CHAPTER

24

WELDING AND ALLIED PROCESSES

24.1 INTRODUCTION

The art of joining metals by heating and then pressing together is a very old one, as described in chapter 19 under the heading **'Smithy Welding'**. However, the latter developments and advancements in this field have given rise to a number of altogether different *processes* and *techniques* for *Welding of metals*. With the more recent researches in the technology and practice of welding this science has gradually become as complicated as it is useful. In most of the modern fabricating works *Welding Science* has numerous applications in different forms, covering a fairly wide range of such work. Sometime ago the application of this science was largely confined to iron and steel only, but with the evolution of a number of recent techniques it has become possible to weld most of the *metals* and *plastics* now. As such, there cannot be two different opinions about the utility of this science, but at the same time it is altogether difficult for a beginner to cope up with the complications of this technology and grasp them fully at this stage. Also, it is not feasible to deal with the details of this science fully in this small chapter. The endeavour of the author in this chapter will, therefore, be to acquaint the readers with the *basic principles* and *applications* of different *Welding Techniques*.

24.2 CLASSIFICATION OF WELDING PROCESSES

The basic purpose of *Welding* is to provide a means to *join* pieces by raising their temperature to the *fusion point* so that they form a sort of *pool* of molten *metal* at the ends to be joined, and if needed, supplement this pool with **Filler Metal** (*wire* or *rod*) which normally has nearly the same composition as that of the *parent pieces* and then allow the *said pool to form a homogeneous mixture* and solidify at the ends to form what is known as a **Weld**. This is known as **Fusion Welding** process. An alternative process of welding is to heat the ends of the metal pieces to be joined to *plastic state* and then apply some external pressure to join them and complete the weld. It is known as **Pressure Welding**. Heat for the above purpose can be obtained from many sources, such as a *Smith's hearth* for *Forge Welding*, electric current for *Resistance Welding*, gas flame for *Gas Welding*, chemical reaction for *Thermit Welding* and *electric arc* for *Arc Welding* etc. Besides the conventional *fusion* and *pressure* welding methods, welding can also be accomplished by *sound* and even by *light* through **laser**. Such wide diversity of welding methods has made the conventional definition of welding obsolete. A more appropriate way to define **Welding** will, therefore, be to say that **welding** *is the art of joining metals and plastics by such methods which do not employ fasteners and adhesives*. The **classification** of different **Welding Processes** which are in general use are given in Table 24.1.

24.3 CONCEPT OF A WELD

Except a few welding methods like **'Cold Welding'**, in most of the other methods a **Welded Joint** or **Weldment** between two metal pieces is the result of fusion of metal, followed by *freezing* of this fused metal at the junction. The common sources of heat generation for effecting the desired fusion of metal are :

1. *Fire of a Smith's Forge* (Forge welding)
2. *Electric arc* (Metal arc, Carbon arc, Argon arc, etc.)
3. *Gas flame* (Oxy-acetylene, Water-gas Welding, etc.)
4. *Gas plus Electric arc* (Atomic Hydrogen Welding)
5. *Electrical resistance* (Resistance and Electro-slag)
6. *Chemical reaction* (Thermit Welding)
7. *Energy ray* (Electron Beam and Laser Weldings)
8. *Mechanical Energy* (Friction and Ultrasonic Welding).

From our discussions in **'Foundry'** it has been clear that when a certain quantity of metal is melted and then allowed to solidify, the resultant metal is called a **'Casting'**. In this sense a weld is basically a **'Casting'**, although on a very small scale. Obviously a **Weld** will inherit the common casting drawback of ***Casting* Brittleness**, which is a disadvantage. The emphasis in welding technique should, therefore, be on preventing this *brittleness* to the maximum possible extent.

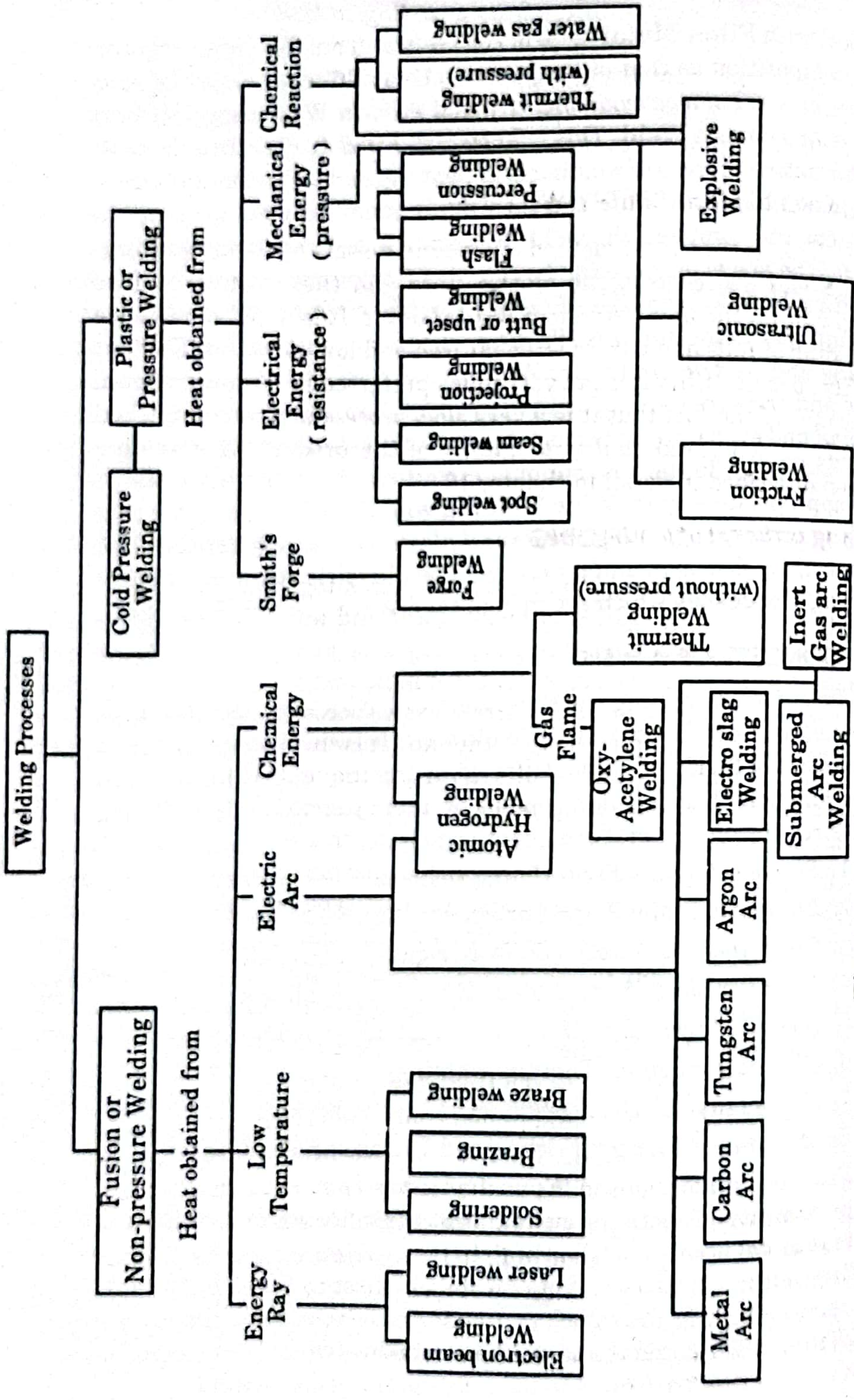


Fig. 24.1. Classification of Common Welding Processes.

A **Weld**, however differs from a *casting* in that the parent metal around it is simply *heated* and *not melted*. This heated surrounding metal gets heat-treated and is known as **Heat Effected Zone**. Obviously its characteristics also change. Thus, a **Fusion Weld** can be described as a *Mini-Casting* surrounded by *Heat Treated Parent Metal*.

24.4 FORGE OR SMITHY WELDING

This is the oldest method of *welding* metals by heating them in a black-smith's forge to the plastic state and then hammering them together on the anvil to from a *Welded Joint*. It is mainly employed in welding of rods and bars of wrought iron and low carbon steels. Inspite of its specific utility it is not very much preferred in modern practice on account of the fact that it is a very *slow process* and at the same time *costly* as compared *quality to quality* of the products. It has already been described in detail in chapter 19.

24.5 RESISTANCE WELDING

It is the process of joining metal pieces together by raising the temperature of the pieces to *fusion point* and applying a mechanical pressure to join them. In this, the pieces to be joined are held together and a strong Electric Current (A.C.) of high *amperage* and low *voltage* is passed through them. This current comes across a certain resistance in passing from one piece to the other and it is this *resistance* offered to the flow of current which results in raising the temperature of the two pieces to *fusion* or *melting point* at their junction. The mechanical pressure applied at this moment completes the weld. This method of welding is widely used in modern practice for making *Welded Joints* in *sheet metal parts, bars* and tubes, etc. This type of welding is further sub-divided into **six** main methods as given below :

1. Spot Welding
2. Butt Welding
3. Flash Welding
4. Seam Welding
5. Projcction welding
6. Percussion Welding.

Successful application of a **Resistance Welding** process depends upon correct application and proper control of the following factors :

1. Welding Current. Enough current is needed to bring the metal to its *plastic* (or sometimes *molten*) state for welding. It should be properly adjusted on the current control device on the machine.

2. Welding Pressure. In *Resistance Welding*, mechanical pressure is required, to be applied at two stages—first to hold the metal pieces tightly between the *Electrodes*, while the *current* flows through them, and secondly when the metal has been heated to its *plastic state*, to forge or squeeze the metal pieces together to form the **weld**. The former is known as **Weld Pressure** and the latter **Forge Pressure.**

3. Time of Application. It can also be described as **Cycle Time** and is the sum total of the following time periods allowed during different stages of welding :

(*a*) **Hold Time.** It is the *time period* during which the current flows through the metal pieces to raise their temperature.

(*b*) **Squeeze Time or Forging Time.** It is the *time period* during which the *Mechanical Pressure* is applied to the metal pieces to squeeze them together to form the **weld.**

(*c*) **Hold Time.** It is the *time period* during which the metal pieces are held together under forge pressure for a short while to enable the **weld** to *solidify*. It can, therefore be called **Cooling Time** also.

(*d*) **Off-Time.** After cooling of weld the electrode pressure is released and the metal pieces removed for the next *Operation Cycle.* The time period between this release of electrodes and the start of next welding cycle is called **Off-Time.**

4. Contact Area of Electrodes. The weld size depends on the *Contact Area* of the face of the *Electrodes*. It can be varied by selecting suitable sets of *electrodes* to provide the desired area of contact at their **tips.**

24.6 RESISTANCE SPOT WELDING

It is the simplest and probably the most commonly used method of making **Lap Welds** in thin sheets (upto a maximum thickness of 12.7 mm) using the principle of *Resistance Welding*. It owes its popularity to the fact that it can quite suitably replace riveting in sheet metal products without altering the design of the article.

The **Principle of Spot Welding** is illustrated in Fig. 24.1, where a *Transformer Core* is shown having *primary* and *secondary* windings *P* and *C* respectively. One end of the secondary windings is connected to the upper *Electrode* E_1 carried in the *movable* copper or bronze arm *A* and the other end to the lower *Electrode* E_2 mounted on the fixed arm *B*. In operation, the metal sheets S_1 and S_2 are

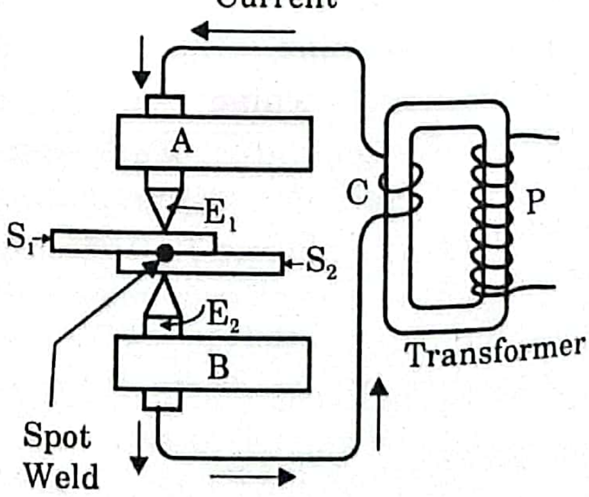


Fig. 24.1. Principle of Spot welding.

held and pressed between the electrodes and a strong *current* at *low voltage* is switched on. Due to the *resistance* offered by the sheet metal to the flow of this current the temperature at the *contact surfaces* rises to *fusion point* and the weld is completed under the **Contact pressure** of the *Electrodes*.

Spot Welding Machines are manufactured in various shapes and varying designs but they all work basically on the *same principle*, as explained above. A simple but common type of these, known as **Pedestal Type Spot Welder,** is shown in Fig. 24.2. It consists of a metallic *casing* having the *Transformer* housed in it. The lower arm, called the *Fixed Arm*, is rigidly fixed to the machine *body* and the *upper arm* (or *Movable Arm*) is pivoted about a point inside the case. A *Pedestal* at the bottom operates the upper arm through a *spring*. When this *pedestal* is pressed downwards the inside end of the *upper arm* is raised up and the outside projecting end, carrying the *upper* electrode, is brought downwards to apply pressure on the sheets held between the *electrodes*. The *Foot Lever* (*pedestal*) in being pressed downwards also simultaneously *switches* on the current, thus enabling the production of the **weld**. The *spring*, described above, enables the application of a *constant pressure* so long as the current is flowing. After a **Weld** is complete the pressure on the foot lever is released and the work moved to the next position where it is to be welded.

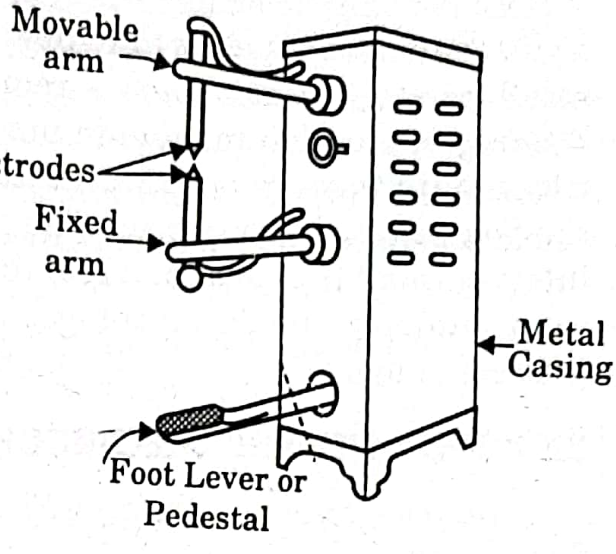


Fig. 24.2. Spot welding machine.

Gun Welding. Many a times it is not feasible to use a *stationary* type of spot welding machine either due to difficulty in bringing the workpiece to the machine, difficulty in the manipulation of the workpiece or due to odd shapes of the workpieces. In such cases a **Portable Type of Spot Welding Machine,** called the **Gun Welder,** is used, which can be easily transporated to site. Also, manipulation of its *electrodes* into different positions is quite easy, which facilitates welding even in odd positions. *Spot Welding* carried out with this machine is known as **Gun Welding.**

The specific use of this method is in welding of irregular surfaces, such as normally needed in the fabrication of automobile bodies. The electrodes are actuated either *hydraulically* or *pneumatically*. The equipment consists of a *Transformer* (supported by an *overhead* *rail*), *Flexible Leads* connecting the transformer to the **Welding Gun**, the *Welding Gun* unit comprising of two *Electrodes* and a *Trigger Switch*. Leads and the gun assembly are also supported by the *overhead rail*.

Shot Welding. This term is used to denote a specific application of *Spot Welding* principle, wherein a very carefully controlled amount of *electric current* is allowed to flow through the *metal pieces* for a very small period of time. Such a requirement normally arises in *Spot Welding* of aluminium, aluminium alloys and stainless steel. Usually **Electronic Timers** are used for controlling the current flow because the *flow interval* is very brief. The purpose of keeping the current flow interval small is to heat and cool the metal pieces at a faster rate and, thus, minimise the disadvantages associated with *oxidation* and *heat treating* of metal.

24.7 SPOT WELDING ELECTRODES AND ELECTRODE HOLDERS

All resistance *Spot Welding Electrodes* have to perform three major **functions** :

1. They *conduct* the *electric current* to the workpieces.
2. They *hold* the *workpieces* together and transmit the required amount of *force* to the work area to complete the **weld**.
3. They have to *dissipate heat* from the *weld zone* as quickly as possible.

Also, during the process of *Welding* these electrodes are subjected to high *compressive stresses* at elevated temperatures. For successful welding the electrodes should be capable of resisting these *stresses* without much deformation in order to confine the conducted current to a *fixed area* within the workpieces. A frequent inspection of *Electrode Tips*, their regular *dressing* and, as and when needed, their *replacement* should, therefore, be made regularly. In order to perform the above functions successfully these electrodes should possess the following **characteristics** :

1. They should be *good conductors* of *electricity*.
2. They should be *good conductors* of *heat*.
3. They should possess high *mechanical strength* and *hardness*.
4. They should not have a tendency of *alloying* with the *metal* of the workpieces.

Electrode Materials

Copper—base Alloys and Refractory Metal-Alloys are commonly used for manufacture of all *Resistance Welding Electrodes*.

Inspite of its good thermal and electrical conductivities pure copper is not used because it lacks in mechanical strength and tends to soften at elevated temperatures.

In all *Copper—base Alloys* the principal alloying element is copper and other elements are added in varying proportions. A few typical compositions of these alloys with their applications are given in Table 24.2.

The common *Refractory-metal Alloys* used as electrode materials are Cu-tungsten mixture, pure tungsten, pure molybdenum, etc. These materials are preferred where there is a likelihood of deterioration of electrodes made of cu-base alloys on account of long welding time, excessive heat, insufficient cooling or application of high pressures. A typical example can be the *Spot Welding* of stainless steel which has a high electrical resistance.

Table 24.2. Characteristics and Applications of Cu-base Alloys

Sl. No.	*Alloy Composition*	*Main Characteristics*	*Recommended Application*
1.	Cadmium 1% copper 99%	High strength and hardness with high thermal and electrical conductivities.	Used for making electrodes for spot welding of galvanised iron, brass, bronze, aluminium alloys, magnisium alloys, hot-rolled low carbon steel.
2.	Chromium 0.8% Copper 99.2%	Better mechanical properties than the former, but inferior thermal and electrical conductivities. Regarded as a better generalpurpose electrode material and suits for a wider range of metals and welding conditions.	For spot welding of low carbon steel, nickel plated steel, stainless steel, nickel alloys, monel metal, copper base alloys.
3.	Beryllium 0.5% Nickel 1.0% Cobalt 1.0% Copper 97.5%	Better mechanical properties, but inferior thermal and electrical conductivities than the above two types. Good wear resistance.	Specifically suitable for electrodes used in spot welding in such conditions where pressures and workpiece resistance are high. Used on stainless steel, inconel, monel, thick sections of mixed-steel, etc.

A few other combinations of *Cu-base Alloys*, like *copper-zirconium* and *copper-cadmium-zirconium* are also used as *Resistance Welding Electrode* materials. Their properties and applications are similar to those described at serial Nos. 1 and 2 in table 24.2 above.

Electrode Holders

Spot Welding **Electrode Tips** are held in suitable **Electrode Holders.** These holders are attached to the ends of the two *arms* of the spot welding machine. Most of these holders are *water cooled*, and so are the *electrode tips* which are made hollow for this purpose. **Holders** carry hose connections for supply of water for cooling. *Ejector mechanisms* are usually provided in holders for easy removal of electrode tips, when needed. In most of the *Spot Welding Machines* these *Electrode Holders* can be adjusted for length and position. *Multiple-electrode Holders* are also available which facilitate making of two or more **spot welds** simultaneously. All the **Electrode Holders** are made of *copper alloys* carrying good electrical conductivity and rigidity.

24.8 RESISTANCE BUTT WELDING

Also known as **Upset Welding,** it is used to join the metal pieces end to end. In this process, the metal pieces, usually bars and rods of the same cross-section, are held in suitable *clamps* or *vices* with their previously squared ends abutting against each other. The projecting lengths of the pieces between the clamps are adjusted according to their *cross-sections* and the corresponding *materials* of which they are made. A longer projection will offer more resistance and a shorter length will provide less resistance. Abutting ends of the pieces having *equal cross-section* should be kept exactly in the *middle* of the clamps. The endeavour should be to adjust the projected lengths in such a way that the resistance offered by them to the flow of electric current is sufficient enough to generate the desired amount of heat at the respective ends. The clamps holding the pieces either form the *Electrodes* themselves or are fitted with *separate electrodes* in them. One of these clamps is rigidly fixed to the frame of welding machine and the other is mounted on a **Movable Slide** operated by a *Hand Lever* in case of large machines and a *Spring* in case of small machines having welding capacity upto 12.7 mm.

After abutting the ends together the *current* is switched on and the contacting surfaces heated to the *fusion point.* At this moment additional *mechanical pressure* is applied by means of the hand lever or the spring attachment and this completes the **Weld**. This pressure should be maintained for a few seconds, *actual time* depending upon the cross-section of the pieces, to allow the metal pieces to join together. In *Hydraulic Type Machines* the hand lever is replaced by a *Hydraulic Plunger*. The **Butt-Welding** method is very suitable for joining end to end the items like bars, rods, tubes and wires etc. It is shown in Fig. 24.3.

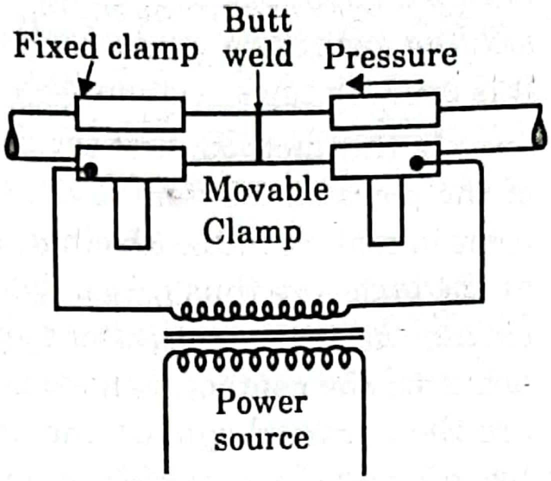


Fig. 24.3. Principle of Butt Welding.

Application of *Correct Pressure* at *right moment* plays a vital role in making of a good quality weld. For welding of wires and rods upto 12.7 mm diameter the *Machine* may be *spring operated*. After clamping the parts in position the spring is released to force the end faces against each other, current is switched on to heat the ends to *plastic state* and the spring pressure itself is sufficient enough to *squeeze* the ends and form the *joint*. A *Trip Switch* automatically breaks the circuit as soon as the upsetting is over.

For larger sizes of *stock* a better practice is to start the weld with a lower pressure to localise the heat at the joint. This can be accomplished by employing a *Hand Wheel* or *Lever* in place of the *Spring*. When molten metal is seen flowing from the outer surface, the weld is consolidated by application of higher pressure, preferably Hydraulically or Pneumatically. Enough care should be taken in gripping very thin wires to ensure that the grip is at the edge of the clamp. Failing this, the *wire* may *bend*, instead of being *upset*, when the pressure is applied. Also in such cases, it is a usual practice to mount the movable clamp on a *swinging arm* instead of the slide, which, in turn, is mounted on a *Ball Bearing* in order to reduce friction and prevent the chances of application of excessive pressure. Too much pressure may damage the wire by overheating.

But Welding can be employed for welding of tubes, increasing lengths of wires and rods, making chains and in welding of those metals which have high electrical conductivity such as copper, brass, aluminium, etc.

24.9 RESISTANCE FLASH WELDING

Flash Welding is also used for joining metal pieces end to end but it differs from the *Butt-welding* process, described above, in the method of heating and *sequence of operations.* It has largely replaced the *Butt-welding* method for welding articles having *thin cross-sections.* Of course, it is used for thick sections also with equal advantage.

In this method, first the current is switched on and then the ends of the pieces to be welded are slowly brought closer until they finally come in contact with each other. This forces the heat generated to localise at the ends and thus raises the temperature of the ends quickly to the *welding heat.* The ends, after they have acquired the contact with each other, are then pressed against one another by applying *Mechanical Pressure.* This forces the *molten metal* and *slag* to be squeezed out in the form of *sparks* enabling the pure metal to form the joint and disallowing the heat to spread back. (See Fig. 24.4) **Single phase A.C.** machines are most commonly used for **Flash Welding.** The main **advantages** and **disadvantages** of *Flash Welding* over simple butt-welding are as follows :

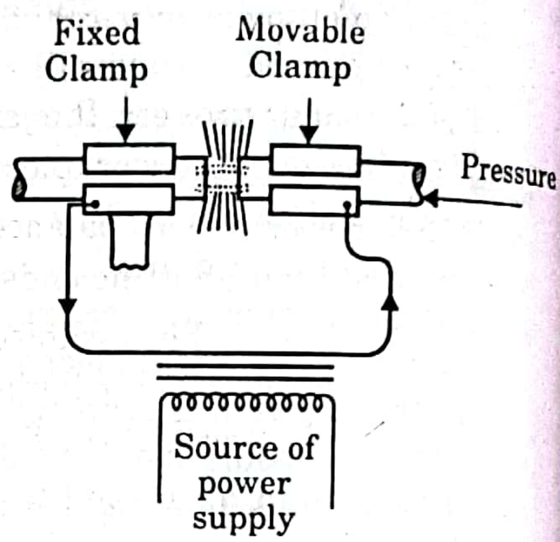


Fig. 24.4. Principle of flash welding.

Advantages of the Process

1. It is comparatively much quicker than butt-welding.
2. On account of only a small portion of the metal being heated the current consumption is less as compared to butt-welding.
3. A flash-welding joint is stronger than the butt-welding joint. It is also reckoned that the strength of the weld produced is comparable to or even more than that of the base metal.
4. The end faces of the metal pieces need not be squared which is a primary requirement in butt-welding.
5. Lengths and alignment of workpieces is maintained to a high degree of accuracy.

Disadvantages of the Process

1. During flashing, particles of molten metal are thrown out, which may enter into the slideways and insulation, etc. This needs periodic maintenance of machine and replacement of insulation.
2. Operator has to take enough care against possible fire hazard due to flashing.

3. Additional stock has to be provided to compensate the loss of metal during flashing and upsetting. This adds to the cost of product.
4. Cost of removal of flash and upset metal by trimming, chipping, grinding, etc. further adds to the product cost.

Limitations of the Process

1. The upsetting pressure and power available in the machine limit the size and cross-sectional area of the workpiece to be welded.
2. Opening between the jaws of the gripping clamps also limits the size of the workpiece.
3. For proper heat balance between workpieces it is necessary that their abutting ends should have same shape and size.
4. Surface of the workpieces, particularly where they come in contact with the gripping surfaces, should be clean otherwise they will restrict the flow of electric current.

Metals which can be Flash Welded. As a general rule it can be said that any metal which can be *forged* can also be *flash welded*. Also, it is possible to weld a number of *dissimilar metals* by controlling the welding conditions carefully. **Metals** *commonly welded* are low carbon steels, low-alloy steels, tool steels, stainless steel, copper alloys, aluminium alloys, nickel alloys, molybdenum alloys magnesium alloys and titanium alloys. This process is unsuitable for welding of lead, tin, antimony, zinc, bismuth and their alloys.

Some Applications. This process is widely used in automobile industry, welding of tubular and solid structural assemblies, etc. in aircraft industry, welding of band saw blades, welding of tool steel, drills, reamers and taps etc., to mild steel or alloy steel shanks, welding of pipes and tubes to increase their lengths, in joining wire ends for producing coils of wires, and many other similar jobs.

24.10 RESISTANCE SEAM WELDING

In principle it is very similar to *Spot Welding* except that in this process the *Spot Welding Tips* are replaced by continuously rotating **Wheel Type Electrodes** (See Fig. 24.5.). With the result, the weld produced is *continuous* instead of being *intermittent*; yielding gas, air, water and steam light joints. A **Seam Weld** can best be described as consisting of a continuous series of *spot welds* produced by passing the workpieces between the *revolving electrodes*. In operation, the current is switched on and the metal pieces pushed together to travel between the revolving electrodes. The metal between the electrodes gets heated to *welding heat* and welded continuously under the constant pressure of rotating electrodes as it passes between them. This is a *quicker operation* than *spot welding* and gives a *stronger joint* than that. The surfaces to be joined should be *cleaned* before being subjected to this process.

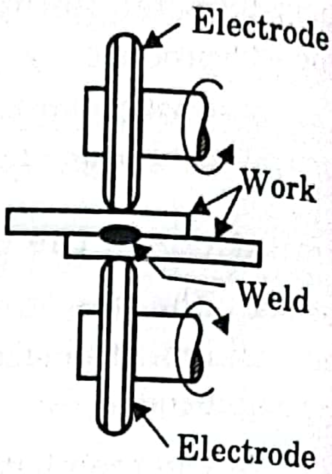


Fig. 24.5. Principle of seam welding.

This process is employed with equal advantage for making **Lap Welds** as well as **Butt Welds**. In welding thick sections the use of an **'Interrupter'** is necessary. It is for the reason that if a continuous current is allowed to flow, the amount of heat generated on account of the high resistance offered to its flow by the thick section, will be too much and the metal will get melted on its surface which will stick to the contacting surfaces of the electrodes. For thin sections, say upto 20 S.W.G. there is no need of using any *interrupting device*.

24.11 SEAM WELDING MACHINES

These machines are similar to *spot welding machines* except that they employ the use of **Disc type Rotating Electrodes**. The work pieces are held between these electrodes and fed forward. The *weld pressure* is provided either hydraulically or pneumatically. Most of these machines work on *single-phase A.C.*, although a few of them are designed to operate on *3-phase supply* also. These machines are available in both—The *Stationary Type* as *well as Portable Type*. The essential **Equipment** required for **Seam Welding** is as follows :

1. Power supply—to supply high-amperage low-voltage current.
2. A means of feeding the workpieces.
3. A means of rotating the electrode wheels.
4. A suitable support for electrodes and workpieces.
5. A means of providing weld pressure.
6. Proper controls for regulating timing, current flow, rate of work feed and application of weld pressure.

The following **four** types of **Resistance Seam Welding Machines** are popular :

1. Circular Type. In this type the faces of electrode wheels are perpendicular to the plane of machine *throat*. This type is widely used for welding of *circular jobs* or such flat jobs which need *long seams*.

2. Longitudinal Type. In this type the faces of electrodes wheels are *parallel* to the plane of machine throat. This type is used in welding of *short longitudinal seams.*

3. Universal Type. In this type the faces of electrode wheels can be set either *parallel* or *perpendicular* to the *plane of machine throat* according to need. To facilitate this, the *Operating Head* is made *swivel type* and the lower arm interchangeable.

4. Portable Type. It facilitates seam welding of objects at site. That is, instead of moving the work to the welding head the latter is moved to the work. Such a need may always arise with very *bulky* jobs.

Electrodes Wheels. These wheels vary in diameter from 50 mm to 600 mm. Their thicknesses also vary accordingly. **Machines** carrying *Knurl* or *Friction Drive* use *thinner* wheels and those having *Gear drives* use thicker wheels. Usual thickness varies from 10 mm to 20 mm. *Materials* for manufacture of seam welding electrode wheels are the same copper-base alloys as described in case of spot welding electrodes.

Metals which can be Welded. The process of **Resistance Seam Welding** can be successfully used for **welding** of mild steel, high carbon and low-alloy steels, stainless steel, a large range of coated steels, aluminium and its alloys, nickel and its alloys, magnesium alloys, and a fairly large combination of dissimilar metals. It is, however, not recommended for welding of copper and copper alloys having higher proportions of copper.

24.12 PROCESS LIMITATIONS OF SEAM WELDING

1. It cannot be applied to those portions where abrupt change in contour occurs along the path of electrode wheels, such as on sharp corners.
2. In longitudinal seam welding machines the maximum length of the seam joint that can be made equals the throat depth of the machine.
3. It is necessary to avoid obstructions in the path of electrode wheel or else a corresponding recess should be provided on the wheel periphery to accommodate these.
4. It is necessary that the weld should proceed along a straight line or a uniform curve.

5. Stock thickness above 3 mm cannot be welded with normal ease.
6. For successful welding and production of defect free welds it is essential that the work surfaces should be perfectly clean and free from grease, paint, oil, rust and scale.

24.13 RESISTANCE PROJECTION WELDING

This process is similar to *Spot Welding*, but differs from the latter in that the spots at which welding takes place are previously located by providing *projections* at the desired locations on the surface of one of the work-pieces, as shown in Fig. 24.6. Thus, the surfaces of the workpieces are in contact with each other only at the *projections*. As current is switched on the projections are melted and the workpieces pressed together to complete the **weld**, by pressing the upper electrode downwards. The melted projections form the *welds*.

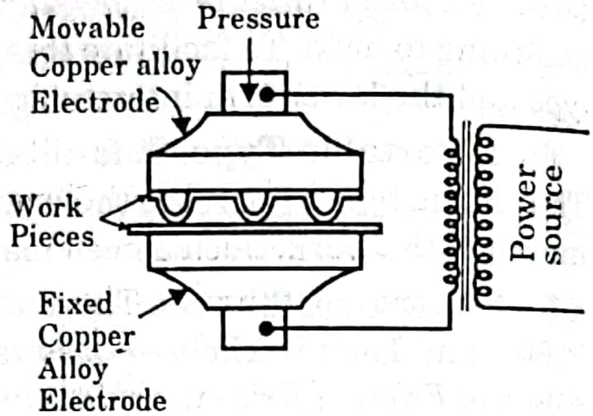


Fig. 24.6. Projection Welding.

This method enables production of several spot welds simultaneously. The *Electrodes*, if required, may be designed and shaped to work as *holding fixtures* for workpieces and assemble them in proper relative location through welding. *Closer welds* than the rough spot welding can be obtained by this process. However, this process is economical only for large-scale production.

24.14 PERCUSSION WELDING

It is a very fast method of welding. It consists of holding the parts at a small distance with their end faces opposite to each other, bringing them closer at a fast speed after switching on the current, thus creating an *arc* between their end faces just before they come in contact and completing the **weld** under *impact*. Some of the metal may *squeeze out* of the joint, but it is very small. The use of this process is limited to very thin wires, with their diameters ranging between 0.05 mm and 0.38 mm. It can also be used for **joining wires of dissimilar metals**, such as copper to nichrome and copper to stainless steel.

24.15 OTHER RESISTANCE WELDING PROCESSES

1. Spike Welding. It is a resistance welding method in which large amount of electricity is stored up in **Capacitors** and then the same is released rapidly through the *electrodes* and the *metal pieces* to be joined. This current flow is allowed for a very small interval and its timing is controlled electronically. The welding is, therefore, very rapid and consequently the chances of *warpage* of workpieces and of *contamination* are altogether eliminated. This process can be successfully used for welding of almost all metals and alloys, metals of different thicknesses together and dissimilar metals also.

2. Metal Foil Welding. This resistance welding process enables **Butt-Welding** of sheet metal. The *Electrodes* used are *wheel type*, as for seam welding. The metal sheets to be joined are placed between electrode wheels and the abutting edges are covered at top and bottom with very thin metal foils, the foil thickness is approximately 0.25 mm and the same is made of the same material as the workpiece metal. A distinct feature of the **weld** formed is that it has a *raised Bead*.

3. Metal Fibre Welding. It can be described as an extension of *Resistance Spot Welding* process. In this, the equipment used is same as in spot welding. It is mainly used for making **Lap Joints**. In this process a small piece of *metal fibre sheet* is introduced between the workpieces to be joined. The workpieces are held as usual between the electrodes. The electrodes pressure employed is very low and, therefore, the indentation on the work surface is also very small.

24.16 GAS WELDING

It is a **Fusion** or **Non-pressure** welding method in which a strong *gas flame* is used to raise the temperature of the ends of the pieces to be joined to a heat sufficient to melt them. The metal thus melted starts flowing along a definite path to form a strong **weld**. A filler metal may be added to the flowing molten metal to fill up the cavity made during the end preparation. So many different combinations of gases can be used to obtain a *heating flame*, but the most common of these are *Oxygen* and *Acetylene*, oxygen and hydrogen and oxygen with coal gas, of which the first one is very extensively used. The **filler rod** or **welding rod** which provides the additional metal required is of the same or nearly same composition as that of the metal of which the pieces to be joined are made.

Oxy-hydrogen mixture can be used for welding of only such metals of which the melting point is low such as aluminium, magnesium, lead, etc. It is for the reason that the temperature of the flame produced is *too low* to produce effective *fusion* of high melting point metals. For similar reasons the other gas mixtures, like *oxygen—natural gas, oxygen—Propane, oxygen—coal gas*, etc., cannot used for welding of high melting point metals. If, however, efforts are made to raise the flame temperature of these mixtures, by increasing the proportion of oxygen, the flame atmosphere becomes highly *oxidizing*, which is an obvious disadvantage. It is only for these reasons that the use of these gases is largely confined to **Brazing** and to some extent to **Braze Welding** only.

The oxygen used should be highly pure since even a small proportion of impurities has a considerable effect on the combustion value of oxygen. Its purity should be above 99.5%. The common impurities associated may be nitrogen, argon and water vapour.

24.17 OXY-ACETYLENE WELDING

The process of **Oxy-Acetylene Welding** can be used for welding almost all metals and alloys used in engineering practice. The advantage of using *Acetylene*, instead of other fuels, with *Oxygen* is that it produces a comparatively *higher temperature* and also an **Inert gas Envelope,** consisting of carbon dioxide and water vapours, which prevents the molten metal from *oxidation*. The *highest temperature* that can be produced by a *flame* of *oxygen* and *acetylene* is nearly 3200°C. There are two systems of **Oxygen-Acetylene Welding.**

***(i)* High Pressure System.** In this method both oxygen and acetylene are derived for use from *High Pressure Cylinders*.

***(ii)* Low Pressure System.** In this system oxygen is taken as usual from a high pressure cylinder but acetylene is generated by the action of water on carbide (usually calcium carbide), in a **Low Pressure Acetylene Generator.**

24.18 OXY-ACETYLENE WELDING AND CUTTING EQUIPMENT

The **High Pressure Oxy-acetylene Welding and Cutting Equipment** consists of two large steel **Cylinders**; one containing *oxygen* at high pressure and the other *Dissolved Acetylene,* also at high pressure (See Fig. 24.7). Both these cylinders are usually painted with *distinct colours* on the outside surfaces; **Oxygen Cylinder** in ***Black*** and acetylene cylinder in **Maroon.** Oxygen is filled in the cylinder at a pressure of 125 kgs to 140 kgs per square centimeter (or 1800 lbs. p.s.i. to 2000 lbs. p.s.i.). **Acetylene Cylinders** carry a *porous mass* inside, soaked in **Acetone,** which has a capacity to dissolve 25 times its own volume of acetylene for every atmosphere of pressure applied. **Acetylene** is compressed into these cylinders so as to dissolve in *acetone* and that is why it is usually termed as **'Dissolved Acetylene'**. These cylinders are usually filled to a pressure of 16 kgs to 21 kgs per sq cm (or 255 lbs p.s.i. to 300 lbs p.s.i. nearly). The *lower pressure* for these gases, out of the ranges given above, are most generally used for filling them in the cylinders which are generally used in common engineering work. Dissolved **Acetylene** cylinder should be handled with enough care and should not be exposed to such conditions which may result in an appreciable rise in temperature. As far as possible, their shifting from one place to the other by hands should be avoided. For transporting them a good **Trolley** of some standard make should be used.

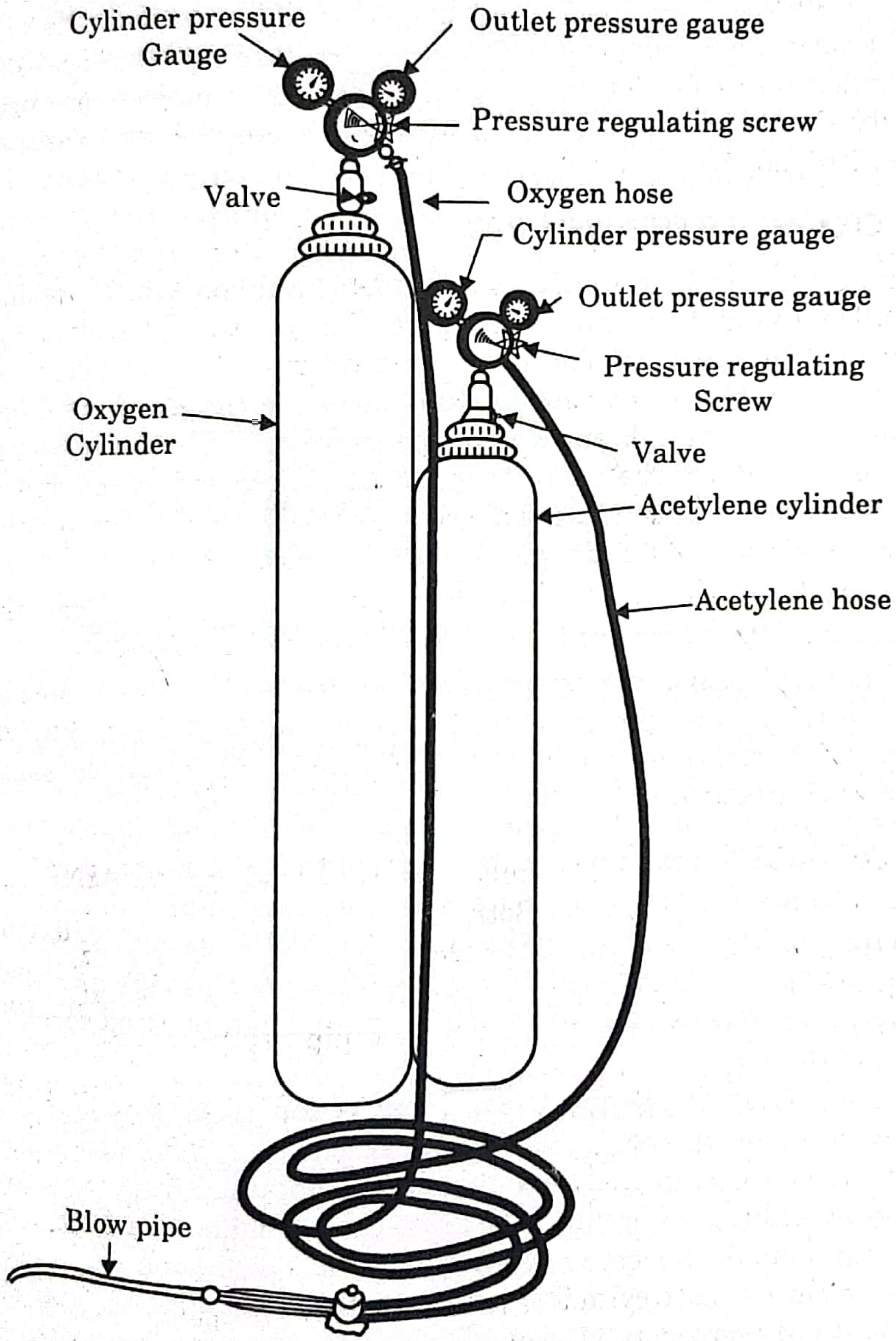


Fig. 24.7. High pressure welding plant.

In the **Low Pressure Equipment** we use oxygen as usual from a high pressure cylinder but acetylene is drawn from a **Low Pressure Acetylene Generator**, where it is generated by the action of water on calcium carbide in a **Water-to-carbide Plant** or by its reverse process in a **Carbide-to-water Plant**. The former is more commonly employed although opinions differ about the relative efficiency of these two plants. Usually acetylene is supplied from the generator, at low pressure, through a **gas holder** which is fitted inside the *generator* itself or placed separately outside. A *Hydraulic non-return* **Back-pressure Valve** is incorporated between the gas-holder and the blow pipes to prevent any chance of oxygen *blowing back* into the generator and causing an explosion. If any pipe connections are required only *iron tubes* should be used. *Copper pipes* should never be used in connection with acetylene plants. In case more than one *Blow Pipes* are connected to the acetylene generator, separate *Back-pressure Valves* should be used for each.

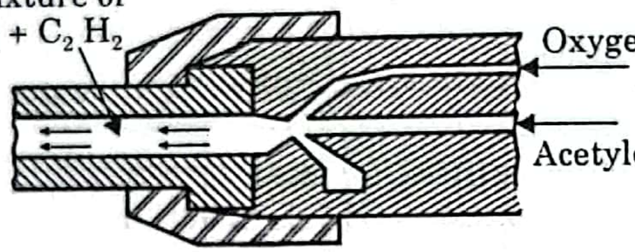


Fig. 24.8. Sectional view of a high pressure blowpipe.

24.19 BLOWPIPES OR TORCHES

Blow Pipes or **Torches** used both in welding and cutting are made in different designs and sizes to suit the work. The **High Pressure Blow Pipe**, shown in Fig. 24.8, consists of different *passages* (connected to hoses) which mix in a chamber. One of these passages is for oxygen and the other for acetylene. Both these gases are mixed in the chamber and then driven out through the *Orifice* of the *Blowpipe Nozzle* with the desired velocity. These *nozzles* are usually known as **tips** and are made interchangeable so that the same blow pipe can be used for different sizes of the **tips**.

The **Low Pressure Blow Pipe** is constructed to work on the principle of an **Injector**, (See Fig. 24.9). The reason for such a design is that the pressure of *acetylene* that can be obtained from the generator is too low calling for *oxygen* to be drawn at a considerably high pressure, ranging from 0.5 kg per sq cm (nearly = 7 lbs. p.s.i.) to about 3.5 kgs per square cm (= nearly 50 lbs. p.s.i.). In this *blowpipe*, oxygen at high pressure is made to pass through the **Injector type Nozzle** which, in doing so, draws the acetylene along with it to the mixing chamber and then to the outlet of the *tip*.

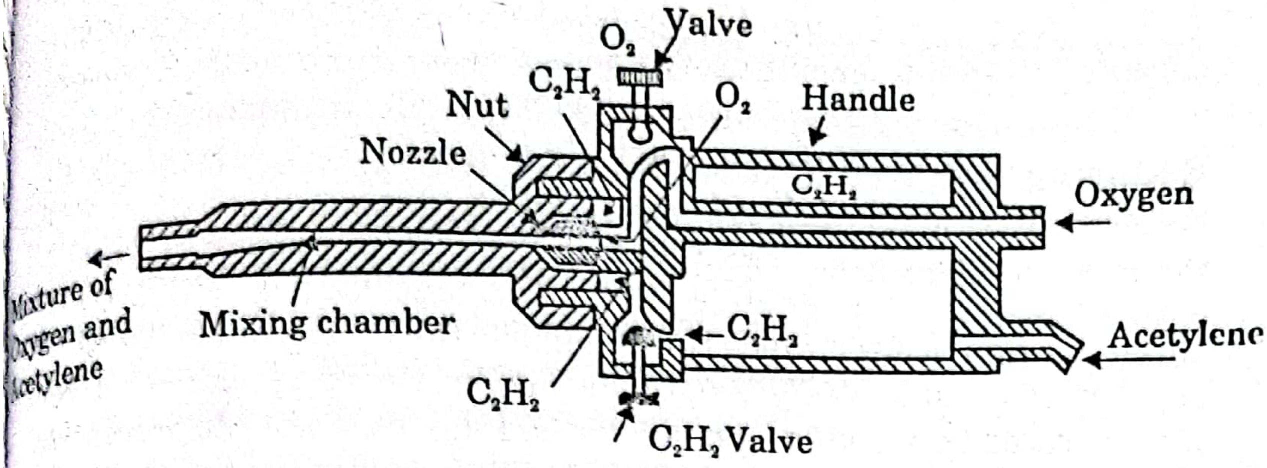


Fig. 24.9. Cross-section through a low pressure blow pipe.

The different *Sizes of Tips* enable the operator to select a suitable one to obtain the desired size of the *flame* that will suit the particular thickness of the metal to be welded. These tips are replaceable and the sizes of their *orifices* control the flow of gas mixture. Different manufactures give their own code number to each size of the *tip-orifice* and their literature should be thoroughly surveyed while selecting a particular size. Tips with *smaller orifices* produce *Smaller Flames* and those with *larger size orifices Larger Flames*. The former should be chosen for fine work and welding of thin sections whereas the latter for heavier work.

For the sake of reference, Table 24.2 provides the welding data of **SAFFIRE 1 HP-1 Welding Blowpipe,** manufactured and marketed by Indian Oxygen Ltd., India. The figures given in the table are recommended only as a guide. They will slightly vary according to local conditions like flame setting, condition of material, skill of operator, hose length, etc. It is recommended that for better results with the given tips a 4.75 mm bore hose should be used.

Table 24.2. Welding data for SAFFIRE 1HP-1 Welding blowpipe

Welding Thickness MS		*Orifice Sizes of Tips*								
	mm	.91	1.2	2.1	2.6	3.2	3.9	4.8	6.4	8.0
Tip Number		1	2	3	5	7	10	13	18	25
Oxygen pressure	kg/cm²	.14	.14	.14	.14	.28	.28	.28	.42	.42
Acetylene Pressure	kg/cm²	.14	.14	.14	.14	.28	.28	.28	.42	.42
Consumption of Each gas	Cubic Meter per Hour	.03	.06	.09	.14	.2	.3	.4	.5	.7

24.20 PRESSURE REGULATORS

These are fixed just on the top of the gas cylinders and carry a **Reducing Valve** each. Gases from the High-pressure Cylinders are just passed through these *regulators* and then fed to the *blowpipe* after their pressure has been reduced to the desired extent by means of these valves. The pressure is regulated according to need by adjusting the *spring pressure* on the **diaphragm** by means of screw called *Pressure Regulating Screw* (Fig. 24.7). The inside portion of the valve is divided into two parts by this *diaphragm*. One side is connected to the cylinder and carries the gas at high-pressure, and is known as *High Pressure Chamber*. The other side, known as *Low Pressure Chamber, is connected to the Blowpipe through hose* and carries the gas at the desired working pressure. Two **Pressure Gauges** are fitted to both these chambers (one each). One of these shows the pressure inside the cylinder, *i.e.*, on one side of the diaphragm, and the other the *Working Pressure* at which the gas is being drawn for operation. Two stage regulators are preferred to the one stage regulator. The total *pressure drop* in the *first stage* is fixed and in the *second stage* it can be regulated, in the same way as described above, to the desired extent by means of the *Pressure Regulating Screw*. The use of this type of regulator reduces the chances of accident to the minimum and ensures a greater life of the diaphragms.

24.21 OTHER EQUIPMENT

The other equipment needed in oxy-acetylene working includes *keys* for *cylinder valves, hoses* for *oxygen* and *acetylene* with *connections* and *spanners, safety equipment* like goggles, screens, leather hand gloves and leather apron, chipping hammer, chipping goggles, wire brush and spark lighter, etc. In addition a Trolley is needed to carry the oxygen and acetylene cylinders from one work place to the other.

24.22 WELDING RODS

Sufficient care should be taken in selecting a suitable *Welding Rod* or *Filler Rod* for welding a particular material. Always the best available quality of the rods should be selected as the cheaper qualities are likely to contain more impurities and they will result in the production of an *unsound Joint*. Welding rods suitable for welding different metals are produced by various standard manufacturers under their own *Trade names* and it is advisable, at least for a beginner, to be guided by the manufacturer's instructions in the selection and use of these rods.

However, it is reckoned that a welding rod will possess the same or nearly same composition of its constituents as that of the metal which is to be welded.

24.23 FLUXES

Except for the common grades of mild-steel, a **Flux** is always necessary for successfully welding of different metals and alloys. Enough restraint should be exercised so that the quantity of flux used should not be above requirement. It should, however, be sufficient enough to dissolve the *scale* (*oxide*) present on the surface of the metal due to its long exposure to the atmosphere and that formed during heating. Also, the *flux* should be *lighter* in comparison to the molten metal so that it may float on the top of this metal during the operation and may deposit on the upper surface of the solidified metal after cooling, so as to be chipped off after this.

It should be stored in a dry place and should not be allowed to mix with other types of fluxes. *Borax* and *Sodium Carbonate* are good fluxes for ferrous metals. The fluxes should not be allowed to remain on the finished weld as their presence will lead to a quick *corrosion* of the *joint*, which may ultimately result in its failure. A weld should, therefore, be *cleaned* well soon after it is finished.

24.24 TYPES OF FLAMES

It is an established fact that the *properties* and *nature* of the **Gas Flame** have the maximum effect on *Oxy-acetylene Welding*. Proper adjustment of the flame leads to successful and efficient welding. This adjustment can be made both in regard to the *characteristics* and the power of the flame by regulating the pressures of oxygen and acetylene. A **Flame** in which only *acetylene* burns is **yellow** in colour and is of no commercial use, because of its incapability to develop high temperature. The three *kinds* of **Oxy-acetylene Flames**, which are used in engineering works, are as follows :

1. Oxidising flame 2. Neutral flame 3. Carburising flame.

The *combustion* of gases takes place in *two* or *three stages* in these flames. Different types of flames, together with the different terms used in connection with them, are shown in Fig. 24.10. The **Cone** or **Inner tip** is the sharp white portion of the flame which extends just next to the *tip* of the *nozzle*.

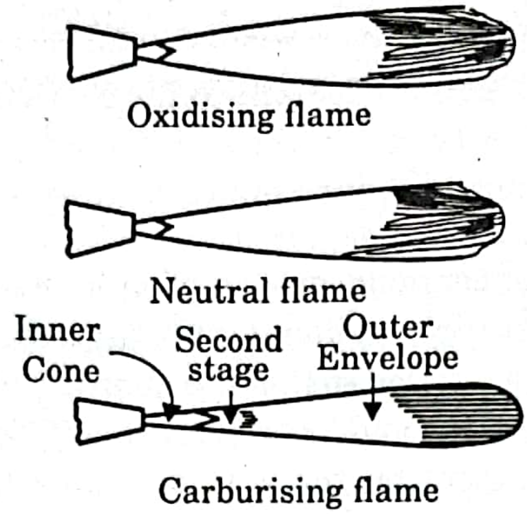


Fig. 24.10. Oxy-acetylene flames.

The maximum temperature is available at the *pointed tip* or *end* of **this cone**. The second stage, or the so-called **Brush**, or **'Feather'** is next to the cone and normally occurs in *Carburising Flame* only. The **Outer Envelope** is relatively much larger than the other two described above and it acts as a *covering* for the molten pool during welding in order to prevent it from being oxidised.

The chemical action that takes place in the flame is that the combustion of gases in the first stage gives *Hydrogen* and *Carbon monoxide*. These products, on receiving oxygen from the atmosphere, burn further to give *Carbon dioxide* and *water vapour* or *steam* which forms the *Outer Envelope*.

These chemical reactions can be shown through equations as follows :

$$C_2H_2 + O_2 \rightarrow 2CO + H_2$$
$$2CO + H_2 + 3O \rightarrow 2CO_2 + H_2O$$

The flame can be adjusted to have desired atmosphere. The formation of *Inner Cone* is the result of increasing oxygen pressure. An **Oxidising Flame** can be attained by increasing the supply of oxygen (*i.e.* having excess of oxygen than acetylene). Such a flame is normally not required except in case of *Brass*. If equal quantities of oxygen and acetylene are mixed they produce a **Neutral Flame** having a well defined *white cone*. This type of flame has the maximum use and a good many metals can be welded successfully by this flame, as shown in table 24.3. A **Carburising Flame** is one in which the supply of *acetylene* is in excess as compared to *oxygen*. The temperature attained by these flames vary from 3100°C to 3500°C and the most commonly used temperature is about 3200°C, which can be attained without any appreciable amount of difficulty. Requirements of different types of Flames for welding of different common metals are given in table 24.3.

Table 24.3. Types of flames required for different metals.

Sl. No.	*Metal*	*Flame*
1.	Brass	Oxidising
2.	Cast Iron	Neutral
3.	Mild steel	”
4.	Stainless steel	”
5.	Copper	”
6.	Aluminium	”
7.	Nickel	”
8.	Monel metal	”
9.	Lead	Carburizing

24.25 WORKING PRESSURES

As already explained in the foregoing articles, the working pressures of *oxygen* and *acetylene* differ considerably from those at which they are contained in the cylinders. The *working pressure* for Oxygen in **High Pressure Welding** varies up to 0.35 kg per sq cm (nearly 5 lbs p.s.i.) and for *cutting* it may go up to 3.5 kg per sq cm (nearly 50 lbs p.s.i.). The normal *working pressure* of Acetylene, in both *welding* and *cutting* in *High Pressure System,* varies between 0.14 kg per sq. cm (nearly 2 lbs p.s.i.) and 0.21 kg per sq cm (roughly 3 lbs p.s.i.). In **Low Pressure Plant** *Acetylene* is drawn at a pressure of about 0.023 kg per sq cm (= 0.3 lbs p.s.i.) whereas the *Oxygen pressure* varies from nearly 0.5 kg per sq cm (7 lbs p.s.i.) to about 3.5 kg per sq cm (nearly 50 lbs p.s.i.) depending upon the thickness of the metal.

24.26 PREPARATION FOR WELDING

Two main types of **Joints** made in gas-welding are the **Butt welds** and the **Fillet Welds**. Their commonly used forms are shown in Fig. 24.11 and 24.12 respectively. Choice of the type of *end preparation* is governed by the kind of metal to be welded, its thickness and the

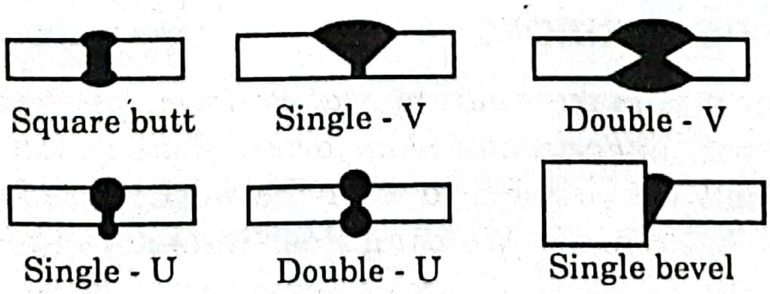


Fig. 24.11. Butt-welds.

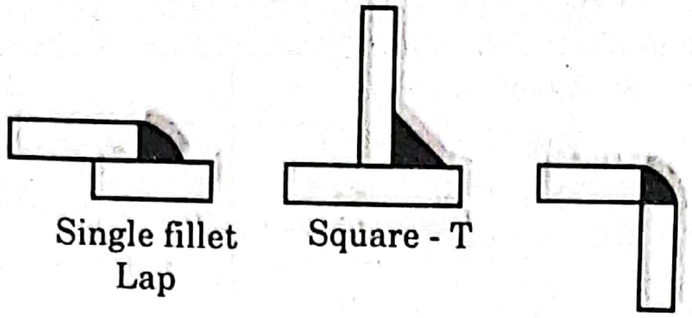


Fig. 24.12. Fillet welds.

technique of welding. **Butt Welds** are very strong in tension and are mainly employed for joining such plates of which the *ends lie* in the *same plane* facing each other. Contrary to this, the plates which are to be joined by means of **Fillet Welds** do not lie in the same plane. This type of **Welds** are mainly used in *structural work*.

A proper **Edge Preparation** should always be adopted in order to achieve good results. Table 24.4 will provide a satisfactory guide in this respect.

Table 24.3. Selection of Edge Preparation

Sl. No.	*Plate thickness*	*Edge preparation*	*Welding method*
1.	Below 1.6 mm (1/16″)	Flanges at the ends	Leftward
2.	1.6 mm—3.2 mm	Square butt	”
3.	3.2 mm—4.8 mm	Single-V (80°)	”
4.	4.8 mm—8.0 mm	Square butt	Rightward
5.	8.0 mm—16.0 mm	Single-V (60°) or single-U	”
6.	Over 16.0 mm	Double-V or double-U (*U-shape is preferred over 25 mm although it can be used for lesser thickness also*).	”

24.27 WELDING POSITIONS

It is easiest to make welds in *Flat Position, i.e.*, both the parent metal pieces lying in *horizontal plane* over a flat surface. But, many a times it becomes unavoidable to weld the workpieces in some other positions also. The common **Welding Positions** can be summarised as follows :

1. Flat Position. In this welding position the workpieces lie flat such that their *upper faces* are nearly in *horizontal plane*, or else they are held in such a way that the *axis* of the *weld* being made remains *horizontal*. *Welding* is done from the upper side of the joint and the *welding material* is normally applied in a downward direction. On account of this downward direction of application of welding material this position is also sometimes called as **Downward Position**. The face of the weld remains nearly horizontal, as shown in Fig. 24.13.

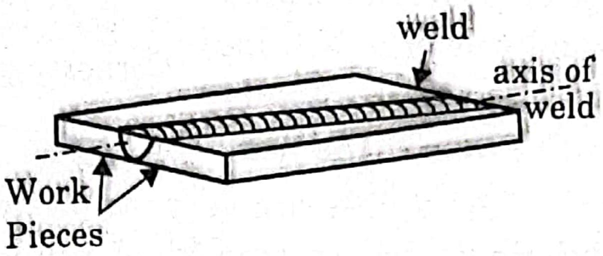


Fig. 24.13. Horizontal welding.

2. Horizontal Position. In *Horizontal Position* of *Welding* the relative location of the two workpieces differs, depending upon whether it is a **Groove Weld** or a **Fillet Weld**. In the former case the two workpieces rest one over the other with their *flat faces* in *vertical plane*, as in Fig. 24.14. After *tacking*, welding commences at the right-hand side and proceeds leftwards, the *filler rod* preceding the *welding torch*. As shown, the *axis* of the weld lies in a *horizontal plane* and its *face* in *vertical plane*.

In case of a *Fillet Weld* (Fig. 24.15) the two workpieces are at right angles to each other. Welding is performed on the upper side of the horizontal workpiece and against the vertical face of the righthand vertical workpiece. As usual, the welding starts from the righthand side and proceeds towards the left. The *axis* of *weld* is again in *horizontal plane*, its face is inclined with both horizontal and vertical planes.

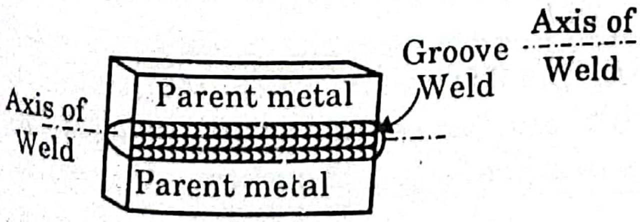


Fig. 24.14. Horizontal welding position—groove weld.

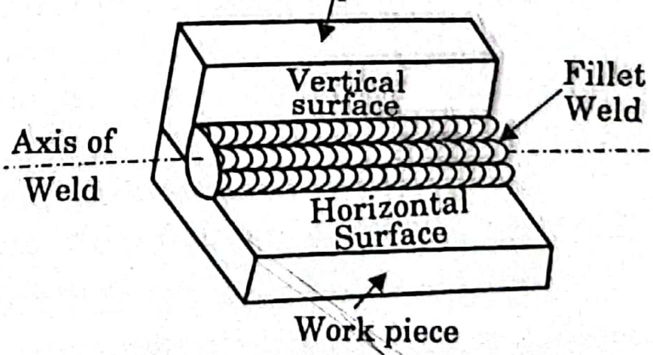


Fig. 24.15. Horizontal welding position—fillet weld.

3. Vertical Position (Fig. 24.16). In this position of welding the *axis* of the *weld* remains either *vertical* or at an *inclination* of less than 45° with the vertical plane. The welding commences at the bottom and proceeds upwards. The *Torch Tip* is kept pointing upwards so that the pressure of the outcoming gas mixture forces the molten metal towards **the base metal** and prevents if from falling down. More details about this welding position are given in the next article.

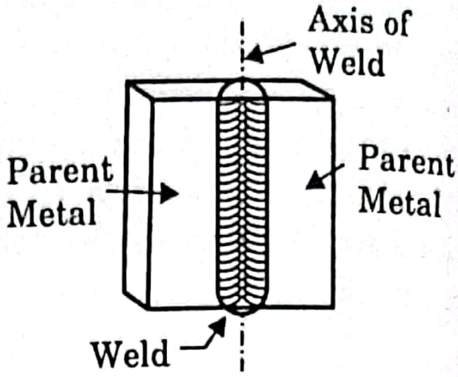


Fig. 24.16. Vertical position of welding.

4. Overhead Position. In this Welding position welding is performed from the underside of the joint. The workpieces remain over the head of the welder. The *workpieces* as well as *axis of the weld* all remain in approximately horizontal plane (See Fig. 24.17).

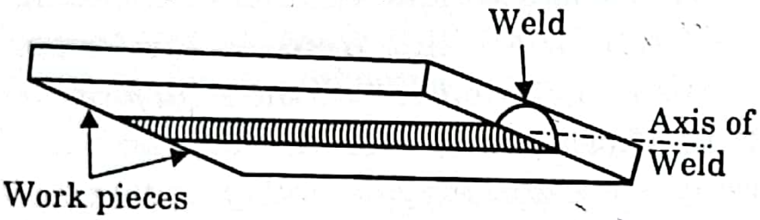


Fig. 24.17. Overhead welding position.

It is the most difficult position and calls for a very high degree of skill on the part of the welder. The *tip of the* welding torch should be so directed that the pressure of the gas flame tends to force the molten metal towards the *parent metal*. This is further helped by the *surface tension* of the molten pool. Inspite of all this, the *gravitational force* always tries to pull the molten metal downwards, although it is considerably counteracted by the above precautions. As a further precaution a welder's endeavour should be to keep the temperature of the molten pool as close to its lowest flow temperature as possible, since overheating of metal will result in higher fluidity and, hence, an increase in chances of its falling down.

All the above four welding positions are equally adopted in Electric Are Welding also with similar relative locations of the workpieces and weld axes as illustrated in the above diagrams.

24.28 WELDING METHODS

The selections of a proper *Technique* or *Method* will depend upon the metal to be welded, its thickness and the properties expected of the weld. The following **Methods** are commonly used :

1. Leftward welding 2. Rightward welding 3. Vertical welding.

1. Leftward Welding. It is also known as **Forward Welding**. In this, the *filler rod* is held in the left hand and the *blowpipe* in the right hand. Welding commences at the right-hand side and proceeds towards the left : blowpipe following the filler rod as shown in Fig. 24.18. This method is widely used for butt welding of steel plates, particularly upto 6 mm thickness. Above this thickness it is found to be uneconomical and is, therefore, replaced by rightward welding. A 80° 'V' is prepared at the ends of the plates to be joined.

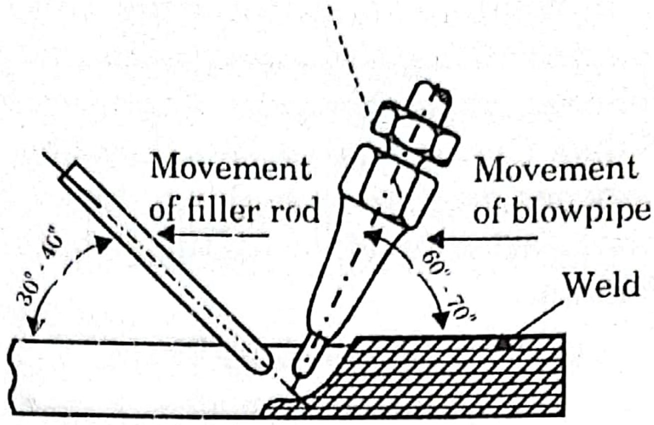


Fig. 24.18. Leftward welding.

2. Rightward Welding. Contrary to the above, in **Rightward** or **Backhand Welding** the *filler rod* follows the *blowpipe* during the welding operation. Filler rod and blowpipe are held, as usual, in the left hand and right hand respectively and the welding commences at the left-hand side and proceeds towards the right, as shown in Fig. 24.19. The preparation of 'V' in this case carries an included angle of 60° instead of 80°, required in leftward welding. Also, it will be observed that the *inclination* of the *Blowpipe* with the plate is comparatively *less*, *i.e.*, only 40°-50° as against 60°-70° in case of Leftward Welding. This method is very widely used for welding of steel plates. For higher thicknesses, its use in place of the former results in a lower consumption of filler rod, quicker welding and less consumption of the gas : thus, effecting a considerable saving.

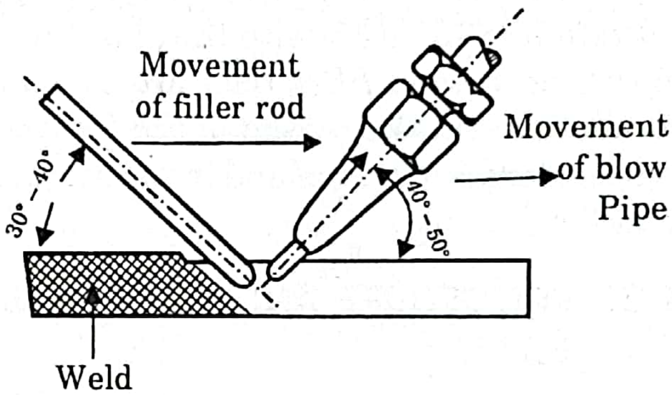


Fig. 24.19. Rightward welding.

3. Vertical Welding. This is a very useful and economical method of welding which can be employed for metal plates of *any thickness*, but only when it is possible to place these plates in a vertical plane. In plates upto 6 mm thickness, *welding* is to be performed from *both sides*. This method does not call for any *edge preparation* upto 16 mm thickness of the plates. With the result, a considerable saving is effected in time and money on account of this factor as well as in the corresponding consumption of the *filler rod*.

Welding *starts* from the *bottom* of the plates and proceeds *upwards* along the *seam*. In this method, the *filler rod* moves ahead followed by the *blowpipe*. The operation can be performed either by a *Single Operator* or by *Two Operators* working simultaneously. When only one operator is working, the *inclination* of the *blowpipe* with the plate varies directly with the plate thickness, and is approximately as follows :

For 1.6 mm thick plates	= 25°
For 3.2 mm thick plates	= 50°
For 5 mm and above	= 90°
Inclination of filler rod in all cases	= 30°

Both the *blowpipe* as well as the *filler rod* are moved is a *zig-zag* way (side to side) as the welding proceeds from the bottom to the top. In case of **Double Operator System** the *blowpipes* are held at the *inclination* of 45° to 55° with the plate on both sides of the seam whereas the *inclinations* of *filler rods* are the same (30°), as in case of single operator system. *Movement* of the *blowpipes* and the *filler rods* of both the operators is *identical* and in the same *zig-zag way* as in case of *Single Operator System*.

24.29 PROCEDURE AND CARE IN OPERATING LOW-PRESSURE PLANT

1. Check up the 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 the oxygen hose to the oxygen regulator. Ensure that the current hoses are connected as above. Acetylene cylinder is usually painted **maroon** and that of the oxygen **black**.
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 outcoming 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.

24.30 PROCEDURE AND CARE IN OPERATING HIGH-PRESSURE PLANT

1. Arrange the two cylinders, one of oxygen and the other of acetylene, in proper position (*upright*).
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 fittings 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 to 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. Then, by means 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, before starting the work, that the nozzle fitted in the blowpipe is of correct size as prescribed by the manufacturers.
14. Ends of the hoses should be properly secured to the regulators by means of suitable clips or any other means.
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. Adjust the required pressure of the two gases and light the mixture.
17. Adjust the flame by regulating the supply of the gases in the current proportion.
18. After the work is completed the oxygen valve should be closed first, followed by the acetylene valve.
19. Care should be taken always that *oil or grease* do not remain on any fitting in the unit otherwise it may lead to an explosion if these materials are exposed to oxygen under pressure.
20. Never fit the pressure gauge by means of hammering, etc., as it is a precision instrument and calls for a careful handling always.
21. As a safety measure, never try to inhale the oxygen directly from the cylinder.
22. The oxy-acetylene flame should not be allowed to impinge upon any gas cylinder.
23. Never use a washer or any other packing made of an inflammable material in fixing any fitting on gas cylinders.
24. Always ensure before starting the operation that you have enough st e of filler rods, flux and gas etc., with you as it is not an appreciable practice to stop the operation in the middle of the job.

24.31 OXY-ACETYLENE CUTTING

It is a **chemical** process in the sense that the metal, at the portion where it is to be cut, is actually made to *oxidise* under the action of the *flame*. All *ferrous metals* 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 metal from there. This process is a very efficient one which enables a fairly *quick* and *clean* cutting of ferrous metals.

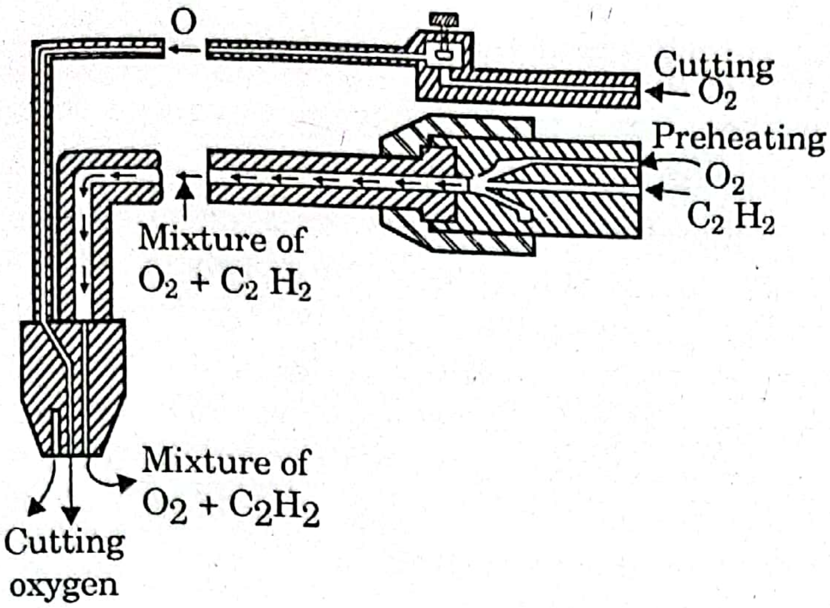


Fig. 24.20. Cross-section through an oxy-acetylene cutting blowpipe.

The **Blowpipe** used for this purpose is of special type which, in addition to the usual passages of oxygen and acetylene of a welding blowpipe, carries an additional provision for supplying a *strong jet* of Oxygen through the *nozzle* after the metal has been sufficiently heated to red heat. Thus, this *Blowpipe* carries two separate *passages* of oxygen; one for supplying oxygen to burn with acetylene to form the **Heating Flame** and the other, placed centrally in the nozzle to provide the required **jet** for oxidation. These passages are respectively known as **Preheating Oxygen Passage** and **Cutting Oxygen Passage** and the gas passing through them is also termed accordingly *i.e.*, **Preheating Oxygen** and **Cutting Oxygen** respectively (See Fig. 24.20). Since this blowpipe can be moved in any desired direction it is possible to cut the metal in any shape we like.

For starting the operation, *Acetylene* and the *Preheating Oxygen* are turned on and the *flame* adjusted to **neutral**. After the metal has been heated to red heat or a little *whitish* the *Cutting Oxygen Valve* is operated to make a sharp **Oxygen Jet** to strike against the hot metal. This forms the iron oxide there and the same gets melted immediately. It is then *blown off* by the oxygen jet; thus providing a narrow **slit** along the cutting line. It is necessary to maintain a proper distance (usually about 6 mm) between the *nozzle tip* and the *top surface* of the *metal plate*. This is accomplished by fixing the blowpipe on a **Guide** which slides on the metal surface during the operation and facilitates the above requirement. The movement of the blowpipe should neither be too fast nor too slow. It should be so controlled that it enables the cut to penetrate fully through the metal thickness, which will be evident from the *sparks* coming out of the slit on the other side of the metal. A too slow movement will spoil the edge of the cut as the *preheating flame* will start melting them. In the same way a *too fast* movement will prevent the cut from penetrating fully through the metal thickness.

For cutting cast iron, a *Carburising Preheating Flame* should be adjusted and the *nozzle* kept at a comparatively greater distance. Also, cast iron needs a relatively longer preheating than steel before actual cutting starts, so much so that the metal gets melted by preheating. After this, the *slag* and *molten mass* are blown off by means of the cutting oxygen jet and the cut then proceeds further in the same way. The *blowpipe* in both the cases *i.e.* for cast iron as well as steel, is drawn towards the operator during cutting.

24.32 ELECTRIC ARC WELDING

It is a **Fusion Welding Process** in which no mechanical pressure is applied for joining the metals. In this, the metal pieces to be joined are heated locally to the melting temperature, by creating an **Electric Arc**, and then allowed to solidify to form the **Welded Joint**. *In some cases only the metal of the pieces to be joined is made to* form the joint while in the others additional metal is provided by melting a **wire** into the weld metal. The weld metal obtained from the work pieces is known as **Parent Metal** while the additional metal provided by melting the wire, as described above, is known as **Filler Metal**. This additional material is provided by the **Core Wire** of the *Electrode* in cases of **Metal Arc Welding** and by a *filler rod* in case of **Carbon Arc Welding**.

The *Electric Arc Welding* processes are divided into the following two main kinds :

1. Metallic arc welding
2. Carbon arc welding.

24.33 METAL ARC WELDING

In this process a **Metal Electrode** is used and the **Arc** is maintained between this *electrode* and the *workpiece,* which respectively form the two *terminals*. The *electrode* used can be either **bare** or **coated type**. **Bare electrodes** have the same or nearly the same composition as that of the parent metal. They have the disadvantage that their surfaces may be subjected to oxidation. **Coated electrodes** may either have a light coating of some material, which prevents their surface from being oxidised, or may carry a strong coating of **Flux**. For welding of ferrous metals the **core** of the electrodes is usually made of mild steel and the coating around it is made such that it acts a as a **flux** as well as provides the necessary constituents to the weld metal.

24.34 ARC WELDING PRINCIPLE (SHIELDED METAL ARC)

The *Principle* of **Shielded Metal Arc Welding** consists of establishing an **Electric Arc** between a metal *electrode* and the *workpiece* to be welded. The *Arc* can be described as a stream of *incandescent vapour* which acts as a conducting medium for *electric current* from one terminal to the other to complete the circuit. The electric current has a fairly *high voltage* to overcome the extra resistance offered by the vapour.

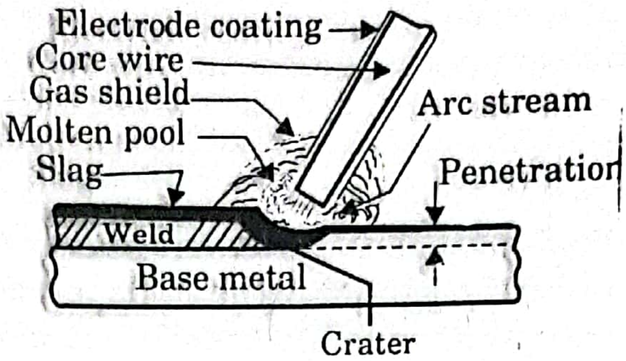


Fig. 24.21. Schematic diagram of shielded metal-arc welding.

The process is illustrated by means of a schematic diagram in Fig. 24.21. The *metal* of the workpiece to be joined is called **Base Metal** or *Parent Metal*, and that provided by the *electrode* as **Filler Metal.** The metal *Electrode* is coated with *Flux* which performs the following **functions** :

1. It produces a gas which provides a shield around the arc to protect it from atmosphere.
2. It forms slag by mixing with impurities of the molten metal and, thus, refines the metal.
3. The slag, being lighter, floats over the surface of the molten metal and on solidification forms a thin layer over the weldment, which helps in gradual and uniform cooling of weld and prevents its oxidation during cooling.
4. In some cases, it also carries necessary alloying elements which are added to the molten metal.
5. It promotes conduction of electric current across the arc and helps in stabilizing the arc.
6. It also helps in controlling the bead shape by providing necessary materials for this purpose.

Arc Crater. This term refers to the depression caused by the *penetration* of electric arc into the parent metal. Its depth depends on the thickness of the parent metal. By observing this *Crater Depth* a welder can have an idea of arc penetration during welding. It should, however, be noted that if such a depression remains in the *Bead*, after welding, the same is considered a defect. This defect (*crater*) occurs where an arc is broken. Care should, therefore, be exercised during welding to prevent the occurrence of this defect.

24.35 ARC BLOW

It is a typical characteristics of D.C. arc welding, which is normally not found when using A.C. During **D.C. Arc Welding** it is quite often observed that the arc *fluctuates* occasionally or is *unstable*. It is due to the *magnetic forces* acting on the arc on account of the *magnetic fields* set-up around it. When the electric current flows through the electrode, workpieces and the ground cable, magnetic fields are set up in planes perpendicular to the direction of flow of current. When these magnetic fields around the electrode or the workpiece are unbalanced they tend to *bend the arc* away from its intended path. This *deflection* of the arc from its intended path is called **Arc Blow.** This effect is more pronounced where there is a greater concentration of *magnetic fields,* that is where there is more crowding of lines of *magnetic flux,* causing a greater magnetic force to act on the arc to deflect it from its normal path. Since this concentration is always more at the ends the chances of *Arc Blow* are always greater at the beginning and the end of the weld. The reason of this phenomenon being present mainly in D.C. welding is that, due to the **Fixed Polarity,** the induced magnetic fields are *constant* in direction. In **A.C. Welding** there is no *fixed polarity* and direction of current flow goes on changing. Therefore, there is no constant direction of magnetic fields and, hence, no chances of an arc blow.

The deflection of arc, or *Arc Blow*, can be in the following directions :

1. In the direction of electrode travel—called **Forward Blow.**
2. Opposite to the direction of electrode travel—called the **Backward Blow.**
3. Towards a side—called the **Side Blow.**

Out of the above three, the chances of arc blow acurring towards the side are very rare. The deflection is normally *forward* or *backwards*. **Backward Blow** occurs while welding towards the end of the joint, into a corner or towards the ground connection. **Forward Blow** occurs while welding away from the ground connection or in the beginning of the joint. This results in *incomplete fusion* of parent metal and excessive *weld spatter*. This, in turn, particularly in case of electrodes having thick coatings, allows heavy *slag deposit* in weld *crater* which runs forward under the arc. These factors sometimes become so troublesome that it becomes impossible to make a satisfactory weld. The problem is more severe at the end of the weld than at the start. In case of *severe Arc Blow* the following **corrective measures** may be adopted :

1. If possible, A.C. may be used instead of D.C.
2. The effect can be minimised by reducing the current and the arc length.

3. Arc blow can also be minimised by welding towards a heavy tack weld or an already existing weld.
4. The ground connections should be placed as far as possible from the joints to be welded.
5. If the problem is of backward blow the ground connection should be placed at the start of the weld and welding should proceed towards a heavy tack weld.
6. If forward blow is the trouble-maker the ground connection should be placed at the end of the weld.
7. The ground cable may be wrapped around the workpieces such that the current flowing in it sets up a magnetic field in a direction which will counteract the arc blow.
8. On long welds, *back stepping* may be used.

24.36 ARC WELDING EQUIPMENT

Both **Alternating Current (A.C)** and **Direct Current (D.C.)** are used for *Arc Welding*. When *D.C. arc welding* is to be employed the current is generated by a *D.C. Generator*. This generator can be driven by means of an *electric motor* or by means of a *petrol* or *diesel engine*. Whether it is a motor generator set or an engine generator set, both can be either of Portable type or Stationary type. With the result, the **D.C. Arc Welding Processes** can be employed irrespective of the fact whether the main *A.C. supply* is available or not. In absence of the same an engine driven *D.C. Generator* set can easily by used.

For **A.C. Arc Welding** a *step down* **Transformer** is used which receives current from the supply mains at 400-440 Volts and transforms it to the required voltage for welding, *i.e.*, 80-100 Volts.

Apart from the above main equipment a number of other equipments, particularly for safety and clamping the work, holding the electrodes etc. are required as illustrated in Fig. 24.22. A brief list of this equipment is given below :

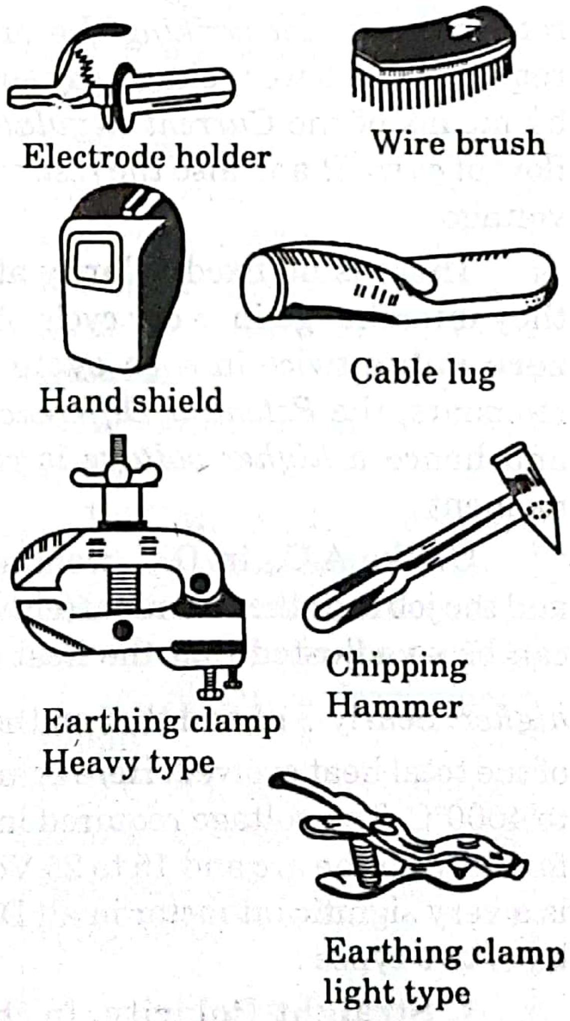


Fig. 24.22. Arc welding and safety equipment.

List of Equipment :

1. Well insulated *Electrode Holders.*
2. *Wire cables* and *cable connectors.*
3. *Welding Helmet* and *Hand Screen* or *Shield.*
4. *Safety goggles.*
5. *Welder's Chipping Hammer.*
6. *Earthing Clamps.*
7. *Cable Lugs.*
8. *Hand Gloves.*
9. *Aprons* and *Sleeves*, etc.
10. *Wire Brush.*

24.37 USE OF A.C. AND D.C. FOR WELDING

As already described in the foregoing articles, we receive **A.C. supply** from power mains at 400-440 volts whereas we require a much less *voltage* for welding. We, therefore, use a **Step Down Transformer** which lowers the voltage to about 80-100 volts. This voltage is actually required only for *striking* the arc and for *maintaining* the same we require a still lower voltage, say about 30 to 40 volts. This is accomplished by means of the *Current Regulator*, through which we can adjust the flow of *current* and also the *resistance* and hence can obtain the desired voltage.

There is no fixed polarity at the terminals when using A.C. and they interchange in every cycle. Also the *Alternating Current* acquires **zero value** twice in each **cycle**. With the result, at these particular moments, the *Potential Difference* between the terminals is also zero and hence a *higher voltage* is required to maintain the arc at this moment.

Unlike A.C., in D.C. welding the electrode acts as one terminal and the job the other terminal (either +ve or –ve). The potential difference can be so adjusted that the heat developed at the *positive terminal* is *higher*, nearly $\frac{2}{3}$rd and that on the *negative terminal lower,* nearly $\frac{1}{3}$rd of the total heat evolved. Here again the temperature of the arc is 3700°C to 4000°C. The voltage required in case of D.C. welding is 60 to 80 Volts for striking the arc and 15 to 25 Volts for maintaining the arc. **Polarity** is a very significant factor in all D.C. welding works. This **polarity** can be of two types :

1. Straight Polarity. In this, the electrode forms the negative terminal and the workpiece positive.

2. **Reverse Polarity.** In this, the electrode forms the positive terminal and the workpiece negative.

These two polarities are known as **Electrode Negative** and **Electrode Positive** respectively. Selection of correct polarity plays a significant role in obtaining a successful weld. It is only due to this factor that almost all the metals can be welded by using D.C. as many metals require more heat to acquire the fusion state than the electrode used *e.g.* copper, and it is possible only through different polarities to have more heat on the job and less on the electrode.

24.38 RELATIVE MERITS AND DEMERITS OF A.C. AND D.C. WELDING

Both **A.C.** and **D.C.** welding sets have their own **Advantages** and **Disadvantages** as shown in Table 24.5 below :

Table 24.5. Comparison between A.C. and D.C.

Use of A.C. in arc welding	*Use of D.C. in arc welding*
1. An A.C. welding transformer is cheaper and simpler in operation.	A D.C. generator set is costlier and more cumbersome in operation.
2. Maintenance of an A.C. transformer is easier and more economical since it has no moving parts.	A D.C. generator carries many moving parts and its maintenance cost is higher.
3. It is less suitable for use at low current with small dia. electrodes.	It is better suited for use at low amperages with small dia. electrodes.
4. Except in case of iron powder electrodes, maintenance of a small arc is difficult.	Maintenance of short arc is easier with D.C.
5. It is preferred for welding at very large distances from the power supply, because voltage drop in long leads is much less as compared to D.C.	In D.C. the voltage drop is relatively higher and, therefore, only short cables are used, prohibiting its use for welding at long distances from power supply.
6. Striking of arc, particularly with thin electrodes, is relatively difficult.	In D.C. it is easier to strike an arc, even with thin electrodes.
7. Bare electrodes cannot be used in A.C. Only specifically designed coated electrodes with coverings containing stabilizers can be used.	Both bare and coated electrodes can be used.

8. Though it can be used for all welding positions but selection of proper electrode has to be made carefully and used of a better skill is needed.	It is easier to use D.C. even for out-of-position welding and for thicker sections because lower currents can be used.
9. It is generally not preferred for welding of sheet metal due to the difficulty in starting the arc.	It is more preferred because starting of arc is easier and the arc remains steady.
10. There is hardly any problem of Arc-blow in A.C.	With D.C. there is always a likelihood of arc-blow, unless proper corrective measures are adopted.
11. Different fixed polarities are not available. Hence it is not suitable for welding all metals, particularly non-ferrous ones.	Distinct fixed polarities can be used for welding almost all metals and different thicknesses.
12. It can be used only when A.C. mains supply is available.	An engine driven D.C. generator set can be used even in absence of A.C. mains supply.

24.39 CARBON ARC WELDING

Only D.C. is used in **Carbon Arc Welding**. The *Negative Terminal* of the supply is connected to the carbon electrode and the *Positive Terminal* to the *workpiece.* The use of **A.C.** is not advisable for the reason that no fixed polarity can be maintained. The reason of connecting the carbon electrode to the negative terminal is that the heat generated at the electrode tip is less than that at the job so that the *carbon content* of the *electrode* is not carried over to the job. If this happens the **resultant weld** will be very brittle and unsound.

This method is suitably used for joining steel sheets and repairing steel castings. **Electrode Holders** used for holding *carbon electrodes* are usually provided with a *magnetic coil* inside, which directs the arc properly and keeps it concentrated at the desired place. This process is carried out both by hands as well as machines. A **flux** is usually employed to prevent the weld metal from picking up carbon from the fused electrode.

24.40 ARC WELDING ELECTRODES

Electrodes commonly used are generally of two types :

1. Bare electrodes
2. Coated electrodes.

Bare electrodes are cheaper but the *welds* produced through these are of poor quality and their use calls for a very high degree of skill on the part of the welder, if satisfactory results are to be expected. They are, therefore, very rarely used in modern welding practice. However, in coil form they are used with *Inert Gases* in a special welding process called **Inert Gas Metal Arc Welding (MIG Welding).**

More popularly used in **Metal Arc Welding** are the **Coated Electrodes** which carry a **core** of bare metallic wire provided with a coating or **covering** on the outside surface. **Mild steel** is the most commonly used material for core wire, but electrodes with *core* of other metals and alloys are also manufactured to suit welding of different metals and alloys under varying welding conditions and requirements. Some of the other *metals* and *alloys* used as *core wire* materials are low alloy steel, nickel steel, chromium-molybdenum steel, manganese-molybdenum steel, nickel-manganese-molybdenum-steel, nickel-molybdenum vanadium steel, aluminium, Albronze, lead-bronze, phosphor bronze, etc. Practically all the *mild steel* coated electrodes are almost similar in composition but differ in the type of *covering* and **flux** used on them. The coverings are provided by either dipping the *wire cores* in a *bath* or during *extrusion*. About 20 to 25 mm length at one end is left bare where the electrode is held in the *Electrode Holder*.

Electrode Coverings. It has been discussed in the earlier articles that the *Flux Coating* provided on the electrodes performs many functions, such as providing a *Reducing atmosphere* to prevent *oxidation*, forming *slag* with metal impurities, stabilising arc, providing necessary alloying elements to the weld metal and so on. To meet these requirements many different materials are used for making electrode coverings. The common *ingredients* of a **flux** which help in *slag formation* and *metal refining* are asbestos, mica, silica, fluorspar, stealite, titanium dioxide, iron oxide, magnesium carbonate, calcium carbonate and different aluminas. *Ingredients* used for producing the *reducing atmosphere* include cellulose, calcium carbonate, dolomite, wood floor, starch, dextrin, etc. *Iron powder* provides a higher deposition rate. *Ferromanganese* and *manganese* oxide provide alloying elements. The latter also helps in slag formation. Potassium silicate and potassium titanate are the principal *Arc Stabilizers*. Arc stability is also helped by titanium dioxide, feltspar and mica.

Normal thicknesses of these coverings on all commonly used *light* and *medium coated* electrodes vary from 10 percent to 55 percent of the total diameter of the coated electrode. However, in some *heavy coated* electrodes it may be as high as 100 percent and above.

Electrode Size. Electrodes are commonly manufactured in *standard lengths* of 250 mm, 300 mm, 350 mm and 450 mm. Similarly, the *standard sizes* of the electrodes being commonly manufactured in this country are 1.6 mm, 2 mm, 2.5 mm, 3.2 mm, 4 mm, 5 mm, 6 mm, 7 mm, 8 mm and 9 mm.

24.41 ELECTRODE CLASSIFICATION AND CODING

According to BIS coding system an **Electrode** is *specified* by six digits with a *prefix letter M*, which indicates its suitability for metal-arc welding. These six digits stand for the following :

1. **First Digit.** Numbering from 1 to 8. Each number stands for a particular type of covering provided on the electrode.

2. **Second Digit.** It also carries numbers from 1 to 6 and each number represents a particular position or positions of welding in which the electrode can be used.

3. **Third Digit.** May carry any number from 0 to 7. Each number represents a particular current condition suitable for that particular electrode.

4. **Fourth Digit.** It indicates the minimum tensile strength of the weld metal. It may carry any number from 1 to 8 and each number represents a particular tensile strength in kg/cm^2.

5. **Fifth Digit.** It indicates the percentage elongation of deposited weld metal in tensile testing. Different percentages are represented by numbers from 1 to 5.

6. **Sixth Digit.** It indicates the minimum impact value of the weld metal. Different values are represented by numbers from 1 to 5.

For detailed study of the above specifications and coding system readers are advised to refer to **IS : 815-1956 and IS : 814-1963.**

24.42 SELECTION OF ELECTRODES

It is evident from foregoing discussions that welding has to be performed in various different conditions and selection of a proper electrode to suit those conditions is a vital factor for successful welding. The factors which influence the *selection* of a particular electrode for *Metal Are Welding* can be summarised as follows :

1. Availability of current—A.C. or D.C.
2. Composition of the base metal.
3. Thickness of the base metal.
4. Welding position—flat, horizontal, vertical or overhead.

5. Fit-up of the components to be welded.
6. Expected physical properties of welded joints—*i.e.*, strength, ductility, soundness, appearance, etc.
7. Amount of penetration required in welding.
8. Skill of the welders in using particular types of electrodes under specific conditions.
9. Economic considerations—welding costs are largely effected by deposition rate and also by electrode costs.

Low Hydrogen Electrodes. Hydrogen adversely affects alloy-steels, causing intergranular underbead cracks. It is known as **Hydrogen Embrittlement** and leads to low strength and reduced fatigue resistance of welded joints. To avoid this *low hydrogen* electrodes are made from such materials which will provide minimum or no hydrogen deposit in the weldment, such as cellulose, asbestos, iron powder, clays, lime, titania, etc. These electrodes should not be allowed to remain exposed to atmosphere for a long period otherwise they may absorb moisture. Also, as a precaution, they should be stored in closed boxes and redried at a temperature of 120°C before using.

Carbon Electrodes. These electrodes are used in **Carbon-arc Welding** and **Cutting**. They are available in two varieties—**Carbon Electrodes** and **Graphite Electrodes**. The latter type is a better conductor and has more uniform structure. Bare carbon and graphite electrodes become **hot** during welding due to the resistance offered by the material to the current flow. Their hot surface starts oxidising by coming in contact with atmospheric air, and this leads to a reduction in electrode size. To prevent this *oxidation* these electrodes are sometimes coated with *copper.*

24.43 INERT GAS-ARC WELDING

It is established that in any type of welding the quality of weld depends to a considerable extent on the effectiveness with which the formation of oxides and the accumulation of these oxides and other contaminants on the metal surface can be prevented. The effort should always, therefore, be to keep atmospheric air and contaminants like dirt, dust, metal oxides, etc., away from the *molten pool* in welding operation. In the conventional *Arc welding* processes the **fluxes** are relied upon for providing the *shielding atmosphere* around the molten pool to prevent the atmosphere from coming in contact with molten metal and prevent contaminants from outside from mixing with molten metal.

In **Inert Gas-arc Welding** processes inert gases, such as *argon, helium, carbon dioxide*, are used for surrounding the electric arc and, thus, keeping the atmospheric air and other contaminants away from the molten metal pool. This prevents *oxidation* and eliminates *impurities* from the weld. It not only results in production of **sound welds** but also enables welding of such metals which are otherwise difficult to weld or impracticable to weld through the conventional *Arc-welding* processes. To meet these requirements various Inert **Gas-Arc Welding Processes** have been developed. Some of these are manual, semi-automatic and some automatic. Some common ones of these will now be discussed in the forthcoming articles.

24.44 INERT GAS TUNGSTEN-ARC WELDING (TIG WELDING)

This process was first introduced for industrial purposes in early 1940's. It is basically an *Arc welding process* in which the arc is struck between a *non-consumable* **tungsten electrode** and the base metal. The **electrode** is held in a special type of *Electrode-holder* which is so designed that apart from holding the electrode, it also carries a *passage* around the electrode for flow of Inert gas to provide the protective shield around the *arc*. This *gaseous shield* protects the electrode, molten metal, the arc and adjacent heated areas of base metal from *atmospheric contamination*. The *Electrode Holder* also carries a provision for *water cooling* or *air cooling*. This process can be adopted for both **manual** and **automatic** operations.

This process is capable of producing *continuous*, *intermittent* or *spot welds*. Due to non-consumable nature of electrode no filler metal is provided by it. However, if needed, additional *filler metal* can be provided from outside by fusing a *filler rod* under the arc in the same way as in *Gas welding*. This process is suitable for welding in all positions. **Thin Metal Foils** upto a minimum thickness of 0.125 mm can be easily welded with this process. It is suitable for welding of most metals and alloys except lead and zinc, which have very low melting points. Its specific applications include welding of *Al-alloys*, *Mg-alloys*, *Nickel alloys*, *Zirconium alloys*, *Titanium alloys*, *Beryllium alloys*, *Refractory metals*, *Carbon* steels, *alloy steels* and *Stainless steels*. It is advisable to use **manual welding** for complex and irregular shapes and difficult to reach sections since manipulation of manual torch is easiler in such cases. For regular shapes automatic welding can be easily adopted.

TIG Welding Equipment. The following equipment is required in TIG Welding (**See Fig. 24.23**):

1. An inert gas *cylinder*.
2. An inert gas *regulator* and *flowmeter*.
3. Inert gas *hoses* and hose connections.

4. An inert gas *shut-off valve.*
5. An *arc-welding machine.*

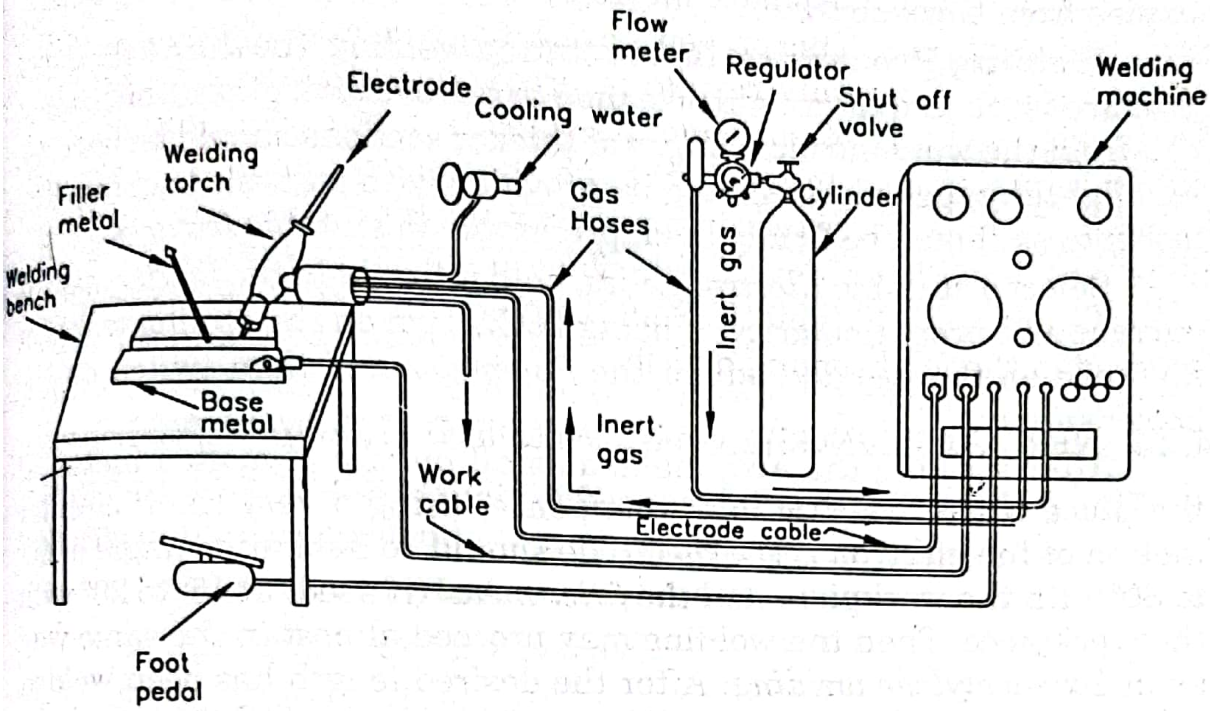


Fig. 24.23. A TIG welding setup (schematic).

6. *Welding cables* for electrode and ground connections.
7. A welding *bench.*
8. *Electrode holder* (water cooled or air cooled).
9. Water supply with inlet and outlet hoses (if water cooled holder is used).
10. Non-consumable *Tungsten Electrode.*

In most of the cases the *inert gas hose, welding cable* for electrode and the *water hose* are all enclosed in a common jacket to form what looks like a *single cable.* Apart from the above equipment the welder should use proper *eye-shield* to protect his eyes since the **Arc** in **TIG Welding** is fully exposed.

Welding Current. Both A.C. and D.C. are used in **TIG Welding.** An important point to ensure is that a stable current be maintained throughout the operation, particularly at lower ranges. **D.C. Welding Machines** are manufactured with this characteristic incorporated in them. But, it is necessary to use a **High Frequency Generator** in conjunction with an **A.C. Welding machine** (*Transformer*). This generator superimposes a *high frequency* current on the arc to reestablish it after the 'zero' period in each **A.C. Cycle.**

A.C. enables *good penetration* and *less surface oxidation.* It is preferred for welding of aluminium, magnesium and beryllium copper. **D.C.** with *straight polarity* is the least used because it provides less penetration, enables flat and wide bead and needs maximum skill. A specific advantage associated with it is that it enables better removal of oxides from work surface.

Welding Procedure. Before stating welding, the **Joint** should be prepared well and thoroughly cleaned to remove dirt, grease, oil, oxides, etc. from the work surface. *Edges* of thicker sections should be bevelled and lighter gauge metal should be provided with suitable backing. The *workpieces* should be firmly held, preferably in suitable *fixtures*.

Select a suitable *Electrode Size*, hold it firmly in the *holder*, set the current and proper polarity, if using **D.C.**, turn on the cooling water or air, turn on the gas and adjust the *flowmeter* and then switch on the *power supply*.

After striking the **arc**, make a small *puddle* of molten metal, at the place where welding is to commence, using a very small circular motion of the electrode. The electrode should be held at an angle of 60° to 80° with the workpiece and the *filler metal* (if used) at 15° to 20° with the workpiece. Then the welding may proceed almost in the same way as in *Oxy-acetylene welding*. After the desired length has been welded the electrode holder should be lifted quickly to break the arc and the current flow switched off. However, the *inert gas flow* should be continued till the electrode cools down.

24.45 INERT GAS METAL-ARC WELDING (MIG WELDING)

This process, popularly known as **Metal Inert Gas (MIG) Welding,** *involves* welding of metals using a **consumable** metal electrode in an *Inert gas* atmosphere. The **arc** is struck between the metal electrode and the workpiece. The electrode is in the form of a *continuous wire* which is fed into the **arc**, by an **Adjustable Speed Electric Motor,** at the same speed at which it is melted and deposited in the weld. A specially designed **Electrode Holder** is used which, in addition to a passage for wire *electrode*, also incorporates passages for supply of *Inert Gas* for *shielding* the electrode, molten weld metal, arc and the adjacent hot area of base metal from atmospheric contamination and for supply of *coding water*. A schematic diagram of **MIG Welding Torch** is shown in Fig. 24.24. Rest of the *Setup* is more or less same as in **TIG Welding**.

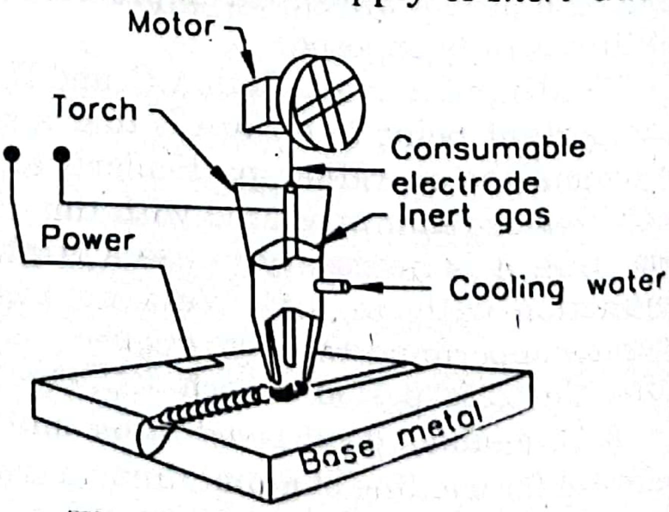


Fig. 24.24. A MIG welding torch.

This method can be employed for welding carbon steels, low alloy steels, stainless steels, aluminium and al-alloys, heat resisting alloys, magnesium alloys, copper and Cu-alloys. With *Special Techniques*, like *preheating of base metal*, a more *close control of inert gas*, in some cases *post-heating* of parent metal and use of *backing gas*, etc., it is possible to weld cast iron, titanium and its alloys, refractory metals, manganese bronze, etc., also. It is not suitable for welding of low melting point metals like lead, tin and zinc and also those metals which carry coatings of these low melting point metals. Economically welded metal thicknesses with this method range from 0.5 mm to 12.5 mm. Although larger thicknesses can also be welded, but other processes prove more economical. This *process* can be used for *welding* in *all welding positions*. However, *best results* are obtained in *flat* and *horizontal* positions. The main equipment needed in this process is as follows :

1. An *Inert gas cylinder*.
2. *Gas regular* and *Flowmeter*.
3. *Gas hoses* and *connections*.
4. A *power source* and *welding leads*.
5. MIG *welding gun*.
6. A *spool of electrode wire*.
7. *Electrode wire feeder*.
8. *Water supply* with water hoses.

Usually, **D.C.** with *Reverse Polarity* is used in **MIG Welding. A.C.** is not used in this method. Even D.C. with Straight Polarity is not often used. It is used only sometimes when a very small penetration is required. Use of D.C. Reverse Polarity enables a *deeper penetration* and a *clean weld surface*.

In **MIG Welding,** inert gases like argon, helium, carbon-dioxide or a mixture of these gases are used for providing the inert gas shield. Formerly only argon and helium were used, but now CO_2 is more widely used, both as a *single gas* and also in *mixture* with other inert gases.

Before starting welding, a similar joint preparation and cleaning is necessary in **MIG Welding** as is done in **TIG welding.** Two *principal* **MIG welding** methods are the following :

1. Spray Arc Method. This method uses a heavy flow of **D.C. Reverse Polarity** causing the electrode to melt in the form of a *steady stream* or *spray* of very minute droplets, which are transferred across the arc to the joint without interfering the stability of arc. It is used for *good fit-up joints* and *faster welding*.

2. Short Circuiting Method. It is also known as **Dip Transfer Method**. In this method, the melted *filler* metal from the *electrode* separates in the form of large drops which touch the *base metal* before separating from the electrode. As a result, the arc is *short circuited* temporarily for an instant, and as soon as the drop is separated and proper *gap* between the electrode *tip* and *workpiece* restored the arc is reestablished. This process is used for *poor fit-up joints* and *thin sections*.

Advantages of MIG Welding :

1. It is faster than shielded metal-arc welding due to continuous feeding of filler metal.
2. There is no slag formation.
3. It provides higher deposition rate.
4. The weld metal carries low hydrogen content.
5. Deeper penetration is possible.
6. More suitable for welding of thin sheets.
7. Welds produced are of better quality.

Disadvantages :

1. Equipment used is costlier and less portable.
2. It is less adaptable for welding in difficult to reach portions.
3. It is less suitable for outdoor work because strong wind may blow away the gas shield.

24.46 CO_2—MIG WELDING

It is similar to the *standard* **MIG Welding** described above, except that in this process the electrode used is either *flux cored* or *magnetized flux coated.* **CO_2** is used as a *shielding gas*. In either case the *filler wire* or *electrode* is fed into the *arc* in the same way as in *MIG Welding*. The *flux cored wire* is a *tubular* metal electrode filled with *flux* inside. The arc is struck between the electrode and the workpiece and shielding is provided by the *gas evolved* during *combustion* of *flux* plus the *CO_2 gas* fed around the arc for this purpose.

While welding with flux coated electrode *magnetized granular flux* is fed into the arc through the *gun nozzle*, and there it attaches itself to the electrode. The coating so provided protects the electrode against atmospheric contamination by the *shield* of CO_2 gas. The method of feeding the electrode wire into the arc is again similar to that in standard *MIG welding* process described in Art. 24.45 above. Thus, it will be observed that the **CO_2 MIG Welding** process is exactly similar to the standard **MIG Welding** process except that the electrode wire uses either magnetized flux *coating* or as its *core*.

Main **advantages** of CO_2 MIG welding process are :

1. It is a fast welding process.
2. The deposition rate is quite high.
3. Penetration of the arc is deep.
4. Minimum edge preparation is required, particularly in butt joints.

24.47 SUBMERGED-ARC WELDING

It is basically an *Arc-Welding Process* in which the arc is struck between a consumable metal electrode and the workpiece. The process derives its name from the fact that the arc remains **submerged (shielded)** inside a layer of a **Granular** and **Fusible Flux**. This blanket of *flux*, apart, from shielding the arc, also protects the molten puddle and base metal near the welding against the atmospheric contamination. The arc is not visible to the welder. Other names given to this process are **Hidden-arc Welding, Submerged-melt Welding, Subarc Welding** and **Flux Covered Arc Welding**. The process can be *Automatic* or *semi-automatic*.

Both **D.C.** and **A.C.** can be used in this process. While using **A.C.** the *Transformer* should have a standard range of **Open Circuit Voltage**. Its value varies from 65 to 75 Volts for transformers with lower current capacities and from 80 to 100 Volts for those having higher current capacities. A proper **Remote Control Unit** is always incorporated in the power supply source with a switch near the **Welding Head**, so that power supply can be cut off or put on at will and the welding stopped or started as desired.

For starting *Welding*, the pieces to be joined are placed in position. *Flux* from the *hopper* is then fed on to joint through a *Flux Feeding Tube*. The electrode wire is fed into this blanket of flux and the *arc* struck. The heat generated melts the surrounding *flux grannules* and the *filler metal*. The latter forms the **Weld Bead** and the former *fuses* to form a *covering* of the *slag* over the **Bead**. It protects the **weld** against atmosphere until it cools down. The process continues as the *Welding Bead* advances along the joint with a proper speed, the flux hopper unit sliding ahead of the arc. The entire **flux** fed by the hopper is not melted. This unused part of the flux is collected by another unit, following the welding head, and fed back to the hopper for further use. After the weld cools down the slag is removed. The rate of feeding of electrode wire and flux grannules and the welding speed are automatically controlled in **Automatic-submerged arc welding machines** whereas in **Semi-automatic machines** the welder has to manually guide a *Welding Gun* (which caries an attached flux hopper) and thus, controls all the feeding operations and welding speed manually.

This process is suitable for welding of plain low carbon steels, medium carbon and low-alloy steel, stainless steel, copper and copper alloys, nickel and nickel alloys. It is not suitable for lead, zinc, aluminium, al-alloys and magnesium alloys.

A specific **limitation** of application of this process is that it can be performed only in *flat* and *horizontal* welding positions. Some other **disadvantages** associated with this process are :

1. Flux may get contaminated and lead to porosity in weld.
2. Slag removal is an additional follow-up operation. In multipass beads it has to be done after every pass.
3. To obtain good weld the base metal has to be cleaned and made free of dirt, grease, oil, rust and scale.
4. It is normally not suitable for welding of metal thicknesses less than 4.8 mm.

Advantages of Submerged-arc Welding Process :

1. As the arc is completely submerged no shielding is needed against the same although it is advisible to protect the eyes as a precautionary measure.
2. Shallow grooves can be used for making joints, requiring less consumption of filler metal. In some cases no edge preparation is at all needed.
3. Higher welding speeds can be employed, effecting saving in welding time.
4. Deposition rate is very high.
5. There is no chance of weld spatter, since the arc is always covered under flux blanket.
6. Flux acts as a deoxidiser to purify the weld metal.
7. If required, the flux may contain alloying elements and transfer them to the weld metal.
8. It can be used with equal success for both indoor and outdoor welding work.

24.48 ELECTROSLAG WELDING

Through this method fairly thick metal plates can be welded without any *edge preparation*. In this process the joint is put in a vertical position with a little gap between the abutting ends of the workpieces. **Fig. 24.25** illustrates a schematic diagram of this process. The weld is completed in a single pass. In this process there is no arc. It is the *heat* of the *molten flux* which melts the consumable metal electrode and the surface of the base metal to create the *Weld Puddle*.

The *equipment* basically consists of a *source of power supply* **(A.C.)** a suitable mechanism for *feeding* the *electrode wire*, a *hopper* to carry flux with a *tube* to feed this *flux* into the *joint*, a vertical *rail* along which the entire *Welding Unit* can travel in a vertical direction inside proper *Guides*.

For commencing welding the **flux** is first fed into the *joint* and then the *current* is switched on, which passes through the layer of flux via the electrode wire. The resistance offered by the flux to the flow of this current creates *heat* and melts the flux which, in turn, heats and melts the *electrode wire* and the *base metal*. The *molten metal pool* so created is contained in the joint between two *water-cooled* copper *slides*, called **Shoes.** One such *shoe* is located on each side of the joint.

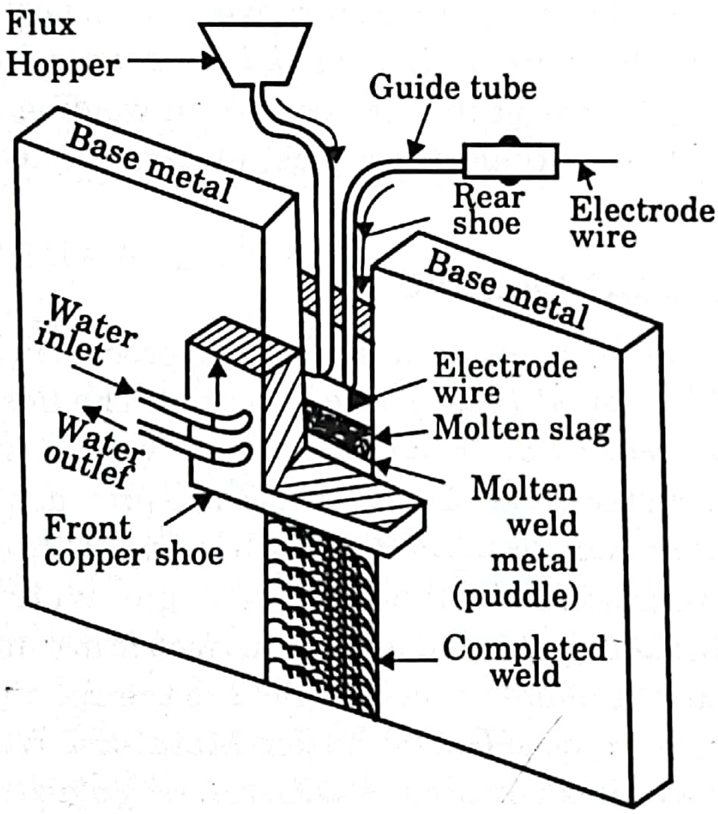


Fig. 24.25. Schematic diagram of Electroslag welding. The copper shoe at the front side is shown in section to show the welding details.

Molten metal puddle, being in contact with both these shoes, solidifies between the base-metal pieces and forms the **Weld**. The solidification is a directional one and non-metallic substances are pushed upwards into the *molten flux* (**slag**) *pool*. As the solidification of weld metal proceeds upwards, more flux is added from hopper, more melting of electrode wire and base metal takes place and more molten puddle is formed, both the shoes also slide upwards simultaneously so that the weld area, molten slag and weld puddle all remain confined within the **mould** formed by them. Thus, the process continues upwards till the whole length of the joint is welded.

In this process, according to requirement, one, two, or three electrode wires can be fed simultaneously into the joint. The electrode wire used can be of solid type or flux cored. This process is quite fast and needs no edge preparation on the base metal. This process is quite fast and needs no edge preparation on the base metal. This process is commonly used for welding metal plate with thicknesses from 25 mm to 350 mm, although with special arrangements higher thicknesses can also be successfully welded. Most common are the **Butt Joints** to be made through this process. With use of modified shapes of shoes and techniques, however, it is possible to make other joints also, like *circumferential joints, corner joints, T-joints,* etc. Specific applications of this process are in welding of heavy steel forgings, large steel castings, thick steel plates and heavy structural members.

24.49 ELECTROGAS WELDING

It is basically a **Gas Metal-arc Welding** process in which either a *Solid Type* or *Flux Cored Type* electrode is used. The *Base Metal* pieces are arranged in *vertical direction* in the same way as in **Electroslag Welding**. Also, water-cooled *Copper Shoes* are provided on either side of the *Base Metal* plates, as in *Electroslag Welding*. The main difference between the two processes is that in **Electrogas Welding** no **flux** is fed into the joint and heat is created by an *electric arc* and an *inert gas* (**CO_2**) is fed into the joint to provide *shield* to the *arc* and *molten weld puddle*. Thus, it is a type of **Gas Shielded Metal-arc Welding** process carried out in a vertical direction. A **D.C.** *reverse polarity* is used in the process.

This process is commonly used or welding of low carbon and medium carbon steels, and with specific precautions for alloy steels and stainless steels as well. *Thickness ranges* commonly welded are from 12 mm to 75 mm. For thinner sections, other processes prove more economical and for thicknesses above 75 mm *Electroslag* process proves superior.

24.50 STUD WELDING

It is an *Arc Welding Process* adopted specifically for welding of **Studs** to *structures* and other surfaces for fastening other components to them. It, thus, eliminates the need of *hole drilling,* which would have been necessary if some other fastener like bolt or rivet was to be used in its place for the same purpose. It is done with the help of a specially designed **Gun** called **Stud Welding Gun**. The *Gun* carries a **Collect** to hold the *stud*, which is placed against the surface where it is to be welded. The gun holds the stud in perfect alignment throughout the operation. A Ceramic Ferrule surrounds the stud. As soon as the gun *Trigger* is pressed the current is switched on and a **solenoid** inside pulls the stud away from workpiece by a predetermined distance. This creates an arc between the *stud* and the *work* and the *stud end* and *base metal* melt. Immediately the *spring* inside the *gun* forces the *stud* into the *molten pool* of work metal. The *ceramic ferrule* helps in confining this molten pool around the *stud end* and giving it a good fitted shape on solidification. If properly designed *jigs* and *fixtures* are used, **studs** can be welded to an accuracy of 0.125 mm, both in height and location. This process can be used for steel and aluminium both, but while welding *aluminium* an *Inert Gas Shield* is to be provided around the **weld** in the *ferrule*.

24.51 PLASMA ARC WELDING

The scientific concept of the term **Plasma** is '*A Stream of Ionised Particles*'. This concept is very true in case of this welding process. In this process a gas (*argon*, *hydrogen* or *helium*) is passed through an *electric arc,* where it is heated up and ultimately gets *ionised.* The *stream of these hot ionised particles* (**Plasma**) is passed through a small *orifice* of a welding torch. This is termed as **Plasma Arc**, *i.e.*, an *Electric Arc* combined with an *energised plasma* or *stream of ionised gas particles.* This *stream* is made to impinge on to the area to be welded and its *energy* is utilised in heating the *base metal.* It provides a deep penetration, faster welding, cleaner welds and narrow **beads**. The electrode used is a **tungsten electrode** with a water-cooled, **copper nozzle**. The *plasma arc* can be effectively used for cutting also, called **Plasma Arc Cutting.**

24.52 ATOMIC HYDROGEN WELDING

There is a fundamental difference between this process and the other *Arc Welding Processes* in that the workpiece does not form any terminal and is, thus, out of the electrical circuit. In this process the arc is maintained between the **tips** of two *tungsten electrodes* which are of adjustable type. A single phase **A.C.** is passed through these electrodes and the arc is struck. *Hydrogen gas* from the *cylinder* is drawn and blown into the *arc*. Thus, an **Arc Flame** is produced which carries a very high intensity of heat, so much so that it is greater than the heat produced by any other *gas flame*.

The basic theory behind this process is that when *hydrogen* is forced through the *arc*, due to the intense heat its molecules break up into *atoms* to form what is known as **Atomic Hydrogen**. In doing so, it absorbs a big quantity of *heat energy* from the *arc*. When this *atomic hydrogen* goes out of the arc the atoms combine again to form *molecules*. During this process of the atoms getting transformed back to molecules the *heat energy*, which was absorbed by the gas in passing through the arc, is *given up* and it is this energy which is utilised for *welding* purposes.

We, therefore, conclude that in the strict sense of previously described *welding methods*, it is neither purely an arc welding process nor fully a gas welding process. It actually is a combination of both. The arc produced is not directly used for heating the job, its purpose is simply to *break up* the *hydrogen molecules* into *atoms*.

The construction of the **Torch** is such that it works as the *Electrode Holder* as well as carries the *Gas Nozzle*. Thus, it supplies both the *gas* as well as the required *current* to the arc. A *Trigger* is provided on the torch, by means of which the distance between the *tips* of the electrodes and their other adjustments are made. *Hydrogen* is supplied normally at a pressure of about 0.07 kg per sq cm (= 1 lb p.s.i. nearly).

24.53 THERMIT WELDING

It is a very useful method and is particularly adopted where neither *electrical power* nor the supply of *gases* is available. The complete unit is a very compact one and is of *Portable type* **(See Fig. 24.26)**.

The apparatus consists of a *cone shaped* **Vessel** carrying fire brick lining inside. A mixture of *powdered aluminium* and *iron oxide* is placed inside the vessel. This *mixture* is ignited by heating to about 1550°C and a chemical reaction takes place due to which aluminium is converted into aluminium oxide and iron is melted. The *reaction* is :

$$\mathbf{8\,Al + 3Fe_3O_4 \rightarrow 9\,Fe + 4\,Al_2O_3 + Heat.}$$

Usually **Barium peroxide** powder is used for igniting the **Thermit mixture**. Many other substances like carbon, nickel, chromium, etc., are also added in desired proportions in order that the *molten metal* has almost similar *composition* as that of the *parent metal*.

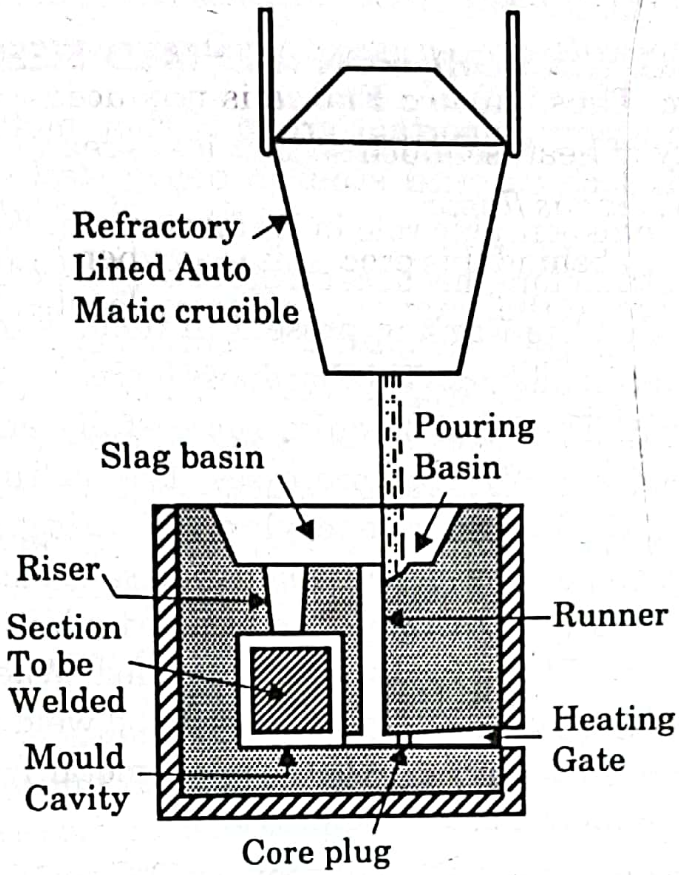


Fig. 24.26. The thermit welding process.

Due to the chemical reaction, as described above, a bright *white heat* is produced inside and the *iron* melted. The molten iron is tapped from the vessel and made to run in the cavity of the *joint*. The temperature attained is about 3000°C. Special care should be taken to ensure that the powders used for forming *thermit mixture* are thoroughly *dried* otherwise *Blowholes* will be produced in the **Weld.**

The process of thermit welding is very quick and economical. It does not require very expensive apparatus and it is reckoned that the welds produced by this process are stronger than those produced by electric welding.

24.54 WELDING DIFFERENT METALS

A large number of **metals** are in use in engineering practice and a detailed study of the properties and behaviour of these metals, when subjected to welding, will be beyond the scope of this small chapter. As such, only a brief description will be given here to give a general idea of the **Weldability** of these metals. In plain words by **Weldability** we mean the ability of the metal to be welded. However it involves many factors, such as effect of heating and cooling during welding and the resulting properties of the metal. We will now discuss the welding of different metals in the light of these factors.

24.55 WELDING WROUGHT IRON AND MILD STEEL

They form a very important group of shop metals and are very commonly used, such as **mild steel** in heavy *steel structures* where *welding* has an indispensable role in its fabrication. *Welding technique* of these metals, therefore, needs a careful study. A common feature of these metals is that the **Carbon** present in them is in *combined form* which renders the metal *hard*. This hardness increases with the increase in carbon content. They can be quite successfully and easily welded through all the *Fusion Welding* processes. The melting temperatures are around 1500°C. When **Oxy-acetylene Welding** is employed the *filler rod* used is made to have *silicon manganese* in suitable proportion to increase the *fluidity* of the metal and impart additional strength to the weld. A *Neutral Flame* is always maintained. When **Electric Arc Welding** is employed, a high current is used and welding proceeds at a fast speed. Careful **shielding** of the molten metal from atmospheric effect always results in a better weld.

Mild steel melts normally between 1450°C to 1550°C. No **flux** is employed in welding mild steel. The welding rods are made of either mild steel or pure iron. When mild steel is heated it starts *oxidising* at dull *red heat*. This oxide melts much earlier than the steel and remains on the upper surface from where it can be removed. In **Welding** with *Oxy-acetylene Flame* care should be taken to keep the flame **neutral** as an *oxidising flame* will result in *oxidation* of steel and similarly a *Carbonising flame* will tend to *carbonise* the steel. After finishing the joint, if it is heated to *red heat*, followed by light *hammering* along the joint, the *structure* of steel will be greatly improved and the joint strengthened. If, however, it is done at a *lower temperature* it will result in *weakening* of the *joint*.

24.56 WELDING MEDIUM CARBON STEELS

There is always a danger of **chilling effect** in these steels, during welding, due to the higher percentage of *carbon*. This can be easily avoided by preheating the job. The normal practice is to preheat the components, having upto 0.4 per cent carbon, from 100°C to 150°C and others up to 300°C according to the *carbon percentage* they possess. Because this steel is *harder* and more *brittle* than mild steel, it may be necessary to *normalise* the components after welding process is over. In absence of the *normalising process* the pieces may be reheated to about 400°C and then cooled uniformly to relieve these *stresses*.

Usually a slight *carbonising* flame is employed for welding these steels when using an oxy-acetylene flame. In **Arc welding**, a high tensile *covered electrode* is usually employed and full precaution is taken against *chilling* and *residual stresses*.

24.57 WELDING HIGH CARBON STEEL

In welding steels having a very high carbon content *preheating* of the job is necessary. When *Arc welding* process is employed, *higher gauge* electrodes should be used. *Heat treatment* of these steels, after welding, becomes almost unavoidable in order to relieve the stresses set up during welding. *Quick heating* and *cooling* should be avoided as far as possible during *welding*.

24.58 WELDING CAST STEEL

This term is employed for those components which have been produced by pouring the *molten steel* in *moulds*. The finished steel casting may have certain defects, like blowholes, etc. *Welding* operation is usually called for to repair the defective castings. *Bevelling* of the surface to be repaired is an important operation before welding. However, larger castings may require preheating also before welding in order to minimise the chances of *straining* of metal due to local heating during welding. **Oxy-acetylene Flame** is usually employed for such repair work. Normally overlapping layers of **weld** are produced for such repairs. In welding at the joint of uneven sections sufficient care should be taken to provide more heat to the thicker part in comparison to the thinner one. A **Neutral Flame** should be used for such repair work.

24.59 WELDING STAINLESS STEEL

This *steel alloy* can easily be welded by *Oxy-acetylene Welding* or *Arc Welding*. When using the Arc welding process a suitable electrode should be selected as per manufacturer's advice. There is always a likelihood of *chromium* being lost during welding. This can be easily made up by using an *Electrode* rich in chromium either in its core or the coating. Usually no heat treatment is necessary after welding. Contrary to mild steel, rapid heating and cooling gives a better effect in welding this metal, and as such *overheating* of the job during welding should be avoided.

In *Gas Welding* of this metal correct adjustment of the *flame* and proper manipulation of *blow-pipe* play an important role. A *Neutral Flame* gives best results. However, maintenance of a perfect *Neutral Flame* throughout the operation may create difficulties. For this, the recommended practice is to adjust the flame having slightly *excess acetylene* in order to avoid the chances of occurrence of an *Oxidising Flame*. It must be carefully noted that an *Oxidising Flame* will lead to a *porous* joint and too much of acetylene will force the weld to lose its *ductility*. The molten metal should always be kept covered with the *gas flame* to prevent the former from *oxidising* and the end of the *Welding rod* should always be kept inside the pool of the molten metal. *Welding* should proceed at a uniform speed. The *Edge Preparation* for this metal should be similar to that used for ordinary class of steel. **Flux** may or may not be used for welding stainless steel.

24.60 WELDING TOOL STEEL

Experiments show that the various important and useful inherent properties of these steels are *lost* during *welding*. As such, *Welding* of these steels is normally discouraged. The prevalent practice is to employ low temperature **Brazing** for the purpose of joining tool steel pieces.

24.61 WELDING CAST IRON

This metal needs special care in welding because of its extreme *brittleness* and *weakness*. The endeavour in welding **cast iron** should be to prevent the occurrence of *contraction stresses* during *Welding* and, thus, produce a **strong joint** free from fractures at the junction of the *parent metal* and the *weld*. Cast iron components are generally *preheated* to a *dull red heat* and then *welded*. It should be carefully noted that once the cast iron has melted it should be cooled slowly so as to allow time to carbon to turn into graphitic state. If the cooling is rapid the *carbon* will be retained in the metal in *combined state* to form **White Cast Iron**. This, being a *hard* and *brittle* substance, will render the iron harder and more brittle and reduce the tensile strength and its machinability. The object, therefore, should be to produce grey iron except when a very hard metal is required, which of course is a very rare need. Cast iron can be welded both by *Arc welding* as well as *Gas welding*. In **Arc Welding** a *Flux coated Electrode* should be used. Sometime *annealing* may be needed after arc welding process.

In **Gas Welding,** a *neutral flame* should always be used for welding cast iron. The *welding rod* used should always be clean and smooth and during the operation its end should always be kept inside the molten pool. The tendency to produce very *good looking welds* in cast iron may prove dangerous. As such, a weld may result in the production of *hard metal* throughout the **weld** or grey iron consisting of a number of hard spots here and there. Cleaning of such welds, if at all desired, should be left to *machining*. Care should be taken that the inner *white cone* of the flame does not hit directly on the molten pool otherwise a *hard weld* will be the result. Also, it should be noted that the metal should not be allowed to become so hot that its *fluidity* results in an **unsound weld**. A good **flux** should always be used so as to disallow the *oxides* from remaining inside the molten metal. This **flux** will dissolve the *oxide* and make it to float on the upper surface. This can easily be removed later. However, enough restraint should be exercised in the application of the flux and as small a quantity should be used as will be just sufficient. A higher quantity of flux will tend to increases *hardness*. A preferable practice is to reheat the cast iron piece a little, after completing the welding, so as to bring the entire welded portion to a common temperature and then allow it to cool down at a slow rate. This can be effected by either leaving the piece in the furnace and allow both of them to cool slowly together or *burry* it in some material like *asbestos pieces*. Cast iron can also be welded successfully by **Thermit Welding**.

24.62 WELDING ALUMINIUM

Pure aluminium can easily be welded by **Gas** and **Arc Welding**. **Resistance Welding** and **Atomic Hydrogen Welding** methods can also be successfully employed for welding aluminium. Aluminium and its alloys have their melting points ranging from 600°C to 700°C. At elevated temperatures aluminium forms its *oxides* and it remains on the metal in the form of a *thick layer* of Al-oxide. It is a very refractory material so much so that its *melting point* is above 2750°C. Another difficulty is that the *specific gravity* of this *oxide* is *higher* than that of aluminium. With the result, if it is not removed, it will be disbursed throughout the weld rendering it *unsound*. It is necessary, therefore, that the said oxide should always be removed by using a suitable **flux**. In *Arc Welding*, D.C. is usually preferred for welding aluminium. A *positive polarity*, or a *reserve polarity* as we call it, is a recommended practice. The size of electrode will be determined by the thickness of the metal. *Edge preparation* can be needed in thicker sections only.

Oxy-acetylene welding can be employed quite successfully for aluminium and its alloys. Welding methods, edge preparation, selection of proper *welding rod* and the *flux* depends upon whether aluminium is in the form of sheets, alloy tubing or cast alloy. Whatever may be the form to be welded, out of the three described above, there will not be any appreciable difficulty except the removal of the *refractory oxide* formed during or before welding. For this, a suitable flux should always be used. These **fluxes** are usually available in *powdered* form and are mixed in water to form a **paste** before being applied.

Spot Welding is very successfully done in aluminium and its alloys because of their thermal and electrical conductivity. Usually high current at short cycles is employed. The process of **Seam Welding** can also be quite successfully employed for this metal and its alloys but a *periodic cleaning* of the *rotating electrodes* is necessary due to the tendency of the metal to stick to them.

24.63 WELDING COPPER AND ITS ALLOYS

Copper is a soft, ductile and tough metal and a good conductor of heat and electricity. It is divided into two categories according to the suitability for welding; those having *oxygen* in them and the others having *no oxygen*. The later form is known as **Deoxidised** or **Oxygen free** copper. The former form has the disadvantage that the oxygen present in it combines with copper to form *cuprous oxides*, when heated, causing the weld *weak*. The deoxidised copper is, therefore, best suited for welding. It is manufactured in the usual way but about 0.05 to 0.15 percent *silicon* is added to it which combines with the *oxygen* present in the copper and thus prevents the formation of *cuprous oxide*. Similarly, a suitable *deoxidising material* is added to the *filler rod material* for the same purpose. Such copper can be suitably welded by most of the **Fusion welding processes. Silver Brazing** and **Soft Soldering** are other useful processes employed for joining this metal. **Carbon arc** and **Metallic arc** processes are both used for welding of copper.

The high thermal conductivity of copper is usually the main difficulty in its welding. For the same reason a great amount of heat is required to be produced at the job, so as to make good the loss of heat due to rapid conduction, in addition to the heat required to melt the metal. Also the *melting temperature* of the metal is high enough (1083°C). **D.C**, having *straight polarity* is usually employed in **Arc Welding.**

Brasses are very successfully welded by **Oxy-acetylene welding** process. Usually a *bronze* filler rod, having silicon as deoxidising agent, is used. A good quality **flux** should always be used if successful results are desired. An **Oxidising flame** is used, which forms a protective coating on the molten metal and, thus, prevents a rapid vaporisation of zinc. The usual procedure of obtaining an oxidising flame is to first adjust a neutral flame and then reduce the proportion of acetylene. The **flux** to be employed is mixed with water to form a *paste* and then applied on the edges to be welded. *Pre-heating* of metal gives better results. All the **Bronzes** can be successfully welded in the same manner but a highly oxidised flame is needed. A greater amount of flux should be added to the welding rods when those alloys are to be welded which contain a large amount of *lead*.

24.64 WELDING NICKEL AND NICKEL ALLOYS

They can be quite easily welded through all the processes which are employed for welding of steel. **Metallic arc, Resistance welding** and **Oxy-acetylene Welding** *are the most widely used methods.* **Silver brazing** and **Soldering** are other useful means employed for joining these metals. A suitable **flux** should always be used to prevent the oxidation of these metals at welding temperatures—a tendency which they normally suffer from. Usually **D.C,** having *reverse* (or +ve electrode) *polarity*, is used in metallic are welding of these metals. The **Electrodes** should be *flux coated*. It is a widely used method for thick sections. For thinner sections *Oxy-acetylene Welding* is preferred, although it can be used for thicker sections also. The procedure for *Gas welding* of these metals is similar to that of steel.

24.65 SOLDERING

It is a *method of joining* metals, particularly when they are in the form of sheets, by using another **metal** or **alloy** which has a fairly *low melting point* as compared to the metals to be joined. The metal or alloy used for this purpose is known as a **Solder**. A *Soft Solder* is primarily an alloy of *lead* and *tin* to which some other metals are sometimes added to lower its melting point. Usual compositions of the **Soft Solders** which are in general use are as follows :

1. Tin 67% ; Lead 33%
2. Tin 50% ; Lead 50%
3. Tin 33% ; Lead 67%.

Similarly, **Hard Solder** is in alloy of *copper* and *zinc* to which *silver* is also added sometimes. **German Silver**, used as a *hard solder* for steel, is an alloy of copper, zinc and nickel. In general, the classification of solders in the above two categories is according to their melting points. **Soft solders** usually melt at a temperature below 350°C and **Hard solders** above 600°C. The operation performed by using a soft solder is known as **Soft Soldering** and when using a *hard solder* it is known as **Hard Soldering.**

Before starting the operation the metal pieces should be properly cleaned and placed abutting each other. The **Soldering Bits** or **Irons** used in the operation are made in different *shapes* and *sizes*. A commonly used type of **Soldering Iron** is shown in Fig. 24.27. It consists of a **Copper Bit** tapered to form an edge at its end. This *Bit* is fastened to an iron rod fitted in a wooden handle. After the joint has been prepared by cleaning the metal parts and placing them in position a **flux** is employed. The purpose of using the *flux* is to prevent the formation of oxides on the metal surface when the same is heated. *Zinc Chloride* is a common *flux* used for this purpose although a number of *patented fluxes* are also available with different trade names given by their manufacturers. However, for electrical work *resin* is best suited as it is not *corrosive*.

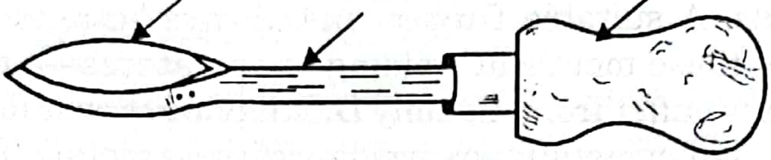


Fig. 24.27. Soldering Iron.

The **Soldering Iron** may either be heated electrically or by some external source of heat such as a gas stove. The former method is gradually becoming more popular. A *Smith's Furnace* can also be used for this purpose but is not preferred very much for the reason that it does not provide a *clean fire*. The **soldering bit** is heated sufficiently so that the heat acquired by it is sufficient enough to *melt* the *solder* immediately when the latter is applied to it. A useful form of soldering iron is the **Universal Type Soldering Iron**, in which the soldering bit is pivoted at a point in the iron rod. This facilitates the *bit* to be inclined at any desired angle to suit the odd shaped jobs.

After the soldering iron has been heated to the desired heat its surface is cleaned by means of filling and then *dipped* in a mixture of *flux* and *solder*. Another practice is to first dip it in a mass of *flux* followed by the application of *solder*. This enables the solder to melt and spread over the hot surface of the bit to form a *coating* over it. This operation is known as **Tinning**. After this, the bit is again dipped in the *flux* to remove the *oxides* from its surface, if any, and then in the *solder* again to pick up its required quantity. It is then ready for application to the work. It is important to keep in mind that the *solders* which have low percentage of tin have a higher melting point. As such, it becomes necessary sometimes to heat up the job instead of the bit to get good results. In soldering big jobs the solder is used in the form of a *wire*, sometimes having a *core* containing *flux*.

24.66 BRAZING

It is the process through which metal pieces are joined by means of a **Hard Solder**. *Brass* is usually the main constituent of this solder. The brazing solder used in modern practice is commercially known as **Spelter**, which is a mixture of copper, zinc and tin. This method of *Hard soldering* provides a much stronger joint as compared to the soft soldering process, but here it is needed that the metal pieces to be joined should be heated instead of the bit. For this a **Muffle** is best suited so that pieces are heated uniformly, although a *Smith's furnace* can also be used.

In operation, the ends of the metal pieces, which are to be joined, are cleaned well by means of *filing* etc. **Brass filings** or **Spelter** is then spread over the surface together with the **flux**. The parts are either clamped or held together through some other suitable means and heated. The *spelter*, together with the *flux*, melts and flows along the contacting surfaces, unites with them and solidifies on cooling to form the joint. It is a good practice to prepare the *Brazing* Mixture in the form of a *paste* and then apply it to the surface. This paste is made by mixing the **spelter** and **borax (flux)** in equal parts and adding proper amount of water to it to form the paste.

24.67 TIPPED TOOLS AND TIPPING OF TOOLS

It has become a common practice to use **Tipped Tools** on almost all the machine tools wherever their use is possible. By the term *Tipped Tools* we mean those tools which have a shank of a cheaper quality of steel, usually mild steel, and previously shaped **tips** of *tool steels*, such as high speed steel or tungsten carbide, are brazed on to them. Such tools are very much preferred on account of economical considerations. It is obvious that if the entire tool is made of **High speed steel** or **Tungsten carbide,** which are relatively very expensive alloys, then its production cost will go very high without any special advantage out of them. Also, the production of **Tool Tips** does not provide any difficulty.

For brazing **H.S.S. bits** the mild steel shanks are first machined to proper shapes to receive these tips. **Copper** is the common brazing alloy used for brazing these tips. After the shank has been prepared as above the **Copper Strip** (*Brazing Alloy*) is placed suitably between the joints and **Borax paste (flux)** applied, followed by the **tip** placed in position. The complete combination is then heated up to the melting point of *Brazing alloy*. After the molten alloy has fully run into the joint the tool is allowed to cool down in air. *Hardening* and *Tempering* of the **H.S.S. Tips** can be done in the usual way. This will not effect the brazed joint. Brazing is usually done between 996°C to 1090°C. Heating can be done either by an *Oxy-acetylene Flame* or in an *Electric Furnace*. Where a mass manufacture of such tipped tools is done a specially designed **Brazing Machine** is employed which works on the principle of *spot welding machine* and the *brazing alloy* is melted due to the heat generated at the joint on account of the resistance offered to the flow of electric current. However in all the cases the pieces to be brazed. *i.e.*, the *shank* and *tip*, should be clamped together properly with slight pressure.

24.68 CARBIDE TIPS

It would be advisable at this stage, it is hoped, to have a slightly detailed study of the **Hard Metal Tools**. A popularly known hard metal is **Tungsten Carbide**. It is a *sintered* ferrous material with additions of one or more of the following with ***Cobalt*** as *bond*.

1. Tungsten carbide
2. Tantalum carbide
3. Molybdenum carbide.

Tips of such carbides are manufactured in a very common way. These ***Carbides*** are obtained in a powdered form and mixed with the desired quantity of *Cobalt*. This mixture is placed in previously formed *carbon moulds*. These moulds are subjected to very high temperatures and pressures. Consequently, the mixture *Sinters*' (*i.e.*, binds together, and on cooling the *shaped Nos.* are obtained from the moulds. These *tips* conform as nearly as possible to the usable sizes of the same. The material so produced has the following main **characteristics :**

(1) High resistance to wear.

(2) Extreme hardness.

(3) Capability of retaining this hardness at elevated temperatures.

(4) Poor resistance to shock.

These properties can be varied, as desired, according to the application of the tools, by varying the proportion of the above *carbides* and the *bond*. All the manufactures usually provide standard charts showing the application of various grades and they should be very carefully consulted before ordering for the *Carbide Tips*. More details about these materials and their processing are available in the chapter on **'Powder Metallurgy'**.

Since the material has a low tensile strength and a poor resistance to shock a shank of a material having high *tensile strength* and *toughness* is always required to support it during operation. This is another reason, apart from the economic considerations, to use this material only in the form of **tips**.

24.69 TIPPING OF TOOLS

Enough care and precision is called for in *fixing* the **Carbide Tips** to the *Tool Shank*. The end of the *shank* is accurately milled to form the *seat* for the *tip* and provide a perfect *bearing surface*. This accuracy becomes particularly more essential where a very thin layer of *brazing alloy* is to be provided. Thin *copper strips* are used as *brazing material* or some standard brazing material like **'Brazotectic rod'** manufactured by M/s. Indian Oxygen Co. Ltd., is procured and used for this purpose. In the later case the *rods* are beaten into *foils* and then used. The **Brazing Strip** is placed on the **Base** and side of the **seat** followed by the application of *flux* and then the **tip**. They are then clamped together and placed in high temperature furnace like a *Muffle*. When the brazing material has melted the tool is taken out and slight pressure is applied to ensure a *sound joint*.

Tin Brazing Foils are used for low temperature brazing of the tips. These foils have a *copper layer* in the middle and the *Brazing material* (*tin*) on the two sides of the same. Their use helps the **tips** to resist *shock*. It is very useful in case of planing, shaping and slotting tools. Heating of such brazing material is usually done with an *oxy-acetylene flame*.

Silver solder is also sometimes used for joining the carbide tips to the tool shank. This is particularly useful when the material of the shank is such that its heating to a high temperature will cause *distortion* on it rendering it unsuitable for a particular operation.

24.70 BRAZE WELDING

It can well be described as a compromise method of joining metals, intermediate between *true welding* and *true brazing*. Strictly speaking it is neither a purely welding process nor brazing. In *Welding*, the edges of the metal to be joined are melted and the molten pool is allowed to run between the edges which solidifies there to form the *joint*. Additional *filler metal* may or may not be used. Contrary to this, in *Brazing* the ends of the parent metal are not melted but an alloy, having low melting point, is used. *Temperature* is raised to the *fusion point* of this *alloy* which, when melted, runs between the edges due to *capillary action* and produces a **tinning effect**, resulting in the brazed joint.

Although it is a recognised fact that a very strong joint can be produced through welding but two *dissimilar metals* cannot be joined through this process, on account of the great difference which occurs between their general properties, structures and melting points etc.

This difficulty has been overcome through **Braze Welding**, and there lies the significance of this process. However, an important condition is that the melting points of the metals to be joined should be higher than the **Bronze filler rod** used for joining them. This *filler rod* usually consists of the 60-40 brass, as the main constituent, added with suitable amounts of *Deoxidisers* like silicon and tin, etc. *Phosphorus*, although being a common deoxidiser, is not preferred; particularly in *Braze Welding* of ferrous metals and alloys, for the reason that it will combine with iron to form hard and brittle compounds rendering the *weld* unsound. A **flux** should always be used in *Braze Welding*.

The *edge preparation* of the metals in this process is similar to that adopted in common *welding process*. After the edges have been prepared the *flux* is applied and then these edges are heated to a temperature corresponding to the fusion point of the *filler rod* material. The filler rod is brought in contact with these edges and it starts melting. This molten filler rod material has a sort of tinning action on the metal surfaces and adheres to them on solidification to form *a strong joint* called the **Braze Weld.**

24.71 WELDING DEFECTS

While the endeavour should always be to obtain a **Sound** (*Defect Free*) **Weld,** it is almost impossible to achieve this *Objective*. Some of these **defects** may be Apparent, *i.e.*, which are visible to the naked eyes while others, which are *concealed* and are of more serious nature, can be revealed through **Non-destructive** methods of testing only. Some of the *defects* may be *acceptable* while others may be *unacceptable* under given conditions. The *Acceptability* or *Unacceptability* of a **Defective Weld** will be governed by the following factors :

1. The environment a weld has to encounter in service.
2. The type of loading a weld has to undergo.
3. The type and size of defect.
4. The type of service the welded part is to render, and
5. The pattern of stresses a weld has to face.

Common Causes. Some common **factors** responsible for causing **Defects** in *welds* are the following :

1. Lack of welding skills in the welder.
2. Use of poor quality welding consumables.

3. Unfavourable characteristics of the parent metal.
4. Faulty welding techniques and procedures.
5. Poor cleanliness.
6. Low welding temperatures, and
7. Humid atmosphere around the weldment.

24.72 COMMON DEFECTS

1. Inclusions
2. Cracks
3. Distortion
4. Poor Penetration
5. Inadequate fusion
6. Undercut
7. Porosity
8. Overlapping
9. Spatter
10. Faulty Profile and Weld Size.

1. Inclusions. Normally the *Slag*, being lighter, is expected to float over the surface of the *Molten Metal Pool*. But, several times, specially in case of **multi-pass welds**, it is not fully squeezed out and a portion of it remains entrapped in the weld **metal** and is known as **Slag Inclusion.** Such inclusions may also be added due to many foreign materials like dirt, mill scale, rust, etc. present on the surface of the base metal. The **Slag Inclusions** appear as *large patches* and other *foreign material inclusions* are dispersed finely in the weld (See. Fig. 24.28). Such inclusions render the welded joint weak.

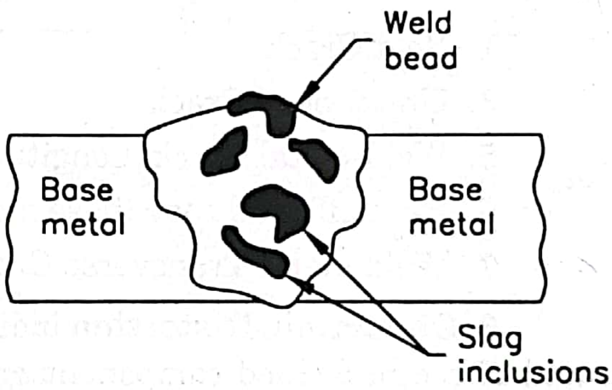


Fig. 24.28. Slag inclusions.

2. Cracks. A **Crack** is the *discontinuity* of metal. This discontinuity may occur in the *Base metal* or *Weld metal* or at *Fusion face* **between** the weld metal and base metal. If the *Crack* is large enough to be visible by naked eye, it is called a **Macrocrack.** If it is too small to be detected by the naked eye, it can be revealed through a *Microscopic Examination* only, then it is known as a **Micro-Crack.** A **Crack** may also appear in the *Crater*, in the *root* of the *bead* or on the surface of the *weld*. Presence of *cracks* in a *welded joint* renders it unsound and weak and may ultimately lead to the failure of the welded joint during service. For details of **cracks** refer to Fig. 24.29.

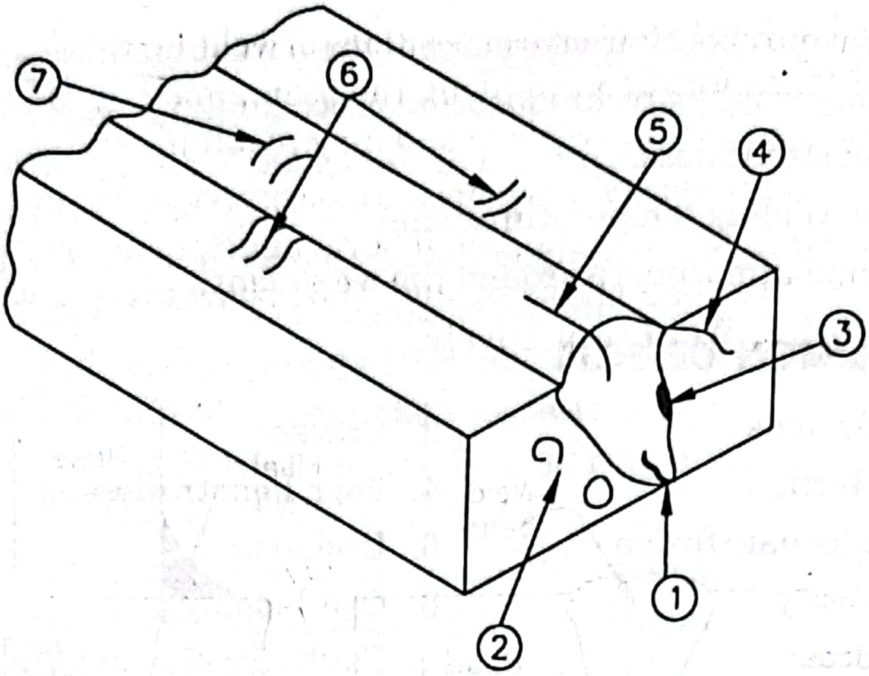


Fig. 24.29. Different types of cracks in welds.

1. Root Crack
2. Fusion face Crack
3. Under bead Crack
4. Toe Crack
5. Weld-metal Crack (Longitudinal)
6. Heat effected zone (base metal) Transverse Cracks
7. Weld metal Transverse Cracks.

3. Distortion. Distortion indicates a *change* in the intended shape and size of a welded component or structure. It occurs on account of uneven *contraction* (*shrinkage*) due to unequal heating and cooling of the base metal and the weld. What exactly happens is that, as the welding starts, the base metal under the *arc* or *gas flame* starts melting and the surrounding metal and that ahead of the weld gets heated up. As the welding proceeds further, more base metal melts. The metal melted earlier starts solidifying and shaping into a layer of **Bead** and more base metal ahead and around the *arc* gets heated up. This process continues upto the end of welding. This sets up different *temperature gradients* in the *welded, being welded* and *to be welded* areas of the **weldment,** resulting in uneven cooling and, hence, *non-uniform shrinkage* of hot metal in these areas. This leads to **distortion.** This can be controlled and minimised by several measures like *Tacking* before welding, use of *Jigs* and *Fixtures, presetting,* use of *clamps* and *wedges*, etc.

4. Poor Penetration. It indicates the failure of the *weld metal* to reach the *Root* of the *Joint.* Consequently, the *root faces* do not fuse fully with the weld metal. This *defect* is more pronounced and more common in overhead and vertical positions of welding. This *defect* results in a sort of **Permanent void** along the seam, making the joint weak. Also, it may carry slag *inclusions* and may result in *cracks*.

The main reasons of this defect are incorrect size of electrode, less welding current, less root gap, small bevel angle, faster welding speed, larger arc length, etc. Figs. 24.30 and 24.31 show this defect in a **Butt Weld** and **Fillet Weld** respectively.

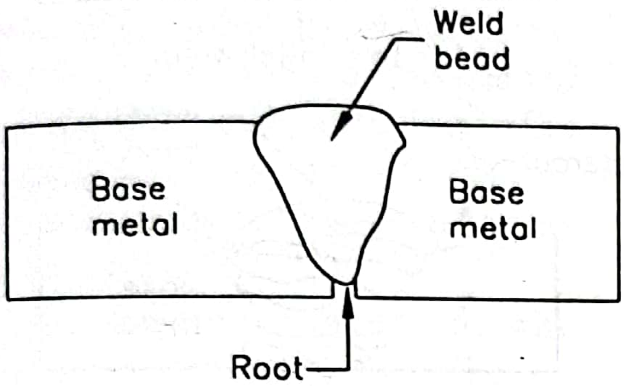


Fig. 24.30. Incomplete penetration at the root of a Butt weld.

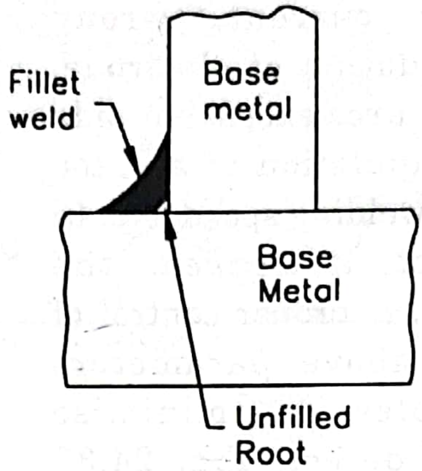


Fig. 24.31. Incomplete penetration at the root of a Fillet weld.

5. Inadequate Fusion. Sometimes the deposited weld metal by the electrode does not *fuse* fully with the *base metal* or with the previously deposited *layer* of the *weld metal* because the latter two are relatively cooler. This leads to the existence of a sort of *cushion* of an unfused metal between the above two.

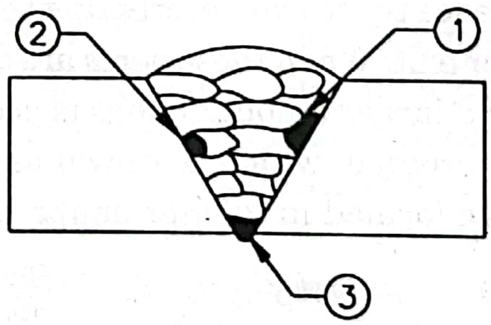


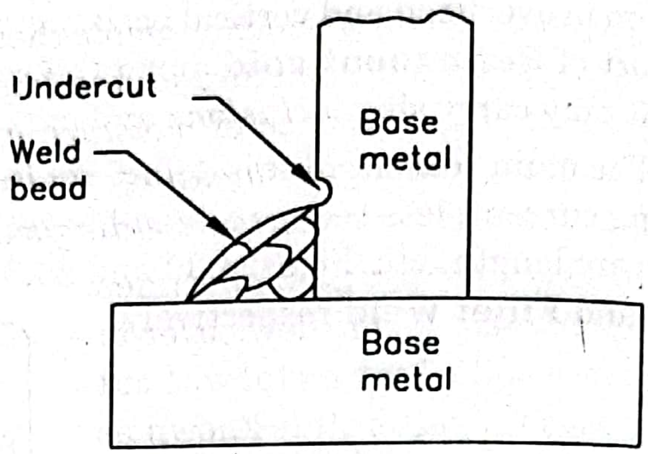
Fig. 24.32. Result of inadequate fusion at different locations in a weld.

Inadequate fusion between :

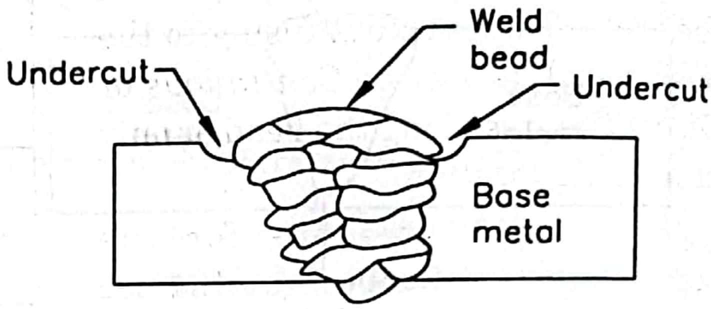
1. Two passes of welding.
2. Parent metal and weld metal on the side of 'V'.
3. Weld metal and parent metal at the root of the joint.

The main *reasons* of this defect are presence of oxide, dirt, scale, slag and other foreign material between the two fusing surfaces. It can be prevented by thoroughly cleaning these surfaces through deslagging, chipping, wire brushing, etc., to remove these materials from the surfaces. Fig. 24.32 shows the results of **Inadequate fusion** at different locations in a weld.

6. Undercut. An **Undercut** is a **Groove** formed in the *parent metal* at the *toe* of a *weld pass*, *i.e.* along the side of a *Weld Bead*. The main *reasons* for its formation are too high current, wrong inclination of electrode, long arc, excessive side manipulation of arc, too fast welding speed, etc. In effect, it *weakens* the joint. A proper control of the above parameters enables to minimise this defect. Fig. 24.33 illustrates the two cases of **Undercutting**.



(*a*) In a Fillet weld.



(*b*) In a Butt weld.

Fig. 24.33. The undercutting.

7. Porosity. This term is used to indicate the presence of small *pores* or *voids* in the weld. These *voids* are created by the entrapment of *gases* in the weld metal. During *solidification* of molten *weld metal* the gases try to evolve, creating the voids, which are actually their passages for exit. When these *pores* are quite small, their group is called **Porosity.** If a larger amount of gas is accumulated at a *single place*, a bigger void is created, which is known as a **Blow Hole.** In some cases these voids are formed in *tabular* shape, then they are called **Piping**.

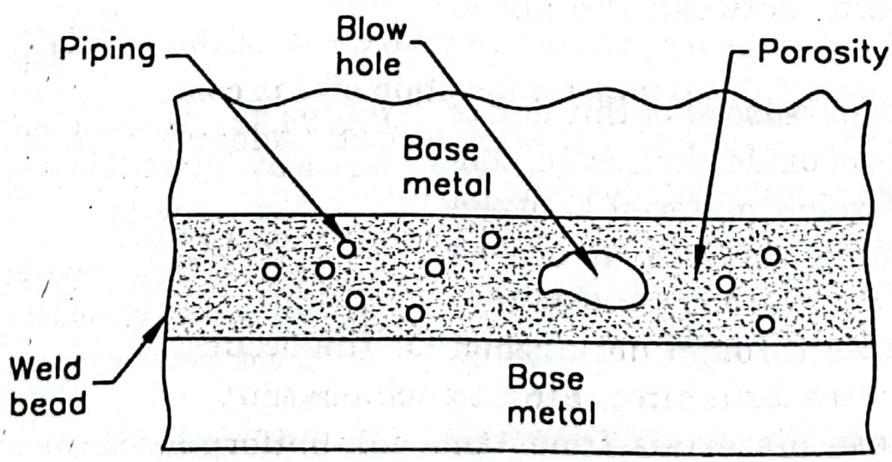


Fig. 24.34. Porosity, blowhole and piping.

The main *Factors* which *promote* these defects are the presence of oil, grease, scale and moisture on the joint surface; use of chemically faulty electrodes, presence of *moisture* in *electrode coating* and *flux*, *longer arc*, *improper gas shielding*, *faulty composition* of base metal, *wrong welding techniques*, *low welding current*, etc. (See Fig. 24.34).

8. Overlapping. Sometimes the molten *Weld metal* flows over to the surface of the base metal without *fusing* with the latter. It is known as *overlap* (Fig. 24.35). In appearance it looks like an unintended extension of the *Weld Bead* without fusing to the base metal. It may be *Continuous* or *Discontinuous* along the bead or only at a single location.

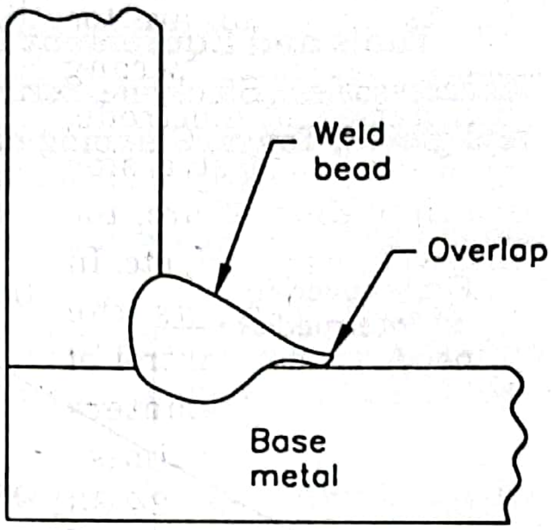


Fig. 24.35. The undercutting.

The main reasons for the occurrence of this *defect* are the use of oversize electrode, very low welding speed, incorrect manipulation of electrode, too high current, too long arc, etc. The defect can be controlled to a large extent by controlling the above parameters.

9. Spatter. During welding, tiny *Electrode metal particles* are blown out of the *arc* which get deposited over the adjoining base metal surface and also on the surface of the *Bead*. These particles strongly adhere to these surfaces and are known as **Spatter**. They give *poor appearance* to the surfaces concerned and their removal adds to the cost of welding, although they don't have any appreciable effect on the *weld strength*.

The main reasons of this defect are use of damp electrodes, too high welding current, wrong composition of flux coating, discontinuous arc, **Are Blow** (in case of D.C. welding), etc. Adequate control of these parameters will prevent this defect.

10. Faulty Profile and Weld Size. A **Weld** is known to have a *Faulty Profile* and *Size* when it differs from the specified shape and size. The main reasons for the occurrence of this defect are lack of skill in the welder, inconsistent arc length, wrong end preparation, discontinuous and non-uniform electrode coating, wrong electrode manipulation, wrong electrode size, wrong welding speed, etc.

24.73 PRACTICAL EXERCISES

EXERCISES 1. To prepare a Butt Joint (Single-V) through Electric Arc Welding in Flat Position.

Raw Material Required. Two mild steel flat pieces of size 140 mm × 45 mm × 10 mm each and M.S. Electrodes.

Tools and Equipment Used. Arc welding Transformer (with all its accessories), Steel rule, Scriber, Files; Safety equipment such as shield and gloves; Tongs, Chipping hammer, Wire brush, etc.

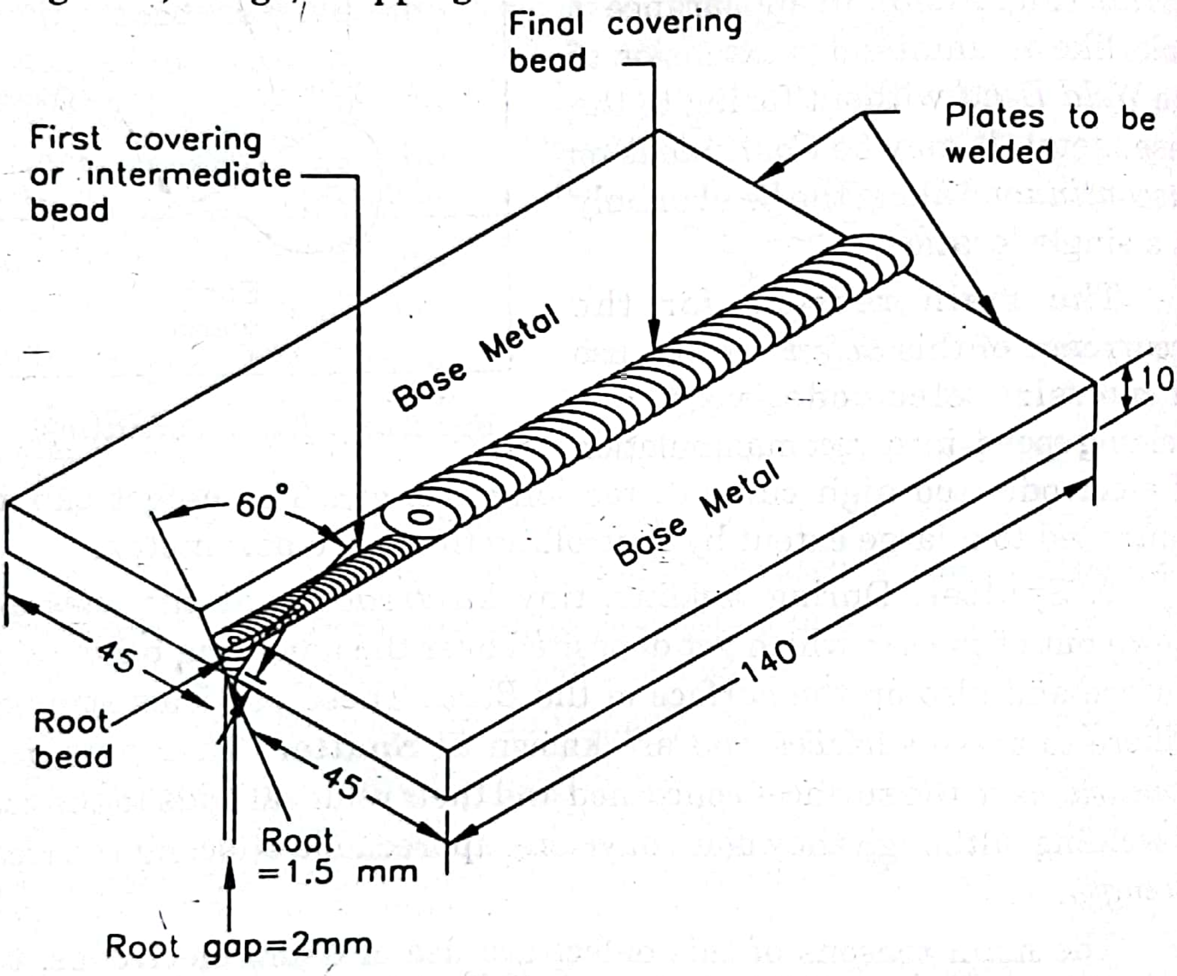


Fig. 24.36. Butt-joint (Single-V) through Arc Welding in Flat position.

Procedure :

1. Cut the two pieces of required length from M.S. Flat (of required width and thickness) by means of a hacksaw.
2. Cut the required bevel on the edges of both pieces to form the 60° 'V' when placed abutted (Fig. 24.36).
3. Then, by means of filing, prepare the root faces.
4. Keep the two pieces in reverse position, *i.e.*, the *root gap* on the top and '*V*' *groove* in inverted position below.

5. Tack weld the two pieces along the root gap from both ends to a reasonable distance (say 12 mm).
6. Invert the tack welded pieces and place them in *Flat Position* to start welding.
7. Set proper current (120 Amps.) and lay the *Root Bead* using a 3 mm diameter M.S. Electrode.
8. Clean the root bead and check the penetration.
9. Then using a 4 mm electrode and setting proper current, deposit the *covering* the *(intermediate bead)*, at a uniform speed and a side-to-side (weaving) motion of electrode.
10. Clean this intermediate (covering) bead by means of the chipping hammer and wire brush.
11. Then, using a 5 mm electrode and 220 Amps. current, deposit the *Final Covering Bead* adopting the same weaving (side-to-side) motion for the electrode.
12. Finally clean the prepared joint thoroughly, using Chipping Hammer and Wire Brush, from both sides and check it for proper root penetration, distortion and visual surface defects, if any.

Common Precautions :

1. Wear proper protective clothing, *viz.*, apron, hand gloves etc., while welding.
2. Also use proper shield during welding.
3. While cleaning the joint, use goggles for protection of eyes.
4. Strike and maintain proper arc throughout welding.
5. Always select and use proper current and correct electrode size.
6. Always use tongs to hold the hot workpieces.

EXERCISES 2. To prepare a Lap Joint (Fillet Weld) through Arc welding in Flat Position (Fig. 24.37).

Raw Material Required. Two mild steel flat pieces of size 120 mm × 45 mm × 8 mm each.

Tools and Equipment Required. Arc welding transformer (with all its accessories), Steel rule, Scriber, Files; Safety equipment such as Shield, Apron and Gloves; Tongs, Chipping Hammer, Wire Brush, C-clamps, etc.

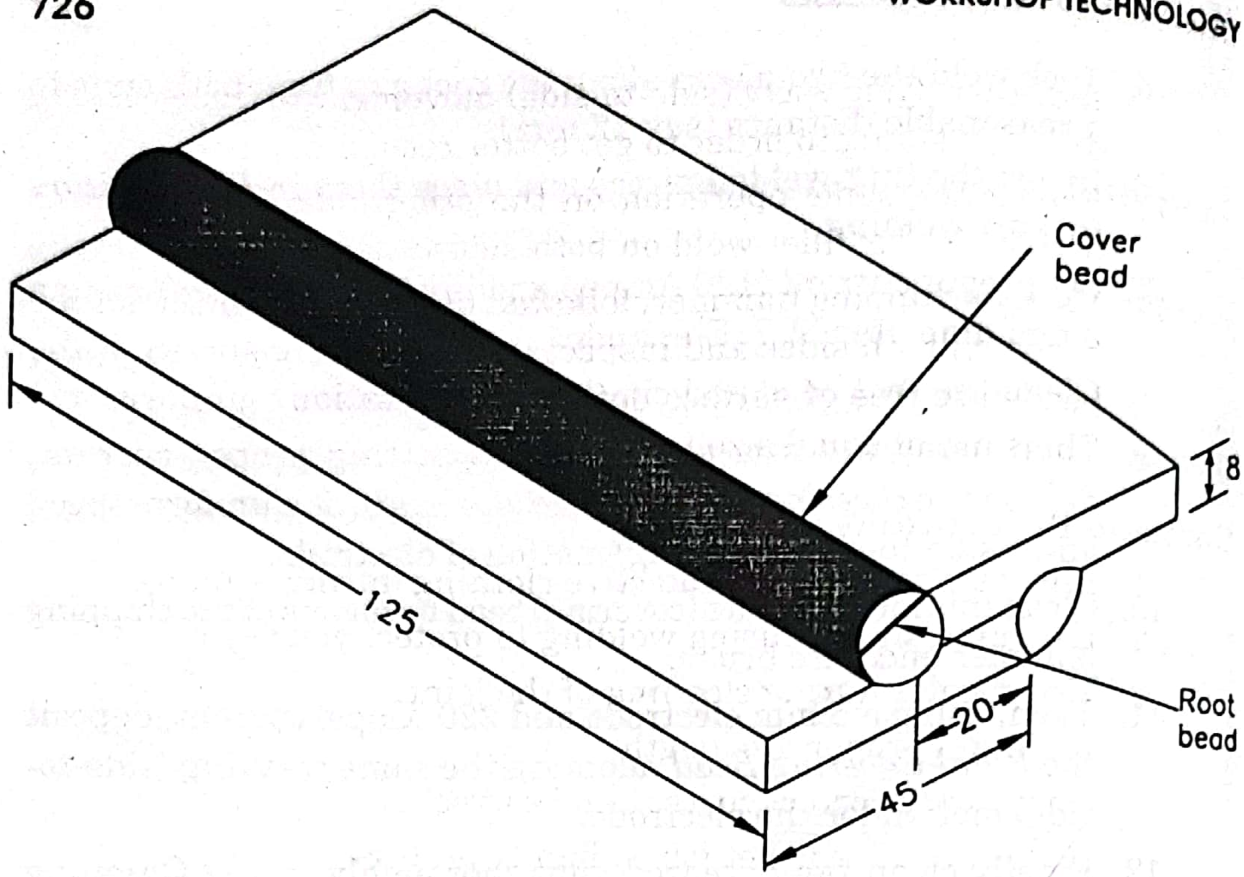


Fig. 24.37. Lap Joint (Fillet weld) through Arc Welding in Flat Position.

Procedure :

1. From M.S. flat of required thickness and width cut two pieces of 120 mm length each by using a hacksaw.
2. Set the two pieces, one over the other, such that the top piece overlaps the bottom piece by 20 mm.
3. Hold the pieces firmly together, in perfect alignment, by means of C-clamps on both ends.
4. Tack weld on both ends, where the fillets will be formed, and also in the middle of the length, if needed.
5. Set the tacked pieces in Flat Welding Position.
6. Set the current at 120 Amps.
7. Select suitable electrode (say 3 mm diameter), hold it in electrode holder, and strike the arc.
8. Maintaining a short arc, deposit the root bead from one end to the other.
9. Using the chipping hammer and wire brush, clean the root bead thoroughly.
10. Then, replace the 3 mm diameter electrode by a 4 mm diameter electrode, increase the current suitably, strike the arc again and deposit the cover bead over the root bead from one end to

the other. Give wavy (side-to-side) movement to the electrode during welding in order to get better results.

11. Repeat the same operation on the other side of the joint to obtain similar fillet weld on both sides.
12. Using a chipping hammer, followed by a wire brush, clean the beads on both sides and inspect it visually to ensure that the beads are free of surface defects, the beads are uniform and fillets are of equal size.

Common Precautions :

1. Always wear proper protective clothing during welding.
2. Use hand shield during welding to protect your eyes.
3. Use goggles during cleaning of the joint.
4. Maintain proper arc length.
5. Always use correct current and correct electrode size.
6. Never handle the hot job by hand, use tongs for this purpose.

EXERCISES 3. To prepare a square Butt Joint through Gas Welding in Flat Position, as per Fig. 24.38.

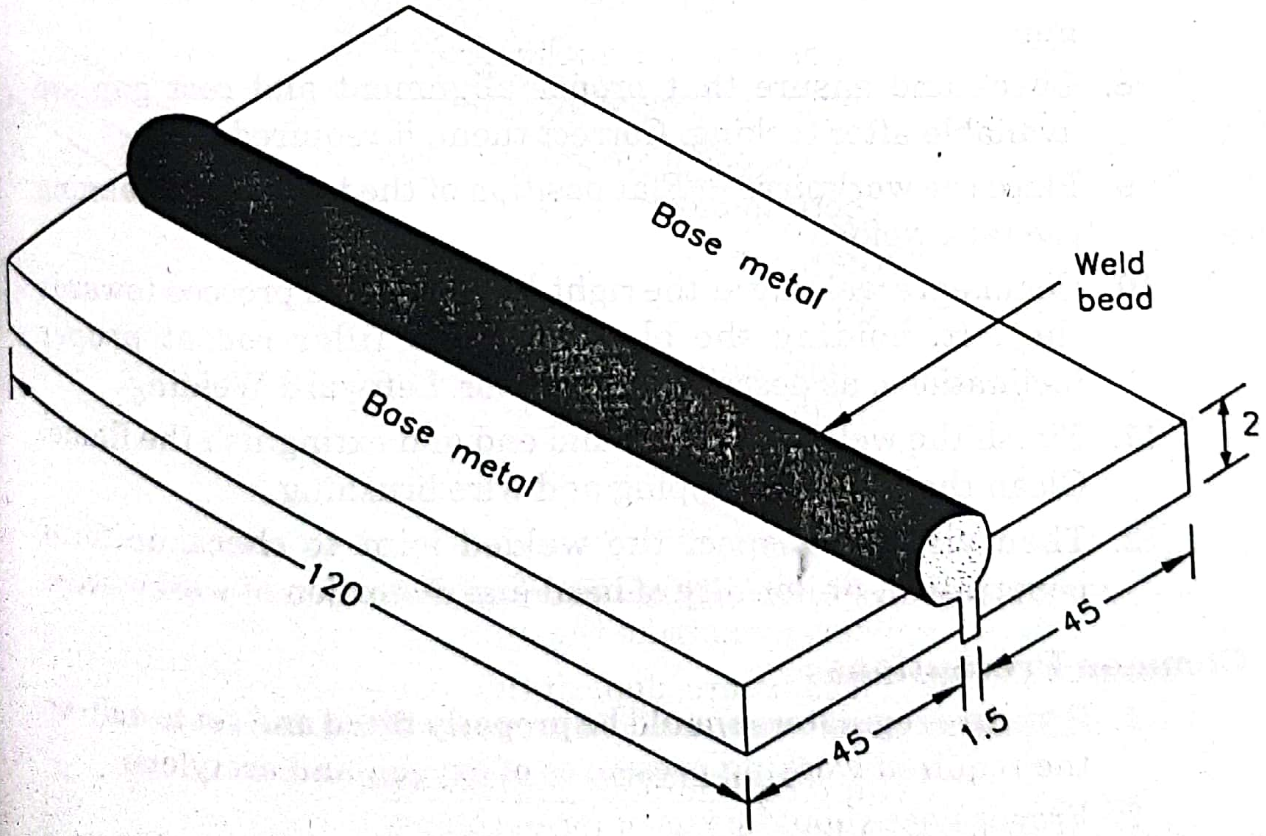


Fig. 24.38. A Square Butt Joint in Gas Welding in Flat Position.

Raw Material Required. Two pieces of 2 mm thick M.S. Sheet, each measuring 120 mm × 45 mm, and filler rods of proper size.

Tools and Equipment Used. H.P. Oxygen and Acetylene cylinders with Pressure Regulators and Hoses, Welding torch, Gas welding table, Steel rule, Scriber, Files, Safety equipment—Welding Goggles, Gloves, Apron, etc., Tongs, Chipping Hammer, Wire Brush, Spark Lighter and Suitable Clamping device.

Procedure :

1. Cut the two pieces of required size from 2 mm thick M.S. sheet.
2. File the edges and make them square.
3. Set up the Gas Welding plant, set the gas pressures in the two regulators and fit proper size nozzle (No. 3 in this case).
4. Place the two prepared pieces on welding table with the squared edges abutting each other and carrying a proper root gap as per Fig. 24.3?.
5. Use 1.6 mm diameter filler rod in the process of welding.
6. Light the flame and adjust the flow of two gases to obtain a neutral flame.
7. Hold the two pieces firmly in perfect alignment and tack weld at both ends, as well as along the seam at intervals of about 40 mm.
8. Check and ensure that proper alignment and root gap are available after tacking. Correct them, if required.
9. Place the workpiece in Flat position of the table after cleaning the tack welds.
10. Commence welding at the right-hand end and proceed towards the left, holding the blow-pipe and filler rod at proper inclinations, as described earlier for 'Leftward Welding'.
11. Finish the welding at left-hand end and extinguish the flame. Clean the bead by chipping and wire brushing.
12. Then visually inspect the welded joint to check uniform penetration, uniformity of bead and distortion of workpieces.

Common Precautions :

1. Pressure regulators should be properly fitted and set to deliver the required working pressures of oxygen and acetylene.
2. Proper hose should be used for each gas.
3. Welding goggles and other safety equipment should be used during welding.
4. Hot job should always be handled by means of tongs.

5. While starting, first start the flow of acetylene and then oxygen. While stopping the gas supply, close the oxygen valve first, followed by acetylene.

EXERCISES 4. To prepare a Lap Joint through Gas Welding in Flat Position, as per Fig. 24.39.

Raw Material Required. Two pieces of 3 mm thick M.S. Sheet, each measuring 140 mm × 55 mm, and filler rods of proper gauges.

Tools and Equipment. Oxygen and Acetylene cylinders with proper Pressure Regulators and Hoses, Welding torch, Gas welding table, Steel rule, Scriber, Files, Safety equipment—Welding Goggles, Apron, Gloves, etc., Tongs, Chipping Hammer, Wire Brush, Spark Lighter, Clamping device, etc.

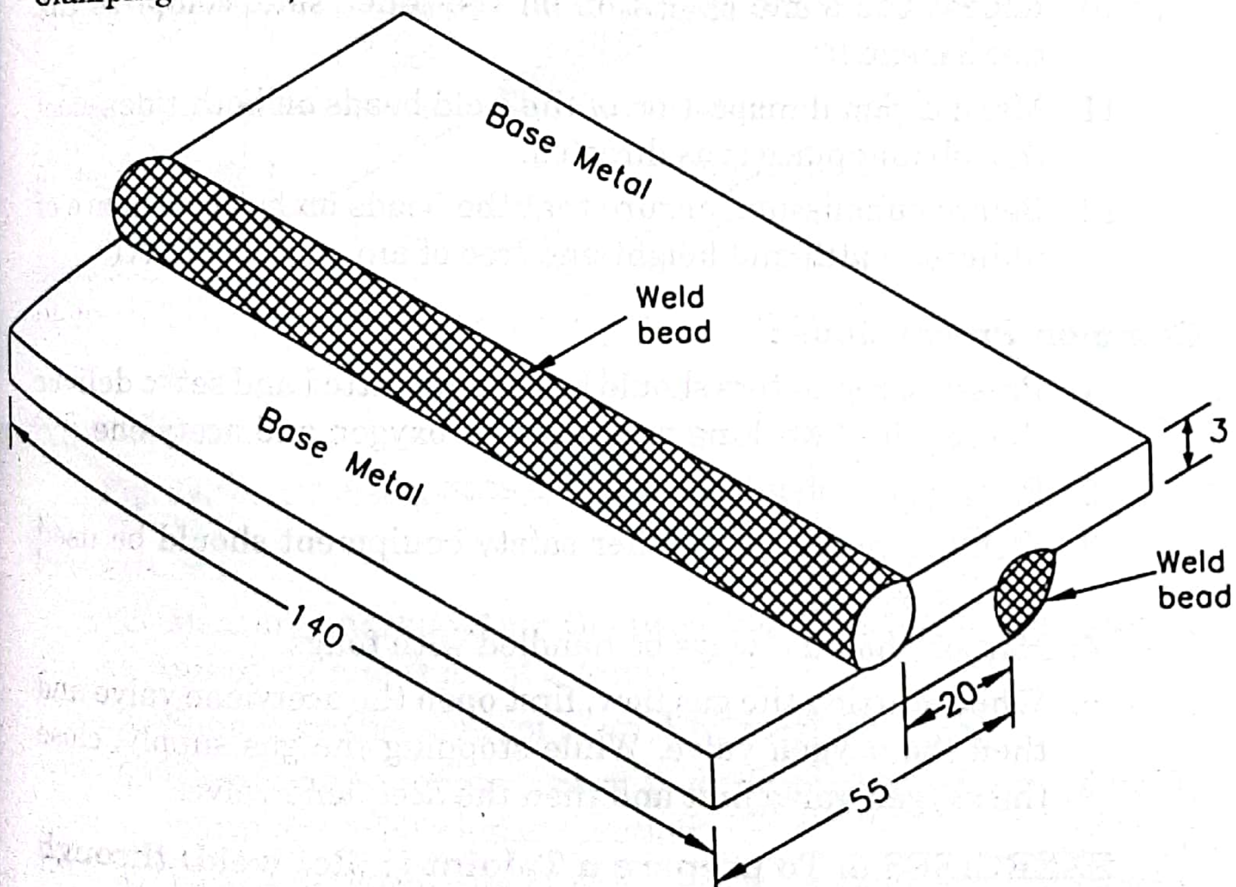


Fig. 24.39. A Lap Joint (Fillet Weld) through Gas Welding in Flat Position.

Procedure :

1. Cut two pieces of required size from 3 mm thick M.S. sheet.
2. File the edges and make them square.
3. Set up the Gas Welding Plant, set gas pressures in the two regulators and fit a proper size nozzle in the blow pipe.
4. Place the two pieces on the welding table, set the overlap as per drawing (Fig. 24.39) and hold them firmly together to maintain the same overlap throughout.

5. Light the flame and adjust it to neutral.
6. Select a suitable size of filler rod and tack weld the two pieces at both ends and also in the middle.
7. Clean the tacks and keep the pieces in Flat position on the table.
8. Using a 3.2 mm thick filler rod, commence welding at the right hand end and proceed towards left employing the 'Leftward Welding Technique'.
9. Stop welding when it reaches the left hand end and extinguish the flame. Clean the bead by chipping hammer and wire brush.
10. Repeat the same operation on the other side, complete the weld, clean it.
11. Make a visual inspection of the weld beads on both sides, cool the job and place it as directed.
12. Before submission, ensure that the beads on both sides are of uniform width and height and free of any surface defect.

Common Precautions :

1. Pressure regulators should be properly fitted and set to deliver the required working pressures for oxygen and acetylene.
2. Proper hose should be used for each gas.
3. Welding goggles and other safety equipment should be used during welding.
4. Hot job should always be handled with tongs.
5. While starting the gas flow, first open the acetylene valve and then the oxygen valve. While stopping the gas supply, close the oxygen valve first and then the acetylene valve.

EXERCISES 5. To prepare a T-Joint (Fillet weld) through Gas Welding in Flat Position, as per Fig. 24.40.

Raw Material. Two M.S. Sheet (2 mm thick) pieces, one measuring 120 mm × 50 mm, and the other 120 mm × 45 mm, and filler rods of proper sizes.

Tools and Equipment. H.P. Oxygen and Acetylene cylinders, Relevant Pressure Regulators and Hoses, Welding Blow-pipe, Gas welding table, Try square, Steel rule, Scriber, Files, Safety equipment—Welding Goggles, Gloves, Apron, etc., Tongs, Chipping Hammer, Wire Brush, Spark Lighter, etc.

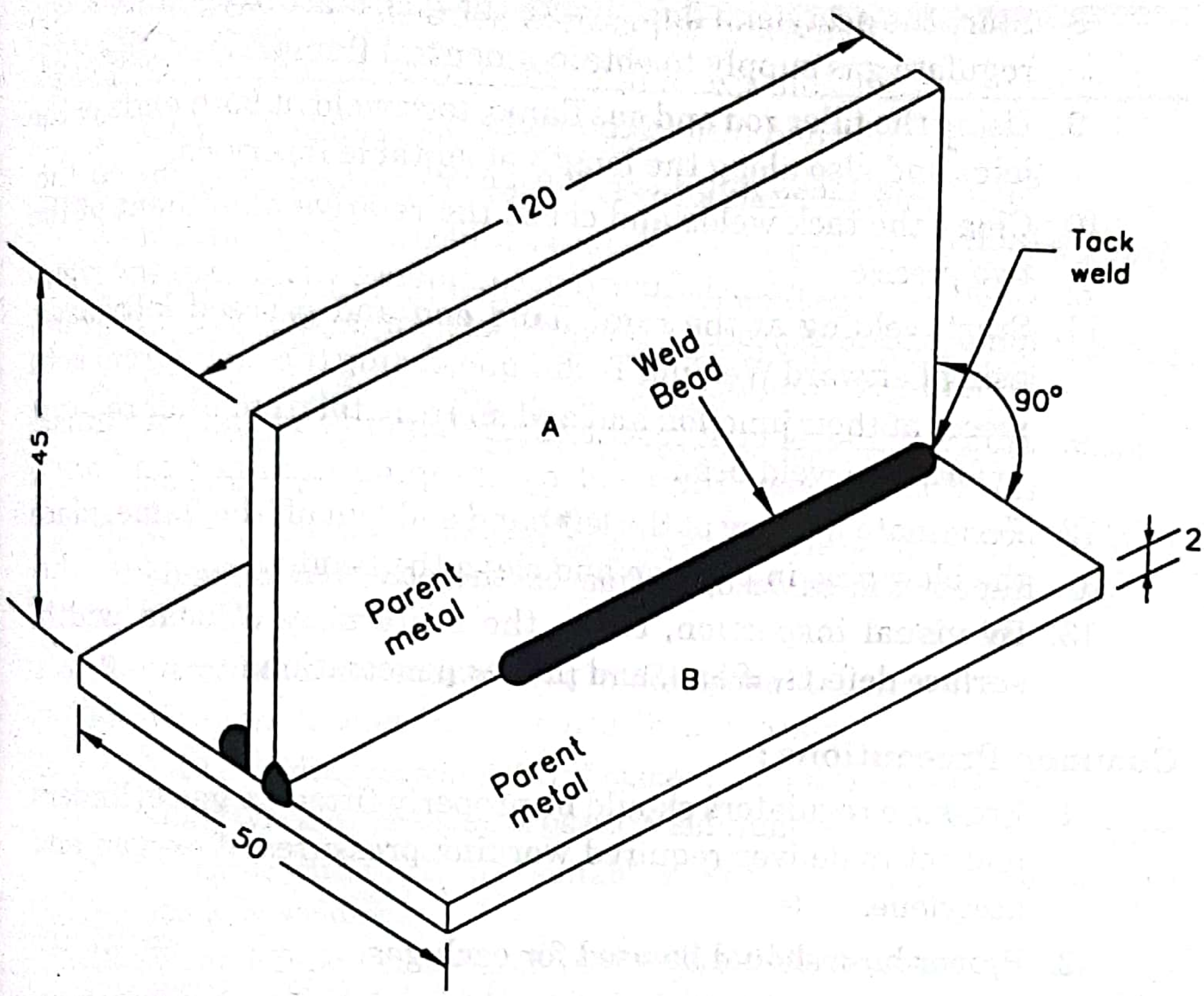


Fig. 24.40. A T-Joint (Fillet Weld) in Gas Welding in Flat Position.

Procedure :

1. Measure, mark and cut the two pieces of required dimensions out of a 2 mm thick M.S. Sheet.
2. Square up the edges of piece *A* by means of filing.
3. Clean up the top surface of piece *B* and the edge of piece *A*, which are to be welded together.
4. Wear safety equipment and place the two pieces on the work table, such that the piece *B* is horizontal and piece *A* vertical.
5. With the help of a try square ensure that the angle between the two pieces is exactly 90°, as shown in the diagram.
6. Hold them in this relative position firmly so that the included angle between them remains 90° throughout the welding operation.
7. Set up the gas welding plant, adjust the two regulators for required working pressures and fit proper nozzle to the blow-pipe.

8. Start the acetylene flow, ignite the gas, start oxygen flow and regulate gas supply to obtain a neutral flame.
9. Using the filler rod and gas flame, tack weld at both ends of the joint and also along the length at suitable intervals.
10. Clean the tack welds and check the relative alignment of the two pieces.
11. Start welding at the right hand end and proceed leftwards, using Leftward Welding Technique, fusing the metal from both pieces at their junction and add more metal from filler rod to it to form the weld bead.
12. Terminate welding at the left hand end, put off the flame, place the blow pipe in position and clean the bead.
13. By visual inspection, check the uniformity of bead width, surface defects, if any, and proper penetration.

Common Precautions :

1. Pressure regulators should be properly fitted on gas cylinders and set to deliver required working pressures of oxygen and acetylene.
2. Proper hose should be used for each gas.
3. Required safety equipment must be used during the operation.
4. Hot job should always be handled with tongs.
5. While starting the gas flow for lighting the flame, first start acetylene and then the oxygen. Similarly, while stopping the gas flame, close the oxygen valve first and then the acetylene valve.

24.74 SUGGESTED BIS CODES FOR FURTHER REFERENCE

IS 2635 : 1975	IS 5206 : 1983	IS 1261 : 1959	IS 193 : 1982
IS 2641 : 1989	IS 5511 : 1969	IS 2811 : 1987	IS 959 : 1980
IS 6008 : 1989	IS 6419 : 1971	IS 2812 : 1964	IS 813 : 1986
IS 1851 : 1975	IS 1395 : 1982	IS 4353 : 1967	IS 815 : 1974
IS 1278 : 1972	IS 1323 : 1982	IS 2927 : 1975	IS 818 : 1968
IS 1040 : 1987	IS 5193 : 1969	IS 1182 : 1983	IS 822 : 1970
IS 4853 : 1982	IS 1870 : 1965	IS 7810 : 1975	IS 8666 : 1977
IS 8736 : 1977	IS 9524 : 1980	IS 9604 : 1980	IS 5139 : 1969
IS 10793 : 1983	IS 10811 : 1984	IS 4944 : 1968	IS 5334 : 1981

TEST QUESTIONS

1. What is Welding and why is it done ?
2. What is Resistance Welding ? Give its classification.
3. Describe with the help of a neat sketch the principle of Spot Welding.
4. Briefly explain Butt welding and Seam welding.
5. Explain with the help of a neat diagram the principle of Flash welding.
6. What do you understand by Gas welding ?
7. Describe in brief the equipment required for Oxy-acetylene Welding and Cutting.
8. What is the main difference between the Blow-pipes used for High pressure and Low pressure gas welding ? Explain with the help of suitable sketches.
9. Describe the working of Pressure Regulators.
10. Write short notes on :
    (*i*) Welding rods (*ii*) Fluxes (*iii*) Gas flames.
    (*iv*) Working pressure of gases in H.P. and L.P. welding and cutting.
11. Describe with the help of suitable sketches the various types of joints made in welding.
12. What different methods of welding you know ? Describe them in brief.
13. What procedure you will follow and what care will you take in operating :
    (*i*) A low pressure plant (*ii*) A high pressure plant.
14. Describe fully the method of oxy-acetylene cutting.
15. (*a*) What is an Electric Arc method of Welding ?
    (*b*) How many methods of Arc welding do you know ?
16. Give a list of equipments required in general for Electric Arc Welding.
17. Explain the principle of Arc-welding.
18. (*a*) What do you understand by the term 'Polarity' ?
    (*b*) What is the advantage of having different polarities ?
19. Compare the merits and demerits of using A.C. and D.C. for arc welding.
20. Describe briefly the methods of Carbon arc and Metallic arc welding.
21. Explain the processes of Soldering and Brazing.
22. What do you know about 'Thermit Welding' ? What are its main advantages ?
23. Explain the processes of Soldering and Brazing.
24. Write short notes on :
    (*a*) Leftward welding (*b*) Rightward welding
    (*c*) Vertical welding (*d*) Forge or smithy welding.

25. What are the electrodes used in Arc Welding made of? What are Electrode Coverings and why are they provided?

26. How is an Electrode specified? What factors govern the selection of an Electrode?

27. Describe the following welding methods and their specific applications:

(*a*) TIG welding (*b*) MIG welding (*c*) CO_2 MIG welding.

28. Describe the process of Submerged Arc Welding stating its advantages and limitations.

29. With the help of a neat diagram explain the process of Electroslag Welding.

30. Write short notes on:

(*a*) Electrogas welding (*b*) Stud welding (*c*) Plasma arc welding.

31. Describe in brief the methods used for welding different metals.

32. Write short notes on:

(*i*) Braze welding (*ii*) Projection welding.

(*iii*) Percussion welding (*iv*) Tipped Tools and Tipping of tools.

33. What are 'Acceptable' and 'Unacceptable' welding defects? What factors govern them?

34. (*a*) What are common courses of Welding Defects?

(*b*) List the common Welding Defects.

35. Write short notes on any two of the following Welding Defects:

(*a*) Inclusions (*b*) Cracks

(*c*) Overlapping (*d*) Incomplete Penetration

(*e*) Inadequate fusion.

36. Describe the following welding defects:

(*a*) Spelter

(*b*) Distortion

(*c*) Faulty profile and weld size

(*d*) Poor Penetration

37. What is Porosity? Why and in how many forms does it occur?