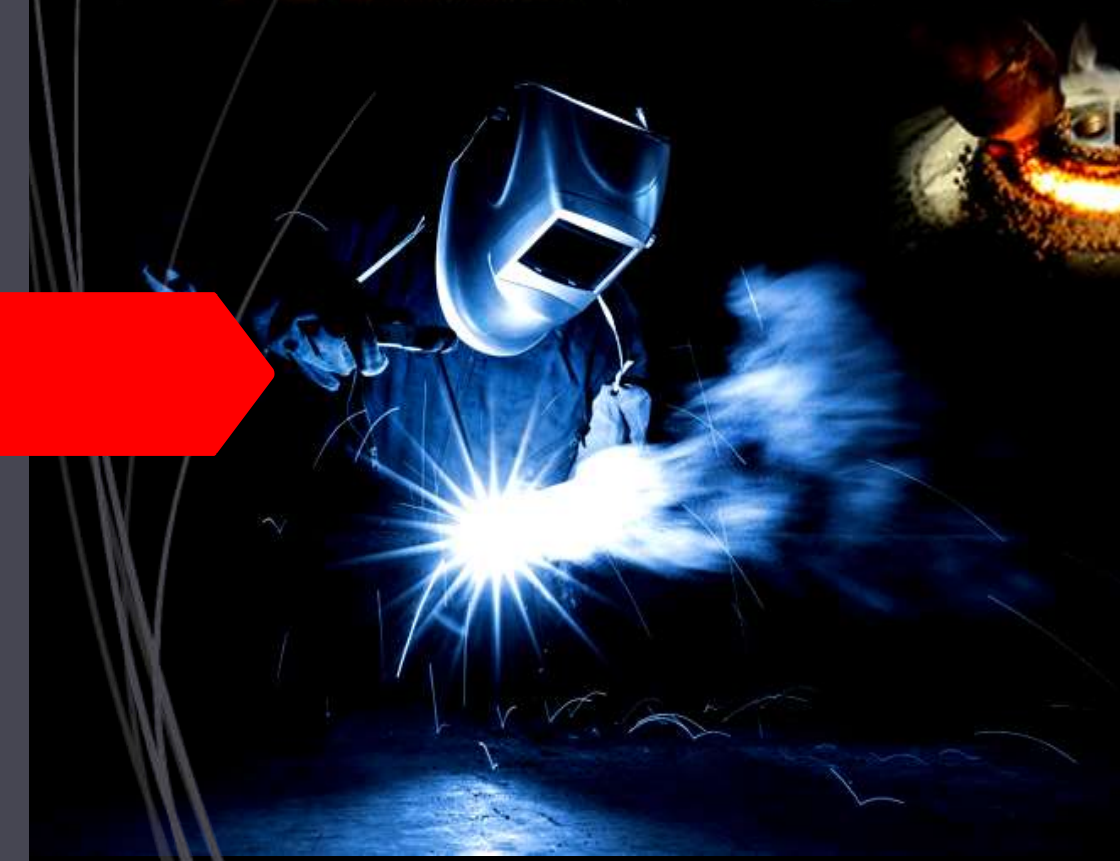
LECTURE – 27 & 28

(FUSION WELDING PROCESSES)



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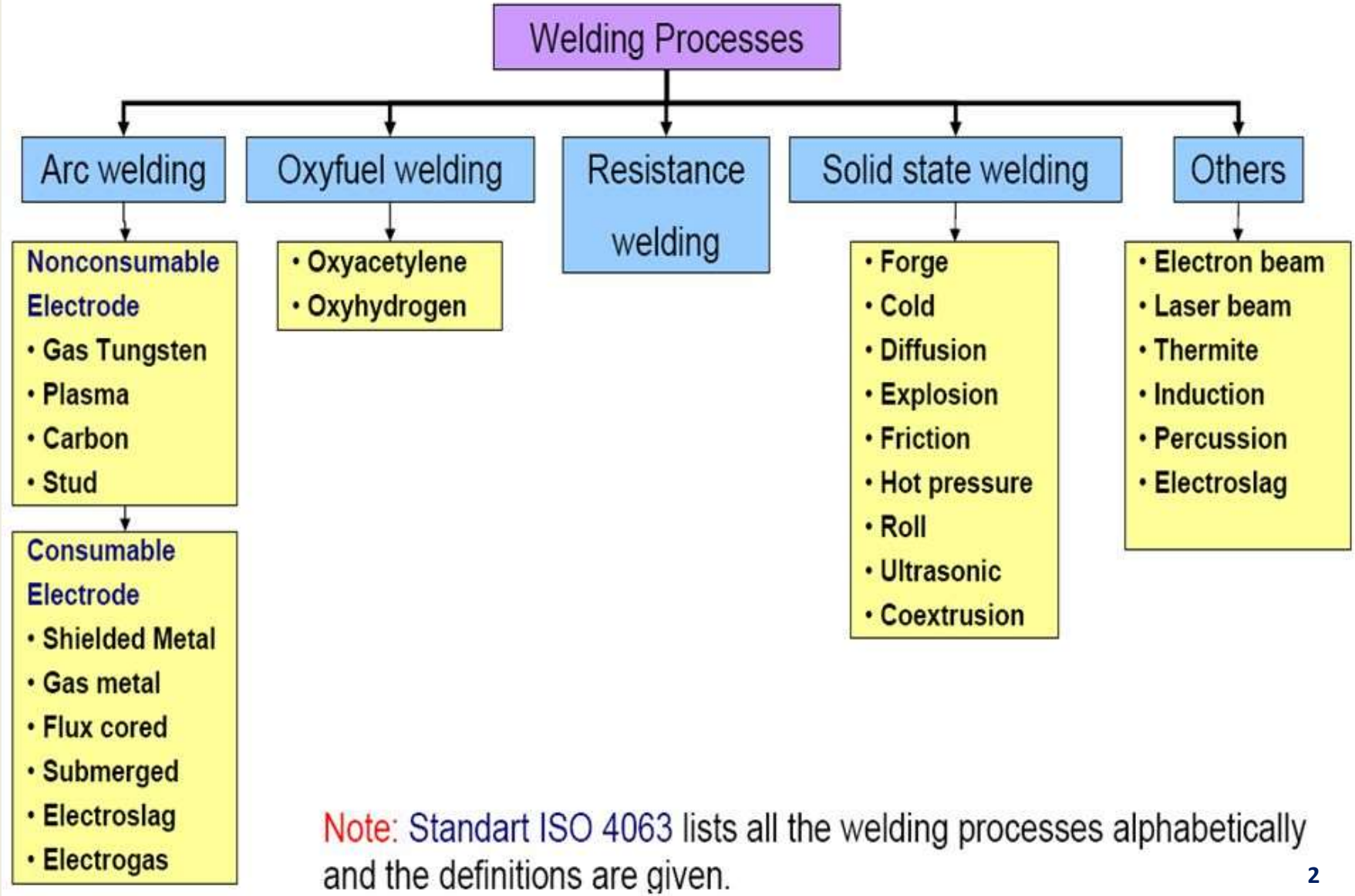
CLASSIFICATION OF WELDING PROCESSES



Note: Standart ISO 4063 lists all the welding processes alphabetically and the definitions are given.

WELDING

➢**Types of welding:** Welding processes can be broadly classified into (i) fusion welding, and (ii) solid state welding Fusion welding: In fusion-welding processes, heat is applied to melt the base metals.

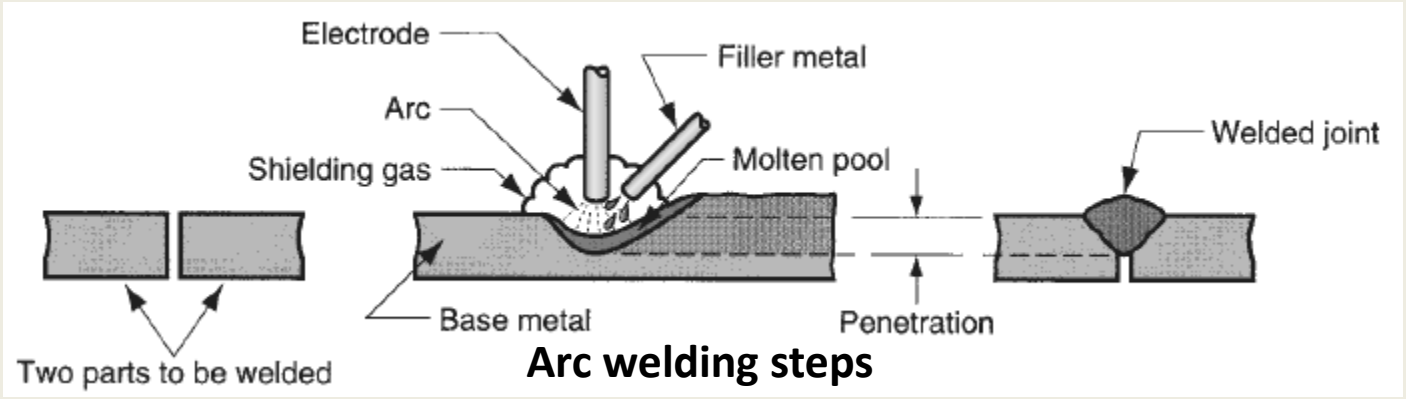
➢In many fusion welding processes, a filler metal is added to the molten pool during welding to facilitate the process and provide strength to the welded joint.

➢When no filler metal is used, that fusion welding operation is referred to as autogenously weld.

➢**Types:** Arc welding, Resistance welding, Oxyfuel gas welding, electron beam welding, laser welding

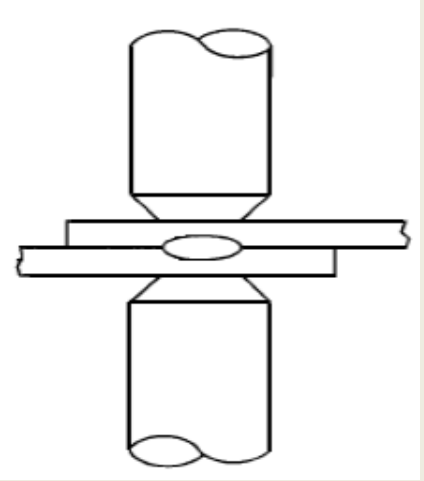
ARC WELDING

- Arc welding: In this operation, electric arc is used to produce heat energy and the base metal is heated. Sometimes, both pressure and heat are applied.



Arc welding steps

- Resistance welding: In this operation, electric resistance is generated to the flow of current that generates heat energy between two contacting surfaces that are held in pressure.



- Gas welding: Oxyfuel gas welding is a welding operation in which heat is generated by a hot flame generated mixture gas of oxygen and acetylene. This heat is used to melt base material and filler material, if used.

SOLID STATE WELDING

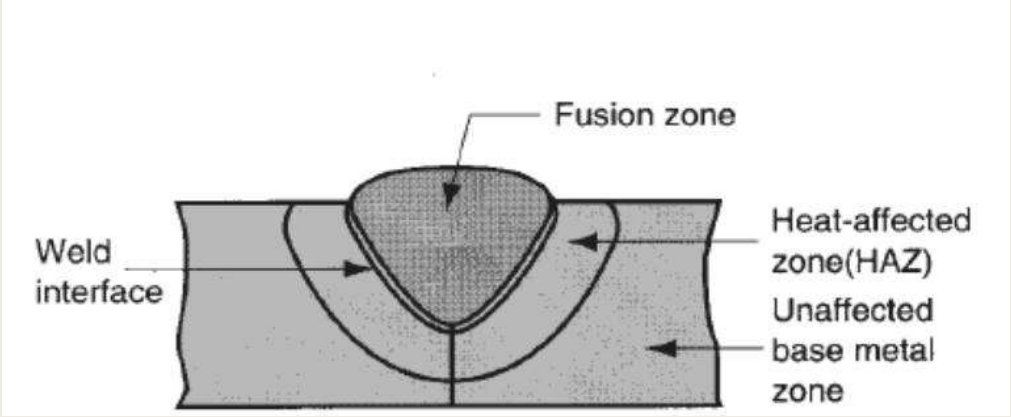
- In this method, joining is done by coalescence resulting from application of pressure only or a combination of heat and pressure.
- Even if heat is used, the temperature in the process is less than the melting point of the metals being welded (unlike in fusion welding). No filler metal is utilized.
- **Diffusion welding:** Two part surfaces are held together under pressure at elevated temperature and the parts join by solid state diffusion.
- **Friction welding/Stir welding:** Joining occurs by the heat of friction and plastic deformation between two surfaces.
- **Ultrasonic welding:** Moderate pressure is applied between the two parts and an oscillating motion at ultrasonic frequencies is used in a direction parallel to the contacting surfaces

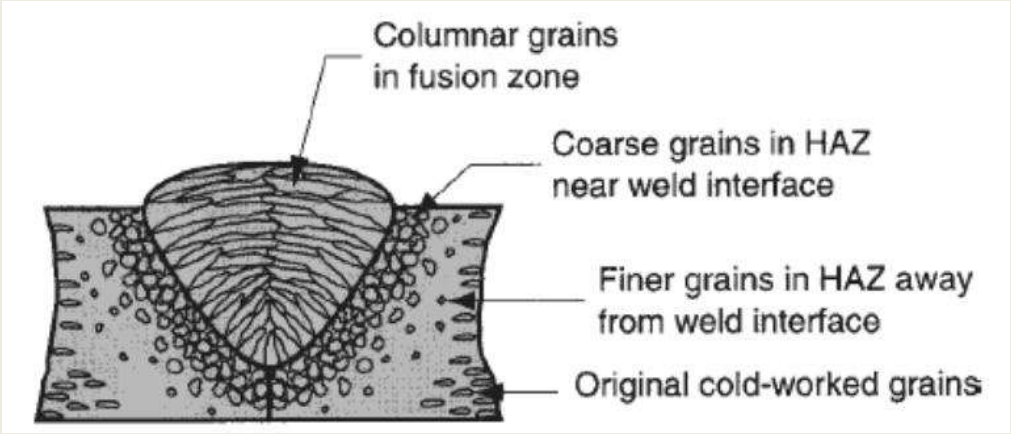
MORPHOLOGY OF FUSION WELD

- A typical fusion weld has got few zones like (i) fusion zone, (ii) weld interface, (iii) heat affected zone, (iv) unaffected base material.

➢ **Fusion zone:** It consists of a mixture of filler metal and base metal that have completely melted. A high degree of homogeneity is present among the component metals that have been melted during welding.

➢ In fusion zone, the solidification occurs by epitaxial grain growth, in which the atoms in the molten metal solidify at the preexisting lattice sites in the unaffected base material. Moreover the grain structure in the fusion zone has got preferred orientation and they are oriented roughly perpendicular to the weld interface. This results in coarse columnar grains in fusion zone.





MORPHOLOGY OF FUSION WELD

- The grain structure depends on various factors namely welding technique, metals being welded like similar metals and dissimilar metals welded, usage of a filler metal, and the traverse speed at which welding is done.
- **Weld interface:** It is a narrow boundary that separates the fusion zone from heat affected zone. This zone consists of a thin band of base metal that was partially melted during the welding process but immediately solidified without mixing with the metal in the fusion zone. Its chemical composition is generally same as that of the base metal.
- **Heat affected zone:** This zone is between weld interface and base material. This experience temperatures below melting point, but sufficient enough to change the microstructure and hence the mechanical properties.
- The mechanical properties are such that most of the failures occur in this region.
- **Base material:** Unaffected because of heat generation and preserve the initial microstructure.

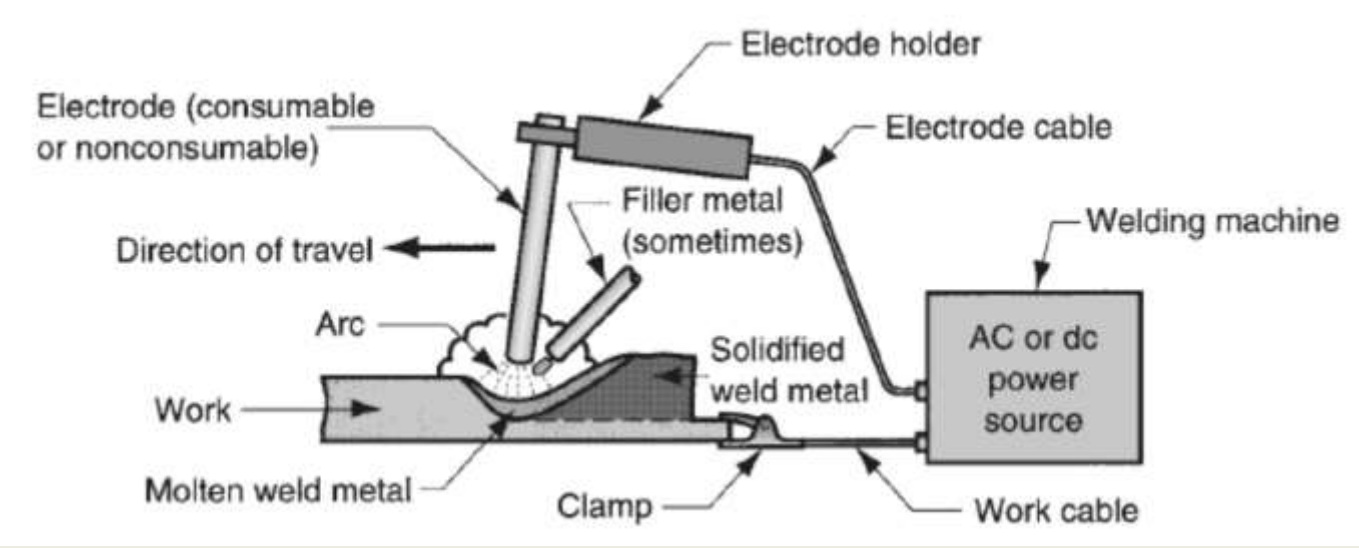
ARC WELDING

✓ It is a fusion welding process in which the melting and joining of metals is done by the heat energy generated by the arc between the work and electrode.

✓ An electric arc is generated when the electrode contacts the work and then quickly separated to maintain the gap. A temperature of 5500°C is generated by this arc.

✓ This temperature is sufficient to melt most of the metals. The molten metal, consisting of base metal and filler, solidifies in the weld region.

✓ In order to have seam weld, the power source moves along the weld line.



ARC WELDING

Electrodes

- Two types of electrodes are used: consumable and non-consumable.

- Consumable electrodes: Present in rod or wire form with 200 to 450 mm length and less than 10 mm diameter. This is the source of filler rod in arc welding. The electrode is consumed by the arc during the welding process and added to the weld joint as filler metal. The consumable electrodes will be changed periodically as it is consumed for each welding trials. This becomes a disadvantage for welder and reduces the production rate.

- Non-Consumable electrodes: The electrodes are not consumed during arc welding. Though this is the case, some depletion occurs because of vaporization. Filler metal must be supplied by means of a separate wire that is fed into the weld pool.

ARC WELDING

- **Arc shielding:**

➢ **Shielding gas:** This covers the arc, electrode tip and weld pool from external atmosphere. The metals being joined are chemically reactive to oxygen, nitrogen, and hydrogen in the atmosphere.

➢ So the shielding is done with a blanket of **gas or flux,** or both, which inhibit exposure of the weld metal to air.

➢ Common shielding gas: Argon, Helium

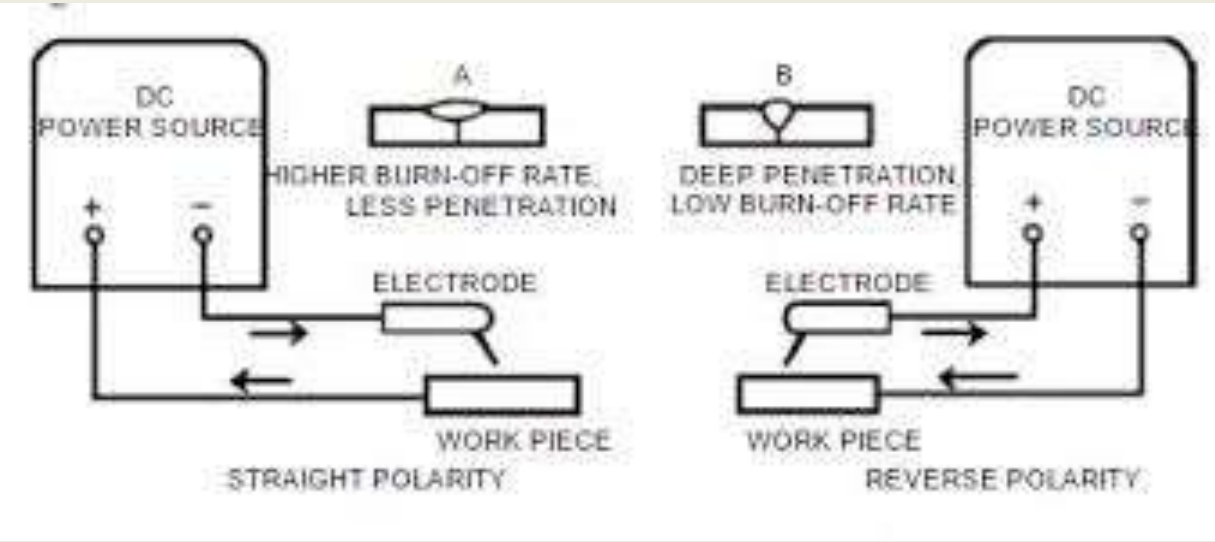
✓ **Flux:** Used mainly to protect the weld region from formation of oxides and other unwanted contaminants, or to dissolve them and facilitate removal.

✓ During welding, the flux melts and covers the weld region giving protection and it should be removed by brushing as it is hardened.

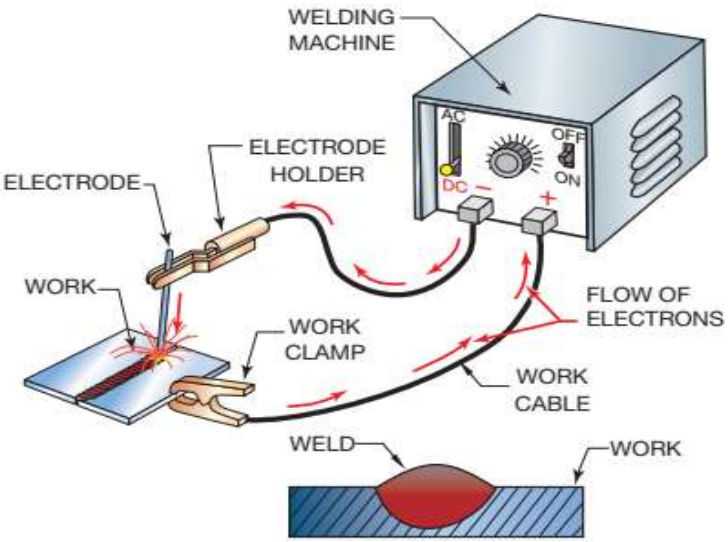
✓ Additional function, other than giving protection: stabilize the arc, and reduce spattering .

ARC WELDING

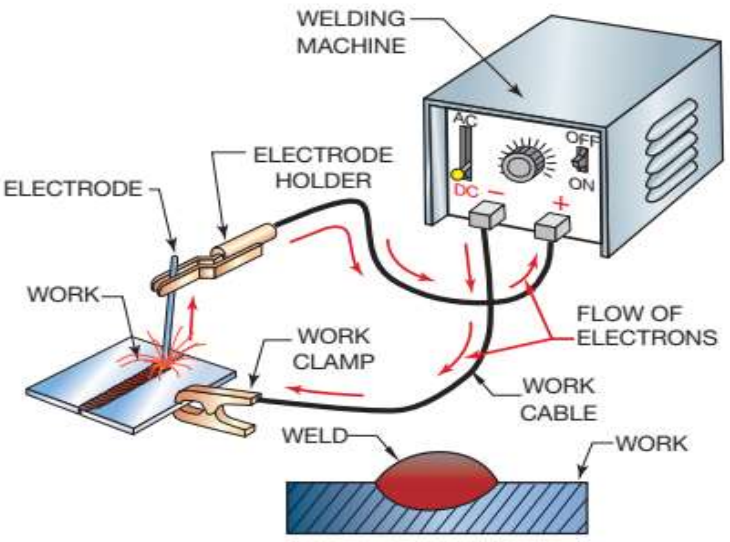
- Power source in arc welding: Both AC and DC can be used; DC is advantageous as better arc control is possible.
- Polarity: Straight polarity in which work piece is positive and electrode is negative (DCEN/DCSP) is suitable for shallow penetration (like in sheets) and joints with wide gaps. Reverse polarity in which work piece is negative and electrode is positive (DCEP/DCRP) is suitable for deeper welds.



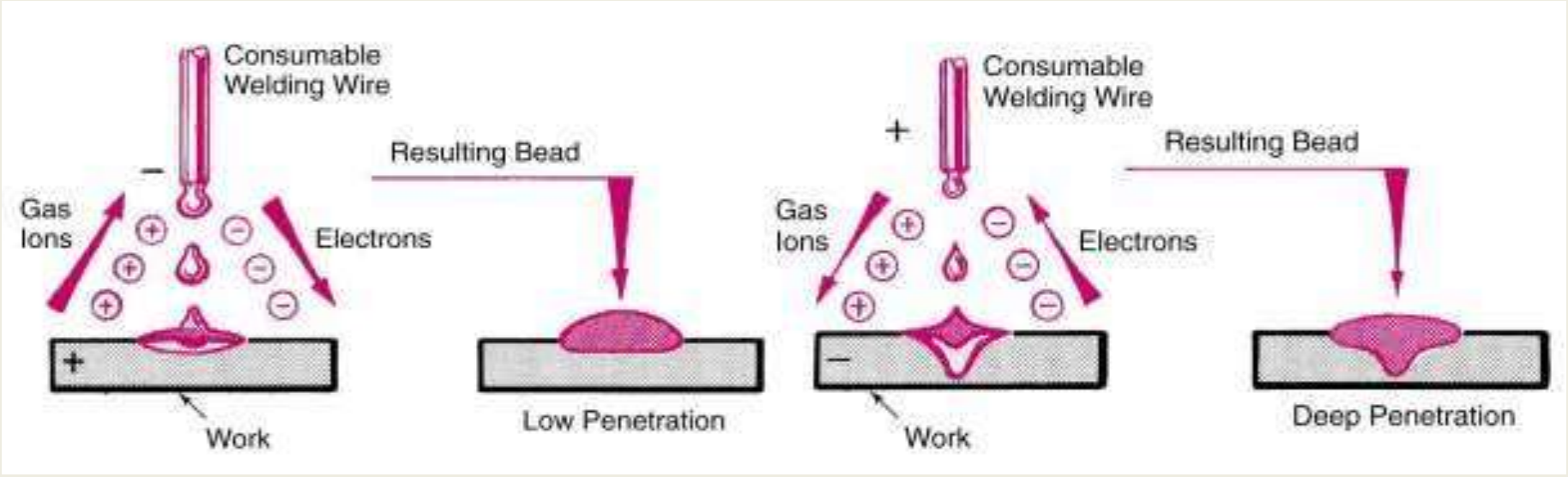
Straight polarity v/s Reverse polarity



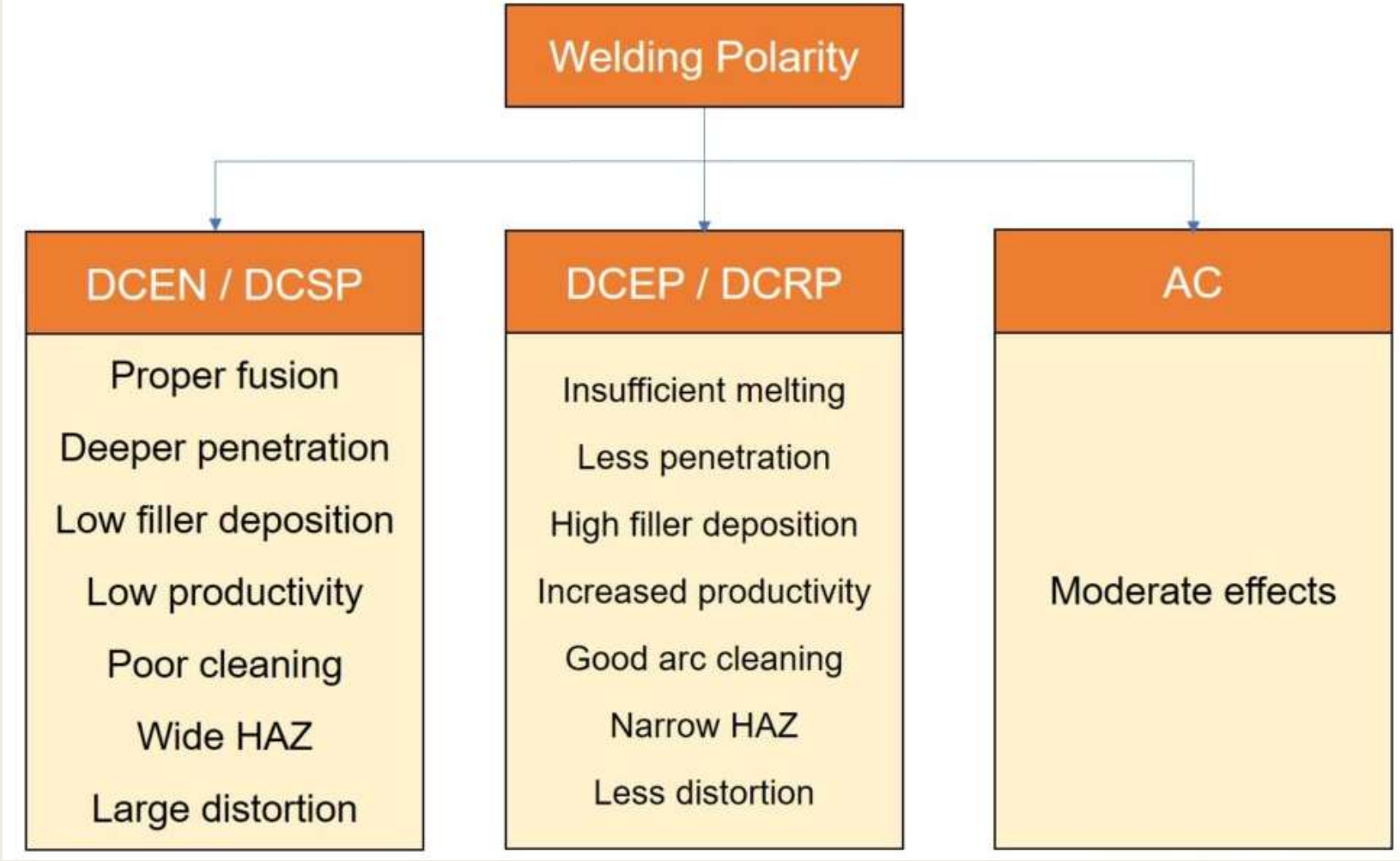
Direct-current electrode negative (DCEN)



Direct-current electrode positive (DCEP)



Straight polarity v/s Reverse polarity



Arc welding processes with consumable electrodes

SHIELDED METAL ARC WELDING (SMAW):

- ✓ In this process, a consumable electrode consisting of a filler metal rod which is coated with chemicals that provide flux and shielding, is used.
- ✓ Generally the filler metal has chemical composition very close to base metal.
- ✓ Filler rod coating: Coating consists of powdered cellulose (cotton and wood powders) mixed with oxides, carbonates, combined using a silicate binder.
- ✓ This coating provides protective layer to the weld pool and stabilizes the arc.
- ✓ Current: < 300 A; Voltage: 15 – 45 V.
- ✓ Applications: ship building, construction, machine structures etc.
- ✓ Materials: grades of steel, stainless steel etc. are welded. Al, Cu, Ti alloys are not welding using SMAW.
- ✓ Disadvantages: repeated change of electrodes, current maintained in typical range

SHIELDED METAL ARC WELDING (SMAW):

❑ Electrode Coating Functions

- Protective gas shield around arc and pool of molten metal
- Provide ionizing elements to stabilize arc, reduce weld metal spatter, and increase efficiency of deposition
- Act as flux to deoxidize and remove impurities from molten metal
- Provide protective slag coating to collect impurities, prevent oxidation, and slow the cooling of weld metal
- Add additional filler metal & Add alloying elements
- Influence arc penetration (depth of melting in work piece)

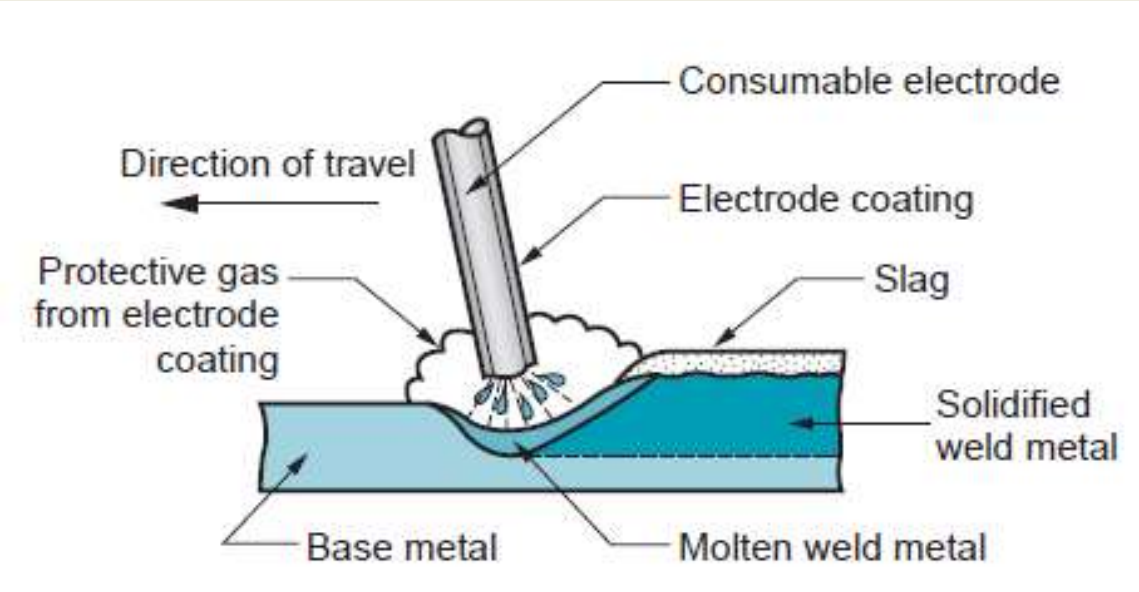
SHIELDED METAL ARC WELDING (SMAW):

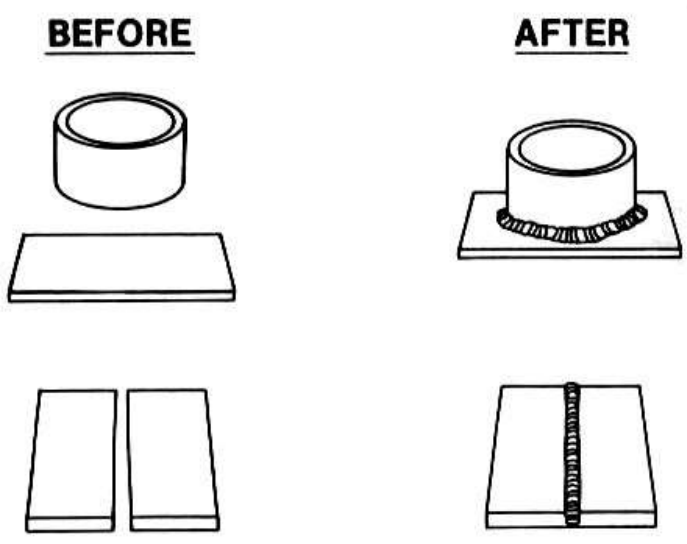
❑ Process Capabilities:

- Weld rates up to 0.2 m/min
- Arc penetration generally < 5 mm
- Minimum sheet thickness = 1.5 mm
- Maximum sheet thickness = 200 mm
- Multiple passes required on sheet thickness ≥ 5 mm (requires slag removal after each pass)
- Commonly welded materials are carbon steels, low alloy steels, stainless steels, Ni alloys and cast iron
- Tolerances ± 1mm (typical)
- Surface finish is fair to good

Arc welding processes with consumable electrodes

SHIELDED METAL ARC WELDING (SMAW):





SHIELDED METAL ARC WELDING (SMAW):

ADVANTAGES

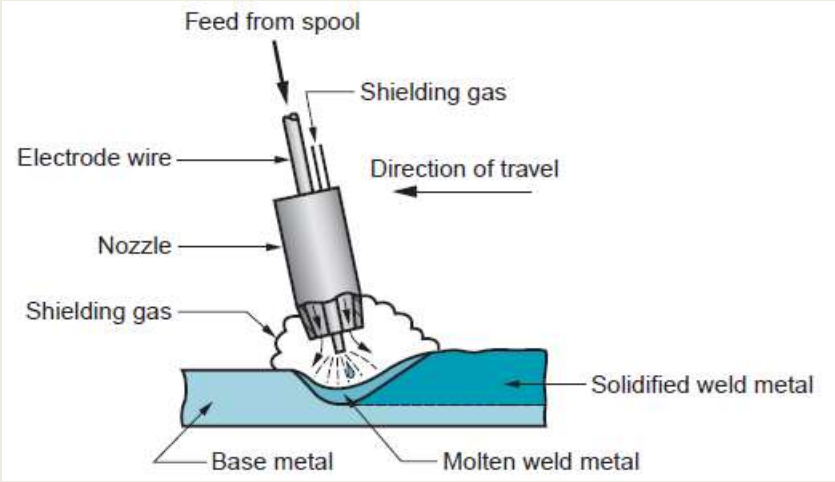
- Most versatile of all welding processes (50%)
- Suitable for site work
- Tooling costs are low
- All levels of complexity are possible
- Economical for low production runs

LIMITATIONS

- ✓ Direct labor costs are high
- ✓ Slag produced at the weld area needs grinding
- ✓ Discontinuous process, frequent electrode changes
- ✓ Heat affected zone is present

GAS METAL ARC WELDING (GMAW):

❑ **Gas metal arc welding (GMAW):**



- In this process, electrode is a consumable wire (0.8 to 6.5 mm diameter).

- shielding gas is provided separately over arc by a pipe

- Shielding gas: Helium, Argon, mixture of gases; used mainly for Al alloys.

- active gases like CO_2 is used for welding steel grade material.

- As compared to SMAW, GMAW can be used for multiple weld passes as there is no deposition of slag and hence no brushing involved. (advantage)

- advantage: automation of welding possible as continuous weld wires are used, and not sticks as in SMAW.

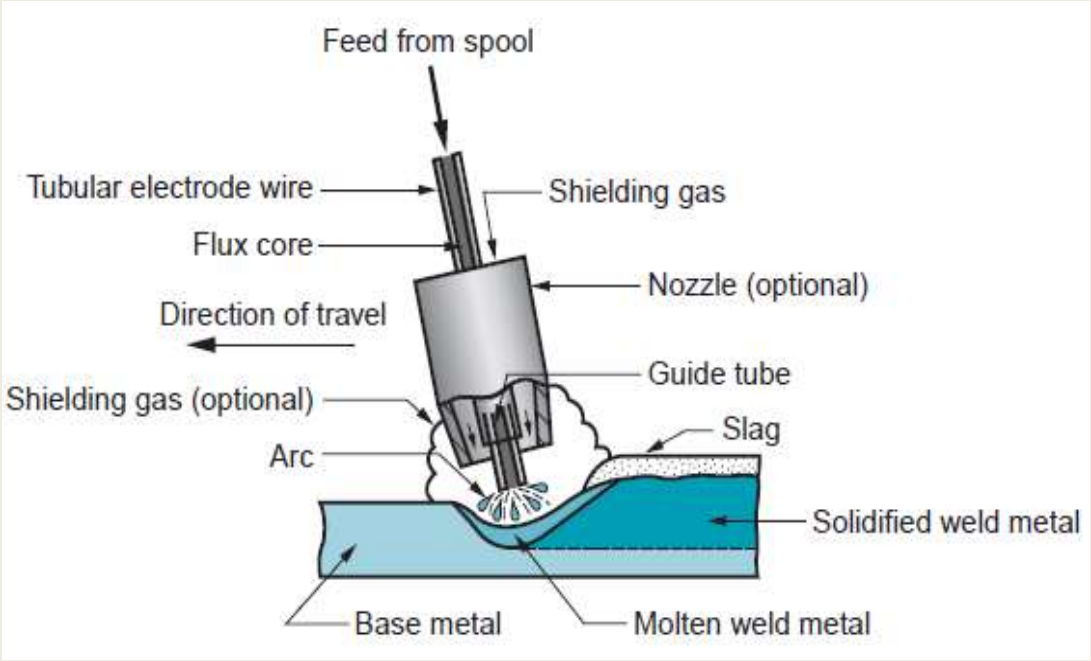
- Also called MIG (metal inert gas) welding, CO_2 welding (when CO_2 is used).

FLUX CORED ARC WELDING (FCAW):

❑ Flux cored arc welding (FCAW):

- arc welding process in which the electrode is a continuous consumable tubing that contains flux. - Self-shielded FCAW: the arc shielding was provided by the flux core. The core also includes ingredients that generate shielding gases for protecting the arc.

- Gas shielded FCAW: Shielding is done from externally supplied gases. Since it uses both flux and shielding gas (provided separately), it is considered as a hybrid of SMAW and GMAW.



SUBMERGED ARC WELDING (SAW)

❑ Submerged arc welding (SAW):

➢ In this process, a continuous bare electrode wire is used. The shielding is provided by external granular flux through hopper.

➢ Granular flux is provided just before the weld arc.

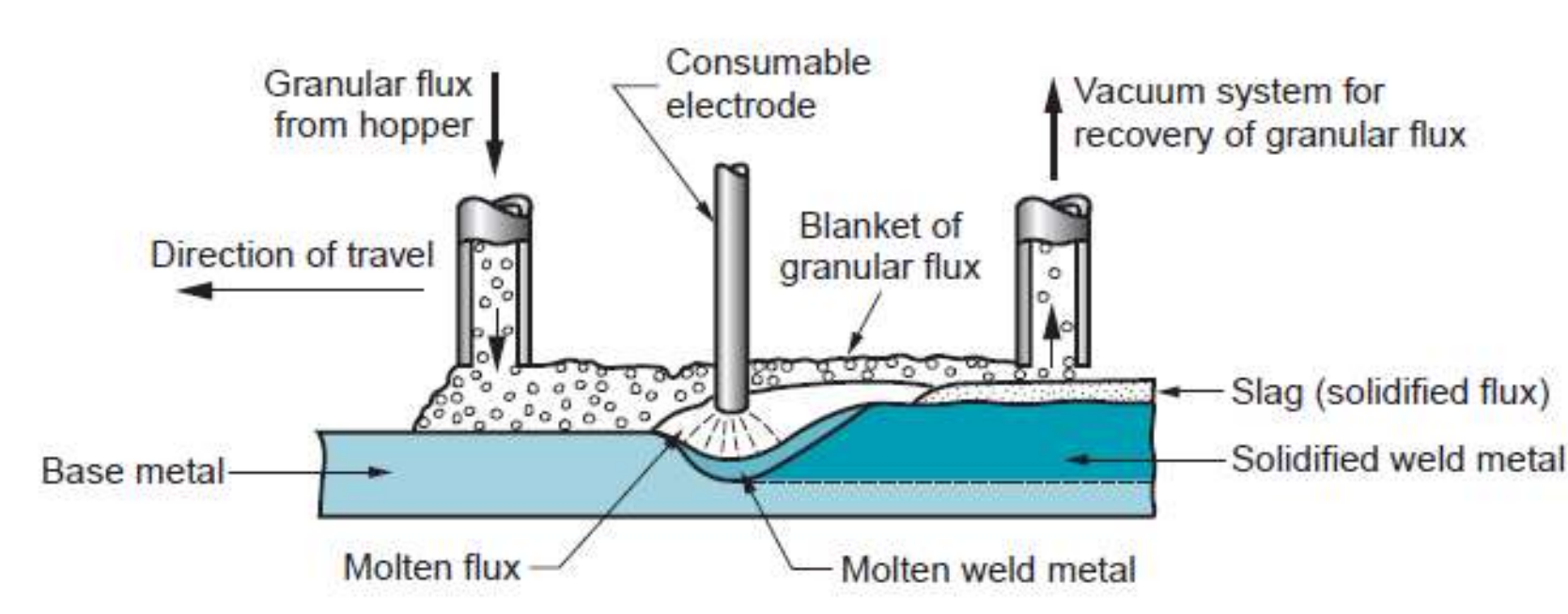
➢ granular flux completely provides protection from sparks, spatter, and radiation and hence safety glasses, gloves can be avoided.

➢ some part of flux gets melted and forms a glassy layer.

➢ This layer and unfused flux results in slow cooling rate and good weld quality.

➢ The unused flux can be reused. - application: longitudinal and circumferential welds for large diameter pipes, tanks, and pressure vessels; welded components for heavy machinery. Steel plates of 25 mm thick are welded.

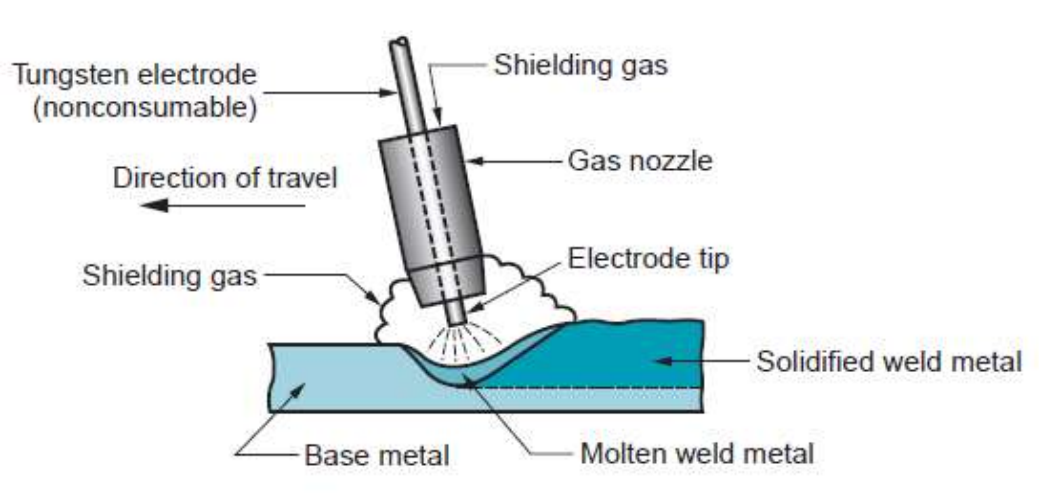
SUBMERGED ARC WELDING (SAW)



Arc welding processes with non-consumable electrodes

GAS TUNGSTEN ARC WELDING (GTAW):

- ✓ It uses a non-consumable tungsten electrode and shielding gas (inert gas) for shielding.
- ✓ Also called tungsten inert gas welding (TIG)
- ✓ usage of filler wire is optional and is heated by arc and not transferred across the arc.
- ✓ Tungsten is a good electrode material due to its high melting point of 3400°C.
- ✓ advantages: high quality welds, no weld spatter because no filler metal is transferred across the arc, and little post weld cleaning because no flux is used.



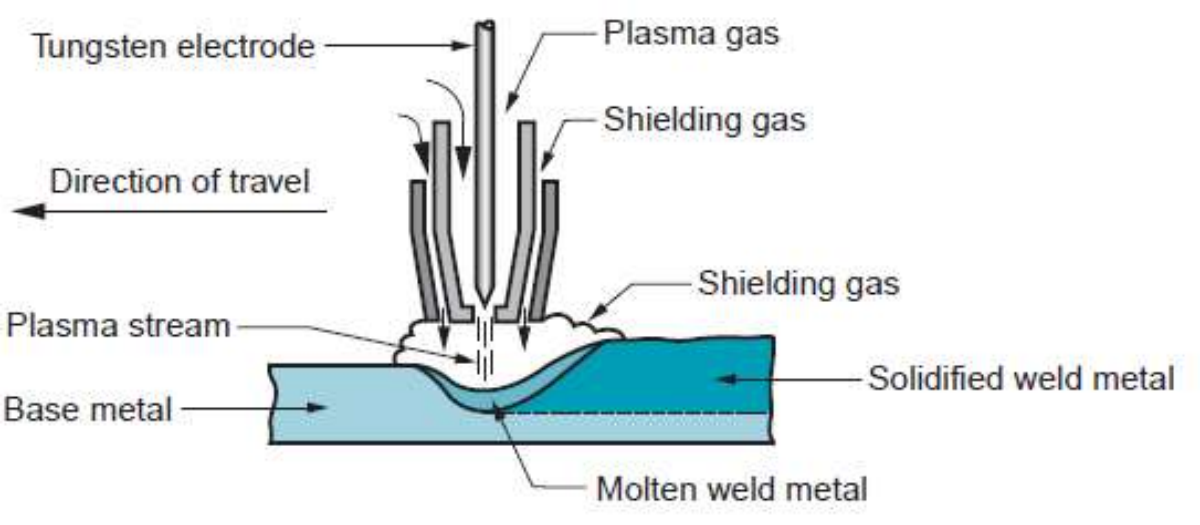
PLASMA ARC WELDING (PAW)

❑ Plasma arc welding (PAW):

➢ It is a variety of gas tungsten arc welding in which a constricted plasma arc is used for welding.

➢ In PAW, a tungsten electrode is kept in a nozzle that focuses a high velocity stream of inert gas into the region of the arc to form a high velocity, intensely hot plasma arc stream.

➢ Temperatures in plasma arc welding reach 17,000°C. This is mainly due to the constriction of the arc. The input power is highly concentrated to produce a plasma jet of small diameter and very high power density. - The process can be used to weld almost any material, including tungsten.

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