Gas Welding

1. Introduction to welding:

The term welding is used to cover a wide range of bonding techniques. Hence Welding is a process of joining two metals parts with the help of heat or pressure or by some other means. The cost of welding is less as compared to other processes and forms a strong joint. Main purpose of welding is to join two pieces. Broadly, welding process can be classified into the following two groups:

a. Fusion Welding : For this temperature of the parent metal is raised up to melting point, then filler metal is used as a supplement for molten pool. A homogeneous mixture is formed at the joint then it is allowed to cool, solidify to form a weld This welding process is called fusion welding.

b. Forge Welding : This is the oldest of all the methods of welding processes. This process is used in the blacksmith shop. In it, the work piece are placed in a forge or other appropriate furnace and heated within the area to be joined, to the condition of plasticity on the surface. The parts are then quickly super imposed and worked into a complete union by hand or power hammering or by pressing together. The quality of the weld depends to a great extent upon the amount of heating. If the ends to be joined are not heated enough, they will not stick together; if overheated, the metal becomes burned, brittle and has spongy appearance. Now a days this method is not used.

For obtaining good results it is desired that the surfaces should be cleaned and free from foreign materials. The cleaning can be done by wire brushing machining or sand blasting. Impurities if present tend to make joint weaker as the weld portion is filled with gas and slag inclusions and metal becomes brittle therefore cohesion between the metals is poor. These processes are discussed in detail, in the following pages.

2. Applications of Welding:

Welding is an outstanding tool for manufacturing, construction and maintenance purposes. Some of its applications are listed below.

i. **Replacing Casting** : A wide variety of machine parts, which were manufactured by casting, are now being designed and fabricated as weldments. Machinery base, frames and brackets are made up of standard steel shapes and rolled plates and joined by any one of the welding processes.

ii. **Replacing riveting and bolting**: Welding is gaining importance day by day in the joining of metals as it gives speedy and sound joints and at the same time, the joined structure is lighter in weight.

iii. **Welding as only means of fabrication:** Welding is the only solution in cases where the equipment is to be constructed of steel plates, the thickness of which is greater than those joined by means of riveting.

iv. **Welding in manufacturing, construction and maintenance**: Welding has been successfully adopted by the aeronautical industry in construction and maintenance of airplane engines and accessories, boiler shells, pressure vessels and tanks, bridges, manufacture of cranes, building construction, cutting tools and dies, earth moving equipment, furnaces and boilers.

3. Fusion Welding:

In the fusion welding process, two parts of metal joined by application of heat. Two parts to be jointed are held in position, heated, with or without addition of filler metal, until they melt and allowed to cool and solidify. Heat can be produced by several ways. In some cases, pressure is also applied along with heat to have better welded joint. For additional strength, some time filler material is also used to supply the molten metal to the joint. Filler metal normally have the composition of the parent metal.

Surface to jointed become plastic or even molten because of the heat(at about *2450°C)*, In the *Fusion welding permanent molecular bonds between sections is produced.*
Flux prevent contact of the metal and joint, from the air, absorption of large amounts of harmful Oxygen and Nitrogen. Some of the Fusin Welding processes are:

i) Electric Arc Welding
ii) Gas welding
iii) Thermit Welding
iv) Resistance Welding (Spot welding, Projection and Seam Welding)
v) TIG Welding
vi) MIG Welding
vii) CO_2 – MIG Welding
viii) Plasma arc welding

4. Gas welding

Gas welding is a process in which the required heat to melt the surface is supplied by a high temperature flame obtained by a mixture of two gases. The gases are mixed in proper proportions in a welding blowpipe (torch). For controlling the welding flame, there are two regulators on the torch by which the quantity of either gas can be regulated. Usually the mixture of oxygen and acetylene is used for gas welding purposes. In gas welding the two surfaces to be welded are properly cleaned, prepared and placed near each other. The metal in the joint area is brought to melting temperate by application of heat from the flame and then weld is completed by supplying additional metal as the filler metal obtained from a filler rod.

4.1. *Oxyacetylene welding*

In *Oxyacetylene* gas welding the heat to melt the metal parts being welded is produced by the combination of oxygen and an inflammable ***gas*** such as acetylene, propane, butane, etc. Acetylene is the most commonly used gas; propane and butane are cheaper but less efficient. A flame temperature is about 3200^{o}C, melts the metals which fuse together to form a strong joint. Extra metal may be supplied from a filler **rod** and a flux may be used to prevent oxidation of welded area. The gas is supplied from high pressure cylinder fitted with special regulators which reduce the pressure to 0.13 - 0. 5 bar. Gauges indicate the pressures before and after the regulators. A welding torch mixes the gases which issue from a copper nozzle designed to suit the weld size. The process produces harmful radiation and goggles must be worn. The process is suitable for steel plate up to 25mm thick, but is mostly used for plate about 2 mm thick.

4.2. Principle of oxy-Acetylene welding

In *Oxyacetylene* gas welding the heat to melt the metal parts being welded is produced by the combination of oxygen and an inflammable ***gas*** such as acetylene, propane, butane, etc. Acetylene is the most commonly used gas; propane and butane are cheaper but less efficient. A flame temperature of about 3250^{o}C melts the metals which fuse together parts to form a strong joint. Extra metal may be supplied from a filler **rod** and a flux may be used to prevent oxidation. The gas is supplied from high pressure cylinder fitted with special regulators which reduce the pressure to 0.13 - 0. 5 bar. Gauges indicate the pressures before and after the regulators. A torch mixes the gases which issue from a copper nozzle designed to suit the weld size. The process produces harmful radiation and goggles must be worn. The process is suitable for steel plate up to 25mm thick, but is mostly used for plate about 2 mm thick.

A very hot flame is produced by burning of the gases coming out of the torch. Edges to be welded are heated up to melting temperature. Then filler metal is added to complete the welding. This molten metal solidify on cooling forms a welded joint.

4.3. Other Gas welding Processes:

i. **Oxy - hydrogen Welding:** In this process, hydrogen is used in place of acetylene and the temperature of flame is very low (1980^{o}C). It is therefore, best suited for welding thin sheets, low melting alloys and for brazing work.

ii. **Air – acetylene Welding :** this is generally used for lead welding, low temperature brazing and soldering operations.

iii. **Pressure Gas Welding :** In it no filler metal is required. In this process, coalescence is produced simultaneously over the entire area of abutting surface by heating with multiple oxy – acetylene flames and then pressure applied.

5. Description operating procedures of oxy-Acetylene welding.

For forming the welded joint, a filler metal is added in the form of welding rod when the surfaces to be welded are just near melting stage. For obtaining satisfactory bond and for floating out impurities, generally some flux is also used. In some cases the joints are formed simply by fusing the parts to be joined, without the application of filler metal. There are two types of gas welding processes. **Low Pressure Gas Welding** and **High Pressure Gas Welding**. The term '**Low Pressure**' and '**High Pressure**' refers to the form in which the acetylene is supplied. In the low pressure process the acetylene is generated in a low pressure generator by the action of water on Calcium carbide and is supplied to the blow pipe at low pressure from a gas holder built in the generator. The gas has to be purified. The generator must be cleaned and recharged periodically. In case of high pressure gas welding acetylene is supplied as dissolved acetylene in a steel cylinder. In both the cases Oxygen is supplied in a steel cylinder. Procedure involved in the both processes as follows:

5.1 Low Pressure Gas Welding Procedure:

1. Check up back pressure value and ensure that it is filled with water and is in perfect operating condition.
2. Check up the acetylene generator
3. Connect the acetylene hose to back pressure valve and oxygen hose to oxygen regulator. Acetylene cylinder is maroon in colour and Oxygen cylinder is Black in colour.
4. Connect the blowpipe to the hoses, ensuring that the passages are correctly connected.
5. Open the acetylene valves on the back pressure valve and the blowpipe, followed by the acetylene in a short while.
6. Ensure that the acetylene has started flowing out of the nozzle by lighting the out coming gas and observing the colour of the flame. A bluish white flame will show a mixture of air and acetylene and a white flame will indicate only acetylene. The latter condition is required to be obtained.
7. Now adjust the required oxygen pressure in the regulator and open the oxygen valve partly.
8. Open the acetylene valve full.
9. Go on increasing the supply of oxygen until and unless the desired flame is obtained. This flame is further adjusted by slightly regulating the supply of acetylene also.
10. When the work is to be stopped, temporarily for some time, close the acetylene valve on the blowpipe followed by closing the oxygen valve at the regulator.
11. When the work is to be stopped for a fairly long period close the acetylene inlet valve at the back pressure valve also.
12. When the operation is to be finally stopped, after completing the work, turn off the cylinder valve to cut off the supply of oxygen totally, and open oxygen cock of the blowpipe to release the pressure of oxygen from the regulator.

5.2 High Pressure Welding Procedure:

1. Arrange one cylinder of oxygen and one cylinder of acetylene, in proper position
2. Blow out both cylinder valves, before fitting the regulators, so that all dirt and unwanted material, if any, is cleaned out.

3. This operation of blowing off and reclosing of valves should be done in quick succession.
4. The regulators and valve fitting should be thoroughly checked to ensure that no dirt, oil or grease, etc., is left over them.
5. Fit the acetylene regulator and pressure gauges on the acetylene cylinder.
6. Fit the oxygen regulator and pressure gauges on the oxygen cylinder.
7. Ensure a gas tight fitting of regulators.
8. Connect the oxygen and acetylene hoses to the respective cylinders and the blowpipe to these hoses.
9. Release the pressure on the regulator diaphragm spring by opening the outlet valves on regulators.
10. With the help of the key, open the cylinder valves gradually to avoid an abrupt strain on the pressure gauge.
11. Check that there is no leakage of gases from the regulators.
12. If a new hose is being used, ensure a clear passage through it by blowing off the gas.
13. Ensure that the nozzle fitted in the blowpipe is of correct size as prescribed.
14. Ends of the hoses should be properly secured to the regulators with suitable clips
15. To start the work, turn on the acetylene first and allow it to pass through the nozzle. Then turn on the oxygen slightly and allow the mixture of these gases to pass through the nozzle so that the hoses and blowpipe are fully cleared of the air.
16. Open the acetylene torch valve slightly and light it with spark lighter. Increase the flow of acetylene till a turbulence is created and sooty smoke is eliminated.
17. Adjust the flame by regulating the supply of oxygen in the correct required proportion. The flame thus obtained will be in the following order: Carburising, neutral and oxidizing
18. For stopping the work turn off the acetylene first by the blow pipe control valve and then the oxygen. Close the cylinder valves. Open the blow pipe vales one at a time to release the pressure in the hose. Finally unscrew the pressure regulating screw on the oxygen and acetylene regulators. In this way no gas is left in regulators and hose pipe,
19. Welding methods followed are as per methods mentioned in article 9 above.

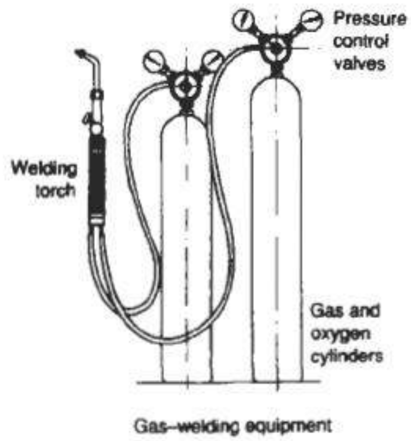


Fig. 5: Gas Welding Equipment

6. Oxy – acetylene Cutting

It is a chemical process in which the metal, at the portion where it is to be cut, is actually made to oxidize under the action of the flame. All ferrous metal can be cut by means of an oxy – acetylene flame. The metal to be cut is heated up to red heat by means of the flame and then a sharp stream of oxygen is made to impinge on to the hot surface to form iron oxide and thus remove the iron oxide.

It is important to note that only those materials can be flame cut whose combustion temperature is below their melting point, as otherwise the material would melt away before oxidation and clean cut edge could not be obtained. Therefore non – ferrous metals cannot normally be flame cut. Steel with a carbon content of up to 1.8% and steel casting can be cut readily with a cutting torch.

7. Gas Welding Techniques: There are three methods of oxyacetylene welding known as:

i. Backhand (Left Ward) Welding
ii. Fore Hand (Right Ward) Welding
iii. Vertical Welding

7.1 Backhand (Left Ward) Welding : In this welding the tip is held at 60 to 70 degree to the plate and the filler rod is inclined at 30 to 40 degrees in opposite direction. In this method the plate edges are heated immediately after the molten metal. The torch tip and filler rod are moved slowly in the direction towards left. Backhand type welding is very suitable for pipe and plate welding because of combined economy and weld quality obtained by its application. Backhand type welding is normally used for welding metals of thickness up to 5mm. The Technique is illustrated in the following figure:

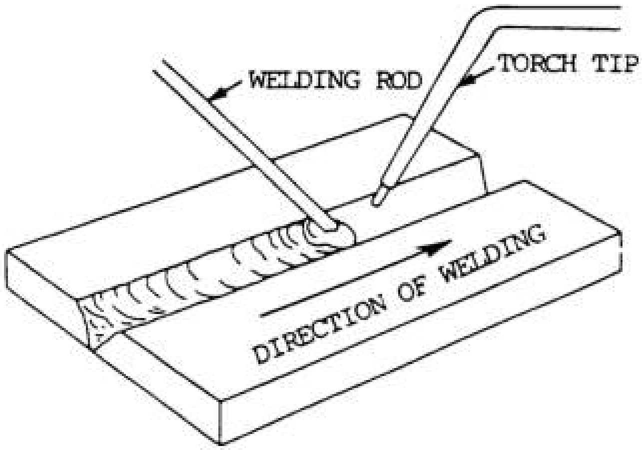


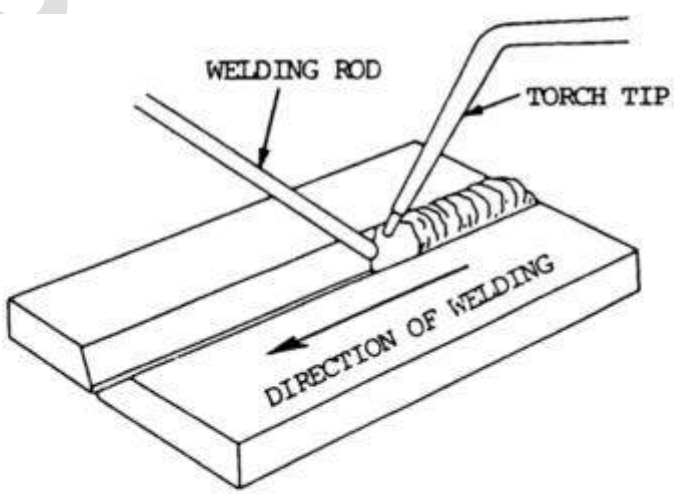
Figure 7.1: Backhand or leftward type oxyacetylene welding

7.2 Fore Hand (Right Ward) Welding:

In the Right Ward Welding, the nozzle tip is kept at 40 to 50 degrees to the job to be welded. The rod held at 30 to 40 degrees, follows in the direction of travel. The filler rod is moved in the straight line and the blowpipe is moved backwards and forwards in a series of loops as the weld proceeds. Forehand method is used for heavier sections only. The inclination of welding rod in either case is about $30^o – 40^o$; and that of torch is $40^o – 50^o$ in case of forehand type welding.

Rightward (forehand) method has the following advantages over the other methods:

i) As the flame is always directed towards the solidified weld, it results in annealing effect and better mechanical properties are obtained.
ii) Smaller V angles are permissible due to better accessibility of the flame.
iii) Very little agitation is produced because torch moves in a straight line.
iv) Less filler metal is required.
v) Gas consumption, welding time and cost are low,
vi) Operator gets a better vision of weld zone.



Figurer 7.2: Forehand or right ward type oxyacetylene welding

7.3 Vertical Welding:

This is the method by which metal of any thickness can be welded. In case the thickness of the sheet is lesser then welding from one side is sufficient but for thicker sheets welding should be done from both the sides. Preparation of edges to be welded is not required. In this case welding starts from bottom and moves till top and the welding blow pipe follows the filler rod. The inclination of the blow pipe is 30 to 80 degrees and that of filler rod is 30 degrees.

8. Equipments for Oxyacetylene Welding:

The Equipments used for Oxyacetylene Welding consists of the following:

i) Oxygen Cylinder
ii) Acetylene Cylinder
iii) Pressure gauges
iv) Valves
v) Hoses and fittings
vi) Welding torch or blowpipe
vii) Welding Tip
viii) Pressure regulators
ix) Spark lighters
x) Goggles
xi) Welding rods
xii) fluxes
xiii) Apron
xiv) Gloves
xv) Steel wire brush

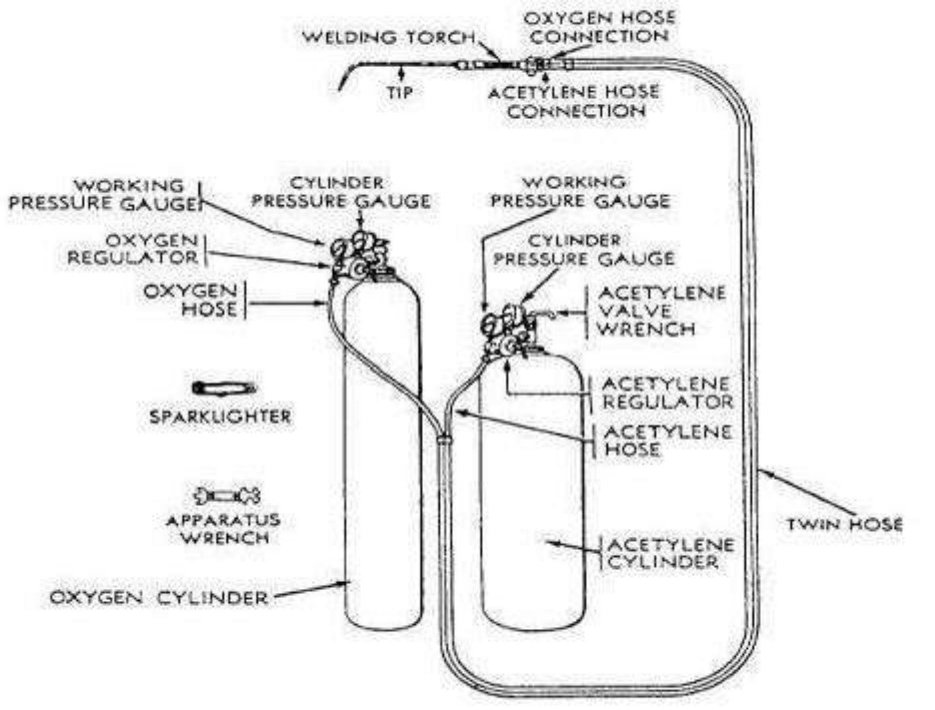


Figure 8: Oxyacetylene welding out fit

8.1 **Oxygen Cylinder**: These are metallic container used to store and supply oxygen at desired pressure. For safety purpose oxygen cylinders are filled at a pressure of 125 to 150 kg/cm^2 at 21^{o}C and cylinder capacity is ranges 2.25 to 6.23 m^3. Oxygen cylinders weigh approximately 66 Kgs. When full and about 58 Kgs. When empty. The oxygen cylinder is provided with a right hand threaded valve. The cylinder is painted black. The cylinders are usually provided with fragile disc and fusible plug to relieve the cylinder of its contents if subjected to over heating or excessive pressure. Melting point of fusible plug is 122^{o}C, the oxygen cylinder is as shown in fig. 8.1

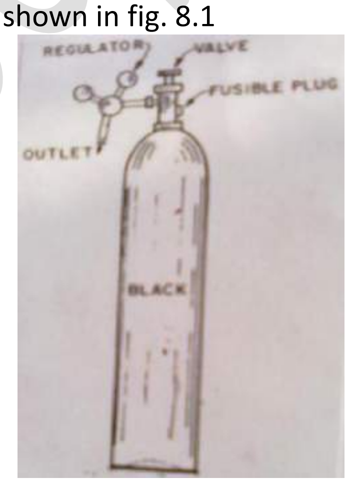


Figure 8.1: Oxygen Cylinder

8.2 Acetylene Cylinder: These are metallic container used to store and supply acetylene at desired pressure, have left hand threads for accommodating pressure regulators and are painted maroon to distinguish from oxygen cylinder. To compress free acetylene to a pressure more than one atmosphere is not safe. Therefore acetylene cylinders contain porous spongy material such as charcoal, asbestos, balsa wood, silicon etc. the main purpose of porous material is to fill the space within the cylinder. The cylinder is partly filled with acetone, which has a capacity to dissolve 25 times its own volume of acetylene for every atmosphere of pressure applied. Acetylene is compressed into cylinder so as to dissolve in acetone that is why it is also termed as dissolved acetylene (D. A. Cylinder). These cylinders are usually filled to pressure of 18 to 20 Kg/cm^2. The acetylene cylinder capacity is about 10 m^3 and is shown in fig. 8.2

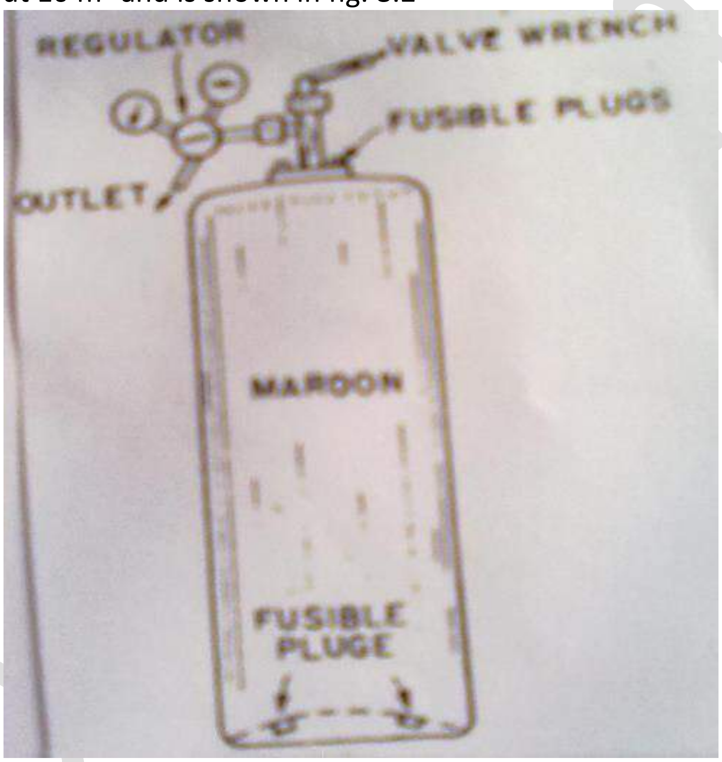


Figure 8.2: Acetylene Cylinder

8.3 Torch :

Torch is a device used to mix acetylene and oxygen in the correct proportion and mixture flows to the tip of the torch. There are two types of torches

i. Low pressure or Injector Torch
ii. Medium pressure or Equal pressure torches

Figure 8.3: Welding Torch

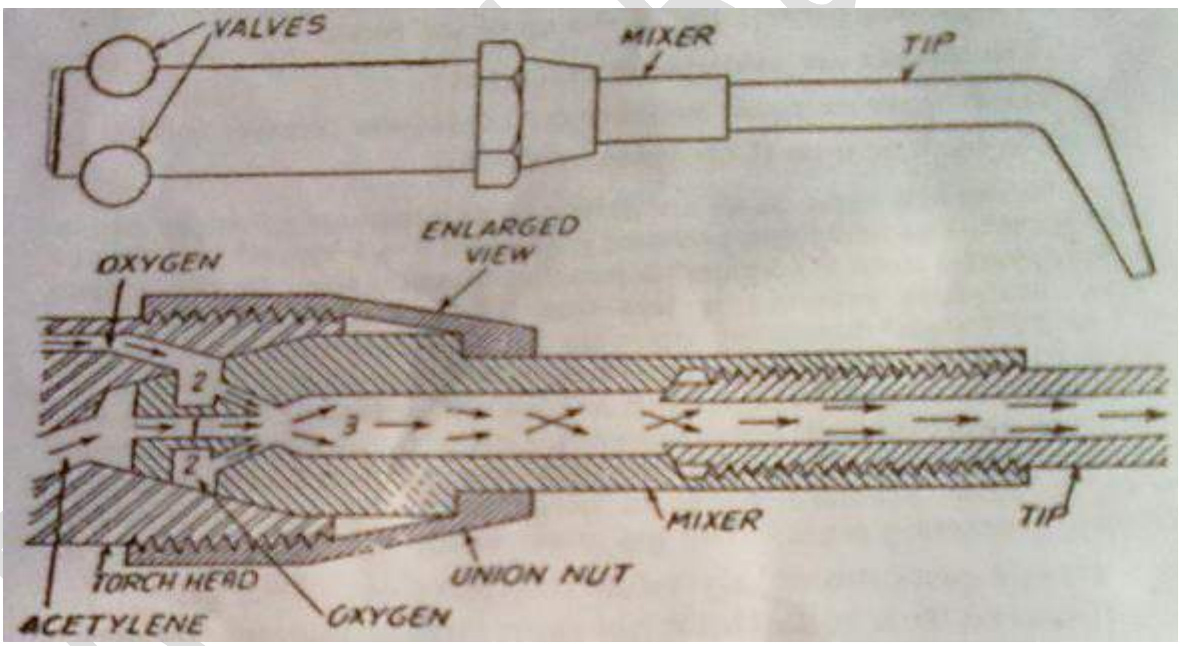


Figure 8.3(c): Cut View of Welding Torch

Torch tips: For different types of jobs, different tips are used. The size of the tip is specified by the outlet hole diameter. More than one hole is also provided in the tips. The tip is screwed or fitted on the front end of the torch.

The tip of the torch is generally made of copper alloys having high thermal conductivity and ability to withstand high temperature. All blowpipes are fitted with a **flashback arrestor** to avoid explosion due to backfire travelling back up to cylinder.

8.4 **Goggles**: Gas flames produce high intensity light and heat rays, which are harmful to naked eyes. To protect the eyes from these rays, goggles are used. Goggles also protect the eyes from flying sparks.

8.5 **Lighter**: For starting the flame, the spark should be given by a lighter. Match sticks should not be used, as there is risk of burning hand.

8.6 **Fire Extinguishers**: Fire Extinguishers are used to prevent the fire that may break out by chance. Sand filled buckets and closed cylinders are kept ready to meet such accidents.

9. **Description and safe operating procedures of oxy-acetylene regulators**

Description: Regulator : Regulator is used to control the flow of gases from high pressure cylinder. A simple type of regulator is shown in the following fig: 9

Fig 9: Regulator

9.1 **Single stage Pressure Regulator:** Its mechanism consists of floating a valve, a diaphragm and balancing springs, all enclosed in a suitable housing.

9.2 **Double stage Pressure Regulator:** It has two independent diaphragms and valve assemblies which make operation extremely efficient. This ensures much more constant delivery pressure

The function of pressure regulator is to reduce the pressure from the cylinder and to maintain it at constant value regardless of the pressure variations at the source. It is also used to adjust the pressure of gas to torch. Changes in the pressure can be made simply by turning the handle at the regulator. Generally there are two types of pressure regulators namely single stage and double stage.

In single stage type, the pressure of the gases from the source pressure is directly reduced to the working pressure of the torch in one stage.

In two stage type Pressure Regulators, the reduction of pressure is accomplished in two stages.

10. Types of Oxy-Acetylene flames and their uses:

This is the phenomenon produced at the surface of the nozzle tip where two gases meet and undergo combustion with the evolution of heat and some light. The chemical reaction for complete combustion of oxygen and acetylene is as follows:

$2C_2H_2$	+	$5O_2$	→	$4CO_2$	+	$2H_2O$
Acetylene		oxygen		carbon dioxide		water vapour

Thus for complete combustion, ration of oxygen to acetylene is $2\frac{1}{2}$ to 1.

The temperature of flame depends upon the relative proportion of the two gases.

For the different purposes, different ratios of gases give the best results. There are following different types of flames used:

a) **Neutral Flame**: For normal welding most suitable flame is Neutral Flame. It is obtained by having equal proportions of oxygen and acetylene. It is neither oxidizing nor carburizing. In this complete combustion take place in the flame. The highest temperature is developed at the inner cone of the flame.
Applications: Neutral Flame is used for welding of all metals like ferrous metals, copper and Aluminium alloys except brass.

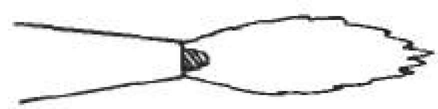


Figure 10(a): Neutral Flame

b) **Carburising Flame**: In this flame quantity of acetylene more. The inner zone of is surrounded by a secondary luminous zone which extends into the outer envelope.
Applications: Carburising flame is very suitable for welding steel as the rate of welding is faster by this flame than with neutral flame. It is also used for depositing satellite.

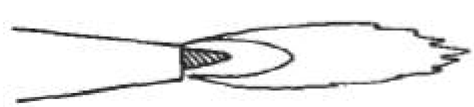


Figure 10(b): Carburising Flame

c) **Oxidizing Flame**: In this flame quantity of acetylene less. The inner cone of is very much shortened and pointed and also luminosity is reduced.

Applications: Oxidizing Flame is used mainly for welding brasses and bronzes due to formation of a tenuous oxide film over the molten metal which prevents vaporization of zinc.. It is also very suitable for cutting operations due to very high temperatures.

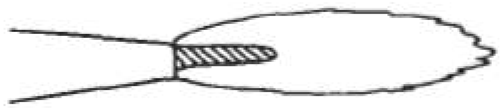


Figure 10(c) : Oxidising Flame

Note: To bring the blowpipe (torch) into operation, the acetylene is first turned on and ignited. The oxygen valve is then gradually opened and regulated to produce the required flame.

11. Safety Precautions in Gas Welding: The following safety precautions must be observed while working in the welding shop:

- **i.** Handle gas cylinders with care.
- **ii.** The adjusting screw on the regulator must be fully released befor opening a cylinder valve.
- **iii.** Always use goggles while working.
- **iv.** Ensure proper ventilation in the shop.
- **v.** Never use match sticks for lighting a torch.
- **vi.** Acetylene cylinder should be kept up right position.
- **vii.** Never lubricate the regulator valve with oil or grease to avoid explosion.
- **viii.** Do not use pliers for removing torch tips.
- **ix.** Do not open acetylene cylinder near spark or fire
- **x.** Always use protective caps over the valves.
- **xi.** Find the location of fire extinguisher before starting welding.

12. Filler rods and fluxes for brazing

(a) Filler rods: The rod which provide additional metal in completing the welding is known as filler rod. Theoretically the composition and physical properties of the filler rods should match with the base metal very closely. Therefore, proper filler (welding) rods should be chosen for welding various ferrous and non ferrous metals. The materials of welding rod should flow smoothly, freely and unite readily with the base metal to produce sound and clean weld. The welding rods coated with flux should always be stored in air conditioned rooms, otherwise the property of the flux will be deteriorated due to moisture leakage in them.

(b) Fluxes: The chemicals which deoxidize the metal surface and provide inert atmosphere around the molten metal are known as fluxes. In welding of certain metals, the fusion of the weld does not take place very readily, particularly when the oxides of the base metal have a higher melting point than the metal itself. Thus these oxides remains on the surface and get entrapped in the solidifying metal instead of flowing from the weld zone thus resulting in weal weld. This oxide can be removed from the weld location by use of fluxes which react chemically with the oxides of most metals and form fusible slag at welding temperature. Slag floats on the top of the molten metal puddle and do not interfere with the deposition of filler metals. Besides it also protects the molten puddle from atmospheric oxygen and thus avoid formation of oxide on the metal surface. It may be noted that the absorption of oxygen into the molten weld pool will result in a poor weld.

13. Functions of Flux:

a) Flux help to clean and protect the surfaces of the base metal.
b) Protects the molten puddle from atmospheric oxygen thus prevent oxide formation in the welded area
c) Floats the impurities on the top of the molten metal puddle in the form of slag.

Fluxes are available in several forms, such as liquid, powder, paste, gas or thick solution or in form of coating on the welding rod. Gas fluxes are used to form inert atmosphere around the joint to be welded.

Use of flux is very essential for welding cast iron, brass, bronze, stainless steel, aluminium etc. But not with carbon steel. In case of carbon steel, the oxide formed is lighter than the parent metal and therefore removes itself by floating to the surface of the weld in the form of a scale.

Common fluxes:

Cast iron flux : is reddish in colour and consists of iron oxide, carbonate and bicarbonate of soda.

Brazing flux : White flux for steel brazing, consist of chlorides. Borax – fresh and chemically pure is reliable flux for brazing, copper welding and silver soldering. Different types of Brazing fluxes are

i. Steel brazing
ii. Cast iron brazing
iii. Cast steel brazing
iv. Copper – aluminium brazing flux

Aluminium flux : A white powdery propriety substance is used for both cast and rolled aluminium. The flux is usually mixed into a paste by adding water, then to the joints to be welded and to the filler rod. The flux must be kept sealed to retain its good qualities. Fresh flux is recommended for good results. Aluminium flux consists of Sodium chloride, Sodium sulphate, Lithium chloride, Potassium chloride and ryotite chloride.

Other fluxes used extensively for welding are Silver soldering flux, monel metal flux, stainless steel flux, Stellite flux and white metal flux.
A general rule to follow the use of flux is to choose the flux specifically made for the parent metal marketed as propriety item.

14. Functions of Flux Coatings: There are following functions of flux coatings on an electrode:

a. It produces a gas which provides a shield around the arc to prevent oxidation of molten metal.
b. Form slags by mixing with molten metal impurities thus refines the metal.
c. It helps in stabilizing the arc
d. Controls depth of penetration
e. Controls the cooling rate.
f. Increases deposition of molten metal
g. Some time is also adds alloy elements to the joint

15. Electrodes Specifications: An Electrode is specified by six digits with letter M as prefix:

M : It shows that it is suitable for metal arc welding**.**

First Digit: First Digit is from 1 to 8, indicates the type of coating on the electrode.

Second Digit: Second Digit is from 1 to 6, It denotes the welding position for which electrode is manufactured.

Third Digit: Third Digit is from 0 to 7, denotes the current to be used for electrode**.**

Fourth Digit: Fourth Digit is from 1 to 8, represents the tensile strength of welded joint.

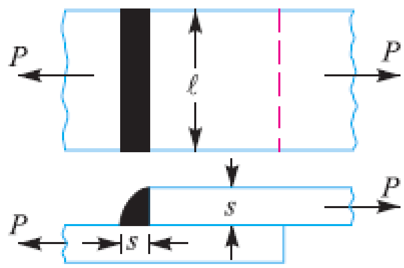
Fifth Digit: Fifth Digit is from 1 to 5, denotes specific elongation in percentage of the metal deposited.

Sixth Digit: Sixth Digit is from 1 to 5, denotes the impact strength of the joint.

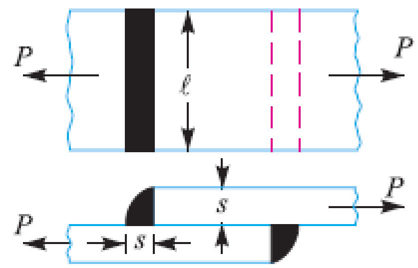
16. **Comparison Between AC and DC Welding:**

Sl. No.	AC Welding	DC Welding
1.	Equipments are simpler and cheaper	Equipments are complicated and costlier
2.	AC transfer is easy to maintain due to absence of moving parts	DC Generator has many moving parts due which its maintenance is costlier
3.	Due to low voltage drop, it can be operated at large distance from power source	In DC voltage drop is high. Therefore shorter cables are used.
4.	Less problem of arc blow	More problem of arc blow
5.	Only coated electrodes are used	Both coated and bare electrodes are used
6.	It can be used for welding ferrous metal only	It can be used for welding almost all metals
7.	It can be used when AC current is available	In case of non availability of AC supply, an engine generator can be used.

17. **Nomenclature of Fillet and groove welds**



(*a*) Single transverse fillet weld.



(*b*) Double transverse fillet weld.

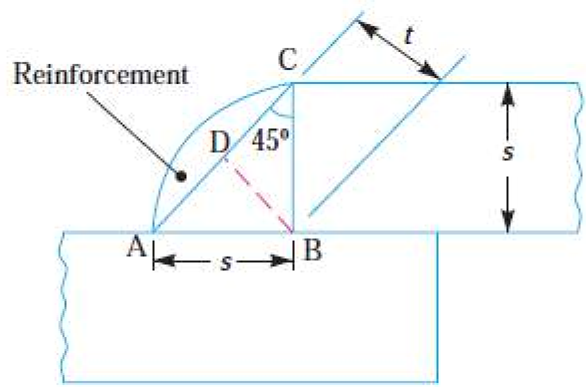


Figure 1 : Fillet Weld Joint Nomenclature

Here in the above figure, fillet weld joint is shown.

Here   *t* = Throat thickness (*BD*),

s = Leg or size of weld = Thickness of plate, and

l = Length of weld,

Weld portion above ADC is known as reinforcement.

18. Elements of a Welding Symbol

A welding symbol consists of the following eight elements:

1. Reference line,   **2.** Arrow,

3. Basic weld symbols,   **4.** Dimensions and other data,

5. Supplementary symbols,   **6.** Finish symbols,

7. Tail, and   **8.** Specification, process or other references.

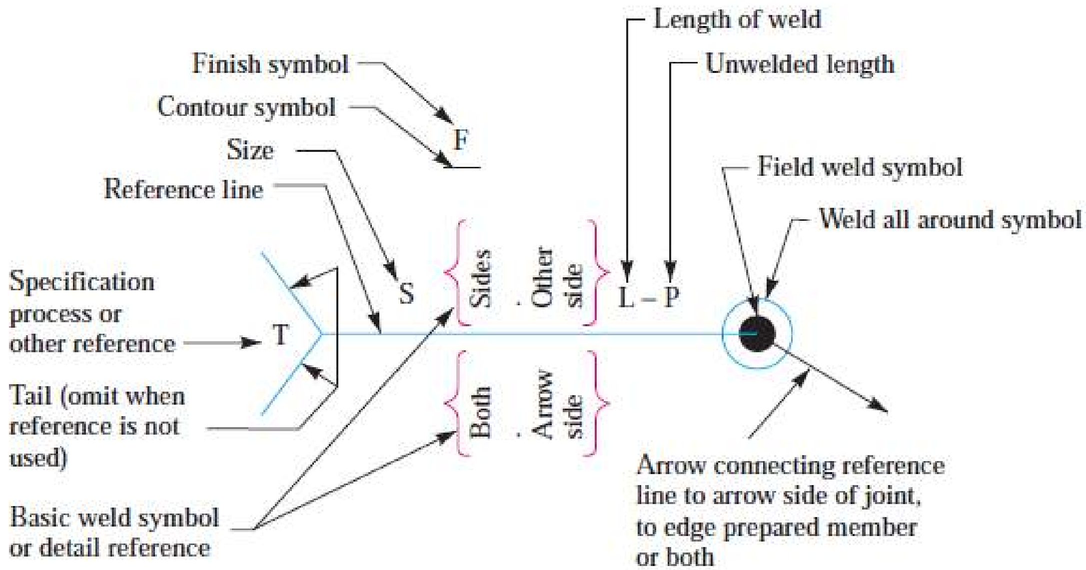
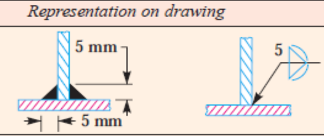
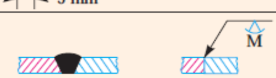
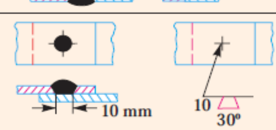
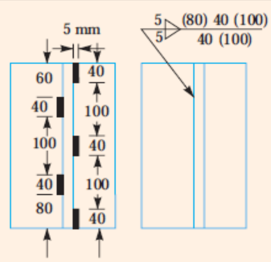


Fig. 2. Standard location of welding symbols.

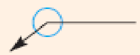
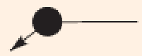
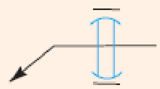
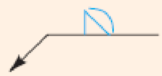
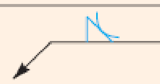
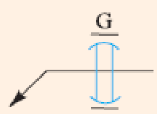
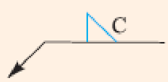
19. **Welding terms, symbols and definitions**

Some of the examples of welding symbols represented on drawing are shown in the following table.

Table 1. Representation of welding symbols.

S. No.	*Desired weld*	*Representation on drawing*
1.	Fillet-weld each side of Tee- convex contour	
2.	Single V-butt weld -machining finish	
3.	Double V- butt weld	
4.	Plug weld - 30° Groove-angle-flush contour	
5.	Staggered intermittent fillet welds	

20. **Some more weld Symbols**

S. No.	*Particulars*	*Drawing representation*	*Symbol*
1.	Weld all round		○
2.	Field weld		●
3.	Flush contour		—
4.	Convex contour		⌒
5.	Concave contour		◡
6.	Grinding finish		G
7.	Machining finish		M
8.	Chipping finish		C

21. Types of welding joints

Following two types of welded joints are important from the subject point of view:

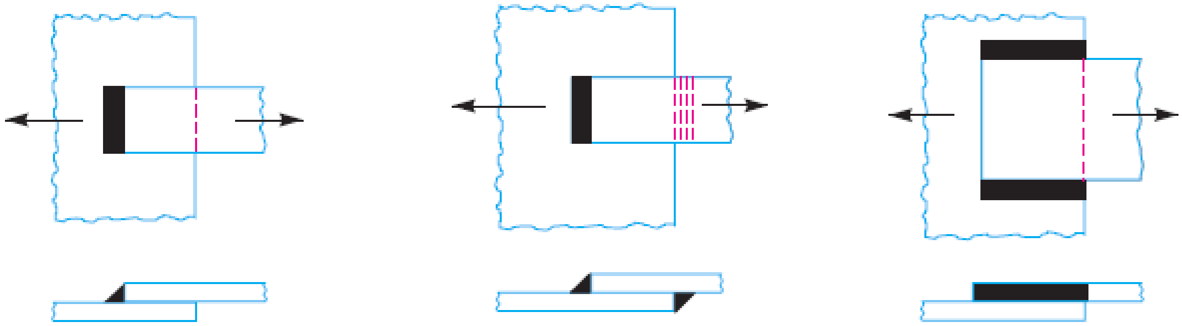
1. Lap joint or fillet joint, and **2.** Butt joint.

a) Lap Joint

The lap joint or the fillet joint is obtained by overlapping the plates and then welding the edges of the plates. The cross-section of the fillet is approximately triangular. The fillet joints may be

1. Single transverse fillet, **2.** Double transverse fillet, and **3.** Parallel fillet joints.

The fillet joints are shown in Fig. 3. A single transverse fillet joint has the isadvantage that the edge of the plate which is not welded can buckle or warp out of shape.

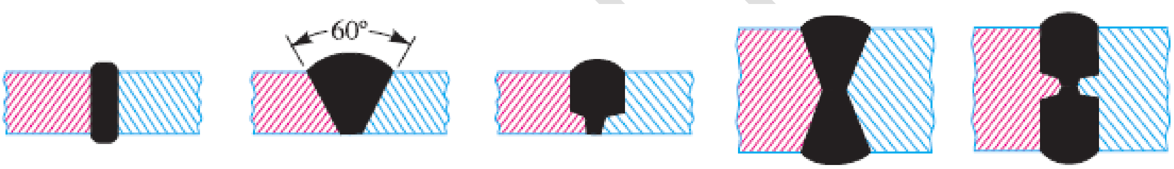


(a) Single transverse. (b) Double transverse. (c) Parallel fillet.

Fig. 3. Types of lap or fillet joints.

a) Butt Joint

The butt joint is obtained by placing the plates edge to edge as shown in Fig. 4. In butt welds, the plate edges do not require beveling if the thickness of plate is less than 5 m. On the other hand, if the plate thickness is 5 mm to 12.5 mm, the edges should be beveled to V or U-groove on both sides.



(a) Square butt joint. (b) Single V-butt joint. (c) Single U-butt joint. (d) Double V-butt joint. (e) Double U-butt joint.

Fig. 4. Types of butt joints.

The butt joints may be

1. Square butt joint,
2. Single V-butt joint
3. Single U-butt joint,
4. Double V-butt joint, and
5. Double U-butt joint.

The other type of welded joints are corner joint, edge joint and T-joint as shown in Fig. 5. (*a*) Corner joint. (*b*) Edge joint. (*c*) *T*-joint.

(a) Corner joint. (b) Edge joint. (c) T-joint.

Fig. 5. (*a*) Corner joint. (*b*) Edge joint. (*c*) *T*-joint.

22. **Special Cases of Fillet Welded Joints**

The following cases of fillet welded joints are important from the subject point of view.

1. ***Circular fillet weld subjected to torsion.*** Consider a circular rod connected to a rigid plate by a fillet weld as shown in Fig. 6.

Let d = Diameter of rod,
r = Radius of rod,
T = Torque acting on the rod,
s = Size (or leg) of weld,
t = Throat thickness,
J = Polar moment of inertia of the

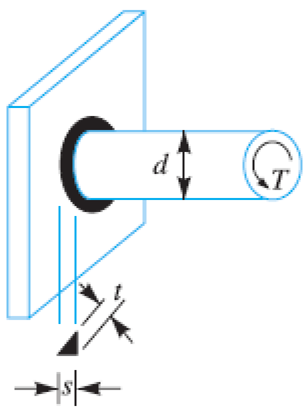


Figure 6 : *Circular fillet weld subjected to torsion*

2. ***Long fillet weld subjected to torsion.*** Consider a vertical plate attached to a horizontal plate by two identical fillet welds as shown in Fig. 11.

Let T = Torque acting on the vertical plate,
l = Length of weld,
s = Size (or leg) of weld,
t = Throat thickness, and
J = Polar moment of inertia of the weld section

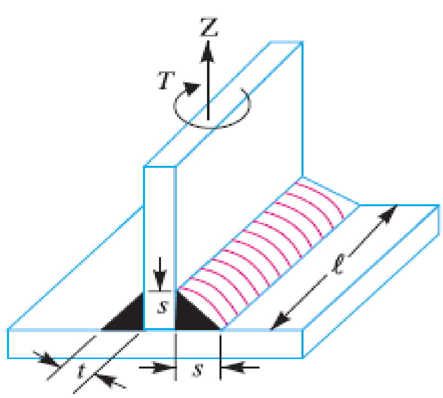


Fig. 7. Long fillet weld subjected to torsion

3. **Axially Loaded Unsymmetrical Welded Sections**

   Sometimes unsymmetrical sections such as angles, channels, *T*-sections etc., welded on the flange edges are loaded axially as shown in Fig. 20. In such cases, the lengths of weld should be proportioned in such a way that the sum of resisting moments of the welds about the gravity axis is zero. Consider an angle section as shown in Fig. 8.

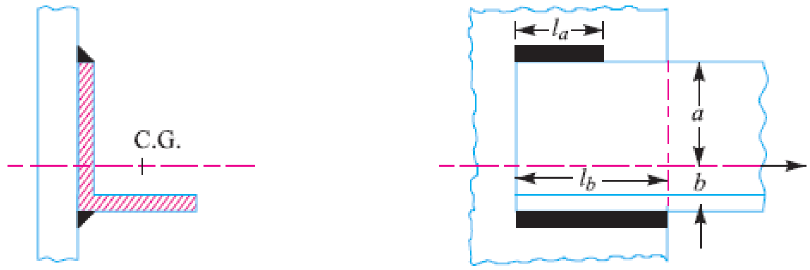


Fig. 8. Axially loaded unsymmetrical welded section

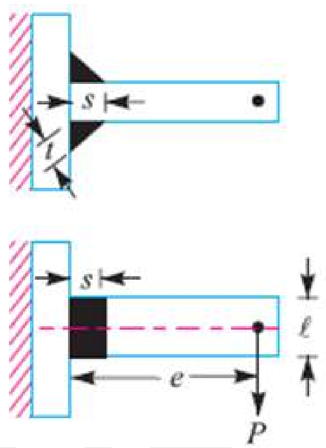
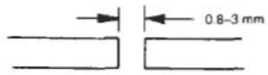
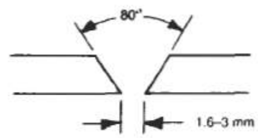
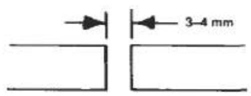
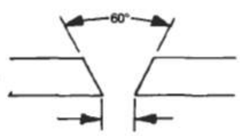
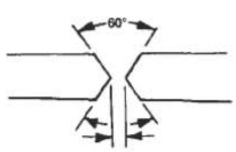


Fig. 9. Ecentrically loaded welded section

Gas welding – edge preparation, speed, and metal thickness

Welding rod diameter (mm)	Edge preparation	Method	Speed (mm min^{-1})	Metal thickness (mm)
1.5	(a) 	Leftward	127–152 100–127	0.8 1.5
1.5–3	(b) 	Leftward	100–127 90–100	2.5 3.0
3–4	(c) 	Leftward Rightward	75–90 60–75	4.0 4.8
3–4	(d) 	Rightward	50–60 35–40	6.0 8.0

Gas welding – edge preparation, speed, and metal thickness (*continued*)

Welding rod diameter (mm)	Edge preparation	Method	Speed (mm min^{-1})	Metal thickness (mm)
3–6.5	(e) 	Rightward	30–35 22–25	9.5 12.5
6.5	(f) 	Rightward	19–22 15–16 10–12	15.0 19.0 25.0

23. Welding defects causes and remedy

Following welding defects are found in metal fabricated work:

a) Dimensional defects:
These defects includes warpage, incorrect joints preparation, incorrect weld size and defective weld profile.

b) Structural Discontinuities:
These defects includes porosity, non metallic inclusions, incomplete fusion, under cutting, inadequate penetration, cracking and surface defects

c) Defective Properties:
These defects includes low tensile strength, low yield strength, low ductility, improper hardness, impact failure, incorrect composition and improper corrosion resistance.

24. Distortion and methods of control:

While welding, dimensions of the parts to joined get affected and changed, which comes under the category of distortion. To avoid the distortion following should be observed:
Use of templates
The workmanship and the type of skill required
Physical properties of the weld metal are equal or superior to those of the base metal.

25. Inspection & testing of welds:

It is very important that for satisfactory operation and working, welds are properly tested and inspected as their failure may result into hazards and great losses. The tests can be either of destructive or non destructive nature. Destructive type tests gives the quantitative information and is used in laboratories, whereas the Non destructive type tests gives the idea of quality of the weld. Destructive tests includes tensile, impact and bend tests. Non destructive tests include dye penetrants, magnetic crack detection, radio graphy, ultrasonic testing

a). **Non destructive tests**

i. **Visual Inspection:** This is suited when appearance is the criterion of checking the quality of weld. Templates are used to check the contour of the welds. It is also used to check welds not requiring high physical strength by inspecting cracks, inclusions, contour, etc. This is a subjective test.

ii. **Magnetic particle inspection: I**t is used to check surface flaws in materials which can be magnetized. The surface to be inspected is coated with a liquid (fine oil) solution containing very tiny coloured magnetic particles, and is then subjected to magnetic field created by either passing a current through it or by placing a powerful magnetic against it. Any lack of continunity at or near the surface on magnetization creates a local north south and magnetic pole, and attracts the metallic particles in the solution. On removal of magnetic field, the flaws are detected by concentrations of magnetic particles. Since best results are obtained when magnetic field flux lines are perpendicular to the crack, the object is tested by magnetizing twice, creating magnetic fields at 90^o to check all flaws.

ii. **Liquid penetration inspection:** This method detects surface flaws in all types of metals. Either a liquids dye penetrant or a fluorescent liquid is applied to the surface to be inspected, and allowed to penetrate for some time (3 to 10 minutes). The liquid is then removed with a cleaner and surface is dried. In former case a developer is then sprayed on the surface which brings out the colour it. The dye penetrant that has penetrated into the flaws. In latter case, a black light source is brought upto the surface so that where fluorescent liquid has penetrated will show up clearly.

iii. **Ultrasonic inspection:** It can detect surface as well as internal flaws. Ultrasonic waves are passed from a transmitter – receiver unit through the metal for 1 – 3 micro seconds and then the selected waves from back surface and flaw surfaces are received back and list ended by the same unit. This action is repeated 0.5 to 5 million times per second. Each wave is visually reperesented on an oscilloscope which is calibrated to show the distance between searching unit and any flaw. The ultrasonic search unit is traversed in a zig zag way to detect any flaws indicated by peaks on the oscilloscope screen.

i. **X – ray inspection:** X – rays can pass through any material and reproduce their image, clearly showing any internal flaws, on film reproduce (radiography), or on a fluorescent screen (fluoroscopy) or on cathode ray tube. X – ray inspection equipment can be portable one also by utilizing radioactive isotope and then field weld can be tested in as installed condition. X – ray inspection equipment selection is dependent on the kind of material to be tested and its thickness, geometry, and access.

ii. **Eddy current inspection**: in this method an a. c. coil is brought up close to the conductive metal to be tested so as to induce eddy currents in it. These eddy currents produce their own magnetic field which opposes the field of the a. c. coil, increasing the impedance of a.c. coil which can be measured and provides alarm to indicate presence of flaw in metal.

iii. **Testing welds for leakage by testing tanks / vessels hydraulically**: In this method CO_2 is pressurized and a soap and water solution is put on the outside of each weld. Leaks are indicated by the formation of bubbles.

In another method, the vessel is pressurized and a pressure gauge is installed to indicate fall in pressure in about 24 hours to indicate the degree of tightness of vessel and leaks.

26. Safety precautions:

following safety **precautions must be observed by every one** engaged in the welding shop to avoid any accident/incidence

(a) In general safety precautions:

i. Wear Lab Coat
ii. wear Gloves pair leather
iii. wear Apron leather
iv. Goggles pair welder
v. Use Tongs for holding hot parts
vi. Do not touch the electrode with bare hand when in use

b) Safety precautions for oxygen cylinders:

i) do not use oil or grease on any part as oil and grease catches fire when pure oxygen under pressure comes in contact with these
ii) leakage should be checked with soap solution
iii) oxygen cylinder should not be stored in an acetylene generator room or near the combustible gases.
iv) Cylinders stored in open should have their valves and safety devices well protected
v) Empty cylinder's valve should be closed and cap on.

C) Safety precautions for Acetylene cylinders:

i) Cylinder should be used and stored with valve end upwards
ii) Acetylene being highly inflammable, don't bring naked flame near the cylinder, valve regulator or hose pipe.
iii) Leakage be checked by smelling or soap water
iv) when opening an acetylene cylinder valve, turn key not more than one and half turns.
v) Acetylene cylinder valve key be kept on valve stem while cylinder is in use so that it could be quickly turned off in an emergency.
vi) in case a leak occur in an Acetylene cylinder, it should be taken out in the open air, keeping well away from fires or open lights.
vii) Never use acetylene from a cylinders without a suitable pressure reducing regulator attached to the cylinder valve.
Viii) Acetylene should never be used at pressure more than 1 kg / cm^2

27. Brazing Procedure and technique:

It is a process of joining two pieces of metals in which a non ferrous alloy is introduced in a liquid state between the pieces of metal to be joined and allowed to solidify. The melting point of the filler metal is above 420^o C, but lower than the melting temperature of parent metal. The filler metal is distributed between the surfaces by capillary action. During the process no forging action is present and also the parts do not melt. The bond is produced either by the formation of solid solution or inter metallic compounds of the parent metal and one of the metals in the filler.

Following metals and their alloys are used for brazing process:

iv. Copper and Copper alloys
v. Silver Alloys
vi. Aluminium alloys

28.1 Brazing Process:

The parts to be joined by brazing are cleaned of oil, dirt or oxide.
Clearance between mating surfaces are very small.
The flux is applied and the pieces are placed together with proper clearance for the filler material.
Parts are heated above 420^oC by any one of the methods namely dipping, furnace heating, torch heating or electric heating.

The molten metal is allowed to flow by capillary action into the space between the parts and then cooled slowly.

Borax or combination with other salts is commonly used as a flux.

Flux is necessary to remove oxide films, to protect the surface of the finished joint from oxidation and to reduce the surface tension of the filler and thereby assist its penetration.

29.2 Advantage of brazing Process:

i. Advantage of brazing Process is that dissimilar metal parts having thin sections can be joined easily.
ii. It is a quick process
iii. The brazed joint requires minimum finishing operations
iv. The brazed parts can be subsequently separated by melting only the joining metal
v. Materials of different thickness can be joined easily.
vi. Cast and wrought metals can be joined
vii. Non metals can be joined to metals, when the non metal is coated.
viii. Metallurgical properties of the base materials are not seriously disturbed.

Soldering :

The method of joining two or more pieces of metal by means of a fusible alloy or metal is called Soldering. The fusible alloy or metal is called Solder. It is applied in the molten state

Classification:

(1) Soft Soldering
(2) Hard Soldering

Soft Soldering : Soft Soldering is used in sheet metal work for joining parts that are not subjected to high temperature and high forces. Soft solder consists of tin and lead, with small amount of antimony, bismuth, silver etc.

Hard Soldering: Hard Soldering is used where strong joint is required than that is obtained by the soft solder. Silver alloyed with tin is used as a hard solder.

Soldering Iron: It is heating tool used for soldering small pieces. Irons are available with electric heating elements of 25 to 150 Watts and 240 volt single phase supply. Normally a 25 watt iron with a 5/32 inch diameter bit is satisfactory for electronic work and small metal works. The heating element is in the shank. The purpose of the bit is to carry heat from the shank down to the work. Bit is made of copper, which is good conductor of heat. The bit is coated with a layer of tin or solder to help conduct heat from the bit into the work.

Fig : Soldering Iron

Soldering Torch: Soldering Torch used to heat large work pieces which can not be heated by soldering bit. In this case work may be heated directly by flam or flame may be used to heat the copper bit

Solder Bath : Solder Baths are used for making large number of joints simultaneously on a large assembly. This is also known as mass soldering. Baths are electrically heated Soldering baths frequently form part of automatic soldering machines.

Soldering Materials: In industries, a wide variety of solders are in use. For most purpose following solders are in use**:**

(1) 40/60 Tin/Lead : It is having fairly high melting temperature and is soft. It is used for making and repairing metal ware of copper, brass, steel or tin plate.

(2) **60/40 Tin/Lead :** It is having fairly lower melting temperature and is stronger. It is best suited for dip soldering and electronic work

(3) **Saubit I - :** This solder is having little higher melting temperature than 60/40. It is cheaper and equally strong. It contains a small amount of copper for preventing solder bits being attacked by the solder. Hence it is preferred for electronic work when plain copper bits are used.

Soldering Procedure: The following steps are involved in joining two metals with solder:

1. Cleaning of the metal is usually done with a wire brush, emery cloth and files.
2. It is important that parts should fit closely to get the stronger joint.
3. Apply the flux. Flux may be contained in the solder, as in resin core or acid core solder. Resin core solder is must for electrical wiring. Acid core is an all purpose solder.
4. Heating, there are many ways of heating the joint area. These include Soldering Iron, Torch, electrical resistance, Hot plates, Oven, Induction heating and dip soldering.
5. Applying Solder: The pieces to be soldered must be held together while soldering. When flux core solder is used, it should be applied only to the joint, not to the soldering tip. If the joint is hot enough, the solder will flow into it by capillary action.
6. Cooling and Cleaning: after removal of heat, parts must remain undisturbed until the solder had cooled to solidify
7. To remove the flux residue, use clean warm water. Wiping with a dry rag is useful against flux traces and water strains.

Applications: Soldering is widely used for sheet metal work, electrical and electronics for joining wires.

Advantages:

1. Joining cost is low.
2. Good sealing in fabrication as compared to rivet, spot weld and bolts.
3. It provides positive electrical connections.
4. The property of base metal are not affected due to low operating temperature.
5. Equipments is very simple and cheap.

Disadvantages:

1. Joints formed are weak hence cannot be used as substitute of welding.

Brazing: It is a process of joining two metals surfaces by heating and adding a non ferrous alloy having melting temperature above 400^{o}C, in a liquid state between the pieces of metal to be joined and allowed to solidify on cooling. The surfaces to be joined are cleaned from all oil, dirt or oxides. Then both the surfaces are placed in joining position. Flux is sprinkled or placed on it. The surfaces and the filler rod are brought to a temperature which is below the melting point of the parts to be joined but above the melting point of the brazing material. The molten filler metal flows to the surfaces to be joined. On cooling brazing joint is formed. The brazing material must wet the surface to be joined and by capillary action draw the melt into the space between the two parts. In Brazing the filler metal or brazing material melts but the surfaces to be joined remain unmelted. The filler metals used are copper, copper alloy, silver alloy and aluminium alloy The various methods used to melt the filler metal and flux are:

i. **Gas Torch Brazing:** It is commonly used process in which Oxy – Acetylene torch is used.
ii. **Furnace Brazing**: The surfaces to be joined are placed in a hot furnace.
iii. **Dip Brazing**: The surfaces to be joined are placed in a bath molten filler metal.
iv. **Electric Brazing:** In the electric brazing heat is prodiced by resistance or induction methods

Applications: Brazing is used for electrical items, radiators, heat exchangers, pipes pipe fittings and tool tips.

Advantages:

1. It is useful for joining dissimilar metals.
2. Thin sections can be easily joined.
3. Good finish on the joint is obtained
4. Less skilled operator is required.
5. High rate of production.
6. Cost is less as compared with other joining processes

Disadvantages:

1. Low joint strength
2. Not applicable for hardened steel.

Differences Between Soldering and Brazing:

Sl. No.	**Soldering**	**Brazing**
1.	Filler metal has melting point below 400^{o}C.	Filler metal has melting point above 400^{o}C.
2.	Less stable joint are formed	More stable joint are formed
3.	Joints are affected by high temperature and pressure	Joints are not affected by high temperature and pressure
4.	Equipment cost is less.	Equipment cost is more.