UNIT-2

Electric Welding & Electrolysis process

Electric Welding

- Welding is the process of joining two pieces of metal or non metal by applying heat or/and pressure.
- Classification:

➢ All the welding processes are classified as

1. Fusion welding
2. Non-fusion welding

Advantages and Disadvantages of Welding

- Some of the advantages of welding are:
  - Welding is the most economical method to permanently join two metal parts.
  - It provides design flexibility.
  - Welding equipment is not so costly.
  - It joins all the commercial metals.
  - Both similar and dissimilar metals can be joined by welding.
  - Portable welding equipment are available.
- Some of the disadvantages of welding are:
  - Welding gives out harmful radiations and fumes.
  - Welding needs internal inspection.
  - If welding is not done carefully, it may result in the distortion of workpiece.
  - Skilled welding is necessary to produce good welding.
- **<u>Fusion welding:</u>**
  - This type of welding takes place by melting the two metals to be welded together.

Examples of fusion welding: which utilize electric energy

- Carbon arc welding
- metal arc welding
- Electron beam welding
- Electroslag welding
- Electrogas welding

– Gas welding and thermit welding which utilize chemical energy for the melting purpose

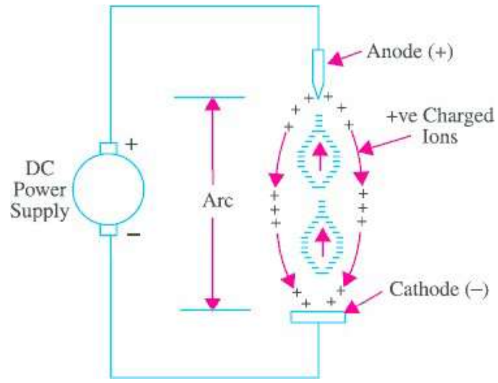
2. Non-fusion welding:

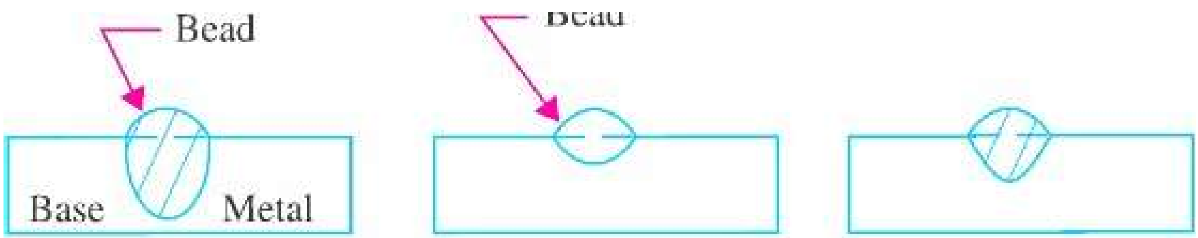
- In this type of welding the metals to be welded together need not be melted. Examples of non fusion welding are as follows:
- (*i*) Forge welding and gas non-fusion welding which use chemical energy.
- (*ii*) Explosive welding, friction welding and ultrasonic welding etc., which use mechanical energy.
- (*iii*) Resistance welding which uses electrical energy.
- **Proper selection of the welding process depends on the**
  - (*a*) kind of metals to be joined
  - (*b*) cost involved
  - (*c*) nature of products to be fabricated and
  - (*d*) production techniques adopted

Formation and Characteristics of Electric Arc

- An electric arc is formed whenever electric current is passed between two metallic electrodes which are separated by a short distance from each other.
- The arc is started by momentarily touching the positive electrode (anode) to the negative metal (or plate) and then withdrawing it to about 3 to 6 mm from the plate.

  When electrode first touches the plate, a large short-circuit current flows and as it is late withdrawn from the plate, current continues to flow in the form of a spark across the air gap so formed.
- Due to this spark (or discharge), the air in the gap becomes ionized *i.e.* is split into negative electrons and positive ions.
- Consequently, air becomes conducting and current is able to flow across the gap in the form of an arc.
- As shown in Fig. 1, the arc consists of *lighter* electrons which flow from cathode to anode and *heavier* positive ions which flow from anode to cathode.
- Intense heat is generated when high velocity electrons strike the anode.
- Heat generated at the cathode is much less because of the low velocity of the impinging ions.
- It is found that nearly two-third of the heat is developed at the anode which burns into the form of a crater where temperature rises to a value of 3500-4000°C.
- The remaining one-third of the heat is developed near the cathode.
- The above statement is true in all d.c. systems of welding where positive side of the circuit is the hottest side.
- As a result, an electrode connected to the positive end of the d.c. supply circuit will burn 50% faster than if connected to the negative end. This fact can be used for obtaining desired penetration of the base metal during welding.





(a) (b) (c)

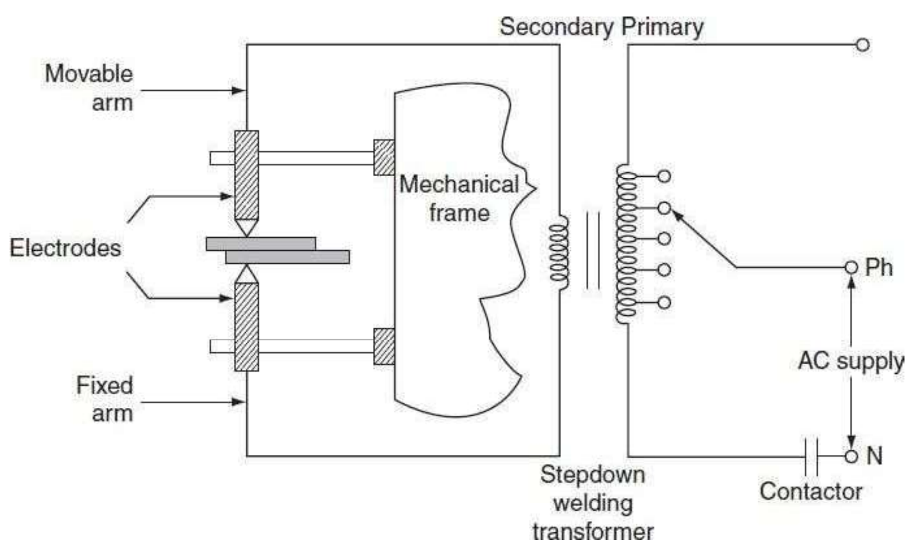
- If positive supply end is connected to the base metal (which is normally grounded), penetration will be greater due to more heat and, at the same time, the electrode will burn away slowly [Fig. 2 (*a*)] since it is connected to the negative end of the supply.
- If supply connections are reversed, the penetration of heat zone in the base metal will be comparatively shallow and, at the same time, electrode will burn fast [Fig. 2 (*b*)].
- AC supply produces a penetration depth that is nearly halfway between that achieved by the d.c. positive ground and negative ground as shown in Fig. 2 (*c*).

Resistance Welding

- Resistance welding is the process of joining two metals together by the heat produced due to the resistance offered to the flow of electric current at the junctions of two metals.
- The heat produced by the resistance to the flow of current is given by:
- where I is the current through the electrodes, R is the contact resistance of the interface, and t is the time for which current flows.

$$H = I^2Rt,$$

- **Here, the total resistance offered to the flow of current is made up of:**
- (i) The resistance of current path in the work.
- (ii) The resistance between the contact surfaces of the parts being welded.
- (iii) The resistance between electrodes and the surface of parts being welded.
- In this process of welding, the heat developed at the contact area between the pieces to be welded reduces the metal to plastic state or liquid state, then the pieces are pressed under high mechanical pressure to complete the weld.
- The electrical voltage input to the welding varies in between 4 and 12 V depending upon area, thickness, composition, etc. and usually power ranges from about 60 to 180 W for each sq. mm of area.



- **Advantages**
- Welding process is rapid and simple.
- Localized heating is possible, if required.
- No need of using filler metal.
- Both similar and dissimilar metals can be welded.
- Comparatively lesser skill is required.

- Maintenance cost is less.
- It can be employed for mass production.

However, the resistance welding has got some drawbacks and they are:

- Initial cost is very high.
- High maintenance cost.
- The workpiece with heavier thickness cannot be welded, since it requires high input current.
- **Applications**
- It is used by many industries manufacturing products made up of thinner gauge metals.
- It is used for the manufacturing of tubes and smaller structural sections

Types of resistance welding

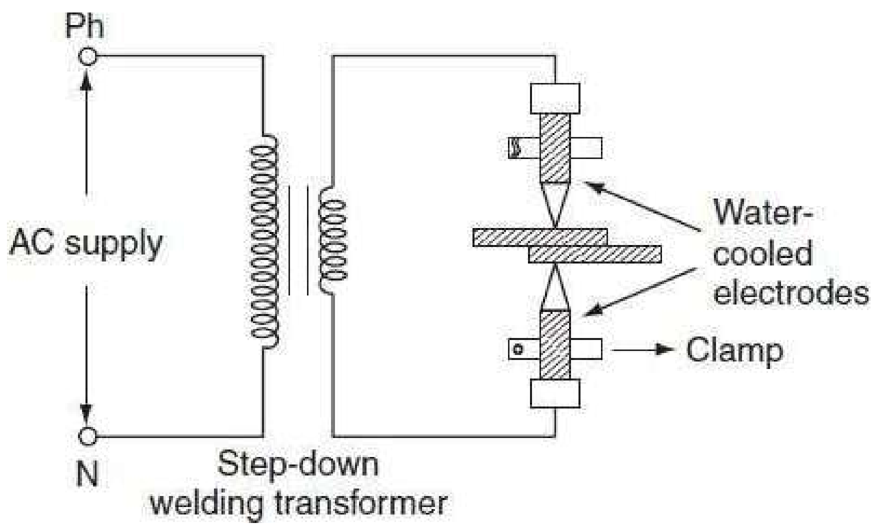
- Depending upon the method of weld obtained and the type of electrodes used, the resistance welding is classified as:
- 1. Spot welding.
- 2. Seam welding.
- 3. Projection welding.
- 4. Butt welding.

Spot welding

- Spot welding means the joining of two metal sheets and fusing them together between copper electrode tips at suitably spaced intervals by means of heavy electric current passed through the electrodes as shown in Fig. 1.
- This type of joint formed by the spot welding provides mechanical strength and not air or water tight, for such welding it is necessary to localize the welding current and to apply sufficient pressure on the sheet to be welded. The electrodes are made up of copper or copper alloy and are water cooled.
- The welding current varies widely depending upon the thickness and composition of the

plates.

- It varies from 1,000 to 10,000 A, and voltage between the electrodes is usually less than 2 V.
- The period of the flow of current varies widely depending upon the thickness of sheets to be joined.
- A step-down transformer is used to reduce a high-voltage and low-current supply to low-voltage and high-current supply required. Since the heat developed being proportional to the product of welding time and square of the current.

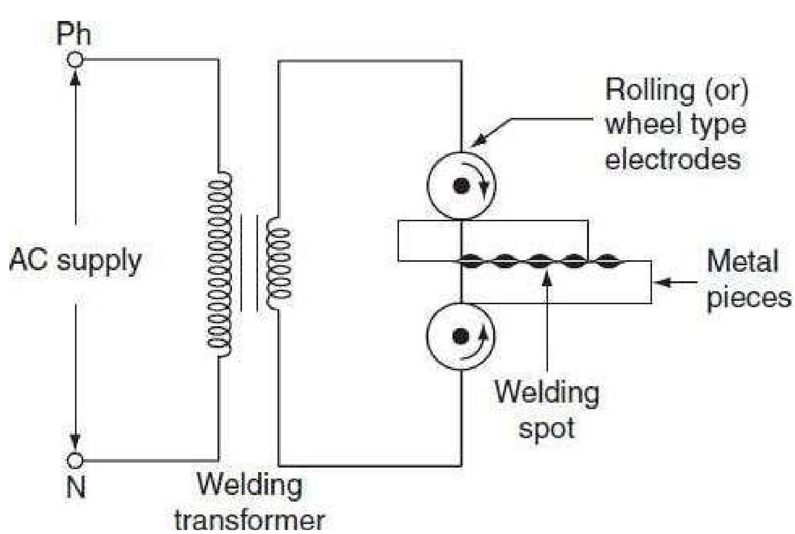


- Good weld can be obtained by low currents for longer duration and high currents for shorter duration; longer welding time usually produces stronger weld but it involves high energy expenditure, electrode maintenance, and lot of distortion of workpiece.
- When voltage applied across the electrode, the flow of current will generate heat at the three junctions, i.e., heat developed, between the two electrode tips and workpiece, between the two workpieces to be joined as shown in Fig. 1.
- The generation of heat at junctions 1 and 3 will effect electrode sticking and melt through holes, the prevention of electrode striking is achieved by:
- (i) Using water-cooled electrodes shown in Fig. 2. By avoiding the heating of junctions 1 and 3 electrodes in which cold water circulated continuously as shown in Fig. 1.
- (ii) The material used for electrode should have high electrical and thermal conductivity.

- Spot welding is widely used for automatic welding process, for joining automobile parts, joining and fabricating sheet metal structure, etc.
- Spot welding is used for galvanized, tinned and lead coated sheets and mild steel sheet work. This technique is also applied to non-ferrous materials such as brass, aluminium, nickel and bronze etc

Seam welding

- Seam welding is nothing but the series of continuous spot welding. If number spots obtained by spot welding are placed very closely that they can overlap, it gives rise to seam welding.
- In this welding, continuous spot welds can be formed by using wheel type or roller electrodes instead of tipped electrodes as shown in Fig. 1.
- Seam welding is obtained by keeping the job under electrodes. When these wheel type electrodes travel over the metal pieces which are under pressure, the current passing between them heats the two metal pieces to the plastic state and results into continuous spot welds.
- In this welding, the contact area of electrodes should be small, which will localize the current pressure to the welding point. After forming weld at one point, the weld so obtained can be cooled by splashing water over the job by using cooling jets.



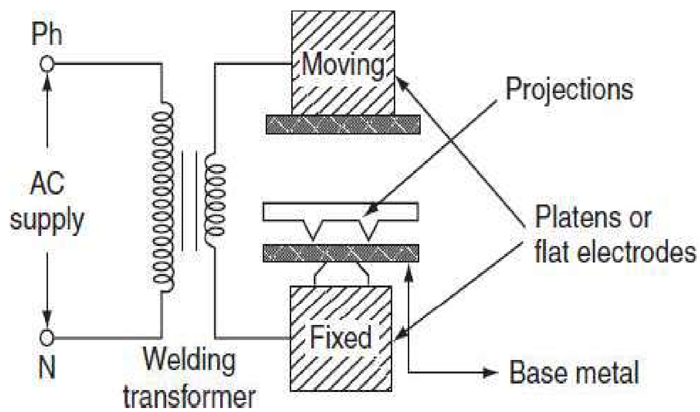
- In general, it is not satisfactory to make a continuous weld, for which the flow of continuous current build up high heat that causes burning and wrapping of the metal piece.
- To avoid this difficulty, an interrupter is provided on the circuit which turns on supply for a period sufficient to heat the welding point.
- The series of weld spots depends upon the number of welding current pulses.
- The two forms of welding currents are shown in Fig. 2(a) and (b).
- Welding cannot be made satisfactorily by using uninterrupted or un-modulated current, which builds up high heat as the welding progress; this will over heat the workpiece and cause distortion.
- Seam welding is very important, as it provides leak proof joints. It is usually employed in welding of pressure tanks, transformers, condensers, evaporators, air craft tanks, refrigerators, varnish containers, etc.

Projection welding

- It is a modified form of the spot welding. In the projection welding, both current and pressure are localized to the welding points as in the spot welding.
- But the only difference in the projection welding is the high mechanical pressure applied on the metal pieces to be welded, after the formation of weld.
- The electrodes used for such welding are flat metal plates known as platens. The two pieces of base metal to be weld are held together in between the two platens, one is movable and the other is fixed, as shown in Fig. 1.
- One of the two pieces of metal is run through a machine that makes the bumps or projections of required shape and size in the metal.
- As current flows through the two metal parts to be welded, which heat up and melt.
- These weld points soon reach the plastic state, and the projection touches the metal then force applied by the two flat electrodes forms the complete weld.
- The projection welding needs no protective atmosphere as in the spot welding to produce

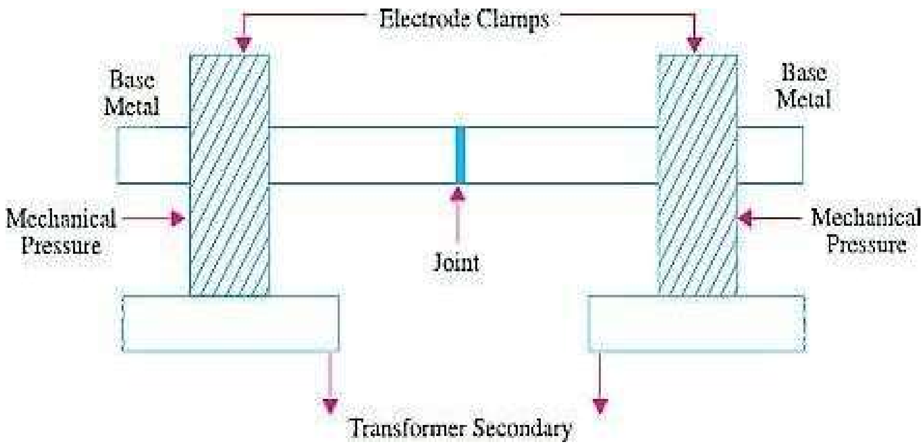
successful results.

- This welding process reduces the amount of current and pressure in order to join two metal surfaces, so that there is less chance of distortion of the surrounding areas of the weld zone.
- Due to this reason, it has been incorporated into many manufacturing process.



- The projection welding has the following advantages over the spot welding.
  - Simplicity in welding process.
  - It is easy to weld some of the parts where the spot welding is not possible.
  - It is possible to join several welding points.
  - Welds are located automatically by the position of projection.
  - As the electrodes used in the projection welding are flat type, the contact area over the projection is sufficient.
- This type of welding is usually employed on punched, formed, or stamped parts where the projection automatically exists.
- Projection welding is used extensively by auto manufactures for joining nuts, bolts and studs to steel plates in car bodies. This process is especially suitable for metals like brass, aluminium and copper etc. manily due to their high thermal conductivity.
- The projection welding is particularly employed for mass production work, i.e., welding of refrigerators, condensers, crossed wire welding, refrigerator racks, grills, etc.

- (a) Upset butt welding.
- (b) Flash butt welding.
- (c) Percussion butt welding.



The weld heat is produced mainly by the electrical resistance of the joint faces. In this case, however, the electrodes are in the form of powerful vice clamps which hold the work-pieces and also convey the forging pressure to the joint.

This process is useful where parts have to be joined end-to-end or edge-to-edge. *i.e.* for welding pipes, wires and rods.

(a) Upset butt welding

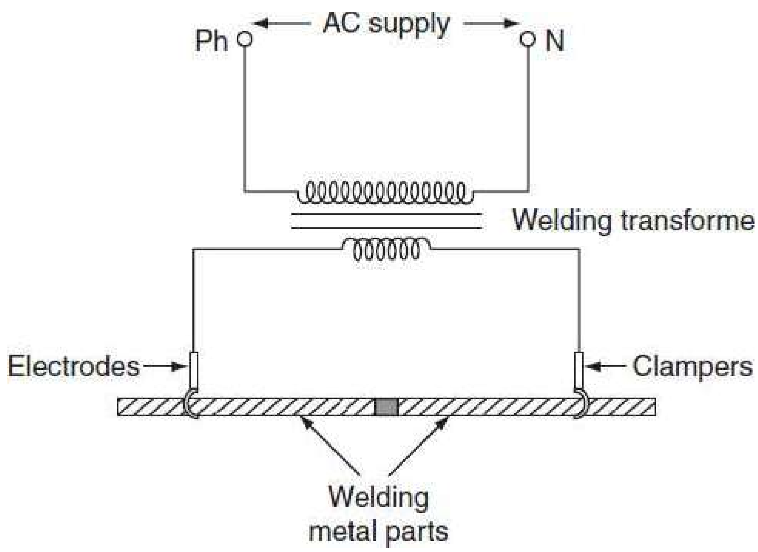
In upset welding, the two metal parts to be welded are joined end to end and are connected across the secondary of a welding transformer as shown in Fig. 1.

Due to the contact resistance of the metals to be welded, heating effect is generated in this welding.

When current is made to flow through the two electrodes, heat will develop due to the contact resistance of the two pieces and then melts.

By applying high mechanical pressure either manually or by toggle mechanism, the two metal pieces are pressed. When jaw-type electrodes are used that introduce the high currents without treating any hot spot on the job.

This type of welding is usually employed for welding of rods, pipes, and wires and for joining metal parts end to end.



(b) Flash butt welding

Flash butt welding is a combination of resistance, arc, and pressure welding.

This method of welding is mainly used in the production welding.

A simple flash butt welding arrangement is shown in Fig. 1.

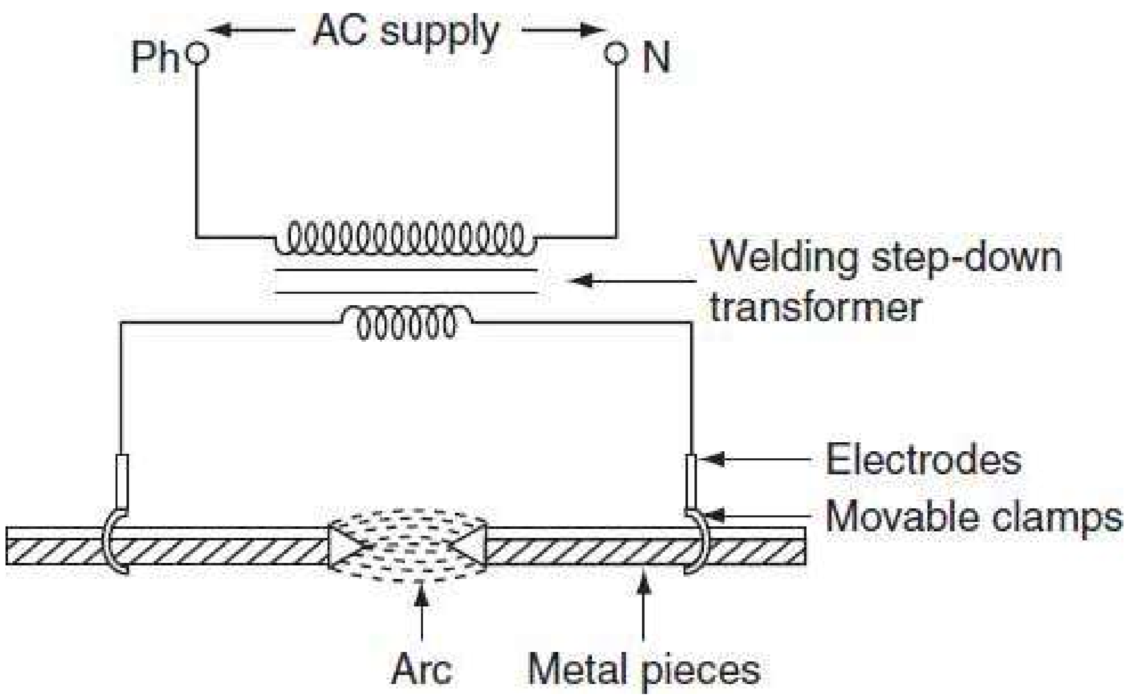
In this method of welding, the two pieces to be welded are brought very nearer to each other under light mechanical pressure.

These two pieces are placed in a conducting movable clamps.

When high current is passed through the two metal pieces and they are separated by some distance, then arc established between them.

This arc or flashing is allowed till the ends of the workpieces reach melting temperature, the supply will be switched off and the pieces are rapidly brought together under light pressure.

As the pieces are moved together, the fused metal and slag come out of the joint making a good solid joint.



- **Advantages**

1. Even rough or irregular ends can be flash-welded. There is no need to level them by machining and grinding because all irregularities are burnt away during flashing period.

2. It is much quicker than butt welding.

3. It uses considerably less current than butt welding.

4. One of its major advantages is that dissimilar metals with different welding temperatures can be flash-welded.

Applications

1. To assemble rods, bars, tubings, sheets and most ferrous metals.

2. In the production of wheel rims for automobiles and bicycles.

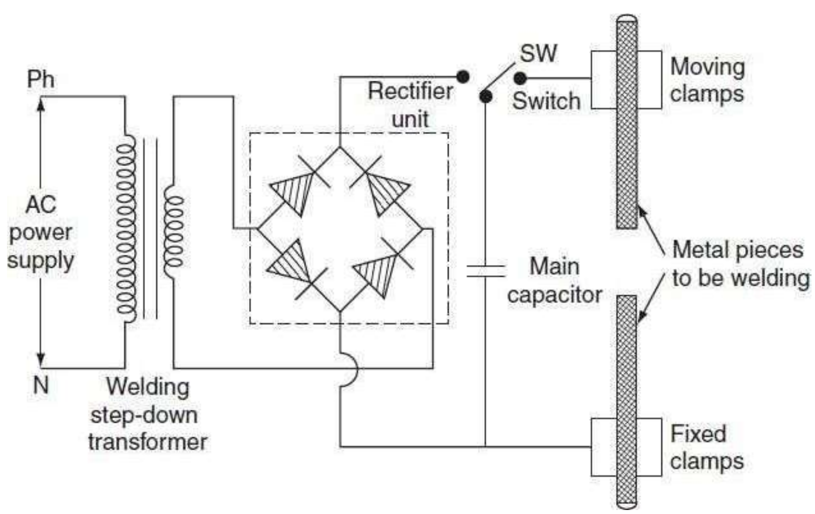
3. For welding tubular parts such as automobile break cross-shafts.

4. For welding tube coils for refrigeration plants etc.

(c) Percussion welding

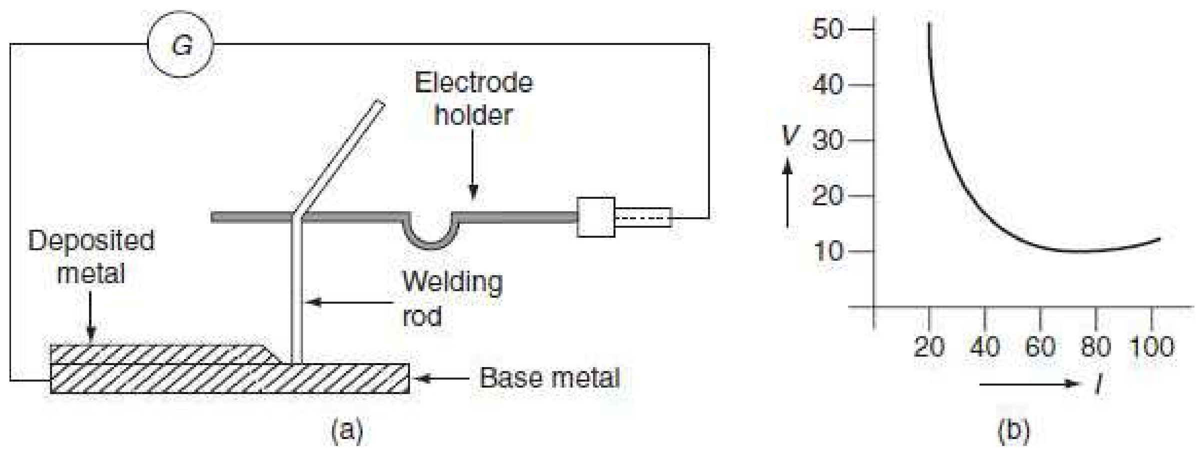
- It is a form of the flash butt welding, where high current of short duration is employed using stored energy principle. This is a self-timing spot welding method.

- Percussion welding arrangement consists of one fixed holder and the other one is movable.
- The pieces to be welded are held apart, with the help of two holders, when the movable clamp is released, it moves rapidly carrying the piece to be welded.
- There is a sudden discharge of electrical energy, which establishes an arc between the two surfaces and heating them to their melting temperature, when the two pieces are separated by a distance of 1.5 mm apart.
- As the pieces come in contact with each other under heavy pressure, the arc is extinguished due to the percussion blow of the two parts and the force between them affects the weld.
- The percussion welding can be obtained in two methods; one is capacitor energy storage system and the other is magnetic energy storage system.
- The capacitor discharge circuit for percussion welding is shown in Fig. 1.
- The capacitor ‗C' is charged to about 3,000 V from a controlled rectifier.



- Electric Arc Welding
- Electric arc welding is the process of joining two metallic pieces or melting of metal is obtained due to the heat developed by an arc struck between an electrode and the metal to be welded or between the two electrodes as shown in Fig. 1 (a).

- In this process, an electric arc is produced by bringing two conductors (electrode and metal piece) connected to a suitable source of electric current, momentarily in contact and then separated by a small gap, arc blows due to the ionization and give intense heat.
- The heat so developed is utilized to melt the part of workpiece and filler metal and thus forms the weld.

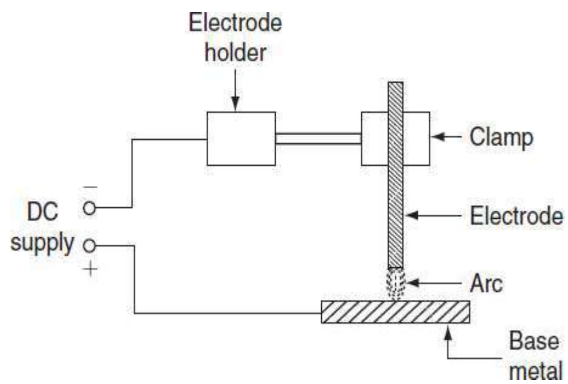


- Electric arc welding is extensively used for the joining of metal parts, the repair of fractured casting, and the fillings by the deposition of new metal on base metal, etc.
- **Classification of arc welding:**

1. Metal arc welding
2. Carbon arc welding
3. Atomic hydrogen welding
4. Inert gas metal arc welding.
5. Submerged arc welding.

- **Carbon arc welding**
- The electrodes used in this system are of carbon or graphite. The supply voltage should be dc.
- The work piece to be welded is connected to positive end of the supply and the carbon electrode is connected to the negative end.

- In the carbon arc welding, carbon or graphite rods are used as electrode.
- Due to longer life and low resistance, graphite electrodes are used, and thus capable of conducting more current.
- The arc produced between electrode and base metal; heat the metal to the melting temperature, on the negative electrode is 3,200¡C and on the positive electrode is 3,900¡C.
- This process of welding is normally employed where addition of filler metal is not required. The carbon arc is easy to maintain, and also the length of the arc can be easily varied.
- Huge current of the order of 800 to 1000 A are drawn from the dc supply at the time of welding.
- One major problem with carbon arc is its instability which can be overcome by using an inductor in the electrode of 2.5-cm diameter and with the current of about of 500–800 A employed to deposit large amount of filler metal on the base metal.
- Filler metal and flux may not be used depending upon the type of joint and material to be welded.



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Advantages

- The heat developed during the welding can be easily controlled by adjusting the • length of the arc.
- It is quite clean, simple, and less expensive when compared to other welding process.•

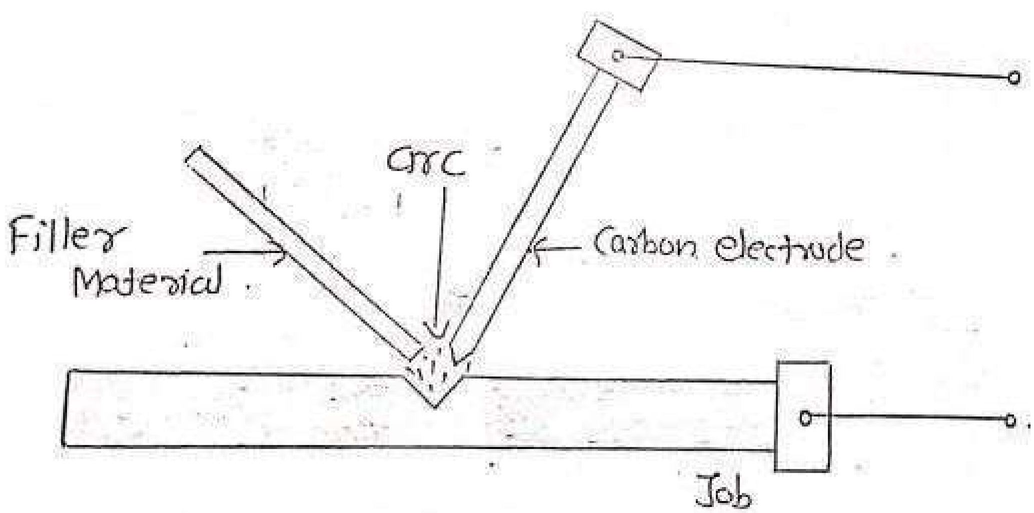
- Easily adoptable for automation.•
- Both the ferrous and the non-ferrous metals can be welded.
- ***Disadvantages***
- Input current required in this welding, for the workpiece to rise its temperature to melting/welding temperature, is approximately double the metal arc welding.
- In case of the ferrous metal, there is a chance of disintegrating the carbon at high temperature and transfer to the weld, which causes harder weld deposit and brittlement.
- A separate filler rod has to be used if any filler metal is required.
- ***Applications***
- It can be employed for the welding of stainless steel with thinner gauges.
- Useful for the welding of thin high-grade nickel alloys and for galvanized sheets using copper silicon manganese alloy filler metal.

Metal arc welding

- In this type, the welding electrode itself is made up of the filler metal.
- At the time of welding the current flows through the welding electrode, arc, work piece to earth.
- In metal arc welding, the electrodes used must be of the same metal as that of the workpiece to be welded.
- The electrode itself forms the filler metal. An electric arc is stuck by bringing the electrode connected to a suitable source of electric current, momentarily in contract with the workpieces to be welded and withdrawn apart.
- It is possible to use ac or dc supply.
- The arc produced between the workpiece and the electrode results high temperature of the order of about 2,400¡C at negative metal electrode and 2,600¡C at positive base metal or workpiece.
- This high temperature of the arc melts the metal as well as the tip of the electrode, then

the electrode melts and deposited over the surface of the workpiece, forms complete weld.

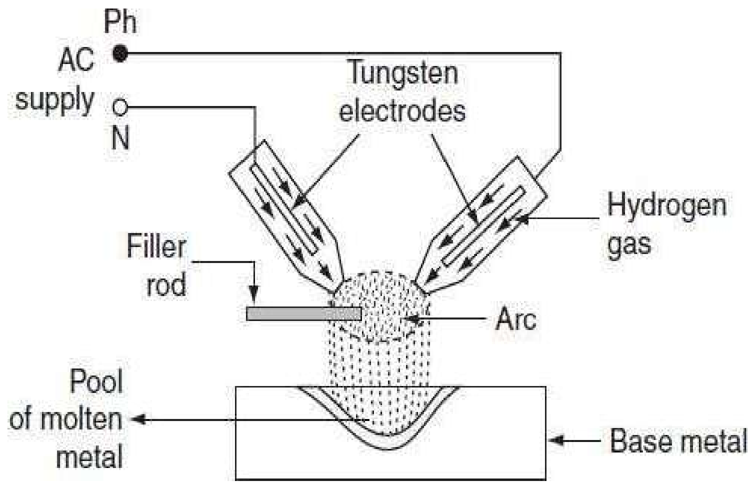
- The voltage required for the DC metal arc welding is about 50–60 V and for the AC metal arc welding is about 80–90 V.
- The main disadvantage in the DC metal arc welding is the presence of arc blow, i.e., distortion of arc stream from the intended path due to the magnetic forces of the non-uniform magnetic field with AC arc blow is considerably reduced.
- For obtaining good weld, the flux-coated electrodes must be used, so the metal which is melted is covered with slag produces a non-oxidizing gas or a molten slag to cover the weld, and also stabilizes the arc.



Atomic hydrogen welding

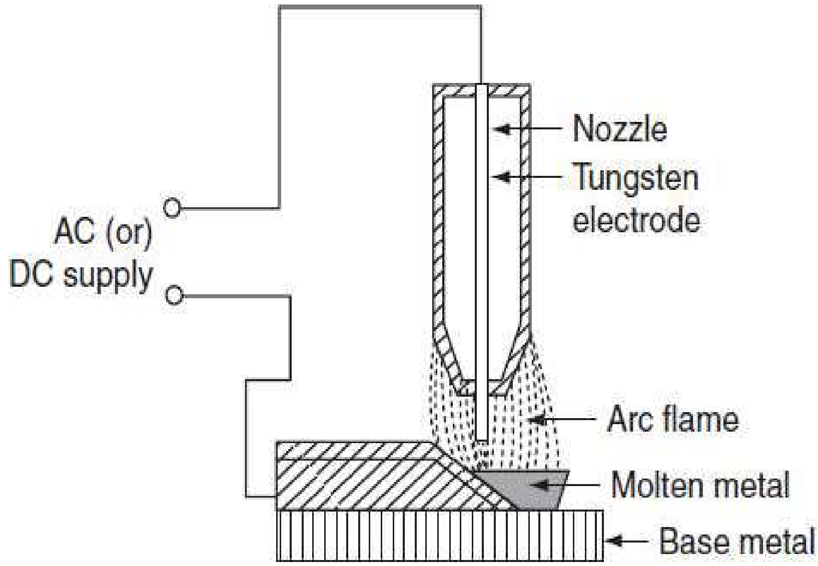
In this method, the tungsten electrodes are kept in the hydrogen atmosphere.

- The arcing takes place between the two tungsten electrodes.
- Hydrogen acts as an agent which atomises and maintains the arc between the electrodes independent of the work pieces to be welded.
- The hydrogen acts in two fold manner, as a cooling agent as well as a protective screen.



Inert gas metal arc welding

- It is a gas-shielded metal arc welding, in which an electric arc is stuck between tungsten electrode and workpiece to be welded. Filler metal may be introduced separately into the arc if required.
- A welding gun, which carries a nozzle, through this nozzle, inert gas such as beryllium or argon is blown around the arc and onto the weld, as shown in Fig. 1.
- As both beryllium and argon are chemically inert, so the molten metal is protected from the action of the atmosphere by an envelope of chemically reducing or inert gas.
- As molten metal has an affinity for oxygen and nitrogen, if exposed to the atmosphere, thereby forming their oxides and nitrides, which makes weld leaky and brittle.
- Thus, several methods of shielding have been employed. With the use of flux coating electrodes or by pumping, the inert gases around the arc produces a slag that floats on the top of molten metal and produces an envelope of inert gas around the arc and the weld.

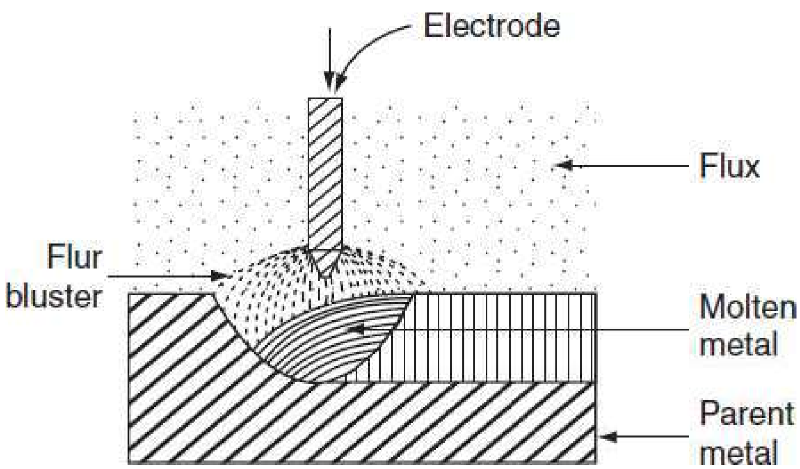


- ***Advantages***
- Flux is not required since inert gas envelope protects the molten metal without forming oxides and nitrates so the weld is smooth, uniform, and ductile.
- Distortion of the work is minimum because the concentration of heat is possible.
- ***Applications***
- The welding is employed for light alloys, stainless steel, etc.
- The welding of non-ferrous metal such as copper, aluminum, etc.

Submerged Arc Welding

- It is an arc welding process, in which the arc column is established between above metal electrode and the workpiece.
- Electric arc and molten pool are shielded by blanket of granular flux on the workpiece. Initially to start an arc, short circuit path is provided by introducing steel wool between the welding electrode and the workpiece.
- This is due to the coated flux material, when cold it is non-conductor of the electricity but in molten state, it is highly conductive. Welding zone is shielded by a blanket of flux, so that the arc is not visible. Hence, it is known as submerged arc welding.

- The arc so produced, melts the electrode, parent the metal and the coated flux, which forms a protective envelope around both the arc and the molten metal.
- As the arc in progress, the melted electrode metal forms globules and mix up with the molten base metal, so that the weld is completed.
- In this welding, the electrode is completely covered by flux. The flux may be made of silica, metal oxides, and other compounds fused together and then crushed to proper size. Therefore, the welding takes place without spark, smoke, ash, etc.
- Thus, there is no need of providing protective shields, smoke collectors, and ventilating systems. Figure 5.18 shows the filling of parent metal by the submerged arc welding.
- Voltage required for the submerged arc welding varies from 25 to 40 V. Current employed for welding depends upon the dimensions of the workpiece.
- Normally, if DC supply is used employing current ranging from 600 to 1,000 A, the current for AC is usually 2,000 A.

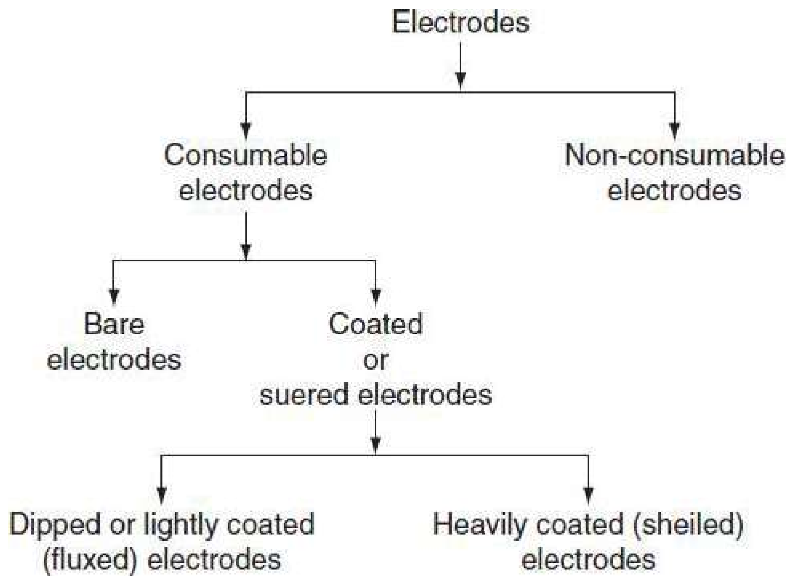


- **Advantages**
- Deep penetration with high-quality weld is possible.
- Job with heavy thickness can be welded.
- The weld so obtained has good ductility, impact strength, high corrosion resistance, etc.
- The submerged arc welding can be done manually or automatically.

- **Applications**
- The submerged arc welding is widely used in the heavy steel plant fabrication work.•
- It can be employed for welding high strength steel, corrosion resistance steel, and • low carbon steel.
- It is also used in the ship-building industry for splicing and fabricating subassem• blies, manufacture of vessels, tanks, etc.

Types of Welding Electrodes

- An electrode is a piece of metal in the form of wire or rod that is either bare or coated uniformly with flux.
- Electrode carries current for the welding operation.
- One contact end of the electrode must be clean and is inserted into the electrode holder, an arc is set up at the other end.
- The electrodes used for the arc welding are classified as follows
- **non-consumable electrodes**
- Electrodes, which do not consume or fuse during the welding process, are called non-consumable electrodes.
- Ex: Electrodes made up of carbon, graphite, or tungsten do not consume during welding.
- **consumable electrodes**
- Electrodes, which are consumed during the welding operation, are consumable electrodes. These are made up of various materials depending upon their purpose and the chemical composition of metal to be welded.
- The consumable electrodes are made in the form of rod having diameter of about 2–8 mm and length of about 200–500 mm. They act as filler rod and are consumed during welding operation.



Electric Welding Equipment

- Electric welding accessories required to carry out proper welding operation are:
- i. Electric welding power sets.
- ii. Electrode holder to hold the electrodes.
- iii. Welding cable for connecting electrode and workpiece to the supply.
- iv. Face screen with colored glass.
- v. Chipping hammers to remove slag from molten weld.
- vi. Wire brush to clean the weld.
- vii. Earth clamp and protective clothing.

Electric Welding Power Sets

- Welding power sets may be of different types and they can be selected depending upon the nature of available power supply (either DC or 1-φ AC).
- Sometimes diesel driven engine may be used under the absence of power supply, initial and running costs, the location of operation, required output and the type of work, and based on the available floor space.

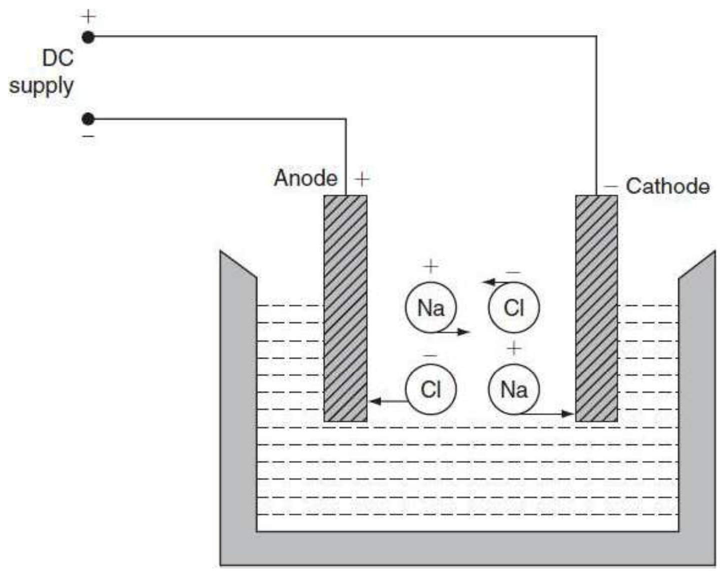
- Based on the nature of available supply, commonly used welding sets are:
- (i) DC welding sets and
- (ii) AC welding sets.

Electrolysis process

- Electrolysis is nothing but the process by which electrical energy produce chemical changes.
- This process can be normally used for the extraction of pure metal from their ores, the refining of metals, the building up of worn parts in metallurgical, chemical, and in other industries.

Principle of Electrolysis

- The basic principle of electrolysis is, whenever a DC electric current is made to pass through the solution of salt, some metals can be separated from them.
- These separated metals can be coated on any object to form a pure thin layer.
- For example, a crucible filled with water in which two electrodes (anode and cathode) are immersed and those are supplied from a DC source as shown in Fig. 1.
- When sodium chloride (NaCl) salt is dissolved in water, it decomposes into positively charged Na+ ion and negatively charge ClÐ ion, moving freely in the solution.
- The positively charged ion (Na+) travels toward the cathode and the negatively charged ion (ClÐ) travels toward the anode.
- On reaching the cathode, each positively charged sodium ion takes one electron from it and forms a sodium metal. Similarly, each of the negatively charged chloride ion will give one electron to anode and cease to be anion.
- Now, as the sodium metal deposited at the cathode, the ions collected at the cathode react with water giving out oxygen and hydrogen chloride



- **In case if the cathode is made up of sodium, again the hydrogen chloride reacts with sodium forming sodium chloride liberating hydrogen gas.**
- **Thus, sodium metal from the sodium chloride in the water is deposited at the cathode. The above process is known as electrolysis.**

$$4Cl + 2H_2O \rightarrow 4HCl + O_2.$$

$$2HCl + 2Na \rightarrow 2NaCl + H_2.$$

Laws of Electrolysis

- The laws governing the electrolytic process were proposed by Michael Faraday. These laws are stated below.
- **<u>Faraday's first law</u>**
- This law states that the mass of substance deposited from an electrolyte is proportional to the quantity of electricity passing through the electrolyte in a given time.
- i.e., m a It
- = ZIt,
- where I is the steady current flowing through an electrolyte in amperes, t is the duration of current flowing through an electrolyte, Z is the constant of proportionality, and m is

the mass of substance deposited.

- An electrochemical equivalent Z equals to the mass of substance deposited, when a steady electric current of 1A is passing through an electrolyte in 1 s:
- i.e., if I = 1A and t = 1 s, then, Z = m.
- Usually, Z is expressed in terms of kilogram per coulomb (kg/c).

- **Faraday's second law**
- This law states that when the same quantity of electric current is passed through different electrolytes, the masses of the substances deposited are proportional to their respective chemical equivalents or equivalent weights.

$$\left[\text{Chemical equivalent} = \frac{\text{atomic weight}}{\text{valency}}\right]$$

- **Some of the important terms related to electrolytic process are discussed below.**
- *(i) Voltage:*
- It is necessary term for the electrolysis. The voltage required for the passage of current through the electrolysis must be equal to the voltage drop across the electrolyte and electrodes.
- If V1and V2 are the voltage drops across the electrolytes and electrodes and V is the total voltage applied across the electrodes, then:
- V = V1 + V2.
- **(ii) Current efficiency:** In the electrolytic process, secondary reactions are caused due to impurities.

- Therefore, the quantity of substance liberated from the electrodes is slightly less than that of the quantity actually calculated by Faradays laws.
- The practical value of the current efficiency lies between 90% and 98%.
- **(iii) Energy Efficiency:** Due to the secondary reactions caused by the impurities present in the electrolyte, the actual value of the voltage required for the deposition of metal from the electrode is higher than the theoretical value of voltage
- **(iv) Equivalent weight:** The equivalent weight of a substance is defined as the ratio of formula weight to its valency.

Applications of Electrolytic Process

- **Some of the applications of electrolysis used in the chemical industry and metal extraction are given below.**

✓ Manufacturers of chemicals-caustic soda, ammonium sulfate, hydrogen, oxygen, and chlorine

✓ Electro metallurgy-extraction of metals from their ores and its refining

✓ Electrodeposition-one metal is deposited over other metal or non-metal, by electrolysis.

✓ Electroplating-deposition of a metal over any metallic or non-metallic surfaces

✓ Electrometallization

✓ Electropolishing

✓ Electrotyping

✓ Electroparting or electrostripping

✓ Anodizing-The process of deposition of oxide film on a metal surface

1. Manufacturers of chemicals

- Various industrial applications of electrolysis such as the manufacturing of chemicals such as caustic soda, ammonium sulfate, hydrogen, oxygen, and chlorine.
- Here, the production of caustic soda and the production of hydrogen and oxygen by

electrolysis process are explained below.

- **Production of caustic soda**
- The production of caustic soda can be done by two processes.
- *Diaphragm process*
- In this process, both anode and cathode compartments are separated by a diaphragm, to prevent the mechanical mixing of two solutions.
- During this process, chlorine is formed at anode; some of it is evolved as gas and the remaining goes into solution.
- And, sodium is discharged at the cathode reacts with the hydroxyl ions forming sodium hydroxide (NaOH) liberating hydrogen gas at the cathode.
- At this stage, brain solution is fed into the anode, which opposes the flow of hydroxyl ions toward the anode.

Production of hydrogen and oxygen by electrolysis

- In this process, the gases such as hydrogen and oxygen obtained are of high purity at a cheap cost.
- This is mainly due to the low consumption of electrical energy for the production of gases by electrolysis.
- In this process, the electrodes are made up of iron and nearly 15–20% of caustic soda is mixed with water.
- The chemical reactions take place at the electrodes as given below:
- Hydrogen gas is liberated at the cathode and oxygen is liberated at the anode.
- The voltage required for this process during the starting is 2–2.2 V and during the operation is 2.3–2.5 V, and energy required for this process is 6 kW-hr/m3.

The factors which affect the electro-deposition of metals

- **Conditions have to be provided so that the deposit will be fine grained and will have a smooth appearance.**
- (i) Current Density
- (ii) Electrolyte concentration
- (iii) Temperature
- (iv) Addition agents
- (v) Nature of electrolyte
- (vi) Nature of the metal on which the deposit is to be made
- (vii) Throwing power of the electrolyte

- **Current density**
- At low values of current density the ions are released at a slow rate and the rate of growth of nuclei is more than the rate at which the new nuclei form themselves.
- Electro-deposition depends upon the rate at which crystals grow and the rate at which fresh nuclei are formed.
- Therefore, at low current densities the deposit will be coarse and crystalline in nature.
- At higher values of current density the quality of deposit becomes more uniform and fine-grained on account of the greater rate of formation of nuclei.
- If the current density is so high that it exceeds the limiting value for the electrolyte hydrogen is released and spongy and porous deposit is obtained.

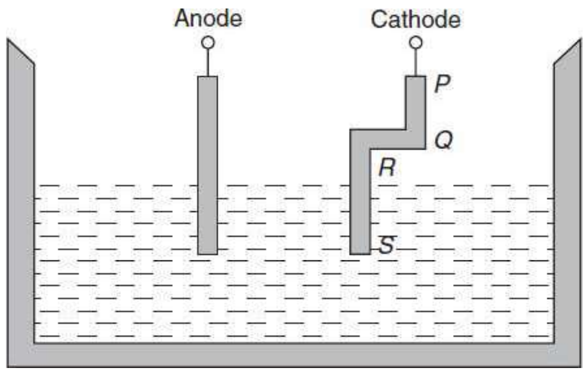
- **Electrolytic Concentration**
- This is more or less complementary to the first factor, i.e. current density, since by increasing the concentration of the electrolyte higher current density can be achieved.

- Increase of concentration tends to give better deposits and some people therefore favour it.
- **Temperature**
- The temperature of the electrolyte has two contradictory effects.
- One, at comparatively high temperature there is more diffusion and even at relatively high current density smooth deposits may be produced.
- Two, the rate of crystal growth increases the possibility of coarse deposits. At moderate temperatures the deposits are good.
- In chromium plating the temperature is maintained at C, and in nickel between 50 deg C to 60 deg C .

- **Addition Agents**
- the quality of a deposit is improved by the presence of an addition agent which may be colloidal matter or an organic compound, otherwise the metal deposits in the form of large crystals and the surface becomes rough.
- Materials used as addition agents are gelatin, agar, glue, gums, rubber, alkaloids, sugar etc.
- The addition agents are supposed to be absorbed by crystal nuclei and prevent their growth into large crystals.
- The discharged ions start to build up new nuclei and the deposit of metal is fine-grained.
- **Nature of electrolyte**
- Smooth deposits are obtained from solutions having complex ions, e.g.,cyanides.
- Silver from nitrate solution forms a coarse deposit while from cyanide solution it forms a smooth deposit.
- Therefore, the formation of smooth deposit largely depends upon the nature of electrolyte used.

- **Nature of the metal on which deposit is to be made**
- This factor influences the growth of crystals since it is believed that the operation of crystals is in continuation of these in the base metal.
- **Throwing Power**
- The throwing power of an electrolyte may be regarded as the quality which produces a uniform deposit on a cathode having an irregular shape.
- Since the shape is irregular, The distance of the various parts of the cathode from the anode is not the same and therefore the conductance of the electrolyte is not the same for all parts of the cathode.
- The phenomenon of throwing power has not been clearly understood so far.
- In an electrolyte of low conductance, the current will concentrate on the parts of the cathode which are nearer the cathode resulting in poor throwing power.
- If the electrolyte has good conductance, the throwing power will also be good.
- One way to improve the throwing power is to keep a good distance between the cathode and the anode thereby providing more or less the same conductance for all parts of cathode.
- Presence of colloidal matter improves, the throwing power but increase of temperature may produce the opposite effect.
- Throwing power can be improved by the following two ways:
- (i) By increasing the distance between the anode and the cathode.
- (ii) By reducing the voltage drop at the cathode surface

Description of throwing power



Electroplating

- Electroplating is defined as the deposition of a metal over any metallic or non-metallic surfaces.
- Electroplating is usually employed to protect the metals from corrosion by atmospheric air, moisture, and CO_2, to give the reflecting properties to reflectors, to replace worn out metals, to give a shiny appearance to articles, etc.
- **Preparation for plating: Electroplating involves two functions. They are:**
- **(i) cleaning operation and**
- **(ii) plating operation.**

- **<u>Cleaning operation</u>**
- In case if a metal is to be electroplated, it should be cleaned, i.e., metal should be polished, degreased oil, and any organic material, rust, scale, oxides, etc. is to be removed from the metal.
- **<u>Plating operation</u>**
- In plating process, the metal or article to be electroplated is arranged as the cathode and the anode is made up of the material that is to be deposited on the metal. And, salt is taken as solution in which the electrodes are immersed. The characteristic features of the plating of various metals are given below.

1. **Copper plating**

- Copper plating baths used for the preparation of plating are of two types.

a) Acid bath

- It is the bath in which solution is taken in a mixture of copper sulfate (15–200 gm) and H2SO4 (25–37 gm) per 1,000 cc of solution.
- Current density maintained for copper plating is 200–400 A/m2 and temperature is maintained at 25–50°. In this plating, the deposit obtained is thick and rough, so that polishing is required.

b) Cyanide bath

- It consists of a solution with a mixture of 25 gm of copper cyanide, 25 gm of sodium cyanide, 5 gm of sodium carbonate, and 6 gm of sodium biphosphate per 100 cc of solution. The current density employed for this bath is 4–150 A/m2 and the temperature is maintained at 35–50°. In both the methods, the anode is made up of copper.
- If this type of bath is employed, the deposit obtained is so thin and smooth. But in both of the above baths, pure copper will be deposited at the anode.
- The copper plating is usually employed to prevent the iron articles from rusting and the inner line coating for silver and nickel plating.

2. **Nickel plating**

- In this plating, nickel bath is employed for steel and brass articles. This bath consists of solution; it is a mixture of 100 gm of nickel sulfate, 12 gm of ammonium chloride, and 12 gm of boric acid per 100 cc of solution. The temperature is maintained at 20–30° and the current density of 10–20 A/m2 is employed.
- In this plating, the anode is made up of nickel. For copper, zinc, and nickel platings, bath consists of solution with a mixture of solution nickel sulfate 150–240 gm, nickel chloride 36 gm, and boric acid 24 gm for 1,000 cc. Bath temperature is maintained at 40–65°. With a current density of 250–500 A/m2.

- In the above processes, pure nickel will be deposited at the anode.

3. **Chromium plating**

- In this plating, bath consists of solution with a mixture of 180–300 gm of chromic acid and 2–3 gm of sulfuric acid per 1,000 cc. The working temperature is maintained at 40–70°C, with the current density of 600–5,000 A/m2 is employed. In this plating, the vats are made up of steel that is coated with lead chromium. The plating produces highly polished and extremely hard coating and it is proffered for the surface where it is to be protected from atmospheric condition.

- **Electrometallization**
  - It is the process by which the metal can be deposited on a conduction base for decoration and for protective purposes.
  - Any non-conductive base is made as conductive by depositing graphite layer over it.

- **Electropolishing**
  - Electropolishing is mainly done for making the work as anode in a suitable position. This process makes the surface smoother.

- **Electrotyping**
- It is used to reproduce printing, set-up, engraving and metals, etc.

- **Electroparting or electrostripping**
- The process of separation of two or more metals electrolytically is known as electroparting or stripping.
- Usually, to stripe off copper from steel, the cathode is made up of iron, the work piece itself acts as anode and are immersed in a solution with a mixture of 75 gm of sodium cyanide and 25 gm of caustic soda in 1,000 cc of water.
- Here, during the electrolysis process, copper will be separated from the anode.