

UNIT II

WELDING

Welding

- Welding is a process of joining similar metals by application of heat with or without application of pressure and addition of filler material

Weldability

- The term “weldability” has been defined as the capacity of being welded into inseparable joints having specified properties such as definite weld strength, proper structure, etc.

Factors affecting Weldability

1. Melting Point
2. Thermal conductivity
3. Thermal Expansion
4. Surface condition
5. Change in Microstructure

Types of welding

1. Plastic Welding

- In Plastic welding or **pressure welding**, the pieces of metal to be joined are heated to plastic state and then forced together by external pressure.

2. Fusion Welding

- In fusion welding or non pressure welding , the material at the joint is heated to molten state and allowed to solidify.

Welding Processes

1. Gas welding

- i. Oxyacetylene
- ii. Air-acetylene
- iii. Oxy-hydrogen

2. Arc Welding

- i. Carbon Arc
- ii. Metal Arc
- iii. Gas Metal Arc (MIG)
- iv. Gas Tungsten Arc (TIG)
- v. Atomic-hydrogen arc
- vi. Plasma Arc
- vii. Submerged Arc welding

viii. Flux-cored arc

ix. Electro-slag

3. Resistance welding

i. Butt welding

ii. Spot welding

iii. Seam welding

iv. Projection welding

v. Percussion welding

4. Thermit welding

5. Solid State welding

i. Friction

ii. Ultrasonic

iii. Diffusion

iv. Explosive

6. Newer Welding Processes

i. Electron Beam

ii. Laser

7. Related processes

i. Oxyacetylene cutting

ii. Arc cutting

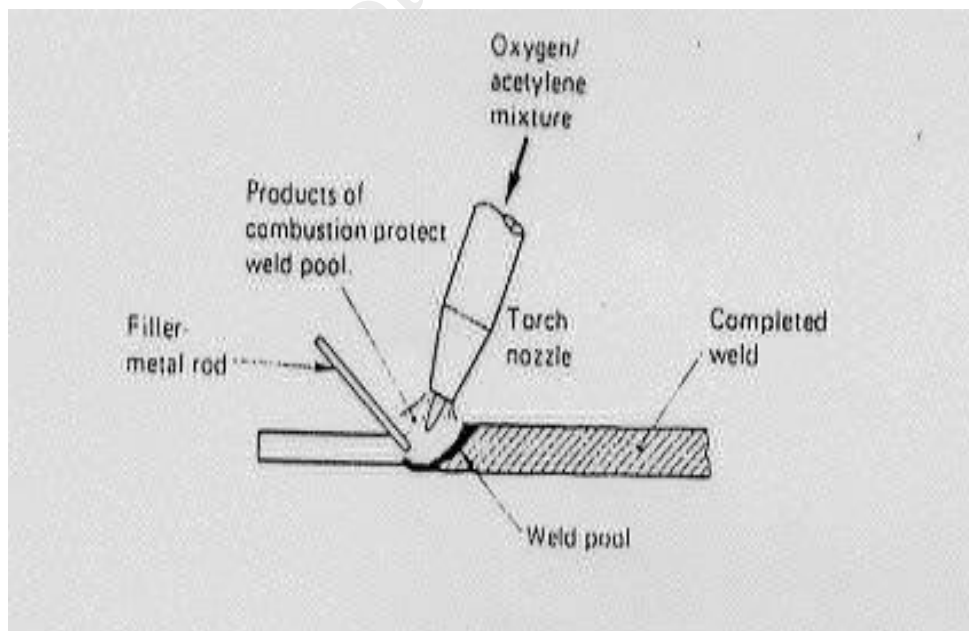
iii. Hard facing

iv. Brazing

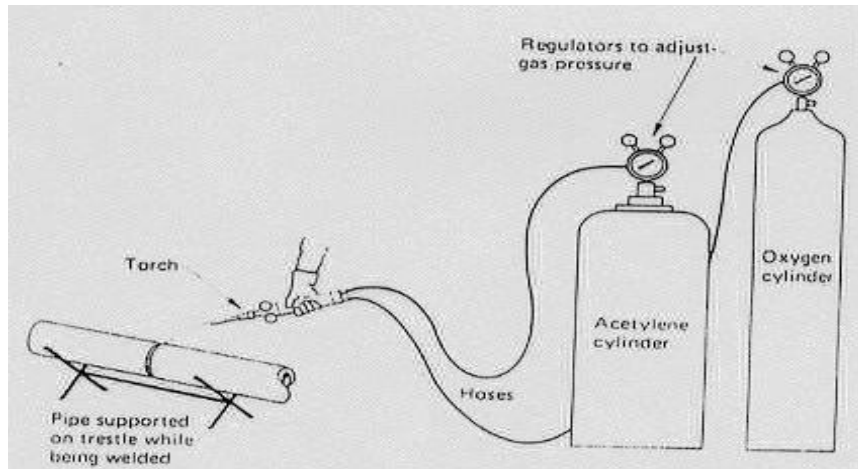
v. Soldering

Oxy-Acetylene Welding

max temperature reached: 3300



Gas Welding Equipments



Gas Welding Equipments

1. Regulator
2. Gas hoses
3. Non-return valve
4. Check valve
5. Torches

Types of Torch

- Welding torch
- Cutting torch
- Rose-bud torch (used to heat metals for bending, straightening, etc)
- Injector torch(equal-pressure torch, merely mixes the two gasses. venturi effect).

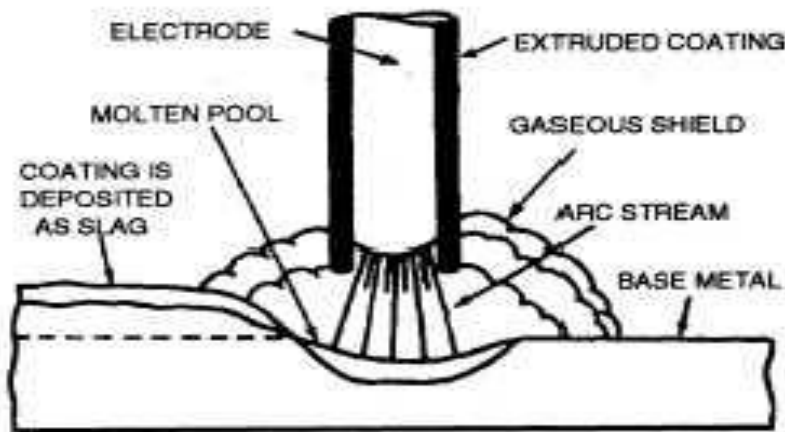
Fuels

- **Acetylene** (Acetylene is the primary fuel for oxy-fuel welding and is the fuel of choice for repair work and general cutting and welding, Acetylene generator as used in Bali by a reaction of calcium carbide with water)
- **Gasoline**
- **Hydrogen** (Hydrogen has a clean flame and is good for use on aluminium)
- **MAPP gas**(methylacetylene-propadiene. It has the storage and shipping characteristics of LPG and has a heat value a little less than acetylene)
- **Butane, propane and butane/propane mixes**
- Butane is like the propane gas, the two are both saturated hydrocarbons and do not react with each other so they are regularly mixed together to form Butane/Propane gas mixture.

- Propane does not burn as hot as acetylene in its inner cone, and so it is rarely used for welding
- Propane is cheaper than acetylene and easier to transport.
- **Propylene**(Propylene is used in production welding and cutting. It cuts similarly to propane. When propylene is used, the torch rarely needs tip cleaning.

Arc Welding

temperature is 6000 to 7000°c



Comparison of AC and DC Arc Welding

Particulars	Direct Current	Alternating Current
No-load voltage	Low (higher safety)	Too high, over 70V (Danger)
Efficiency	low	High (advantageous)
Prime cost	High 2 to 3 times of AC	low
Connected load	normal	High (disadvantage)
Electrodes	Both bare (non-coated) cheaper electrode can be used	Only coated electrodes i.e. expensive electrodes can be used
Welding of non-ferrous	suitable	Not suitable

metals		
Heat generation	High in +ve pole and low in -ve pole	Same at each pole

Electrode

- In arc welding an electrode is used to conduct current through a work piece to fuse two pieces together. Depending upon the process, the electrode is either consumable, in the case of gas metal arc welding or shielded metal arc welding, or non-consumable, such as in gas tungsten arc welding.

Coating and Specification

All mild steel and low-alloy electrodes are classified with a 4 or 5 digit number prefixed by "E."

Prefix "E" = Electrode

First two (or three) digits = Tensile strength (psi) (stress relieved or as welded)

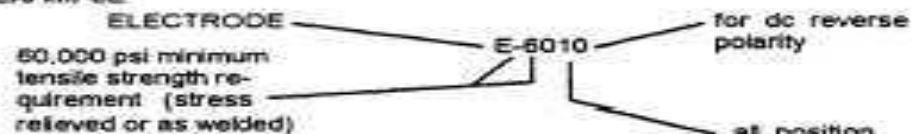
Third (or fourth) digit = Position of welding

1 = all positions (flat, horizontal, vertical, overhead)

2 = horizontal and flat positions only

FOURTH DIGIT	TYPE OF COATING	WELDING CURRENT
1	cellulose potassium	ac or dc Reverse or Straight
2	titania sodium	ac or dc Straight
3	titania potassium	ac or dc Straight or Reverse
4	iron powder titania	ac or dc Straight or Reverse
5	low hydrogen sodium	dc Reverse
6	low hydrogen potassium	dc or dc Reverse
7	iron powder iron oxide	ac or dc
8	iron powder low hydrogen	dc Reverse or Straight or ac
0*	see reference below	

EXAMPLE



*When the fourth digit is 0, the type of coating and current to use are determined by the third digit. For example, E-6010 indicates a cellulose sodium coating and operates on dc reverse, while E-6020 has an iron oxide coating and operates on ac or dc.

Electrode Types

- E6010** This electrode is used for all position welding using DCRP. It produces a deep penetrating weld and works well on dirty, rusted, or painted metals
- E6011** This electrode has the same characteristics of the E6010, but can be used with AC and DC currents.

- **E6013** This electrode can be used with AC and DC currents. It produces a medium penetrating weld with a superior weld bead appearance.
- **E7018** This electrode is known as a low hydrogen electrode and can be used with AC or DC. The coating on the electrode has a low moisture content that reduces the introduction of hydrogen into the weld. The electrode can produce welds of x-ray quality with medium penetration. (Note, this electrode must be kept dry. If it gets wet, it must be dried in a rod oven before use.)

Purpose of Coated Electrodes

1. To facilitate the establishment and maintenance of the arc.
2. To protect the molten metal from the Oxygen and nitrogen of the air
3. To protect the welding seam from rapid cooling
4. To provide the means of introducing alloying elements not contained in the core wire.

Precautions in Arc Welding

1. Because of the intensity of heat and light rays from the electric arc, the operator's hand face and eyes are to be protected while arc is in use
2. Heavy gloves are worn
3. Hand shield or a helmet with window of coloured glass should be used to protect the face
4. The space for the electric arc welding should be screened off from the rest of the building to safeguard other workmen from the glare of the arc.

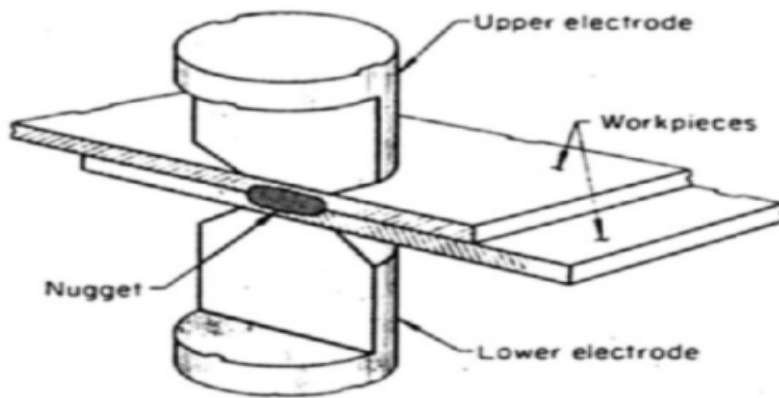
Resistance welding

1. Resistance welding is a process used to join metallic parts with electric current. There are several forms of resistance welding, including spot welding, seam welding, projection welding, and butt welding.
2. The heat generated is expressed by the equation

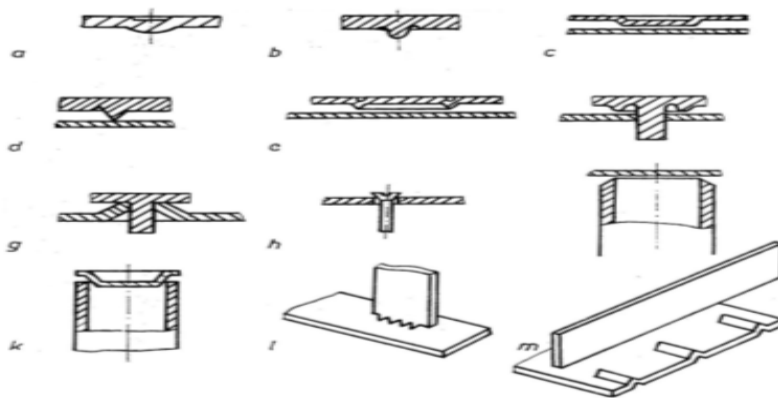
$$i. E = I^2 \cdot R \cdot t$$

where E is the heat energy, I is the current, R is the electrical resistance and t is the time that the current is applied.

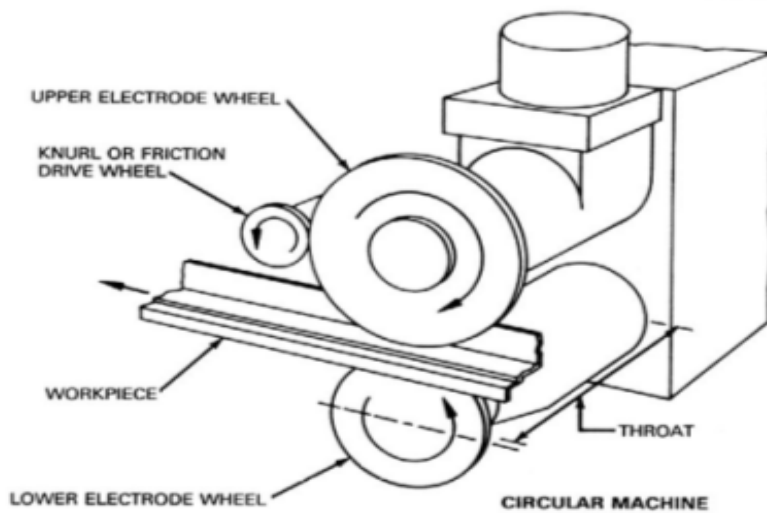
Spot Welding



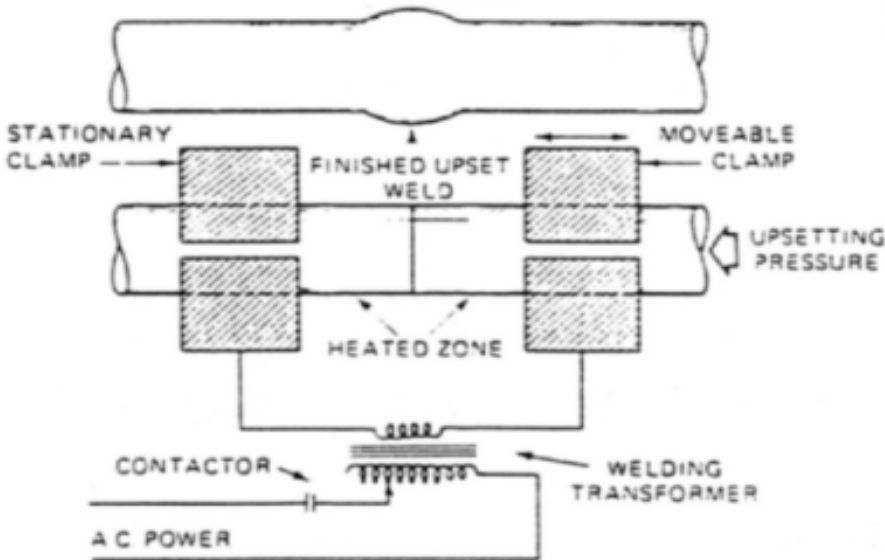
Projection Welding



Seam Welding



Butt Welding



Percussion Welding

- Percussion Welding uses electrical energy stored in a condenser to produce an intense momentary power discharge to provide the localized heating at the interface. It is suitable for joining dissimilar metals that are not weldable by flash butt welding, or when flash is not desirable at the weld joint.

Process steps in Percussion Welding

1. The two materials to be welded are positioned with a preset air gap between them
2. A burst of RF energy ionizes the air gap.
3. Capacitor banks discharge, creating an arc that heats the two materials to a weldable temperature.
4. When the materials reach the proper welding state, electromagnetic actuators accelerate them together. The molten masses combine, metal to metal, and are forged together. As the weld cools, a complete alloy bond is formed.

MIG welding

Gas Metal Arc Welding (GMAW) is frequently referred to as MIG welding. MIG welding is a commonly used high deposition rate welding process. Wire is continuously fed from a spool. MIG welding is therefore referred to as a semiautomatic welding process

MIG Welding Benefits

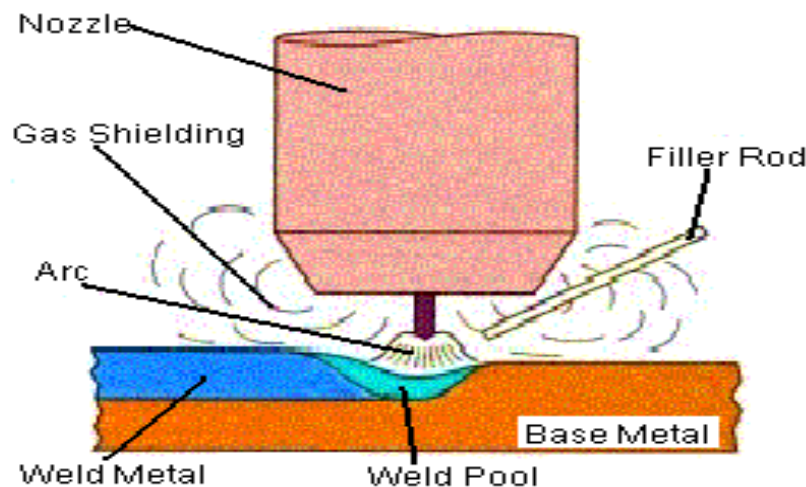
1. All position capability

2. Higher deposition rates than SMAW
3. Less operator skill required
4. Long welds can be made without starts and stops
5. Minimal post weld cleaning is required

Shielding Gases

- Argon
- Argon - 1 to 5% Oxygen
- Argon - 3 to 25% CO₂
- Argon/Helium
- CO₂ is also used in its pure form in some MIG welding processes. However, in some applications the presence of CO₂ in the shielding gas may adversely affect the mechanical properties of the weld.

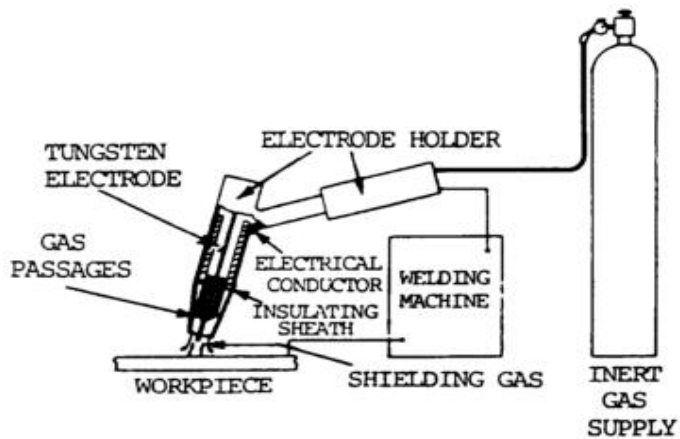
TIG Welding



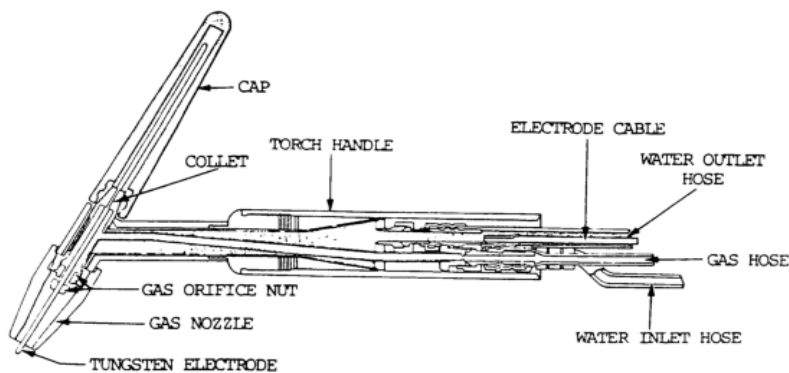
TIG Welding

- Gas Tungsten Arc Welding (GTAW) is frequently referred to as TIG welding.
- TIG welding is a commonly used high quality welding process.
- TIG welding has become a popular choice of welding processes when high quality, precision welding is required.
- In TIG welding an arc is formed between a non consumable tungsten electrode and the metal being welded.
- Gas is fed through the torch to shield the electrode and molten weld pool.
- If filler wire is used, it is added to the weld pool separately.

TIG Welding



TIG welding



TIG welding torch.

TIG Welding Benefits

- Superior quality welds
- Welds can be made with or without filler metal
- Precise control of welding variables (heat)
- Free of spatter
- Low distortion

Shielding Gases

- Argon

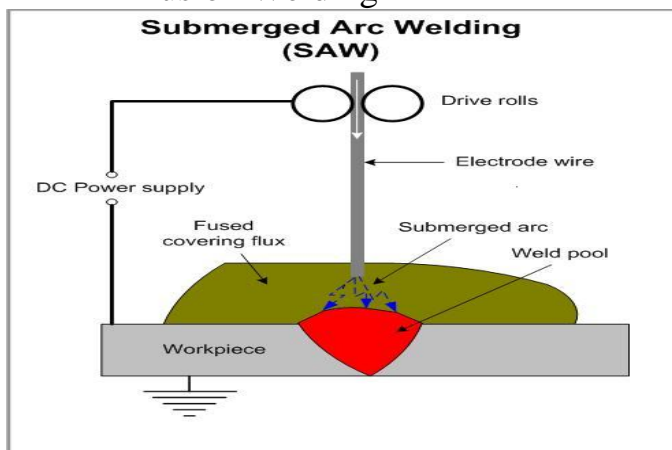
- Argon + Hydrogen
- Argon/Helium
- Helium is generally added to increase heat input (increase welding speed or weld penetration). Hydrogen will result in cleaner looking welds and also increase heat input, however, Hydrogen may promote porosity or hydrogen cracking.

TIG Welding Limitations

- Requires greater welder dexterity than MIG or stick welding
- Lower deposition rates
- More costly for welding thick sections

Special Welding Processes

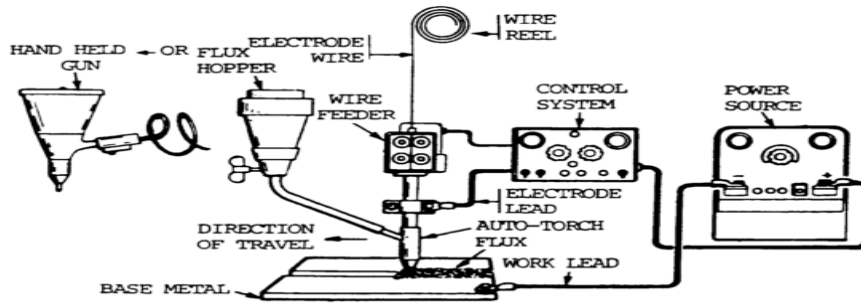
- Submerged Arc Welding
- Plasma Arc Welding
- Thermit Welding
- Electron Beam Welding
- Friction Welding
- Diffusion Welding



Submerged Arc Welding

- Submerged arc welding (SAW) is a common arc welding process. It requires a continuously fed consumable solid or tubular (flux cored) electrode.
- The molten weld and the arc zone are protected from atmospheric contamination by being “submerged” under a blanket of granular fusible flux consisting of lime, silica, manganese oxide, calcium fluoride, and other compounds.
- When molten, the flux becomes conductive, and provides a current path between the electrode and the work. 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 SMAW (shielded metal arc welding) process.

SAW



Equipment Used

- Power supply
- Start plate
- Copper mold
- Electrode
- Guide tube
- Wire feed
- Power source
- SAW head
- Flux handling
- Protective equipment

Advantages

- High deposition rates (over 100 lb/h (45 kg/h) have been reported).
- High operating factors in mechanized applications.
- Deep weld penetration.
- Sound welds are readily made (with good process design and control).
- High speed welding of thin sheet steels up to 5 m/min (16 ft/min) is possible.
- Minimal welding fume or arc light is emitted.
- Practically no edge preparation is necessary.
- The process is suitable for both indoor and outdoor works.
- Distortion is much less.
- Welds produced are sound, uniform, ductile, corrosion resistant and have good impact value.
- Single pass welds can be made in thick plates with normal equipment.
- The arc is always covered under a blanket of flux, thus there is no chance of spatter of weld.
- 50% to 90% of the flux is recoverable

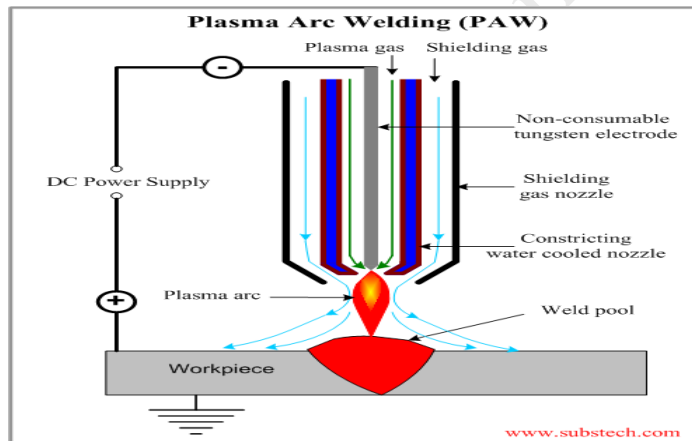
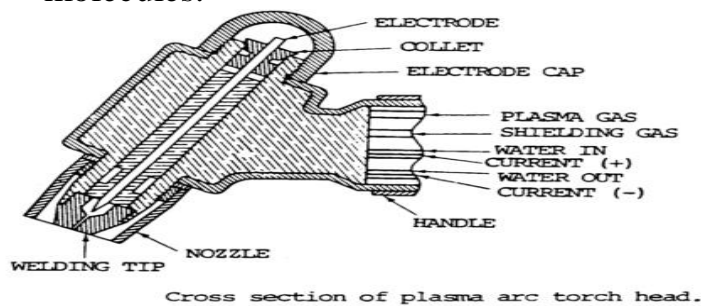
Limitations

- Limited to ferrous (steel or stainless steels) and some nickel based alloys.
- Normally limited to the 1F, 1G, and 2F positions.
- Normally limited to long straight seams or rotated pipes or vessels.
- Requires relatively troublesome flux handling systems.
- Flux and slag residue can present a health & safety issue.
- Requires inter-pass and post weld slag removal

Plasma Arc Welding

- Plasma Arc Welding is the welding process utilizing heat generated by a constricted arc struck between a tungsten non-consumable electrode and either the work piece (transferred arc process) or water cooled constricting nozzle (non-transferred arc process).

Plasma is a gaseous mixture of positive ions, electrons and neutral gas molecules.



Plasma arc welding (PAW)

- Plasma arc welding (PAW) is an arc welding process similar to gas tungsten arc welding (GTAW). The electric arc is formed between an electrode (which is usually but not always made of sintered tungsten) and the workpiece.

- The key difference from GTAW is that in PAW, by positioning the electrode within the body of the torch, the plasma arc can be separated from the shielding gas envelope.
- The plasma is then forced through a fine-bore copper nozzle which constricts the arc and the plasma exits the orifice at high velocities (approaching the speed of sound) and a temperature approaching 20,000 °C.
- Plasma arc welding is an advancement over the GTAW process.
- This process uses a non-consumable tungsten electrode and an arc constricted through a fine-bore copper nozzle.
- PAW can be used to join all metals that are weldable with GTAW (i.e., most commercial metals and alloys).

Advantages of Plasma Arc Welding (PAW):

- Requires less operator skill due to good tolerance of arc to misalignments;
- High welding rate;
- High penetrating capability (keyhole effect);

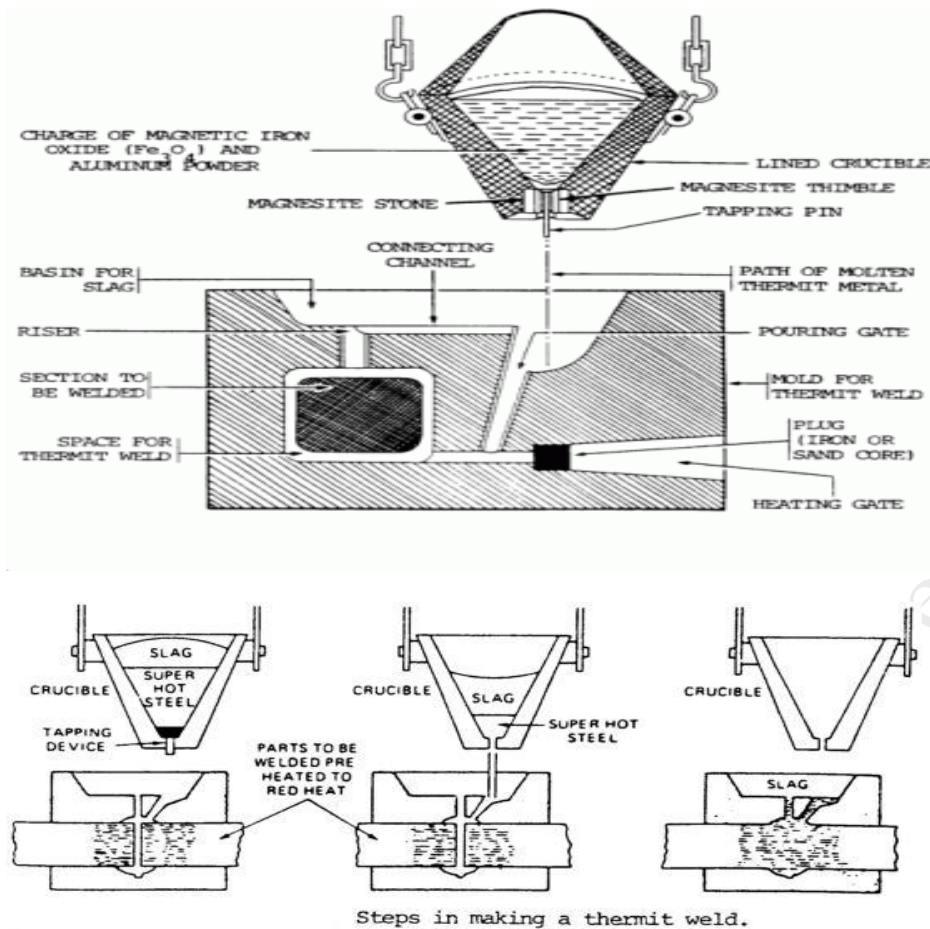
Disadvantages of Plasma Arc Welding (PAW):

- Expensive equipment;
- High distortions and wide welds as a result of high heat input.

Thermite welding

- Thermite welding is the process of igniting a mix of high energy materials, (which is also called thermite), that produce a molten metal that is poured between the working pieces of metal to form a welded joint
- Thermite is a pyrotechnic composition of a metal powder and a metal oxide, which produces an aluminothermic reaction known as a thermite reaction. It is not explosive, but can create short bursts of extremely high temperatures focused on a very small area for a short period of time.

Thermite Welding



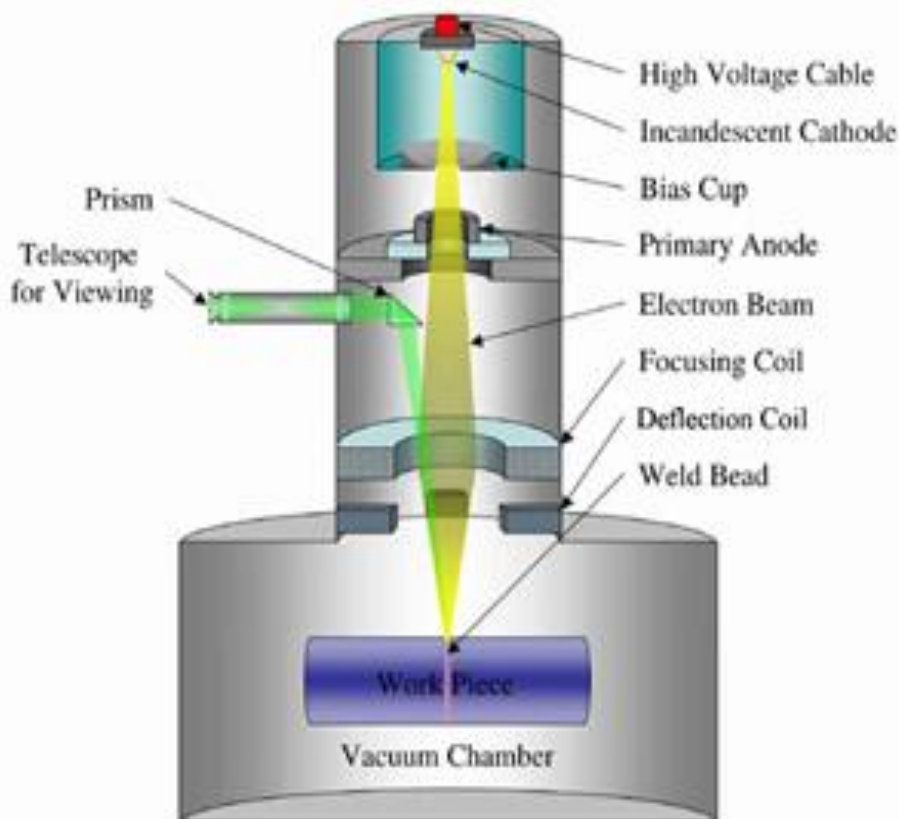
Steps in Thermite Welding

1. Thermit material is a mechanical mixture of metallic aluminum and processed iron oxide.
2. Molten steel is produced by the reaction in a magnesite-lined crucible.
3. At the bottom of the crucible, a magnesite stone is burned, into which a magnesite stone thimble is fitted.
4. This thimble provides a passage through which the molten steel is discharged into the mold.
5. The hole through the thimble is plugged with a tapping pin, which is covered with a fire-resistant washer and refractory sand.
6. The crucible is charged by placing the correct quantity of thoroughly mixed material in it.
7. In preparing the joint for welding, the parts to be welded must be cleaned, aligned, and held firmly in place.

8. If necessary, metal is removed from the joint to permit a free flow of the metal into the joint.
9. A wax pattern is then made around the joint in the size and shape of the intended weld.
10. A mold made of refractory sand is built around the wax pattern and joint to hold the molten metal after it is poured.
11. The sand mold is then heated to melt out the wax and dry the mold.
12. The mold should be properly vented to permit the escape of gases and to allow the proper distribution of the metal at the joint.

Electron Beam Welding

- **Electron beam welding (EBW)** is a fusion welding process in which a beam of high-velocity electrons is applied to the materials being joined.
- The work pieces melt as the kinetic energy of the electrons is transformed into heat upon impact, and the filler metal, if used, also melts to form part of the weld.
- The welding is often done in conditions of a vacuum to prevent dispersion of the electron beam.



EBW Process

- The EB system is composed of an electron beam gun, a power supply, control system, motion equipment and vacuum welding chamber. Fusion of base metals eliminates the need for filler metals. The vacuum requirement for operation of the electron beam equipment eliminates the need for shielding gases and fluxes.
- The electron beam gun has a tungsten filament which is heated, freeing electrons. The electrons are accelerated from the source with high voltage potential between a cathode and anode. The stream of electrons then pass through a hole in the anode. The beam is directed by magnetic forces of focusing and deflecting coils. This beam is directed out of the gun column and strikes the work piece.
- The potential energy of the electrons is transferred to heat upon impact of the work piece and cuts a perfect hole at the weld joint. Molten metal fills in behind the beam, creating a deep finished weld.
- The electron beam stream and work piece are manipulated by means of precise, computer driven controls, within a vacuum welding chamber, therefore eliminating oxidation, contamination.

EBW Benefits

- Single pass welding of thick joints
- Hermetic seals of components retaining a vacuum
- Low distortion
- Low contamination in vacuum
- Weld zone is narrow
- Heat affected zone is narrow
- Dissimilar metal welds of some metals
- Uses no filler metal

EBW Limitations

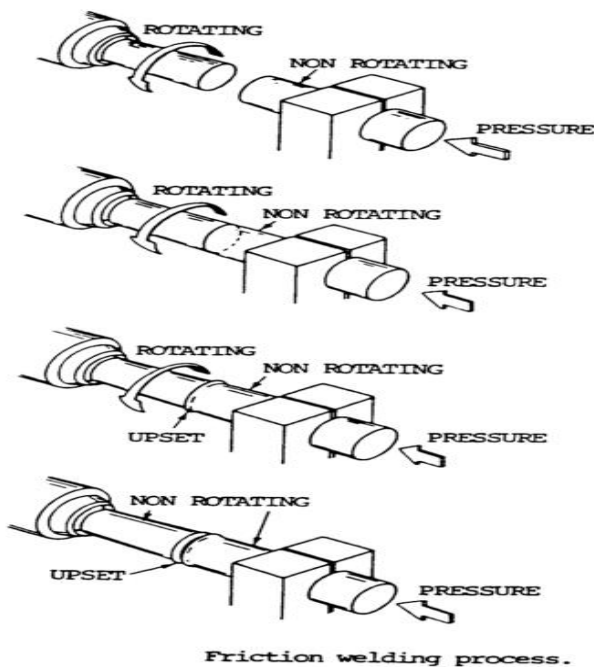
- High equipment cost
- Work chamber size constraints
- Time delay when welding in vacuum
- High weld preparation costs
- X-rays produced during welding
- Rapid solidification rates can cause cracking in some materials

Applications for electron beam welding

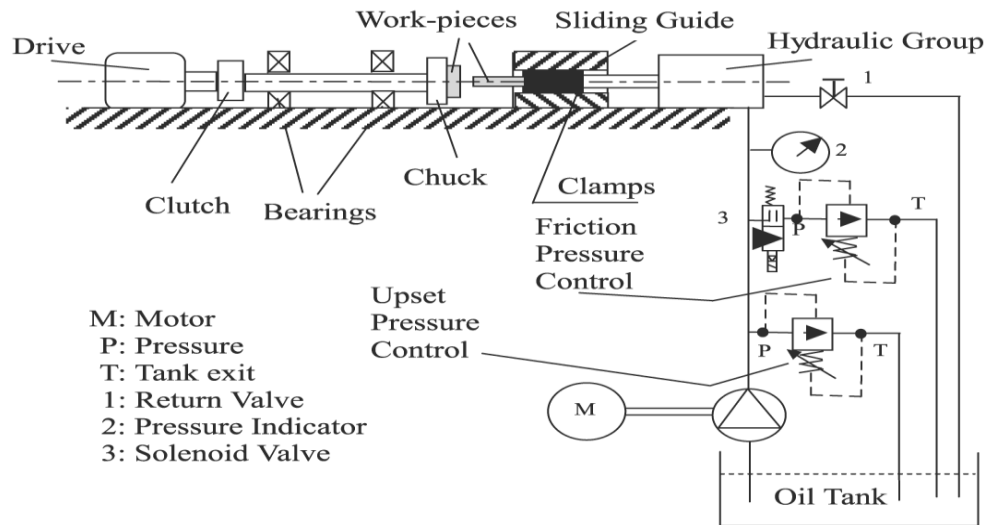
- aerospace, automotive, semi-conductor, electronic components and jewelry.
- The process has proved very reliable and cost-effective in high volume production due to the advent of small vacuum chamber machines.

Friction welding

- Friction welding (FW) is a class of solid-state welding processes that generates heat through mechanical friction between a moving work piece and a stationary component, with the addition of a lateral force called "upset" to plastically displace and fuse the materials.
- Technically, because no melt occurs, friction welding is not actually a welding process in the traditional sense, but a forging technique.
- However, due to the similarities between these techniques and traditional welding, the term has become common.
- Friction welding is used with metals and thermoplastics in a wide variety of aviation and automotive applications.



Friction Welding Machine



Advantages of Friction Welding

- Dissimilar materials normally not compatible for welding can be friction welded
- Creates narrow, heat-affected zone
- Consistent and repetitive process
- Joint preparation is minimal - saw cut surface used most commonly
- Greatly increases design flexibility; choose appropriate materials for each area of a blank
- Suitable for quantities ranging from prototype to high production
- No fluxes, filler material, or gases required
- Environmentally friendly process - no fumes, gases, or smoke generated
- Solid state process - no possibility of porosity or slag inclusions
- Creates cast or forge-like blanks, without expensive costs of tooling or minimum quantity requirements
- Reduces machining labor, thereby reducing perishable tooling costs while increasing capacity
- Full surface weld gives superior strength in critical areas
- Reduces raw material costs in bi-metal applications; only use expensive materials where necessary in the blank

Application

- Bimetallic Engine Valve * Brake Caliper * Steering Shaft * Conventional Tubular Prop Shaft * C.V. Joint Bell Shaft * F.W.D. Tubular Axle * Tie Rod End * Air Brake Pus Pad Assembly * Universal Joint Yoke * Drive Axle Shaft * Axle Banjo Bearing * Shift Lever * Brake "S" Cam * Pinion Shaft * Chain Saw Clutch Drum * Track Roller * Turbine Shaft * Sprocket Hub * Diesel Injector * Helicopter Rotor Shaft * Projectile * Landing Gear Strut * Twist Drill * Profile Cutter * Lathe Spindle Blank * Drill Pipe * Sucker Rod * Gear Hub * Cluster Gear * Rock Drill Piston Blank * Valve Body * Eccentric Shaft *

Diffusion welding

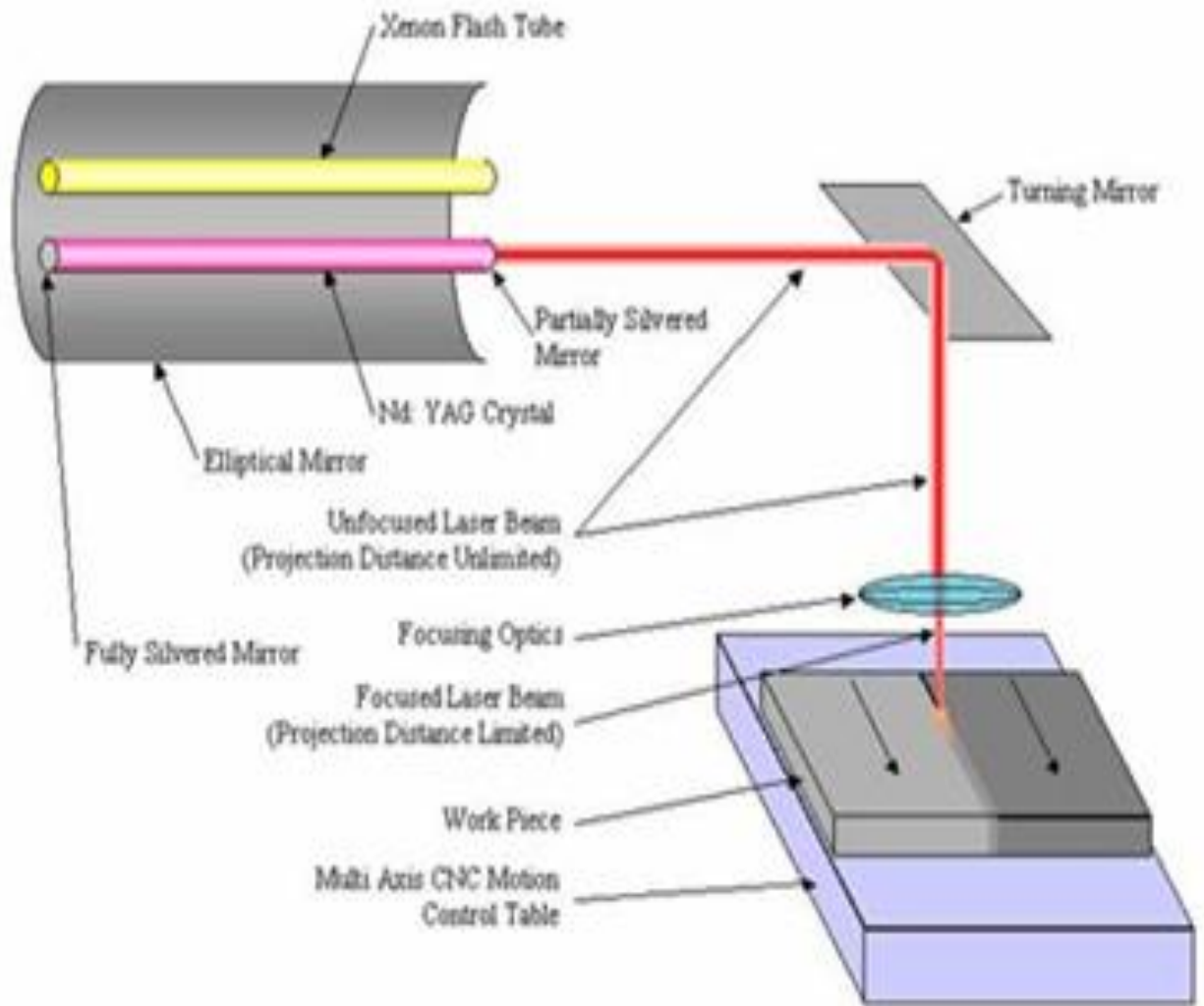
- The machine is used for diffusion welding process.
- It is a solid state welding process that creates fusion of surfaces to be joined by applying pressure at high temperatures.
- The welding process may or may not use filler material. If used, they may be in the form of electroplated surfaces.
- These welders are ideal for joining refractory metals and many other dissimilar metals.

Diffusion Welding Process

- Diffusion welding process does not comprise microscopic deformation melting or relative motion of the parts.
- Heat required for melting the parts is commonly obtained by resistance, induction or furnace.
- Atmosphere and vacuum furnaces are used for welding general metals. But for joining most refractory metals, a protective inert atmosphere is used.

Laser beam welding

- **Laser beam welding (LBW)** is a welding technique used to join multiple pieces of metal through the use of a laser.
- The beam provides a concentrated heat source, allowing for narrow, deep welds and high welding rates.
- The process is frequently used in high volume applications, such as in the automotive industry.
-
- Laser welding is a high energy beam process and in this regard is similar to electron beam.
- With that exception they are unlike one another. The energy density of the laser is achieved by the concentration of light waves not electrons.
- The laser output is not electrical, does not require electrical continuity, is not influenced by magnetism, is not limited to electrically conductive materials and in fact can interact with any material whether it be metal, plastic, wood, ceramic, etc.
- Finally its function does not require a vacuum nor are x-rays produced.



Laser Welding Process

(1) Laser beam welding (LBW) is a welding process which produces coalescence of materials with the heat obtained from the application of a concentrate coherent light beam impinging upon the surfaces to be joined.

(2) The focused laser beam has the highest energy concentration of any known source of energy. The laser beam is a source of electromagnetic energy or light that can be projected without diverging and can be concentrated to a precise spot. The beam is coherent and of a single frequency.

(3) Gases can emit coherent radiation when contained in an optical resonant cavity. Gas lasers can be operated continuously but originally only at low levels of power. Later developments allowed the gases in the laser to be cooled so that it could be operated

continuously at higher power outputs. The gas lasers are pumped by high radio frequency generators which raise the gas atoms to sufficiently high energy level to cause lasing. Currently, 2000-watt carbon dioxide laser systems are in use. Higher powered systems are also being used for experimental and developmental work. A 6-kw laser is being used for automotive welding applications and a 10-kw laser has been built for research purposes. There are other types of lasers; however, the continuous carbon dioxide laser now available with 100 watts to 10 kw of power seems the most promising for metalworking applications.

(4) The coherent light emitted by the laser can be focused and reflected in the same way as a light beam. The focused spot size is controlled by a choice of lenses and the distance from it to the base metal. The spot can be made as small as 0.003 in. (0.076 mm) to large areas 10 times as big. A sharply focused spot is used for welding and for cutting. The large spot is used for heat treating.

(5) The laser offers a source of concentrated energy for welding; however, there are only a few lasers in actual production use today. The high-powered laser is extremely expensive. Laser welding technology is still in its infancy so there will be improvements and the cost of equipment will be reduced. Recent use of fiber optic techniques to carry the laser beam to the point of welding may greatly expand the use of lasers in metal-working.

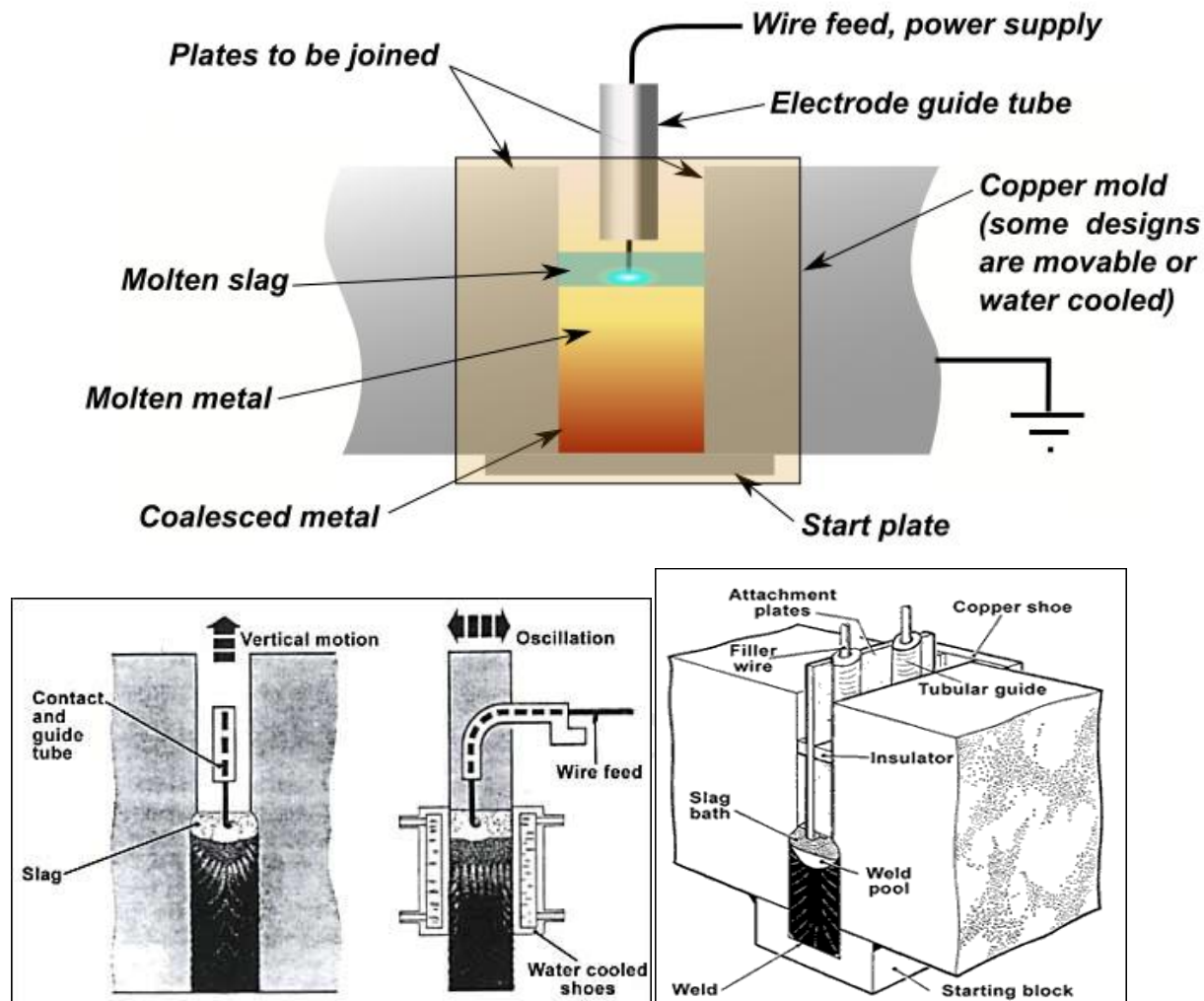
Applications

There are almost unlimited applications for marking, engraving, cutting, and welding in a substantial amount of companies and industries. Below are just a few of these applications. Please contact us and we would be most happy to process one of your samples that you think has merit at no charge to you.

Electro slag welding (ESW)

1. **Electro slag welding (ESW)** is a highly productive, single pass welding process for thick (greater than 25mm up to about 300mm) materials in a vertical or close to vertical position.
2. (ESW) is similar to electro gas welding, but the main difference is the arc starts in a different location.
3. An electric arc is initially struck by wire that is fed into the desired weld location and then flux is added.
4. Additional flux is added until the molten slag, reaching the tip of the electrode, extinguishes the arc.
5. The wire is then continually fed through a consumable guide tube (can oscillate if desired) into the surfaces of the metal work pieces and the filler metal are then melted using the electrical resistance of the molten slag to cause coalescence.
6. The wire and tube then move up along the work piece while a copper retaining shoe that was put into place before starting (can be water cooled if desired) is used to keep the weld between the plates that are being welded.
7. Electro slag welding is used mainly to join low carbon steel plates and/or sections that are very thick.
8. It can also be used on structural steel if certain precautions are observed.

9. This process uses a direct current (DC) voltage usually ranging from about 600A and 40-50V, higher currents are needed for thicker materials. Because the arc is extinguished, this is not an arc process.



Flux Core Welding

1. FCAW, Flux Core Flux-cored, tubular electrode welding has evolved from the MIG welding process to improve arc action, metal transfer, weld metal properties, and weld appearance.
2. It is an arc welding process in which the heat for welding is provided by an arc between a continuously fed tubular electrode wire and the work piece.
3. Shielding is obtained by a flux contained within the tubular electrode wire or by the flux and an externally supplied shielding gas. A diagram of the process is shown in figure

4. FCAW, Flux Core Flux-cored arc welding is similar to gas metal arc welding in many ways.
5. The flux-cored wire used for this process gives it different characteristics.
6. Flux-cored arc welding is widely used for welding ferrous metals and is particularly good for applications in which high deposition rates are needed.
7. At high welding currents, the arc is smooth and more manageable when compared in using large diameter gas metal arc welding electrodes with carbon dioxide.
8. The arc and weld pool are clearly visible to the welder. A slag coating is left on the surface of the weld bead, which must be removed.
9. Since the filler metal transfers across the arc, some spatter is created and some smoke produced.

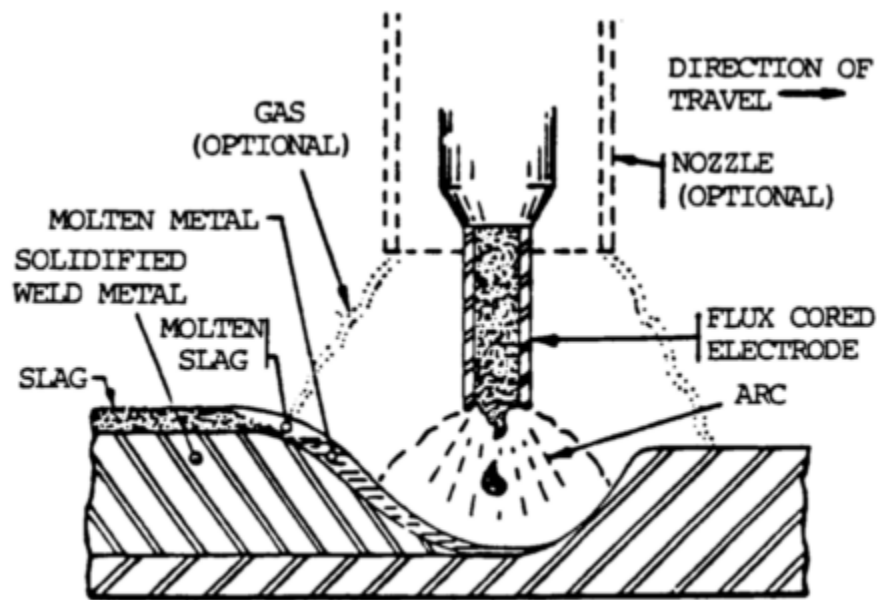


Figure 10-55. Flux-cored arc welding process.

Soldering is defined as "the joining of metals by a fusion of alloys which have relatively low melting points". In other words, you use a metal that has a low melting point to adhere the surfaces to be soldered together. Soldering is more like gluing with molten metal than anything else. Soldering is also a must have skill for all sorts of electrical and electronics work. It is also a skill that must be taught correctly and developed with practice.