Welding

Permanent Metal Joining Process


WELDING

Welding Definition

Weldability depends upon following factors.

- ✓ Melting Point
- ✓ Thermal Conductivity
- ✓ Thermal Expansion
- ✓ Surface Condition
- ✓ Change in Microstructure

Welding is the joining of two or more pieces of metal by applying heat or pressure or both with or without the addition of filler metal to produce a localized union through fusion or recrystallization across the interface.

Weldability is the capacity of being welded into inseparable joints having specified properties like definite weld strength , proper structure etc.

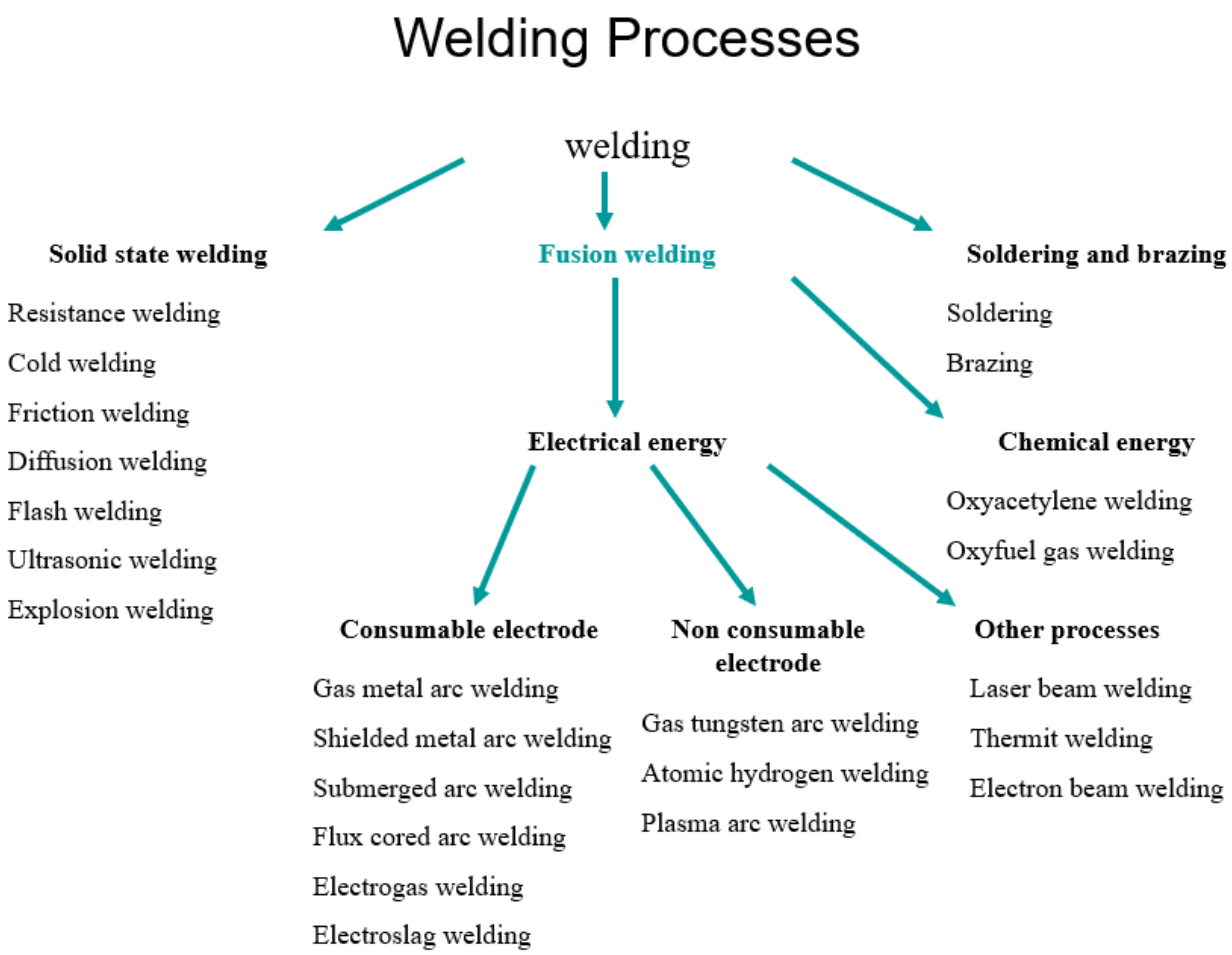
Types of Welding

- These characteristics if found undesirable then they may be corrected by proper shielding atmosphere , proper fluxing material , proper filler material , proper welding procedure.
- Welding may be classified as :

1. **Fusion Welding/Non-Pressure Welding**
2. **Plastic Welding/Pressure Welding**

- **Fusion Welding**: In fusion weld, metal melted from edges and solidifies from the liquid state without any applied deformation. Fusion welds are essentially castings. Moreover, **chilled** casting as molten pool is surrounded by metal wall that are god conductor of heat.
- **Pressure Welding** :In pressure welding, metals pieces needed to be joined are heated to the plastic stage and then compressed while hot. The joint is essentially a forging.

❖ Types of Welding



Types of welding

- ❖ **Gas Welding** (Fusion)
- ✓ Oxy Acetylene Gas welding
- ❖ **Electric arc welding (Fusion)**
- ✓ Introduction to Arc welding
- ✓ Carbon Arc Welding
- ✓ Metal Arc Welding
- ✓ Submerged Arc Welding
- ✓ Metal Inert Gas Welding
- ✓ Tungsten Gas Welding
- ✓ Atomic Hydrogen Welding
- ✓ Electroslag Welding
- ❖ **Resistance welding (Pressure Welding)**
- ✓ Butt welding
- ✓ Spot welding
- ✓ Seam Welding
- ✓ Projection Welding
- ✓ Percussion Welding

Gas Welding Oxy-Acetylene (C_2H_2)

- Gas welding is done by burning a combustible gas with air or oxygen in a concentrated flame of high temperature. the purpose of the flame is to heat and melt the parent metal and filler rod of a joint and allow molten metal to flow together , thus forming a solid continuous joint upon cooling.
- This process is good for sheets and plates having thickness 2 to 50 mm.
- Filler metal is added if material thickness is more then 15 mm in form of welding rod.
- The composition of filler rod is same as base metal.
- Flux is added to remove impurities and oxides from surface.
- The mixture of oxygen and acetylene is used to generate flame of temperature 3200 °C.

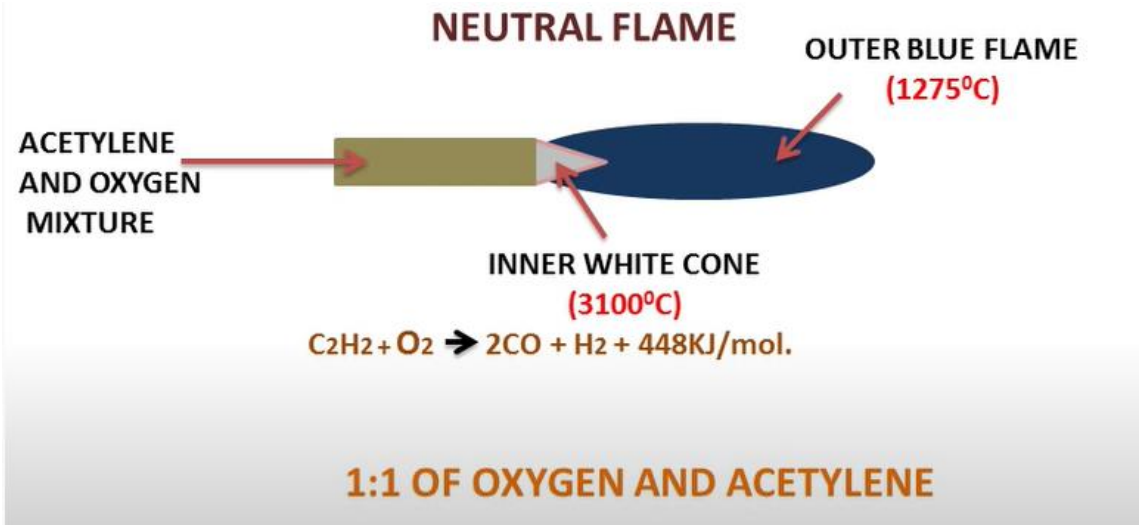
Types of Gas Flame

❖**Neutral Flame :** It has equal amount of oxygen and acetylene by volume. it has maximum temperature of 3200°C. It has two definite zones :

✓Sharp brilliant cone extending a short distance from tip of the torch and develops heat.

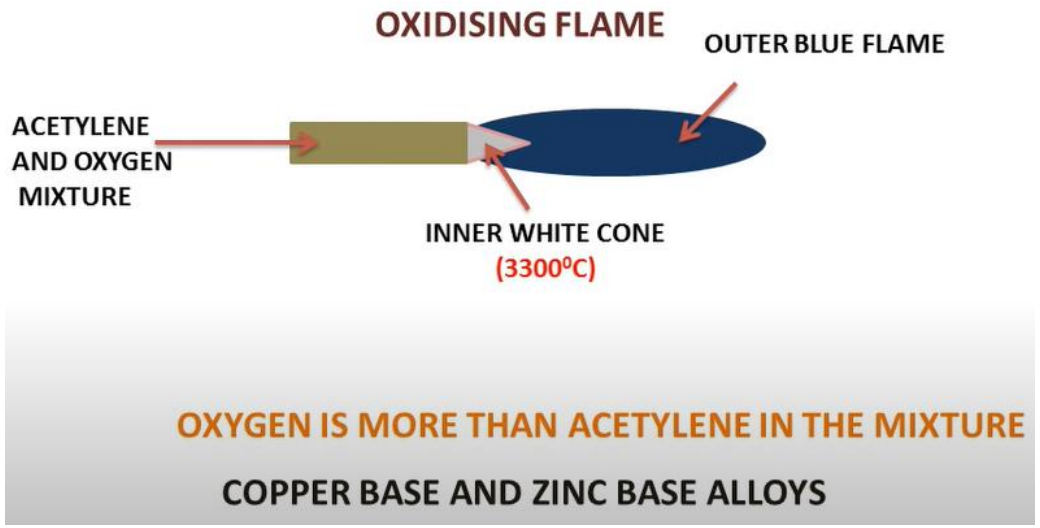
✓An outer cone faintly luminous and of bluish color. It protects the molten metal from oxidation.

✓Used for welding steel , stainless-steel , cast-iron aluminum etc.



Types of Gas Flame

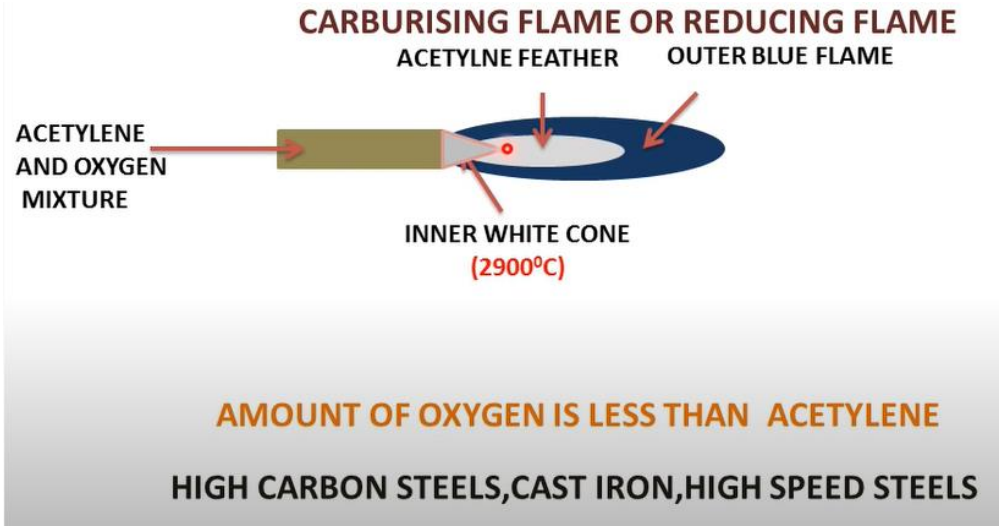
- **Oxidizing Flame :** This flame has an excess of oxygen. this has two zones.
  - ✓ The smaller inner cone which has white purple tinge and the outer cone or envelope.
  - ✓ Here the inner cone is not sharply defined as in neutral or carburizing flame.
  - ✓ This flame is necessarily used for brass welding.



Types of Gas Flame

❖ **Carburizing Flame :**This has excess of acetylene. This has three zones.

- ✓ Sharply defined inner zone.
- ✓ An intermediate zone of whitish color. The length of this zone indicates excess of acetylene. This tends to give carbon content to steel in weld.
- ✓ The bluish outer cone.



Gas Welding Technique

❖According to the position of welding all welds are classified as

✓Down Hand/Flat welds(F): On a horizontal surface so that flame is above the face of weld.

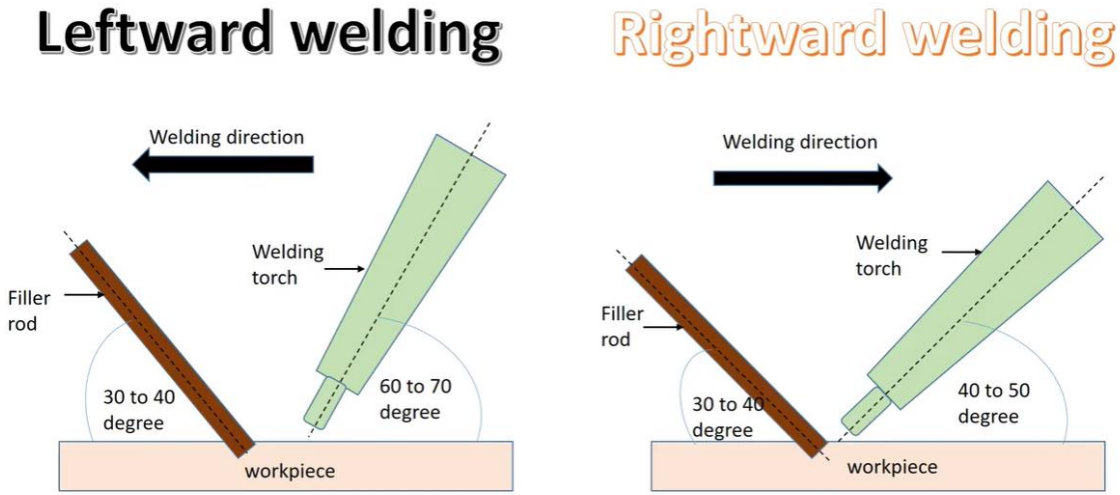
✓Vertical Welds(V) : Weld deposit on vertical surface in upward or downward direction.

✓Inclined Welds(I) : Weld deposit on inclined surface.`

✓Overhead Welds(OH): Weld deposit in horizontal direction such that face of weld is above the flame.

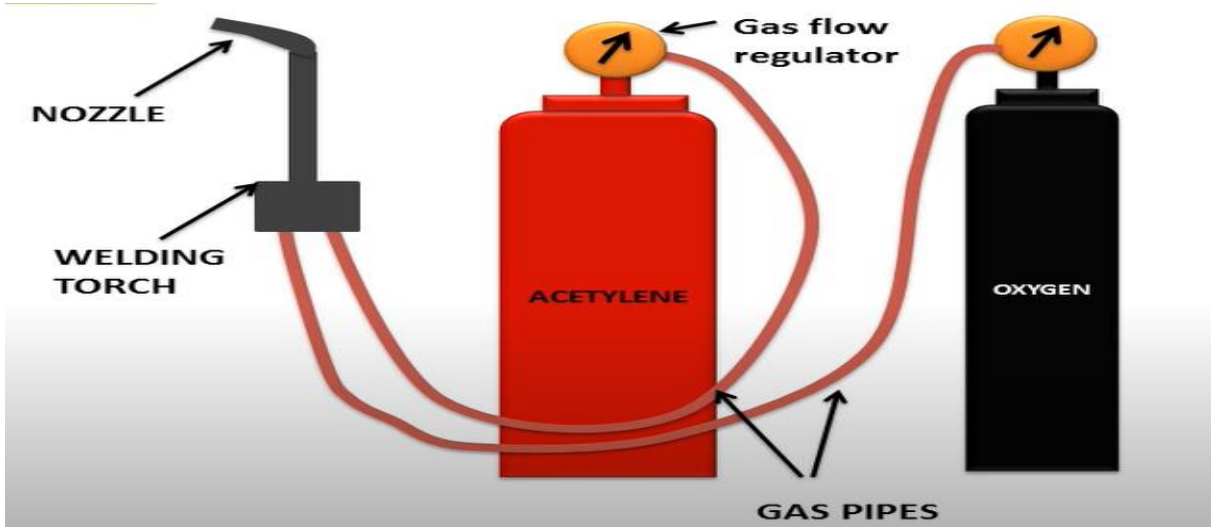
Gas Welding Procedure

- **Leftward or Forward** : weld is made working from right to left. The blow pipe should be given small sideways movement and rod should be moved steadily without sideways movement. the blow pipe is held at an angle of 60 to 70 ° to the plane of weld and welding rod at 30 to 40°.this is good for thin section of plate up to 3mm.
- **Rightward or Backward** : Welding is carried out from left to right , the rod following the blowpipe. The blow pipe should make an angle of 40 to 50° plane of plate. welding rod should be at an angle between 30 to 40°.This provide better shielding against atmospheric oxidation of weld meal. Thick can be welded easily .



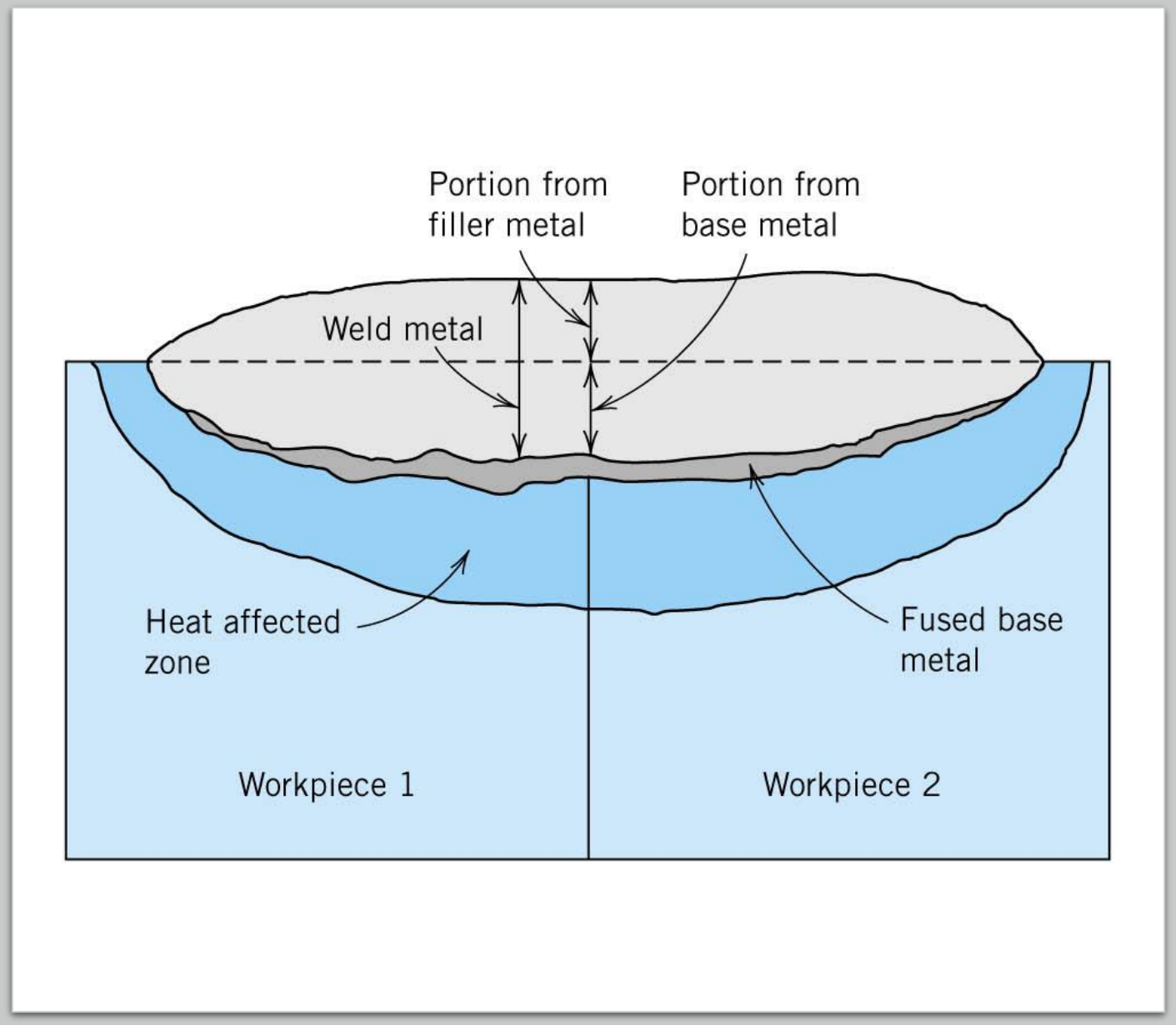
Gas Welding Equipment

- **Oxygen Gas cylinder** : Oxygen gas is usually stored in black color cylinder
- **Acetylene gas** is stored in maroon color **cylinde**r under pressure. This gas can be manufactured by water to carbide or carbide to water method. The cylinder should not be charged above 2kgf per sq cm otherwise it may explode. Acetone has capacity to absorb acetylene to the extent of 35 times its volume, so the cylinder packing is saturated with acetone.
- **Hose and hose fitting** : Hose used for welding torches should be strong , durable ,non-porous and light. oxygen hose Green color , Acetylene hose red color , Black color for any other gas.
- **Pressure Regulator**: The function of pressure regulator is to reduce cylinder pressure to the required working pressure.
- **Welding Torch** : for mixing of oxygen and acetylene in correct proportion and burning the mixture at the end of tip. Two types : Equal Pressure and Injector type.
- **Welding Tip** : It is that portion of the welding apparatus through which the gases pass just prior to their ignition and burning.



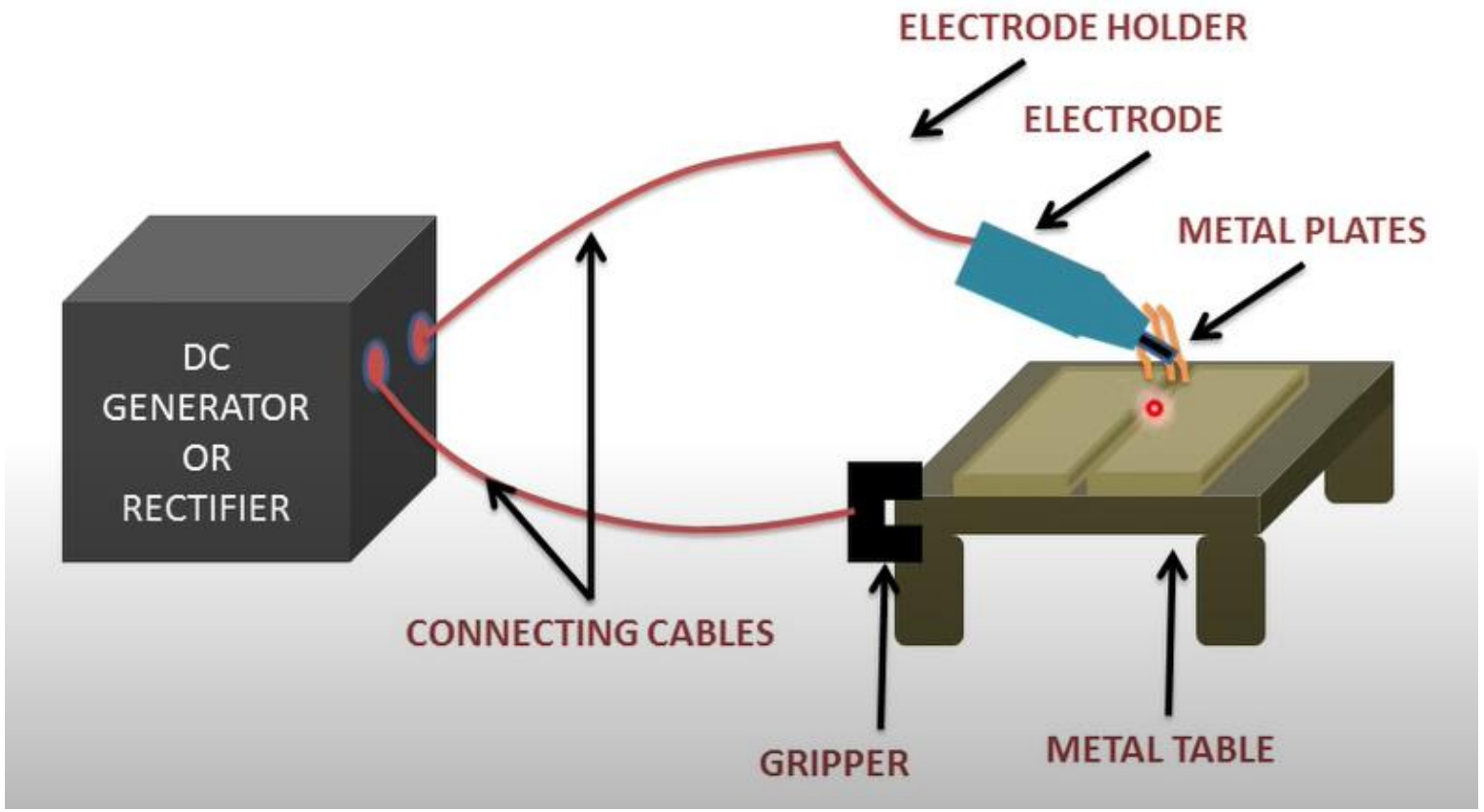
Various Zone in Weld

- **Composite Zone**: It has the mixture of filler metal and melted base metal.
- **Unmixed Zone: Narrow** region surrounding the composite zone , which consist of a boundary layer of melted base metal that froze before experiencing any mixing in composite zone.
- **Weld interface:** This surface clearly describe the boundary between unmelted base metal on one side and solidified base metal on other side.
- **Partially Melted Zone:** In the base metal immediately adjacent to the weld interface where some localized melting may occur, the partially melted zone can be observed.
- **Heat-Affected Zone:** the true HAZ is the portion of the weld joint which experienced peak temperatures high enough to produce solid state micro structural changes but too low to cause any melting.
- **Unaffected Base Metal**: it is that part of the work piece that has not undergone any metallurgical change.



Fusion Welding Processes

ELECTRIC ARC WELDING

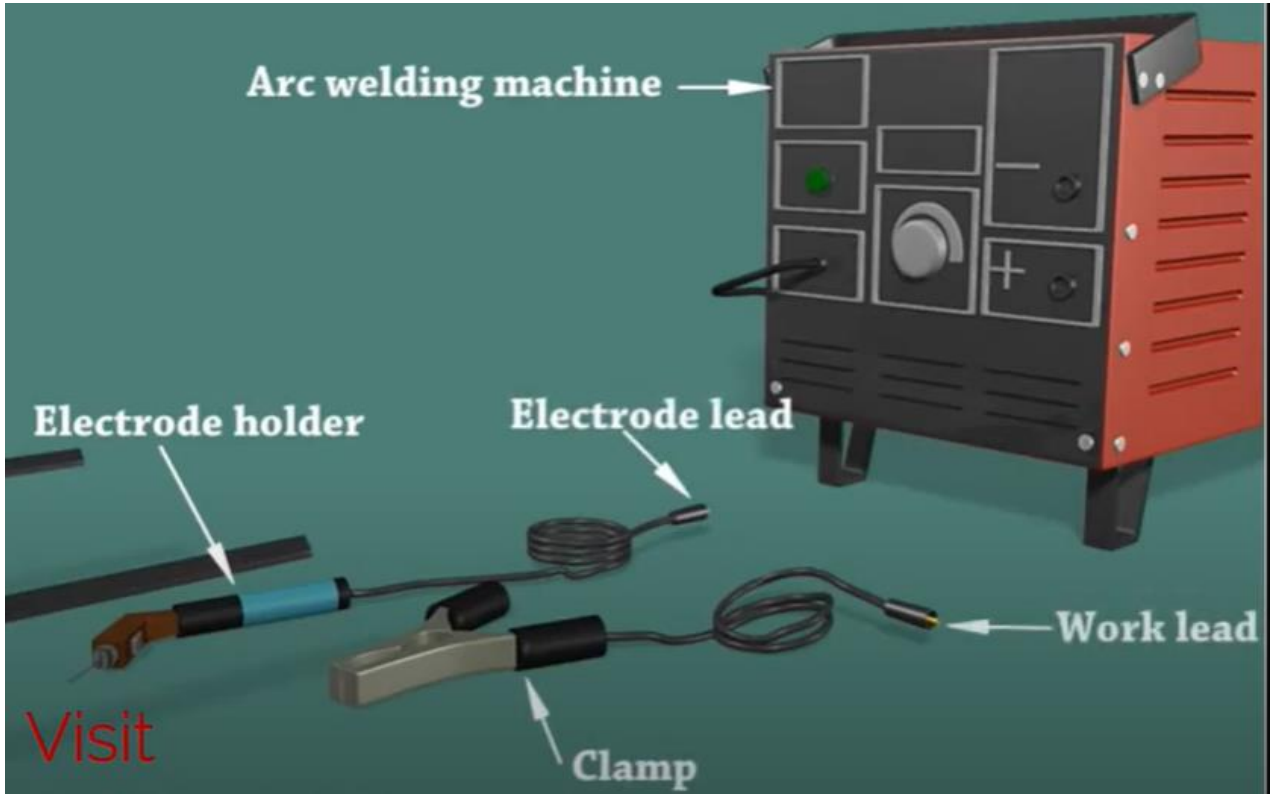


ELECTRIC ARC WELDING

- Introduction to Arc welding
- Carbon Arc Welding
- Metal Arc Welding
- Metal Inert Gas Welding
- Tungsten Gas Welding
- Submerged Arc Welding
- Electro slag welding
- Resistance welding

Introduction : Basic of electric arc welding

- Arc welding is the most extensively employed method of joining metal parts. The source of heat is an electric arc. The arc column is generated between an anode , which is positive pole of D.C. power supply and cathode , the negative pole.
- To generate an electric arc these two conductors are brought together and separated for a small distance (2-4) mm such that the current continues to flow through a path of ionized particles (Gaseous medium) called plasma .



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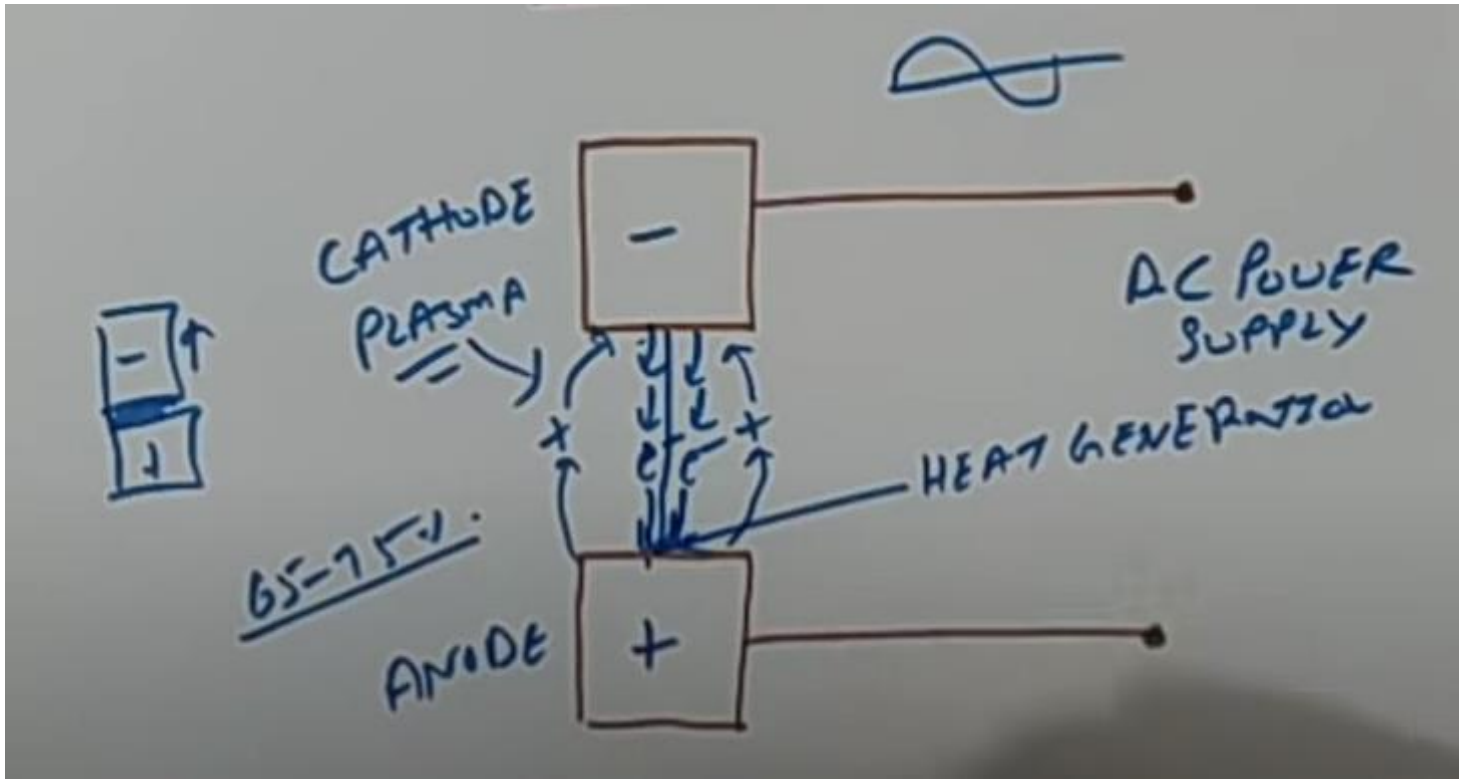
- The ionized gas column acts as a high resistance conductor that enables more ions to flow from anode to the cathode and electrons from cathode to anode. The striking of these ions on cathode and electron on anode produce heat on both electrodes. However, amount of heat produce is not same.
- Moreover, third source of heat generation is collision of electron and ions that are passing through ionized gas column.
- The temperature at the centre of an electric arc being 6000°C to 7000 °C .
- Two third of the heat is developed near positive pole (Anode) and remaining one third of heat at negative pole (Cathode).
- Due to high temperature of arc, parent metal melt off and form a molten metal pool that on solidification produce weld joint.



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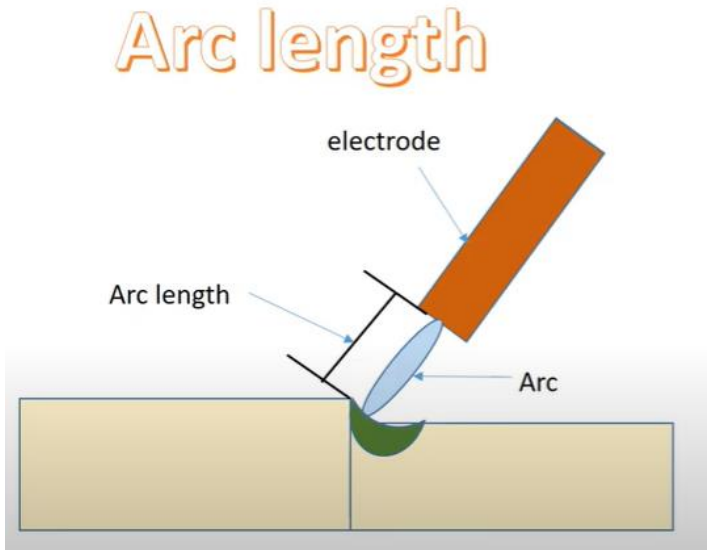
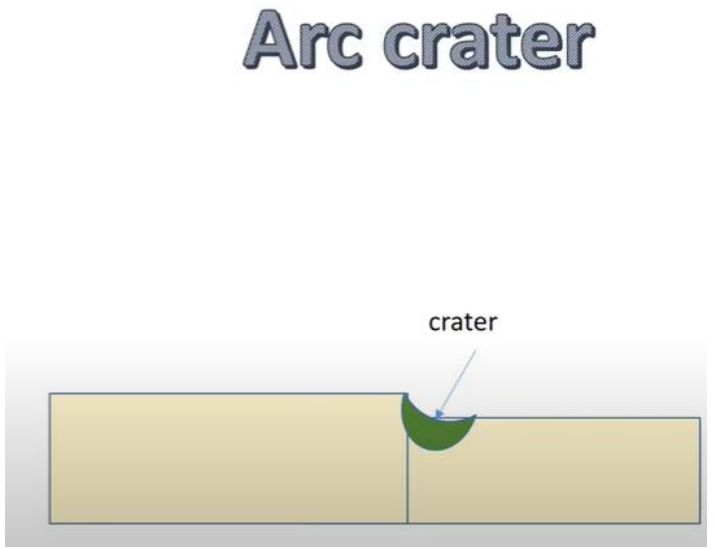
- The blast of arc forces the molten metal out of the pool thus forming a small depression in the parent metal known as ARC CRATER .
- The distance through the centre of the arc from the tip of the electrode to the surface is termed as ARC LENGHTH and it should be 3 to 4 mm. it is directly proportional to the arc voltage. The optimum arc length is important in making sound weld.
- Arc length should not exceed the diameter of electrode wire.





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- ARC BLOW : The electric current flowing through the electrode, work piece , and ground cable sets up circular magnetic field around current path. When the fields around the work piece or around the electrode are unbalanced , the arc bends away from the greater concentration of the magnetic field. This arc deflection from the intended path is known as ARC BLOW.
- It is usually encounter when using DC current because induced magnetic field are constant in direction but almost negligible with AC. Because the induced magnetic field that builds up collapse as soon as the current reverses. Arc blow causes unstable arc and poor-quality weld.

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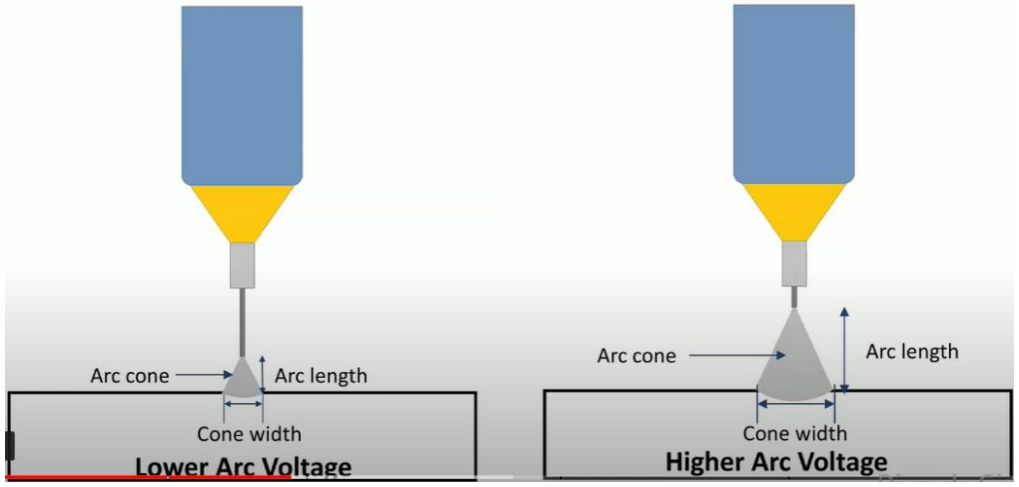
- **Arc Voltage** : The voltage fall after the arc is established and continue for welding is called Arc Voltage. The voltage across the arc in metal arc welding ranges from 17 V to 40 V.

- While the current for manual operation from 30 to 500 A and for automatic operation from 75 to 600 A.



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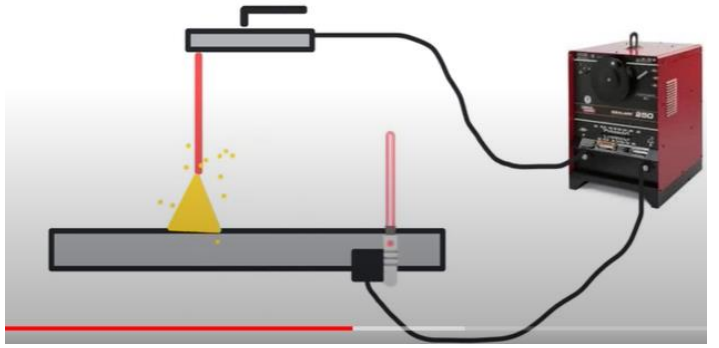
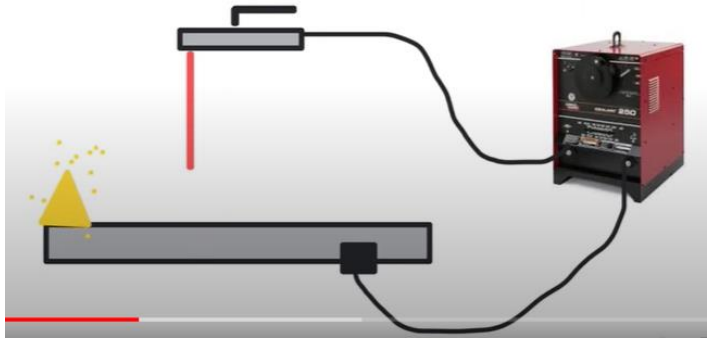
- **Open Circuit Voltage** : The voltage needed to strike the arc is higher than the arc voltage for easy starting of arc. It ranges from 80 to 100 V.





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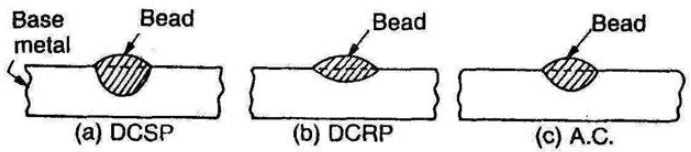
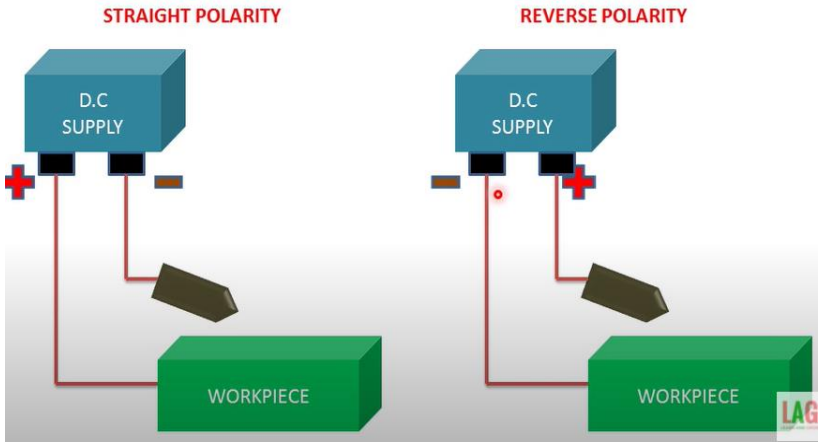
- **Polarity** : Possession of negative and positive pole is called polarity and the direction of current flow is important when direct current is used for welding.
  - **Straight Polarity** : (DCEN): (Direct current electrode negative): Produces maximum heat at workpiece thus deep penetration and used for thick section.
  - **Reverse Polarity** : (DCEP) : (Direct current electrode positive): Produces maximum heat at electrode thus shallow penetration . it is preferred for thin sheet metal.





ELECTRODE

Non-Consumable Electrode

Consumable Electrode

Coated Electrode

Bare Electrode

❖ **Non-Consumable Electrode**

✓ These electrodes are not consumed during the welding operation but just provide heat for melting.

✓ They are made of Carbon , Graphite , tungsten.

➢ **Consumable Electrode**

✓ They are made of various metals depending upon their purpose and the chemical composition of the metals to be welded.

✓ **Coated Consumable Electrode** : Have following advantage :

- Arc stabilization and maintenance.
- Provide shield from atmosphere.
- Slag formation to protect welding seam from rapid cooling.
- Provide means of introducing alloying elements.

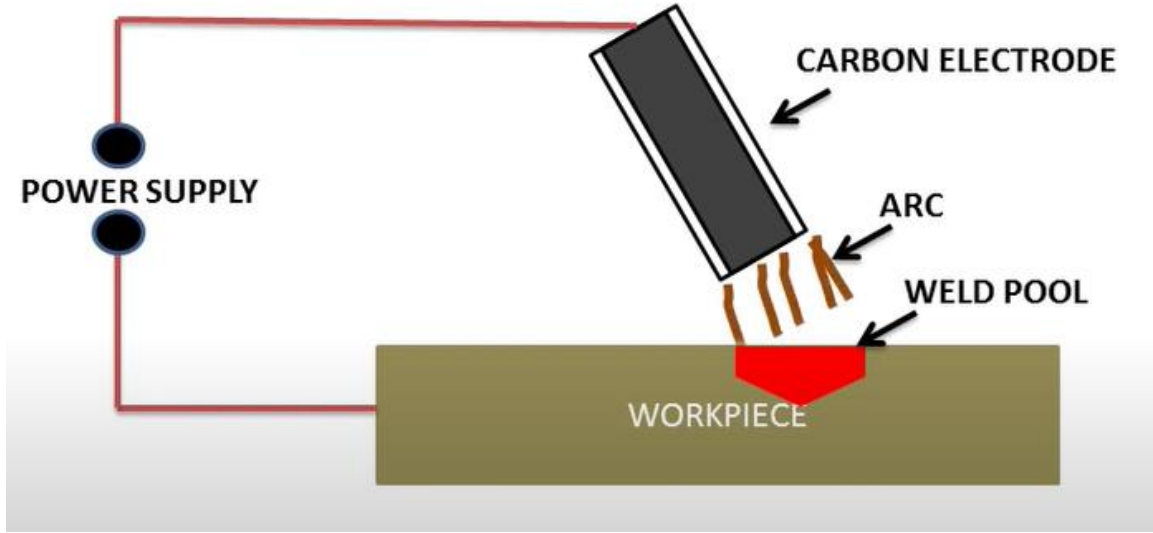
❖ **Lightly Coated Electrode** : electrode with a coating layer several tenths of a millimeter. This helps to increase arc stability

❖ **Heavily Coated Electrode** : They have relatively thick high-quality covering from 1 to 3 mm. They are also referred as shielded arc electrode. Heavy coatings are consisting of chalk , deoxidizer , starch , slag former ,alloying and binding material. Length of electrode varies up to 450 mm and diameter up to 12 mm.

❖ **Bare Electrode:** This type of electrode have a limitation that as the globules of metal pass from electrode to the work , they are exposed to the oxygen and nitrogen of air. Results in formation of some non-metallic constituents which are trapped in solidifying weld metal and decrease the strength of joint.

Carbon Arc Welding

- In this method a rod of carbon connected to negative terminal and the work piece to be welded connected to positive terminal.
- The arc produced between these two electrode, heats the metal to the melting temperature.
- The temperature of negative electrode and positive electrode is 3200^0C and 3900^0C)
- As less heat is produced at negative terminal, so carbon from the electrode will not fuse and mix up with the job otherwise it will cause joint very brittle and unsound.
- Always use DC with carbon arc welding.

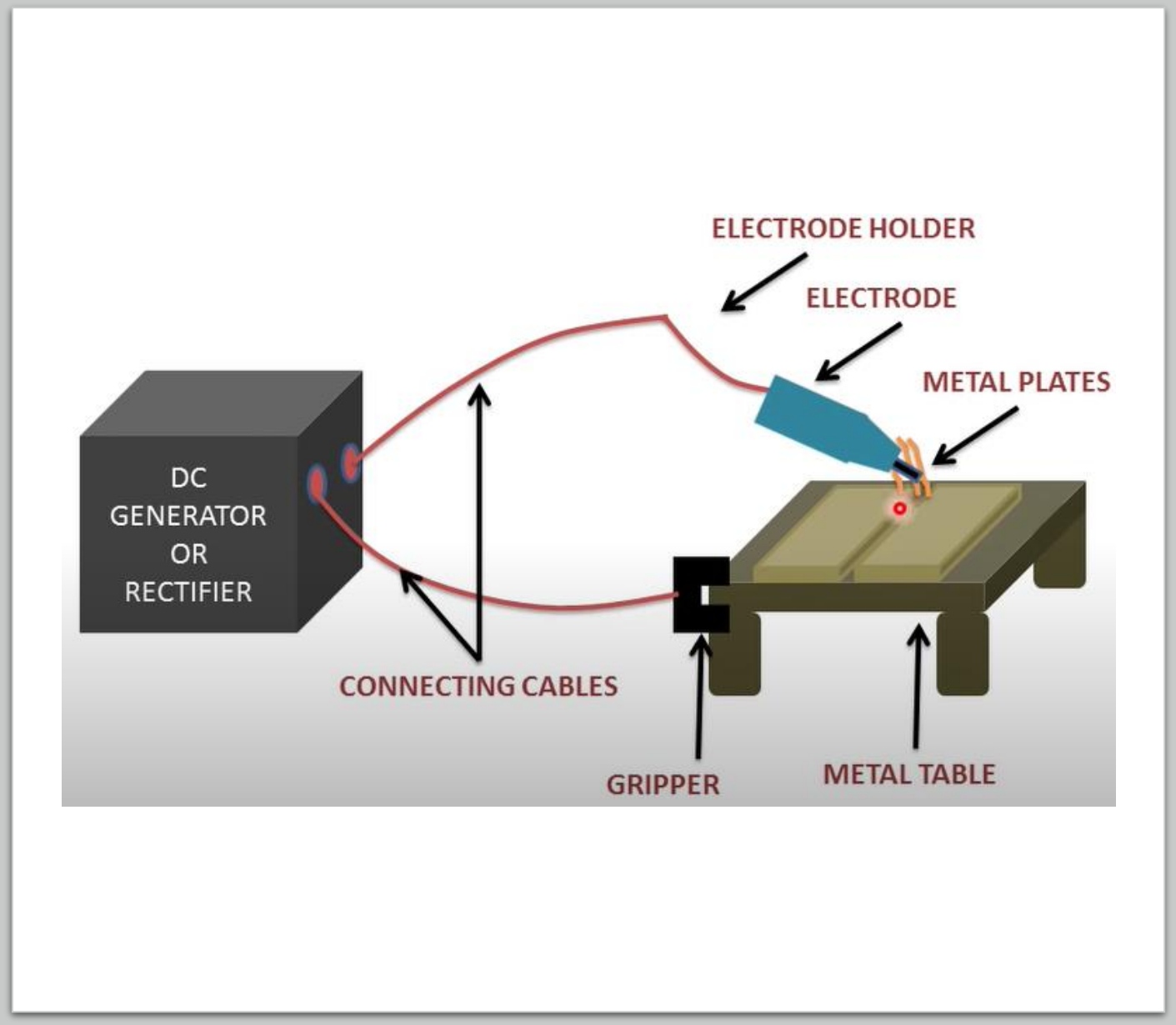


Metal Arc Welding

- In metal arc welding, a metal rod is used as one electrode, while the work being welded is used as another electrode.
- During welding this metal electrode is melted by the heat of the arc and fused base metal, thus forming a solid union after the metal has been cooled.
- Specification of Electrode used in MAW :

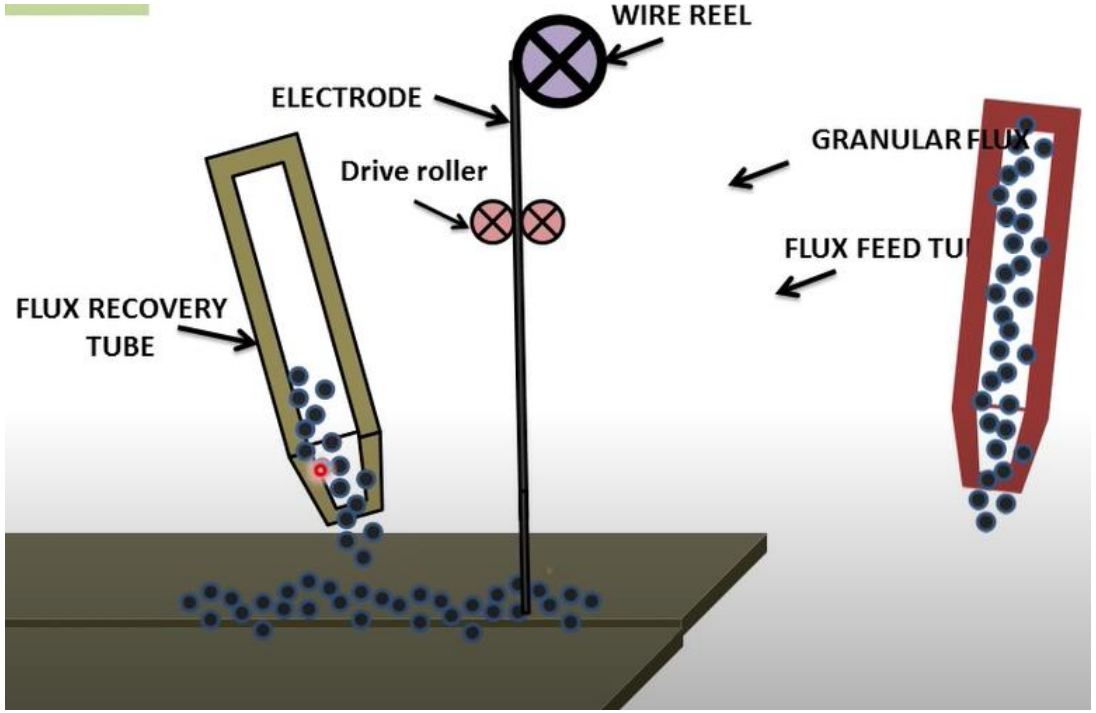
  E6012, E6013 etc,

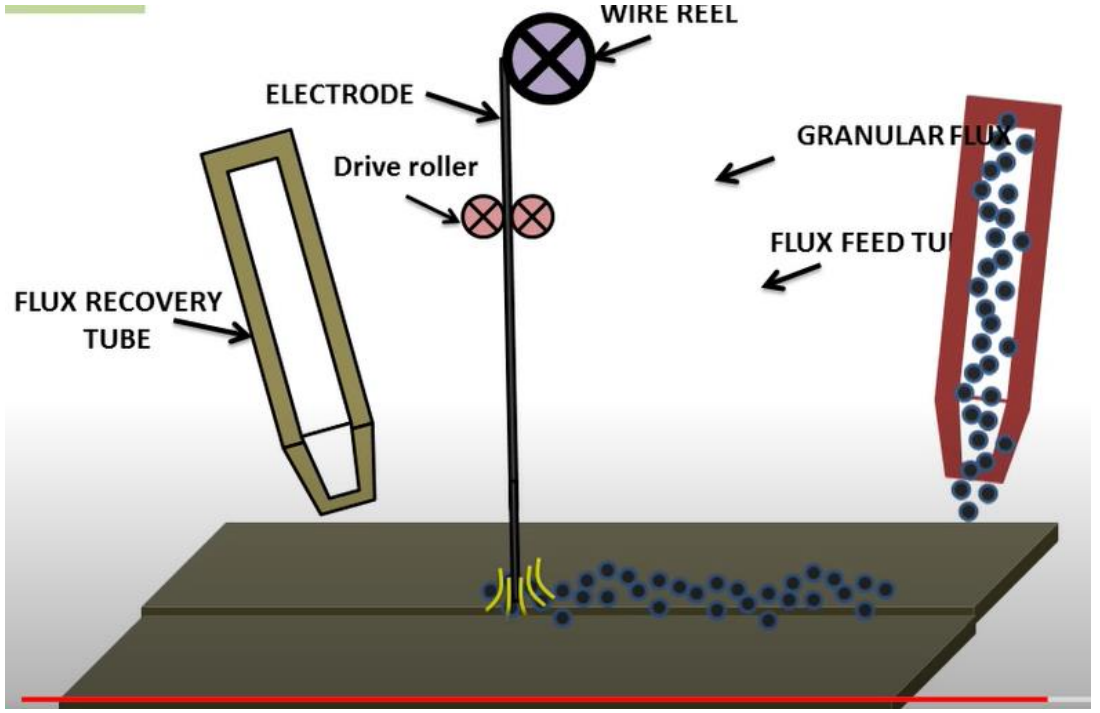
- ✓ Where Ist two digit shows tensile strength
- ✓ Third digit shows weld position
- ✓ Fourth digit shows flux coating
- ✓ Temperature produced is about 2400 ^{0}Cand 2600 ^{0}C on the negative and positive electrode.
- ✓ Polarity :DCEP or DCEN can used.



Submerged Arc Welding

- It is a common arc welding process that involves the formation of an arc between a continuously fed electrode and the workpiece.
- A blanket of powdered flux generates a protective gas shield and a slag (and may also be used to add alloying elements to the weld pool) which protects the weld zone.
- This thick layer of flux completely covers the molten metal thus preventing spatter and sparks as well as suppressing the intense ultraviolet radiation and fumes that are a part of the shielded metal arc welding (SMAW) process.

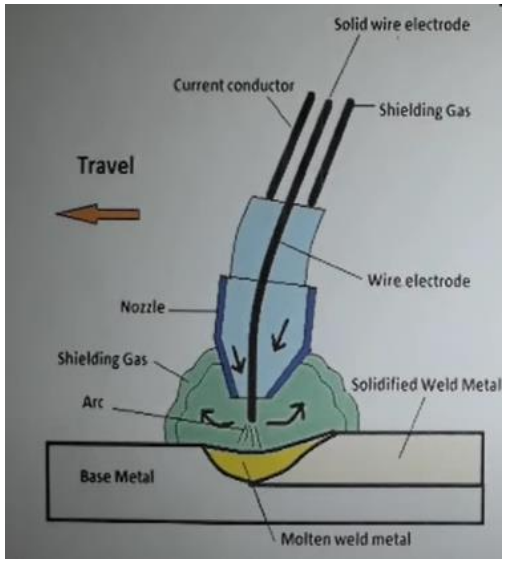


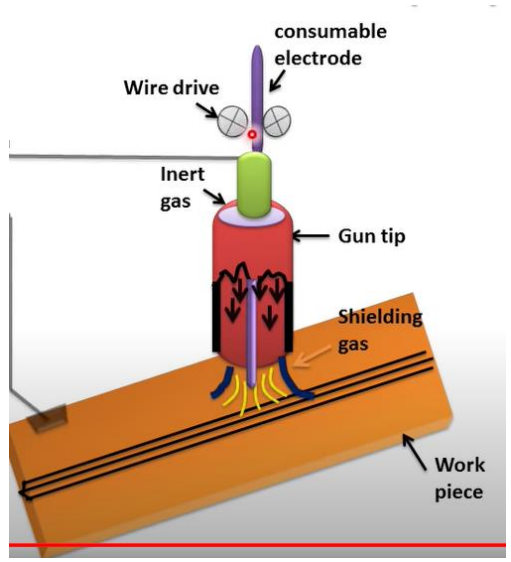


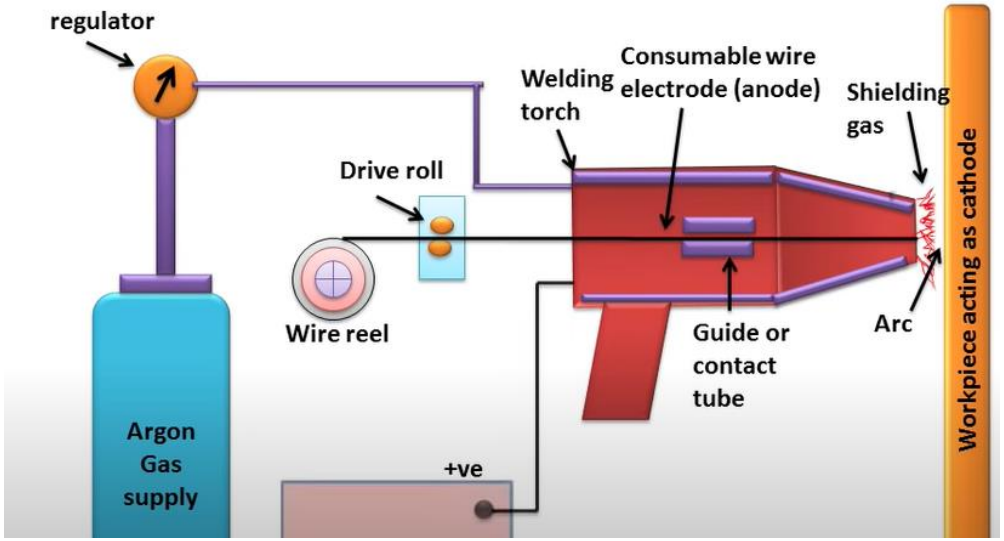
Metal Inert Gas Welding(MIG/GMAW)

- Metal Inert Gas Welding is an arc welding process in which the heat for welding is generated by an arc between a consumable electrode and workpiece.
- The electrode , weld pool , arc and adjacent areas of the base metal are protected from atmospheric contamination by a gaseous shield provided a stream of gas or mixture of gases , fed through the welding gun.
- The gas shield must provide full protection.
- MIG overcomes the restriction of using an electrode of limited length.
- MIG is an all-position weld.
- Polarity (DCEP) or reverse polarity provide stable arc , smooth metal transfer , low spatter.
- Constant voltage power supply is used in MIG.
- The electrode is a consumable bare solid wire continuously fed to the weld area , also called the filler metal.

❖Metal Inert Gas Welding







Metal Inert Gas Welding

- **Constant voltage power supply** : The constant voltage power supply along with a constant wire feed rate results in a self-correcting arc length. As a result, any change in arc length (which is directly related to voltage) results in a large change in heat input and current.
- A shorter arc length causes a much greater heat input, which makes the wire electrode melt more quickly and thereby restore the original arc length. This helps operators keep the arc length consistent even when manually welding with hand-held welding guns.
- In constant arc voltage system instead of regulating the wire to maintain a constant arc length , the wire is fed into the arc at fixed speed , and the power source is designed to melt off the wire at the same time speed.
- Classification of MIG wire electrode :

ER70S-2:

where E = Electrode

R = Filler Rod

70 = Tensile Strength

S = Solid wire / C = Metal cored wire

2 = Special Chemical Composition

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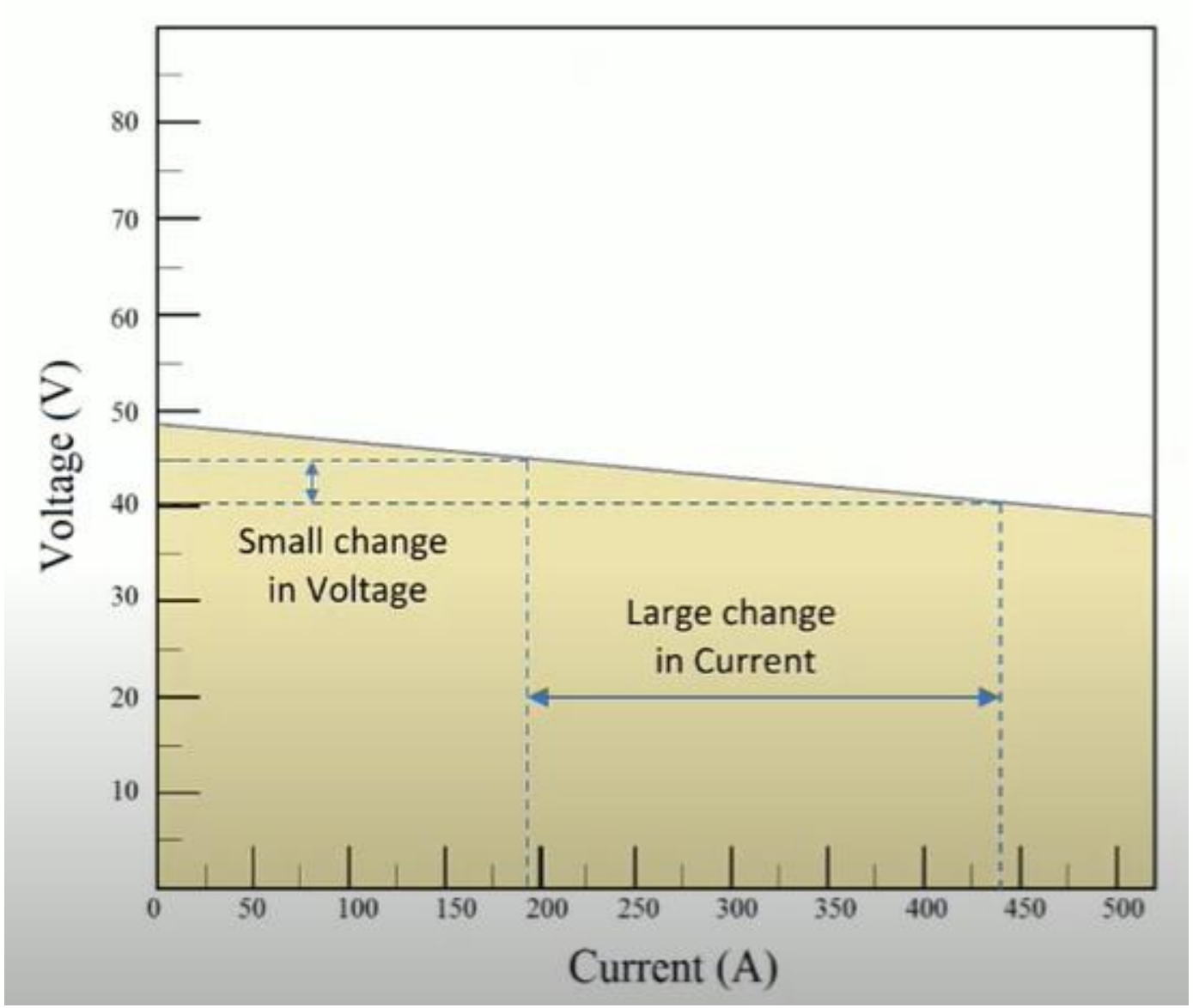
❖ **Volt-Ampere Characteristics :**

✓ **In Flat characteristics or Constant Voltage** characteristics , For small variation in arc voltage there will be large variation in current. current decreases as the arc length becomes longer and increases as the arc length become shorter. It is specially used for MIG welding for synchronizing the feeding rate of wire with melt off rate of wire.



Shielding Gases

- ❖ The primary purpose of shielding gas is to protect the molten weld metal and the heat affected zone from oxidation and other contamination .
- ✓ **Argon** : It is inert gas and insoluble in molten metal. Argon is 38 % heavier than air which is advantageous for welding in flat position. Argon has a lower ionization potential than helium , which result in lower arc voltage for given arc length , result in less heat is produced at a given amperage with argon than with helium , which makes argon preferable to helium for the welding of thin section. Argon is about 10 times as heavy as helium. it is cheaper than helium and easily available.
- ✓ **Helium :** Helium is also inert gas and is used for welding Al, Mg, Cu alloys. It is a light gas and obtained from natural gas . It is lighter than air .So high gas flow rate must be maintained. It is often preferred for overhead welding. Globular metal transfer is preferred with helium. It has high ionization potential. It will produce hotter arc and good for thick section.
- ✓ **Carbon Dioxide** : this gas is extensively used as itself or as mixtures to improved arc action. It is widely used in the welding of steel by the short-circuiting mode of metal transfer. it is less expensive than argon-based welding.

Table of Lower Ionisation Potential

Gas	Ionisation Potential	Specific Gravity
Argon (A)	15.68-75	1.3800
Hydrogen (H_2)	15.06-59	0.0695
Helium (He)	24.46-58	0.1378
Nitrogen (N_2)	15.51-54	0.9670
Carbon dioxide (CO_2)	14.04-61	1.5290
Air	Nil	1.0000

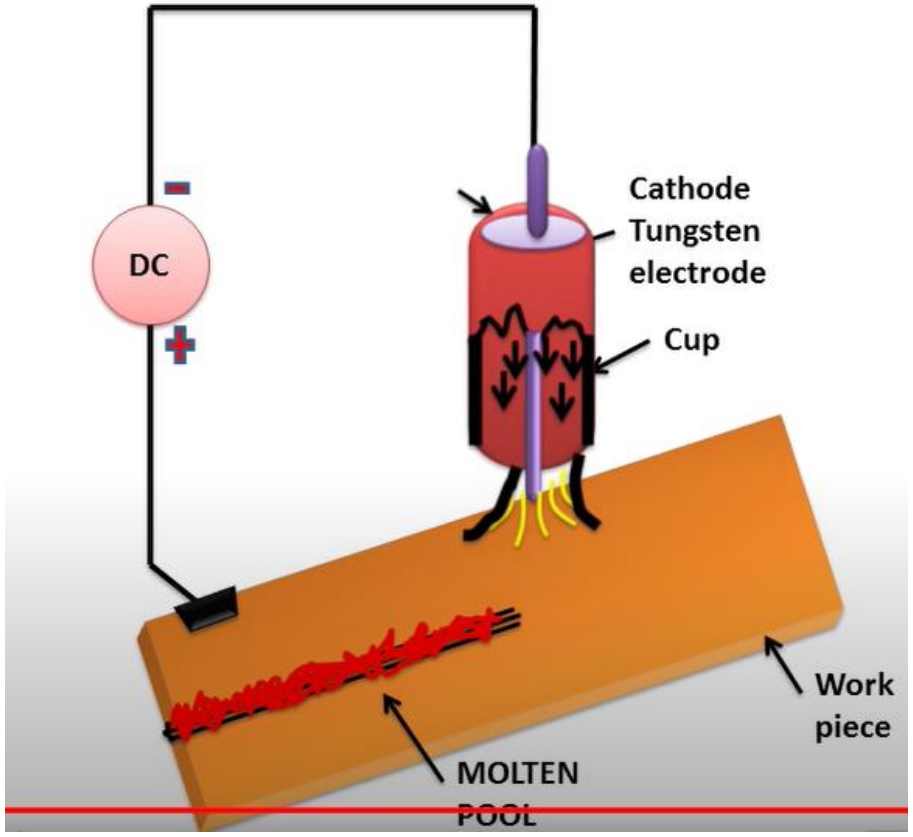
Density of Shielding Gases

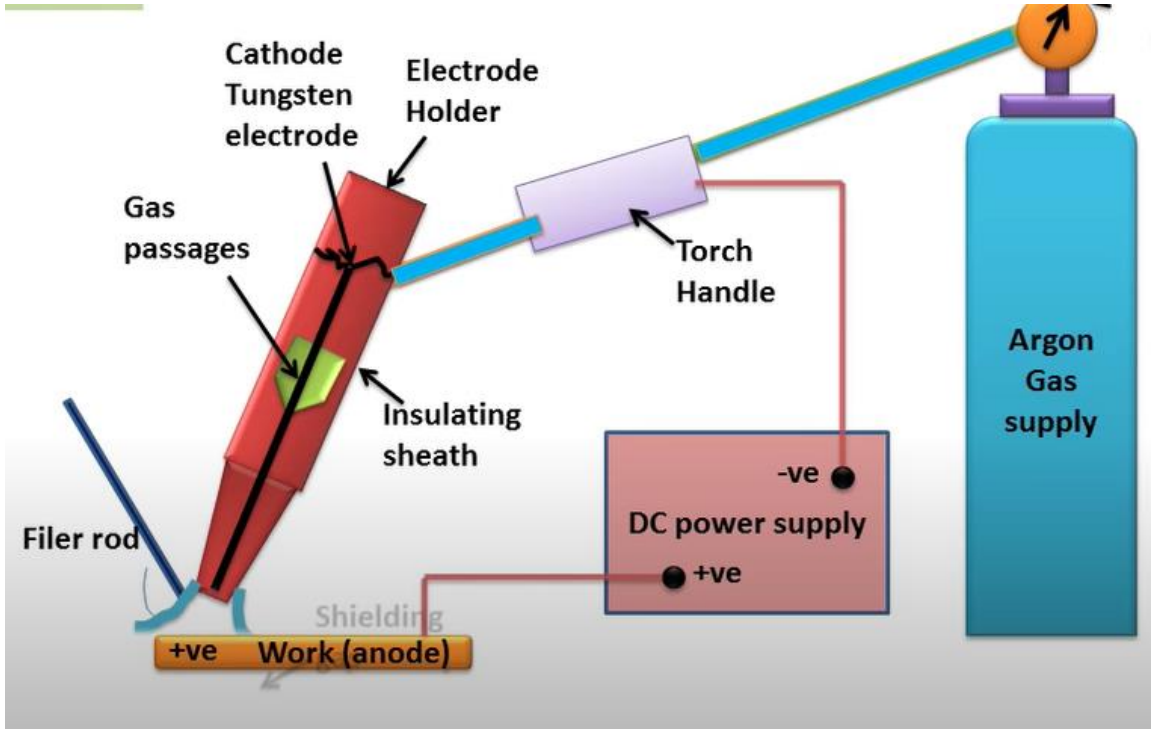
Gas	Density
Argon	1.785
Helium	0.178
Hydrogen	0.085
Nitrogen	1.165
Oxygen	1.325
Carbon dioxide	1.970

Tungsten Inert Gas Welding (TIG)

- It is an arc welding process in which the heat for welding is generated by an arc between a non-consumable electrode and workpiece.
- The electrode , weld pool , arc and adjacent areas of the base metal are protected from atmospheric contamination by a gaseous shield provided a stream of gas or mixture of gases , fed through the welding gun.
- TIG overcomes the problem of contamination or addition of impurity from an electrode to the weld.
- DCEN (Straight) polarity is recommended with TIG welding.
- Gas tungsten arc welding uses a constant current power source, meaning that the current (and thus the heat flux) remains relatively constant, even if the arc distance and voltage change.
- This is important because most applications of GTAW are manual or semiautomatic, requiring that an operator hold the torch. Maintaining a suitably steady arc distance is difficult if a constant voltage power source is used instead, since it can cause dramatic heat variations and make welding more difficult.
- The electrode is a non-consumable bare solid wire thus additional filler metal can be used if required. The electrode is made of tungsten or a tungsten alloy, because tungsten has the highest melting temperature among pure metals, at 3,422 °C (6,192 °F).

Tungsten Inert Gas Welding





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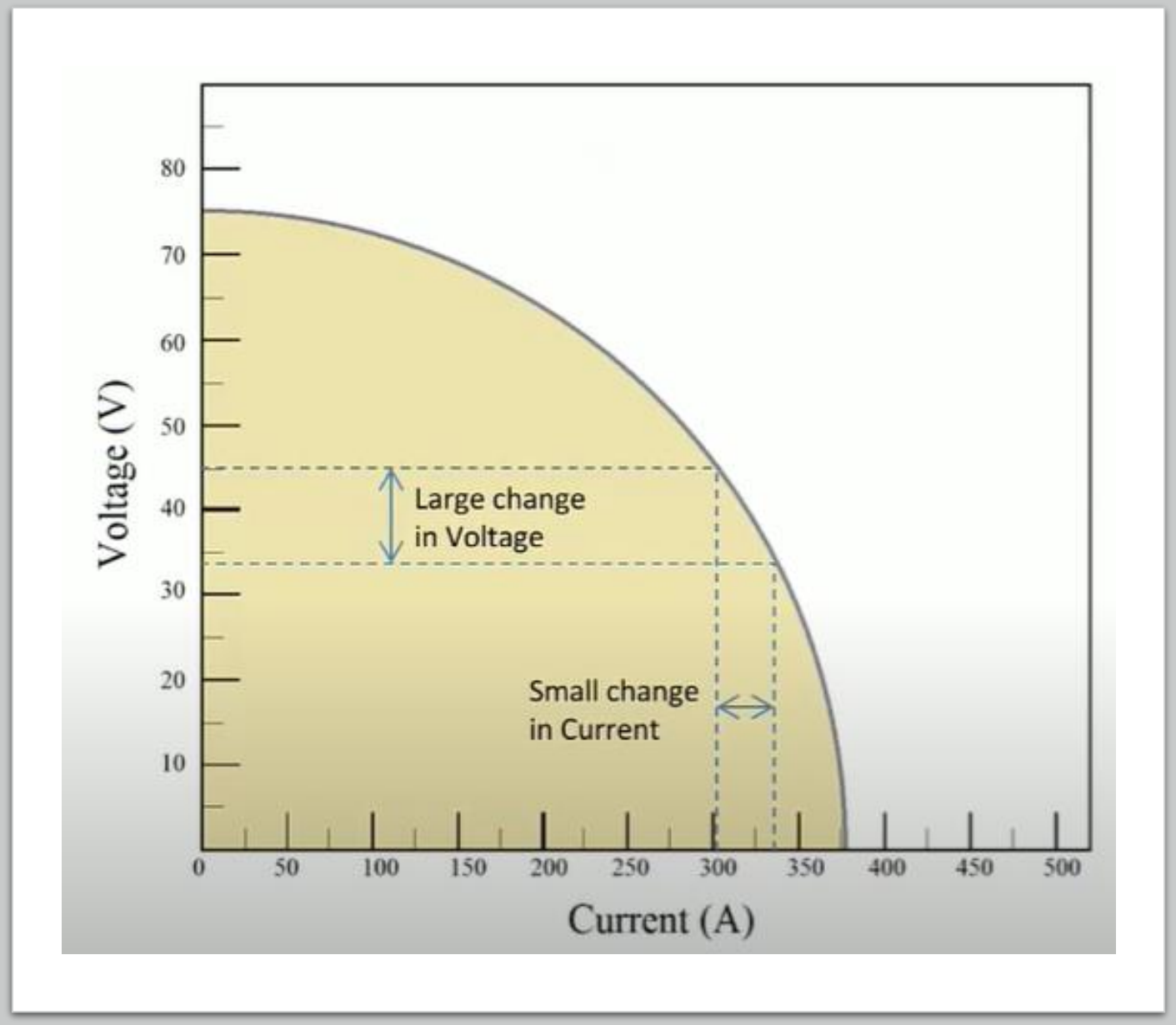
❖ **Volt-Ampere Characteristics :**

✓ **In Drooping volt ampere characteristics** or constant current characteristics, With constant current output, small variation in arc length causes small variation in voltage do not significantly affect current.

✓ E.g., a 10 drop in voltage result only 35 A increase in current as compared to hundreds of ampere with constant voltage.

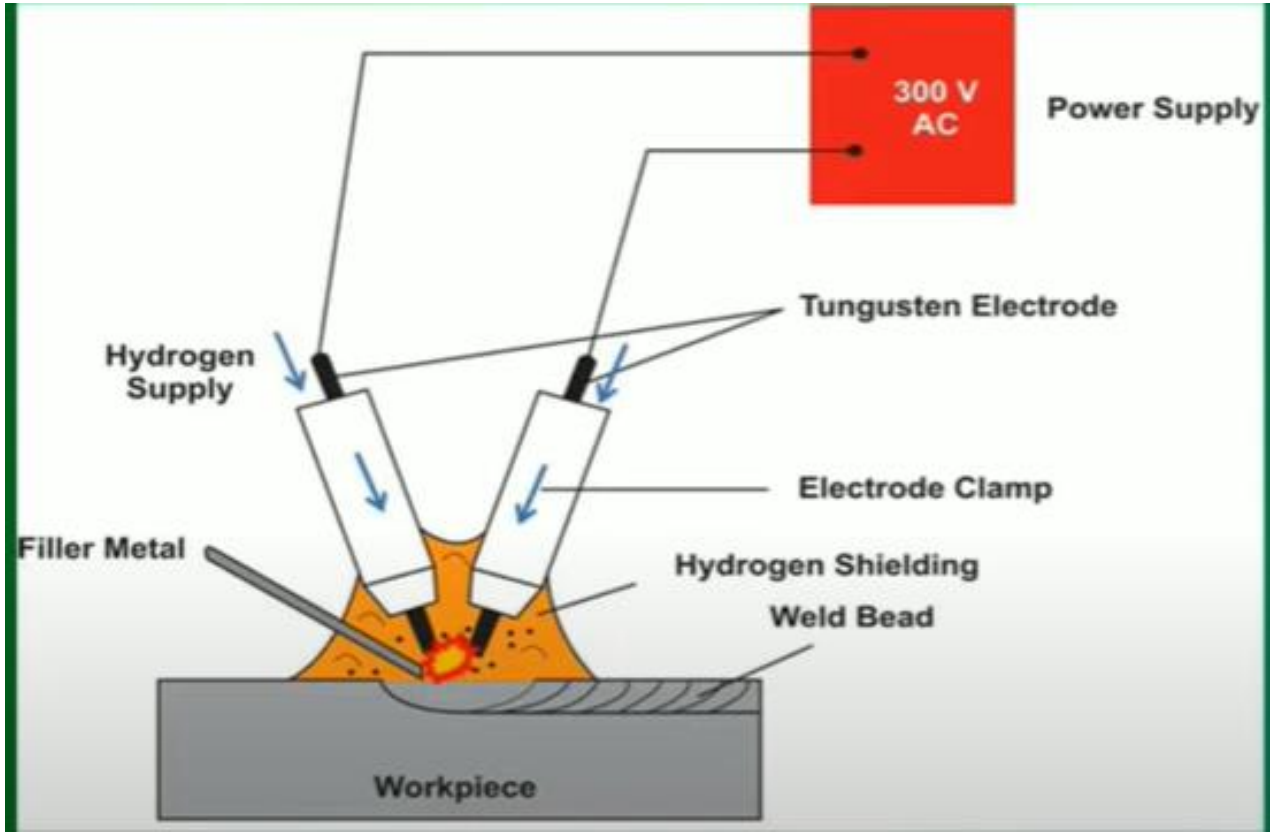
✓ E.g., Manual welding , TIG welding.



Atomic Hydrogen Welding

- In this, the coalescence is produced by heating with an electric arc maintained between two tungsten electrodes in an atmosphere of hydrogen.
- Shielding is obtained from the hydrogen.
- Hydrogen gas flows by the tungsten electrodes in the holder, keeping them cooler and lengthening the electrode life.
- Since hydrogen is not inert, it will react chemically with its environment to form water vapors.
- In this process an AC arc is formed between two tungsten electrodes along which streams of hydrogen are fed to the welding zone. The molecules of hydrogen are dissociated by the high heat of the arc in the gap between the electrodes. The formation of atomic hydrogen proceeds with the absorption of heat.

H_2 = 2H - 421.2 kJ/mol.



Atomic Hydrogen Welding

- This atomic hydrogen recombines to form molecular hydrogen outside the arc, particularly on the relatively cold surface of the work being welded, releasing the heat gained previously :

  $2H = H_2 + 421.2$ kJ/mol.

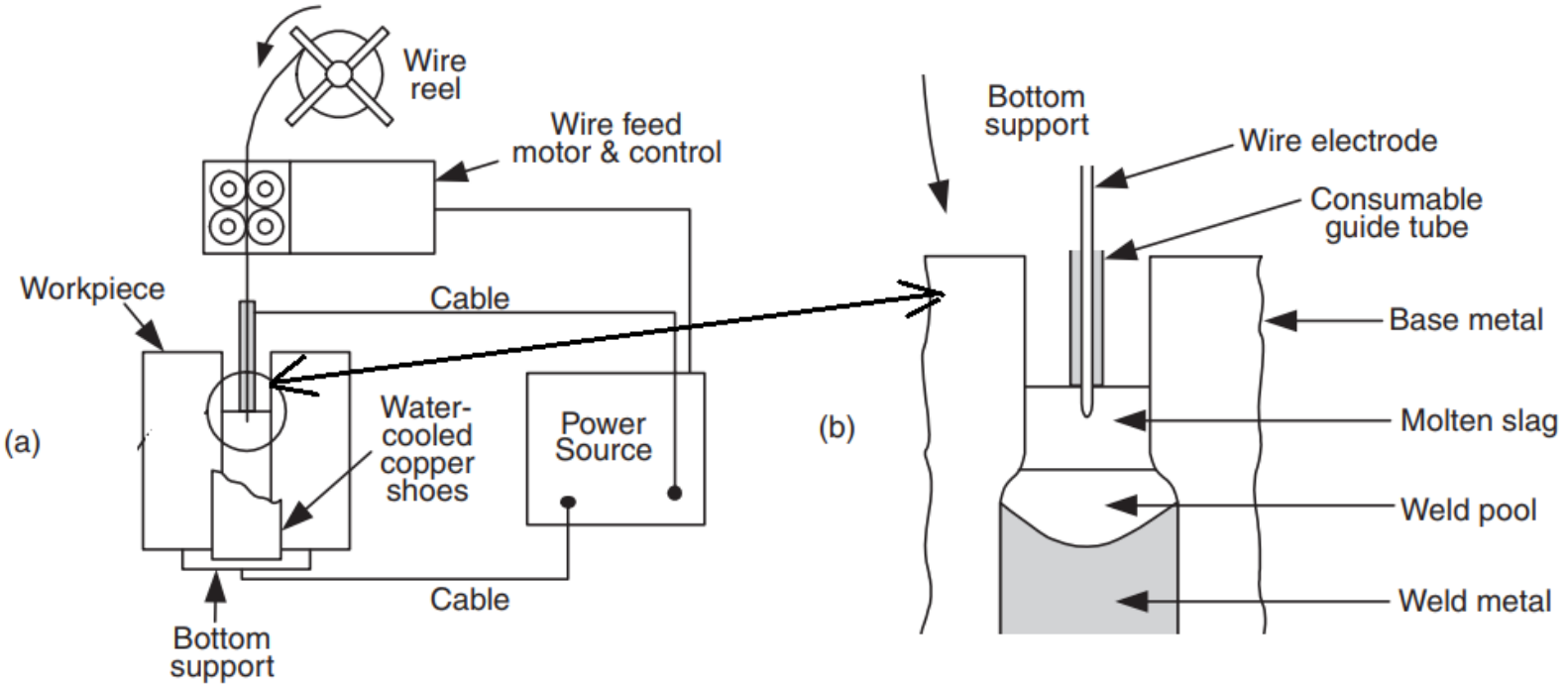
- The metal is heated by the indirect arc and by the heat evolved above, producing a temperature of about 3700 ^{0}C of the flame. The hydro-gen protects the electrodes and the welding pool from oxidation and from saturation with nitrogen. At the outer surface of this gaseous shield, the hydrogen combined with oxygen of the air to form water vapor, making a bright orange flame.
- Atomic hydrogen welding is mainly used in the welding of very thin sheets or small diameter wires

  (2 to 10 mm thick),

Electroslag welding (ESW)

- Electroslag welding (ESW) is a process that melts and joins metals by heating them with a pool of molten slag held between the metals and continuously feeding a filler wire electrode into it as shown in figure(a).
- The weld pool is covered with molten slag and moves upward as welding progresses.
- A pair of water-cooled copper shoes, one in the front of the workpiece and one behind it, keeps the weld pool and the molten slag from breaking out.
- Like SAW, the molten slag in ESW protects the weld metal from air and refines it.
- Strictly speaking, however, ESW is not an arc welding process, because the arc exists only during the initiation period of the process, that is, when the arc heats up the flux and melts it. The arc is then extinguished, and the resistance heating generated by the electric current passing through the slag keeps it molten.
- In order to make heating more uniform, the electrode is often oscillated, especially when welding thicker sections. Figure (b) is the transverse cross section of an electroslag weld in a steel 7cm thick .
- Typical examples of the application of ESW include the welding of ship hulls, storage tanks, and bridges.

Electroslag welding (ESW)



(*a*) overall process; (*b*) welding area enlarged.

Resistance Welding

- It is a group of welding processes wherein coalescence is produced by the heat obtained from resistance of the work to electric current in a circuit of which the work is a part, and by the application of pressure and without the use of a filler metal. The amount of heat generated at the contacting area of the elements to be welded, is determined from Joule's law,

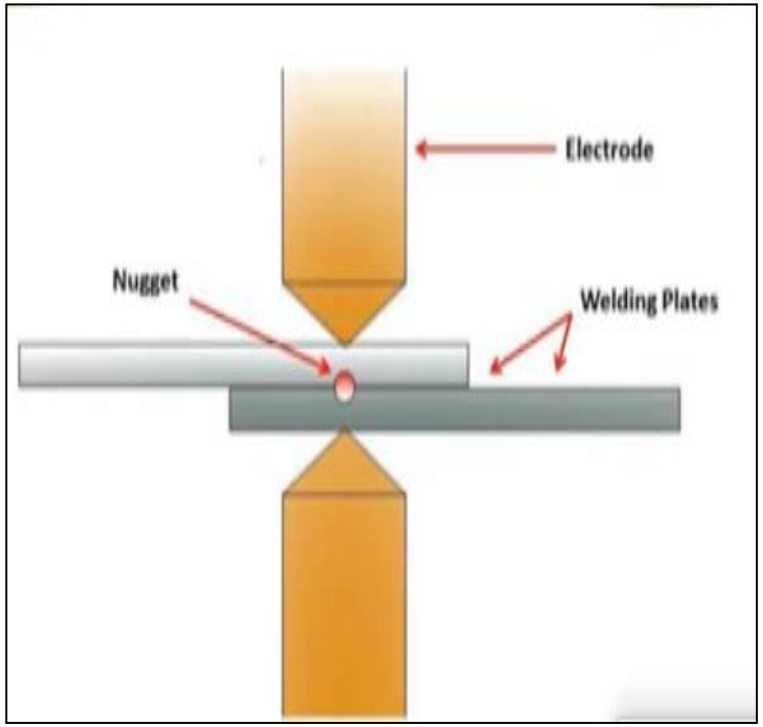
  $Q = I^2Rt$, joules

  where I = current in amperes

  R = resistance of the circuit at the contacting area of the elements in ohms.

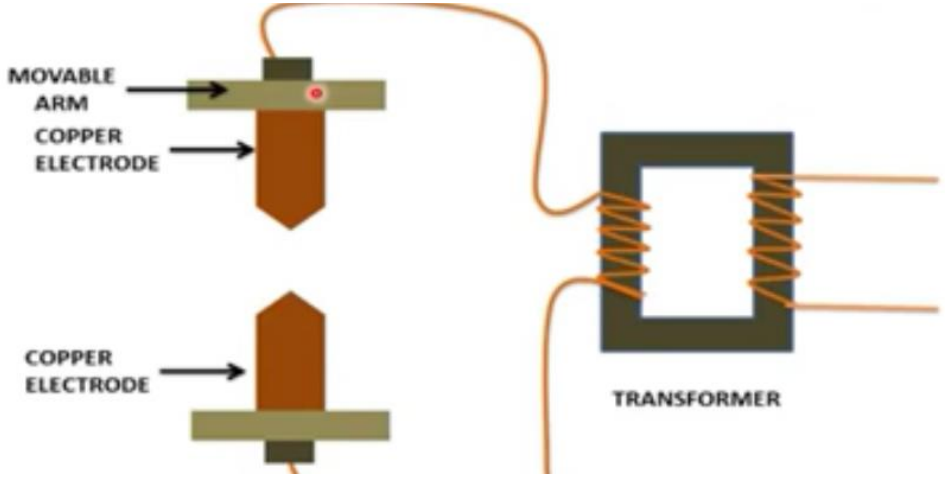
  t = time during which the current flows,(sec).

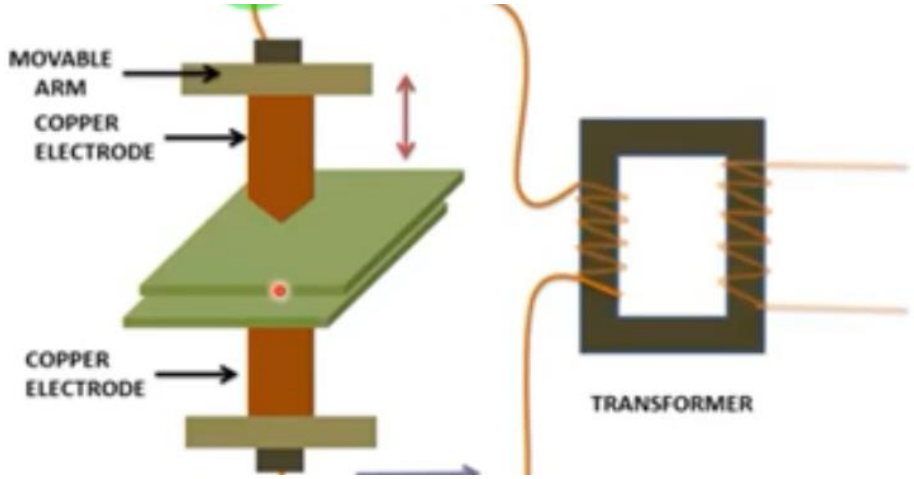
- **Types of Resistance welding**
  - ✓ Spot Welding
  - ✓ Projection Welding
  - ✓ Seam Welding
  - ✓ Percussion Welding
  - ✓ Flash/Butt Welding

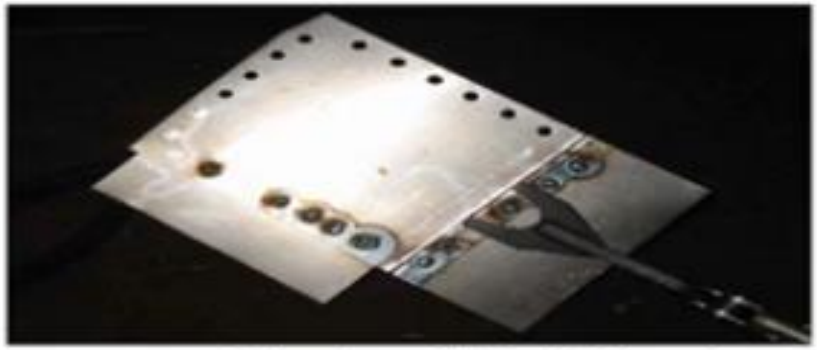


Spot Welding

- Resistance Spot Welding is a sheet metal joining process in which parts to be welded are held together under pressure by electrodes.
- When current is applied, the resistance at the interface of sheets causes a coalescence only at the contact point(spot) and result in spot weld.

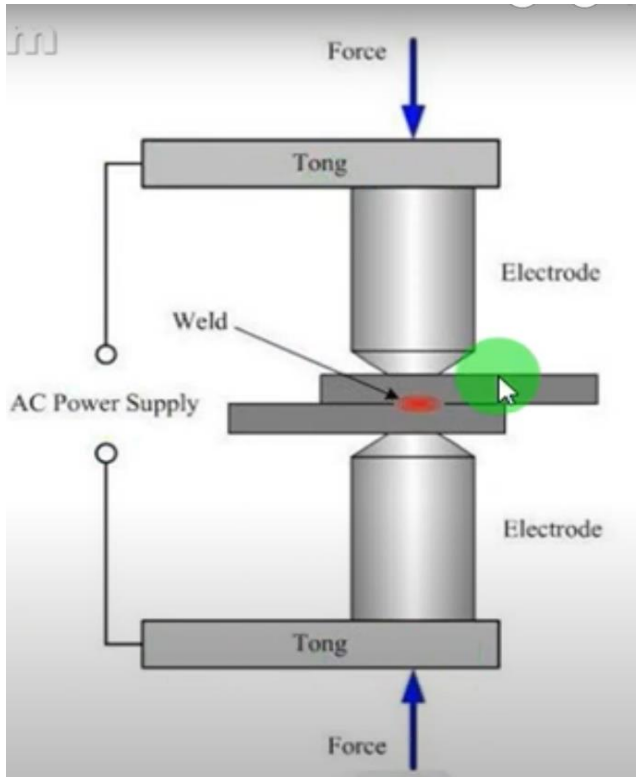






Join two Metal Sheets

Spot Welding



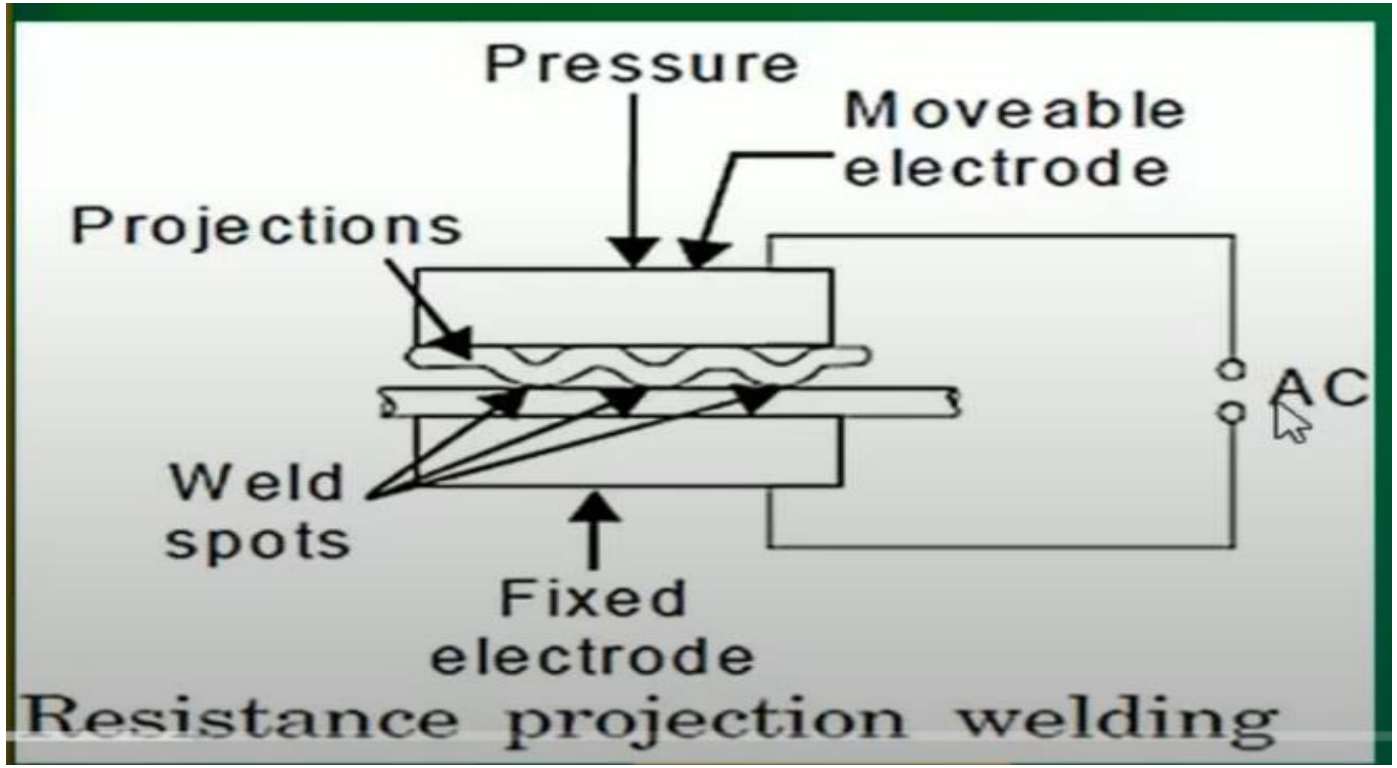
- In Resistance Spot Welding the pieces to be joined are clamped between two electrode under force and electrical current is sent through them
- Force is applied before during and after the application of current to prevent arcing at workpiece
- In spot welding fusion of faying surfaces of a lap joint is achieved at one location by opposing electrodes.

Advantages of Spot Welding

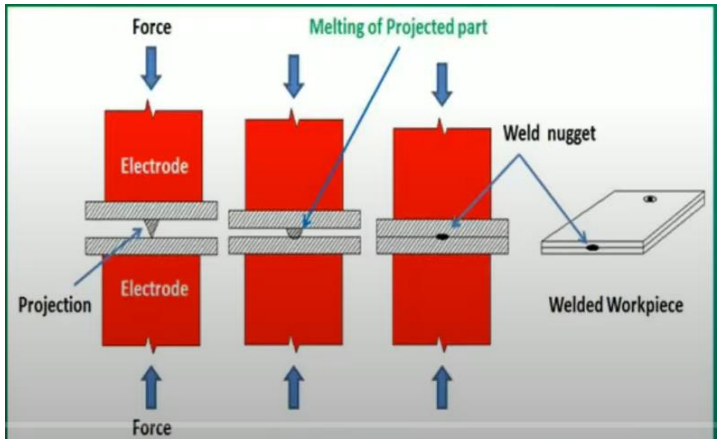
- ✓ Spot welding is quick and easy
- ✓ No need to use any fluxes or filler metal
- ✓ Multiple sheets joined together at the same time.
- ✓ No dangerous open flame
- ✓ Saves production costs.

Projection Welding

- Projection welding is a resistance welding process in which the workpieces are joined by the heat generated due to the resistance of the workpieces to the flow of electric current through them.
- The resulting welds are localized at predetermined points by projections, embossments, or intersections.



Projection Welding



- The workpieces are cleaned to remove dust, scale and other oxides either chemically or mechanically to obtain a sound weld.

- The process uses two flat, large cylindrically shaped water cooled copper electrodes in which one electrode is fixed, while the other to which the pressure is applied is movable.
- The electrodes are connected to a step-down transformer that provides the required electric current for heating.
- One of the work pieces contains small projections or embossment (similar to a pimple on a human face) made at a particular location where the joint is to be made.

Projection Welding

Advantages

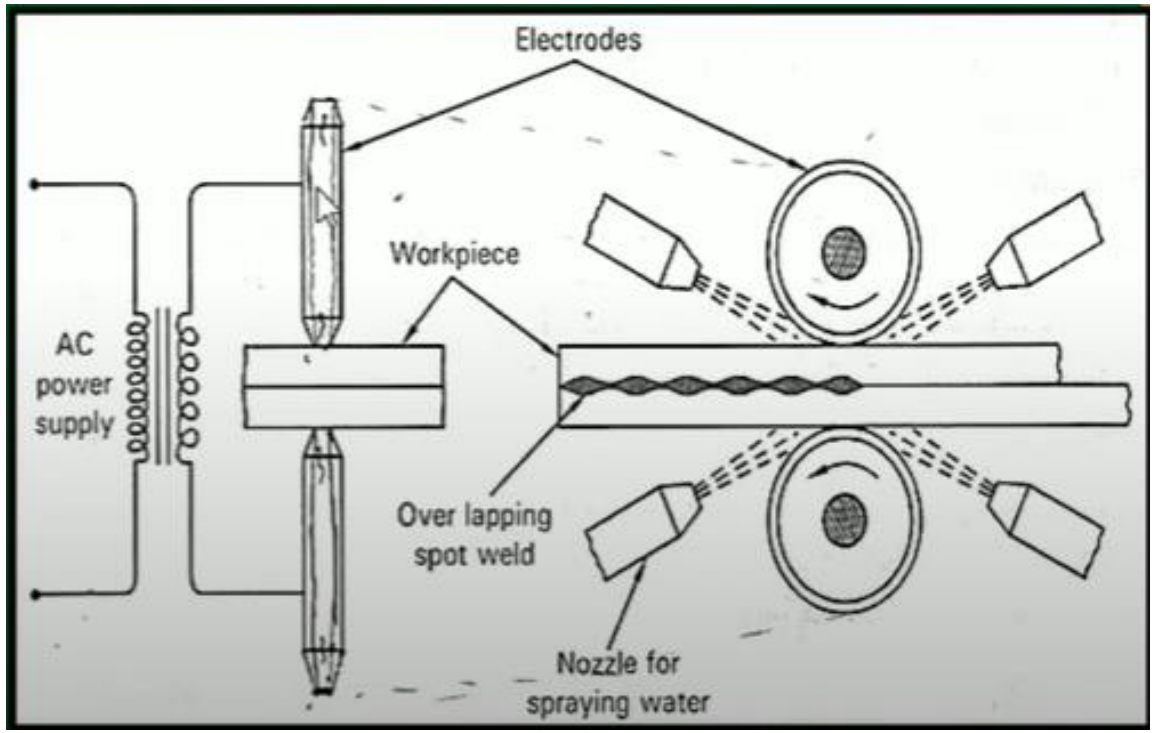
- More than one spot weld can be made in a single operation.
- Welding current and pressure required is less.
- Suitable for automation.
- Filler metals are not used. Hence, clean weld joints are obtained.

- The work pieces are then placed between the two electrodes and held firmly under external pressure.
- When the welding current is made to pass through the electrodes, to the work pieces, maximum heat is generated at the point of contact of the two work pieces, i.e., at the projections.
- This heat softens and melts the projections causing it to collapse under the external pressure of the electrode thereby forming a spot weld.

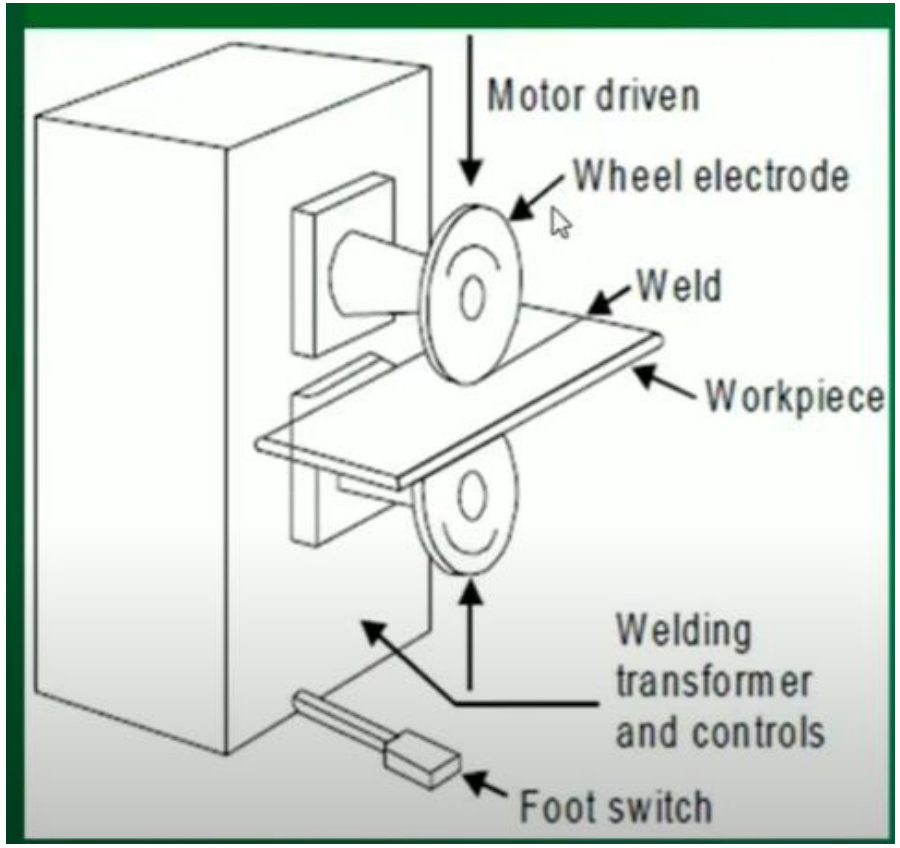
Resistance Seam Welding

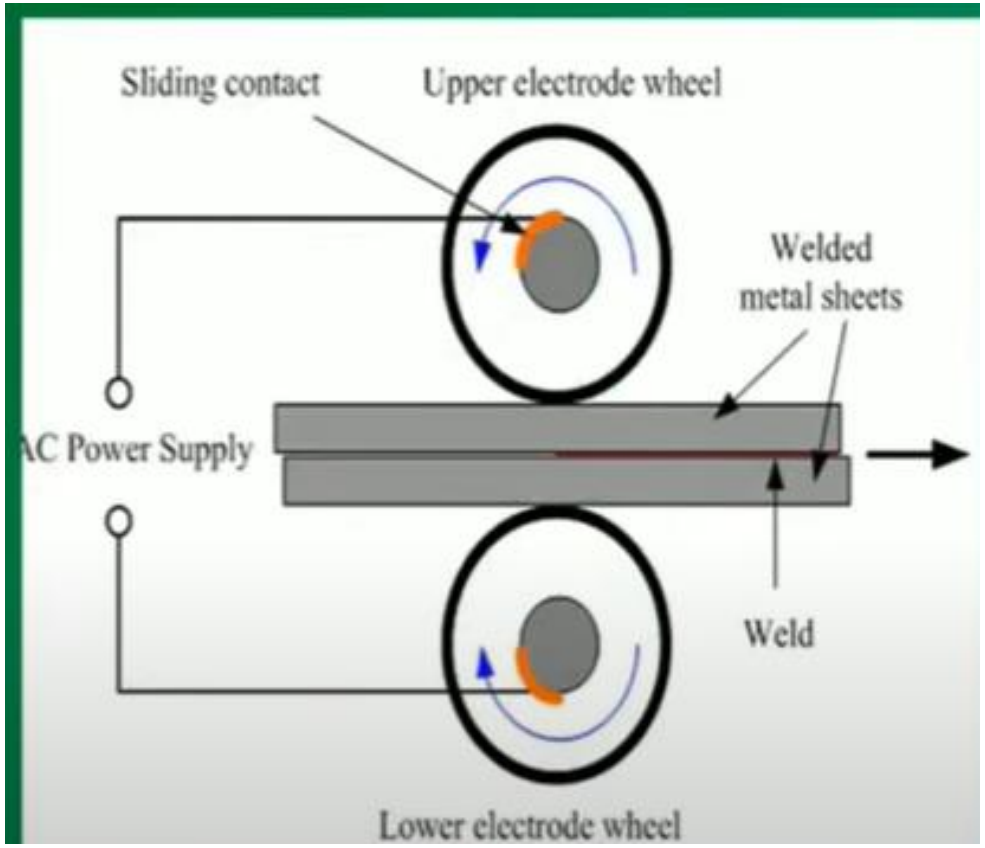
- Seam welding is a resistance welding process in which the overlapping workpieces held under pressure are joined together by a series of spot welds made progressively along the joint utilizing the heat generated by the electrical resistance of the workpieces.

- Seam welding is similar to spot welding process, but, instead of pointed electrodes, mechanically driven wheel shaped electrodes are used to produce a continuous weld.



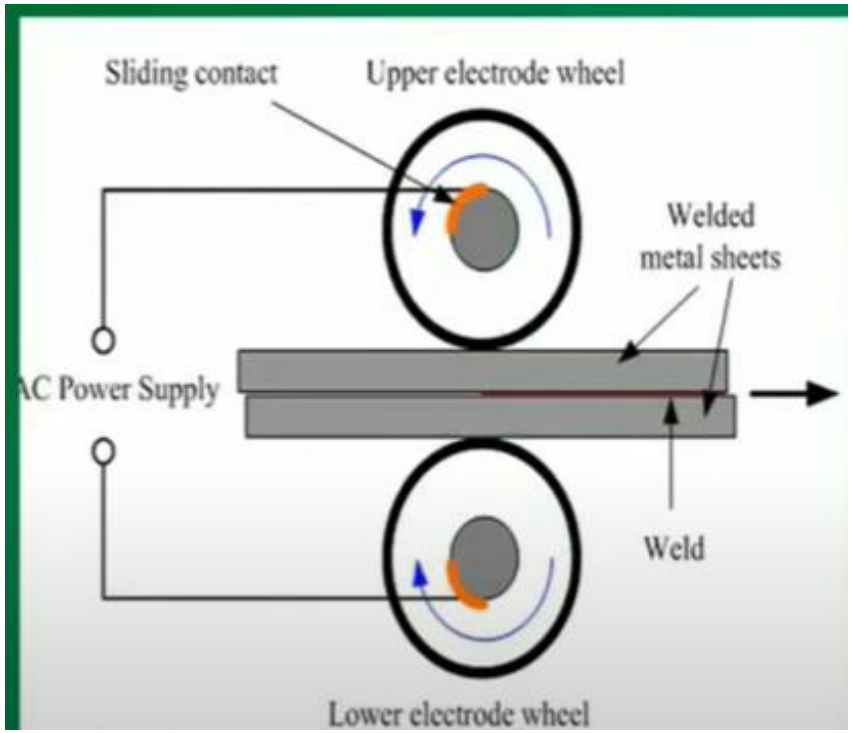
Resistance Seam Welding





Resistance Seam Welding

- The two workpieces to be joined are cleaned to remove dirt, grease and other oxides either chemically or mechanically to obtain a sound weld.
- The workpieces are overlapped and placed firmly between two wheel shaped copper alloy electrodes, which in turn are connected to a secondary circuit of a step-down transformer.
- The electrode wheels are driven mechanically in opposite directions with the workpieces passing between them, while at the same time the pressure on the joint is maintained.
- Welding current is passed in series of pulses at proper intervals through the bearing of the roller electrode wheels.



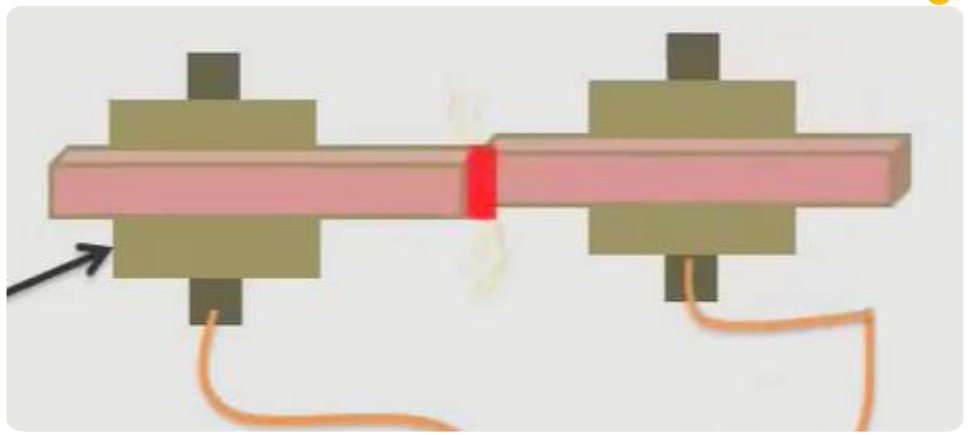
- As the current passes through the electrodes, to the workpiece, heat is generated in the air gap at the point of contact (spot) of the two workpieces.
- This heat melts the workpieces locally at the contact point to form a spot weld.
- Pressure is applied by air, spring or hydraulically.

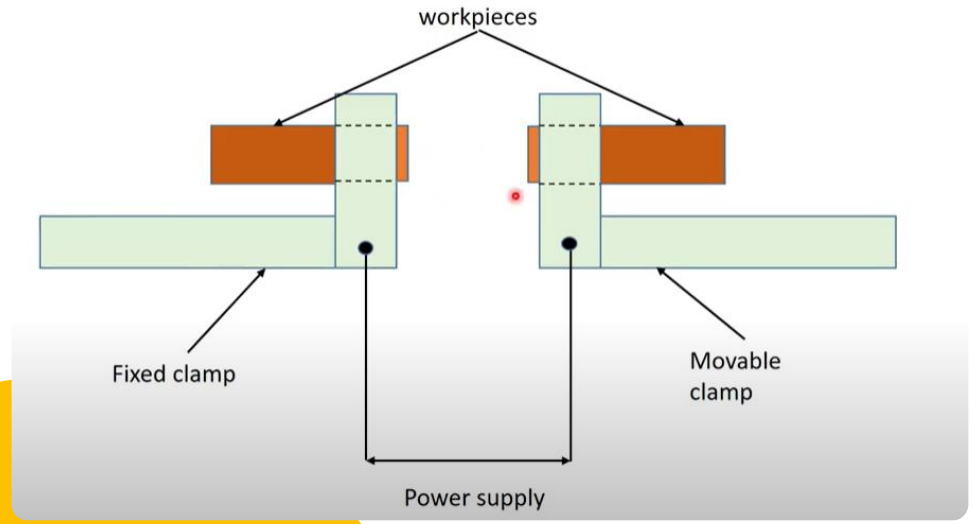
Resistance Seam Welding

Advantages

- A continuous overlapping weld produced by the process makes it suitable for joining liquid or gas tight containers and vessels.
- Efficient energy use.
- Filler metals are not required. Hence, no associated fumes or gases. This results in clean welds.

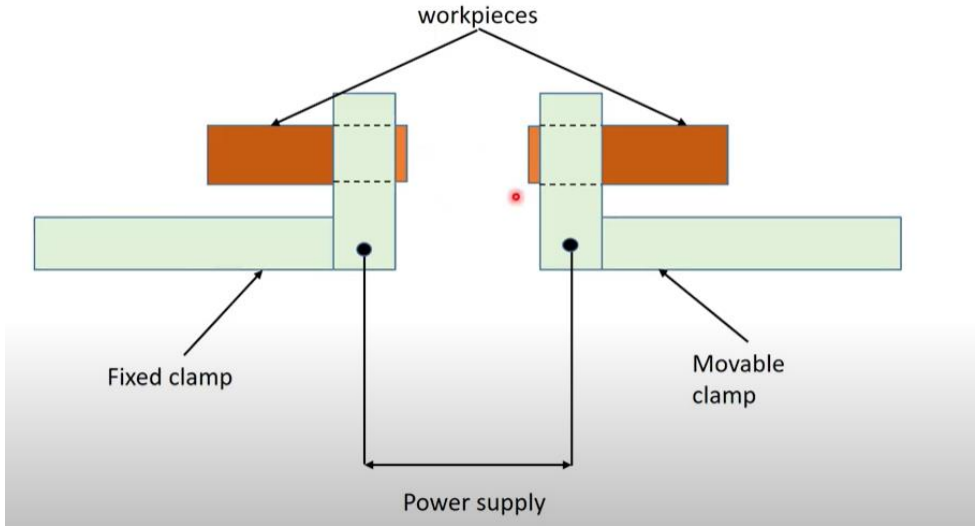
- Under the pressure of continuously rotating electrodes and the current flowing through them, a series of overlapping spot welds are made progressively along the joint.
- The weld area is flooded with water to keep the electrode wheels cool during welding.

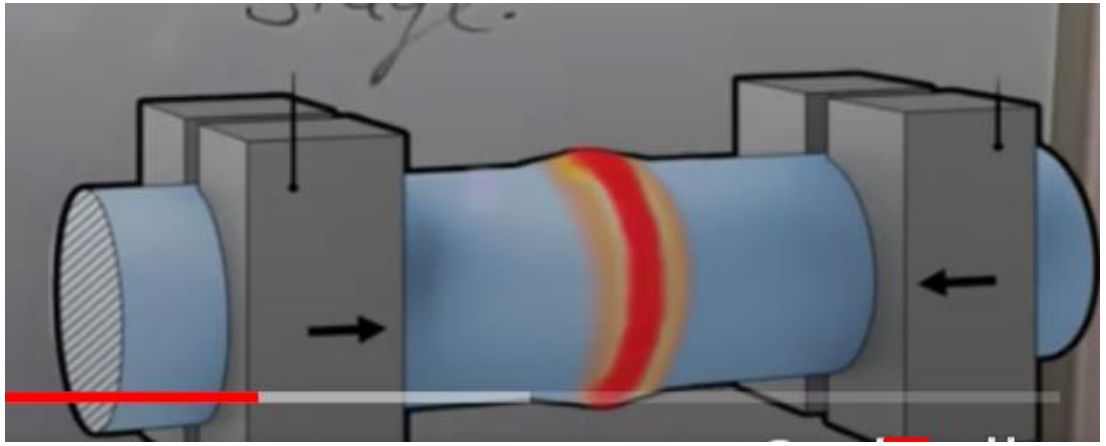




❖ **Flash Butt Welding :** It is a kind of resistance welding with heat and pressure for butt joint.

❖ **Upset Butt Welding :**It is also a kind of resistance welding with heat and pressure for butt joint.

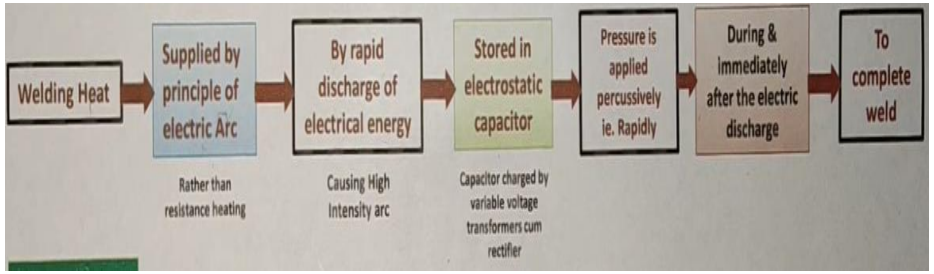


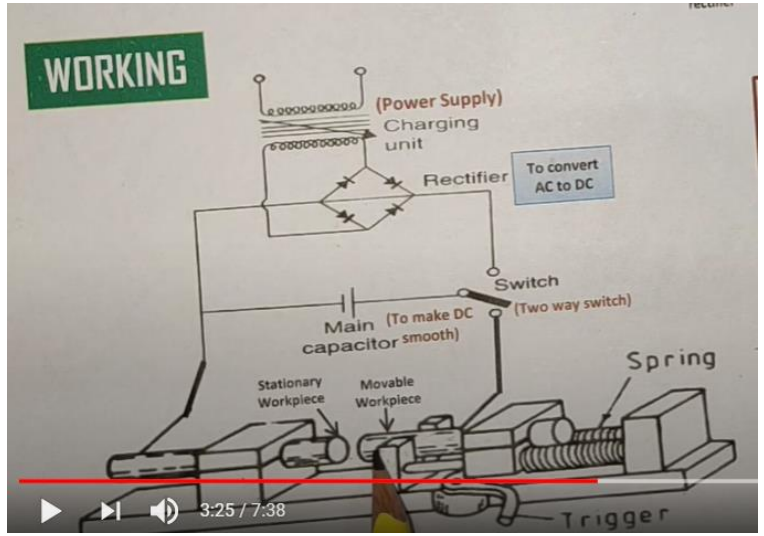


Percussion Welding

It is also a kind of resistance welding and like flash butt welding.

It is a rapid welding process use for joining of dissimilar metals





Welding Defects :

- ***CRACKS:*** It is the most dangerous of all defects. Cracks may be of any size or shape; it can be either microscopic or macroscopic. Cracks may appear anywhere i.e., on the surface, subsurface, at any depth, or at the root. The crack occurs when localized stress exceeds the ultimate Tensile Stress (UTS) of the material. It may propagate within the material.

Welding Defects

❖ ***Cracks are of two types;***

•Hot Cracks

•Cold Cracks

❖ ***HOT CRACKS:***

Hot cracks occur during welding or soon after the completion of welding, It is most likely to occur during the solidification of the molten weld pool. Hot cracks mostly occur in the weld metal, but it may occur at the Heat Affected Zone (HAZ) region too.

When a hot crack occurs on the weld metal, then it is termed as Solidification Crack and if it occurs in the HAZ then called Liquation crack.

❖ **COLD CRACKS:**

Cold cracks occur after the solidification of weld metal; it can even develop several days after completion of welding. Most of the time it develops in the HAZ but may occur on the weld metal too. It is often associated with non-metallic inclusion.

❖ ***POROSITY & BLOW HOLES:***

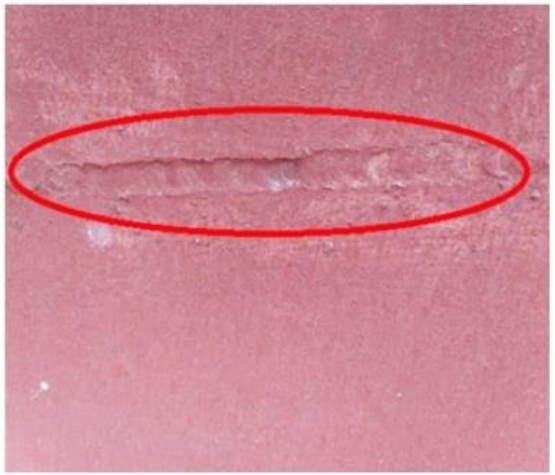
Porosity is a cavity-like discontinuity and occurs due to the entrapment of gases in the molten weld pool. These entrapped gases don’t get a chance to escape from the molten weld pool and hence cause porosity or blowholes. Porosity is basically a small pore or void, whereas blowholes are larger hole or cavity.

❖ ***UNDERCUT:***

Undercut appears as a narrow groove on the base metal adjacent to the weld metal along the edge. Undercut always runs parallel to the weld metal. It acts as a stress raiser during fatigue loading**.**

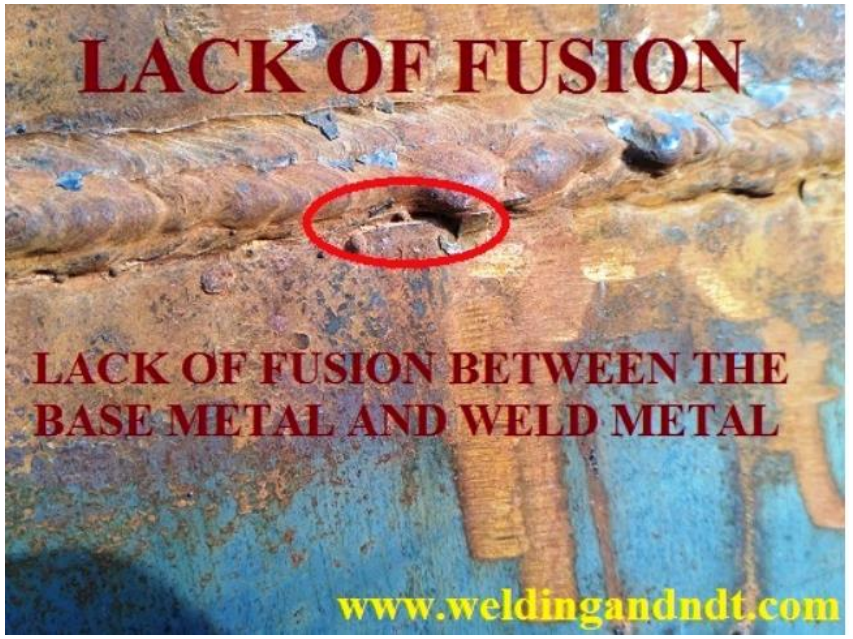
❖ **UNDERFILL:**

When the weld metal surface remains below the adjacent surface of the base metal then it is called an underfill. Basically, Underfill is undersized welding.



❖ **LACK OF PENETRATION (INCOMPLETE PENETRATION):**

When the weld metal doesn’t completely penetrate the joint, then it is called a Lack of Penetration or Incomplete Penetration. It is one of the most dangerous defects since it acts as a stress raiser, and hence crack may originate or propagate from there.



❖ **LACK OF FUSION (INCOMPLETE FUSION):**

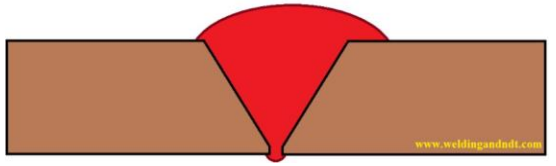
It is the lack of proper melting (or proper fusion) either between the weld metal with the base metal or one layer of the weld with the other layer. Lack of fusion is also called as Cold lapping or cold shuts. One of the most prominent reasons for the cause of lack of fusion is poor welding techniques. Lack of fusion is an internal defect, but it can occur on the external surface too if the sidewall of parent metal doesn't get properly fused with the base metal, as shown in the below figure and for this case lack of fusion can also be called as 'lack of sidewall fusion'.

❖ **SPATTERS:**

Spatters are small globular metal droplets (of weld metal) splashed out on the base metal during welding. Spatters stick on the base metal hence can be removed by wire brush or buffing.

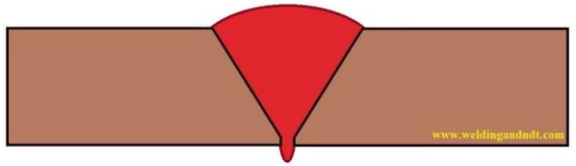
❖ OVERLAP:

Overlap occurs due to the overflow of weld metal on the surface of base metal. During welding, molten metal overflows on the base metal without fusing with the base metal.



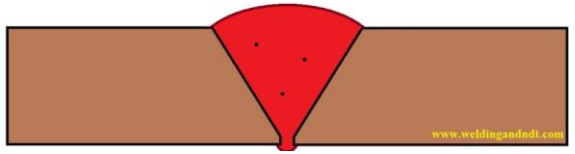
❖ EXCESSIVE PENETRATION:

When the penetration of weld metal is too high, through the joints, then it is called as excessive penetration. It acts as a notch where stress concentration takes place. In addition to this, it results in economical wastage too.



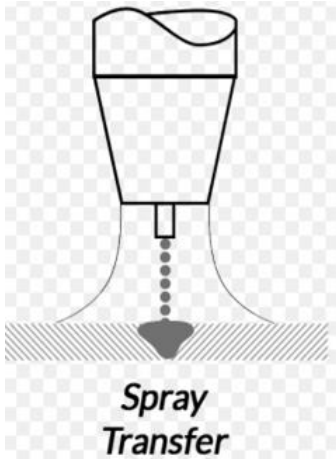
❖ INCLUSION:

Any entrapped solid material (either metallic or non-metallic) in the weld metal, is called as Inclusion. Tungsten, Oxides, Slag, and Flux are some of the common foreign materials which are entrapped in the molten weld pool and form inclusion.



Various Metal Transfer Modes

- **Spray Transfer** :In this mode metal is transferred from the end of the electrode wire to the pool in an axial stream of fine droplets. these small droplets starts from tapered end of the electrode ; one drop follow the another, but not connected. This generally occurs at high current density with argon or helium gas.
- **Globular Transfer** : Occurs at low current density and characterized by the formation of relatively large drop of molten metal at the end of the tapered electrode wire. the drop detach from the electrode when force of gravity overcomes the surface tension of the molten drop.



Various Metal Transfer Modes

- **Pulsed Current Transfer** : this is a spray type transfer that occurs in pulses at regularly spaced intervals rather than at random intervals. In the time interval between pulses, the welding current is reduced, and no metal transfer occurs .

- The pulsing action is obtained by combining the outputs of two power supplies working at two current levels. One act as a background current to preheat and precondition the advancing continuously fed electrode ; the other power supply furnishes a peak current for forcing the drop from the electrode to joint being welded.

- **Short circuit metal transfer** :

It specially used for thin metal section as heat input is low. At start, the end of the electrode wire melts into a small globule of liquid metal and molten metal moves towards the work piece then the molten metal makes contact with work, creating a short circuit .At this stage metal is transfer by gravity and surface tension and arc is extinguished. Finally , the molten metal bridge is broken by pinch force.