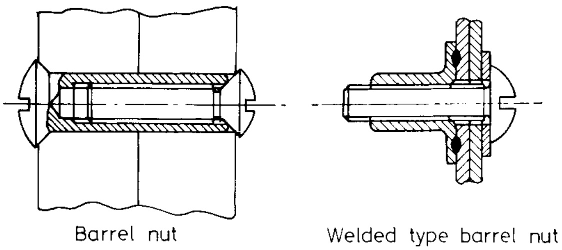


Figure 1.28 *Barrel nuts*

Barrel nut This nut has a tubular form. One type has a slotted head similar to that of the mating screw, while another has a flange which is welded to sheet metal.

Captive nut A nut which is loosely fastened to a machine part so that it is held in position until a bolt or screw is fitted.

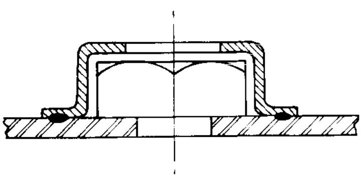


Figure 1.29 *Captive nut*

Locking nuts Nuts subject to shock loads and vibration have a tendency to work loose and cause damage or failure in machines. A wide range of locking devices is available including special nuts, lock washers and adhesives.

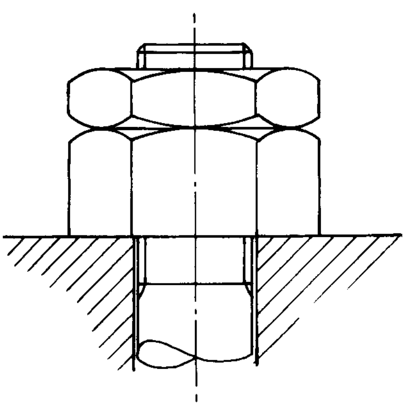


Figure 1.30 *Locked nuts (jam nuts)*

Locked nuts (jam nuts) A nut can be locked by tightening another nut against it and for this purpose a thin nut is used for the sake of economy. Ideally this should be situated below the normal-sized nut although this necessitates the use of a thinner spanner. Two spanners are required when locking the nuts.

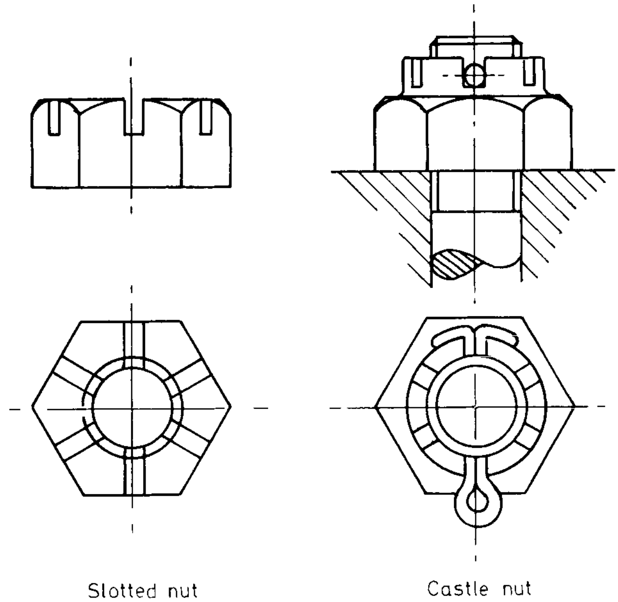


Figure 1.31 *Slotted and castle nuts*

Slotted nut and castle nut A slotted nut is a hexagonal nut with six radial slots cut in the top face two of which line up with a hole in the bolt so that a split pin may be passed through to lock the nut. Alternatively, wire can be used to lock a group of nuts.

In a castle nut the slots are cut in a circular section of the nut above the hexagon.

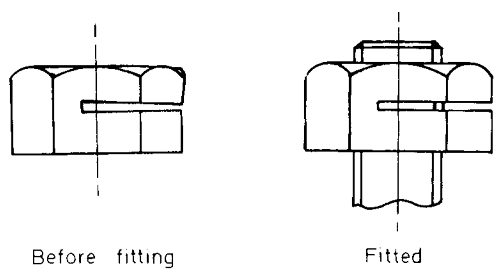


Figure 1.32 *Split nut*

Split nut A slot cut in the side of a hexagon nut is closed before fitting. The bolt forces the slot open with a resulting high frictional force which reduces the tendency for the nut to loosen.

Spring lock nut (compression stop nut) This is a hexagonal nut similar in appearance to a castle nut but the slots in the top of the nut form tongues which are initially pressed down to apply a frictional force on the bolt when fitted (Figure 1.33).

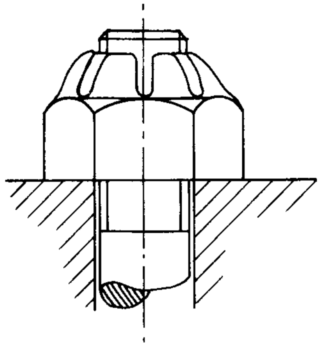


Figure 1.33 *Spring lock nut (compression stop nut)*

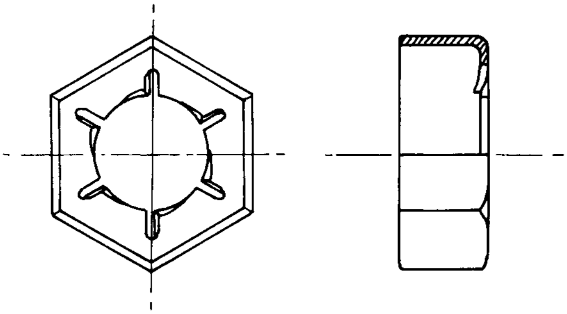


Figure 1.34 *Stamped spring nut*

Stamped spring nut This is stamped out of spring steel sheet in a variety of patterns with a hexagonal form and projections which engage with the bolt thread to give a high degree of friction.

Elastic stop nut (Nyloc nut) A ring of material such as fibre or nylon is inserted into a groove in the bore of a hexagon nut to provide a high frictional force when the nut is fitted.

The Nyloc nut is a proprietary type with a nylon insert.

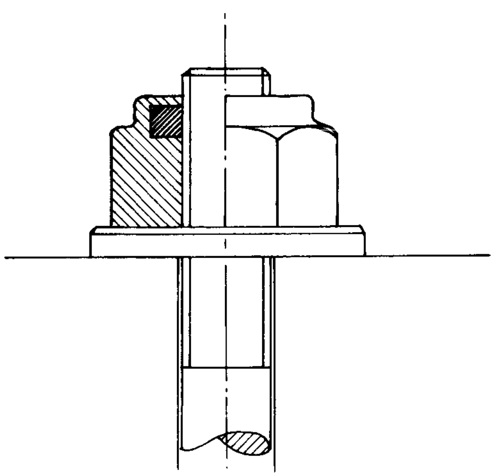


Figure 1.35 *Elastic stop nut (Nyloc nut)*

WASHERS

A washer is an annular disk of metal, plastic, rubber, etc., usually flat, which is placed either under a nut or between the surfaces of a joint to distribute the load when the nut or joint is tightened.

Most washers are made of steel but brass is used in conjunction with brass screws and nuts. Washers of copper, aluminium, fibre and leather are used extensively for sealing fluids.

Plain washer (flat washer) This is a flat washer, usually made of steel, and used under a nut to prevent damage to the face and to distribute the load. Cheap washers are punched out of black plate but more expensive ones are machined and have a bevelled edge for improved appearance. In addition to washers of 'normal' proportions, 'narrow' and 'wide' varieties are available.

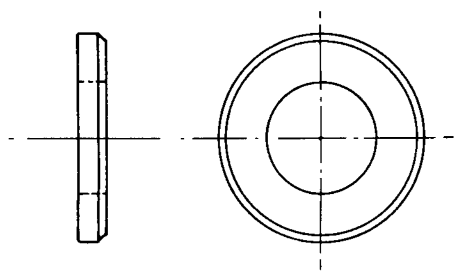


Figure 1.36 *Plain washer (flat washer)*

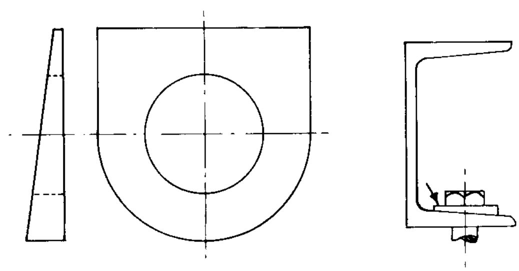


Figure 1.37 *Taper washer and application*

Taper washer A washer where the thickness varies from one side to the other to allow for the taper on the flanges of rolled steel sections such as channel and I beams.

Lock washer To prevent the loosening of nuts due to shock and vibration, lock washers are used extensively as an alternative to locknuts. There are two main types, those which rely on increased friction between the nut and the face, and those which use the faces of the nut to give a positive fixing.

Helical spring lock washer This consists of one or more turns of a helical spring made of rectangular section spring steel wire. When the nut is tightened the washer is compressed to cause a large friction force between the nut and the face. This is aided by sharp ends on the washer which cut into the faces to give positive locking.

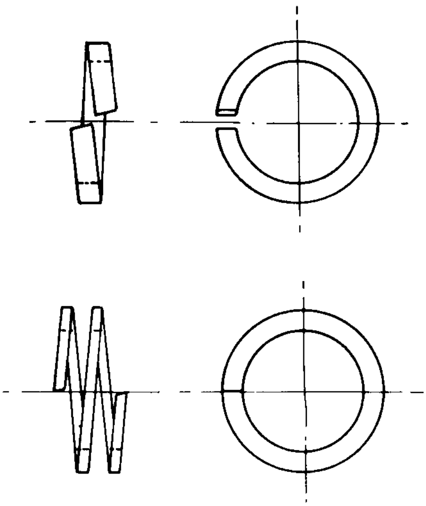


Figure 1.38 *Helical spring lock washer and two-coil spring lock washer*

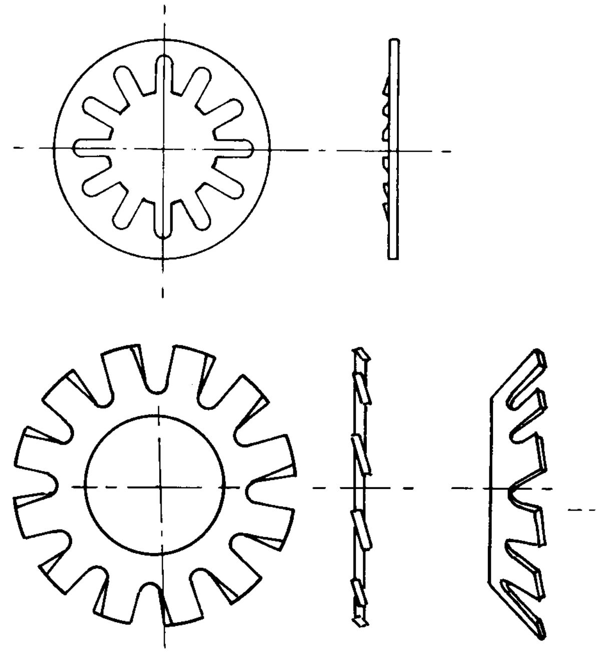


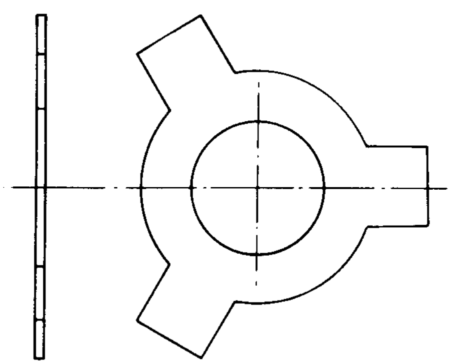
Figure 1.39 *Internally serrated lock washer (tooth lock washer) and externally serrated lock washer, flat and for countersunk hole*

Serrated lock washer (tooth lock washer) These are made of spring steel and consist of annular disks with serrations on either inner or outer diameter. The resulting projections are twisted and have sharp edges. When the nut is tightened the projections are flattened and cut into the faces of the nut and the part in contact.

A conical washer with external serrations is available for use with countersunk head screws.

Tab washer The tab washer is made from sheet metal and has a hole for the bolt or stud with tabs on the periphery which are bent at right angles against the faces of the nut and against a face on the adjacent part.

Alternatively, the tab may be punched into a hole previously drilled in the part.



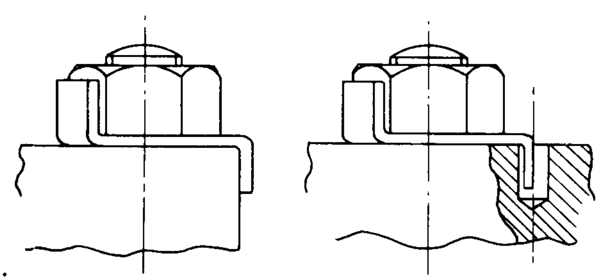


Figure 1.40 *Tab washer and application*

RIVETS

A rivet is a metal pin with a circular shank and a head. It is used to make a permanent joint between two or more pieces of plate. The shank is passed through mating holes in the plates and 'closed' by forming a head on the projecting shank by hammering or pressing.

Steel rivets are often closed when red hot but rivets of softer metals such as copper and aluminium are closed cold. The heads may be round, countersunk, pan-shaped, etc.

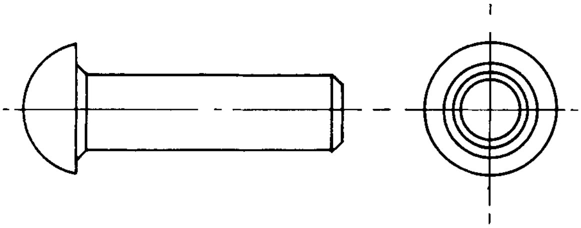


Figure 1.41 *Rivet*

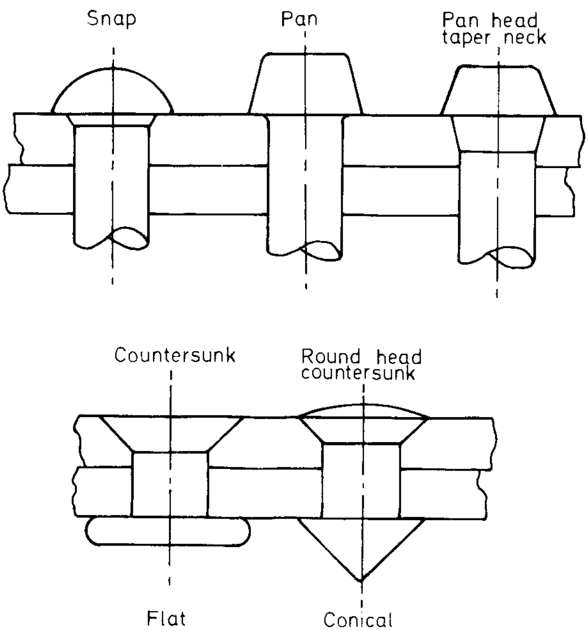


Figure 1.42 *Types of rivet*

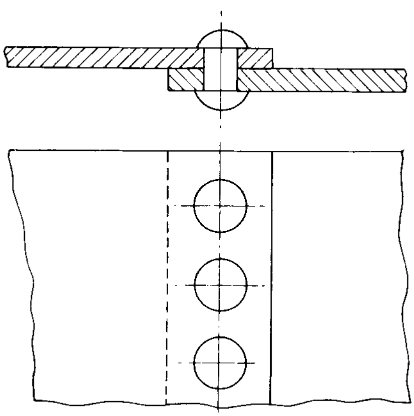


Figure 1.43 *Riveted lap joint*

Riveted joint Metal plates may be joined together by overlapping the edges and riveting using one or several rows of rivets. Alternatively, the plates may be placed edge-to-edge and a butt joint made with butt straps on one or both sides of the joint. One or more rows of rivets are passed through the plates and straps on each side of the joint.

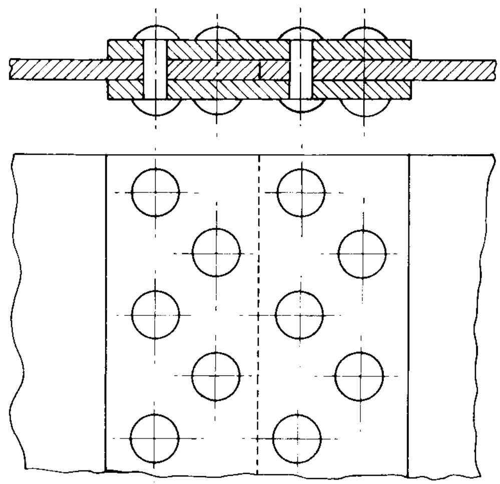


Figure 1.44 *Double riveted butt joint with two straps*

Flush rivet (aircraft type) The head of this rivet is flat and countersunk so that it is flush with the face of one of the plates. This is advantageous in aircraft construction where a smooth surface is required for aerodynamic reasons. The rivets are mostly made of aluminium.

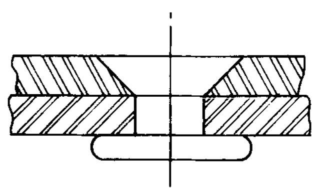


Figure 1.45 *Flush rivet*

Tubular rivet This consists of a piece of soft metal tubing the ends of which are deformed by a special tool. They are used for joining thin metal sheets.

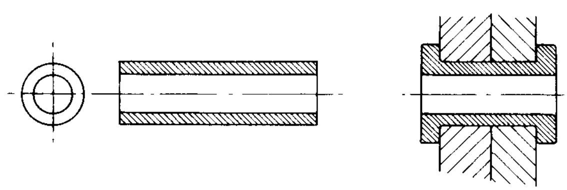


Figure 1.46 *Tubular rivet*

Pop rivet This is a type of tubular rivet which initially has a hard steel pin passing through it. When the rivet is fitted by means of a special tool the head of the pin closes the rivet and snaps off. Riveting is done from one side of the plate.

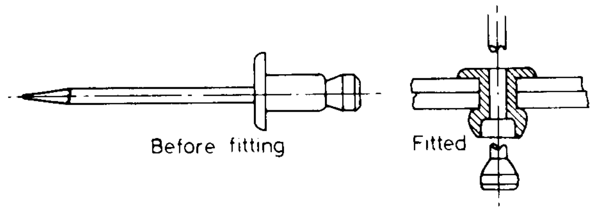


Figure 1.47 *Pop rivet*

Explosive rivet The end of the shank of this rivet is hollowed out to take a small explosive charge. When this is exploded the protruding shank expands to form a joint. This type is used extensively in the aircraft industry.

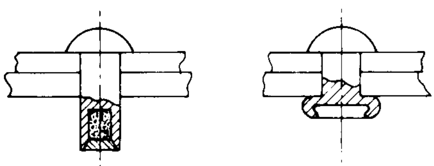


Figure 1.48 *Explosive rivet*

PINS

This term refers to a large range of components consisting basically of a piece of rod or bar, usually of circular section and either solid or hollow. They are used for fixing, locating and load carrying.

Plain pin This is simply a piece of bar which, in most cases, is machined to a good finish and accuracy. It is used for locating parts.

Dowel pin A dowel pin is a straight circular pin, sometimes with a head, which is accurately fitted into holes to locate two or more parts together. This is often used in conjunction with bolts and studs.

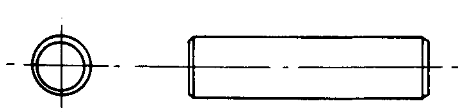


Figure 1.49 *Plain pin*

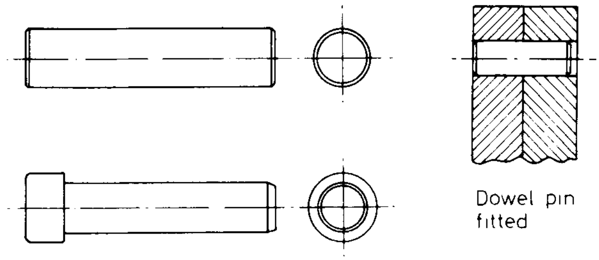


Figure 1.50 *Dowel pins*

Taper pin A type of dowel which has a fine taper so that a tight fit is obtained when it is lightly tapped into a hole which has been drilled and then finished with a taper reamer. Taper pins are often used in conjunction with a sleeve for connecting shafts transmitting low power (*see* Section 2.2 on Shaft couplings).

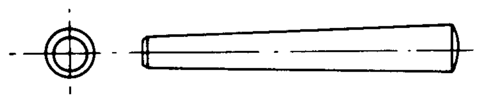


Figure 1.51 *Taper pin*

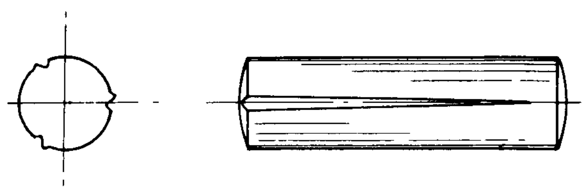


Figure 1.52 *Grooved pin*

Grooved pin This is a straight, circular and solid pin which has longitudinal grooves with raised edges formed by rolling. A tight fit in the hole is achieved when the pin is hammered in. Grooved pins are useful as keys for light power transmission.

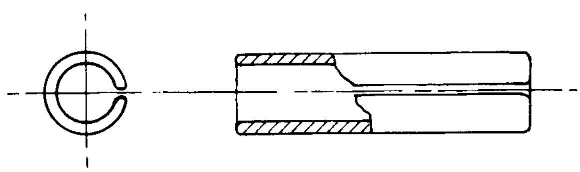


Figure 1.53 *Roll pin*

Roll pin A roll pin is a spring steel tube, with a longitudinal slit, which is driven into a slightly smaller hole so that the slit closes to give a tight fit.

It is easier to fit than solid pins and taper pins, and an example of its use is for attaching hand wheels to valve spindles.

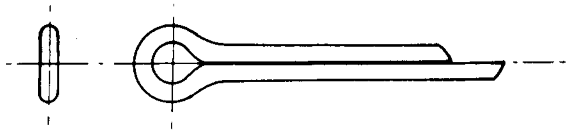


Figure 1.54 *Split pin (cotter pin)*

Split pin (cotter pin) A pin formed from half-round wire folded to give a shank and a head. The pin is passed through mating holes in parts and the protruding ends bent outwards to secure it. It is used mainly for locking slotted nuts.

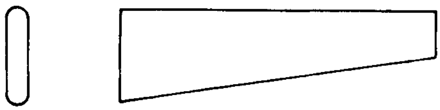


Figure 1.55 *Cotter*

Cotter A tapered pin of rectangular cross-section. It is used to provide a rigid joint between rods under an axial force. The cotter fits into slots in the ends of the rods and may easily be removed if desired (*see* Section 1.7 Cottered joint).

CLIPS

Clips are used for attaching pipes, tubes and cables to other parts to prevent rattling and provide location relative to those parts.

Band hose clip In this type of clip a steel band formed into a circle is tightened onto a hose by means of a screw and nut.

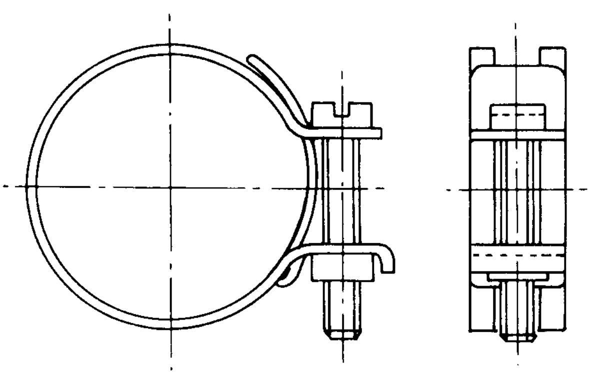


Figure 1.56 *Band hose clip*

Worm-drive hose clip (Jubilee clip) In another type, known as a worm-drive *Jubilee clip*, the screw engages with serrations in the steel band instead of a nut. These clips are used for clamping rubber and plastic hoses to metal pipes.

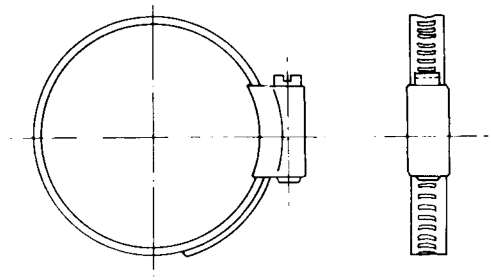


Figure 1.57 *Worm-drive hose clip (Jubilee clip)*

Spring wire hose clip A loop of spring wire with projecting ends is used to clamp a hose onto a pipe. The clip is fitted or removed by opening the loop with pliers.

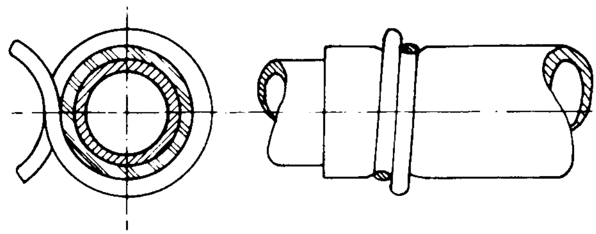


Figure 1.58 *Spring wire hose clip*

Pipe and cable clips These are used for fastening pipes, tubes and cables to machines to provide location and prevent vibration. They are usually made of metal strip, sometimes ribbed for strength, and are fastened by screws or rivets.

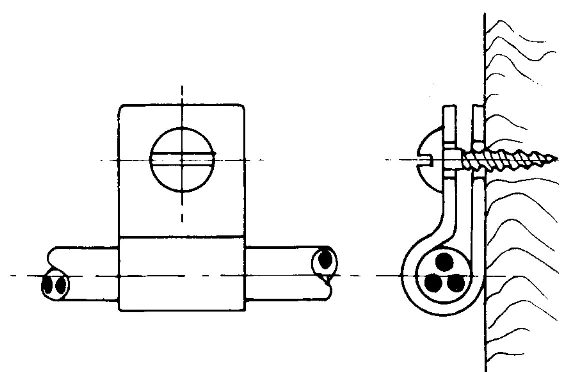


Figure 1.59 *Cable clip*

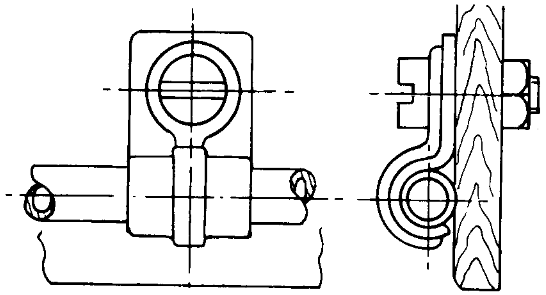


Figure 1.60 *Pipe clip*

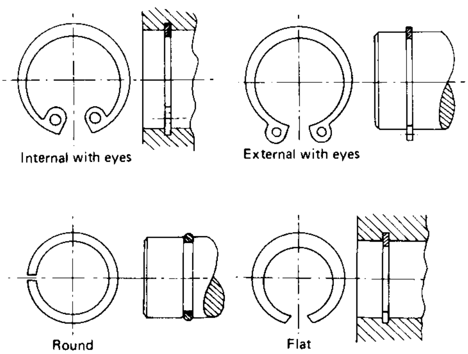


Figure 1.61 *Circlips (retaining rings)*

Circlip (retaining ring) A spring steel clip in the form of an incomplete ring which fits tightly into a circumferential groove on a shaft or in a bore and locates parts axially. Circlips may be of circular or rectangular cross-section. Rectangular section circlips may have internal or external eyes for easier fitting using a special tool.

1.2 SCREW THREADS

A screw thread is formed by cutting or forming a helical groove, or thread, on the surface of a circular bar or in a circular hole. The thread may be right-handed or left-handed, and of various cross-sections such as V, square, trapezoidal, etc. External threads of large diameter are usually produced by machining with a single point tool. Smaller bar is screwed in a lathe using a die box, or by hand using stocks and dies. Threads on bolts, screws and studs are often produced by rolling. The bar is formed by means of a pair of flat or circular dies having the thread form. The method is cheaper for large quantities and gives a better finish as well as a higher strength.

Internal threads of large size are machined with a single point tool. Smaller holes are machine-tapped in quantity or hand-tapped for small numbers off.

V threads are used mainly for fasteners while square and trapezoidal threads are used for power transmission.

V THREAD

A V thread is in the form of an isosceles triangle with the 'crest' and 'root' either flattened or rounded. The main dimensions are: pitch (the distance between adjacent threads); major and minor diameters; V angle; area of cross-section at the bottom of the threads.

V threads are used almost exclusively for fasteners such as nuts and bolts.

The main types of thread form are: Whitworth (BSW) 55°; British Standard Fine (BSF) 55°; British Association (BA) 47.5°; Metric (ISO) 60°; USA Standard 60°; Unified Coarse and Fine (UNC-UNF) 60°.

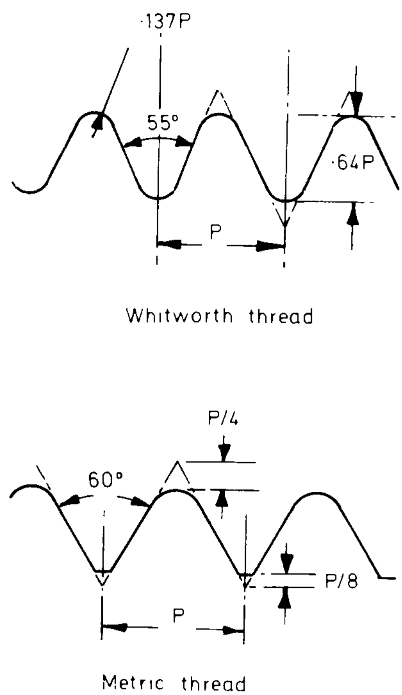


Figure 1.62 *Thread details*

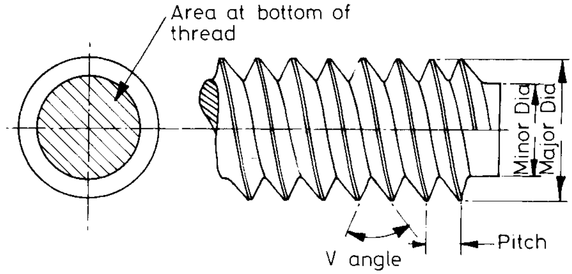


Figure 1.63 *V screw thread*

SQUARE THREAD

The square thread is mechanically strong and is used mainly for power transmission. There is no radial force on the nut and friction is low.

Square threads, and Acme and buttress threads, are formed by machining on a lathe, whereas V threads are often cut by hand with taps and dies.

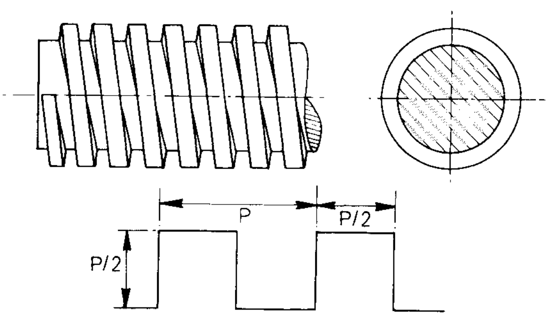


Figure 1.64 *Square thread*

ACME THREAD

Used for power transmission, this is a trapezoidal thread of greater root strength and easier to cut than the square thread. It is sometimes used for the lead screw in lathes.

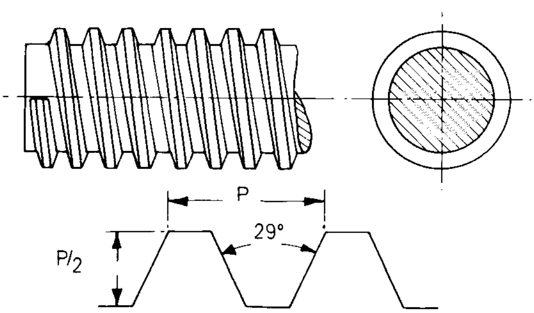


Figure 1.65 *Acme thread*

BUTTRESS THREAD

This is a thread used for power transmission which combines the advantages of both square and Acme threads. The load must be applied in one direction only, and that is on the vertical face.

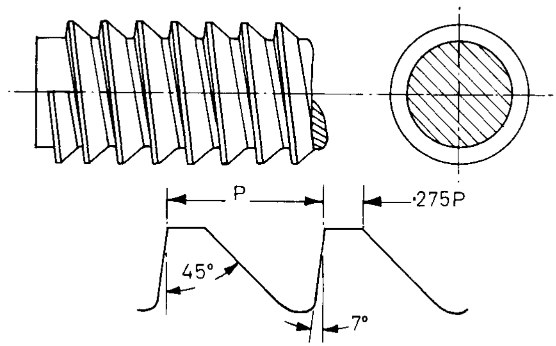


Figure 1.66 *Buttress thread*

MULTI-START THREAD

To obtain a larger pitch without increasing the depth of thread and reducing the strength, two or more threads may be cut on the same screw side by side. The nut advances N times the pitch, where N is the number of thread 'starts' in each revolution. The advance is known as the 'lead'.

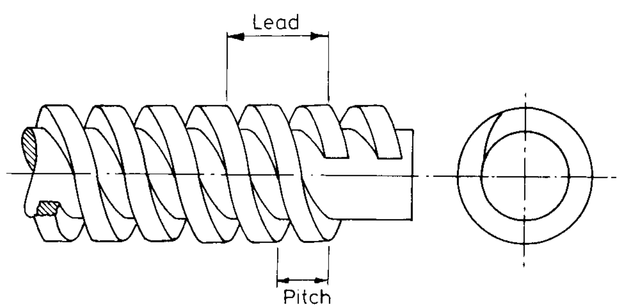


Figure 1.67 *Two-start square thread*

BALL-BEARING POWER SCREW

This is an extremely low friction power screw in which the screw and nut have opposing helical grooves of part-circular cross-section to suit ball bearings situated between them.

Power is transmitted between the screw and nut via the ball bearings which circulate continuously through a tube attached to the outside of the nut.

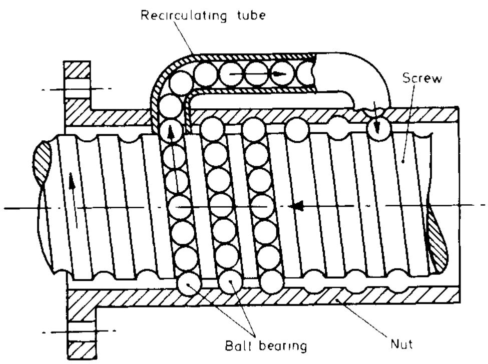


Figure 1.68 *Ball-bearing power screw*

EFFICIENCY OF SCREW THREADS

The efficiency of screw threads is defined as the ratio of the work done by the nut to the work put into the screw.

This may be as low as 20% for a poorly-lubricated V thread but up to 80% for a well-lubricated square or Acme thread. The ball bearing screw has an efficiency approaching 100%.

1.3 SPRINGS

Springs are used extensively in engineering to control movement and to apply forces in machines. They limit impact forces, reduce vibrations by storing energy, and are often used to measure forces.

HELICAL COIL SPRING

This consists of a wire of circular, square, rectangular or other section wrapped around a cylinder to form a helix.

HELICAL COMPRESSION SPRING

In a helical compression spring the coils are sufficiently open to allow shortening of the spring under a compressive load. The ends of the spring are usually flattened and ground to provide a seating and the wire is generally round, but rectangular section wire is also used.

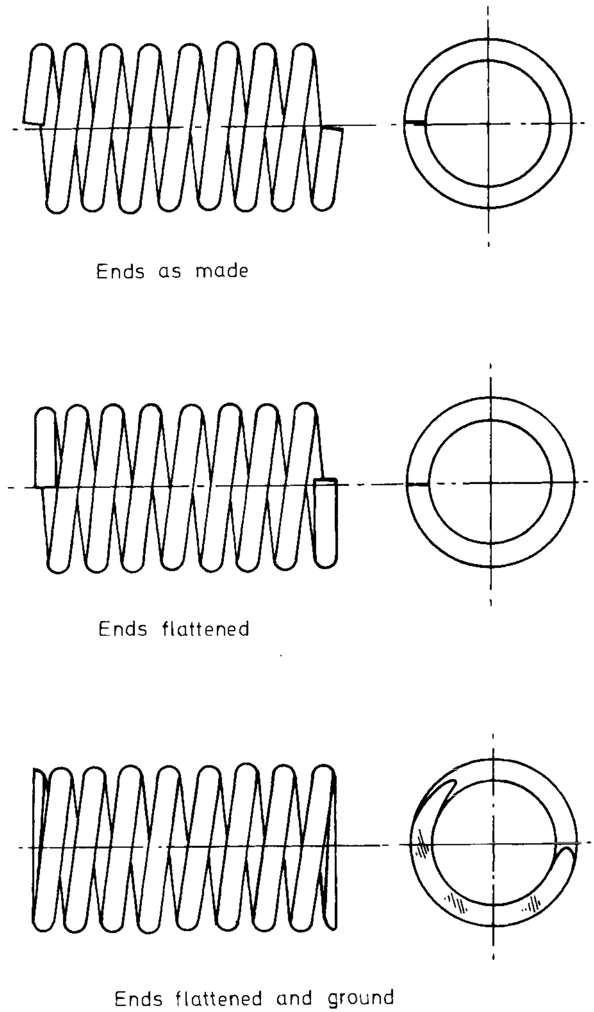


Figure 1.69 *Helical compression springs*

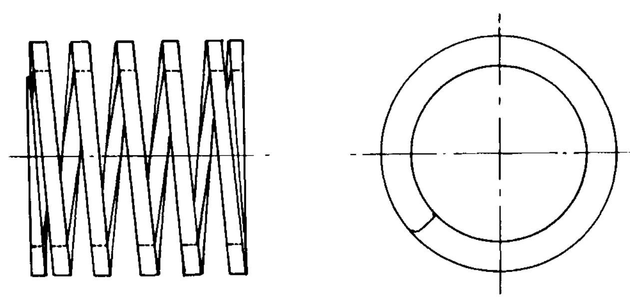


Figure 1.70 *Rectangular-section spring*

HELICAL TENSION SPRING

The ends of helical tension springs are formed into hooks of various types and the springs are usually pre-tensioned so that a small initial load is required to open the coils.

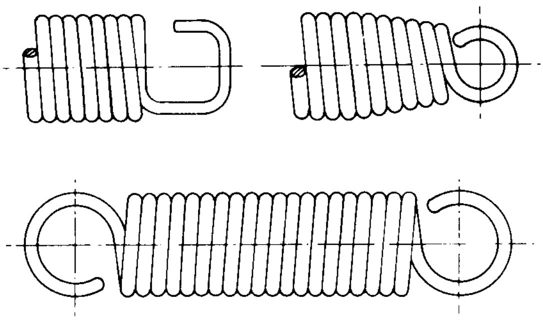


Figure 1.71 *Helical tension springs*

HELICAL TORSION SPRING

This is a helical spring with suitable ends which is subject to a twisting moment or torque.

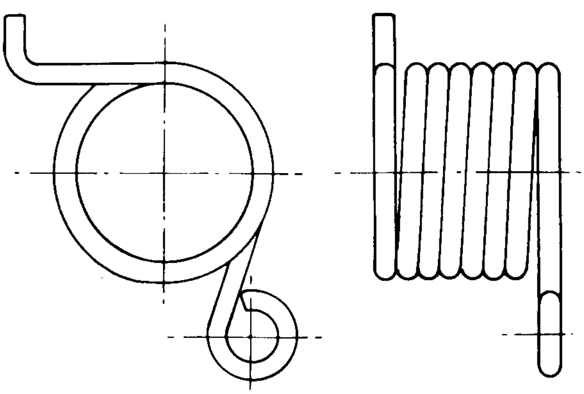


Figure 1.72 *Helical torsion spring*

HELICAL SPRING DATA

The important dimensions are: mean diameter of coils, wire size, free length, loaded length, clearance between coils, number of coils.

It is also necessary to know: design load, material, spring rate or stiffness (the load per unit deflection).

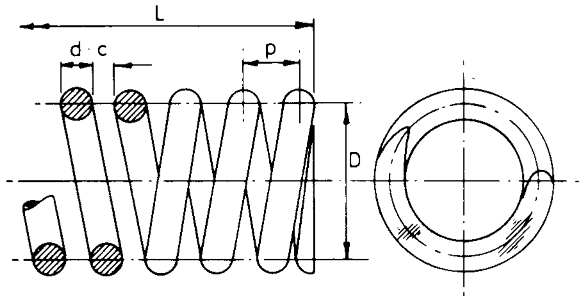


Figure 1.73 *Helical spring dimensions: D = mean diameter of coils; d = wire diameter; c = coil clearance; L = spring length; p = pitch*

HELICAL SPRING MATERIALS

Most springs are made of hard, drawn, spring steel but many other metals are used including chrome vanadium steel, phosphor bronze, beryllium copper and stainless steel. Drawn steel wire is often termed *piano* or *music wire*.

SPIRAL TORSION SPRING

In this spring, the wire of round or rectangular cross-section is wound in a flat spiral and the spring is deformed under the application of a twisting moment, or torque. Small round wire spiral springs are used in locks and catches and as return springs for control rods. The clock spring is a case in which rectangular wire is used.

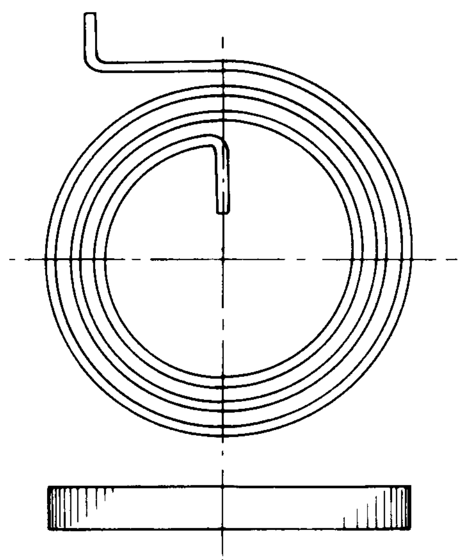


Figure 1.74 *Spiral torsion spring (rectangular section)*

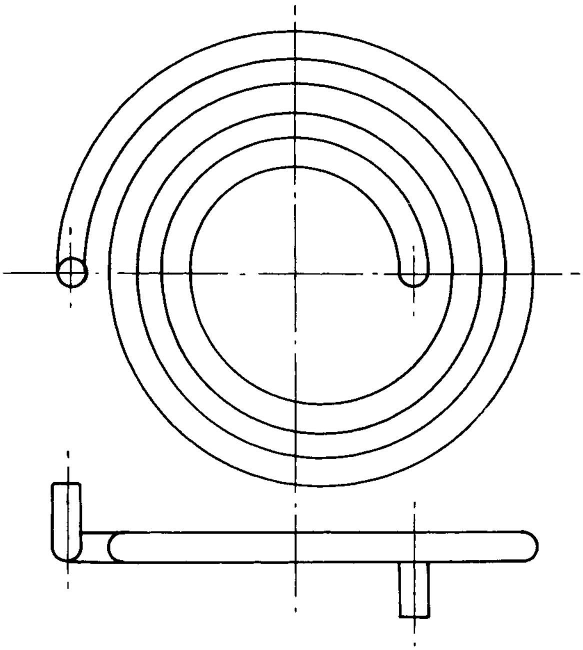


Figure 1.75 *Spiral torsion spring (round wire)*

CONICAL SPRING (UPHOLSTERY SPRING)

This is a helical compression spring in which the coil diameter changes from one end to the other so that a conical form is obtained. The larger diameter coils, which are the least stiff, close first so that the spring becomes stiffer as the load is increased.

An advantage is that the length of the spring when fully compressed is only the diameter of the wire. These springs are used extensively for upholstery.

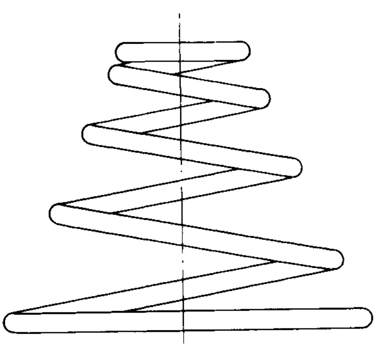


Figure 1.76 *Conical spring (upholstery spring)*

VOLUTE SPRING

A volute spring is made of thin rectangular strip wound into a conical spiral with each successive coil overlapping the previous one, and the cone flattens under sufficient load.

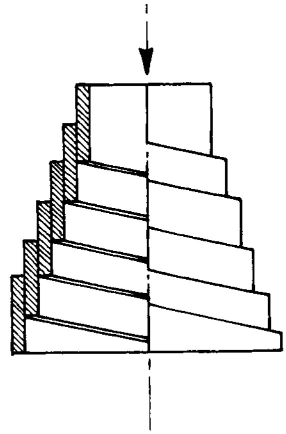


Figure 1.77 *Volute spring*

LEAF SPRINGS

These springs consist of one or several flat or slightly curved bars of steel held at one end and loaded at the other (cantilever) or held at both ends and loaded at the centre (beam).

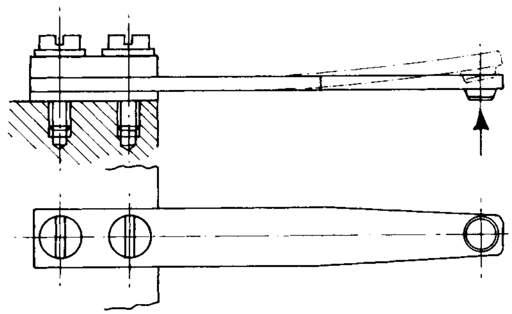


Figure 1.78 *Cantilever leaf spring (electrical contact)*

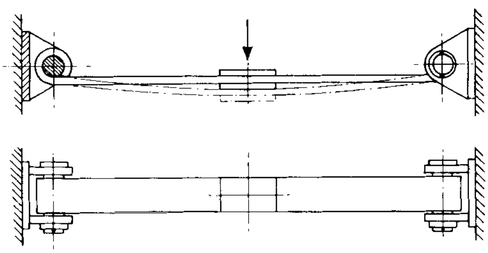


Figure 1.79 *Beam leaf spring*

LAMINATED LEAF SPRING (CARRIAGE SPRING)

A spring used extensively for vehicle suspensions. It consists of several flat strips clamped together and these vary in length to give a higher strength. The ends of the longest strip (usually at the top) are formed into eyes which take the suspension bolts, and the load is applied at the centre. Half of one of these springs may be used as a cantilever spring (Figure 1.80).