(generally 0.4 mm) apart, a sudden discharge of stored energy from the condenser takes place and an arc is produced just before coming in contact and bringing the ends to a molten state. The pressure is applied and the joint is allowed to cool to form the weld. It is a very quick method of welding but its use is limited to 0.40 cm diameter objects. This process has the advantage that it can be used for welding dissimilar metals like nichrome to copper; copper to stainless steel, brass to high carbon steel, etc.

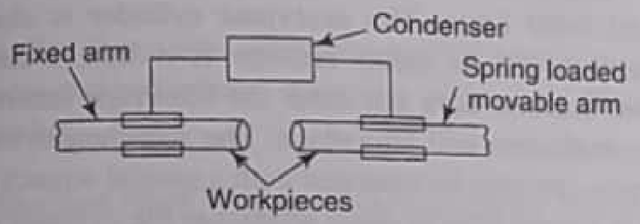

Fig. 9.9 *Percussion welding*

9.8 GAS WELDING

It is a nonpressure fusion-welding process and includes all processes in which gas is used as a source of heat to melt the ends of the pieces to be joined on solidification. A filler metal is needed in welding of sheets above 1.5 mm thickness but no filler metal is needed for welding below 1.5 mm thickness. A filler metal is added in the form of a filler rod and must be having the same composition as that of the parent metal.

Various gas combinations like oxy-hydrogen, oxy-propane, oxy-acetylene and oxy-coal gas may be used for producing a hot flame for welding of metals. The oxy-acetylene flame is most widely used as it produces very high temperatures (3500°C) and can be used for welding of a variety of ferrous and non-ferrous materials. It forms an inert gas envelope over the surface and the flame is easily controllable. In addition oxy-acetylene flame can be used for other operations like soldering, brazing and preheating. The main disadvantage of oxy-acetylene flame is that different blow pipes are needed for different operations. Each operation also requires different pressure of gases.

9.8.1 Welding Flames

Combustion of acetylene at the nozzle tip takes place according to the following reaction.

$$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$$

The above reaction shows that for complete combustion, one part of acetylene requires $2\frac{1}{2}$ parts of oxygen, but different processes require different proportions of gases. For normal welding the most suitable mixture is obtained by using equal proportions of oxygen and acetylene. The remaining 1½ parts of oxygen required is supplied by the air present in the atmosphere.

Welding flames can be classified broadly into the following three categories.

Neutral Flame A neutral flame is produced when almost equal volumes of oxygen and acetylene drawn from the cylinders burn at the tip of the nozzle. It consists of two clearly visible zones as shown in Fig. 9.10 (a). It is the most widely used flame and consists of a luminous blue inner zone. This type of flame is used for welding of mild steel, stainless steel, copper, aluminium and their alloys.

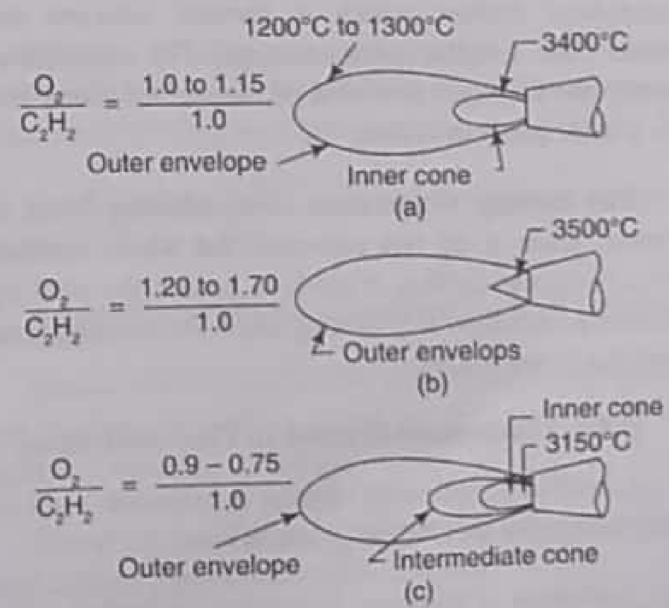

Fig. 9.10 *Various types of flames (a) Neutral (b) Oxidising and (d) Reducing*

Oxidising Flame When more than one volume of oxygen is mixed with one volume of acetylene, an oxidising flame is produced. This type of flame as shown in Fig. 9.10(b) is used as a cutting flame or producing flame.

An oxidizing flame is recognized by the small white inner cone which is shorter, comparatively bluer in colour and more pointed than the neutral flame. The outer flame envelope is much shorter and tends to fan out at the end.

An oxidizing flame burns with a decided loud roar. Though excess of oxygen ($O_2 : C_2H_2 = 1.5:1$) produces higher temperatures and would have been an advantage but welding with oxidizing flame tends to oxidise the metals. Due to these reasons it is not used for welding steel. It is used for welding copper base metals, zinc base metals and manganese steel.

Reducing Flame A reducing flame is produced by burning of more than one part of acetylene with one part of oxygen. As a reducing flame consists of excess carbon. Its use ensures that steel will absorb carbon. This flame consists of three distinct zones (a) inner cone (b) intermediate cone and (c) outer envelop, as shown in Fig. 9.10 (c).

By a welder, a reducing flame is recognized by acetylene feather which is formed between the inner cone and the outer envelope. The outer flame envelope is longer than that of the neutral flame and is also brighter in colour.

The burning temperature of a reducing flame is lesser, since it do not consume the whole carbon. Due to excess carbon, it tends to harden the steel by forming carbides. It is mainly used for welding lead and lead base alloys.

9.8.2 Instruments used in Oxy-acetylene

A brief description of various instruments used in oxy-acetylene welding is given below.

Acetylene Cylinders Acetylene cylinders are used for storing dissolved acetylene. It is not safe to store acetylene in a cylinder above one atmospheric pressure. So acetylene cylinders are filled with acetone. Acetone has the property of absorbing 25 times its own volume of acetylene for each atmospheric pressure applied. An acetone cylinder is partly filled with acetylene. Acetone is stored in these cylinders at a pressure of 16 kgf/cm^2 and capacity of each cylinder is about 8 m^3. To distinguish from oxygen cylinders, acetylene cylinders are painted maroon. The gas is taken out of the cylinders through a valve provided at the top of the cylinder [Fig. 9.11 (a)].

The usual sizes of acetylene cylinders are 2800 and 5600 litres. The acetylene cylinder is always kept upright for safety reasons. It is done to ensure that acetone does not enter the blowpipe otherwise an explosion will take place. The acetylene cylinder valve can only be operated with a special wrench and it is always kept in place whenever the cylinder is in use. An acetylene cylinder is provided with a number of fusible plugs at its bottom designed to melt at 104°C. These plugs melt and release the pressure in case the cylinder is exposed to excessive heat. It ensures safety of the cylinder.

Oxygen Cylinder These are black coloured cylinders (shown in Fig. 9.11 (b)) containing 6.25 cubic metres of oxygen at a pressure of 130 to 140 kgf/cm^2. Oxygen cylinders are provided with right-handed threaded valves whereas acetylene cylinders are provided with left-handed threaded valves, so that the regulator of an oxygen cylinder does not fit on an acetylene cylinder or vice versa. To check against any explosion or accident, oxygen cylinders are also fitted with safety valves.

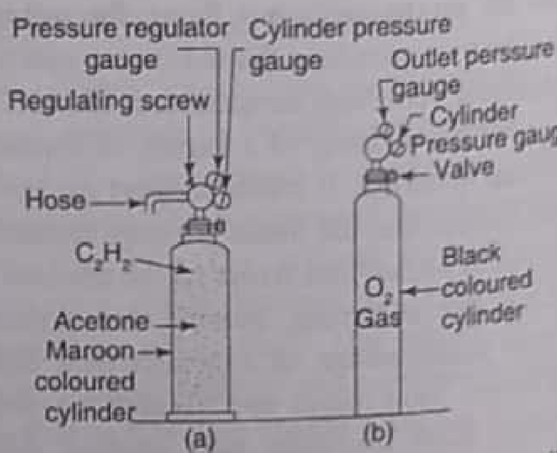

Fig. 9.11 *(a) Acetylene cylinder (b) Oxygen cylinder*

The usual sizes of oxygen cylinders are 3400, 5200 and 6800 litre. The volume of oxygen in the cylinder is directly proportional to its pressure. In other words if the original pressure drops by 4%, it means the volume of gas in the cylinder has decrease 1/25 of its original volume.

For safety of the cylinder against bursting due to excessive pressure, oxygen cylinder is equipped with a safety nut that allows the oxygen to drain off slowly in the event of increase of temperature of the cylinder beyond safety norms.

Trolley It is a steel structure used for transporting oxygen and acetylene cylinders from one place to another.

Hose and Hose Fitting These are rubber tubings used for connecting the cylinder regulators to the blowpipe. Hoses used are also of red and black colours. A red-coloured hose is used for acetylene, and a black-coloured hose is used for supply of oxygen.

Pressure Regulators Pressure regulators are used for reducing the pressure of the gas being drawn from the cylinder. A red coloured pressure regulator is used for acetylene and a black coloured one is used for oxygen. Two types of pressure regulators (shown in Figs. 9.12 and 9.13) are single stage regulator and two stage regulator respectively. The two stage regulator is preferred over a single stage regulator as pressure reduction in this regulator is accomplished in two stages.

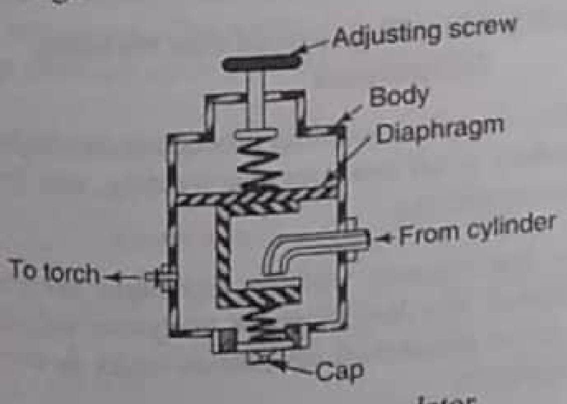

Fig. 9.12 *Single stage regulator*

Welding Torch The oxy-acetylene welding torch is the tool in which gases are mixed in the desired volume and burning of the mixture takes place at the end of the tip. It consists of a handle with two inlet valves for oxygen and acetylene gases at one end. Each inlet has a valve to control the volume of the gases passing through it. The mixing of gases takes place at the tip of the nozzle. The flame is produced by igniting the mixture with a spark lighter. The two types of commonly used torches are (a) high pressure welding torch and (b) low pressure welding torch (shown in Fig. 9.14). Torches are classified according to acetylene pressure available from the source. Acetylene used from cylinders is known as high pressure acetylene while that generated by water and calcium carbide in a drum is known as low pressure acetylene.

The welding nozzle or torch is that portion of the torch which is located at the end of the torch. The tip of the nozzle contains many openings through which oxygen and acetylene mixture passes prior to ignition and combustion. A welding nozzle helps the welder to adjust it and direct it towards the welding portion with ease and efficiency. The selection of a welding nozzle depends on many factors like (i) the type of joint, (ii) the thickness of the job, (iii) the position of the weld, and (iv) characteristics of the metals to be welded.

Goggles Welding goggles consist of blue coloured glasses and are used for protection of eyes from harmful effects of heat and ultraviolet rays.

Spark Lighter It is a tool used for lighting the gas at the tip of the nozzle.

Apron It is a protective covering made of leather.

Gloves Gloves are used to protect the hands from any accident or mishap. These are generally made of leather, asbestos or canvas.

Spindle Key It is an instrument used for opening and closing valves of the gas cylinders.

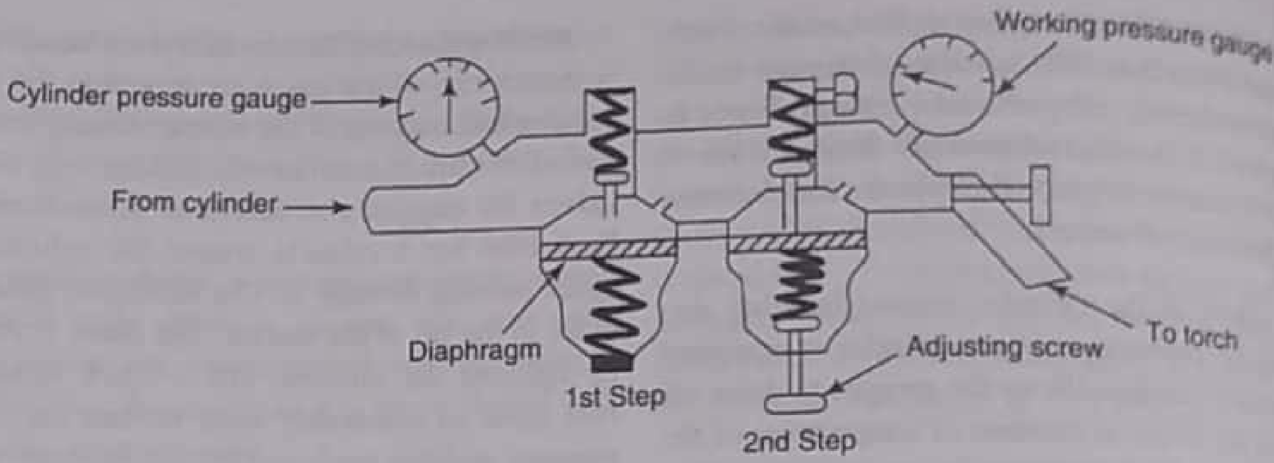

Fig. 9.13 *Two-stage regulator*

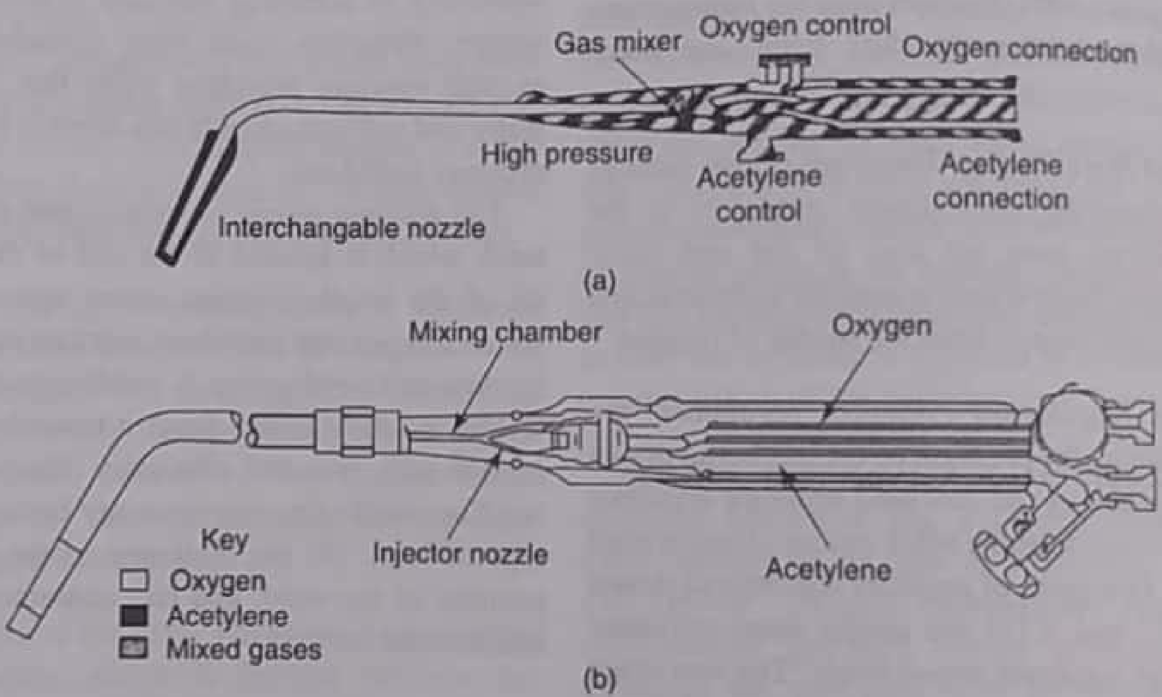

Fig. 9.14 *(a) High pressure blowpipe and (b) Low pressure welding torch (blowpipe)*

Wire Brushes Wire brushes are used for cleaning a weld prior to welding and removal of rust after welding.

File and Hammer A file is used for cleaning the surface and a hammer is used for removal of chips.

Welding Rods and Fluxes Welding rods are used as filler metal and fluxes are used for preventing oxidation.

Spanner Set A tool used for opening and closing the regulators, blowpipes and nose fittings.

9.8.3 Classification of Gas Welding Techniques

Oxy-acetylene welding procedures can be broadly classified as (a) low pressure welding, and (b) high pressure welding.

In low pressure welding technique, acetylene is generated in a low pressure acetylene cylinder by the action of calcium carbide on water as shown in the equation.

$$CaC_2 + 2H_2O = Ca\,(OH)_2 + C_2H_2$$

Calcium carbide is dropped on water at a controlled rate by a special hopper. The acetylene thus produced is impure and is purified by passing through a purifier. In this system a special injector type blowpipe is used which draws acetylene from the generator by the injector effect of an oxygen jet.

High-pressure welding is the most commonly used method of gas welding. In this system both acetylene and oxygen are used from high pressure cylinders and these cylinders are kept in upright position for easy portability. The main difference between high pressure and low pressure welding is the pressure of acetylene and design of a welding torch. Low-pressure welding process uses low-pressure acetylene with specially designed injector blowpipe.

9.9.4 Gas-Welding Techniques

The commonly used gas-welding techniques are

(i) Leftward or forehand welding
(ii) Rightward or backhand welding
(iii) Vertical welding
(iv) Overhead welding

In all the welding techniques proper cleaning and edge preparation is a must for strong welds.

Leftward Welding It is also known as forehand welding. In this process the torch is held in the right hand at an angle of 40° to 50° and the welding rod in the left hand at an angle of 30° to 40° from the workpiece as shown in Fig. 9.15. The flame is given circular, rotational or side to side motion to obtain uniform fusion throughout. This method is more efficient for welding materials up to 6.00 mm thickness.

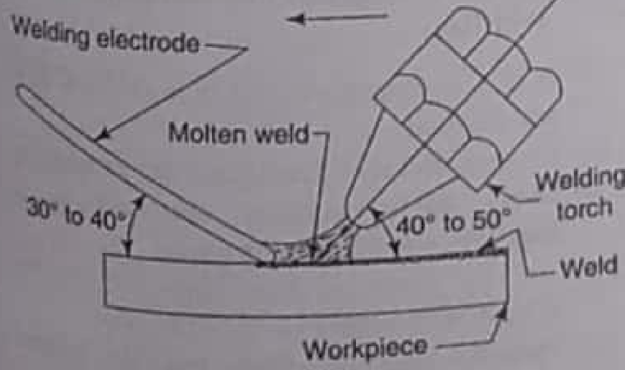

Fig. 9.15 *Leftward welding*

Rightward Welding It differs from leftward welding in the direction of movement of the torch. In this system the torch moves from left to right. The torch is held in the right hand at an angle of 60° to 70° and the filler rod in the left hand at an angle of 30° to 40° as shown in Fig. 9.16. The cone of the flame in rightward welding is deeper than the flame in leftward welding. This process in more suitable for welding plates above 6.0 mm thickness.

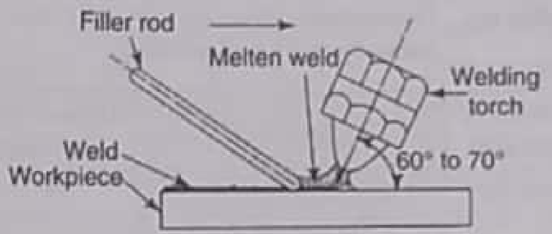

Fig. 9.16 *Rightward welding*

Advantages of rightward welding over leftward welding are the following:

(i) The consumption of filler rod and fuel is less.
(ii) It is a quicker method.
(iii) The weld thus produced is stronger and tougher.
(iv) The expansion and contraction of material is lesser.
(v) The molten pool is better visible, thus it gives a better control on the weld.

Table 9.2 *Preparation of various plates for butt joints by leftward welding*

Thickness of Plate (mm)	*Joint design*	*Diameter of rod*
0.5 to 1.6	No gap	No rod
1.6 to 2.5	No gap	No rod
2.5 to 3.5	1.5 mm gap	2.5 mm
3.5 to 4.5	70° to 80° 2.0 mm gap or butt	3.0 mm
4.5 to 6.0	90° 2.5 mm gap	3.5 mm

Vertical Welding This process is used when plates are lying in the vertical position. In this process welding starts at the bottom of the plates and proceeds upwards. The welding torch is held in the right hand and filler rod in the left hand. The filler rod moves ahead of the blowpipe. This process is useful and economical for welding plates up to 6.00 mm thickness specially the tanks, etc., that cannot be dismantled easily.

Table 9.3 *Preparation of various plates for butt joints by rightward welding*

Thickness of Plate (mm)	*Joint design*	*Diameter of rod (mm)*
6.0 to 8.0	2.5 to 3.0 gap No.V	3.0
8.0 to 10.0	60° 3.0 mm gap or butt	4.0
10.0 to 15.0	60° 3.4 to 4.0 mm gap	5.0
15.0 to 25.0	60° 3.0 to 4.0 mm gap double V	5.0 to 6.0

Overhead Welding In this process the blowpipe is held almost at right angles to the plates. The molten metal is entirely controlled by the flame. In this process, correct degree of penetration is difficult as the welding operation is performed overhead.

9.8.5 Steps in Gas Welding

The following steps are followed in gas welding operations.

(i) Always keep the cylinder upright preferably in a trolley.
(ii) Blow out the acetylene valves, open acetylene cylinder valve, dislodge any dirt, etc., and close the valve. Repeat the operation with the oxygen cylinder.
(iii) Thoroughly check the surfaces to be welded, cylinder valves and blowpipe valves.
(iv) Tighten the regulators on the cylinders.
(v) Connect the hose pipes to cylinders and torch.
(vi) Insert the required size of tip in the blow-pipe.
(vii) Ignite acetylene with a spark lighter.
(viii) Open the valve of oxygen and adjust the flame.
(ix) When work is to be stopped, first stop the supply of acetylene and then of oxygen. Close all valves and remove blow-pipe, hole and regulators.

9.8.6 Advantages of Gas Welding

(i) It is the most versatile process of welding and is applied to wide variety of manufacturing and maintenance.
(ii) The rate of heating is relatively slow. In some cases it is advantageous.
(iii) The equipment is low in cost, self-sufficient and usually portable. In addition to welding, it can be used for pre-heating, post-heating, torch brazing and oxygen cutting.
(iv) The temperature of weldment and workpieces can be easily controlled.
(v) During a gas-welding process the source of heat and filler metal are different, the filler-metal deposition rate can easily be controlled by a welder. Heat can be applied preferentially to the base metal or the filler metal.
(vi) The cost of welding equipment as well as cost of its maintenance is low as compared to other welding processes.

9.8.7 Disadvantages of Oxy-acetylene Welding

(i) It is a comparatively slower process than arc welding.
(ii) Oxygen and acetylene gases are expensive.
(iii) Many safety problems are involved in handling and storing the gases.
(iv) An oxy-acetylene flame does not provide complete shielding of the weld pool.
(v) Harmful thermal effects exist in welded sections.

(vi) Heavy sections cannot be joined easily.
(vii) The temperature of the flame is less than the temperature of the arc.
(viii) High melting metals like tungsten, molybdenum, tantalum etc. and reactive metals like titanium and zirconium cannot be welded by gas welding.
(ix) Handling and storing of gases require greater attention.

9.8.8 Applications of Gas Welding

(i) It is a versatile process for joining thin materials
(ii) For joining material that contain certain elements that will escape into the atmosphere under the effect of high temperature
(iii) For joining most of the ferrous and non-ferrous metals, e.g., mild steels, low-carbon steels; alloy steels, cast iron, copper, aluminium, nickel, magnesium etc., and this alloys
(iv) In automotive and aircraft industry
(v) Sheet metal fabrication plants

9.8.9 Safety Precautions in Gas Welding

(i) Always keep the cylinders in upright position.
(ii) Never tamper with cylinder valves.
(iii) Always keep the cylinder key at valve stem.
(iv) If any leakage is noticed in an acetylene cylinder, remove all materials from its vicinity and let the gas escape into the atmosphere.
(v) Always use protective glasses while welding, chipping or grinding.
(vi) Before starting any welding operation, make sure that connections are gastight.
(vii) Always use a friction lighter for lighting torches.
(viii) Never use oxygen near inflammable materials.
(ix) Never use acetylene above 1 kgf/cm^2 pressure.
(x) Do not drop the cylinders.
(xi) Keep hoses and cylinders away from flying sparks and open flames.

9.9 OXY-ACETYLENE GAS CUTTING

This is a very commonly used process for cutting materials. It is based on the principle that oxygen has great affinity for iron and steel at elevated temperatures. When a metallic piece of iron is heated up to 1000°C, it forms iron oxide which has low melting temperature. Thus if the steel is heated to about 1000°C and then a jet of pure oxygen is blown on the surface, the steel is instantaneously burnt to iron oxide and shows slag like appearance, which falls down under pressure and the steel is cut. The process is very rapid and pieces up to 75 mm thickness can be cut easily.

The operation is carried out with a special torch having several small holes for preheating the steel to red colour as shown in Fig. 9.17. The main central hole in the torch, carries oxygen for cutting action. This process is only suitable for cutting steel and is not suitable for cutting nonferrous alloys and high manganese steels.

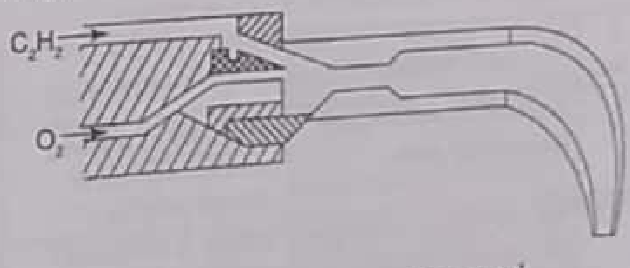

Fig. 9.17 *Oxy-acetylene cutting torch*

9.10 FLAME MACHINING

It is an oxy-acetylene gas-cutting process of removal of material with the help of a cutting blowpipe like any other machining operation. The torch is held at a small angle to the workpiece and cuts the material as it advances. This process is rapid and does not require power like other machines. The surface finish of the cut portion is poor and it also gets hardened on cutting. This process is suitable for initial rough machining only.

9.11 ARC WELDING

It is a welding process in which, to form a molten pool of metal, heat is produced by an electric arc, generally without the application of pressure and with or without the application of a filler metal. It uses either ac or dc for striking the arc between the electrode and the workpiece. The differences between ac or dc arc welding are listed in Table 9.4. One terminal is connected to the electrode, the other to the workpiece and the circuit is completed through an air gap between the electrode and the workpiece. An air gap is generally 3 to 6 mm. The temperature of the arc varies from 3600°C to 4000°C. The commonly used arc welding processes are

(i) Carbon arc welding
(ii) Metal arc welding
(iii) Inert gas arc welding
(iv) Submerged arc welding
(v) Atomic hydrogen welding
(vi) Shielded metal arc welding
(vii) Dip transfer arc welding

Table 9.4 *Comparison between ac and dc Arc Welding*

S. No.	ac welding	dc welding
1.	A transformer contains no rotating parts.	A number of rotating parts are needed to convert ac to dc.
2.	Tapping gives a number of stepped voltages.	Supply is at a fixed voltage.
3.	Maintenance cost of a transformer is less.	Maintenance cost of the set is high.
4.	No problem of arc blow.	Severe arc blow occurs which cannot be easily controlled.
5.	Only ferrous metals can be welded as polarity does not exist.	By changing the polarity, both ferrous and nonferrous metals can be welded.
6.	The arc is never stable.	The arc is quite stable.
7.	Output depends upon the voltage supplied.	Output is not affected by normal variations in power line supply.

All the arc welding processes are based on the principle of striking the arc generally between the electrode and the workpiece. The additional metal if required is supplied by the filler rod. Fig. 9.18 shows an electric arc welding circuit. The welding circuit consists of a welding machine, lead cables, electrode holder, electrode and the workpiece itself. Other accessories required are welding helmet, chipping hammer, wire brush and file.

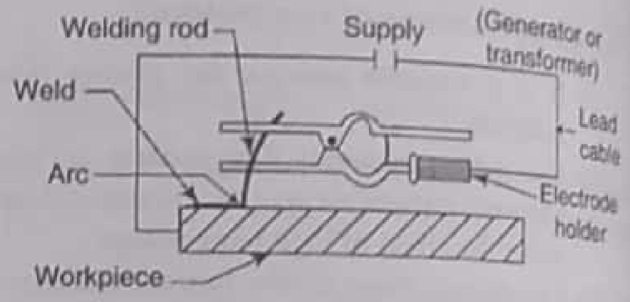

Fig. 9.18 *Arc welding technique*

9.11.1 Carbon-Arc Welding

Carbon-arc welding can be classified into two categories, (i) single electrode arc welding, and (ii) twin electrode arc welding. Depending upon the nature of shielding these can be further classified as (i) inert gas shielded arc welding, and (ii) flux shielded carbon arc welding. The inert gases used may be helium, argon, nitrogen, etc.

In the carbon-arc welding process the fusion of the metal is accomplished by the heat of an electric arc. Generally no shielding atmosphere is used. Pressure is not applied and a filler rod is used only when it is necessary. The carbon-arc welding process differs from the commonly used processes as in the case of former carbon or graphite rod is used instead of the consumable flux-coated electrode. The carbon-arc processes use either dc or ac power sources. Either of these two processes may be manually operated or automated.

Single carbon arc welding process is shown in Fig. 9.19. The power supply for releasing the heat is dc. The electrode always acts as cathode (negative). The arc is created between the electrode and the workpiece which always act as anode (+ve). The