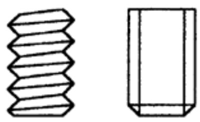
METAL FABRICATION – MECHANICAL

Machine Screws

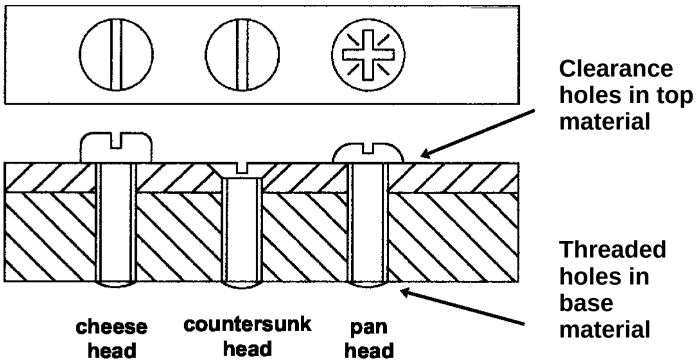
Machine screws have a parallel thread and need a threaded hole to screw into. They come in a wide variety of materials and sizes and are used for semi-permanent joining.

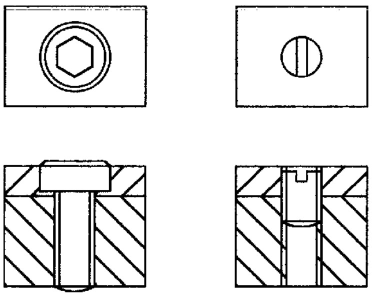
Instead of drawing a complicated thread each time, a simple schematic drawing can be used.



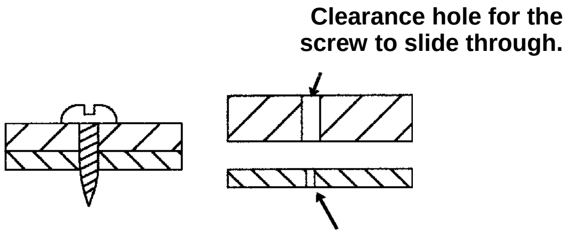
Schematic drawing of a thread cheese head countersunk head pan head

Common machine screws





socket head **Grub screw (no head)**

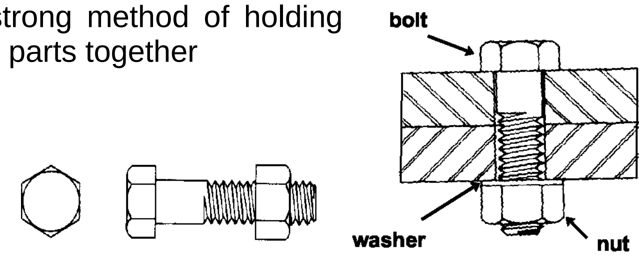


Self-tapping screw **Pilot hole for the screw to bite into.**

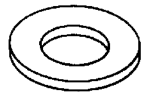
The self-tapping screw is used on thin sheet metal. It cuts its own thread into the pilot hole. This can speed up the manufacturing process, cheaply.

Nut and bolt

A strong method of holding two parts together

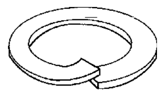


Washers are used to spread the load over a slightly larger area and to prevent damage to the material as the nut is tightened.

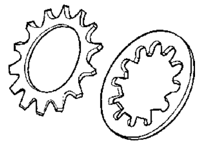


Some washers are used to prevent vibration from loosening the nut.

Spring washer



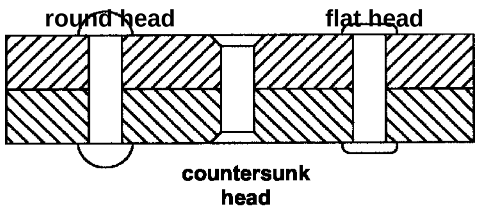
Serrated washers

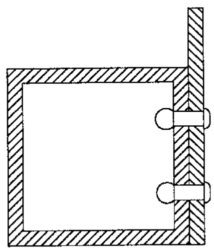


Rivets

Rivets are a quick and easy method of permanently joining materials. However, they can be drilled out if the materials need to be separated later.

Rivets are made from iron, aluminium and brass and come in many lengths and diameters.





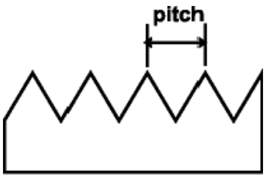
Pop rivets are used when it impossible to get to both sides of the joint.

Pop rivets holding a sheet of metal to square tubing.

METAL FABRICATION – THREADING

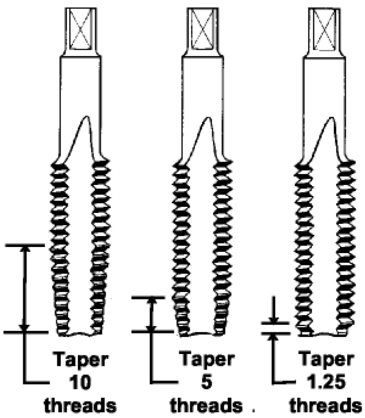
Metal can be held together by screws screwed into threaded holes, and also threaded rod can be screwed into a threaded hole. Cutting an internal thread into the side of a hole is known as **Tapping** the hole, because the tools used to cut the thread are called **Taps.** Cutting an external thread on the outside of a length of rod is known as **Threading** and the tool used to cut the thread is known as a **Die.**

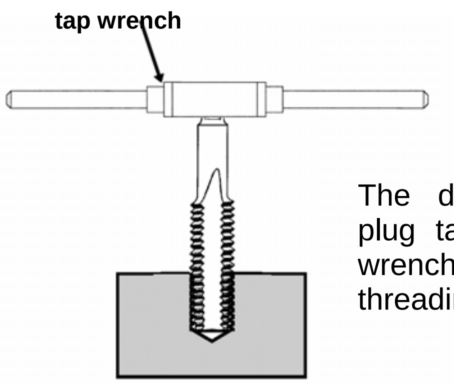
Before a hole can be threaded, the size of the thread must be decided. In school, threads from 2mm diameter to 12mm diameter in 1mm jumps can be cut. A tap and die have the size stamped on them, e.g. M8 x 1.25. The 'M' stands for Metric. The 1.25 is the distance in millimetres, between the tip of each thread tooth, this is called the **Pitch.**



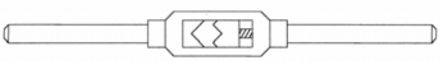
When the size of the thread has been decided the hole has to be drilled to the correct **tapping size**. This is a hole that is smaller in diameter than the thread diameter (nominal size), so that the thread can be cut into its side. There are printed tables to tell you which size drill bit to use.

Taps are normally sold in sets of three. If a **blind hole** (a hole that does not go all the way through a piece of material) is to be tapped all three taps are used in turn, starting with the taper tap. The taper allows the tap to start with its tip firmly in the hole and the thread to be cut gradually deeper into the side, with each turn.



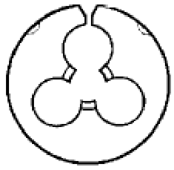


The diagram shows a plug tap, held in a tap wrench, completing the threading of a blind hole.

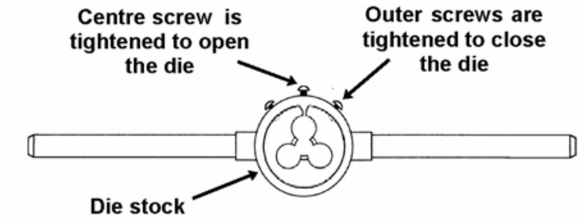


Tap wrench viewed from above

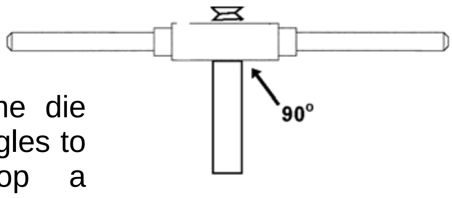
An external thread on a metal rod is cut by using a **die** held in a **die stock**. The die is adjustable so that threads that are slightly smaller or larger than the nominal size can be cut. This allows for a loose or tight fit between the external and internal threads.



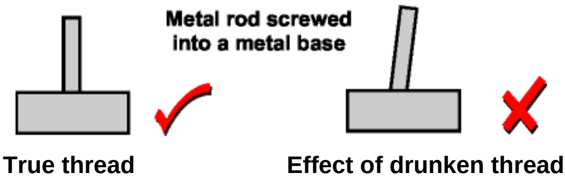
Adjustable split die



It is a good idea to cut the thread with the die split open as far as possible and then test the fitting of the external and internal threads. If the threads are too tight then close the die a little, re-cut and test again. Repeat the process until the thread runs smoothly.



Make sure that the die stock is at right angles to the rod to stop a 'drunken' thread being cut.



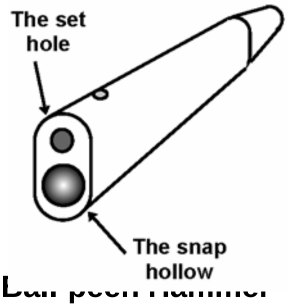
KEY WORDS **Tap: Die: Blind hole: Tap wrench: Tapping size: Die stock: Drunken thread:**

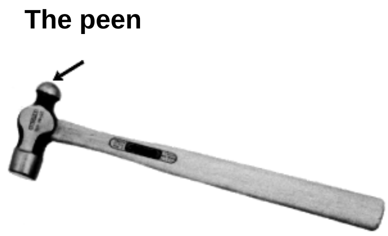
1. What does the term 'tapping a hole' mean?
2. Where would you find M10x1.5 printed and what does each part stand for?
3. How can you measure the 'pitch' of a thread?
4. What is a 'tapping size' hole?
5. Illustrate a 'blind' hole.
6. What are the three taps that make up a set? How can you tell the difference between them?
7. Make a neat sketch of a Tap Wrench.
8. What is used to cut an external thread?
9. Explain the use of the three screws found on the Die Stock.
10. With the help of diagrams explain the effect of a drunken thread. How can this be avoided?

The tools required for riveting with solid rivets are:

Rivet Set & Snap

The hole in this tool is used to set up the joint by making sure that the pieces of metal and the head of the rivet are pressed firmly together. The hollow is used to form the shank of the rivet into a second 'head'.



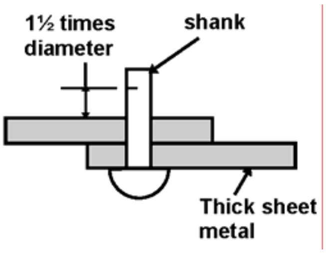


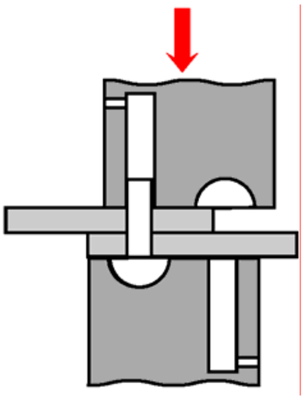
Ball-peen hammer

The peen (also spelt 'pein') is used to roughly form the second head of the rivet.

Stage 1

Place the rivet in the joint and mark a line 1½ times the diameter of the shank from the metal to be joined. Remove the rivet and cut the shank to the line.



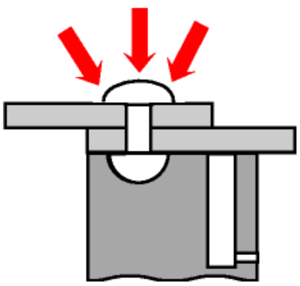


Stage 2

Use two 'Set & Snaps'. Hold the lower one in the vice and tap the upper one with the normal face of the hammer. Make sure that there are no gaps in the joint.

Stage 3

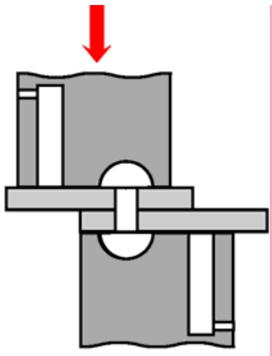
Hammer the rivet shank into a rough mushroom shape using the Ball Peen part of the hammer head.



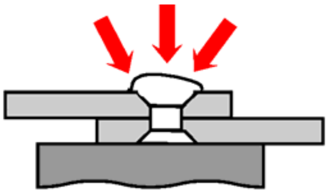
KEY WORDS Set: Snap: Ball Peen: Pop rivet

Stage 4

Use the snap part of the upper snap & set to smooth and shape the second head by hitting it with the hammer. The rivet is now complete.

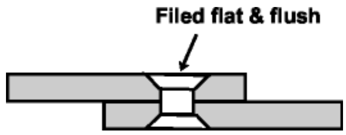


Countersink Riveting



Stage 1 and 2 are the same as for a round head rivet, except the head of the countersunk rivet should be placed on a solid flat surface. The shank is hammered by the peen until it fills the countersunk hole.

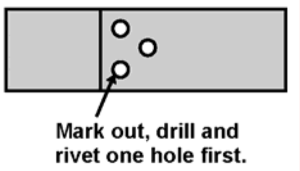
The rough mushroom shape is then filed until the head is flat and flush with the surface of the metal sheet.



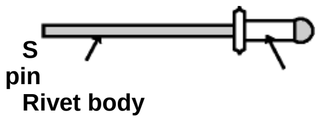
Lining up rivet holes

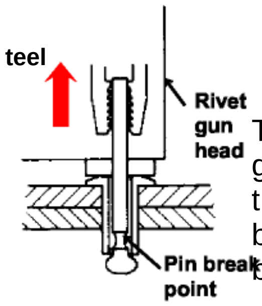
When more than one rivet is used it is important that all the holes in one metal sheet line up with the holes in the sheet to be joined to it.

To make sure the holes line up, mark out and drill one pair of holes only. Rivet them together and then line up the metal sheets. The remaining holes can then be marked out and drilled.



Pop Riveting





The pin is pulled by jaws in the gun. The pin head squeezes into the tube of the rivet. The pin then breaks away and leaves the head behind.

1. Illustrate how the ball peen of a hammer may be used, when riveting.
2. What is the purpose of the Rivet Set & Snap?
3. How can you make sure that all the holes line up when using more than one rivet to make a joint?
4. How is the second head formed on a pop rivet?

SOFT SOLDERING

Soft soldering is a permanent method of joining most metals such as steel, tinplate, copper and brass.

Note: Aluminium cannot be soft soldered.

Solder is an alloy of **Lead** and **Tin**. The amounts of lead and tin vary, depending on the melting point and flow rate that is required e.g.

Purpose	Alloy	Melting Point	Hardness
Electrical work	More tin than lead	183^oC	Soft and slightly flexible
Plumbing (e.g. Joining copper pipes)	More lead than tin	Up to 250^oC	Hard and rigid

Electrical soldering

Soft solder in wire form is used with an electric soldering iron to solder components to an electric wire or to a Printed Circuit Board (PCB)

1. Check that the parts to be joined together and the soldering iron tip are clean. (use emery cloth to clean them)

2. Hold the parts to be joined together in place.

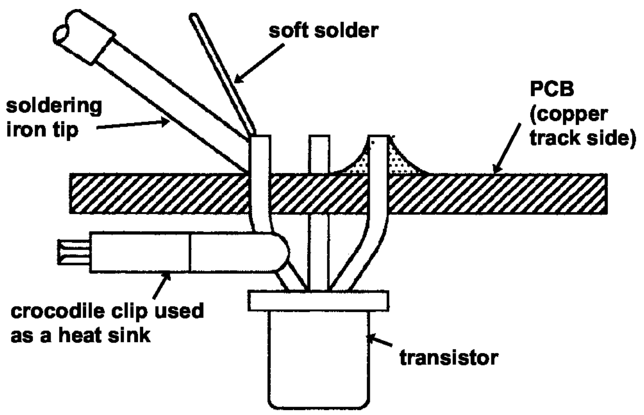
3. Attach a heat sink (a device placed between the joint and the component that will soak up the heat and stop the component from getting too hot) e.g. a crocodile clip.

4. Check that the soldering iron is hot enough by melting a little solder onto the tip.

5. Hold the hot tip of the soldering iron against the joint for approximately 3 seconds, to preheat the joint.

6. Touch both the joint and the tip of the soldering iron with the solder wire, then remove it and the soldering iron the moment the end of the wire melts. (approximately 1 second).

7. Wait until the surface of the joint sets and goes dull before you remove the heat sink.



Sheet metal soldering

To make a strong joint between sheets of metal a **Flux** must be applied before soldering.

Flux

A flux is a chemical that does two essential jobs to help create a strong joint.

1. When the metal is heated up for soldering it stops an oxide layer forming (tarnish). Molten solder must be able to soak into the surfaces of the metal sheets being joined, to make a strong joint.

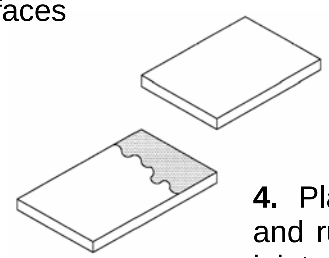
2. It breaks down the surface tension of the molten solder to allow it to flow in between the metal sheets.

There are two types of flux for soft soldering:

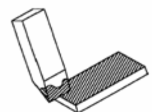
Acid - a clear liquid that when applied will clean the surface of the sheet metal by dissolving any oxide layer or grease, before soldering starts. This flux must be washed away with water as soon as the joint has been soldered, otherwise it will weaken the joint.

Passive - a brown resin that looks like grease. This does not dissolve any old oxide layers, so surfaces need to be cleaned with emery cloth first. It does not need to be washed away at the end.

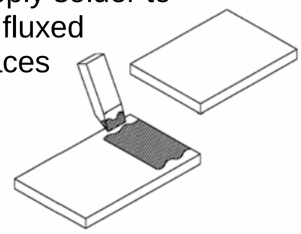
1. Apply flux to both surfaces



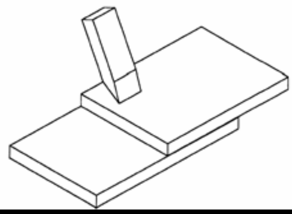
2. Melt solder onto the hot tip (tinning the iron)



3. Apply solder to both fluxed surfaces



4. Place the parts together and rub the hot iron over the joint to re-melt the solder. Then let it cool and set.



KEY WORDS Heat sink: PCB: Flux:

1. Which metals is soft solder made from?
2. What is the melting point range of soft solder?
3. Why must the parts being soldered be clean?
4. Why do you need to use a heat sink when soldering electrical components and how does it work?
5. Why do you need to wait until the surface of the joint goes dull before moving it?
6. What are the two main reasons for using a flux?
7. Explain the difference between the two types of flux.
8. Illustrate the stages of soldering two sheets of metal together.

A. Create an illustrated instruction sheet for soft soldering a resistor onto a PCB.

HARD SOLDERING

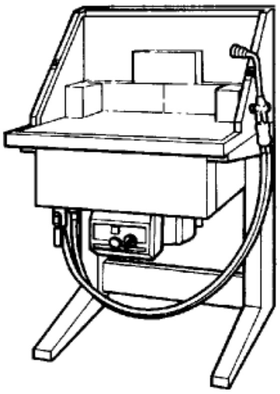
Hard soldering is a similar technique to soft soldering except that far higher temperatures are used and far stronger joints are made.

Brazing

The 'solder', called **spelter**, is brass, (copper and zinc). It melts at 870°C.

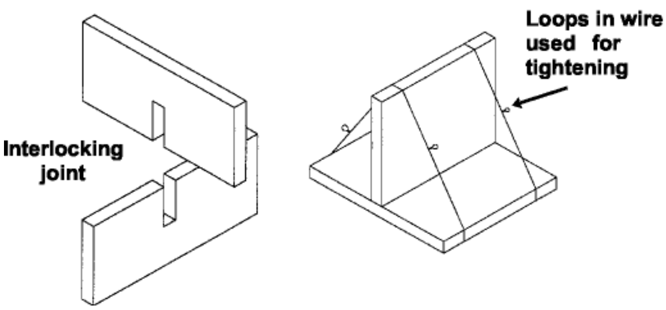
The heat is supplied by a **gas blowtorch** attached to a **brazing hearth**, or by an oxyacetylene torch (see welding).

Brazing is normally used for joining steel together.



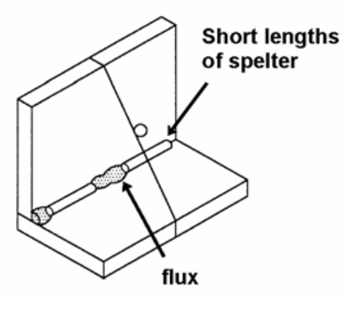
Brazing Hearth

Joints need to be held together with wire or interlocked because the flame is powerful and can move loose sections of steel.



Brazing Flux

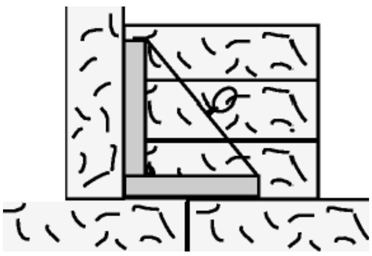
For brazing, the flux is a powder made from the salt **Borax**. It needs to be mixed with water to form a paste so that it is not blown away by the flame.



The flux, in paste form, should be spread over the joint.

Short lengths of spelter can be cut and laid along the joint at intervals, on top of the flux.

Place the joint on the brazing hearth surrounded by fire bricks. The bricks are important because they reflect the heat and flame so that the joint can get to a high enough temperature to melt the spelter.

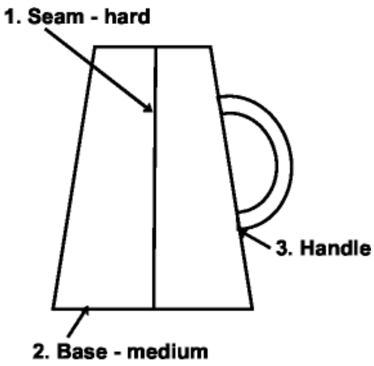


Silver soldering

Silver solder is an alloy of copper, zinc and silver. The melting point is lower than spelter and ranges from 625°C to 800°C. The lowest melting point solder has the most silver added. Silver solder is used for joining brass, copper, nickel and pure silver. There are three grades of silver solder:

Easy flow - melts between 625°C and 690°C
Medium - melts between 690°C and 725°C
Hard - melts between 725°C and 800°C

The grade system is useful when a number of joints are close together and cannot be soldered in one go.

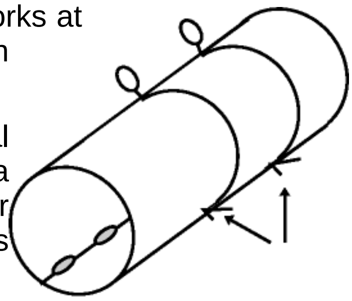


Tankard
(made from nickel-silver)

If one type of solder only was used, then the solder put on the seam would re-melt and the joint would spring open when the base was being heated for joining. When the three grades are used, as shown in the diagram, each joint melts at a lower temperature than the last, so earlier joints stay set.

Flux used for silver soldering is also called **Easy-Flow**. It works at a lower temperature than brazing flux

The diagram shows a typical set-up for silver soldering a seam. Small pieces of solder are laid at regular intervals on the fluxed joint.



Wires to stop the cylinder from opening up when heated

KEY WORDS Spelter: Brazing: Easy flow:

1. What is 'spelter' and what is it used for?
2. Why do joints need to be held in place for hard soldering?
3. Why do the wires used for holding joints together have a loop put in them?
4. What type of flux is used when brazing and in what form is it applied?
5. Make an annotated sketch of the set-up of a joint ready for brazing on the brazing hearth.
6. What are the constituents of silver solder?
7. What are the three grades of silver solder and what are their melting point ranges?
8. Illustrate how the three grades of silver solder are used and explain why they are necessary.

WELDING METAL

Welding is a permanent method of joining two pieces of the same metal together by melting them both and letting them fuse together as they cool down and become solid again.

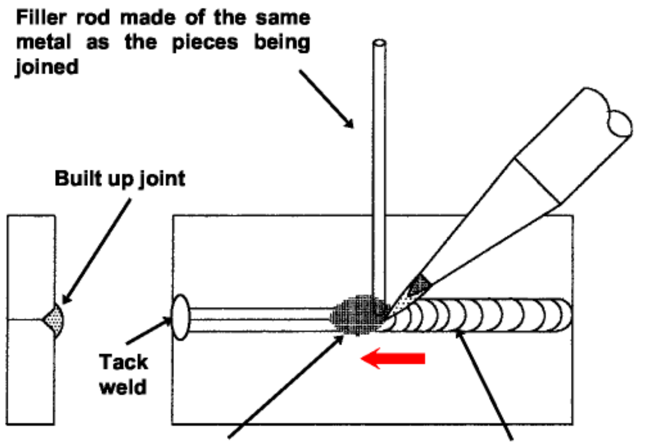
Welding is normally used for steel and aluminium. There are three main types of welding:

Gas - using an oxyacetylene gas flame
Arc - using an electric spark
Resistance - using an electric current.

Gas Welding

This is the most common form of welding used in schools. Heat is supplied by an oxyacetylene torch that burns acetylene gas mixed with pure oxygen, to a temperature of 3,500°C.

Cross section Pool of molten metal Completed weld

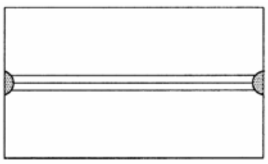


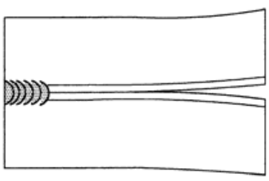
(showing evidence of circular flame movement)

The filler rod is used to build up the joint and to replace the metal that has evaporated. The flame is moved forward in a series of small circular movements to heat a wider area than the diameter of the flame.

Flux is not normally used for welding steel, but is essential in large quantities, when welding aluminium.

Before welding along a joint, both ends need a small weld to hold the ends together. This is called a **tack weld**.

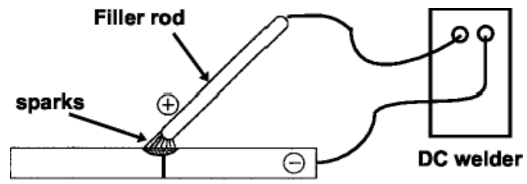




If the ends are not tacked the pieces will warp in the heat and the joint will separate.

Arc Welding

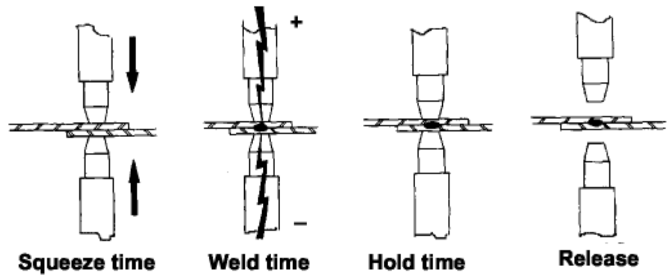
The joint metal and the filler rod are both connected to an electric circuit. When the rod is held a short distance away from the joint, sparks fly between the two. The temperature of the sparks is so high that both the end of the rod and the joint metal melt and form a weld pool.



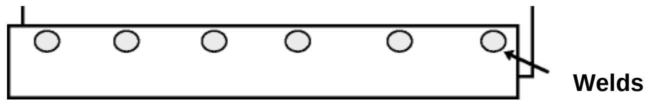
Resistance Welding

Also known as '**spot welding**', this is suitable for thin sheet steel. It relies upon passing a current through the sheets of metal and heating them up where they touch each other, because this is where there is most resistance. (Electrical resistance produces heat).

Two electrodes squeeze the sheets together and then pass an electric current through for approximately 2 seconds, then hold until the weld sets (2 or 3 seconds).



Resistance welding does not produce a continuous weld. The result is like a line of tack welds 30 to 40 mm apart.



KEY WORDS Oxyacetylene: Tack welding: Arc: Resistance:

1. What are the three main types of welding?
2. Which gases are burnt to produce a welding flame and at what temperature do they burn at?
3. Why is filler rod used?
4. The flame is moved in a series of small circles, why is this?
5. Illustrate why a joint should be tack welded at both ends first.
6. Explain, with illustration, how arc welding works.
7. What provides the heat when spot welding?
8. Illustrate the spot welding cycle and the resulting joint.