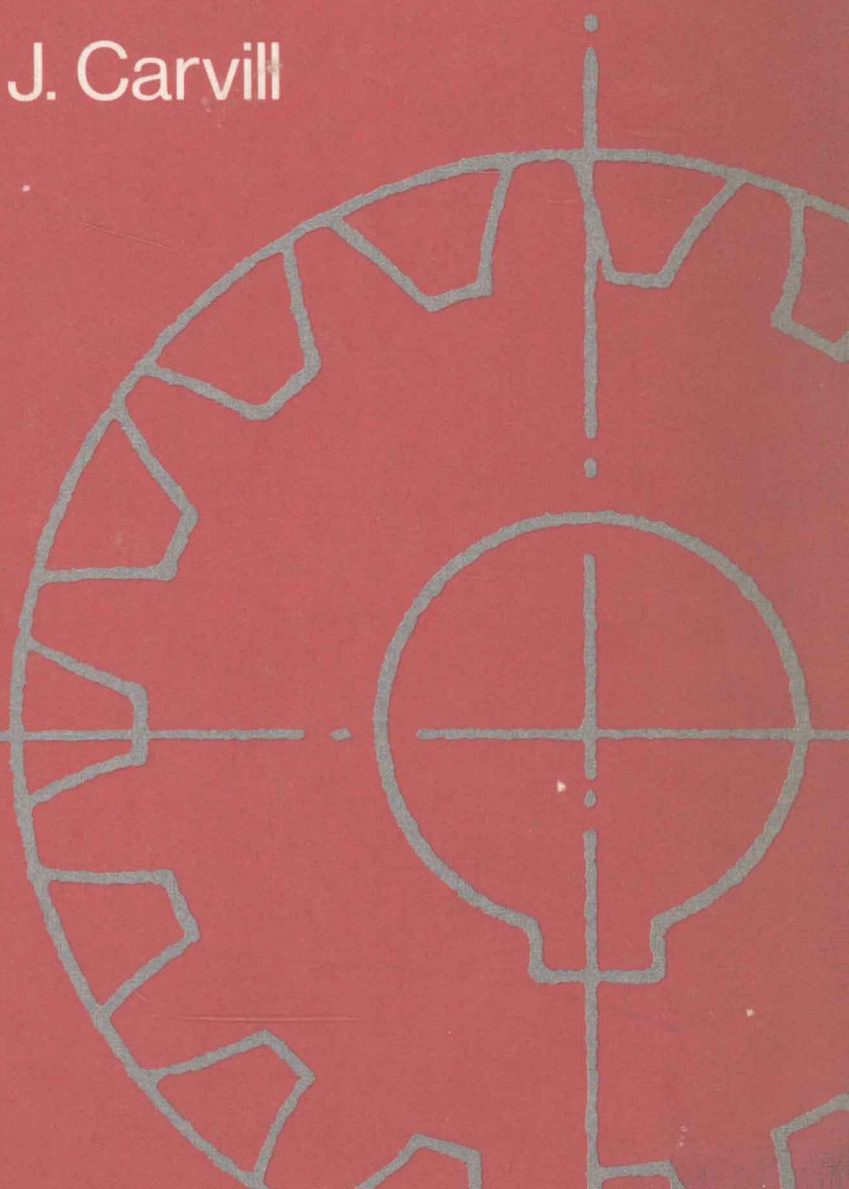
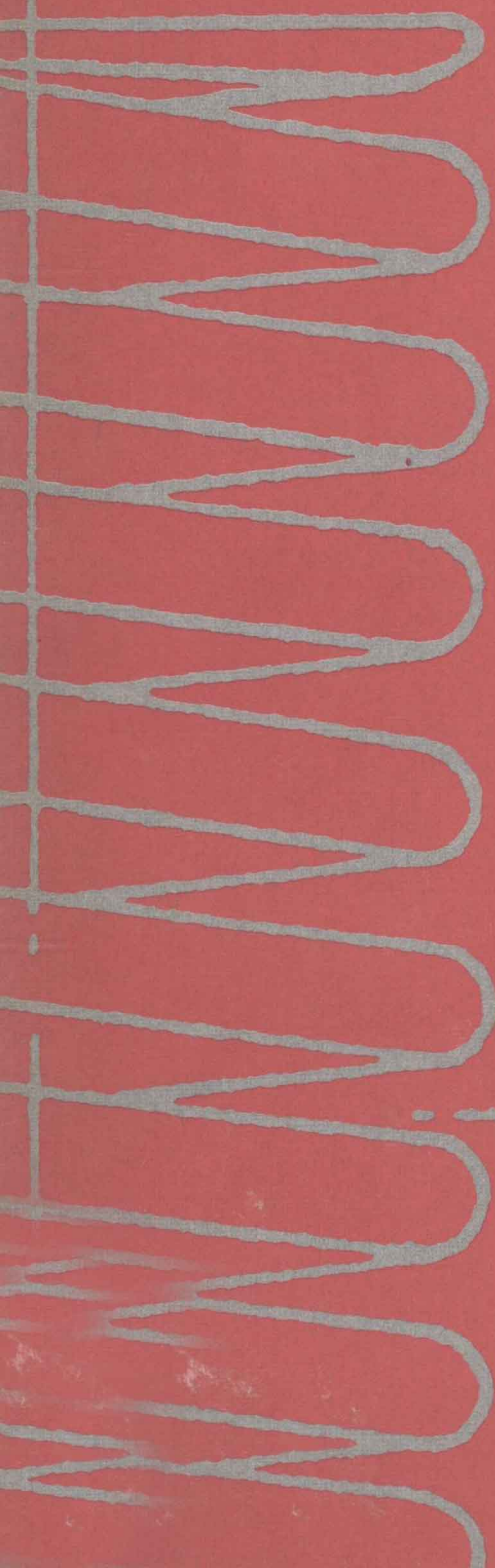


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The student engineer's companion

J. Carvill



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THE BUTTERWORTH GROUP

UNITED KINGDOM

Butterworth & Co (Publishers) Ltd
London: 88 Kingsway, WC2B 6AB

AUSTRALIA

Butterworths Pty Ltd
Sydney: 586 Pacific Highway, NSW 2067
Also at Melbourne, Brisbane, Adelaide and Perth

CANADA

Butterworth & Co (Canada) Ltd
Toronto: 2265 Midland Avenue, Scarborough, Ontario, M1P 4S1

NEW ZEALAND

Butterworths of New Zealand Ltd
Wellington: T & W Young Building, 77–85 Customhouse Quay, 1
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SOUTH AFRICA

Butterworth & Co (South Africa) (Pty) Ltd
Durban: 152–154 Gale Street

USA

Butterworth (Publishers) Inc
Boston: 10 Tower Office Park, Woburn, Mass. 01801

First Published 1980

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British Library Cataloguing in Publication Data

Carvill, J

The student engineer's companion

1. Mechanical engineering – Equipment and supplies

I. Title

621.8

TJ153

79-42954

ISBN 0 408 00438 X

Typeset by Butterworths Litho Preparation Department

Printed in England by Page Bros Ltd, Norwich, Norfolk

The Student Engineer's Companion

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.

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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.

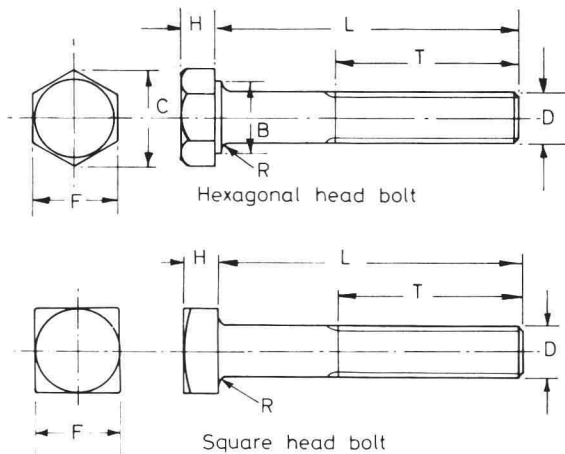


Figure 1.1 Types of bolt

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. $\frac{1}{4}$ in., $\frac{1}{2}$ in., 1 in., with standard lengths, e.g. 1 in., $2\frac{1}{2}$ 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 | 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*.

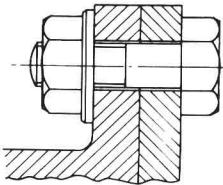


Figure 1.2 Bolted joint (through bolt) application

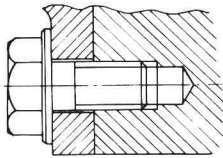
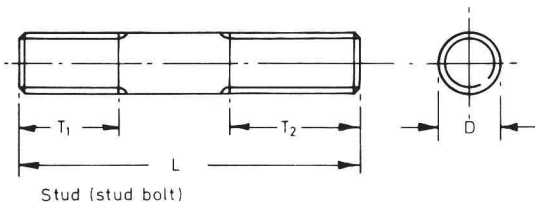
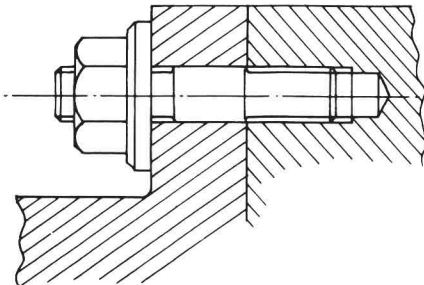


Figure 1.3 Tap bolt application

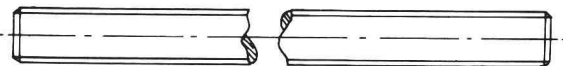
Tap bolt In circumstances where a nut cannot be accommodated it may be replaced by a threaded hole in one of the machine parts connected by the bolt. Passing through a clearance hole in the first part, the bolt is screwed into the threaded hole in the second part. Closer spacing of the bolts is achieved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



Stud (stud bolt)



Stud application



Studding

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.

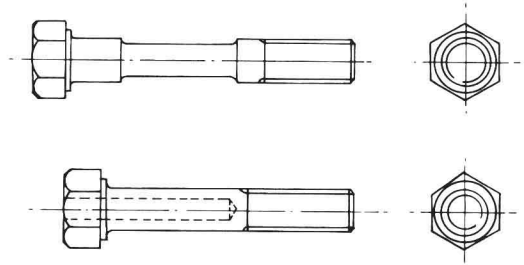
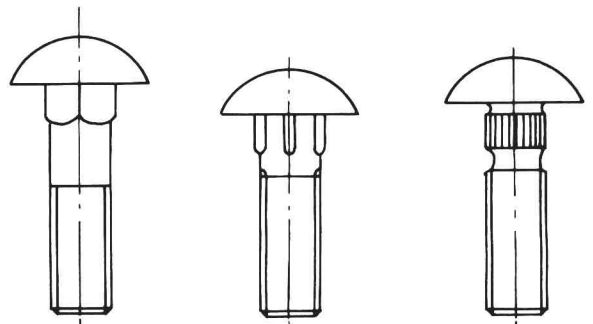


Figure 1.5 Uniform strength bolts



Square neck

Ribbed neck

Serrated neck

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.

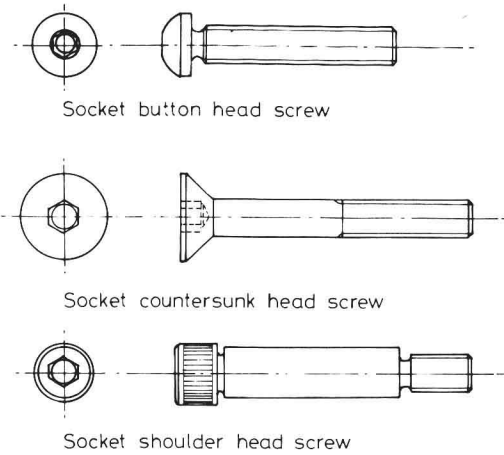
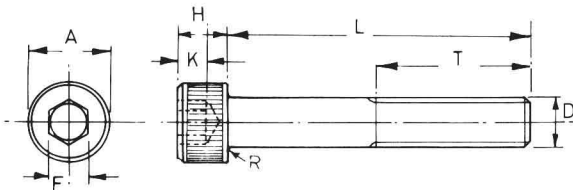


Figure 1.10 Types of socket head screws



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

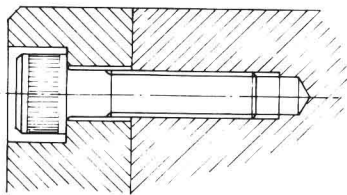


Figure 1.8 Hexagon socket head screw application

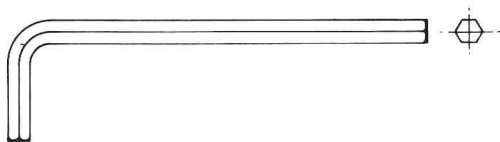


Figure 1.9 Hexagon socket wrench (Allen key)

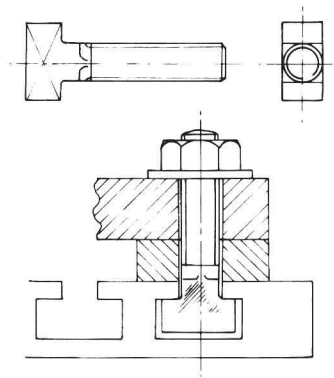


Figure 1.11 T bolt and application

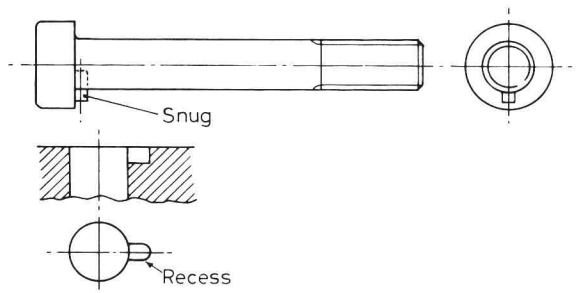


Figure 1.12 Cheese head bolt

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.

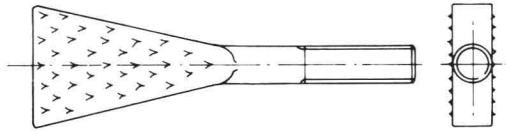


Figure 1.13 Rag bolt



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.

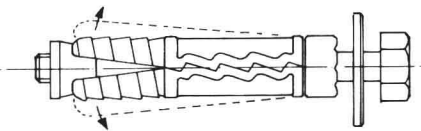


Figure 1.15 Rawlbolt

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,

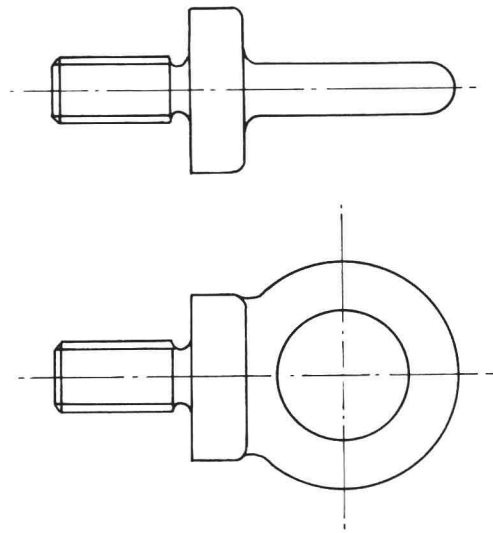


Figure 1.16 Eye bolt

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.

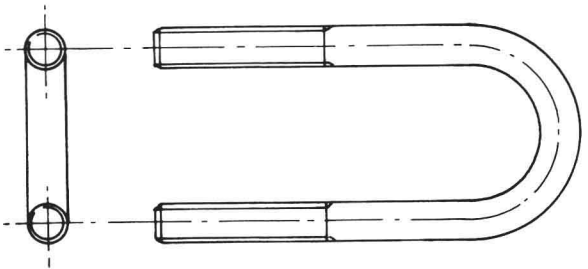


Figure 1.17 U bolt

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 (BA), threads are used.

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

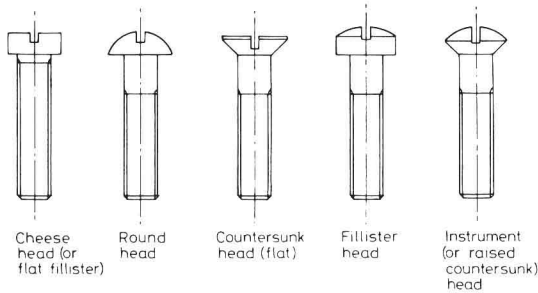


Figure 1.18 Slotted head machine screws

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 power 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.

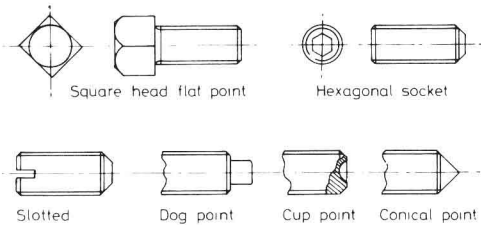


Figure 1.19 Set screws

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.

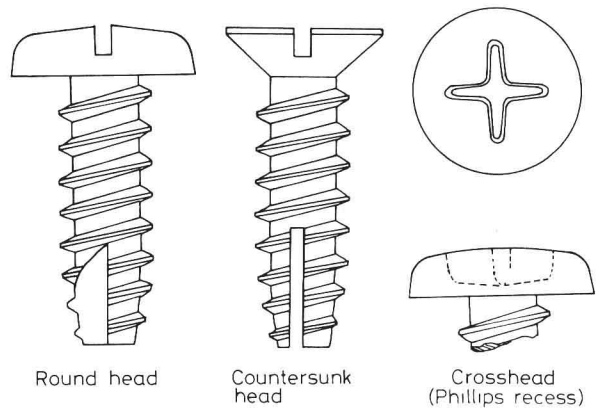


Figure 1.20 Self-tapping screws

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.

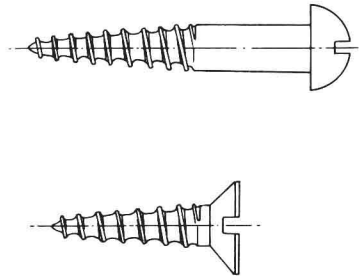


Figure 1.21 Wood screws

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.

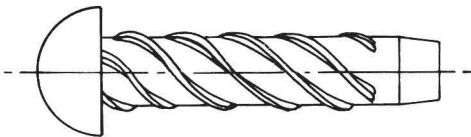


Figure 1.22 Drive screw

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

| <i>Nominal size and diameter</i> | <i>Thread pitch (coarse)</i> | <i>Width across flats</i> | <i>Width across corners</i> | <i>Thickness of nut</i> | |
|----------------------------------|------------------------------|---------------------------|-----------------------------|-------------------------|----------|
| <i>d</i> | <i>p</i> | <i>s</i> | <i>c</i> | <i>m</i> | <i>t</i> |
| 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).

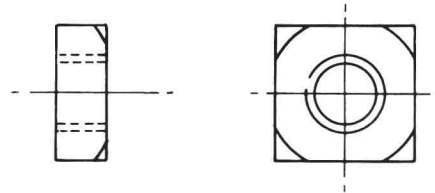
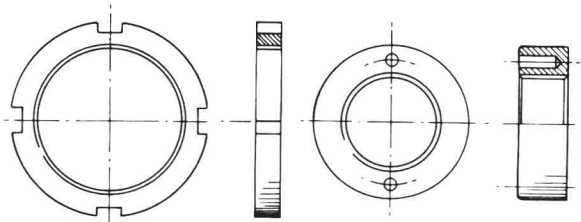


Figure 1.24 Square nut

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.



Slotted ring nut

Drilled ring nut

Figure 1.25 Ring nuts

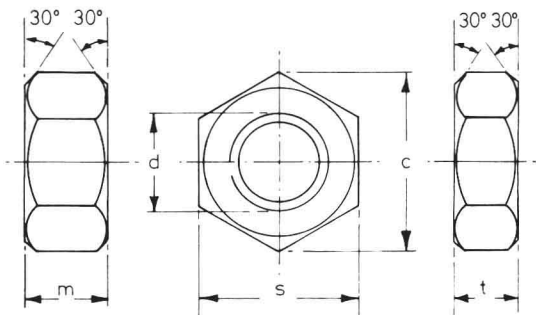


Figure 1.23 ISO metric precision hexagon nut and thin nut

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.

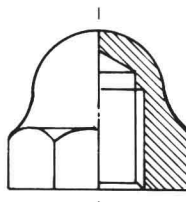


Figure 1.26 Cap nut (crown nut, dome nut)

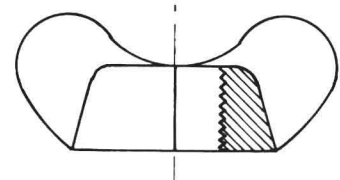


Figure 1.27 Wing nut

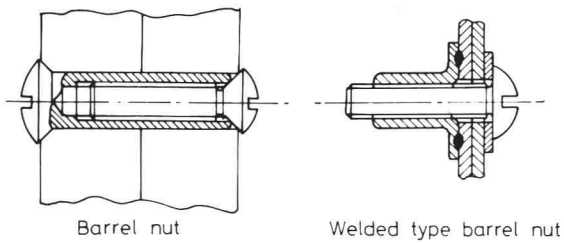


Figure 1.28 *Barrel nuts*

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.

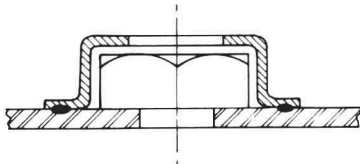


Figure 1.29 *Captive nut*

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.

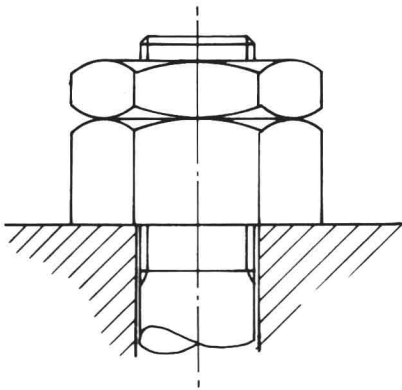


Figure 1.30 *Locked nuts (jam nuts)*

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.

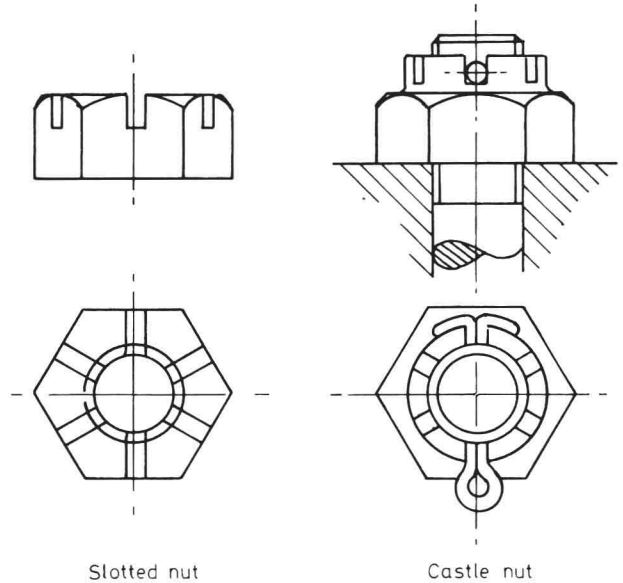


Figure 1.31 *Slotted and castle nuts*

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.

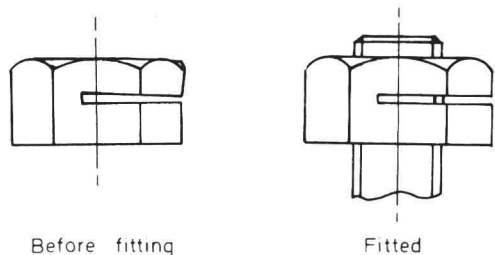


Figure 1.32 *Split nut*

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).

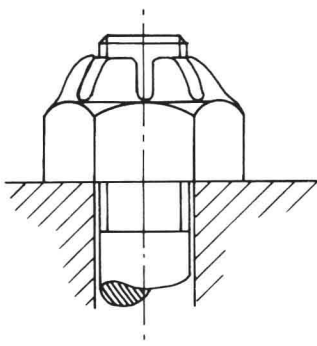


Figure 1.33 Spring lock nut (compression stop nut)

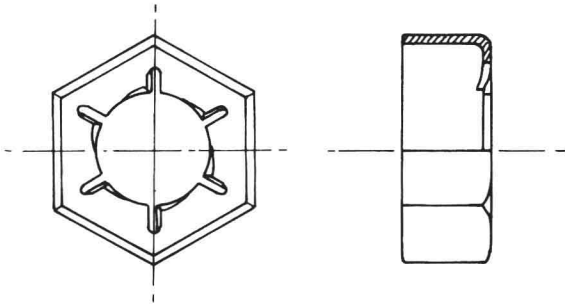


Figure 1.34 Stamped spring nut

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.

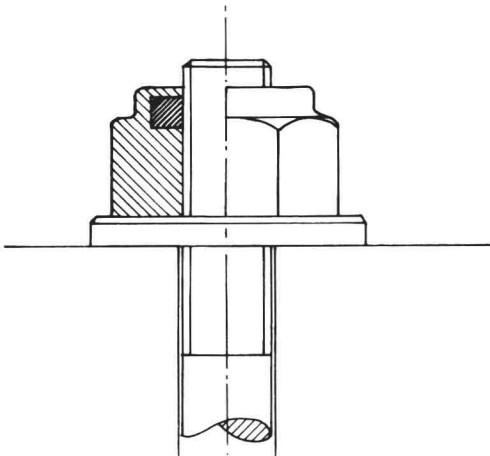


Figure 1.35 Elastic stop nut (Nyloc nut)

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.

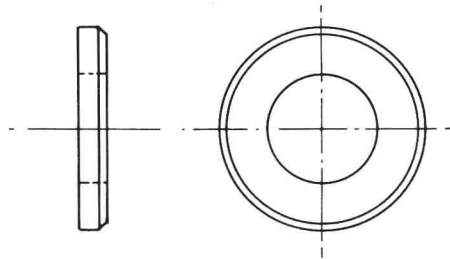


Figure 1.36 Plain washer (flat washer)

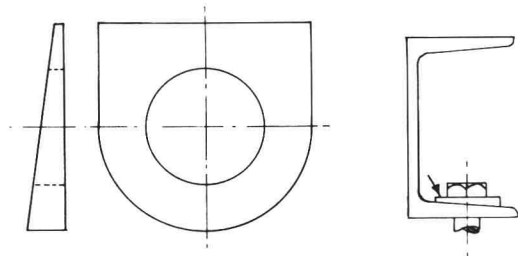


Figure 1.37 Taper washer and application

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.

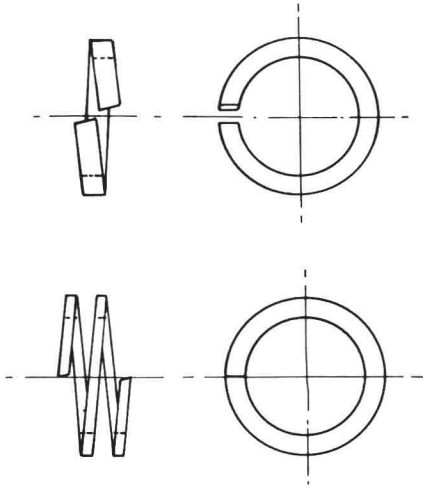


Figure 1.38 Helical spring lock washer and two-coil spring lock washer

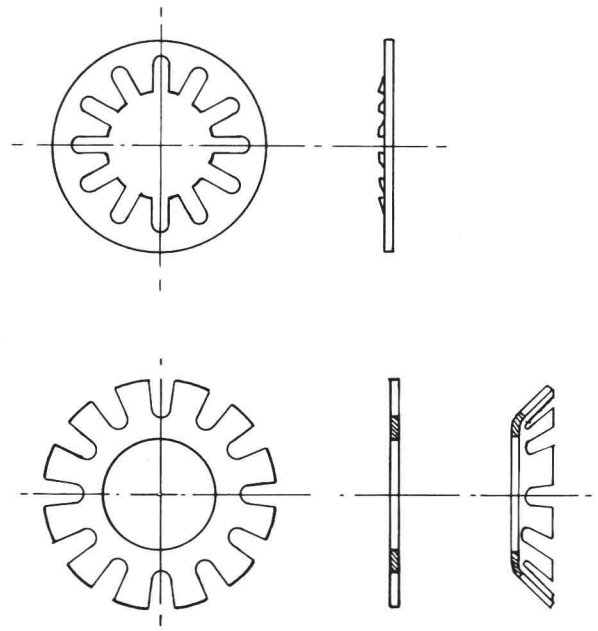


Figure 1.39 Internally serrated lock washer (tooth lock washer) and externally serrated lock washer, flat and for countersunk hole

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.

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.

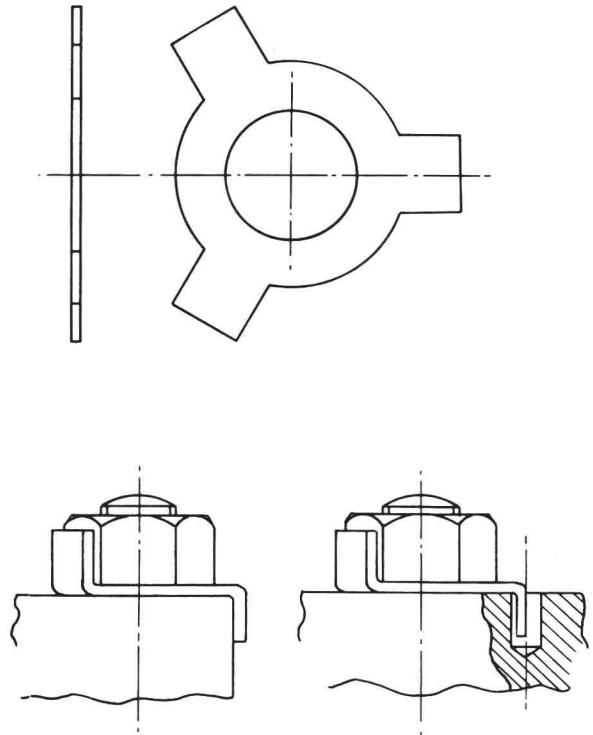


Figure 1.40 Tab washer and application

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.

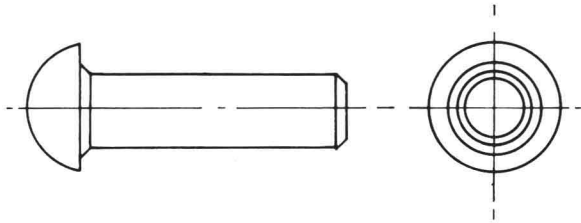


Figure 1.41 Rivet

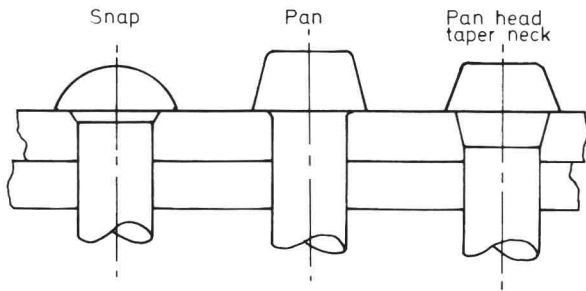


Figure 1.42 Types of rivet

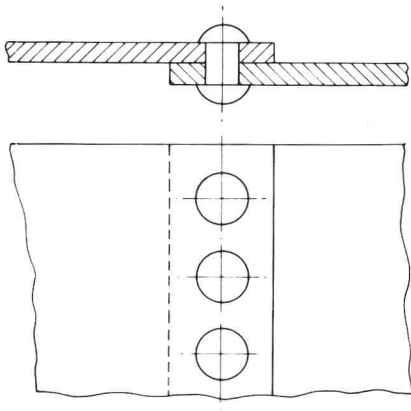


Figure 1.43 Riveted lap joint

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.

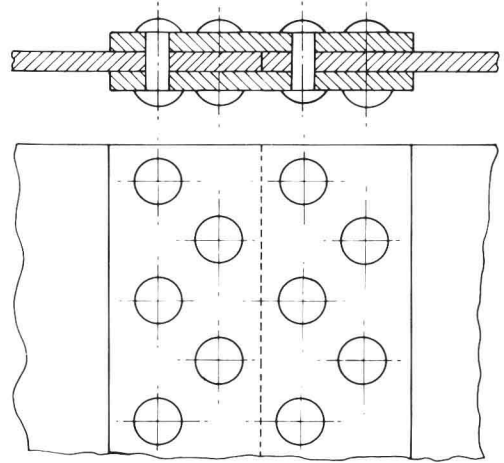


Figure 1.44 Double riveted butt joint with two straps

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.

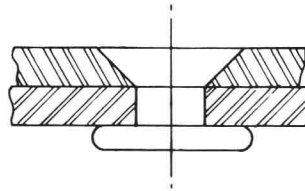


Figure 1.45 Flush rivet

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.

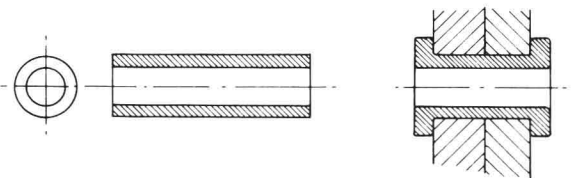


Figure 1.46 Tubular rivet

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.

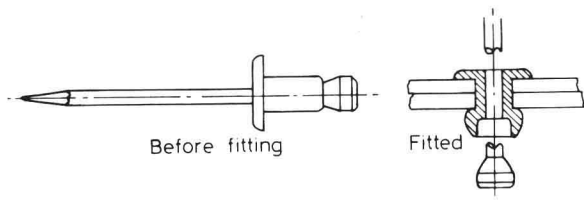


Figure 1.47 Pop rivet

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.

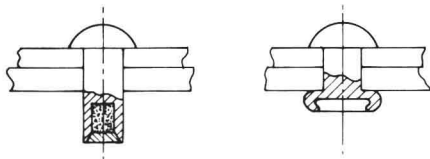


Figure 1.48 Explosive rivet

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.

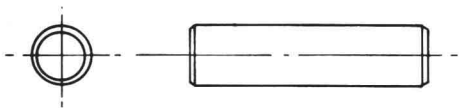


Figure 1.49 Plain pin

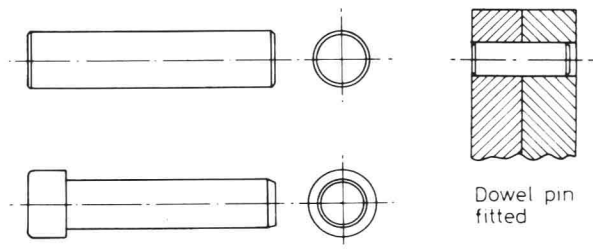


Figure 1.50 Dowel pin

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).

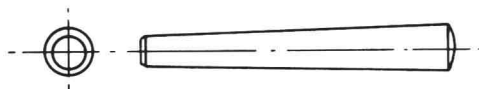


Figure 1.51 Taper pin

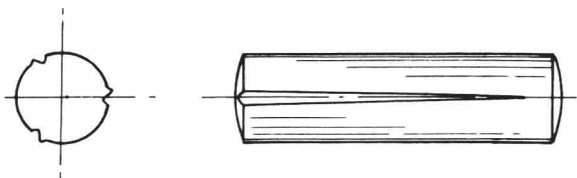


Figure 1.52 Grooved pin

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.

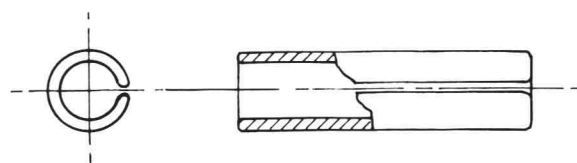


Figure 1.53 Roll pin

Roll pin A roll pin is a spring steel tube, with a longitudinal slit, which is driven into a slightly larger 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.