

WELDING

Welding is the process of joining two metallic pieces together in permanent manner. Heat and/or pressure is applied to get the joint.

- Gas welding**
- Arc welding**
- Resistance welding**
- Solid state welding**

HISTORY OF WELDING.....

- Began when people found they could shape rocks by chipping them with other rocks
- Copper probably first metal to be worked
 - Ductile (easily hammered, bent or drawn)
 - In Egypt as early as 4000 B.C. and USA before 2000 B.C.
- Welding began more than 3000 years ago
- Bronze developed between 3000 and 2000 B.C.

- Iron became known to Europe about 1000 B.C.
- Working of metals followed one another in great ancient civilizations
Copper, bronze, silver, gold, and iron
- Chinese developed ability to make steel from wrought iron in 589 A.D.
- Belgians responsible for progress with steel in Europe
- Japan manufactured steel by repeated welding and forging and controlling amount of carbon by use of fluxes

- Industrial Revolution in the middle of the eighteenth century brought many improvements

- Working of dies and molds became commonplace by beginning of nineteenth century

Early Developments in Welding

- ❑ Edmund Davy discovered acetylene at beginning of nineteenth century
- ❑ Sir Humphrey Davy discovered the electric arc in 1801
- ❑ Workable electrical generating devices invented and developed on practical basis by 1850

Bare Metal Electrode Welding

- ✓ Introduced in 1888 by N. G. Slavianoff (Russian)
- ✓ Discovery first recognized in western Europe in 1892
- ✓ C. L. Coffin was pioneer of welding industry in United States
- ✓ 1889 received patent on equipment and process for flash-butt welding
- ✓ 1890 received additional patents for spot welding
- ✓ In 1908, Benardos patented *electroslag* process of welding thick plates in one pass

Welding Associations

- American National Standards Institute (ANSI)
- American Petroleum Institute (API)
- American Society of Mechanical Engineers (ASME)
- American Welding Society (AWS)
- American Bureau of Shipping (ABS)

Welding is joining two pieces of metal by:

- Heating to temperature high enough to cause softening or melting
- With or without application of pressure
- With or without use of filler metal

ELEMENTS OF WELDING PROCESS

- **FILLER MATERIAL**

- Filler materials are used to fill the space between the welded joint.
- Filler material is melted and added to the joint during the welding process.
- It adds strength to the joint.

FLUXES-

is a **cleaning agent** used to avoid the contamination of welded joint by impurities like oxides, by oxygen combined with metal during welding.

Flux dissolve oxide, trapped gases and slag(impurities) from base metal.

WELD POOL -

dime-sized workable portion of a weld where the base metal has reached its melting point and is ready to be infused with filler material.

Weld pool is central to the success of the welding process.

Weld pool solidifies to become weld bead.

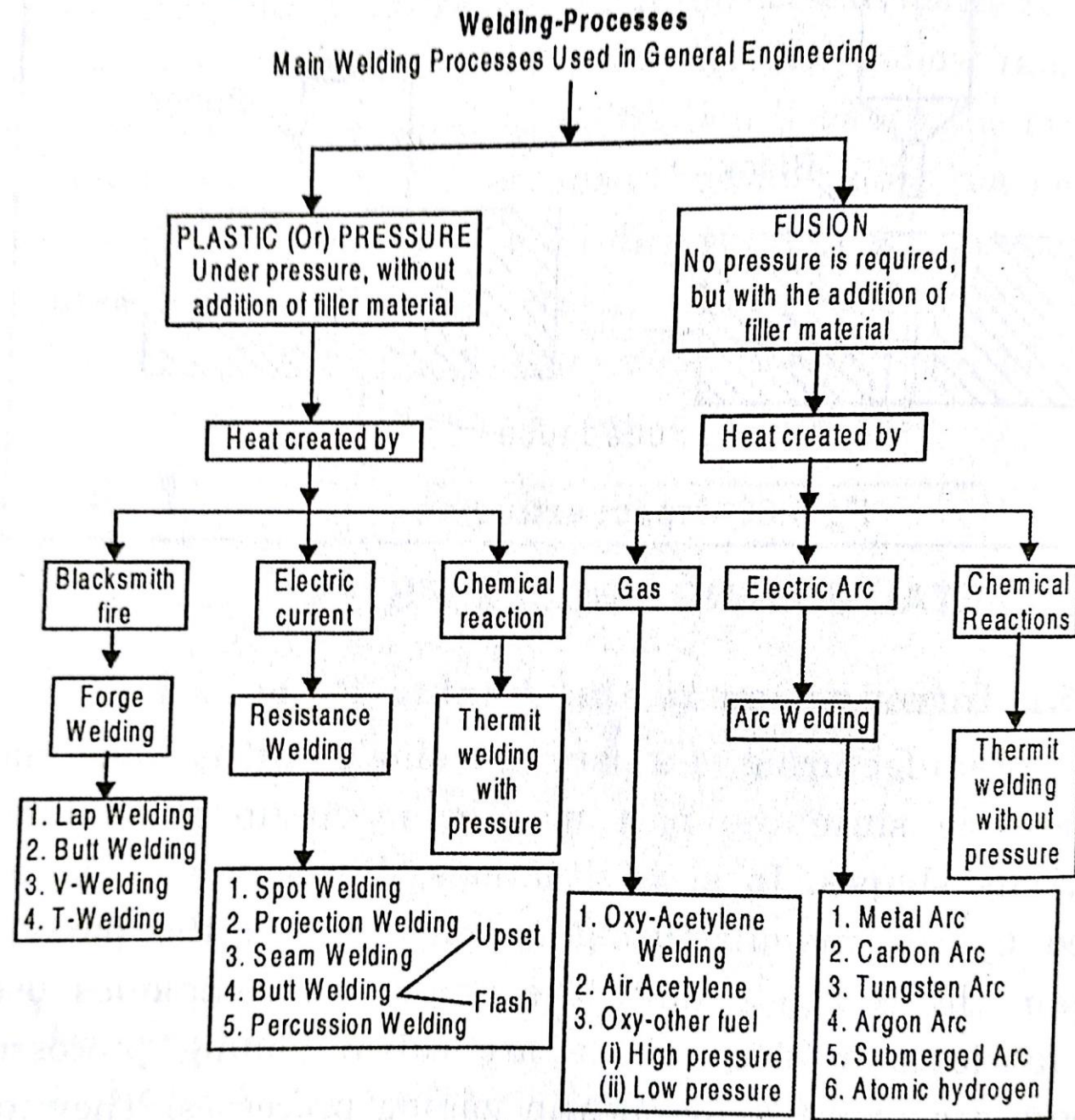


Fig. 5.61 Types of welding processes

WELDING

Classification of welding processes:

(i). Arc welding

- Carbon arc
- Metal arc
- Metal inert gas
- Tungsten inert gas
- Plasma arc
- Submerged arc
- Electro-slag

(ii). Gas Welding

- Oxy-acetylene
- Air-acetylene
- Oxy-hydrogen

(iii). Resistance Welding

- Butt
- Spot
- Seam
- Projection
- Percussion

(iv)Thermit Welding

(v)Solid State Welding

Friction

Ultrasonic

Diffusion

Explosive

(vi)Newer Welding

Electron-beam

Laser

(vii)Related Process

Oxy-acetylene cutting

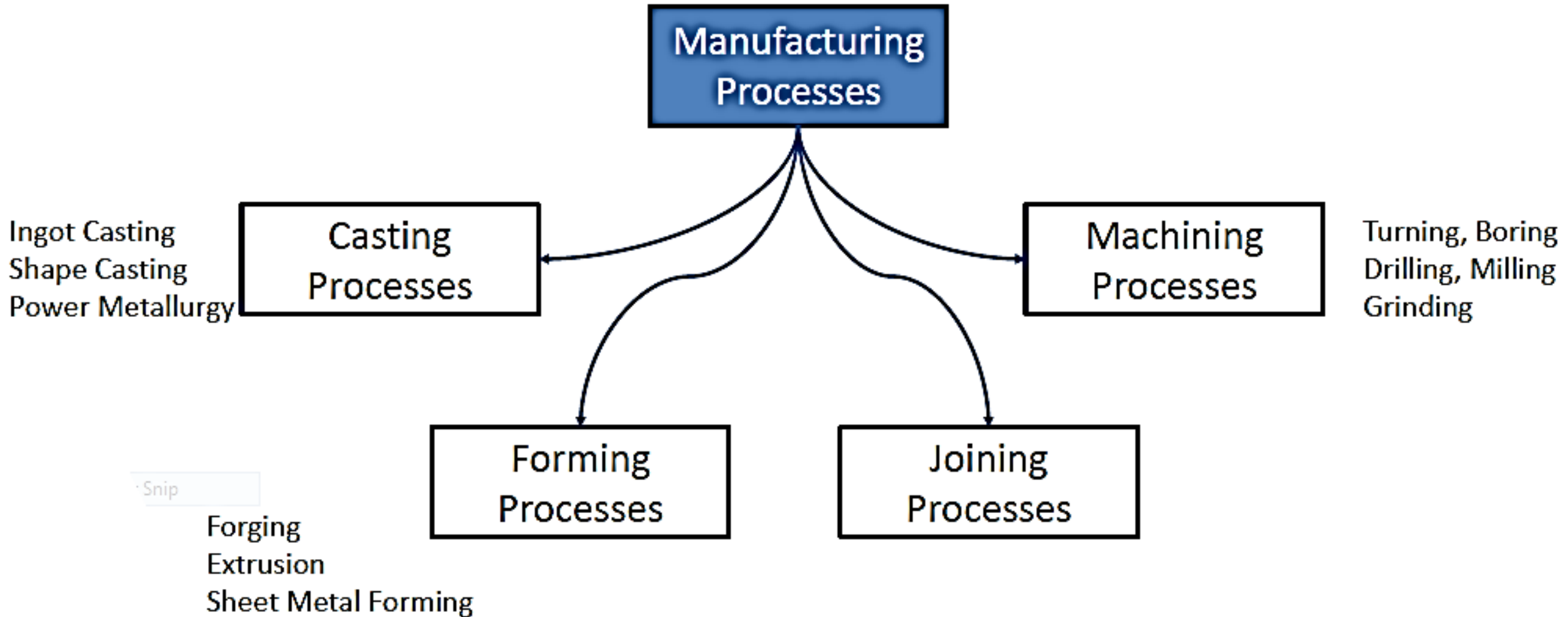
Arc cutting

Hard facing

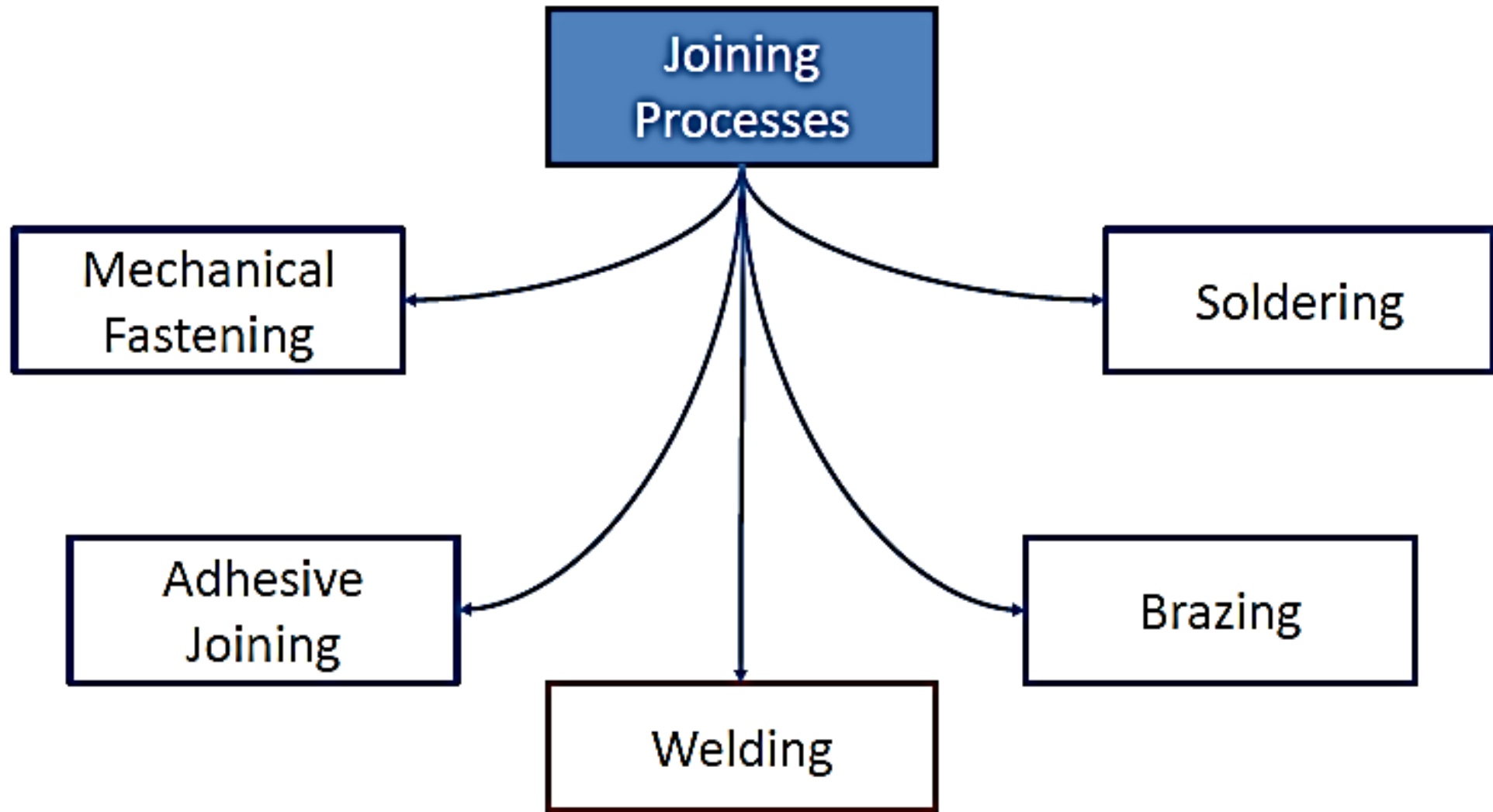
Brazing

Soldering

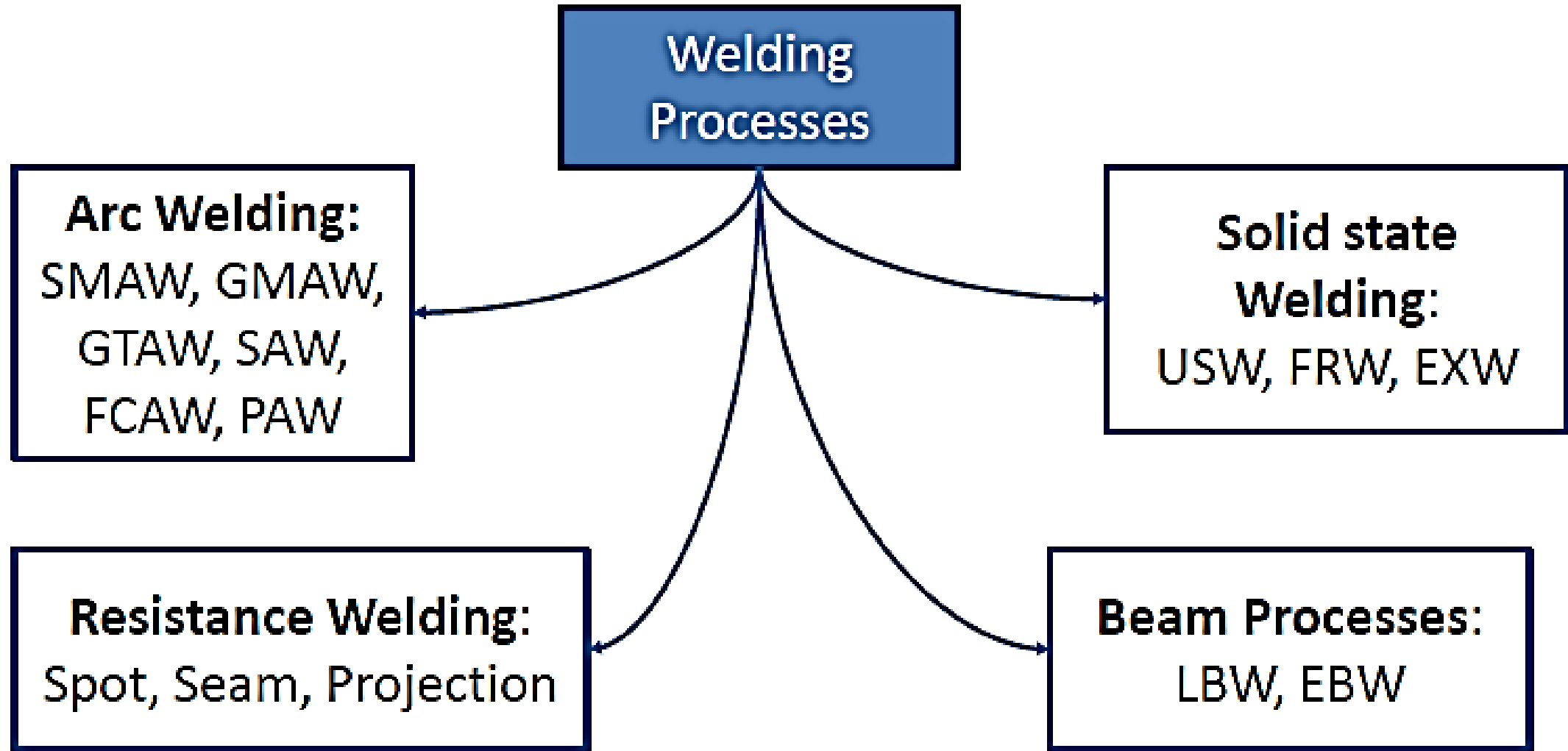
Classification of Manufacturing Processes



Classification of Joining Processes



Different Welding Processes



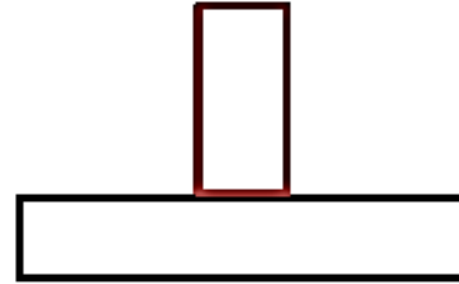
Five basic joint designs



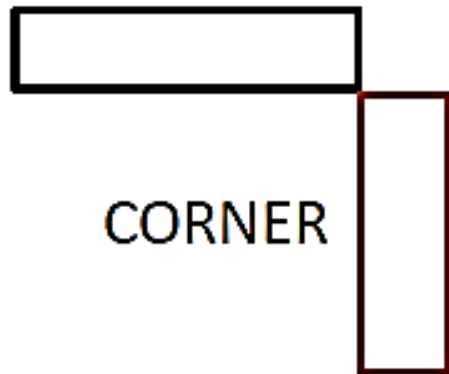
BUTT



LAP



TEE



CORNER

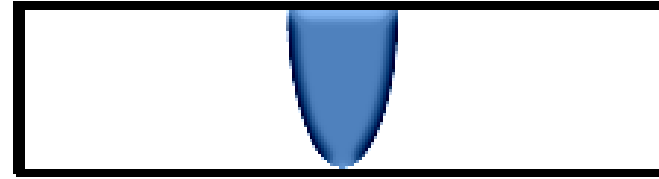


EDGE

Four basic types of fusion welds



Bead / Surface Weld



Groove Weld

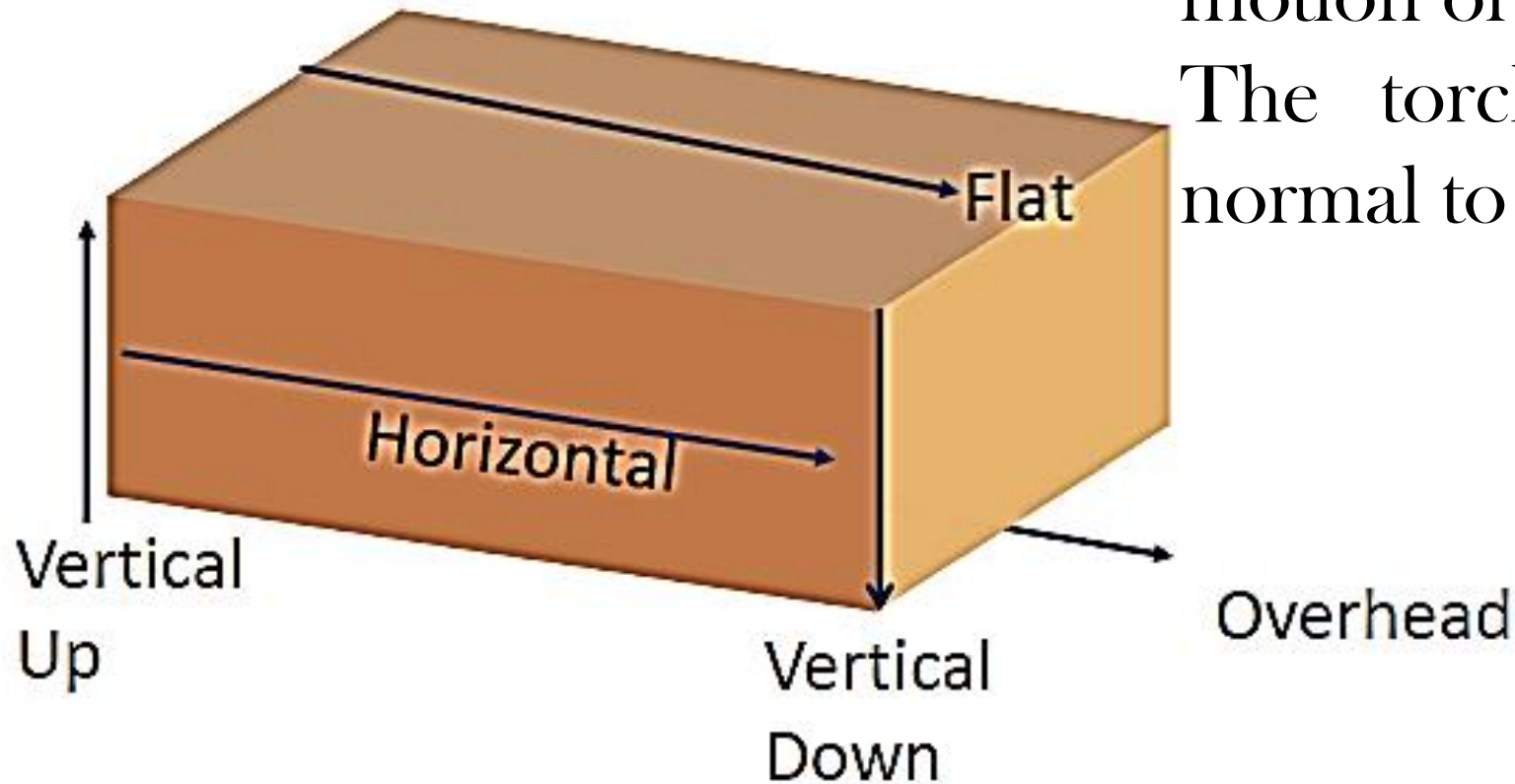


Fillet Weld



Plug Weld

Five Welding Positions



Arrow shows the direction of motion of the electrode / torch.
The torch is held approximately normal to this direction.

FLAT POSITION

A

HORIZONTAL POSITION

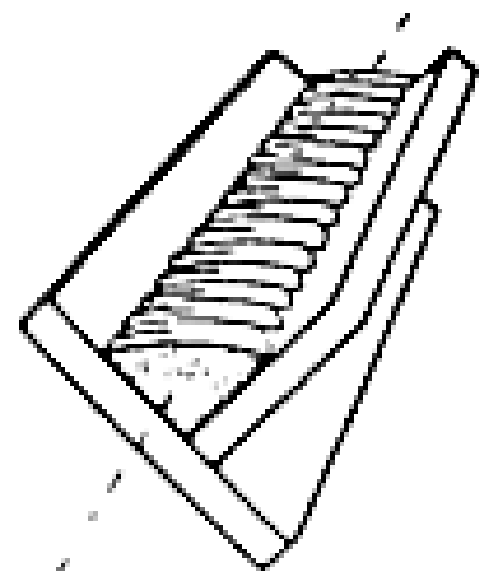
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VERTICAL POSITION

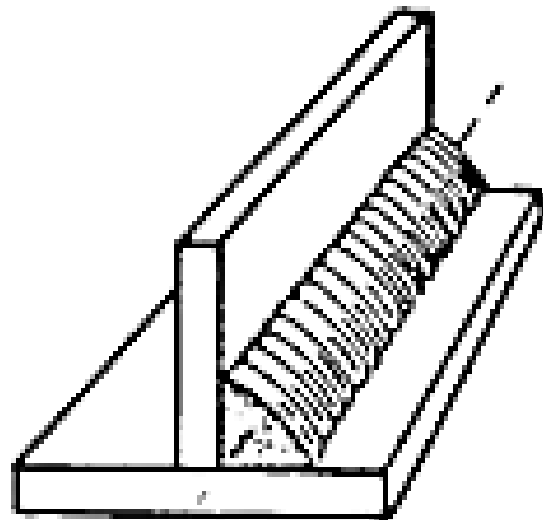
C

OVERHEAD POSITION

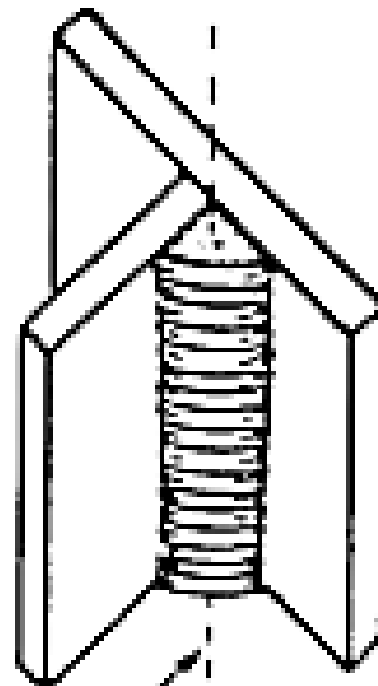
D



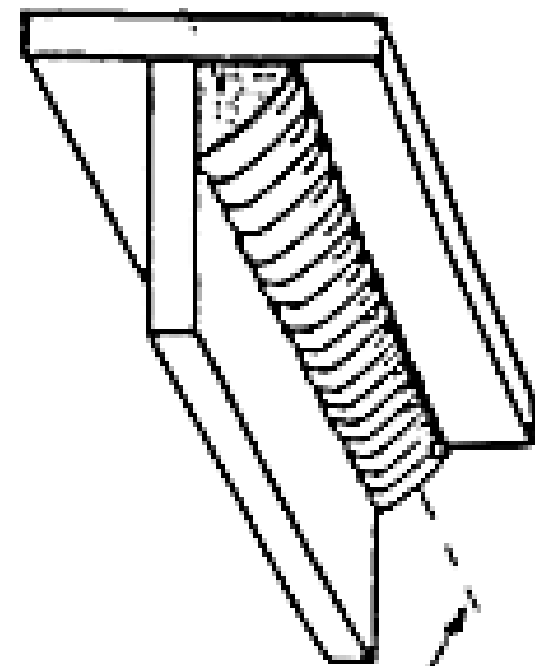
AXIS OF WELD
VERTICAL



AXIS OF WELD
HORIZONTAL



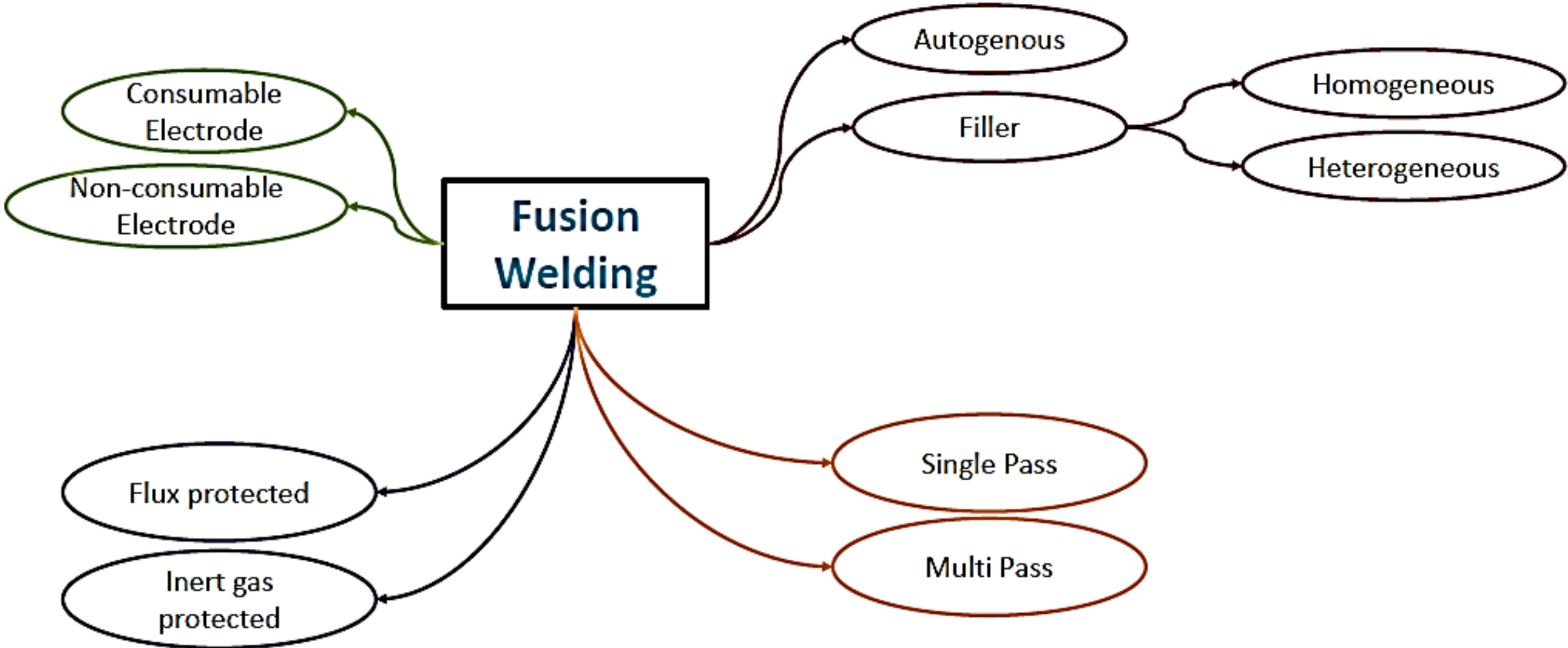
AXIS OF WELD
VERTICAL



AXIS OF WELD
HORIZONTAL

Welding positions--fillet welds--plate.

Classification of Welding



Terminology in welding

- Traverse rate : velocity of the welding source : m/s
- Heat Input : ratio of power to velocity : J/m
- Rate of heat input or heat intensity : W/m^2
- Heat intensity distribution

Arc Welding (AW)

- ❖ A fusion welding process in which coalescence of the metals is achieved by the heat from an electric arc between an electrode and the work
- ❖ Energy from the arc produces temperatures $\sim 10,000^\circ\text{F}$ (5500°C), hot enough to melt any metal
- ❖ Most AW processes add filler metal to increase volume and strength of weld joint

ELECTRIC ARC ?

- ✓ An electric arc is a discharge of electric current across a gap in a circuit
- ✓ It is sustained by an ionized column of gas (*plasma*) through which the current flows
- ✓ To initiate the arc in AW, electrode is brought into contact with work and then quickly separated from it by a short distance

Two Basic Types of AW Electrodes

- **Consumable**

- consumed during welding process
- Source of filler metal in arc welding

- **Nonconsumable**

- not consumed during welding process
- Filler metal must be added separately if it is added

Arc Shielding

- At high temperatures in AW, metals are chemically reactive to oxygen, nitrogen, and hydrogen in air
 - Mechanical properties of joint can be degraded by these reactions
 - To protect operation, arc must be shielded from surrounding air in AW processes
- Arc shielding is accomplished by:
 - Shielding gases, e.g., argon, helium, CO₂
 - Flux

Flux

- A substance that prevents formation of oxides and other contaminants in welding, or dissolves them and facilitates removal
 - Provides protective atmosphere for welding
 - Stabilizes arc
 - Reduces spattering

Various Flux Application Methods

- Pouring granular flux onto welding operation
- Stick electrode coated with flux material that melts during welding to cover operation
- Tubular electrodes in which flux is contained in the core and released as electrode is consumed

Power Source in Arc Welding

Direct current (DC) vs. Alternating current (AC)

- AC machines less expensive to purchase and operate, but generally restricted to ferrous metals
- DC equipment can be used on all metals and is generally noted for better arc control

Direct current (D.C.) always flows from:

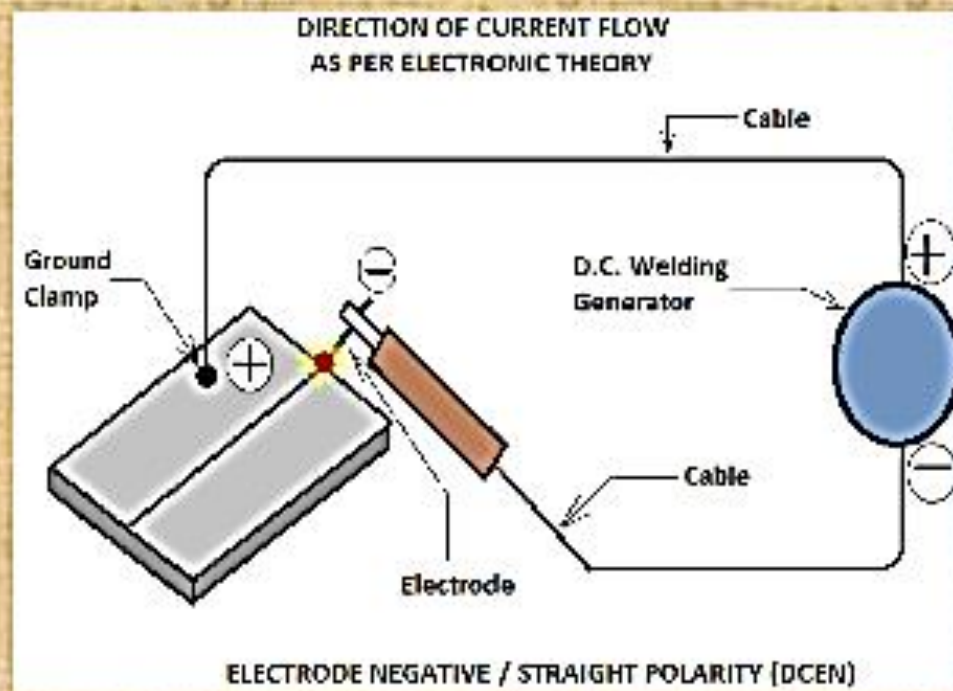
- The positive (higher potential) terminal to the negative (lower potential) terminal, as per the conventional theory.
- Negative terminal to positive terminal as per electronic theory.

In the latest machines a polarity switch is used to change the polarity.

Kinds of polarity

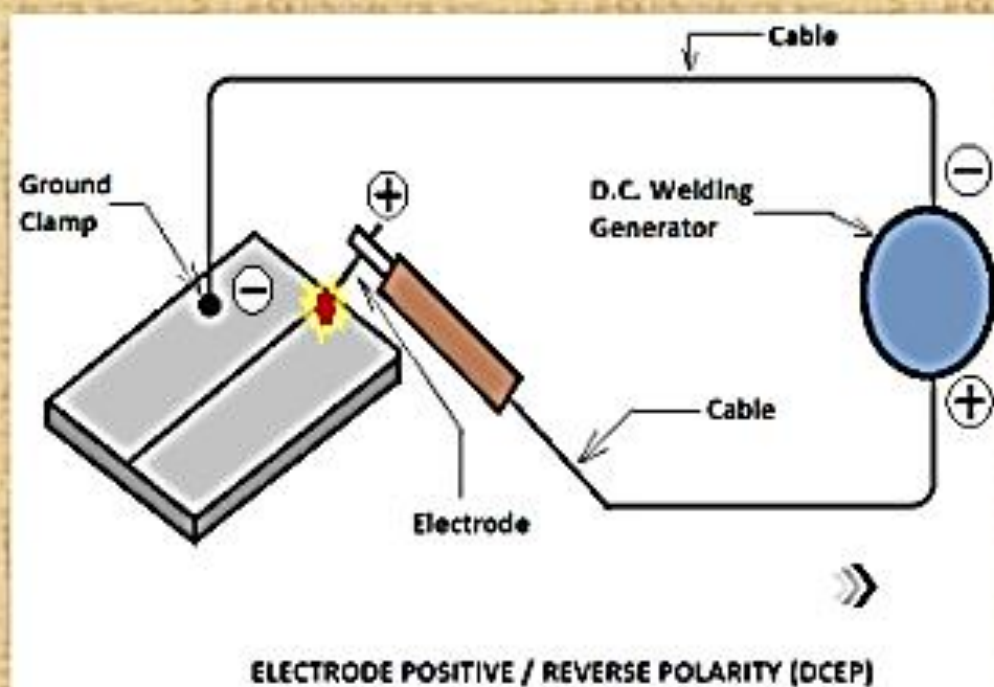
Straight polarity / electrode negative (DCEN):

In straight polarity the electrode is connected to the negative and the work to the positive terminal of the power source.

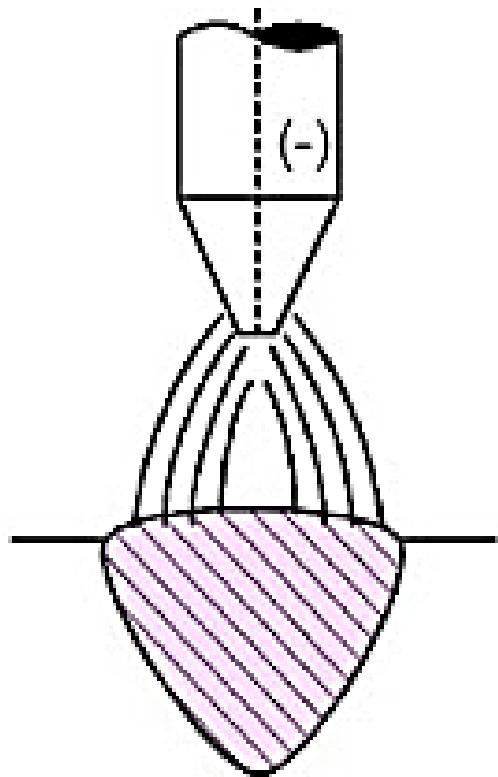


Reverse polarity / electrode positive (DCEP):

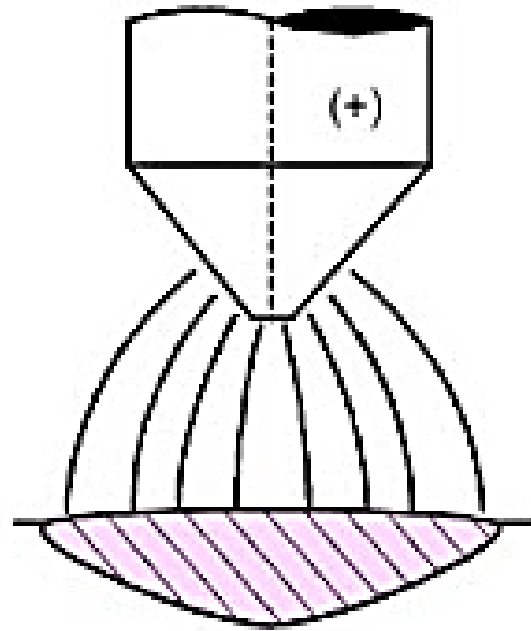
In reverse polarity the electrode is connected to the positive and the work to the negative terminal of the power source.



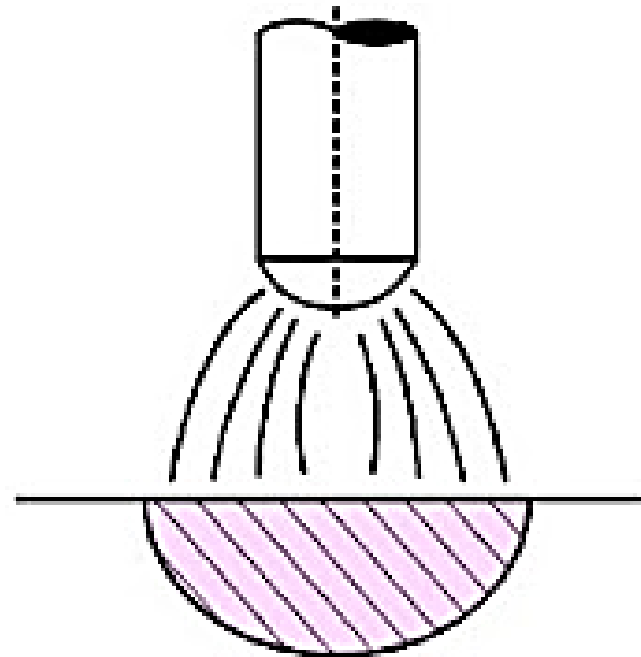
DCSP

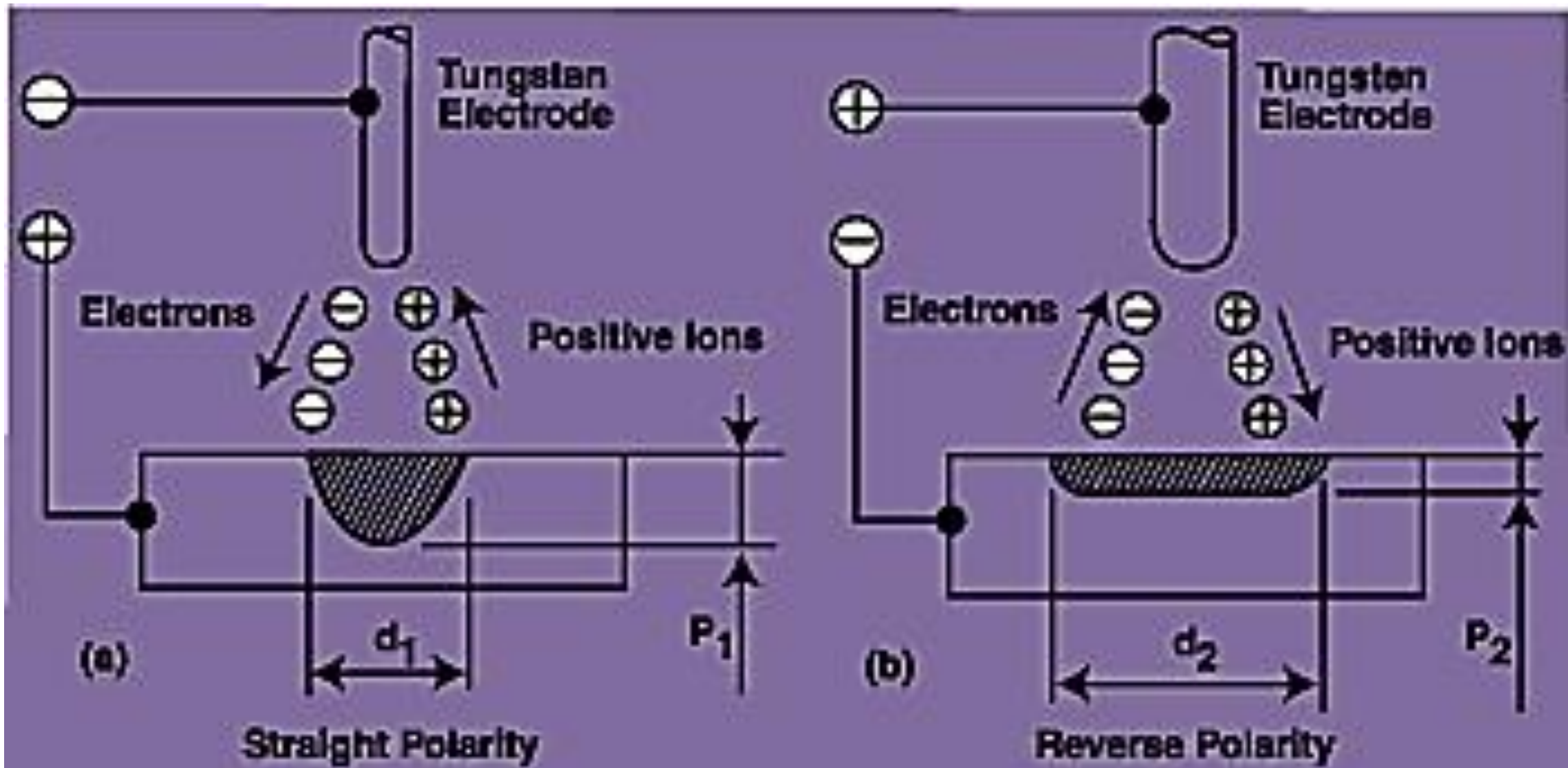


DCRP



AC





Application of polarity

Straight polarity is used for:

- ❖ Welding with bare light coated and medium coated electrodes.
- ❖ Welding the thicker sections in down hand position to obtain more base metal fusion and penetration.

Reverse polarity is used for:

- ❖ Welding of non-ferrous metals.
- ❖ Welding of cast iron.
- ❖ Welding with heavy and super heavy coated electrodes.
- ❖ Positional welding.
- ❖ Sheet metal welding.

Consumable Electrode

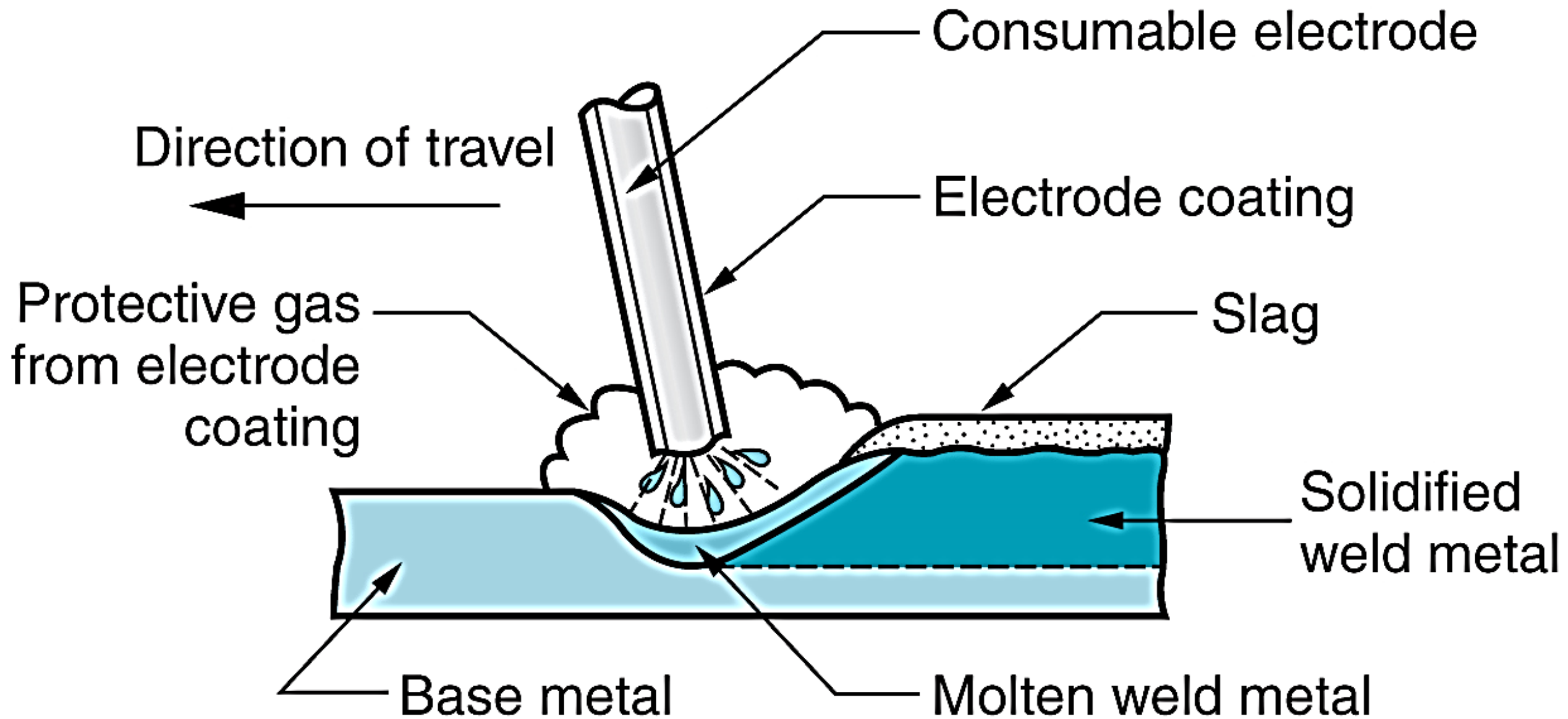
AW Processes

- Shielded Metal Arc Welding (SMAW)
- Gas Metal Arc Welding (GMAW)
- Flux-Cored Arc Welding (FCAW)
- Electrode Gas Welding
- Submerged Arc Welding (SAW)

Shielded Metal Arc Welding (SMAW)

Uses a consumable electrode consisting of a filler metal rod coated with chemicals that provide flux and shielding

Sometimes called "stick welding"



SMAW

Welding Stick in SMAW

- Composition of filler metal usually close to base metal
- Coating: powdered cellulose mixed with oxides and carbonates, and held together by a silicate binder
- Welding stick is clamped in electrode holder connected to power source

Disadvantages of stick welding:

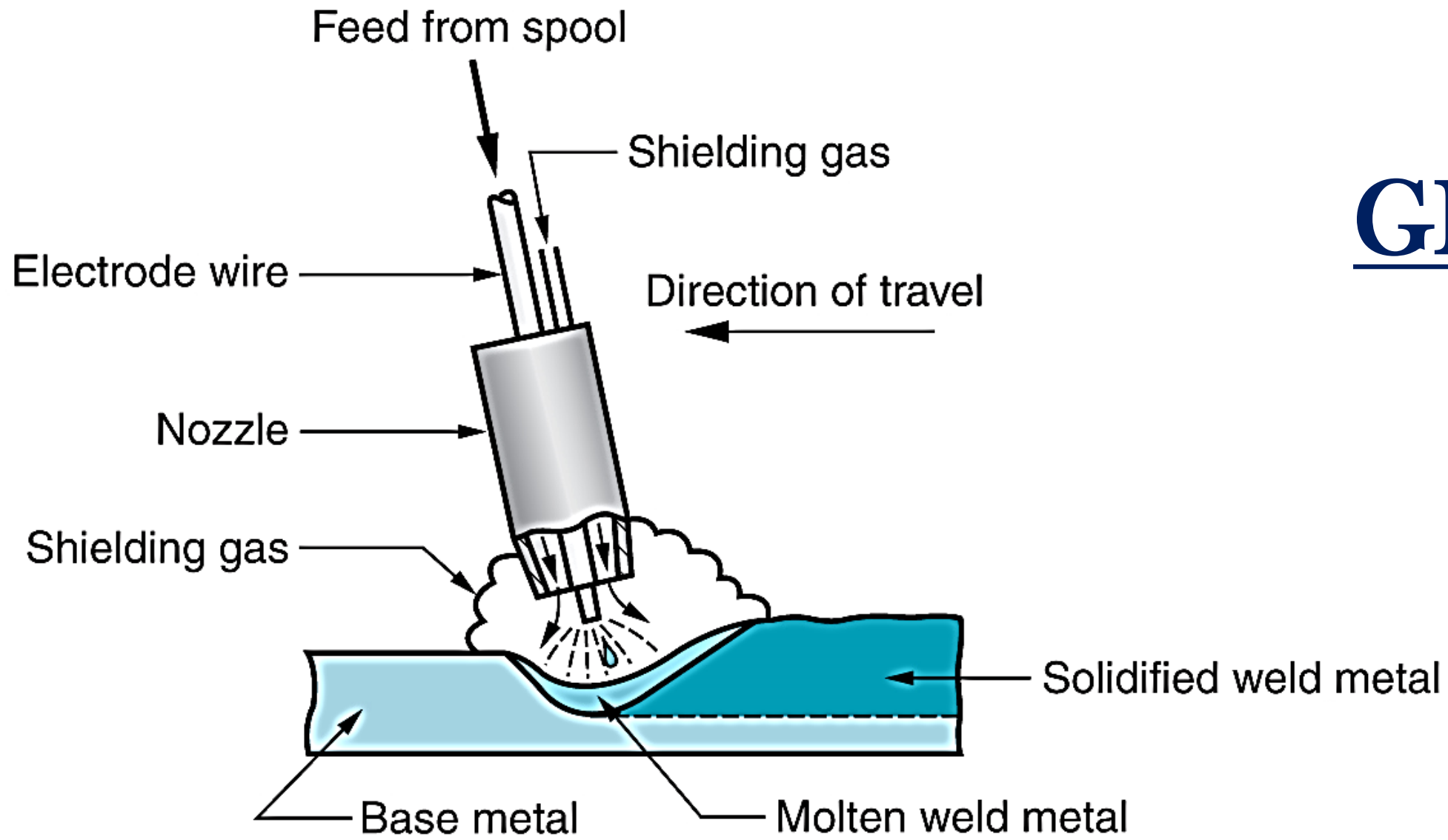
- Sticks must be periodically changed
- High current levels may melt coating prematurely

SMAW Applications

- ❑ Used for steels, stainless steels, cast irons, and certain nonferrous alloys
- ❑ Not used or rarely used for aluminum and its alloys, copper alloys, and titanium

Gas Metal Arc Welding (GMAW) or MIG

- Uses a consumable bare metal wire as electrode with shielding by flooding arc with a gas
- Wire is fed continuously and automatically from a spool through the welding gun
- Shielding gases include argon and helium for aluminum welding, and CO₂ for steel welding
- Bare electrode wire plus shielding gases eliminate slag on weld bead



GMAW

GMAW Advantages over SMAW

- Better arc time because of continuous wire electrode
- Sticks must be periodically changed in SMAW
- Better use of electrode filler metal than SMAW
- End of stick cannot be used in SMAW
- Higher deposition rates
- Eliminates problem of slag removal
- Can be readily automated

Flux-Cored Arc Welding (FCAW)

- Adaptation of shielded metal arc welding, to overcome limitations of stick electrodes - two versions

Self-shielded FCAW - core includes compounds that produce shielding gases

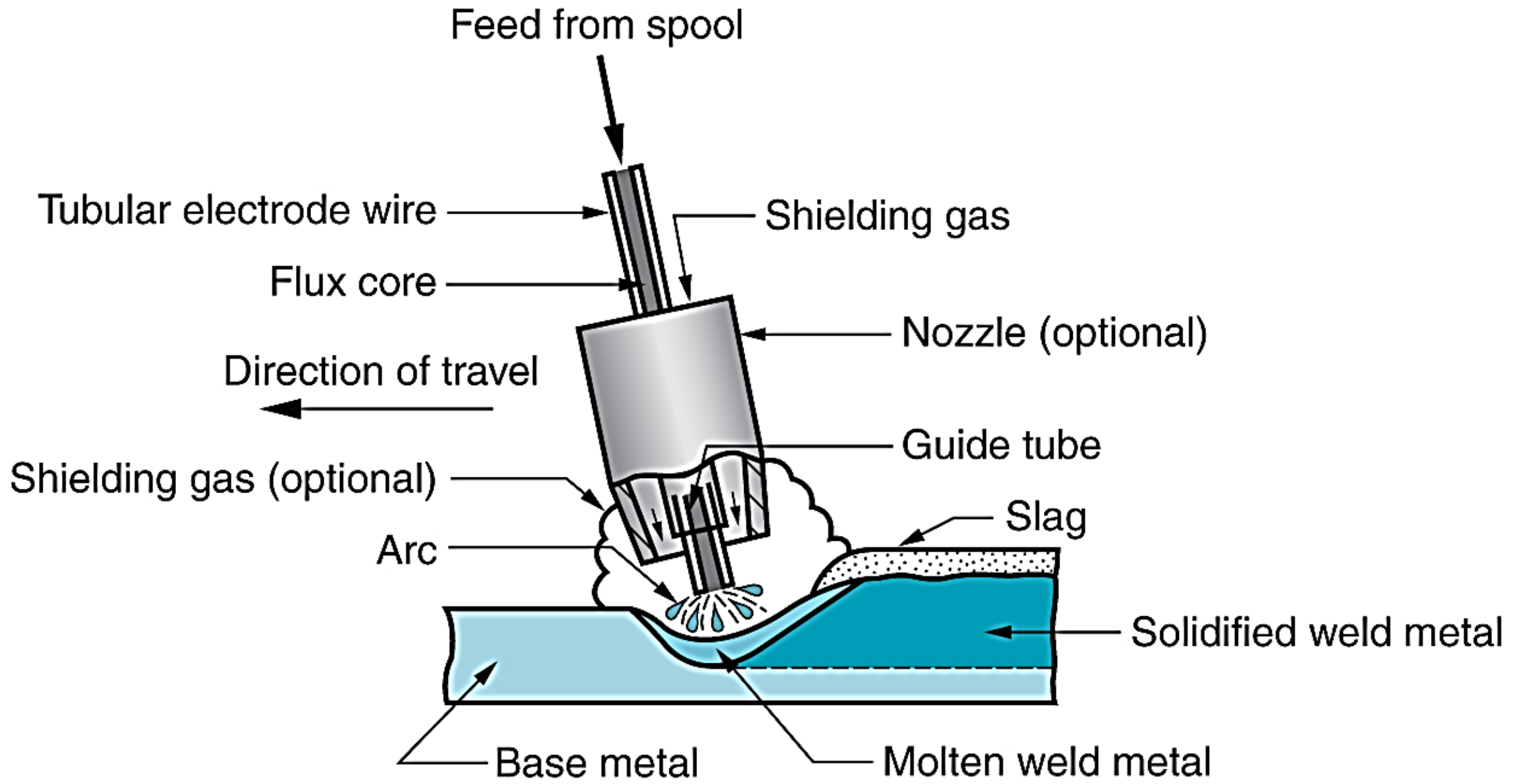
Gas-shielded FCAW - uses externally applied shielding gases

- Electrode is a continuous consumable tubing (in coils) containing flux and other ingredients (e.g., alloying elements) in its core

Flux-Cored Arc Welding

Presence or absence of externally supplied shielding gas distinguishes:

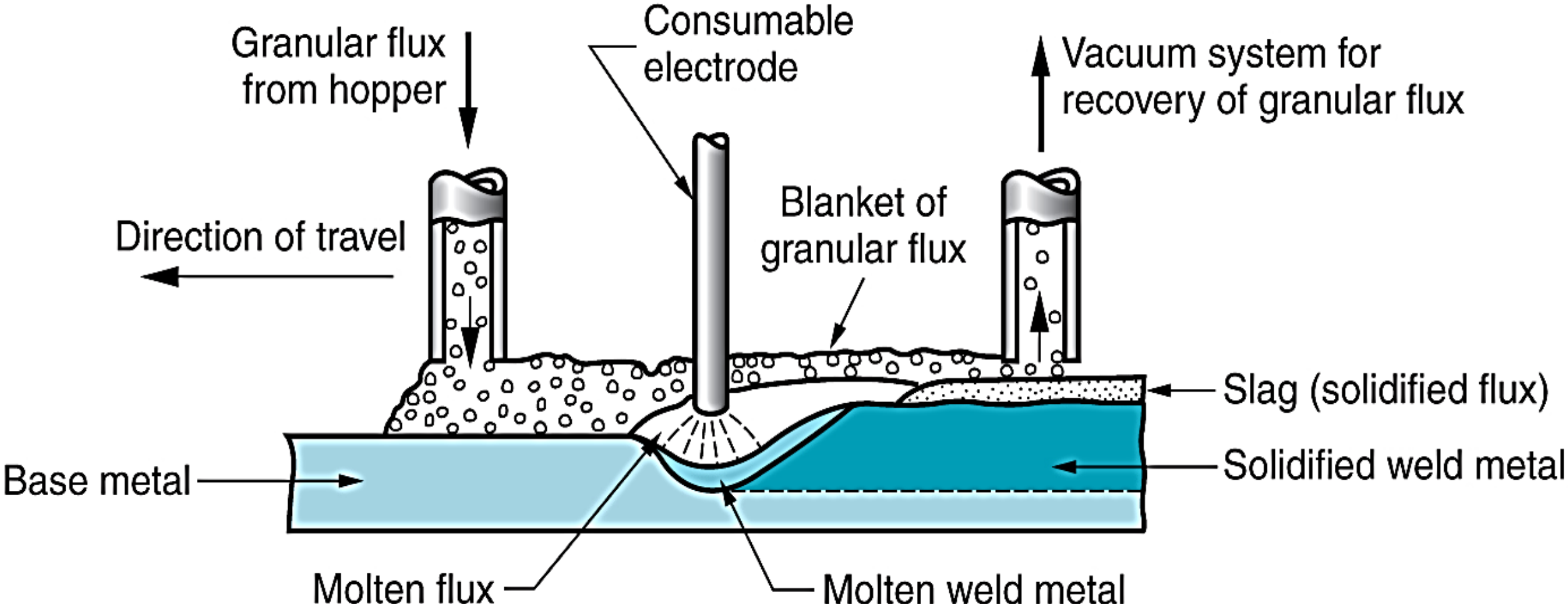
- (1) self-shielded - core provides ingredients for shielding,
- (2) gas-shielded - uses external shielding gases



FCAW

Submerged Arc Welding (SAW)

- Uses a continuous, consumable bare wire electrode, with arc shielding by a cover of granular flux
- Electrode wire is fed automatically from a coil
- Flux introduced into joint slightly ahead of arc by gravity from a hopper
- Completely submerges operation, preventing sparks, spatter, and radiation



SAW

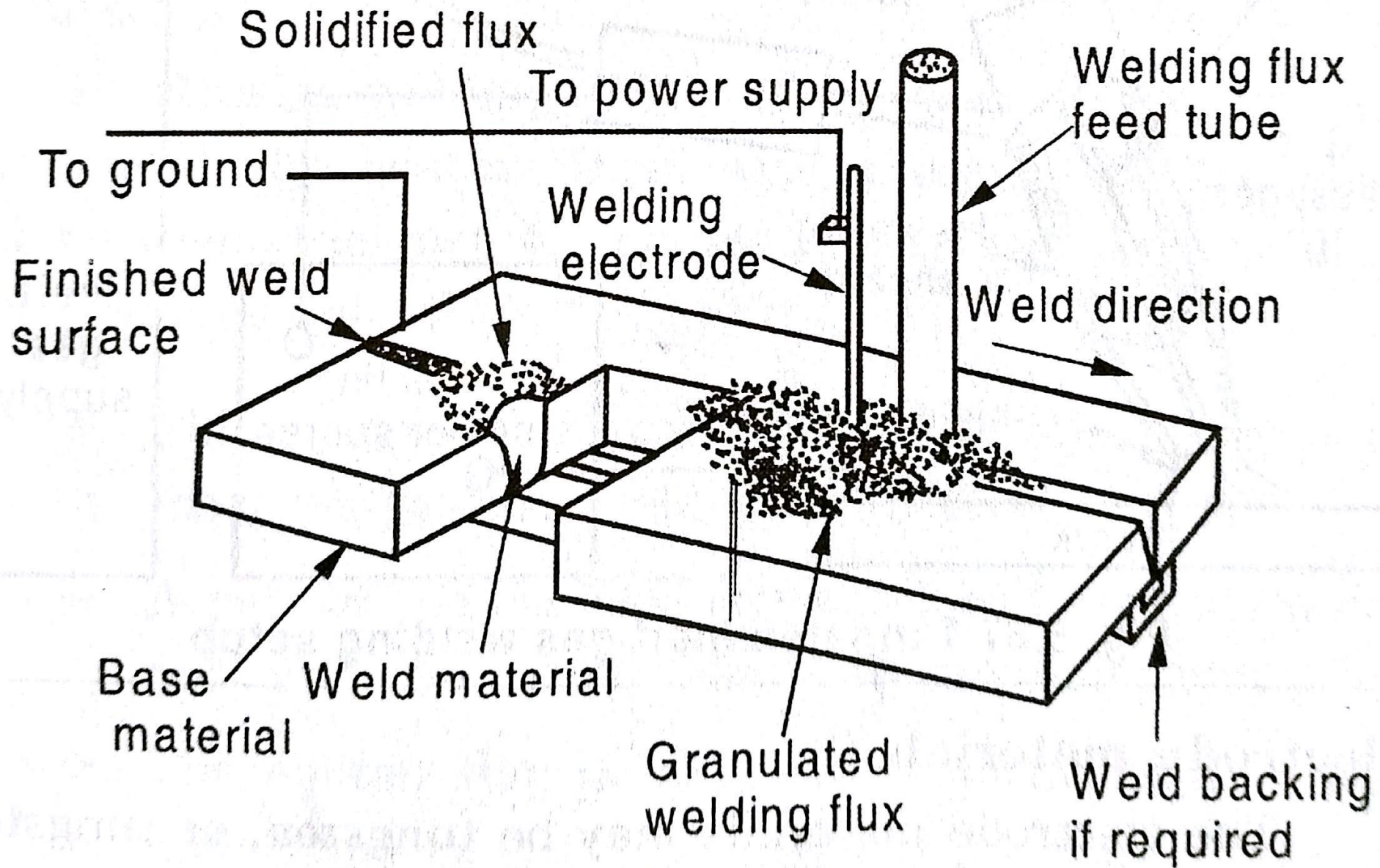
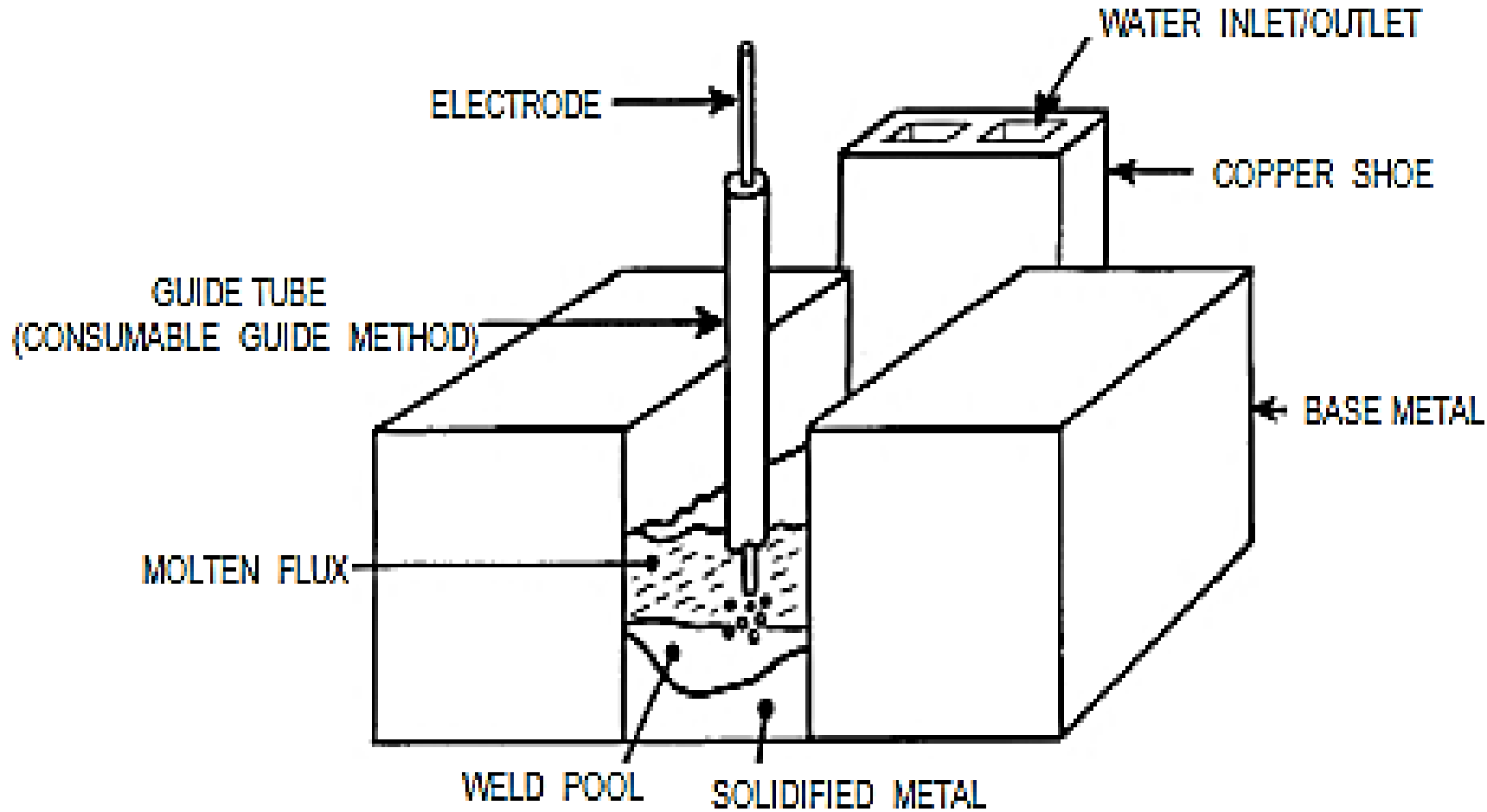


Fig. 5.66 Schematic submerged arc welding process

SAW Applications

- Steel fabrication of structural shapes (e.g., I-beams)
- Seams for large diameter pipes, tanks, and pressure vessels
- Welded components for heavy machinery
- Most steels (except hi C steel)
- Not good for nonferrous metals

ELECTROSLAG WELDING



ELECTROSLAG WELDING

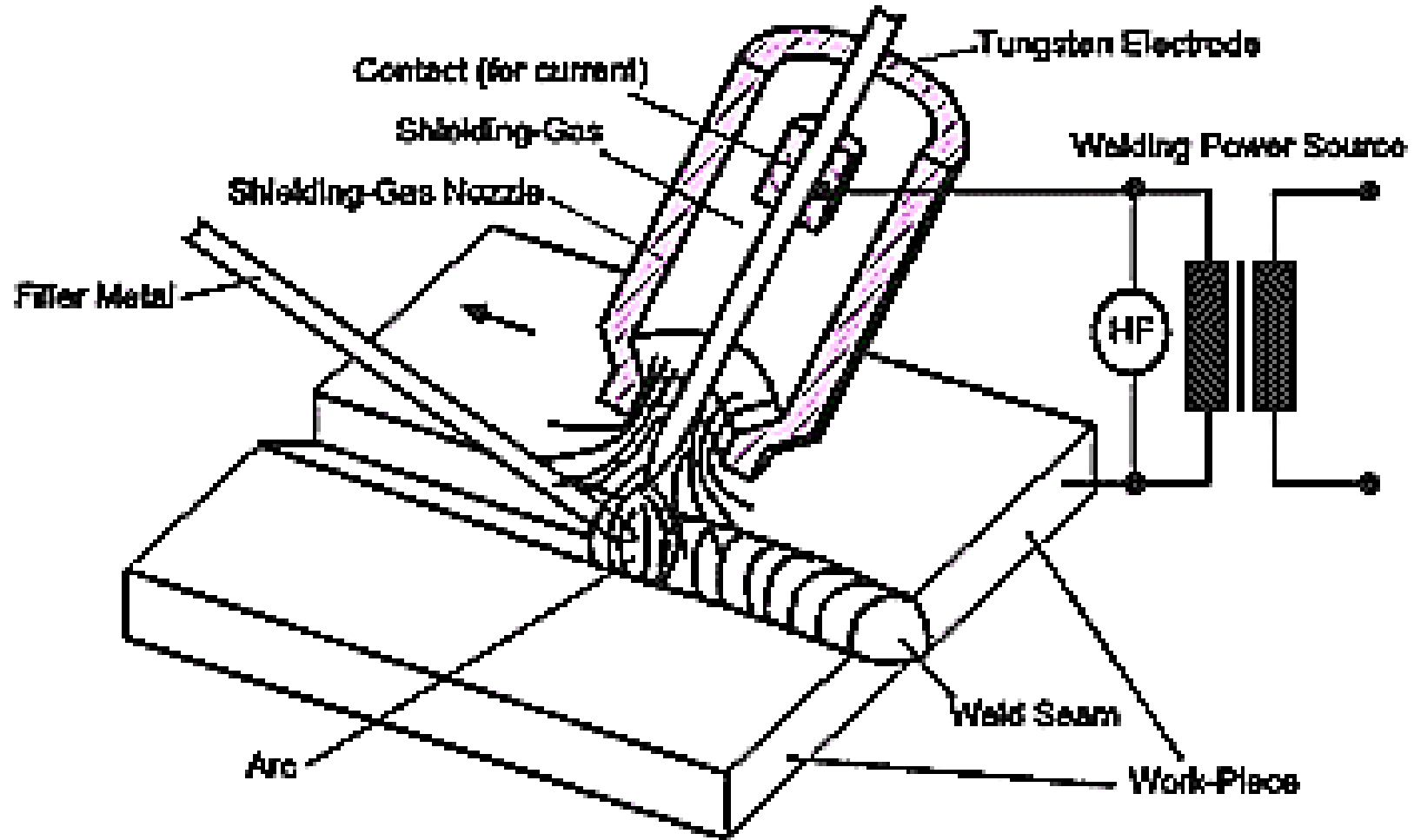
This initial charge heats a layer of loose flux that becomes molten and extinguishes the arc.

ARC WELDING - NONCONSUMABLE ELECTRODES

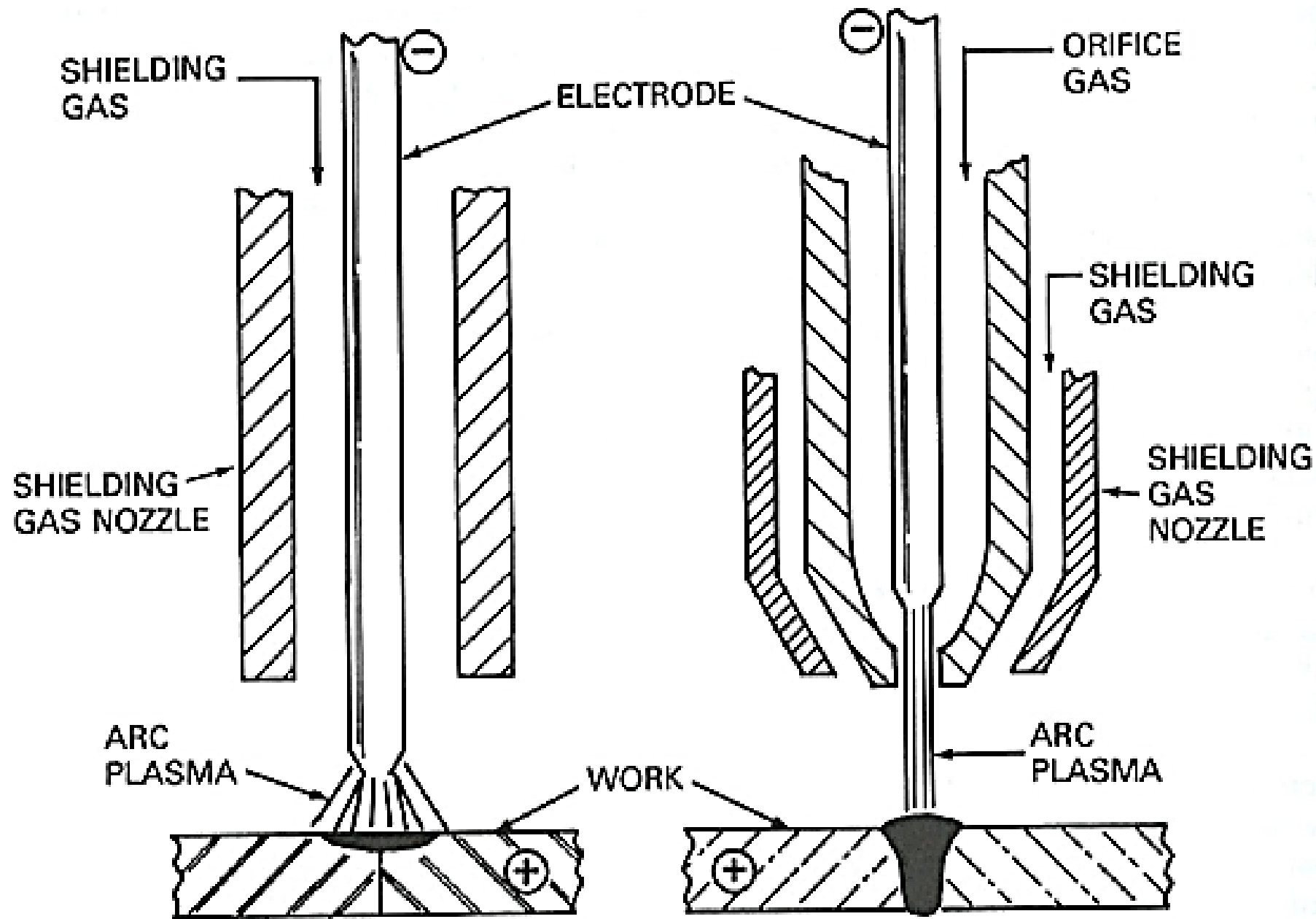
- GTAW (Gas tungsten arc welding) or TIG welding
- Plasma arc welding

TIG WELDING or GTAW

Principle of TIG Welding

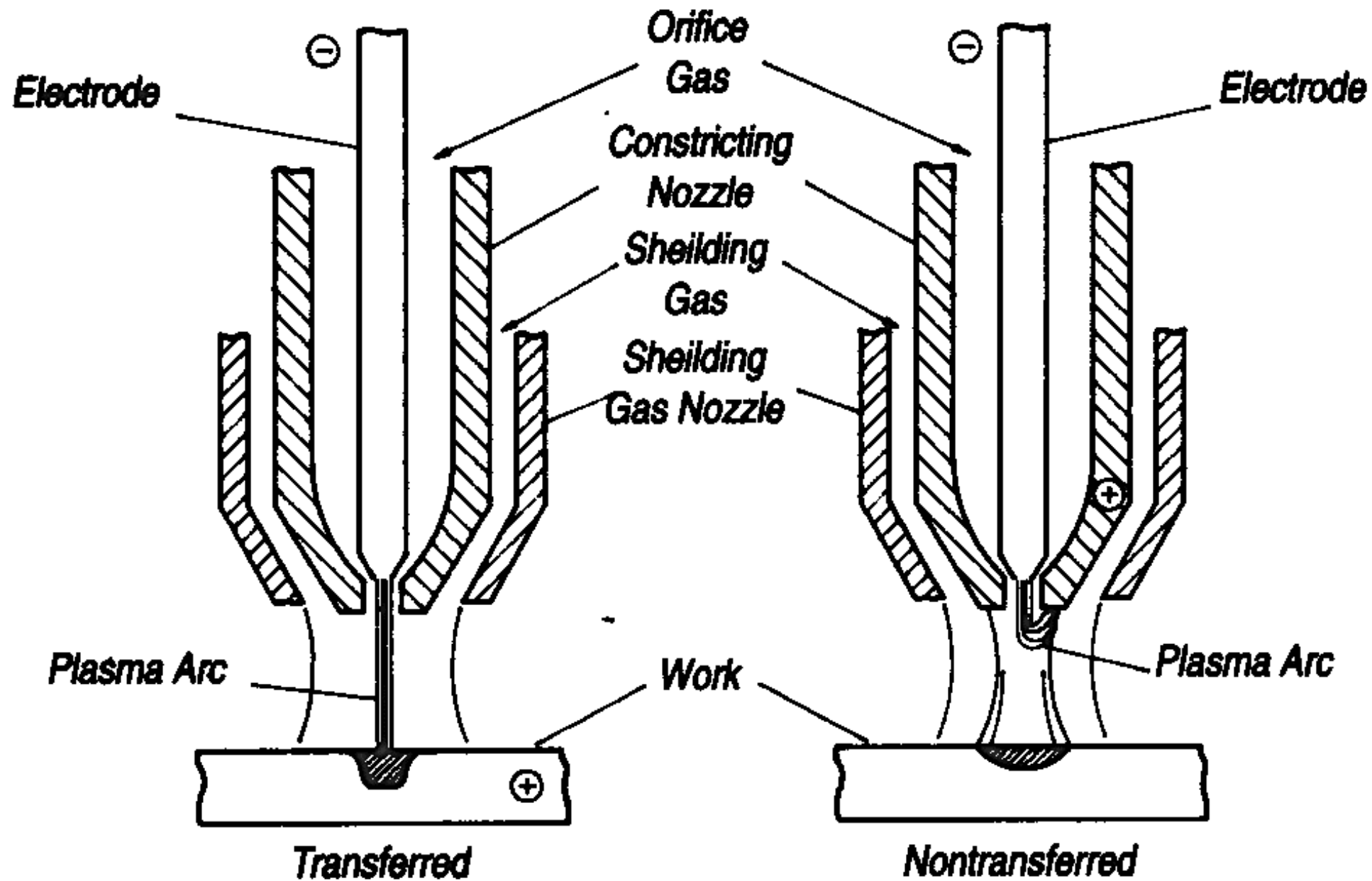


Typical flow rate of shielding inert gas may vary from 5-50 liters/min.



GAS TUNGSTEN ARC

PLASMA ARC



Transferred plasma arc welding process	Non-transferred plasma arc welding process
Arc is established between electrode and workpiece	Arc is established between electrode and nozzle.
The work piece is part of the electrical circuit and heat is obtained from the anode spot and the plasma jet. Therefore, higher amount of energy is transferred to work. This is useful for welding.	The work piece is not part of the electrical circuit and heat is obtained from the plasma jet. Therefore, less energy is transferred to work. This is useful in cutting.
Higher penetration is obtained, so thicker sheets can be welded.	Less penetration is obtained, so thin sheets can be welded.
Higher process efficiency.	Less process efficiency.

Merits and Demerits of Arc Welding

Advantages	Disadvantages
<ul style="list-style-type: none"> • Simple welding equipment 	<ul style="list-style-type: none"> • Not clean enough for reactive metals such as aluminium and titanium.
<ul style="list-style-type: none"> • Portable 	
<ul style="list-style-type: none"> • Inexpensive - Lowest cost joining method. 	<ul style="list-style-type: none"> • The deposition rate is limited because the electrode covering tends to overheat and fall off.
<ul style="list-style-type: none"> • Used for maintenance, repair, and field construction 	
<ul style="list-style-type: none"> • Most efficient way to join metals 	
<ul style="list-style-type: none"> • Affords lighter weight through better utilization of materials. 	<ul style="list-style-type: none"> • The electrode length is ~ 35 mm and requires electrode changing → lower the overall production rate.
<ul style="list-style-type: none"> • Joins all commercial metals. 	<ul style="list-style-type: none"> • Manually applied, Therefore high labor cost.
<ul style="list-style-type: none"> • Provides design flexibility. 	<ul style="list-style-type: none"> • Need high energy, hence causing danger
	<ul style="list-style-type: none"> • Not convenient for disassembly.
	<ul style="list-style-type: none"> • Defects are hard to detect at joints.

PROPERTIES OF ELECTRODES, SHIELDING GAS AND FLUX

- **Consumable electrodes** materials are selected such that finished weld metal should have similar mechanical properties that of base metal with no defects,

Consumable Electrodes contains **de-oxidising metals (Si, Mn, Ti, Al) and de-nitrating metals (zirconium)** in small percentages to prevent entrapment of oxygen and nitrogen in the weld, **reducing the porosity** and giving continuous weld.

- **Shielding gas** is necessary to protect weld area from atmospheric gases, thereby reducing porosity and cracking.

EG. argon, helium, carbon dioxide etc

- **Flux** when melted by the arc, mixes with the impurities in the weld pool and **forms slag and covers the weld pool from contamination.**

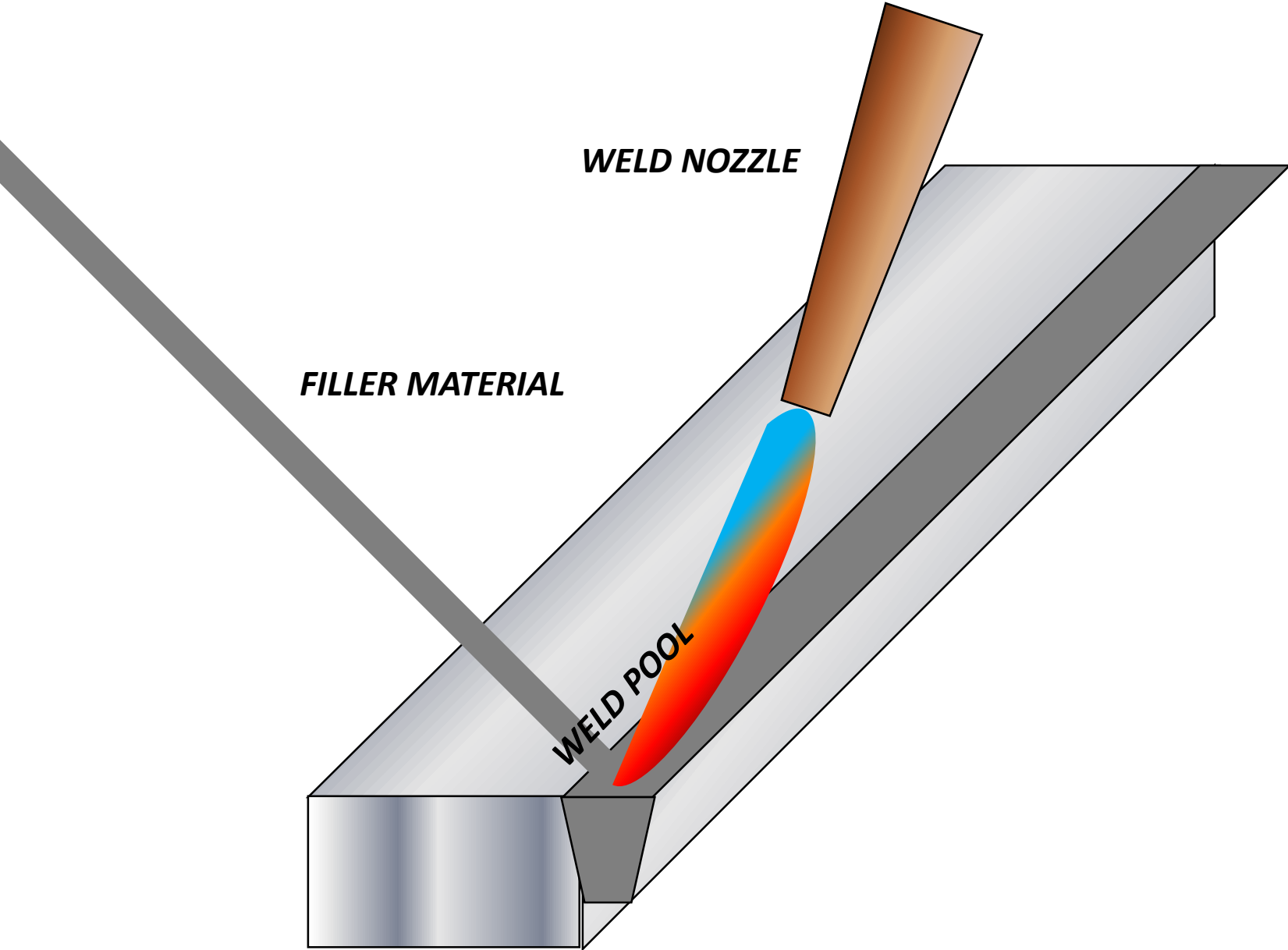
E.G. lime, silica, manganese dioxide, calcium fluoride etc

flux is either **coated on the electrode surface, or inside the electrode, or provided additionally(non-consumable electrodes).**

GAS WELDING

OXY – ACETELYNE GAS WELDING

OXYGEN + ACETELYNE



WELD NOZZLE

FILLER MATERIAL

WELD POOL

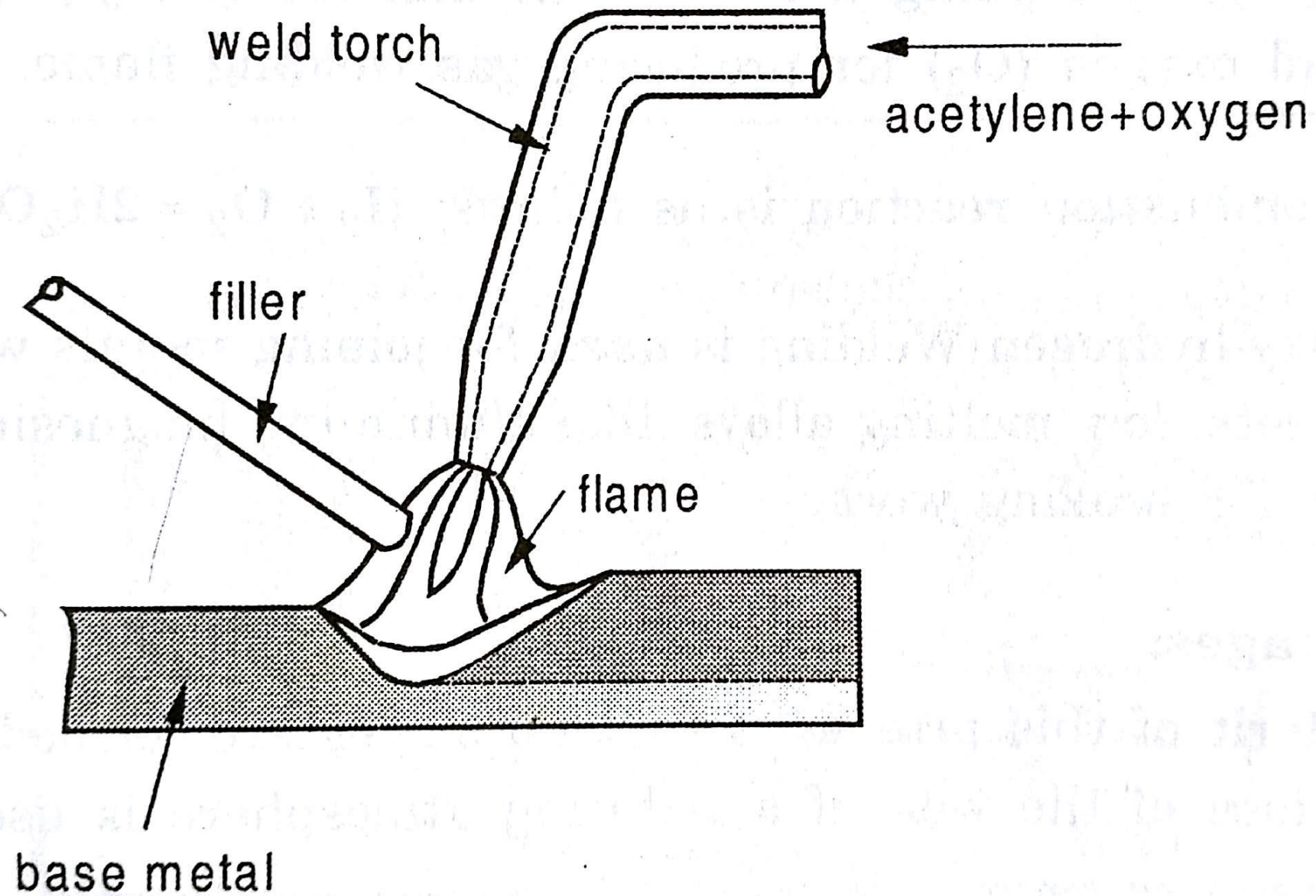
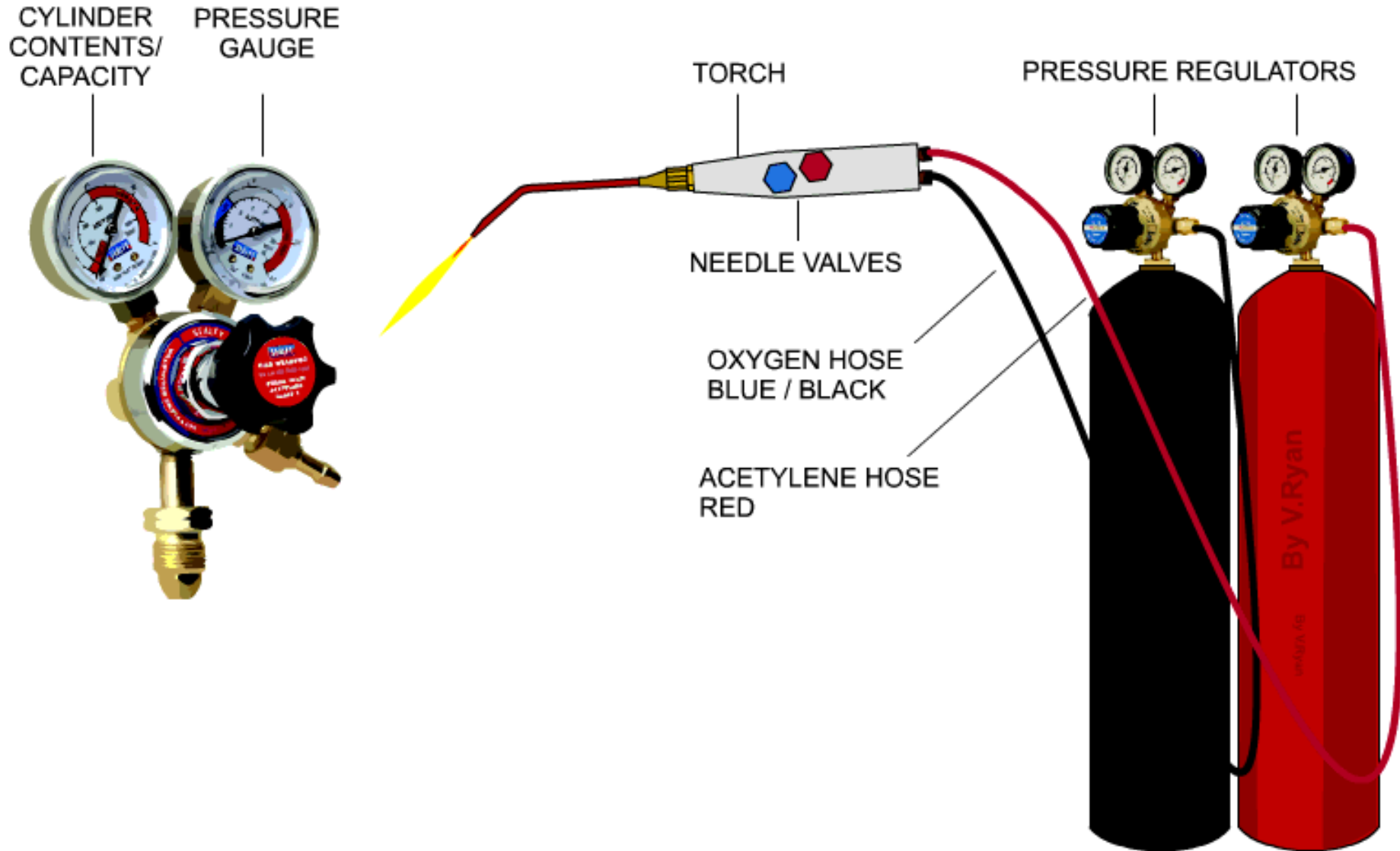


Fig. 5.62. Typical Oxy- Acetylene gas welding process.

OXY-ACETELYNE GAS WELDING SETUP



- Gas welding is a fusion welding process.
- Acetylene burned in oxygen is used as source of heat. This heat is used to fuse the metal joints.

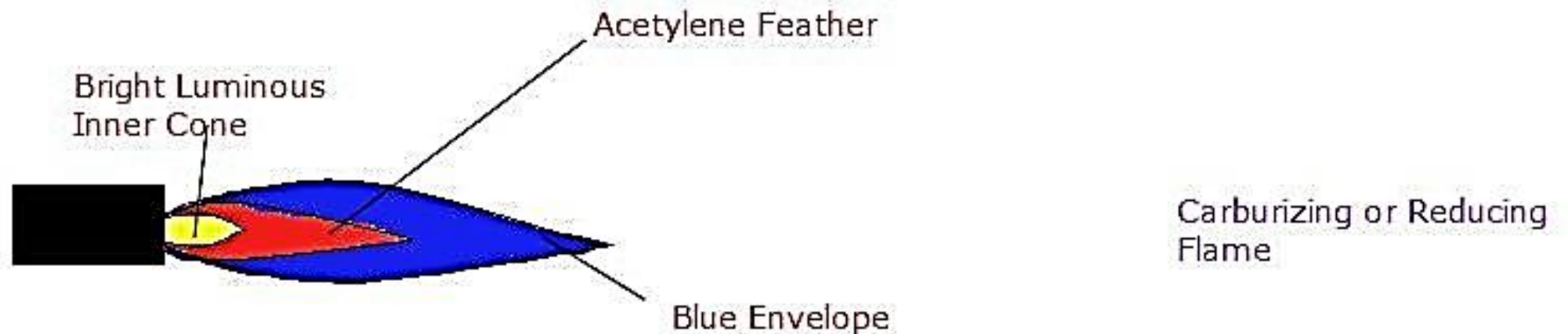
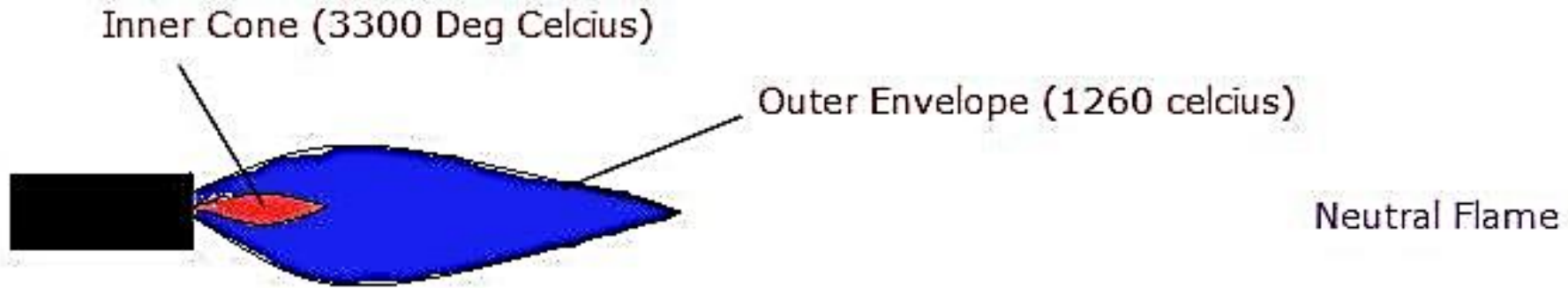
ADVANTAGES

1. Simple
2. Portable
3. Easy maintenance

DISADVANTAGES

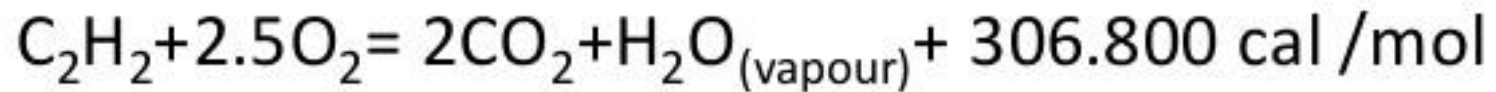
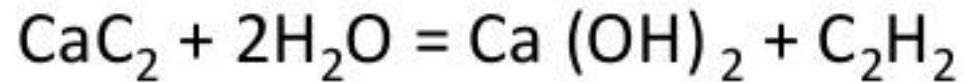
1. Very low welding speed,
2. Large amount of heat is required, **some amount of heat is wasted, since heat is distributed over a large area.**
3. large **heat affected zones.**
4. Should not be used with reactive metals like **Titanium and Zirconium.**

TYPES OF FLAMES

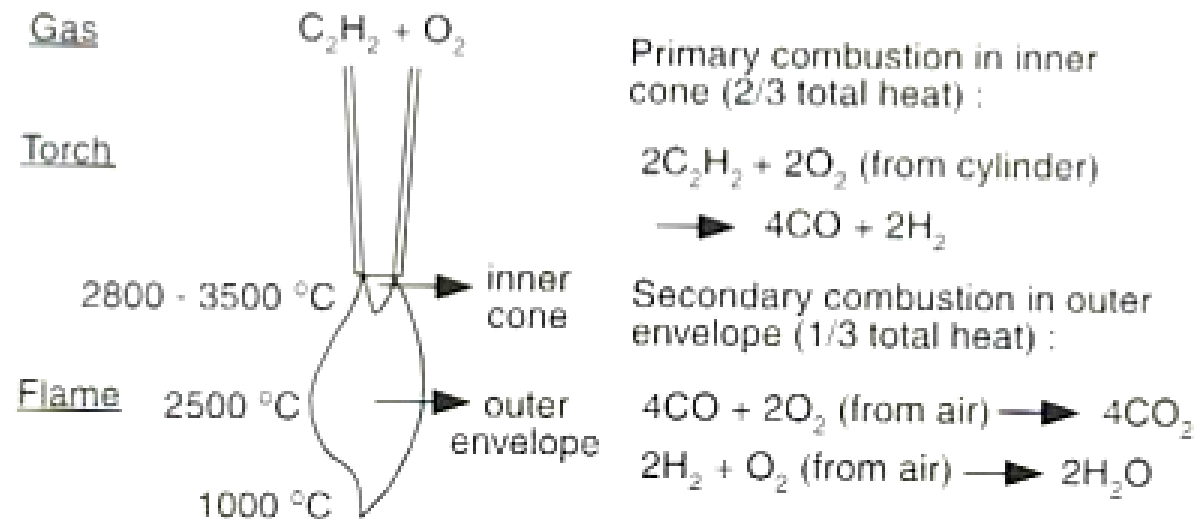


Gas Welding

- **Oxy-acetylene Welding:**



Chemical reactions and temperature distribution in a neutral oxyacetylene



The secondary combustion is also called the protection envelope since CO and H₂ here consume the O₂ entering from surrounding air, thereby protecting the weld from oxidation.

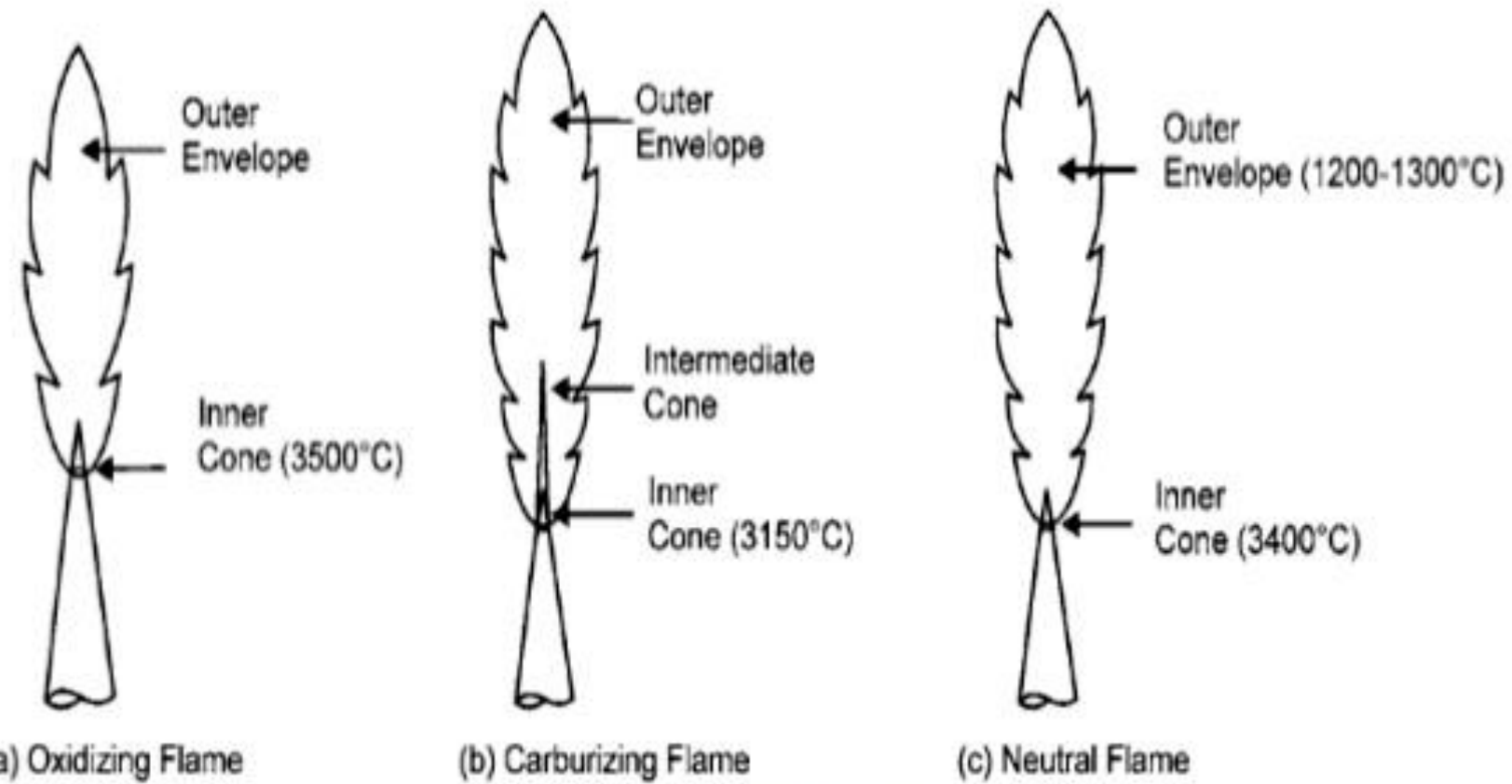
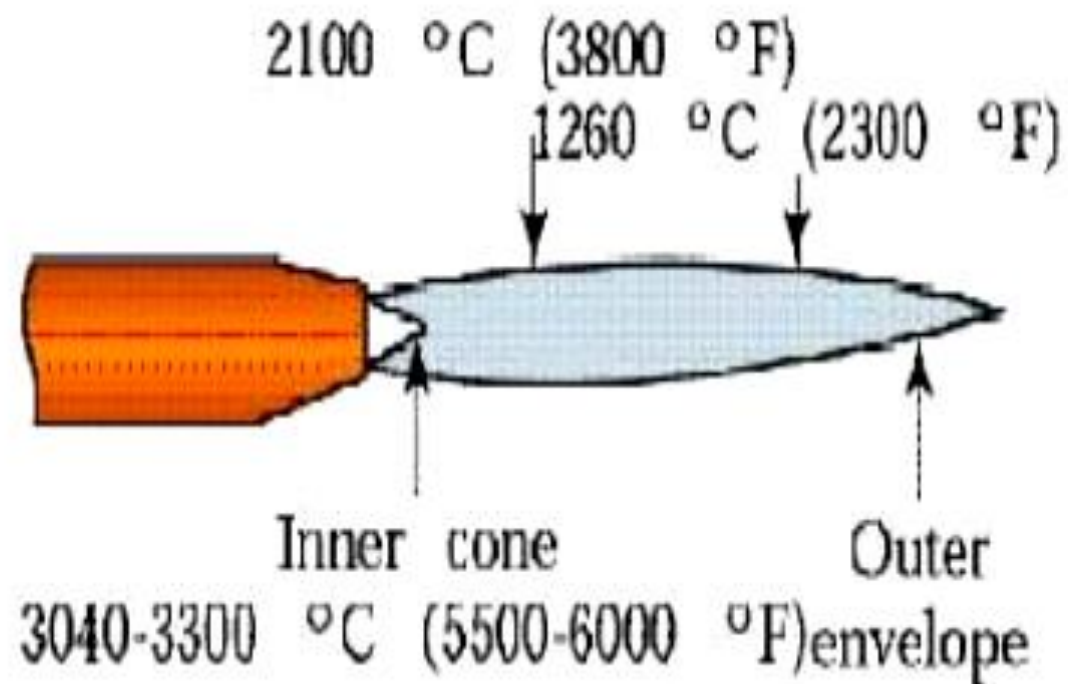


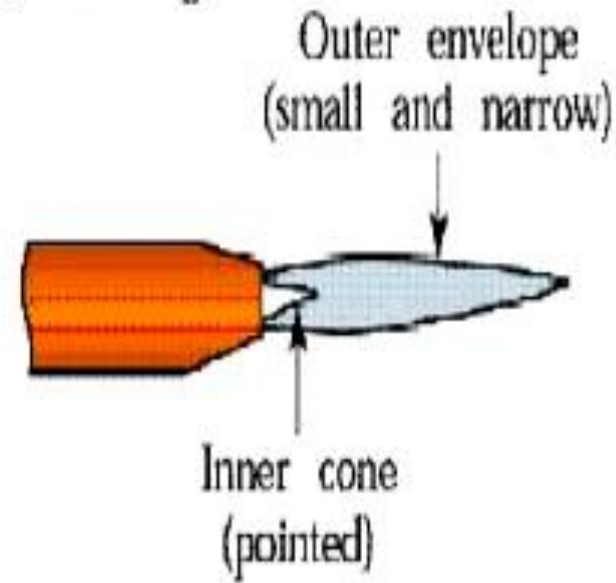
Fig. 7.3: Types of Flames

(a) Neutral flame

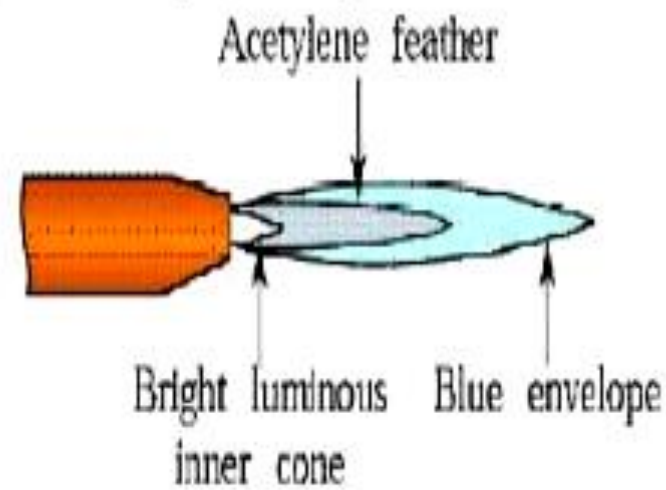


Three basic types of oxyacetylene flames used in oxyfuel-gas welding and cutting operations: (a) neutral flame; (b) oxidizing flame; (c) carburizing, or reducing flame.

(b) Oxidizing flame



(c) Carburizing (reducing) flame



Three basic types of oxyacetylene flames used in oxyfuel-gas welding and cutting operations:

(a) neutral flame; (b) oxidizing flame; (c) carburizing, or reducing flame.

Types of Gas Welding

- 1. Leftward Welding
- 2. Rightward Welding

Gas welding two types

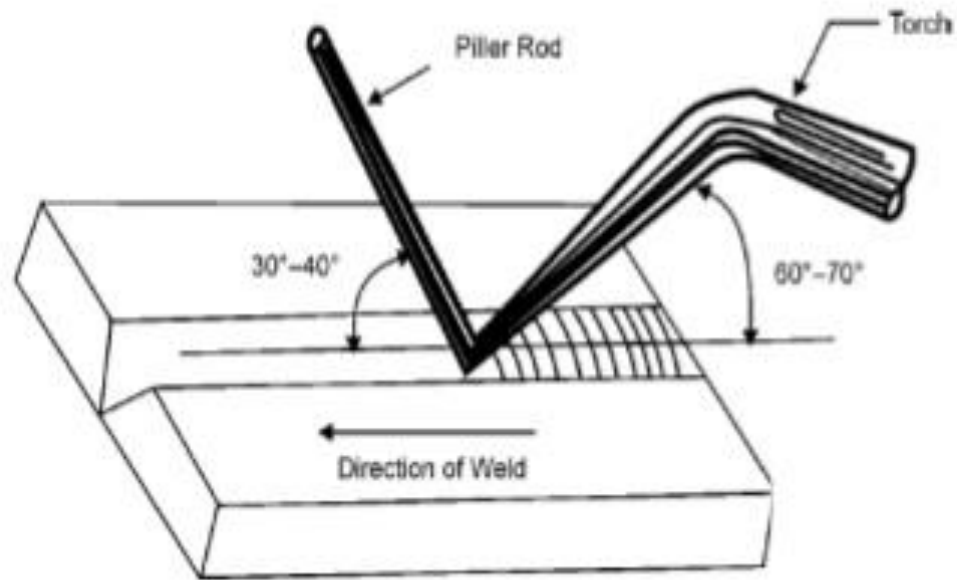


Fig. 7.4: Leftward Welding

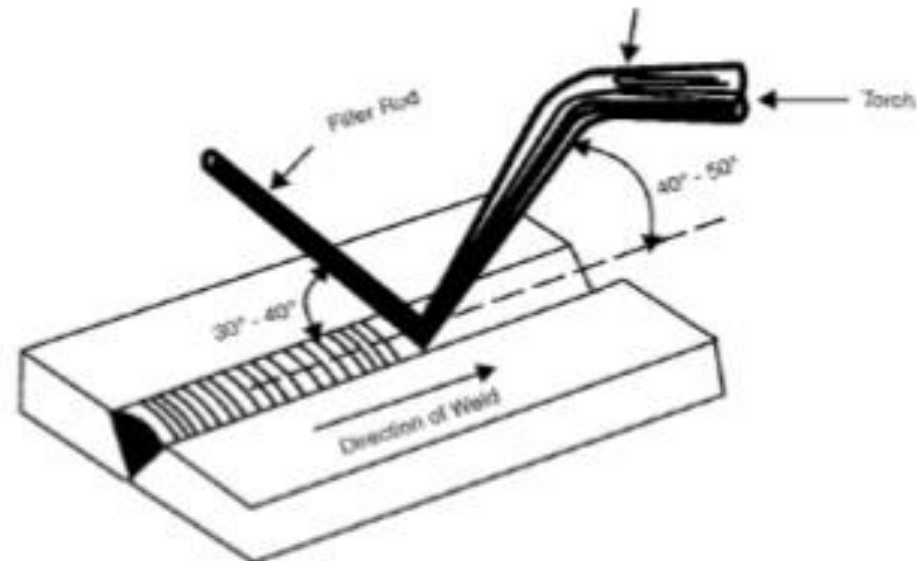


Fig. 7.5: Rightward Welding

GAS WELDING EQUIPMENTS

1. Gas Cylinders

Pressure

Oxygen – 125 kg/cm²

Acetylene – 16 kg/cm²

2. Regulators

Working pressure of oxygen 1 kg/cm²

Working pressure of acetylene 0.15 kg/cm²

Working pressure varies depending upon the thickness of the work pieces welded.

3. Pressure Gauges

4. Hoses

5. Welding torch

6. Check valve

7. Non return valve

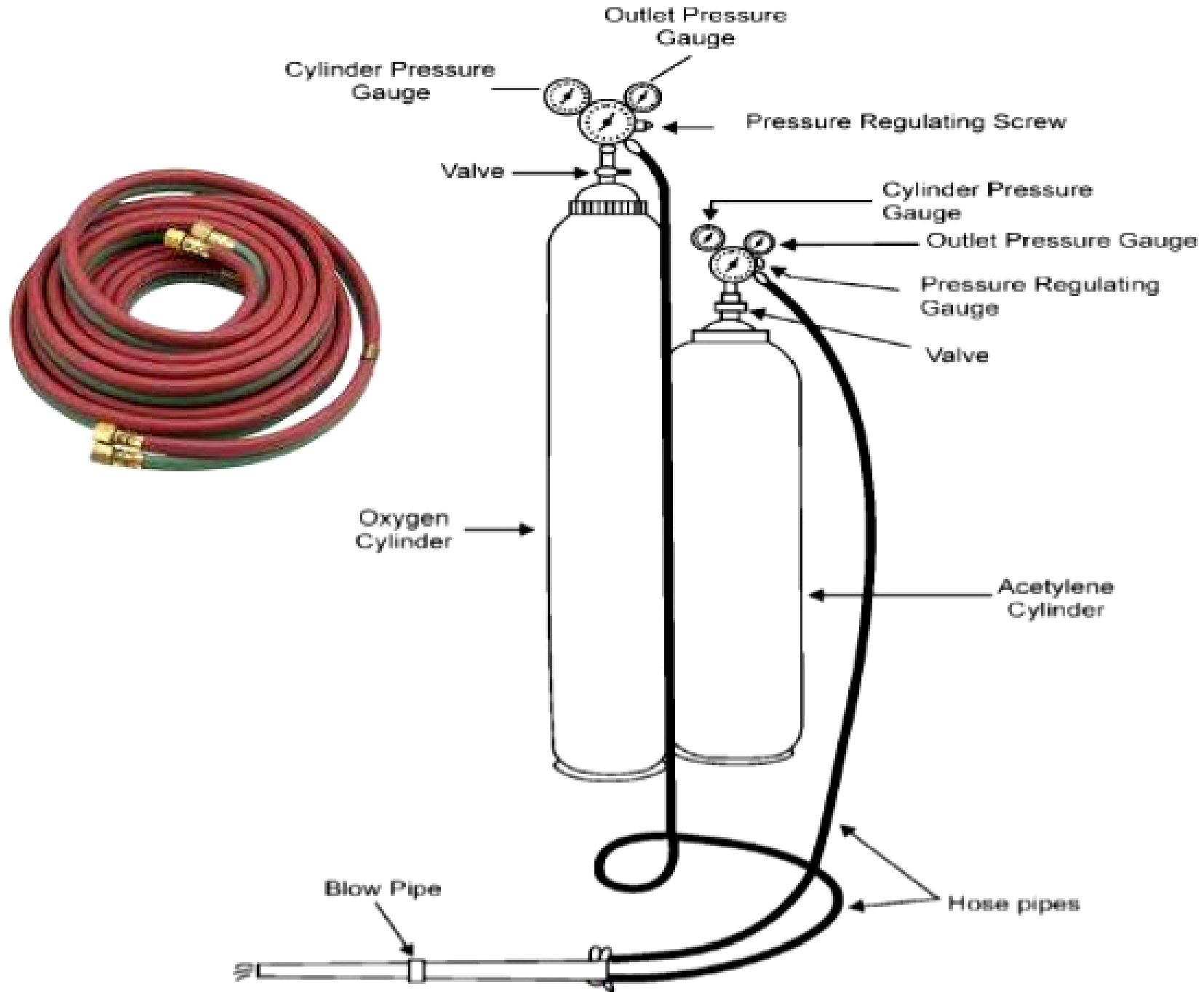


Fig. 7.2: Apparatus for Gas Welding

Gas welding Apparatus

1. Oxygen cylinder
2. Acetylene cylinder
3. Pressure gauges
4. Valves
5. Hose pipes
6. Torch
7. Welding tip
8. Pressure regulators
9. Lighter
10. Goggles



Gas welding torch

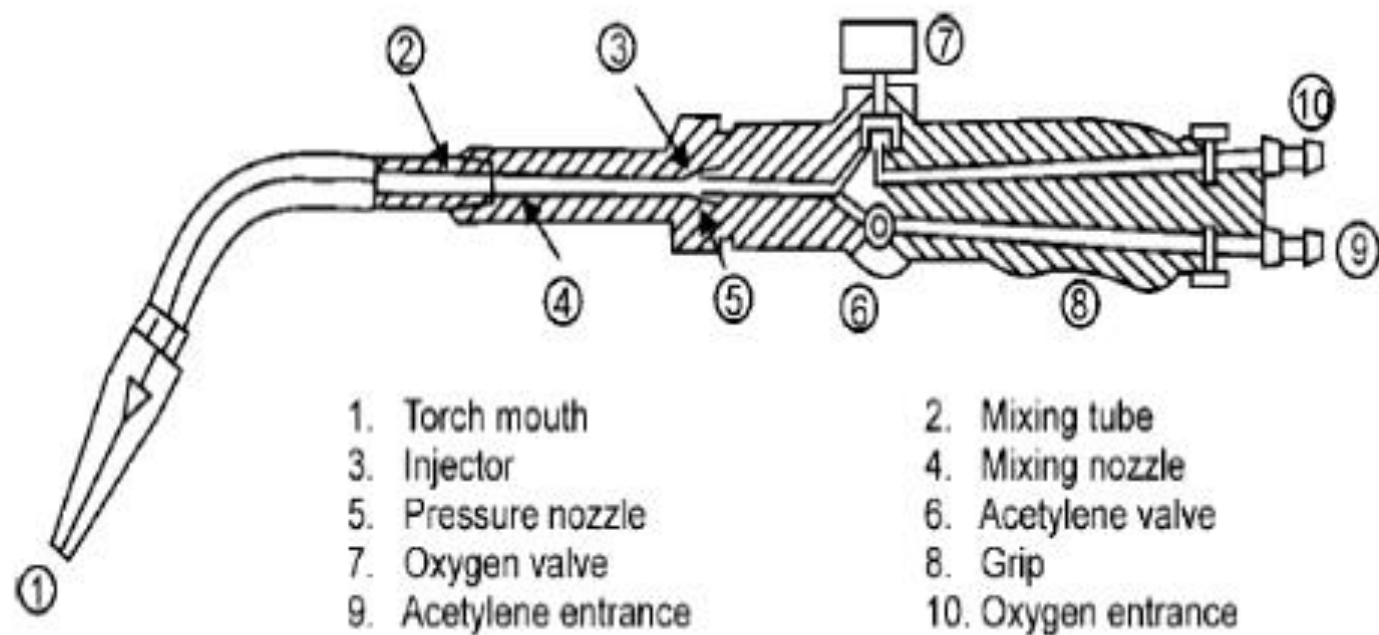


Fig. 7.9: Welding Torch

Gas Welding - Advantages

- Simple equipment
- Portable
- Inexpensive
- Easy for maintenance and repair

Gas Welding - Disadvantages

- Limited power density
- Very low welding speed
- High total heat input per unit length
- Large heat affected zone
- Severe distortion
- Not recommended for welding reactive metals such as titanium and zirconium.

WELD DEFECTS

- **WELD SPATTER-**

*Caused by a long arc length, very high current, or a phenomenon called **arc blow (electric arc being deflected away from the weld pool by magnetic forces).***

Damages appearance of the weld and increases cleaning cost.

- **POROSITY-**

*Caused due to **arc blow***

- **POOR FUSION-**

Caused by low current, contaminated joint surface, improper electrode

- **SHALLOW PENETRATION –**

Caused by decreased melting of electrodes. This can be prevented by decreasing weld speed, increasing the current , using smaller electrodes

- **CRACKING-**

High carbon content, high allow content, high sulphur content and Excessive restraining of base metal which causes internal stress inside the weld, which leads to cracking when cools down or contracts.

TYPES OF WELD JOINTS

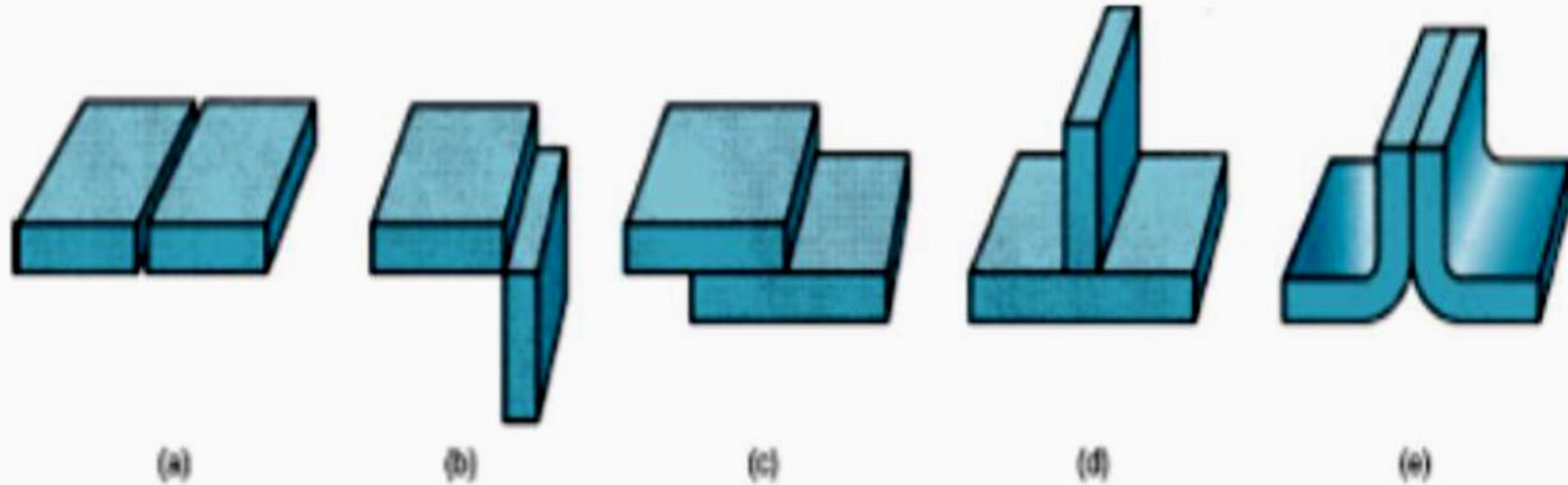
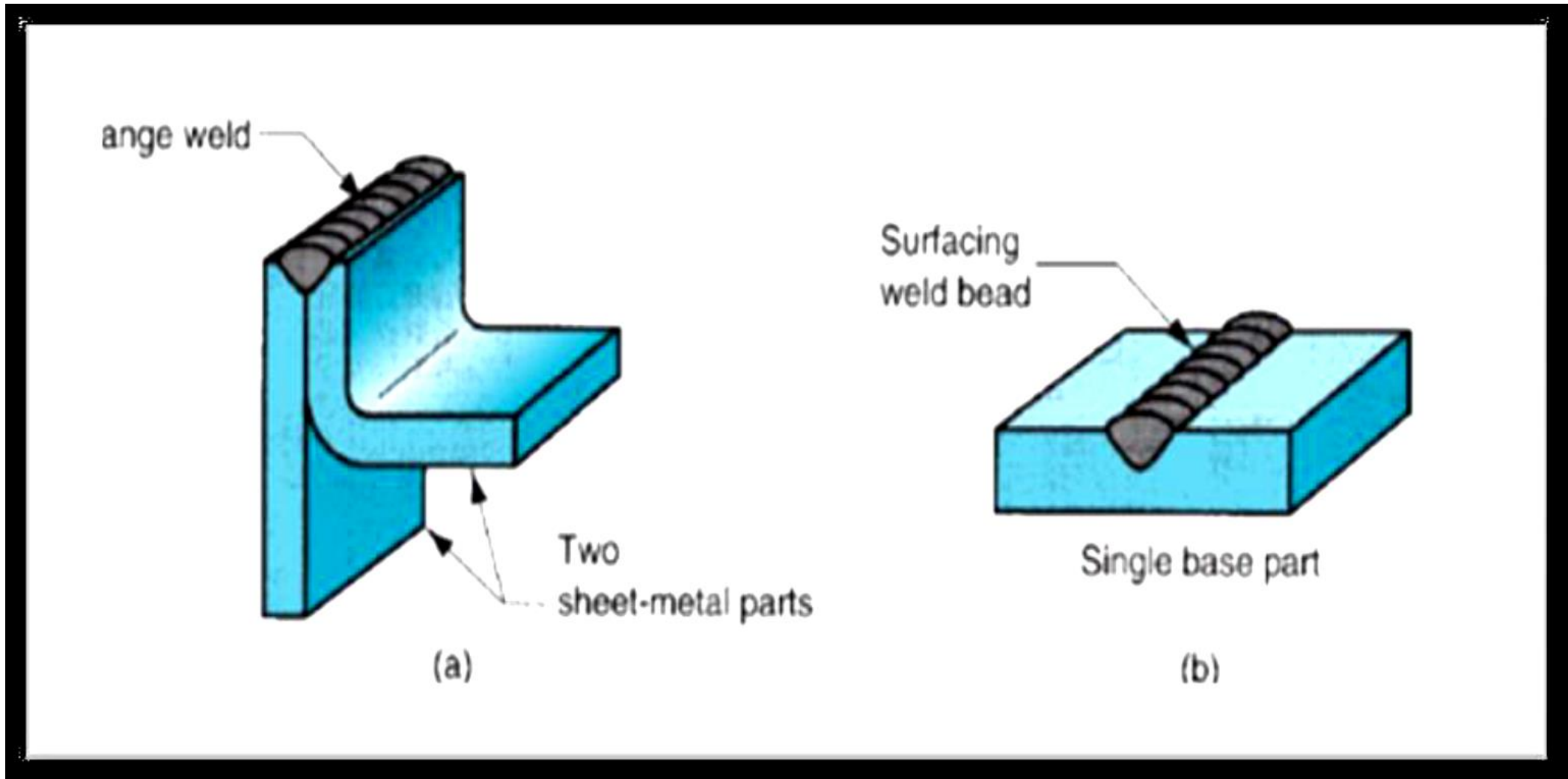


FIGURE 29.2 Five basic types of joints: (a) butt, (b) corner, (c) lap, (d) tee, and (e) edge.

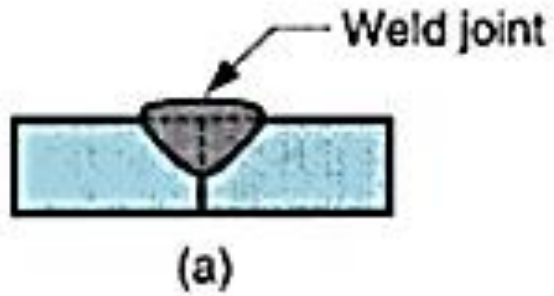
BUTT JOINT, CORNER JOINT, LAP JOINT, TEE JOINT, EDGE JOINT



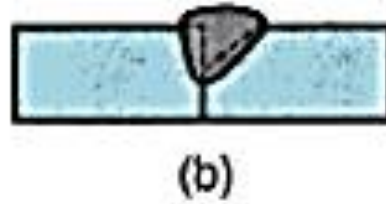
FLANGE WELDS AND SURFACING WELDS

GROOVE WELDS

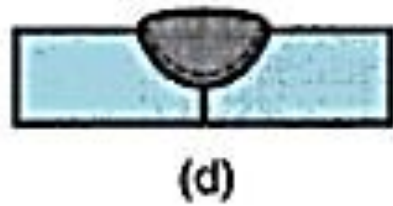
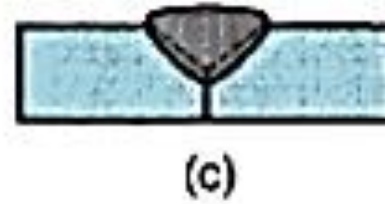
(a) square groove weld,



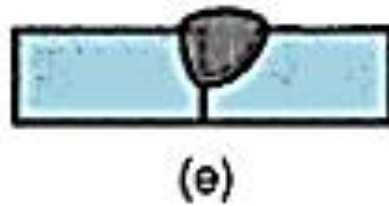
(b) single bevel groove weld



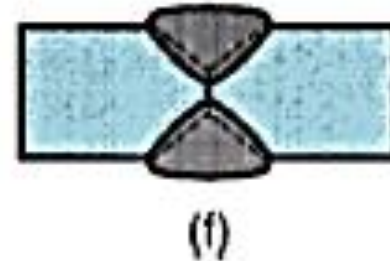
(c) single V-groove weld



(d) single U-groove weld

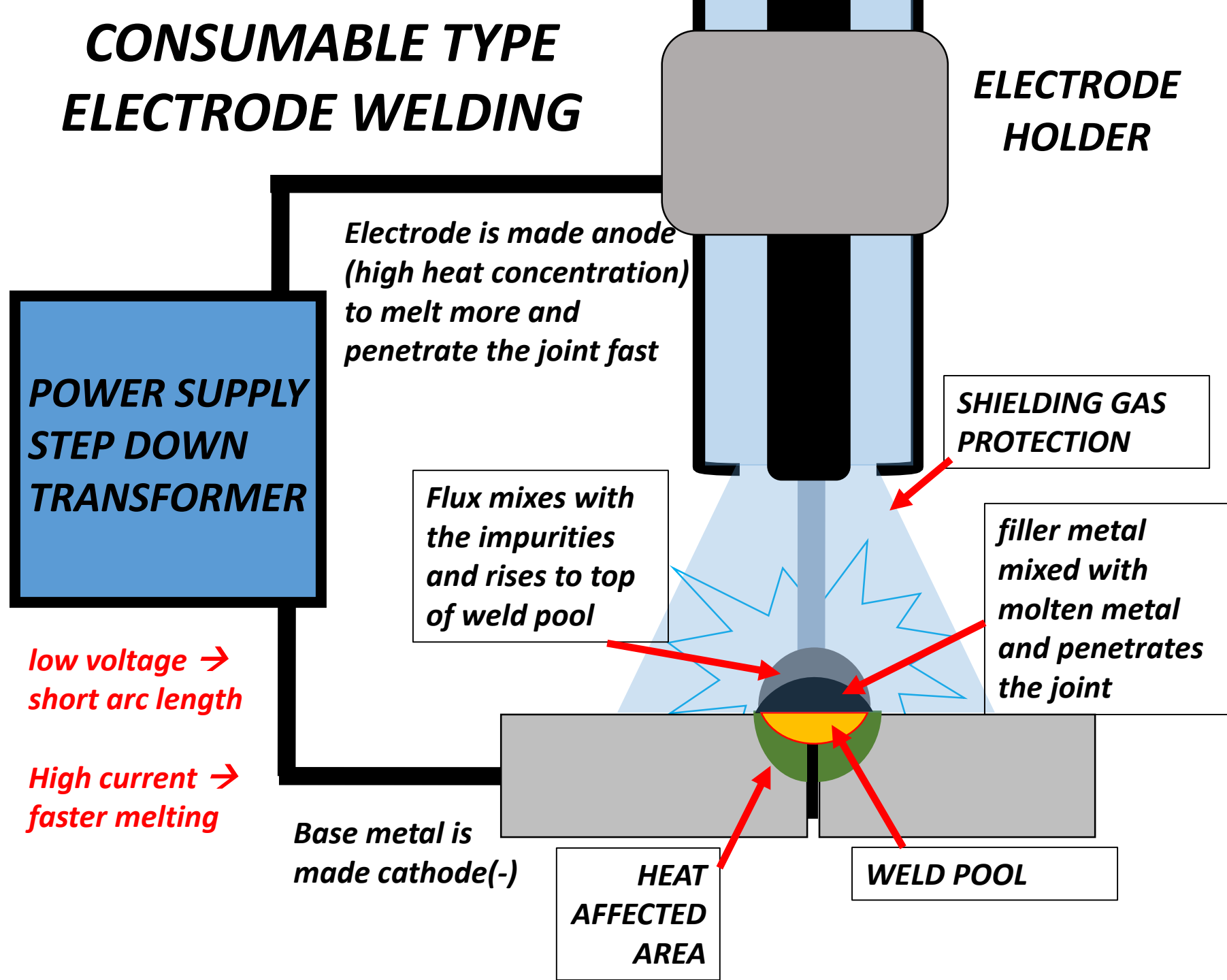


(e) single J-groove weld

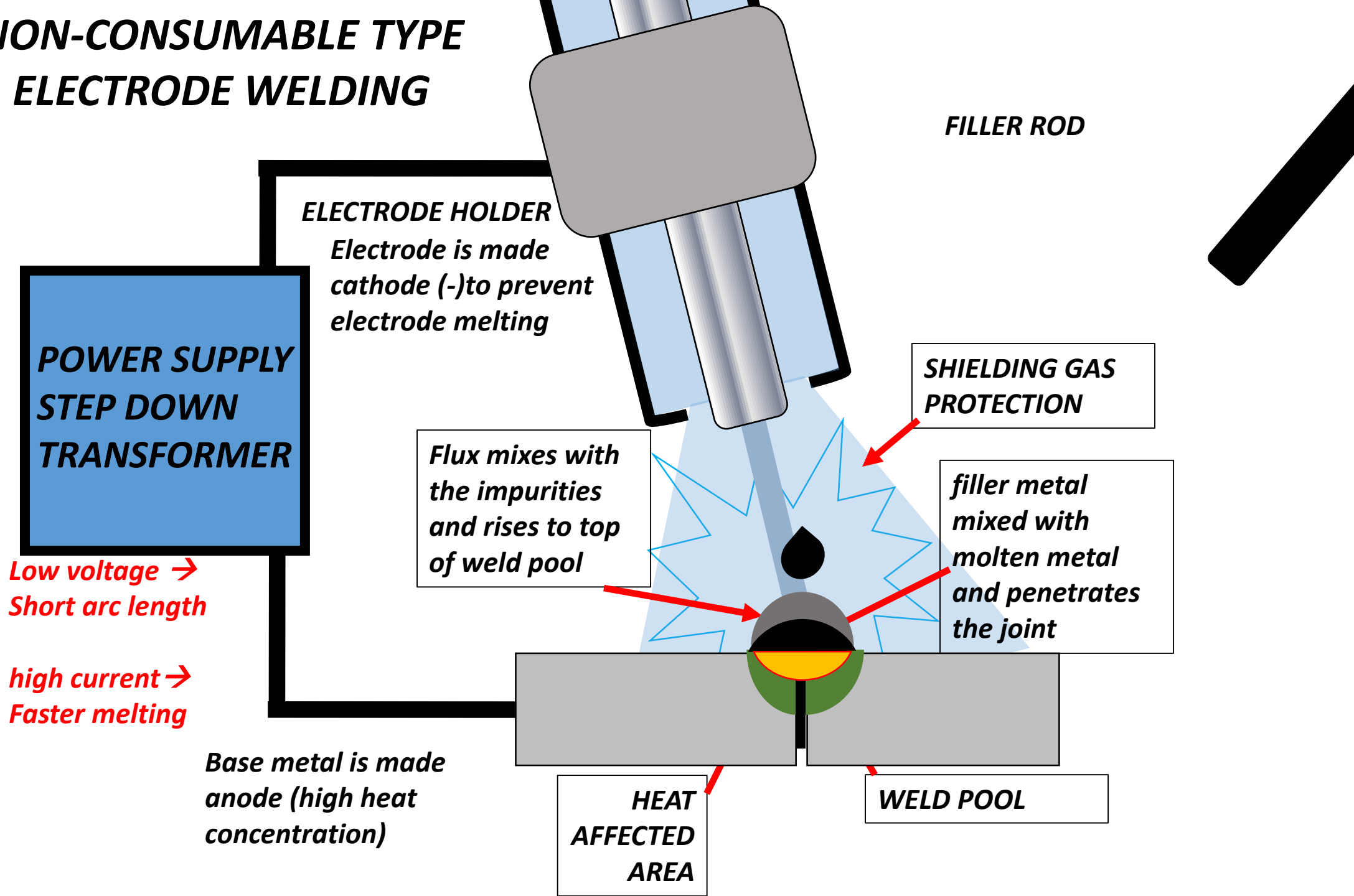


(f) Double V-groove weld for thicker sections

CONSUMABLE TYPE ELECTRODE WELDING



NON-CONSUMABLE TYPE ELECTRODE WELDING



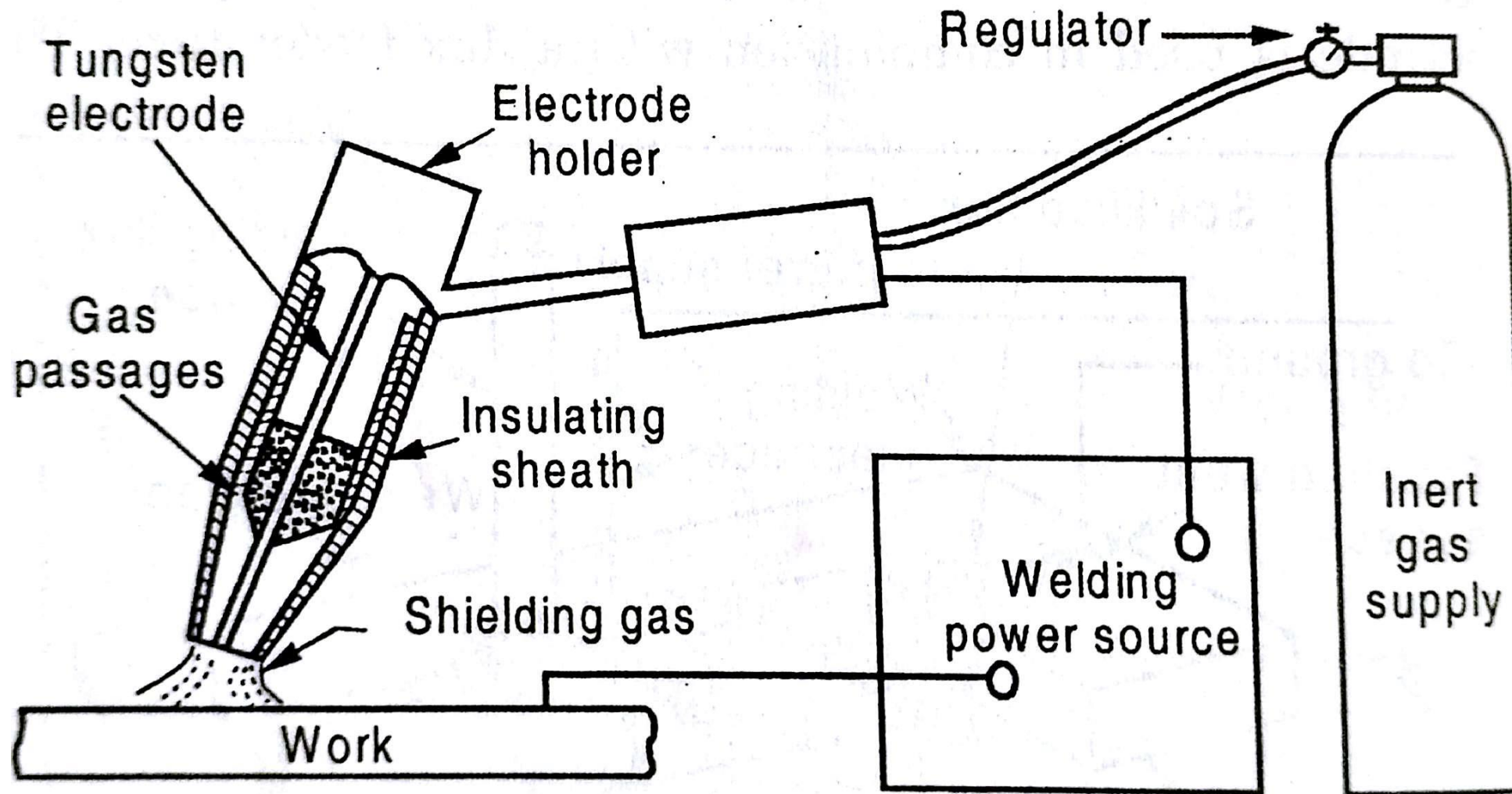


Fig. 5.67 Tungsten inert gas welding setup

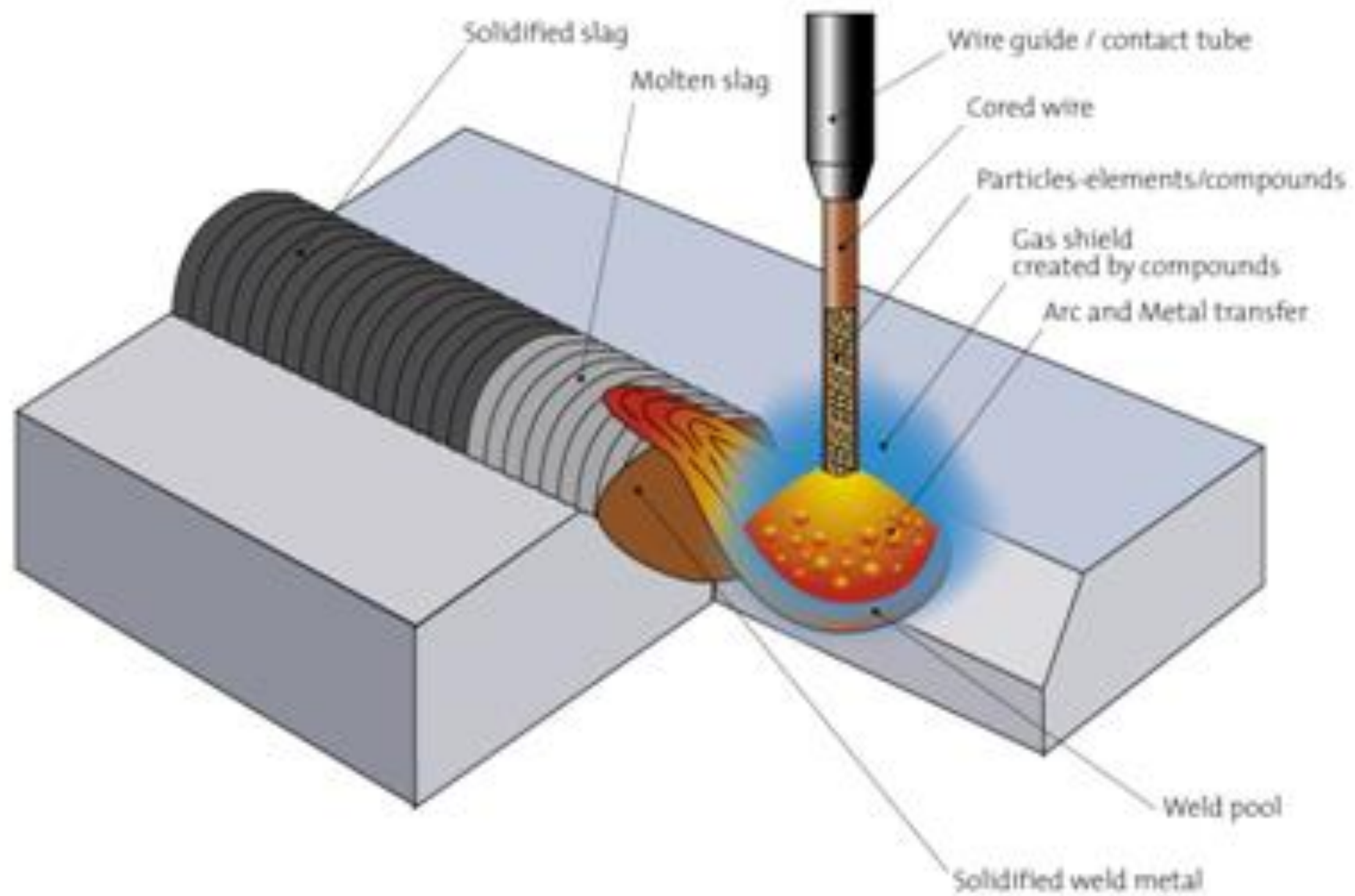
	GAS WELDING	ARC WELDING
1.	Heat is produced by the gas flame	Heat is produced by electric arc
2.	The flame temperature is about 3200°C	In arc welding, the temperature of arc is about 4000°C
3.	Separate filler rod introduced	Arc producing as well as filler rod material is the electrode
4.	Suggested for thin materials	Suggested for medium and thick materials
5.	Gas welded parts do not have much strength	Arc welded parts have very high strength.
6.	Filler metal may not be the same parent metal.	Filler metal must be same or an alloy of the parent metal.
7.	Brazing and Soldering are done using gas.	Brazing and Soldering can't be carried out by electric arc.

METAL INERT GAS WELDING

ADVANTAGES	DISADVANTAGES	METALS	APPLICATIONS
<p>1. <i>Speed due to continuously fed filler electrodes</i></p>	<p>1. <i>cannot be used in areas of high air movement, Because of the need to maintain a stable shroud of shielding gas</i></p> <p>2. <i>Pority of the welded joints because solidification of the weld pool takes place before the escape of entrapped gas.</i></p> <p>3. <i>Forms Solid impure Aluminium dross floating on the weld pool</i></p> <p>4. <i>complicated equipment</i></p>	<p>1. <i>welding metals with high thermal conductivities like <u>aluminium</u> and other <u>non-ferrous, steels</u>.</i></p>	<p><i>automobile industries.</i></p>

FLUX-CORED ARC WELDING

- *Flux-cored arc welding (FCAW or FCA) is a semi-automatic or automatic arc welding process.*
- *Tubular consumable electrode containing a flux which provides necessary protection from the atmosphere and metal impurities, is continuously-fed to weld point.*
- *constant-voltage or, less commonly, a constant-current welding power supply.*
- *An externally supplied shielding gas is sometimes used*



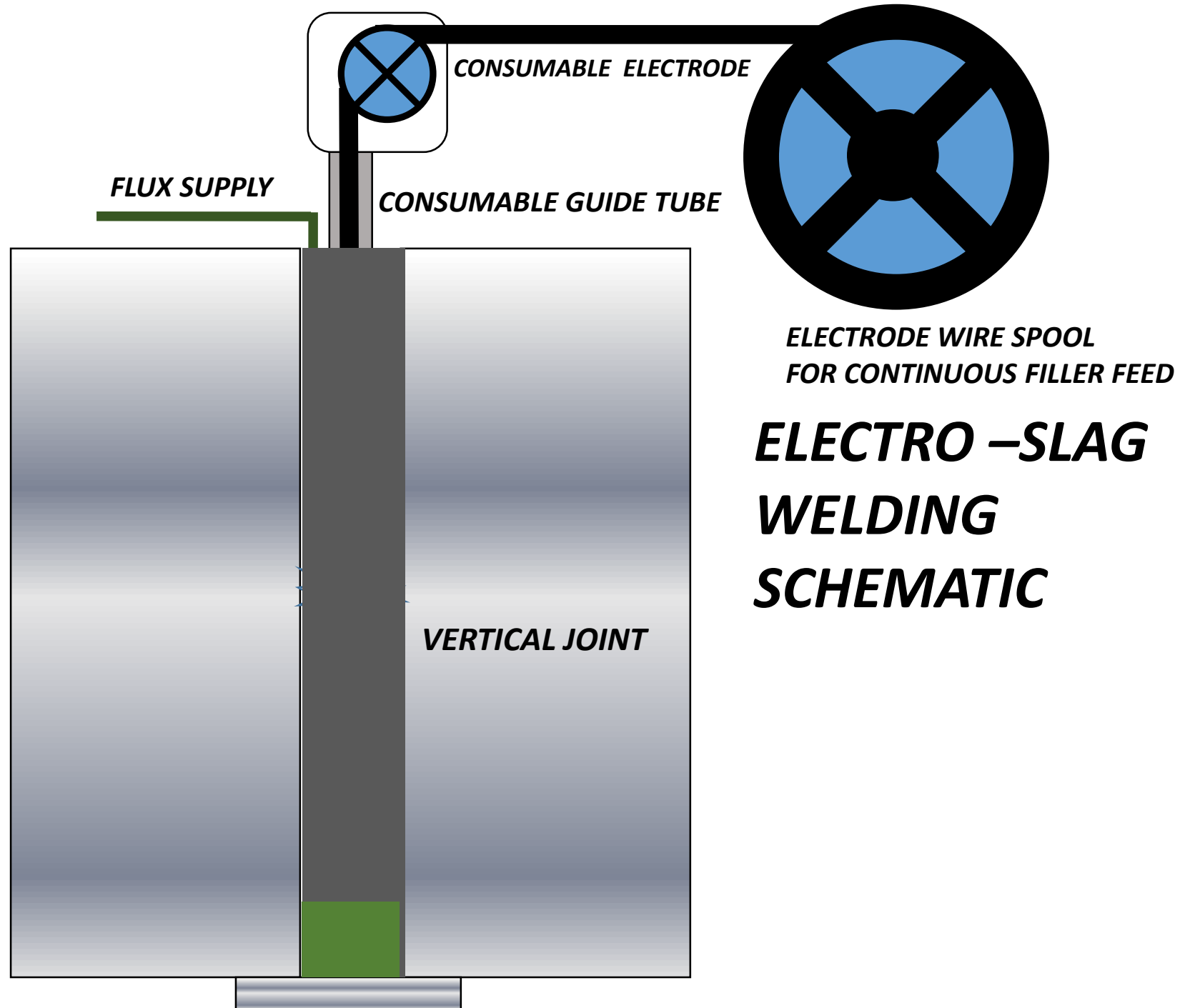
ADVANTAGES	DISADVANTAGES	METALS	APPLICATIONS
<ol style="list-style-type: none"> 1. All position welding 2. high welding speed 3. Portability 4. thicker and out-of-position metals 5. higher production rate 6. fewer weld defects 7. slag is also easy to remove 	<ol style="list-style-type: none"> 1. cannot be used in a windy environment 2. excessive, noxious smoke (making it difficult to see the weld pool) 3. Skilled operation 4. Contact tip melting, preventing flux flow. 5. Costly electrode 6. Irregular wire feed 	<ol style="list-style-type: none"> 1. Alloy steels 2. Nickel alloys 	<ol style="list-style-type: none"> 1. Construction 2. Automotive industries

SUBMERGED ARC WELDING

<i>ADVANTAGES</i>	<i>DISADVANTAGES</i>	<i>METALS</i>	<i>APPLICATIONS</i>
<ol style="list-style-type: none"><i>1. No weld spatters</i><i>2. No fumes</i><i>3. No visible spark</i><i>4. High welding speed</i><i>5. Deep weld penetration for thick plates</i><i>6. Suitable for indoor and outdoor work</i><i>7. Minimal weld defect</i>	<ol style="list-style-type: none"><i>1. Limited to flat horizontal surfaces</i><i>2. Non visibility of process.</i>	<ol style="list-style-type: none"><i>1. Steels</i><i>2. Nickel alloys</i>	<ol style="list-style-type: none"><i>1. Structural and ship/barge constructions</i>

TUNGSTEN INERT GAS WELDING

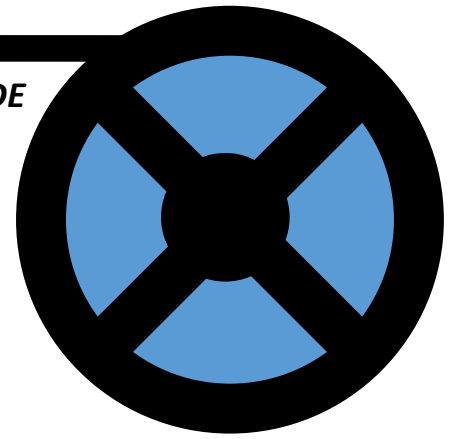
ADVANTAGES	DISADVANTAGES	METALS	APPLICATIONS
<ol style="list-style-type: none">1. Great control over weld area2. Strong high quality welds.3. Filler metal is not in direct contact with the arc, so no filler metal is wasted by vaporization	<ol style="list-style-type: none">1. Complex2. More operator skill3. Slower process4. Manual filler metal feed5. Difficult to maintain short arc length6. Ultra-violet radiation7. Formation of ozone due to arc plasma8. If current exceeds, tungsten inclusion may take place in the base metal.	<ol style="list-style-type: none">1. Stainless steel2. Aluminium3. magnesium4. Zinc and alloys	<ol style="list-style-type: none">1. Aerospace industry2. Space vehicles3. Bicycle industry4. Naval applications



CONSUMABLE ELECTRODE

FLUX SUPPLY

CONSUMABLE GUIDE TUBE



*ELECTRODE WIRE SPOOL
FOR CONTINUOUS FILLER FEED*

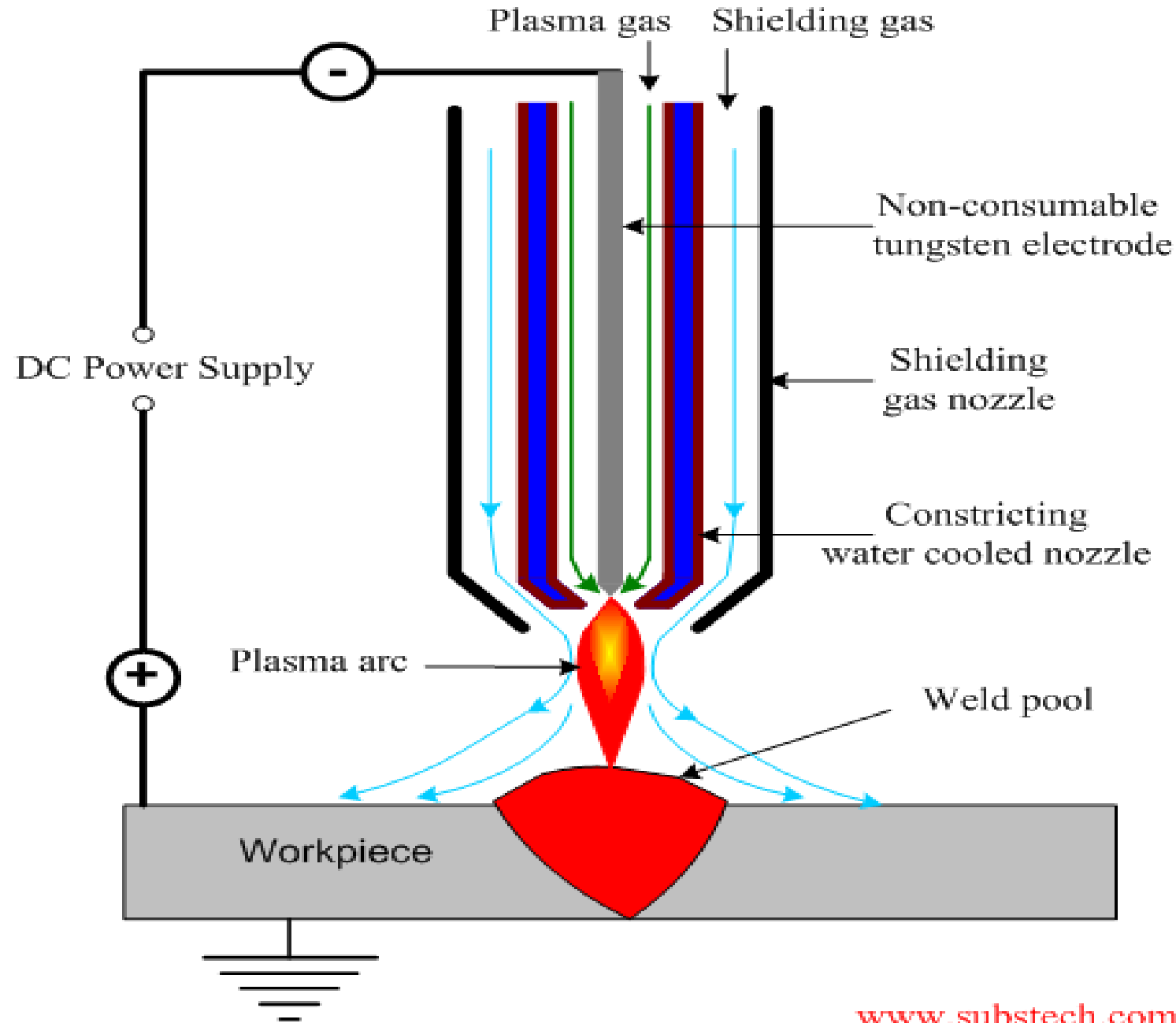
***ELECTRO –SLAG
WELDING
SCHEMATIC***

VERTICAL JOINT

Electroslag Welding

<i>ADVANTAGES</i>	<i>DISADVANTAGES</i>	<i>METALS</i>	<i>APPLICATIONS</i>
<ol style="list-style-type: none"><i>1. Single pass is sufficient</i><i>2. Thick materials</i><i>3. High filler metal utilization</i><i>4. No weld spatter, because no arc</i><i>5. Skilled operators not required</i><i>6. Minimum joint preparation and cleaning</i>	<ol style="list-style-type: none"><i>1. Restricted to vertical position</i><i>2. High heat input leads to poor weld quality.</i>	<ol style="list-style-type: none"><i>1. Cast iron</i><i>2. Aluminium</i><i>3. Magnesium</i><i>4. Copper</i><i>5. titanium</i>	<ol style="list-style-type: none"><i>1. Ship building</i><i>2. Building Construction</i><i>3. Machine frames</i><i>4. Heavy pressure vessels</i><i>5. Joining turbine casting</i>

Plasma Arc Welding (PAW)

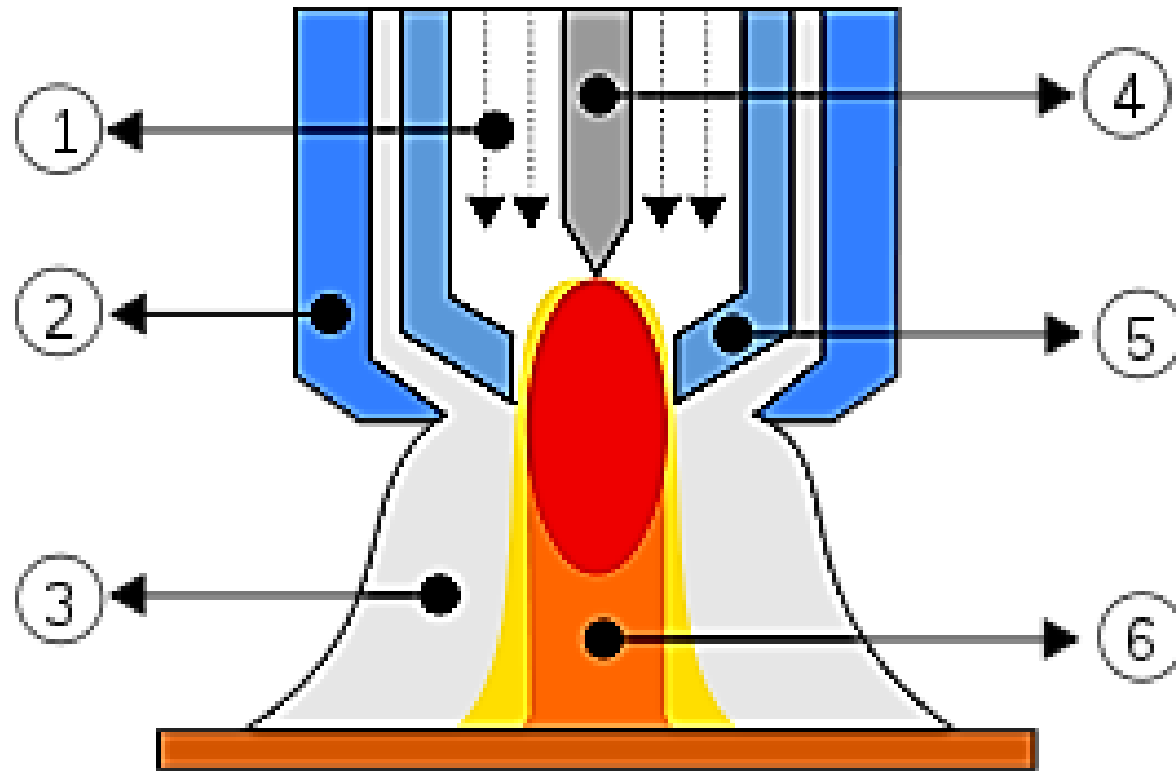


torch body

electrode and

nozzle and its
the base

arc



1. Gas plasma, 2. Nozzle protection, 3. Shield Gas, 4. Electrode, 5. Nozzle constriction, 6. Electric arc

STEP 3:

Heat the refractory coating with a torch until the coating is removed and a joint is allowed to solidify. The refractory coating is then removed and a joint is allowed to solidify. Excess refractory is removed by grinding.

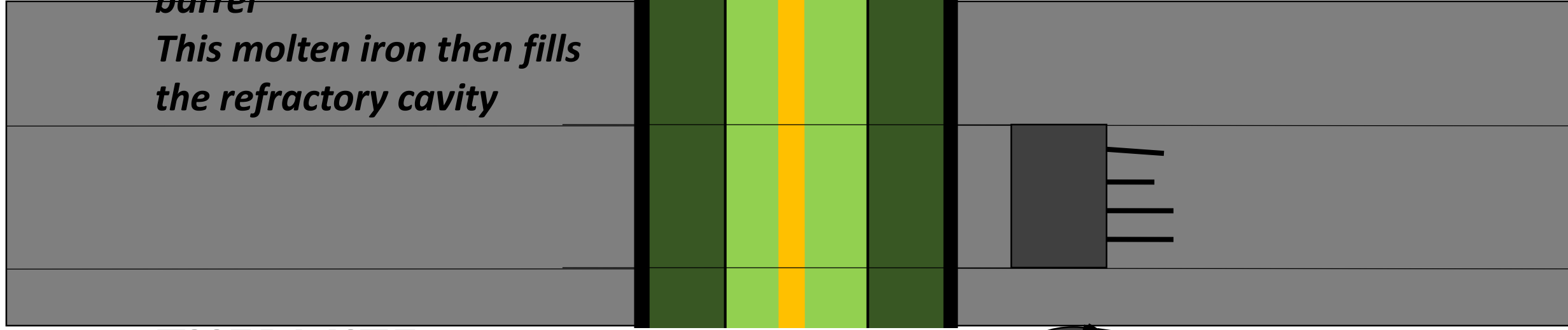
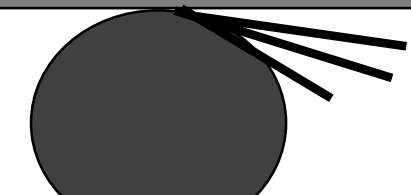
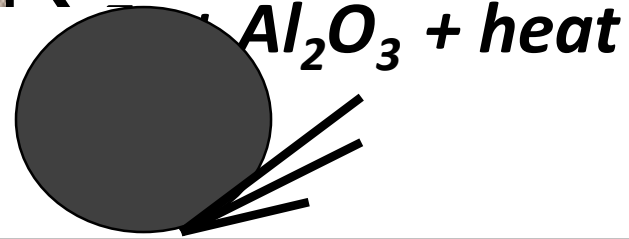
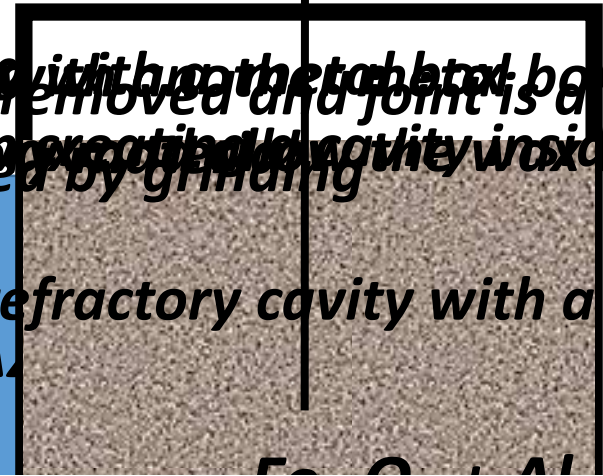
Remove the wax coating from the joint.

Cover the bottom part of refractory cavity with a plug.

Molten iron and reaction mixture should be ignited.

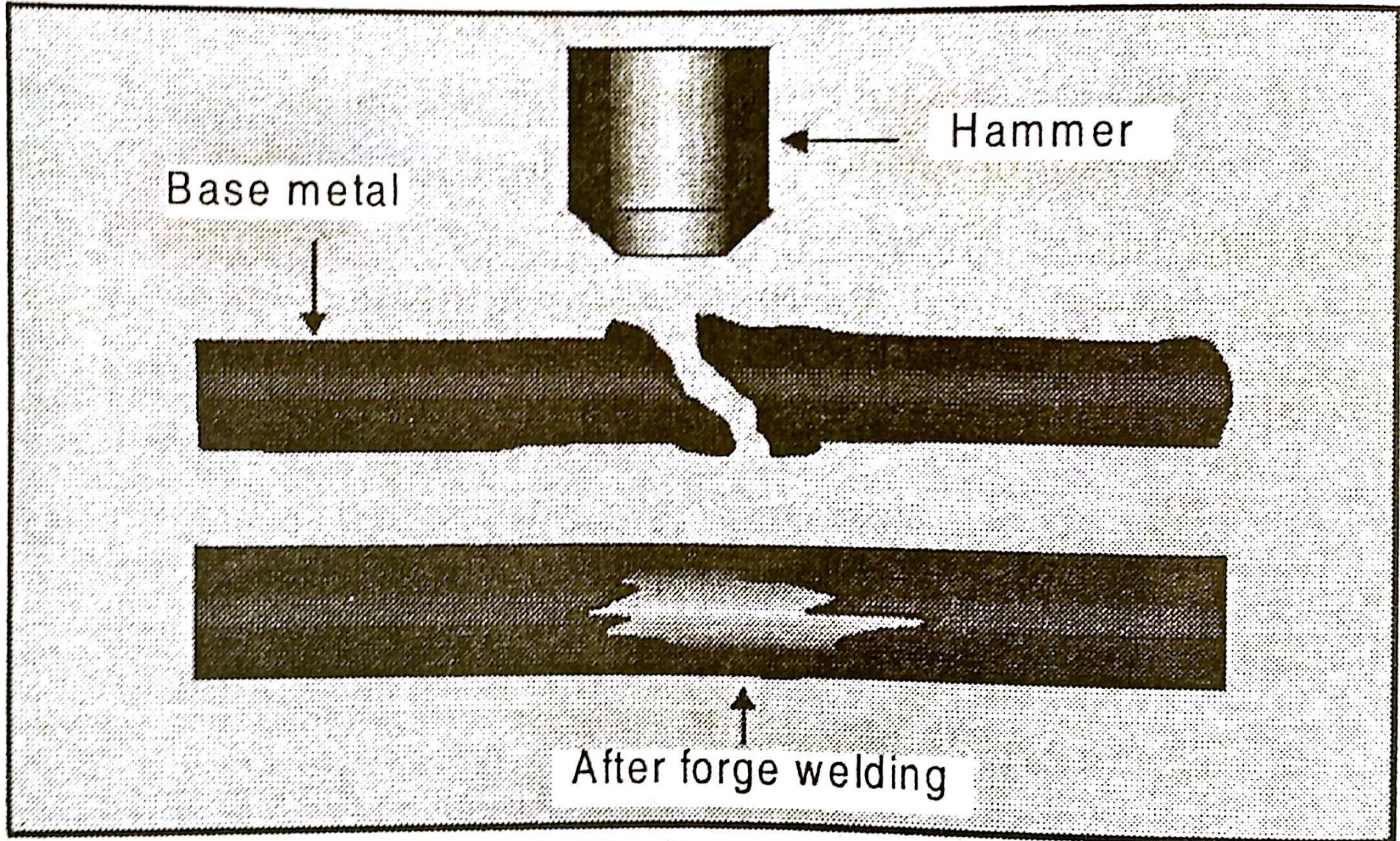
For this an ignition wire is inserted into the mixture barrel.

This molten iron then fills the refractory cavity.

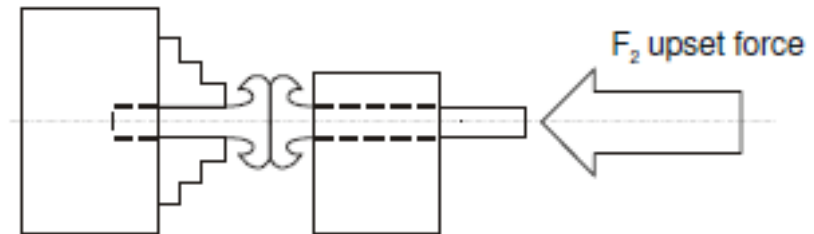
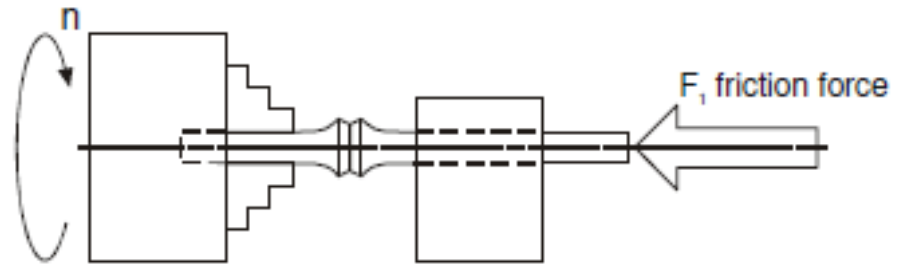
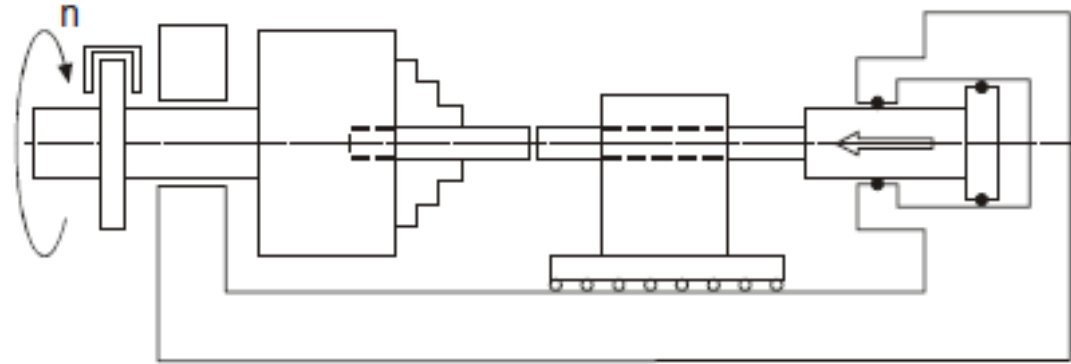


THERMITE WELDING

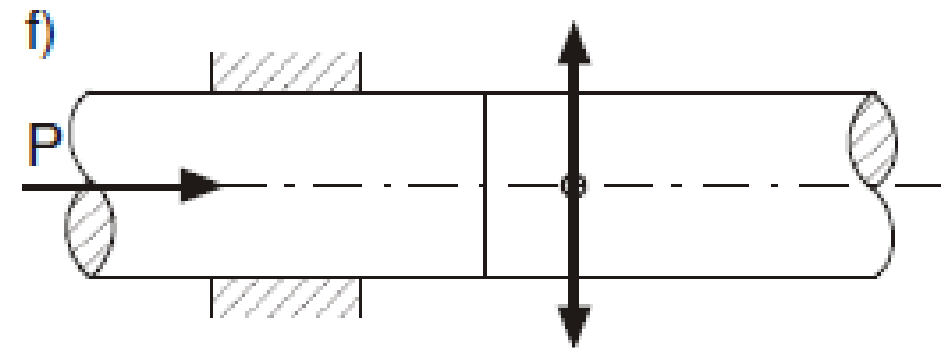
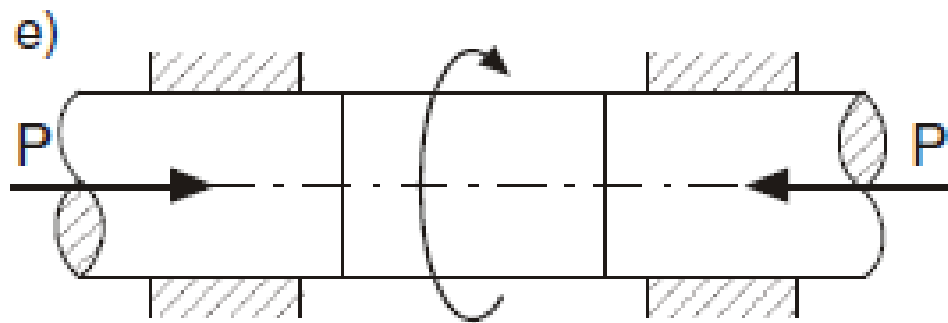
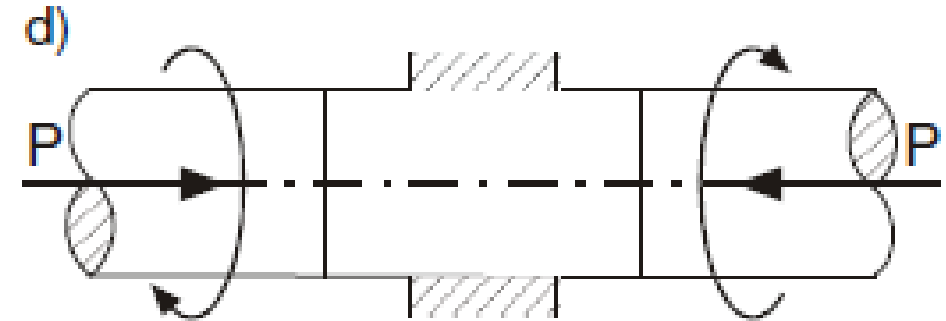
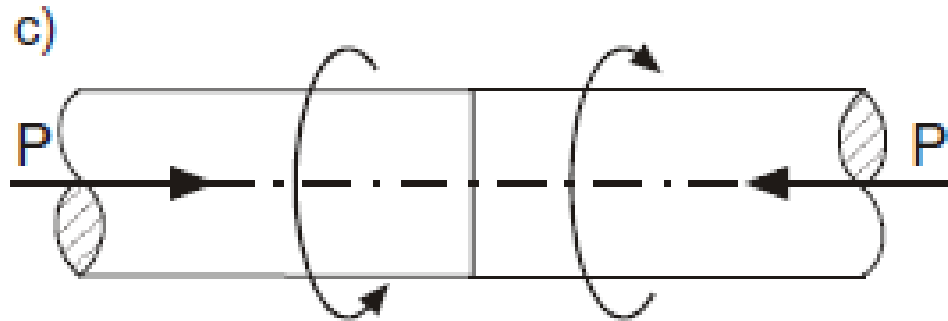
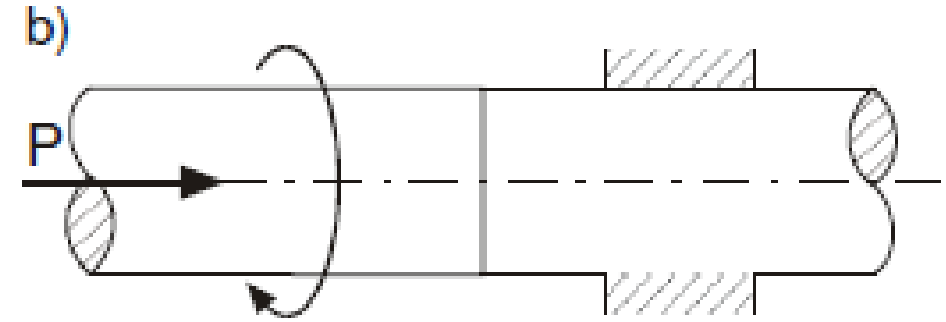
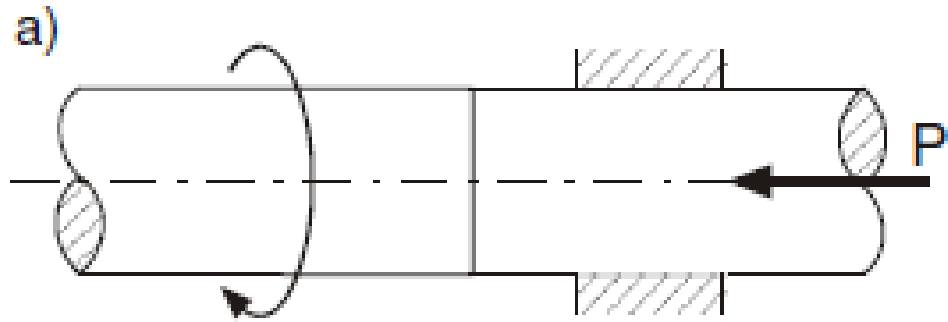
PRESSURE WELDING METHODS



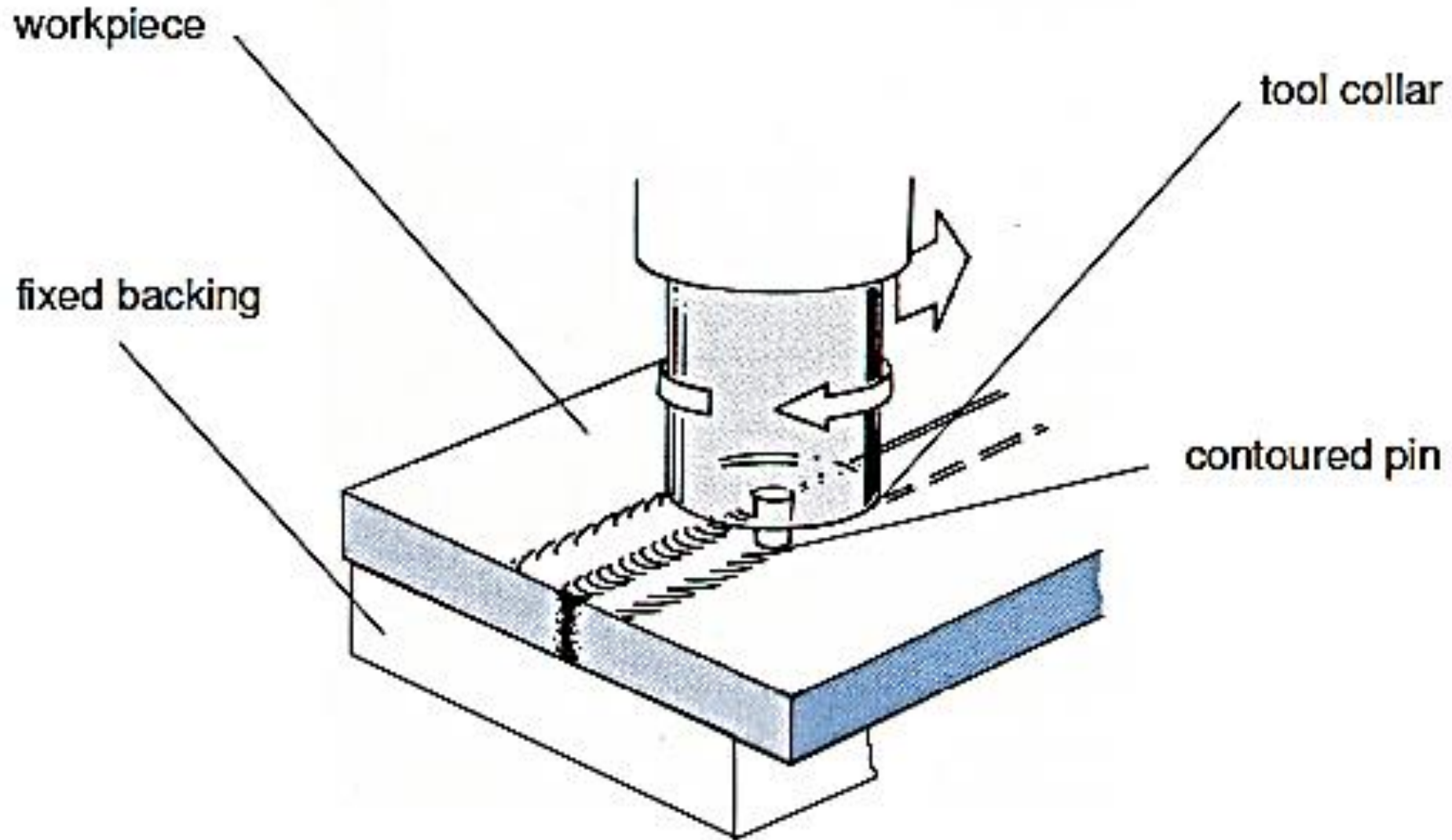
FRICION WELDING

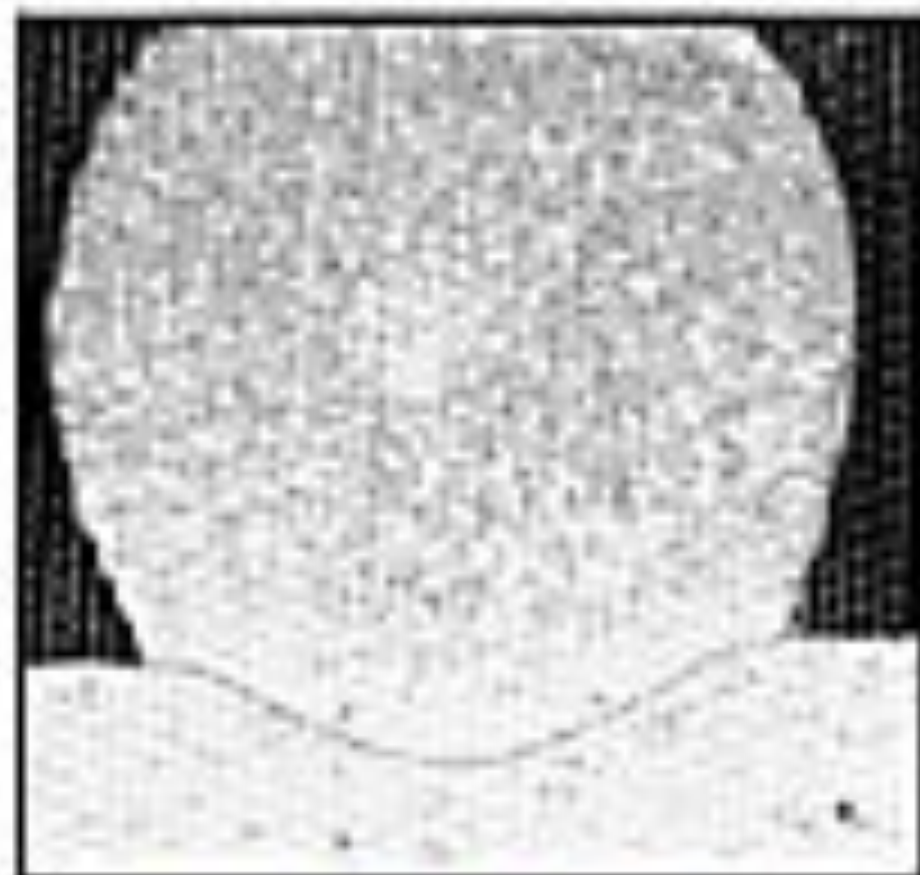


TYPES OF FRICTION WELDING PROCESSES

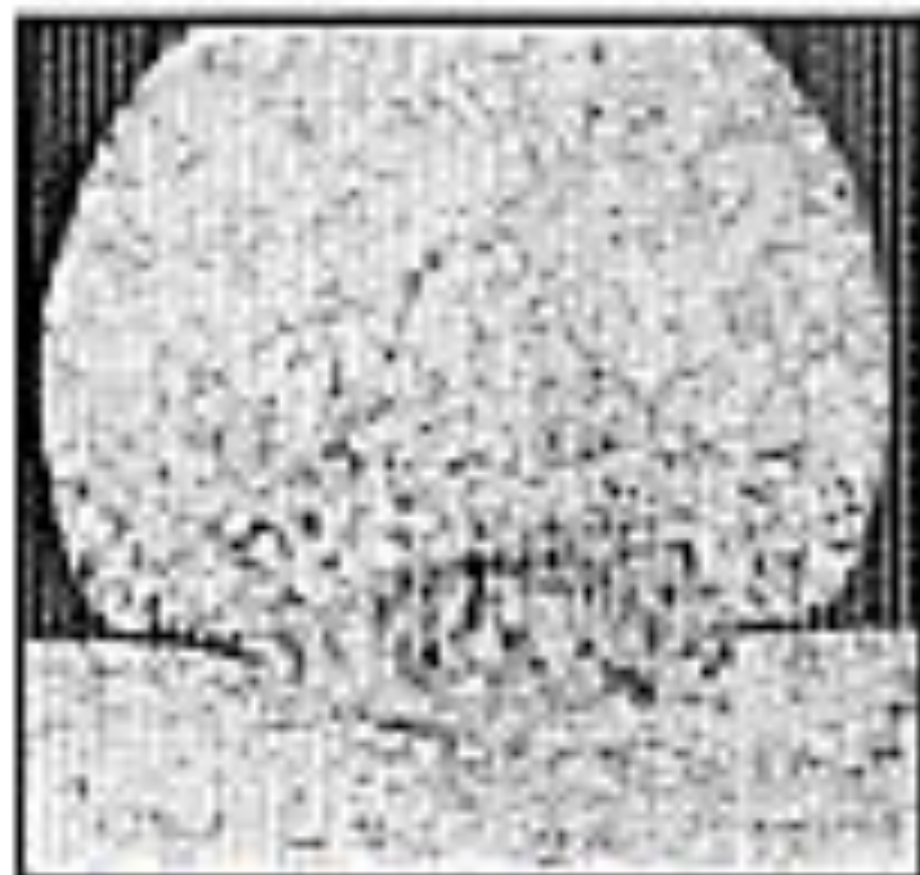


FRICTION STIR WELDING





Solid State Bond



Fusion Bond

RESISTANCE WELDING

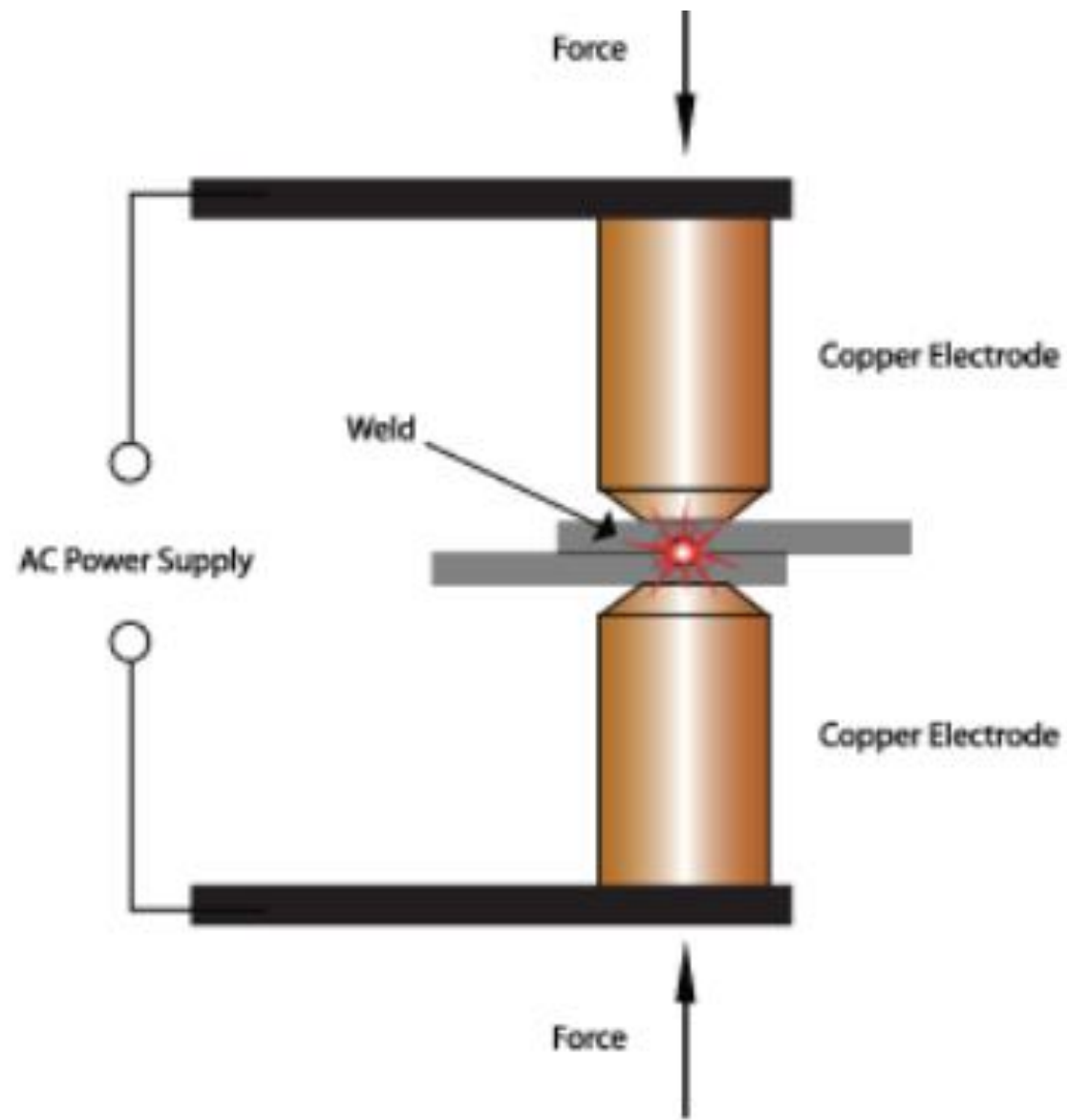
Resistance welding process makes use of the electrical resistance for generating heat required for melting the workpiece. It is generally used for joining thin plates and structures. It has different variants such as Seam welding, Projection welding and Spot welding.

general heat generation formula for resistance welding is:

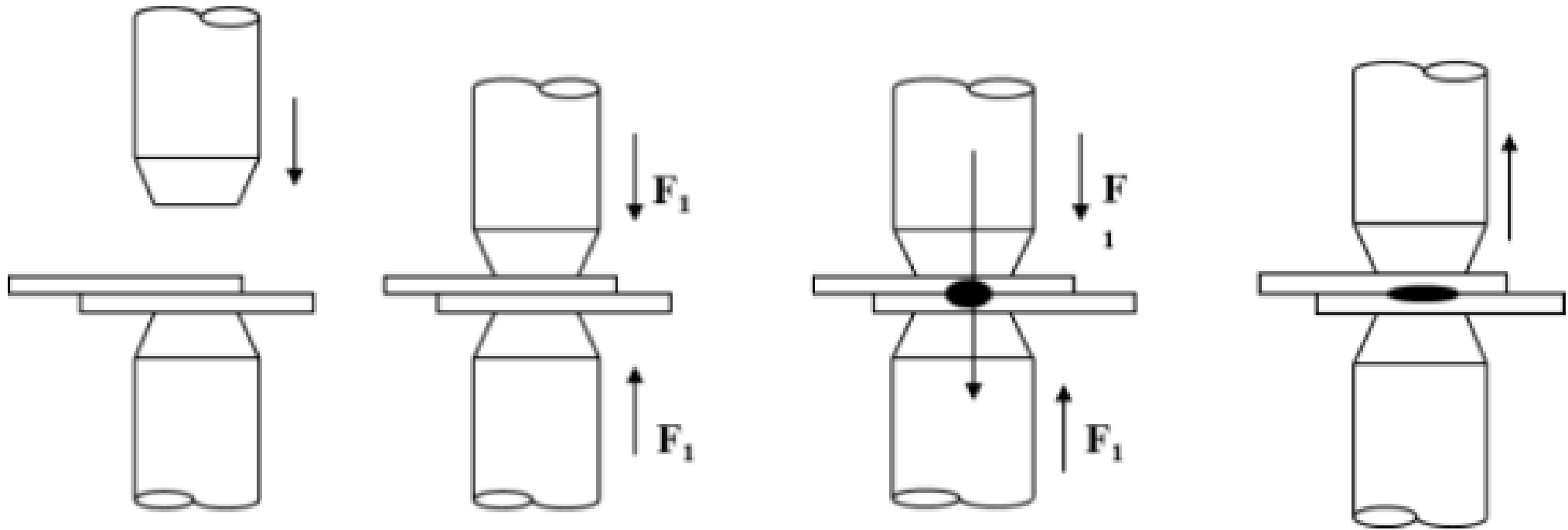
$$\text{Heat} = I^2 \times R \times t,$$

Primary functions of Electrode

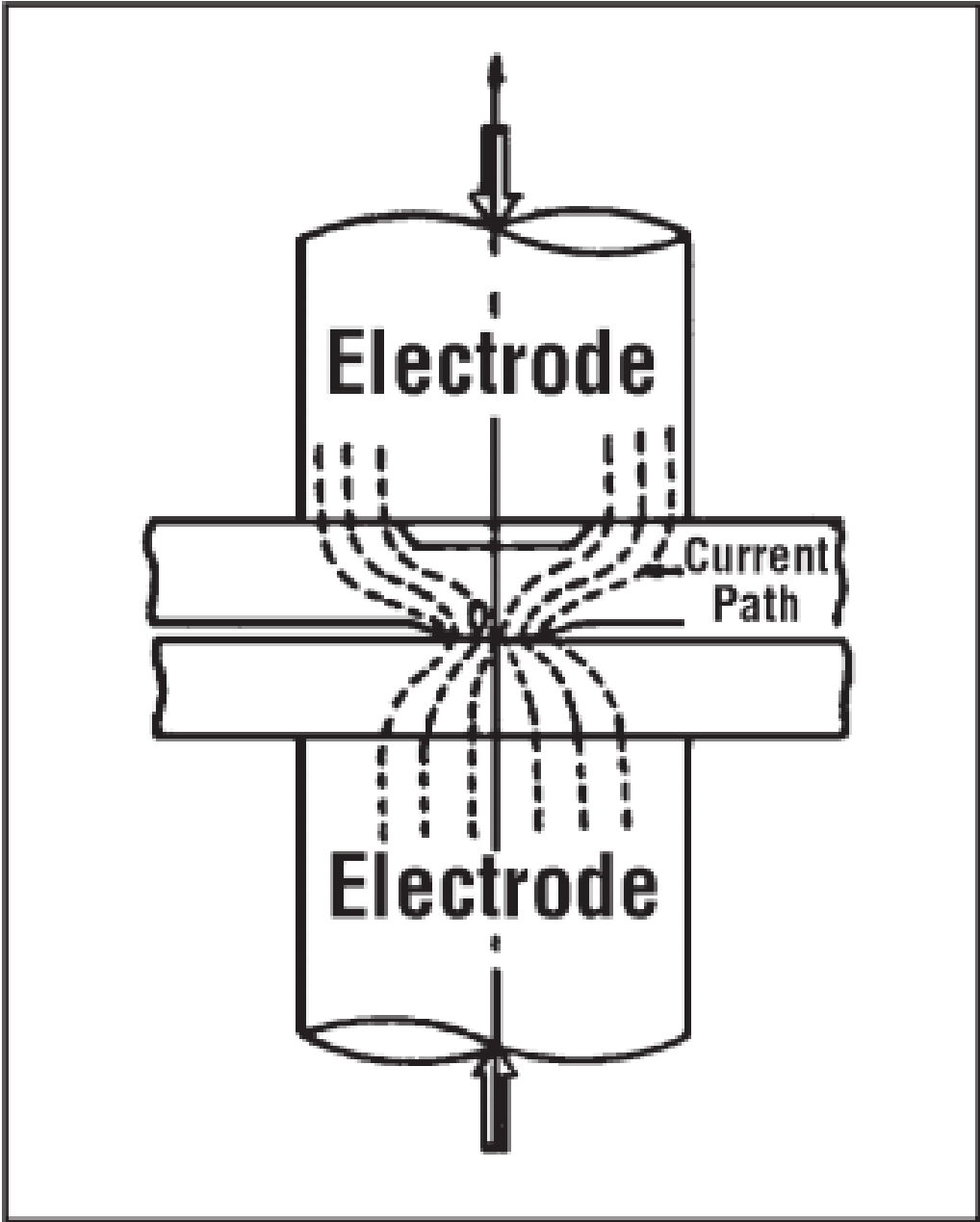
- ▶ Conduct the required heat to the weld zone
- ▶ Transmit the necessary force to the weld area
- ▶ Help the dissipate the heat from the weld zone



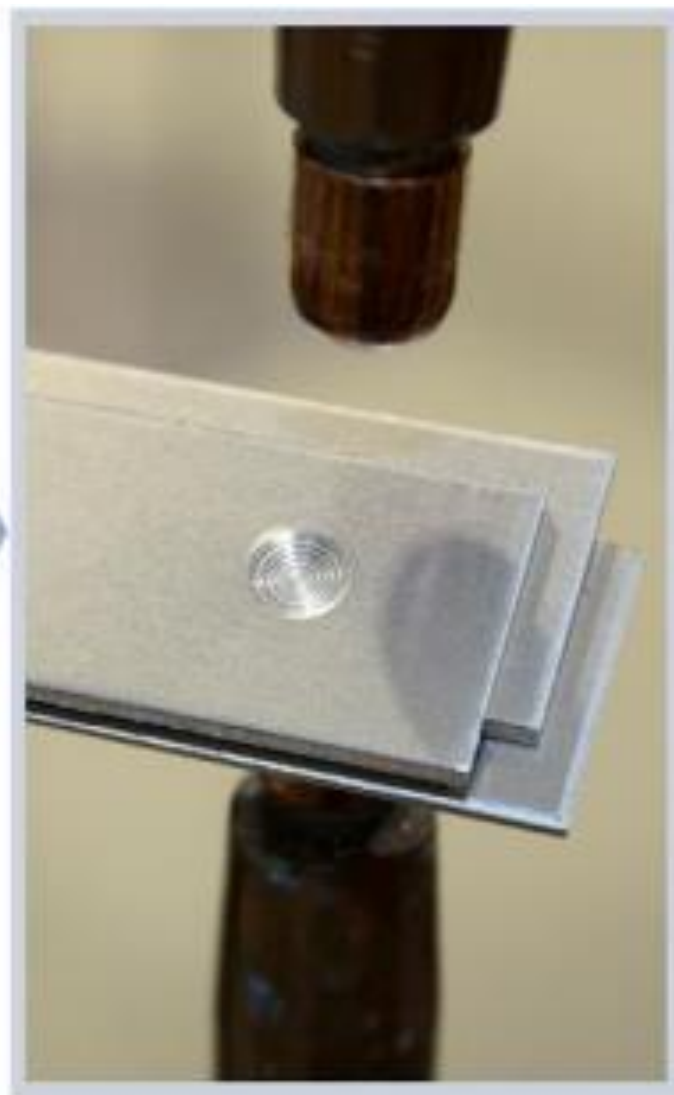
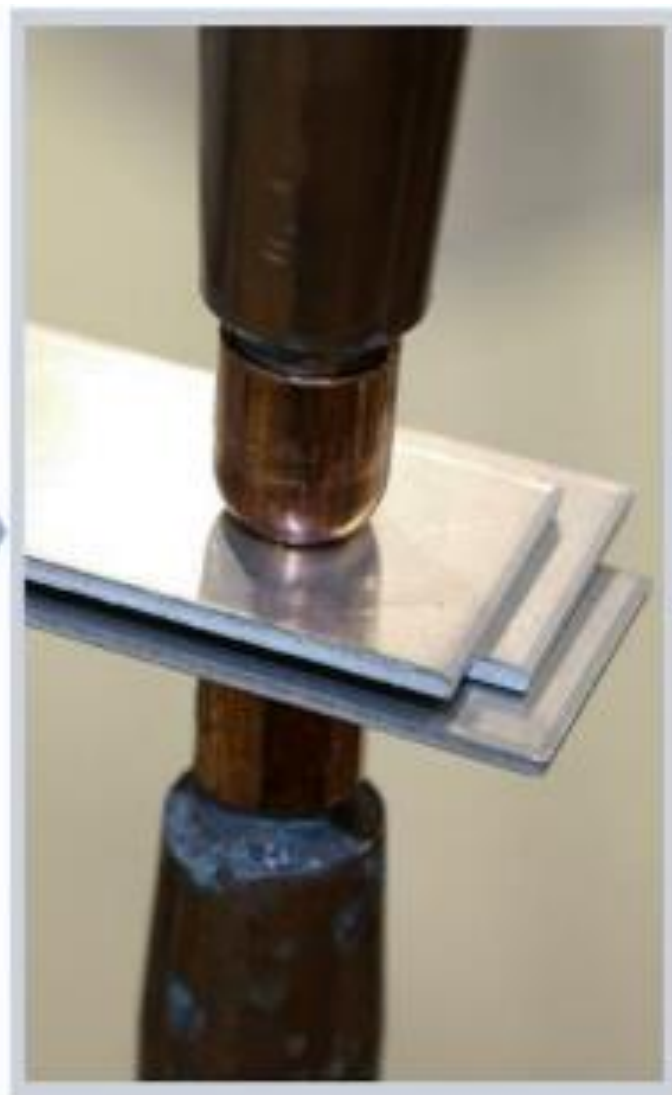
Schematic of resistance spot welding process



Typical steps in producing a resistance spot weld







ADVANTAGES OF RESISTANCE WELDING

- They are very rapid in operation.
- The equipment can be fully automated.
- They conserve materials as no filler material, shielding gas or flux is required.
- Skilled operators are not required.
- Dissimilar metals can be easily joined.
- A high degree of reliability and reproducibility can be achieved.

DISADVANTAGES OF RESISTANCE WELDING

- The equipment has a high initial cost.
- There are limitations to the type of joints that can be made (mostly suitable for lap joints).
- Skilled maintenance persons are required to service the control equipment.
- Some materials require special surface preparations prior to welding.

RESISTANCE SEAM WELDING

Seam consists of a series of overlapping spot welds.

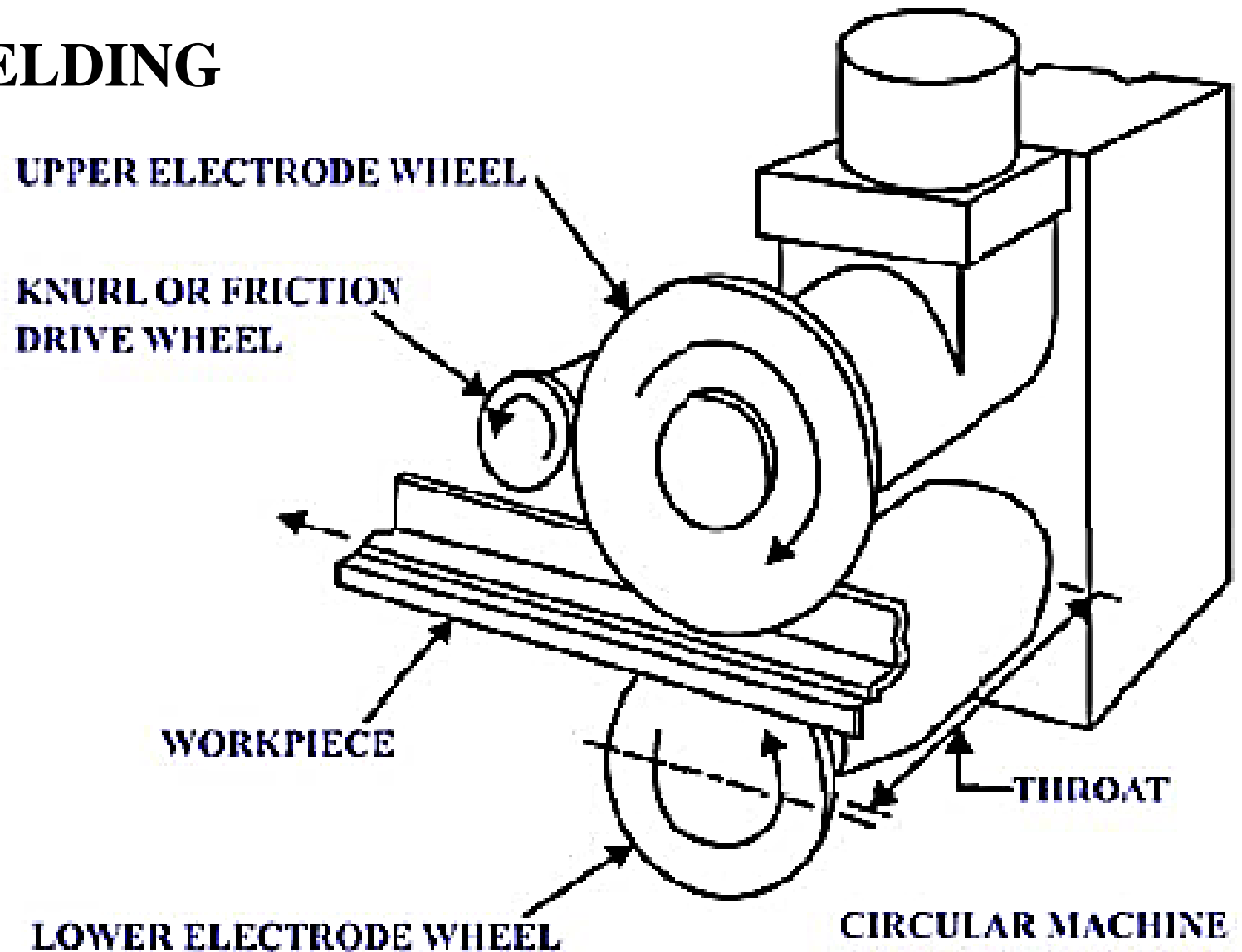
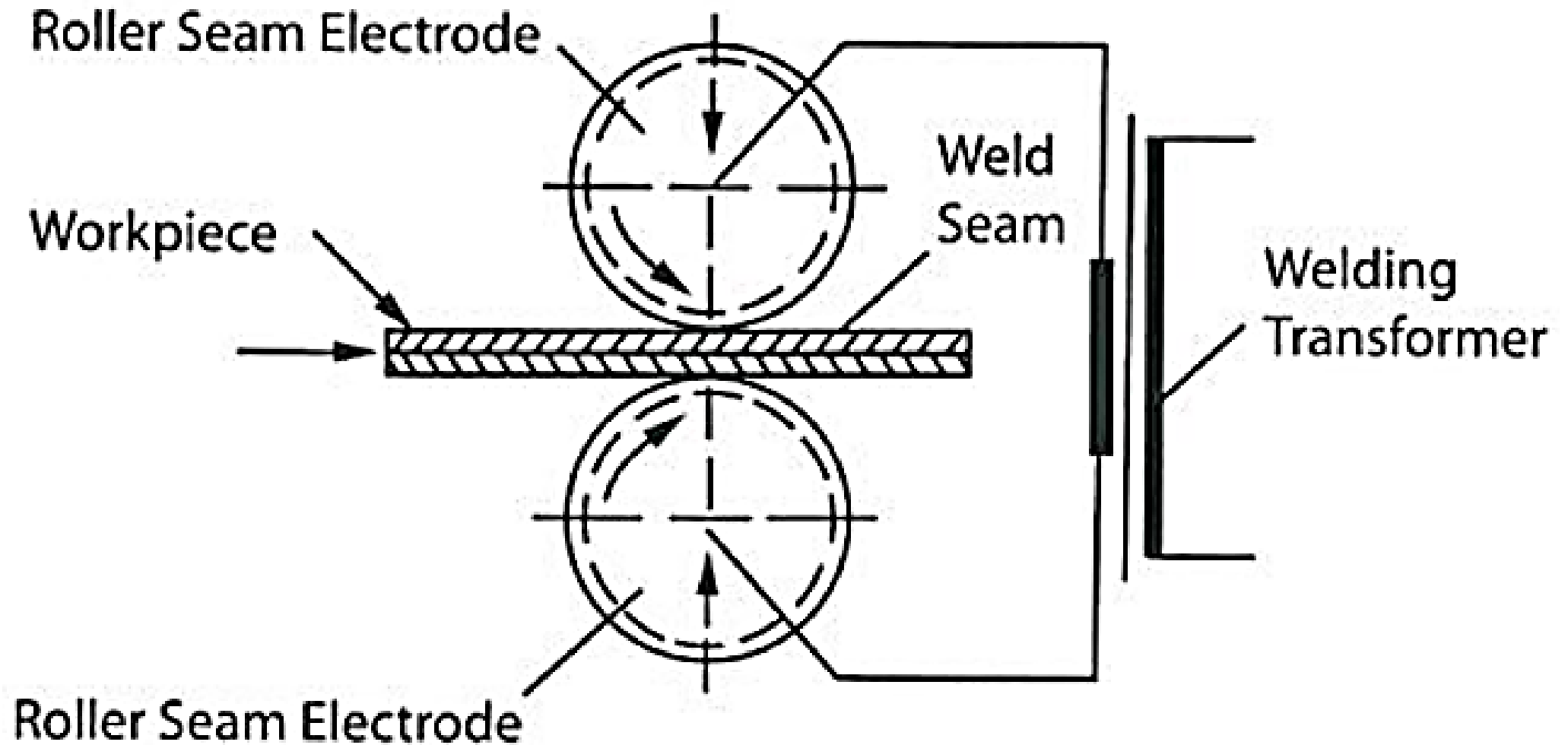
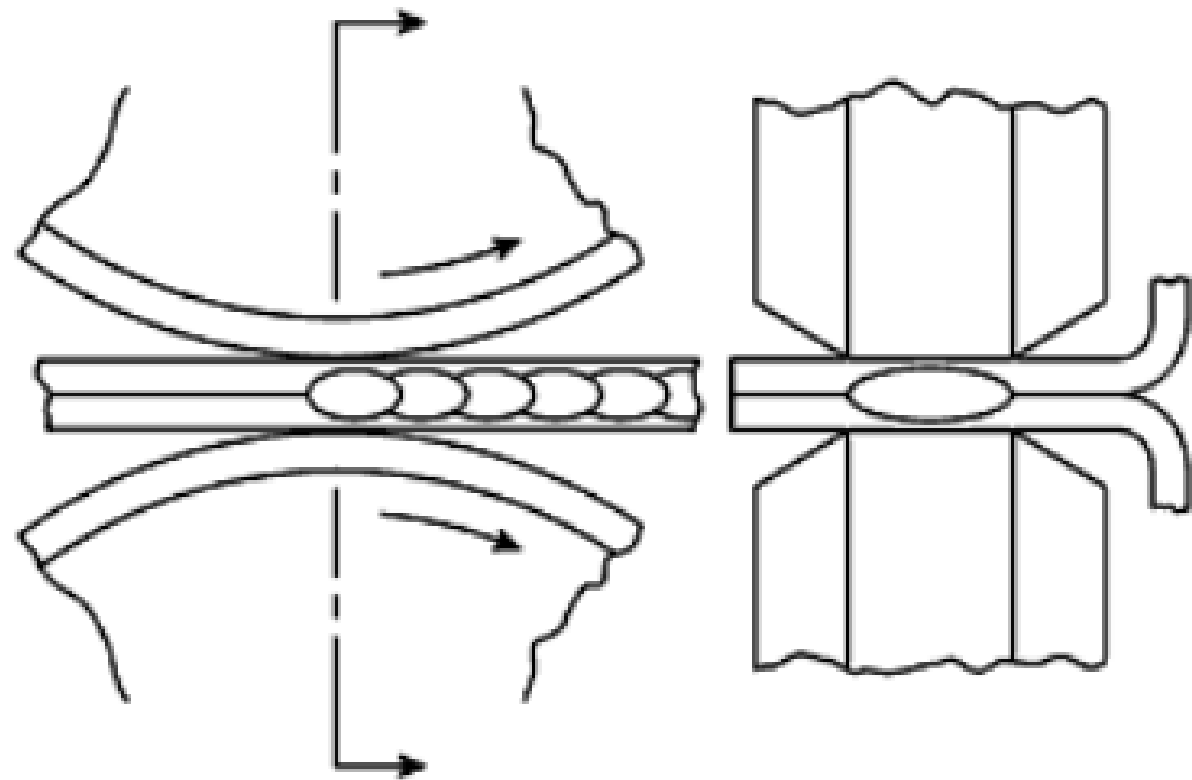


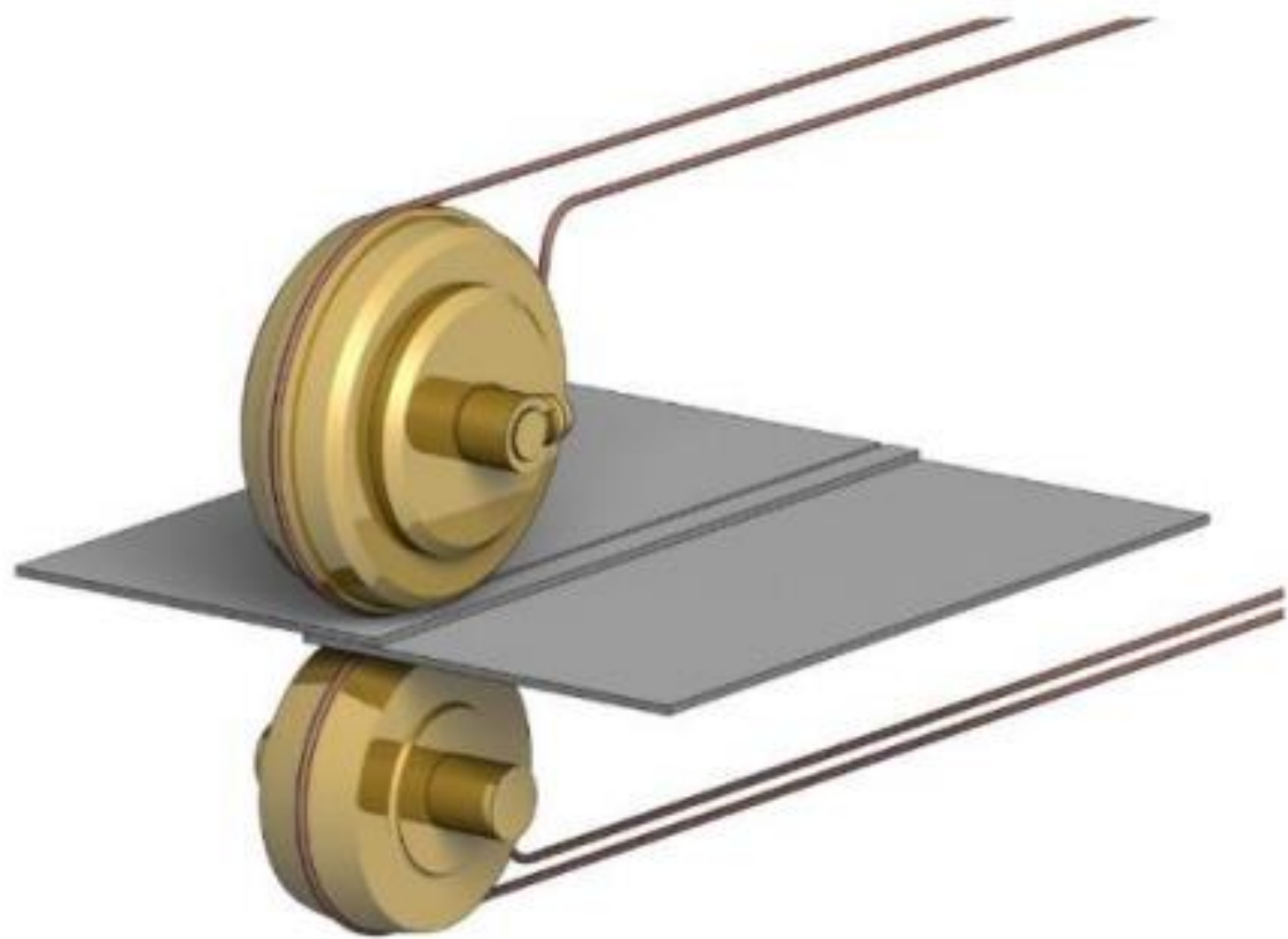
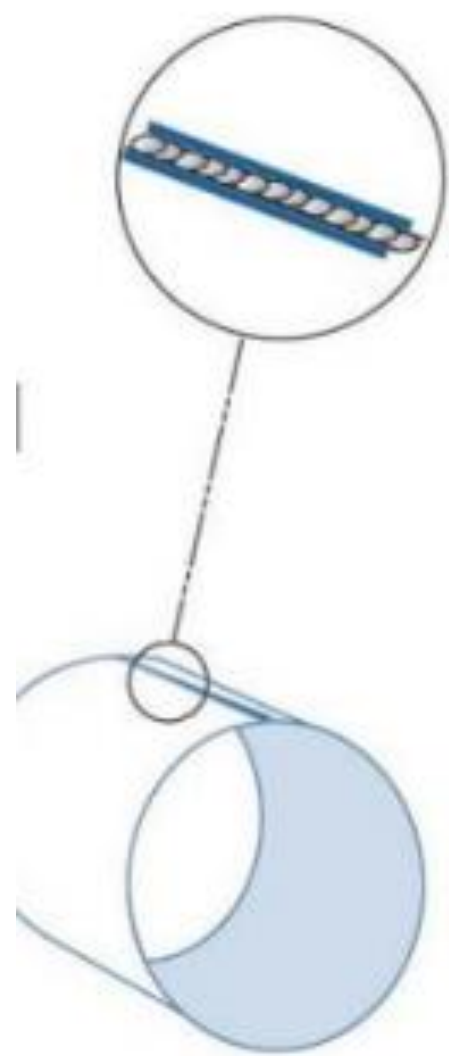
Fig. 4.2.1 Schematic of the Resistance Seam welding process



Resistance seam welding process







Roll Spot Weld

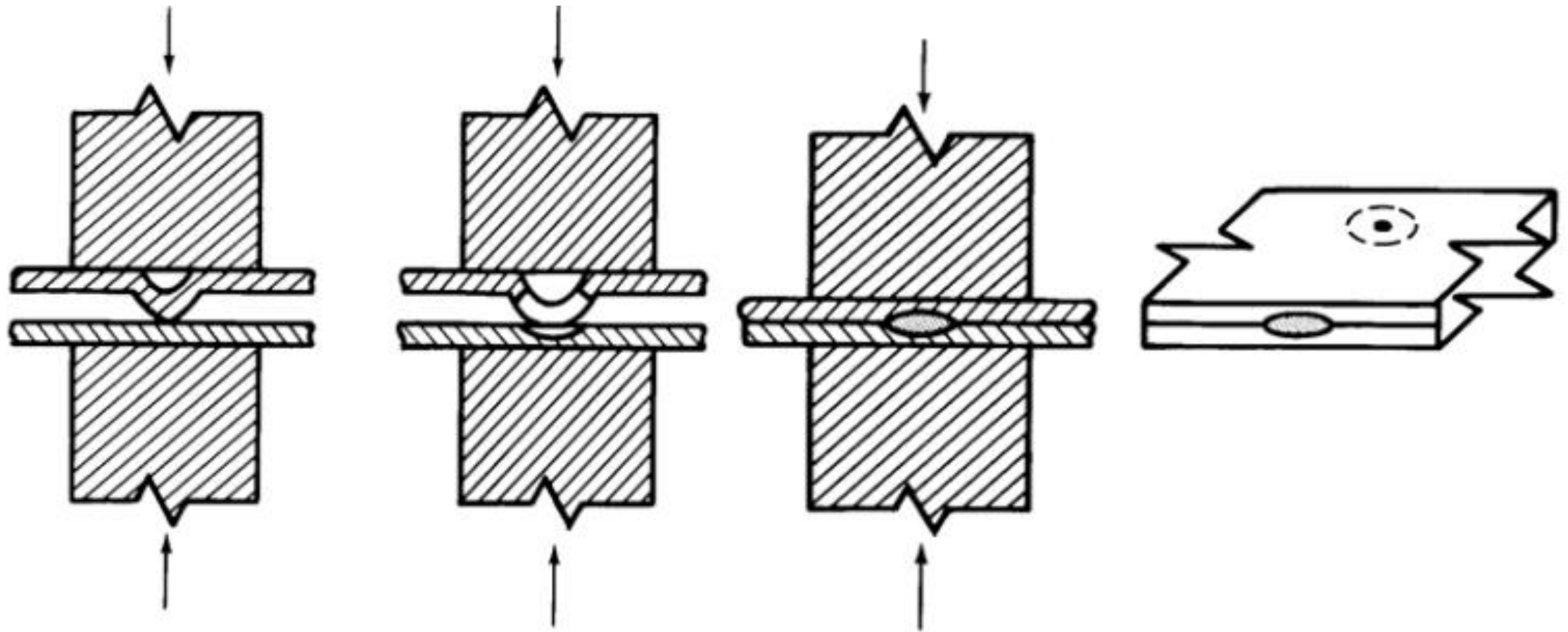


Overlapping Seam Weld

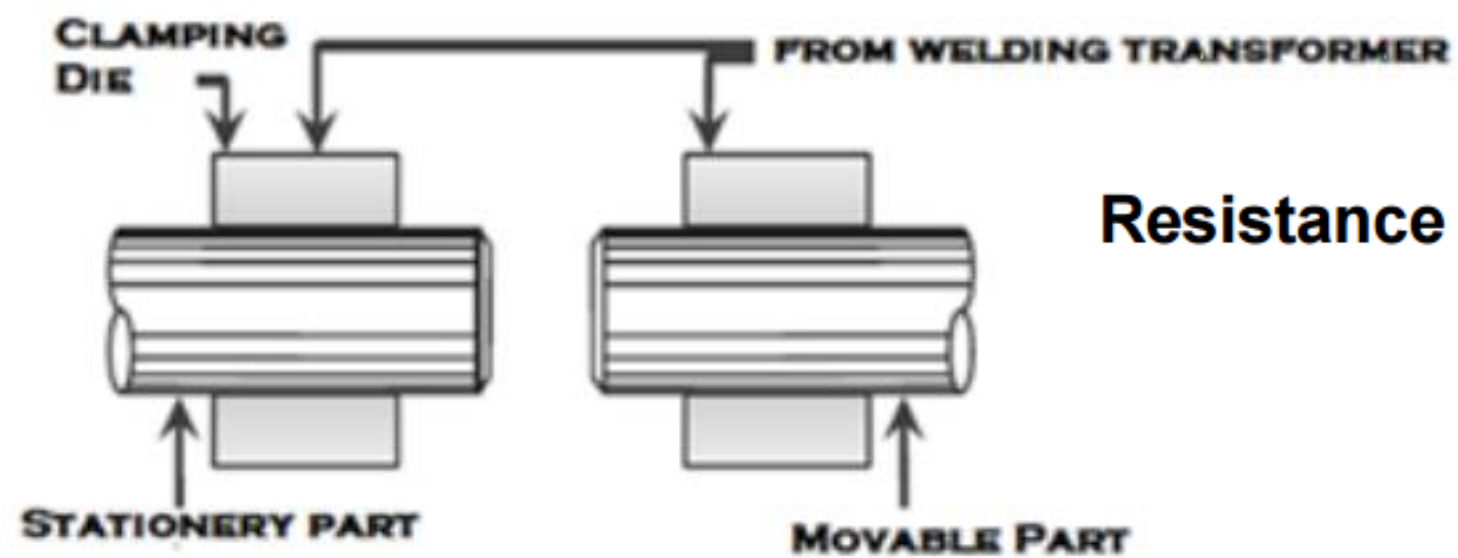


Continuous Seam Weld

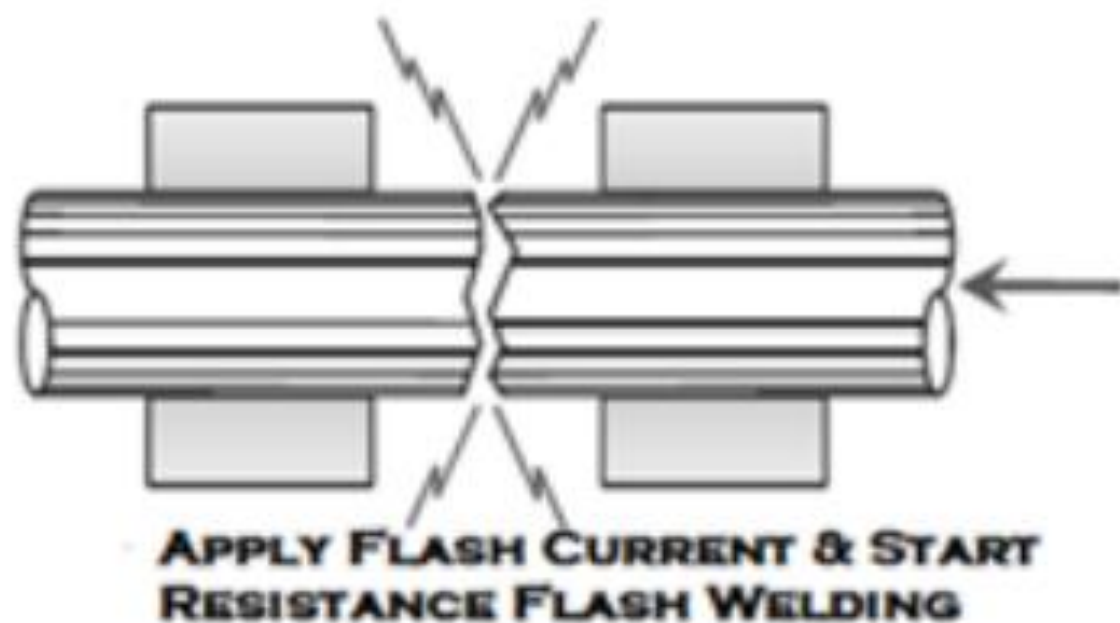


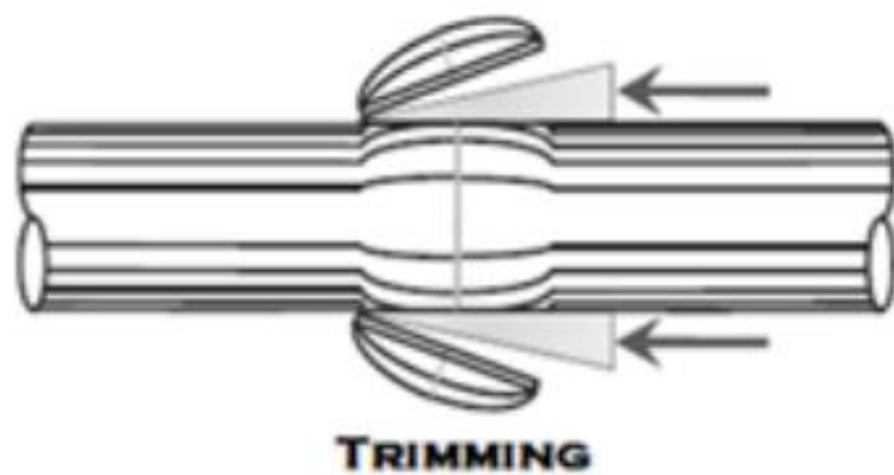
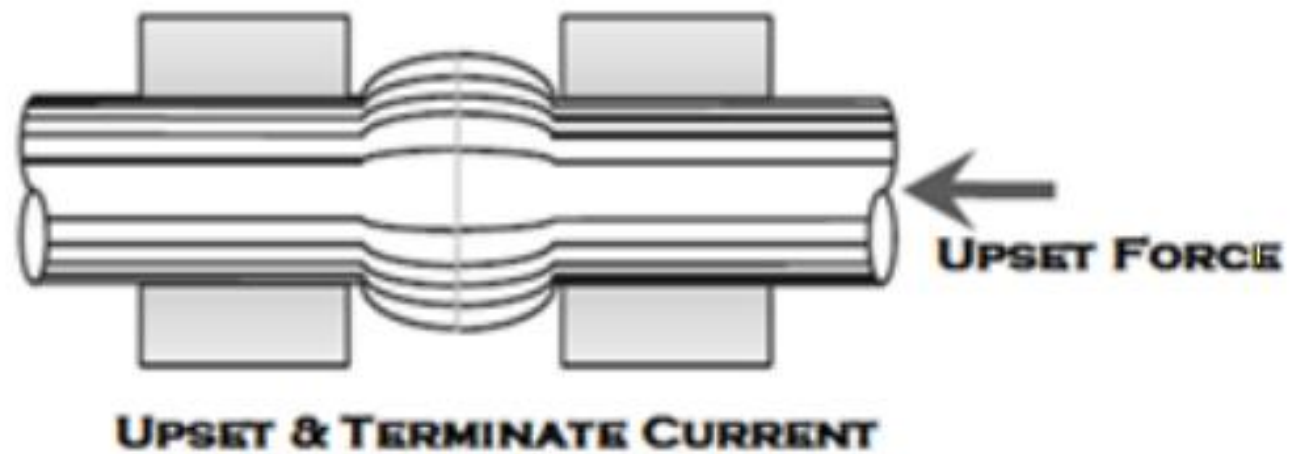


Process sequence of resistance projection welding



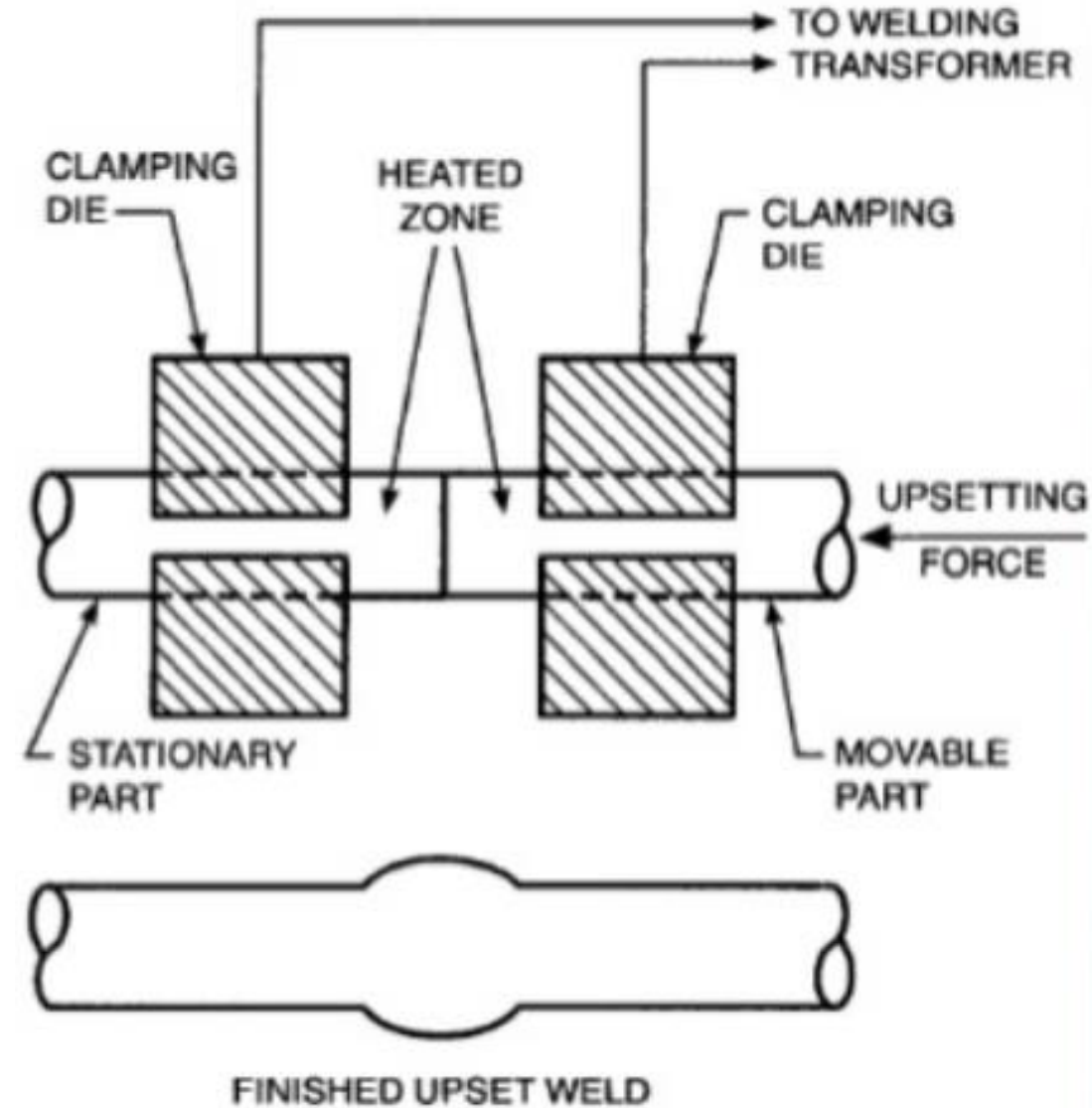
Resistance butt welding (flash welding)



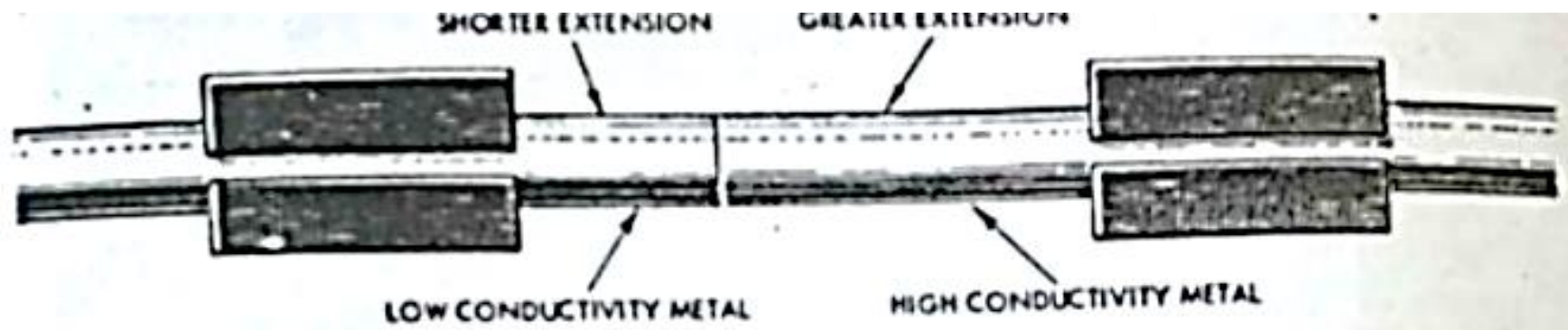


Flash butt welding process sequence

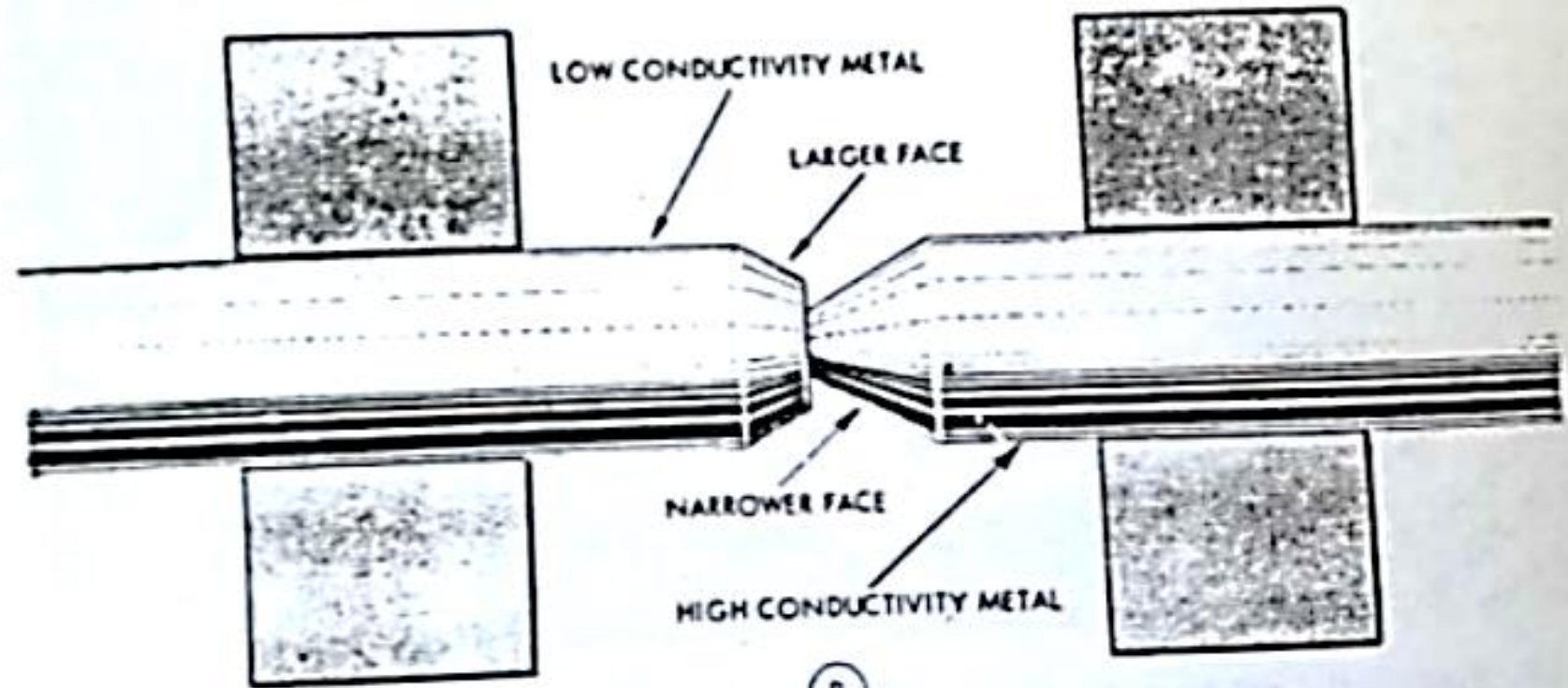
UPSET WELDING/BUTT WELDING



HOW TO ACHIEVE HEAT BALANCE

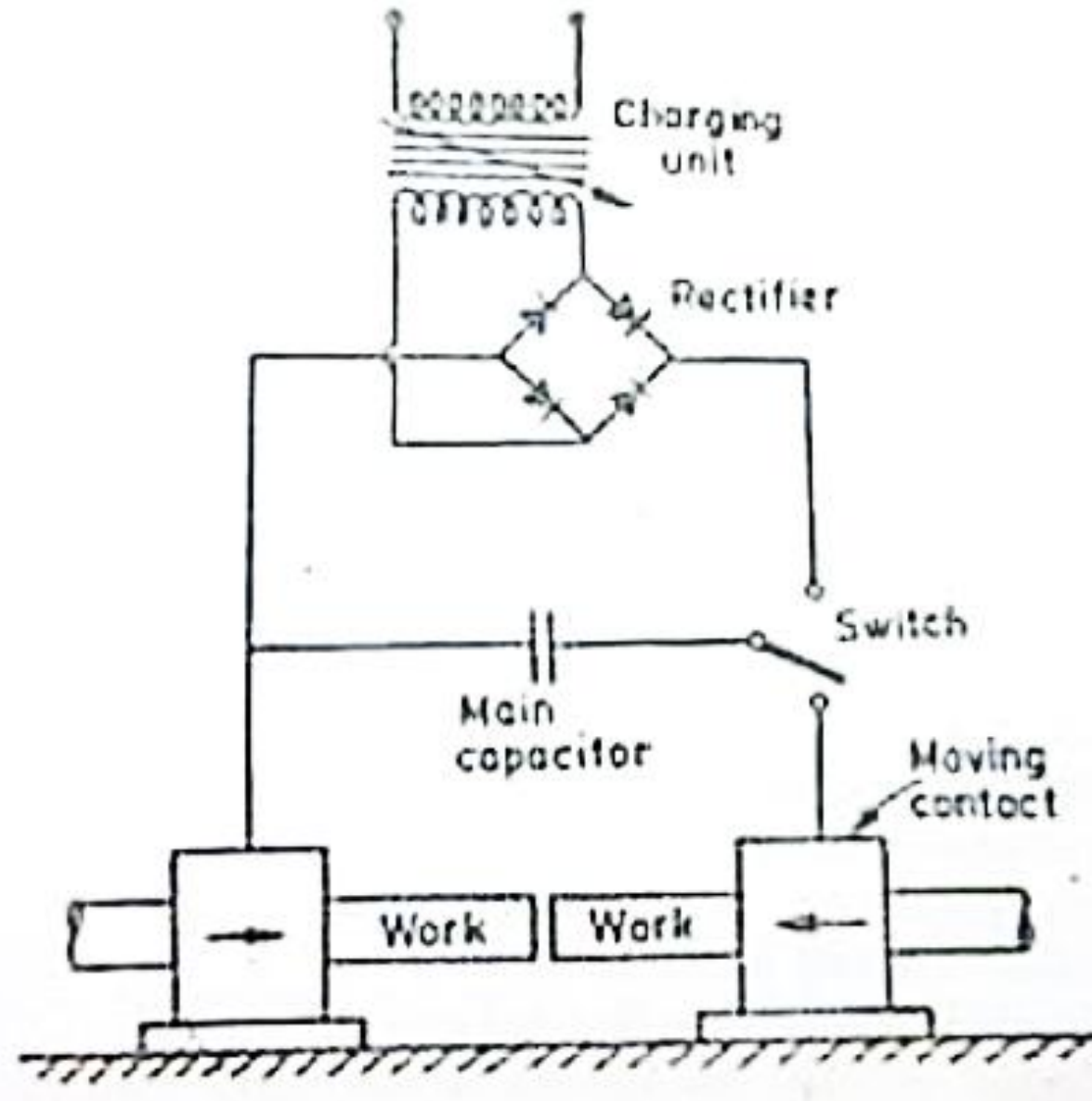


(A)



(B)

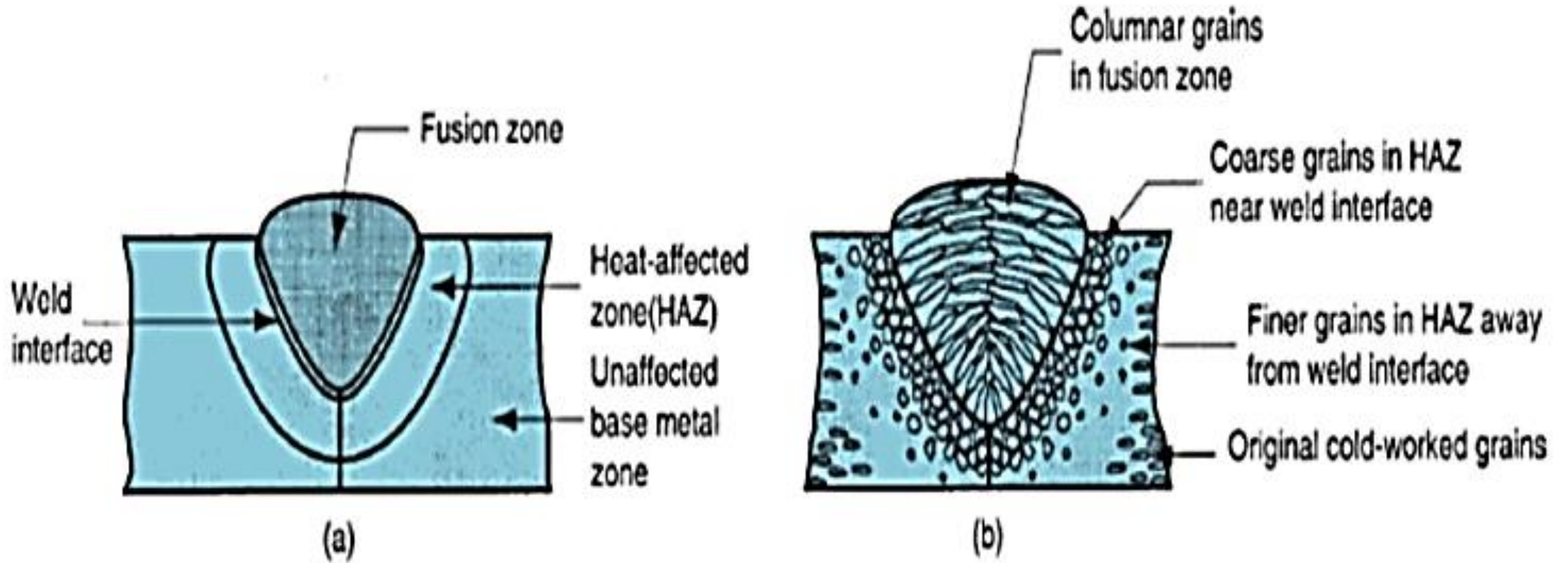
PERCUSSION WELDING



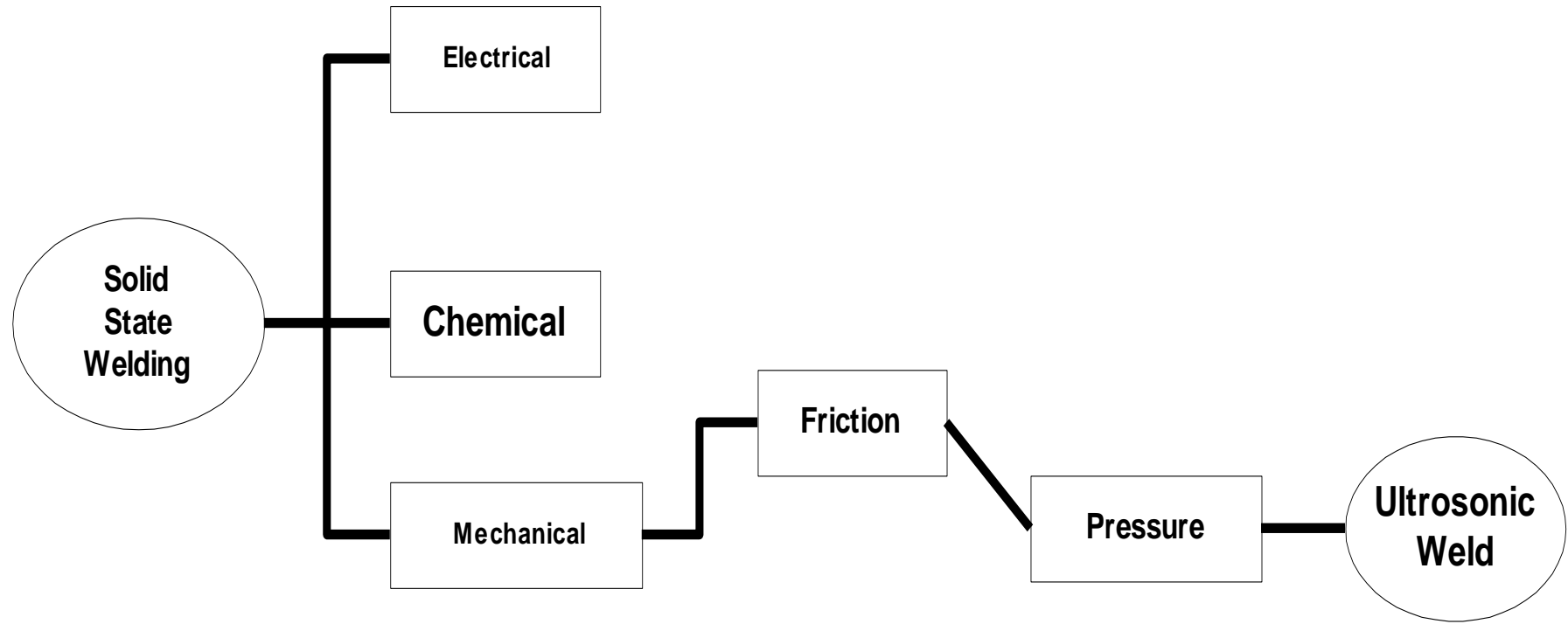
PERCUSSION WELDING

PROCESS IN WHICH HEAT IS PRODUCED FROM AN ARC THAT IS GENERATED BY THE RAPID DISCHARGE OF ELECTRICAL ENERGY BETWEEN THE WORKPIECES AND FOLLOWED BY IMMEDIATELY BY AN IMPACTING FORCE WHICH WELD THE PIECES TOGETHER

CROSS SECTION OF A TYPICAL FUSION WELDED JOINT



The fusion zone consists of a mixture of filler metal and base metal that have completely melted.



Ultrasonic welding (USW)

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. The combination of normal and vibratory forces results in shear stresses that remove surface films and achieve atomic bonding of the surfaces.

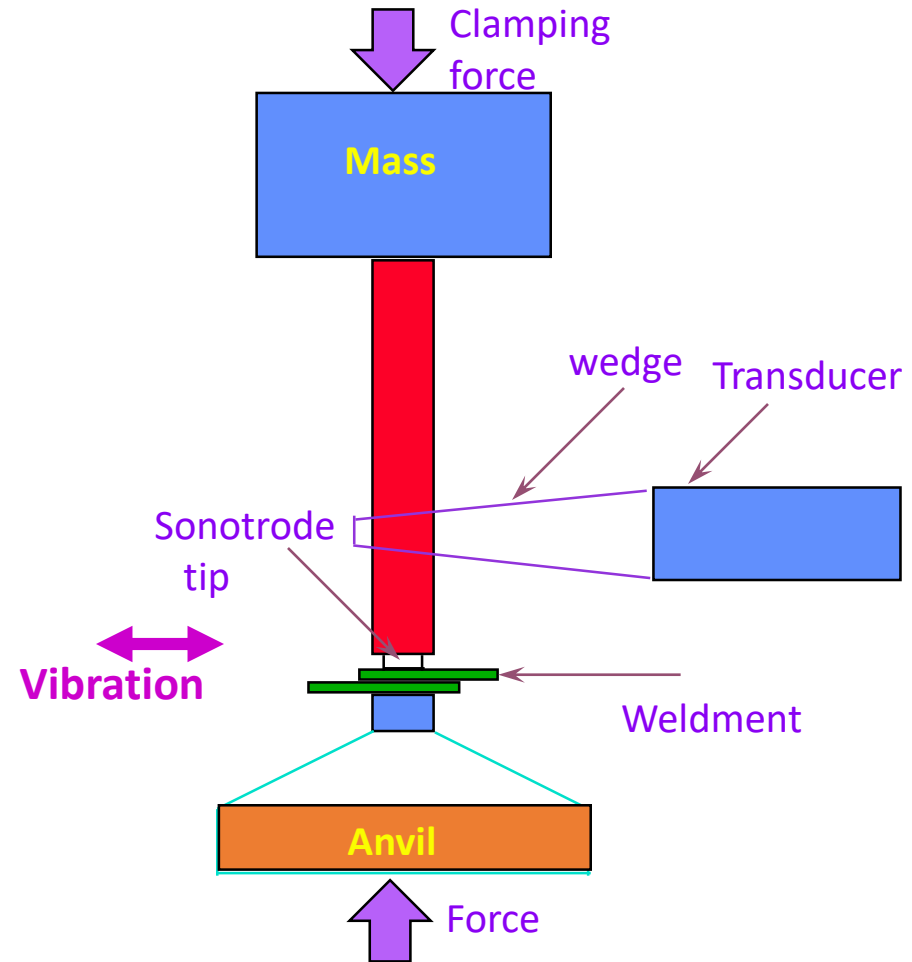
Definition of Ultrasonic Welding

A solid state welding process in which coalescence is produced at the faying surfaces by the application of high frequency vibratory energy while the work pieces are held together under moderately low static pressure.

Ultrasonic Welding Process

Process
Description:

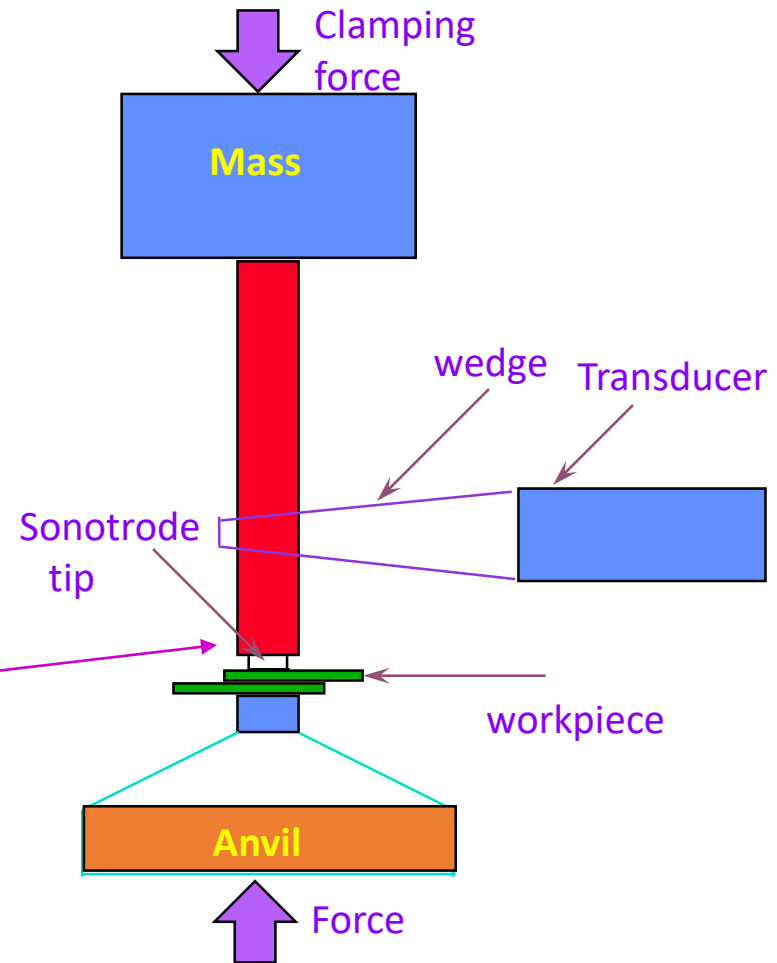
- Components of ultrasonic welding system include:
 - Transducer
 - Sonotrode
 - Anvil

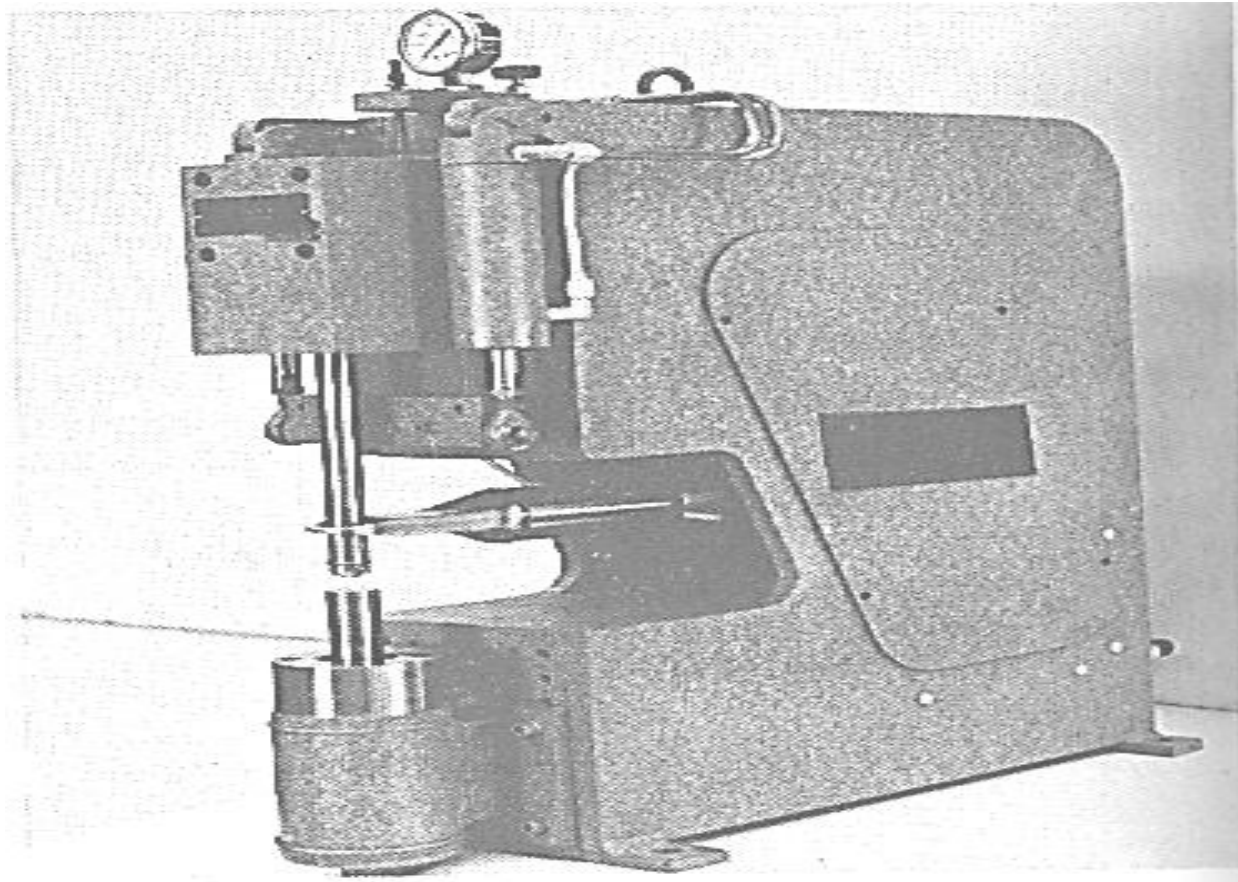


Ultrasonic Welding Mechanism

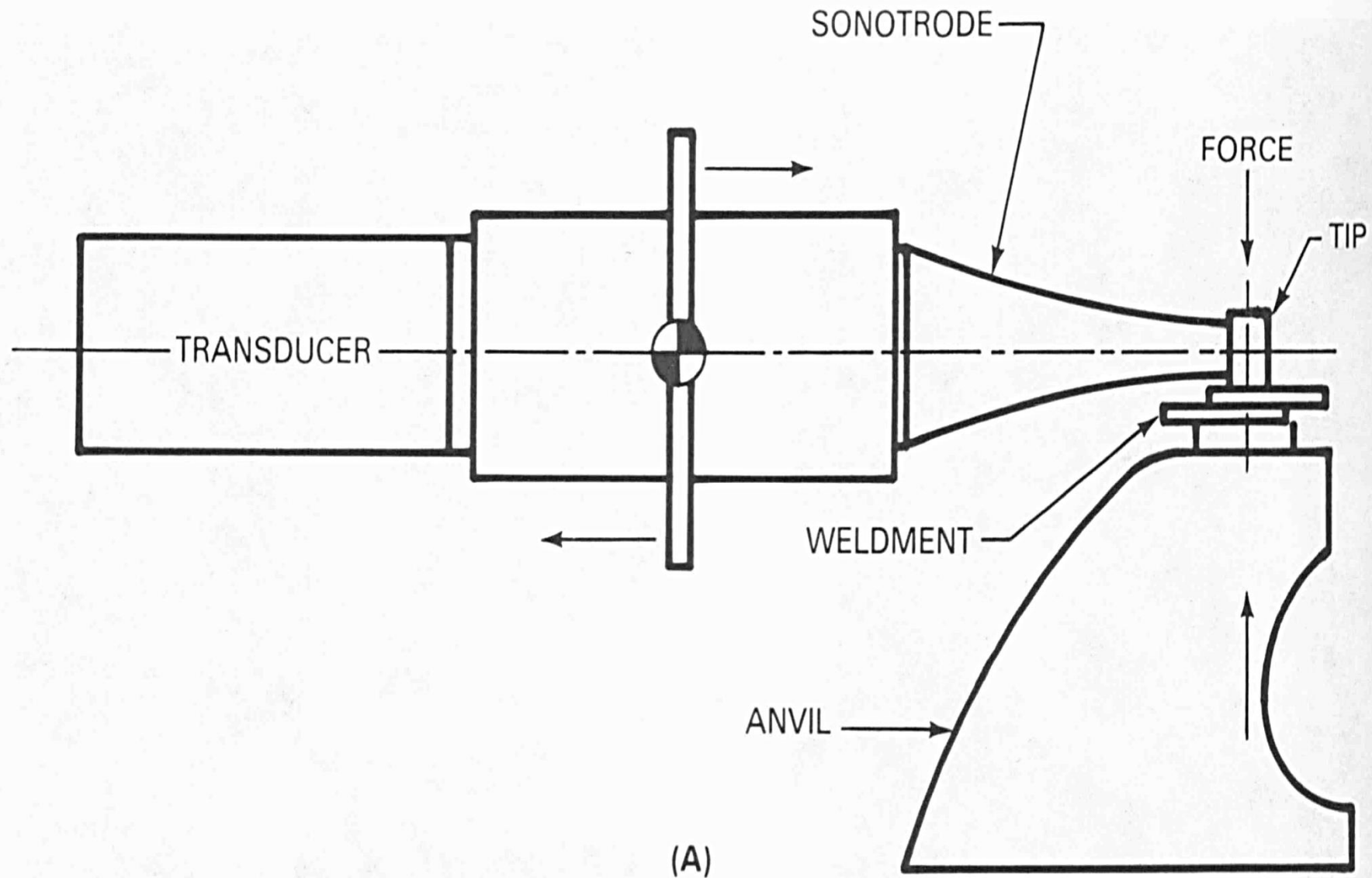
- A static clamping force is applied perpendicular to the interface between the work pieces.
- The contacting sonotrode oscillates parallel to the interface.
- Combined effect of static and oscillating force produces deformation which promotes welding.

10-75 KHz





**ultrasonic
spot-type welding machine**



(A)

Advantages of Ultrasonic Welding

- No heat is applied and no melting occurs.
- Permits welding of thin to thick sections.
- Welding can be made through some surface coatings.
- Pressures used are lower, welding times are shorter, and the thickness of deformed regions are thinner than for cold welding.

Limitations of Ultrasonic Welding

- The thickness of the component adjacent to the sonotrode tip must not exceed relatively thin gages because of power limitations of the equipment.
- Process is limited to lap joints.
- Butt welds can not be made because there is no means of supporting the workpieces and applying clamping force.

SOLDERING



- Soldering is a process in which two or more metal items are joined together by melting and flowing a filler metal (solder) into the joint
- the filler metal having a lower melting point than the adjoining metal.
- Soldering differs from welding in that soldering does not involve melting the work pieces.
- In brazing, the filler metal melts at a higher temperature, but in soldering filler alloy melts at lower temperature than brazing.
- Used for low strength applications like electronics and plumbing

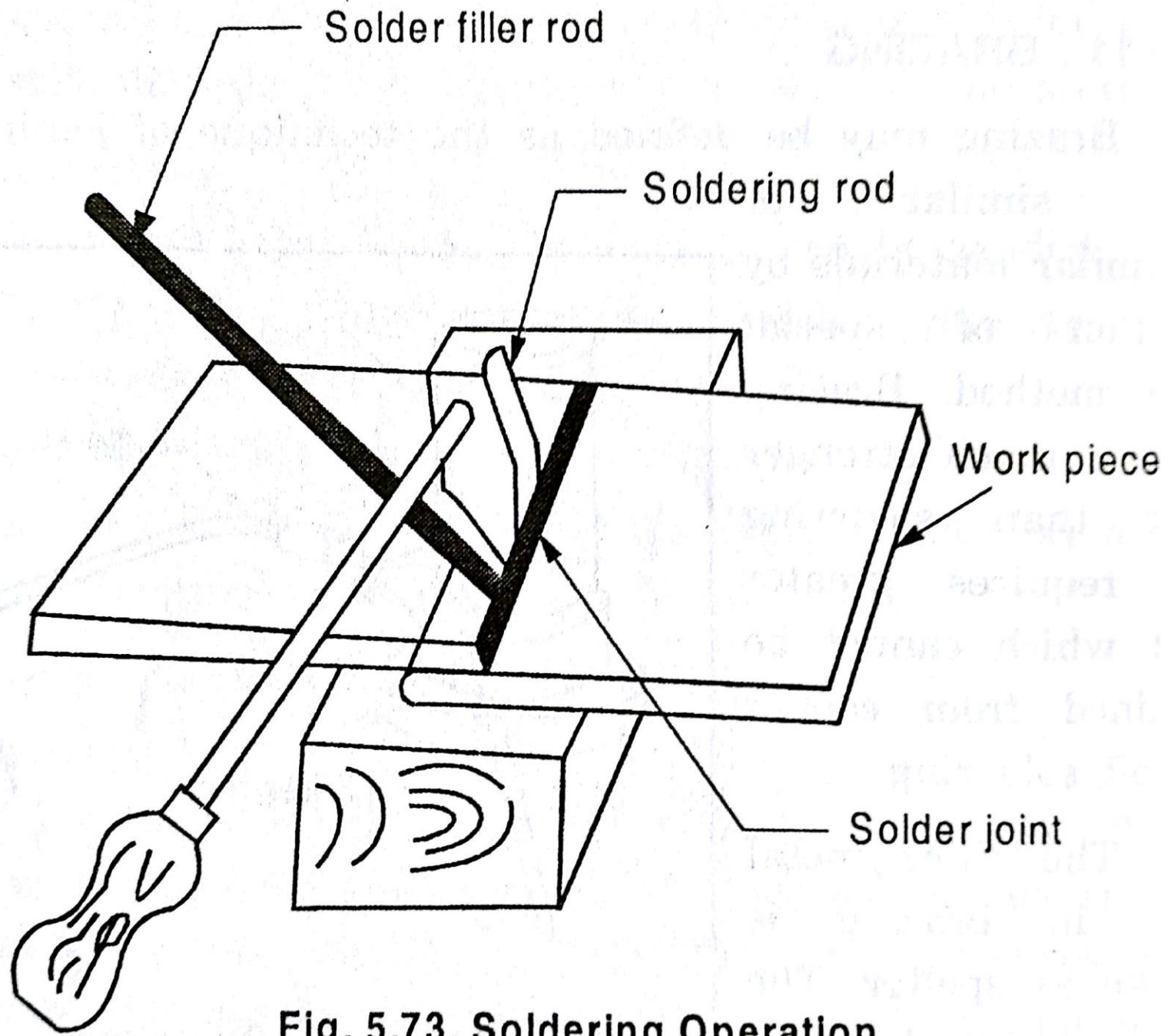


Fig. 5.73. Soldering Operation

TYPES OF SOLDERS

- Tin Lead solders
- 60% Tin and 40% lead
- 50% Tin and 50% lead
- Tin-Antimony-Lead solders
- Lead Silver solders
- Cadmium Silver Solders

FLUXES USED FOR SOLDERING

1. INORGANIC ACIDS

2. NON CORROSIVE RESIN BASED FLUXES

TYPES OF SOLDERING METHODS

1. SOLDERING IRON METHOD

2. DIP AND WAVE METHOD

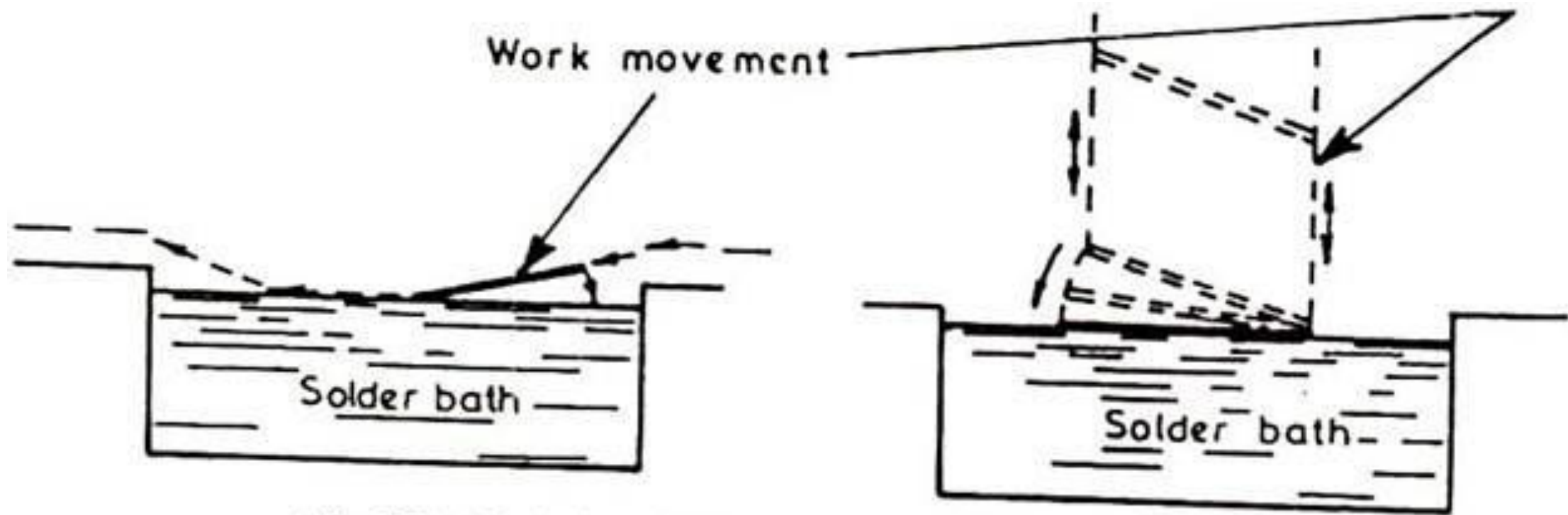


Fig. 17.4 Typical workpiece movements in dip soldering.

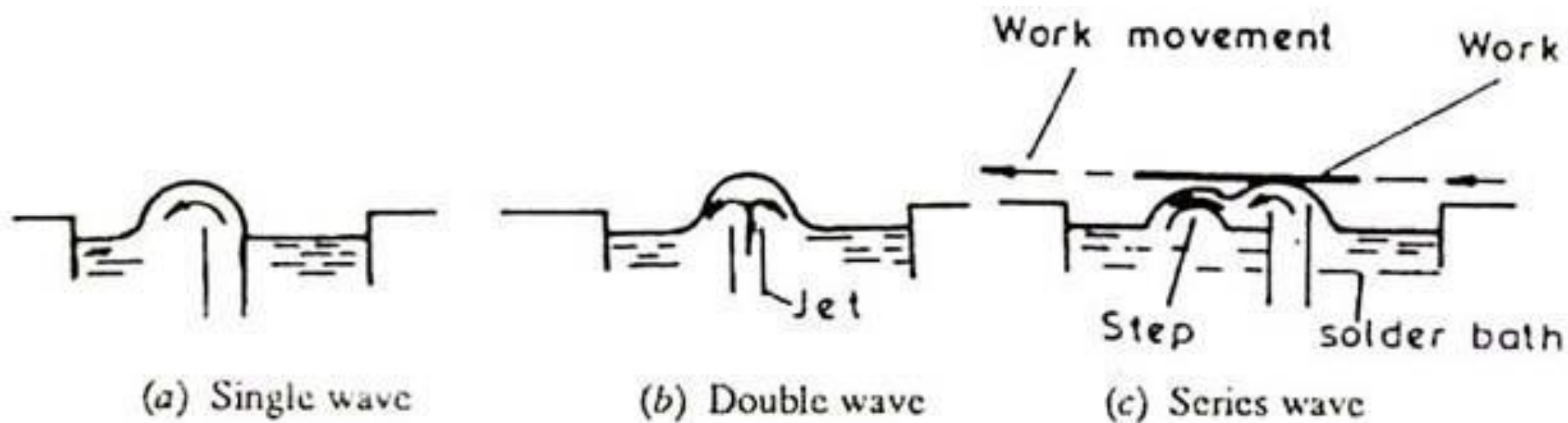


Fig. 17.5 Wave soldering techniques.

BRAZING



Aluminum or copper alloys are used as filler materials

Brazing is a metal-joining process in which two or more metal items are joined together by melting and flowing a filler metal into the joint, the filler metal having a lower melting point than the adjoining metal.

Brazing differs from welding in that it does not involve melting the work pieces and from soldering in using higher temperatures for a similar process.

It is similar to soldering, except the temperatures used to melt the filler metal are higher for brazing than soldering.

A major advantage of brazing is the ability to join the same or different metals with considerable strength.

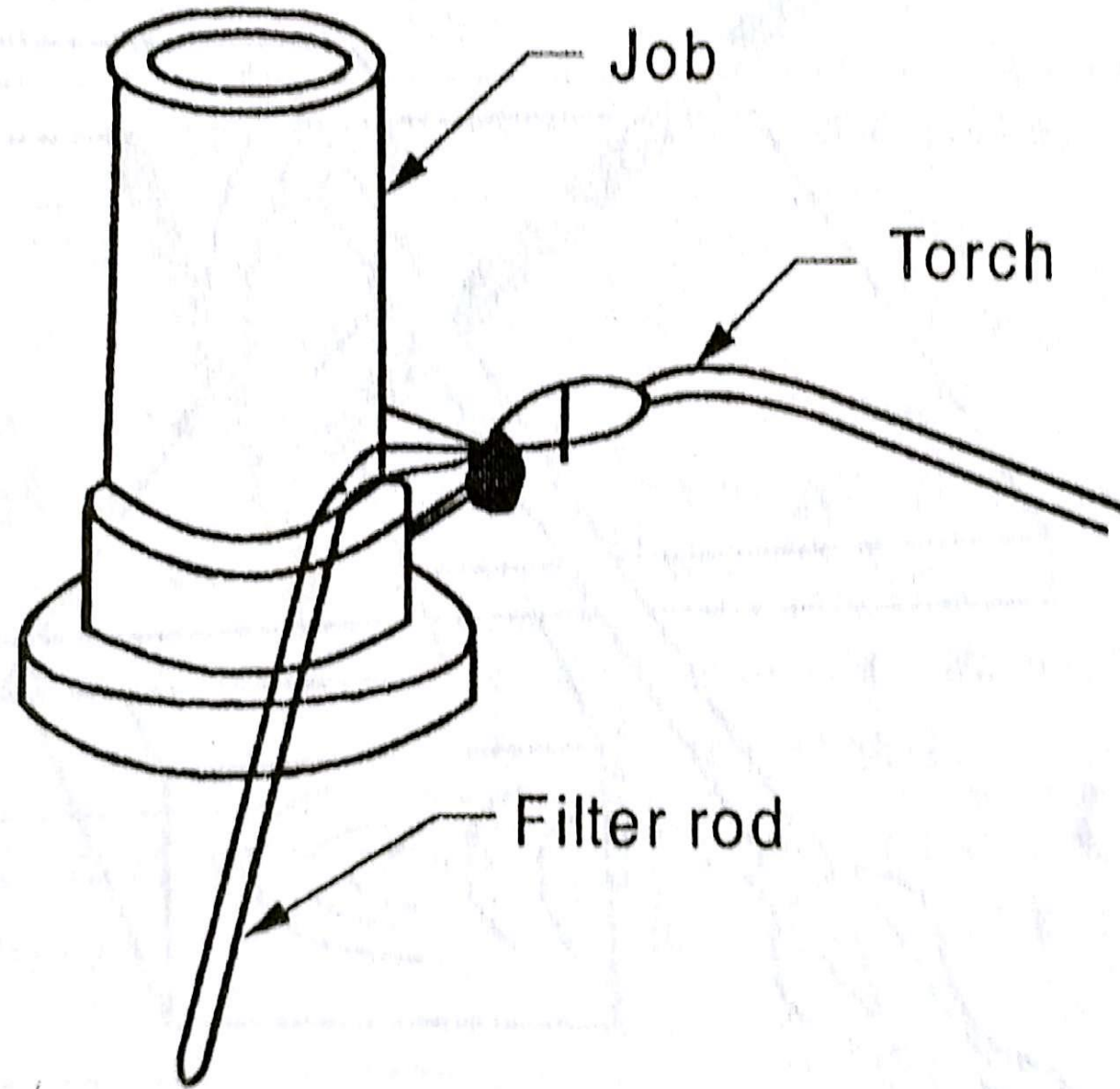


Fig. 5.72 Brazing Operation

FILLER METALS IN BRAZING

1. ALUMINIUM & SILICON

2. COPPER & PHOSPHEROUS

3. COPPER & ZINC

BRAZING PROCESSES

1. TORCH BRAZING
2. VACUUM BRAZING

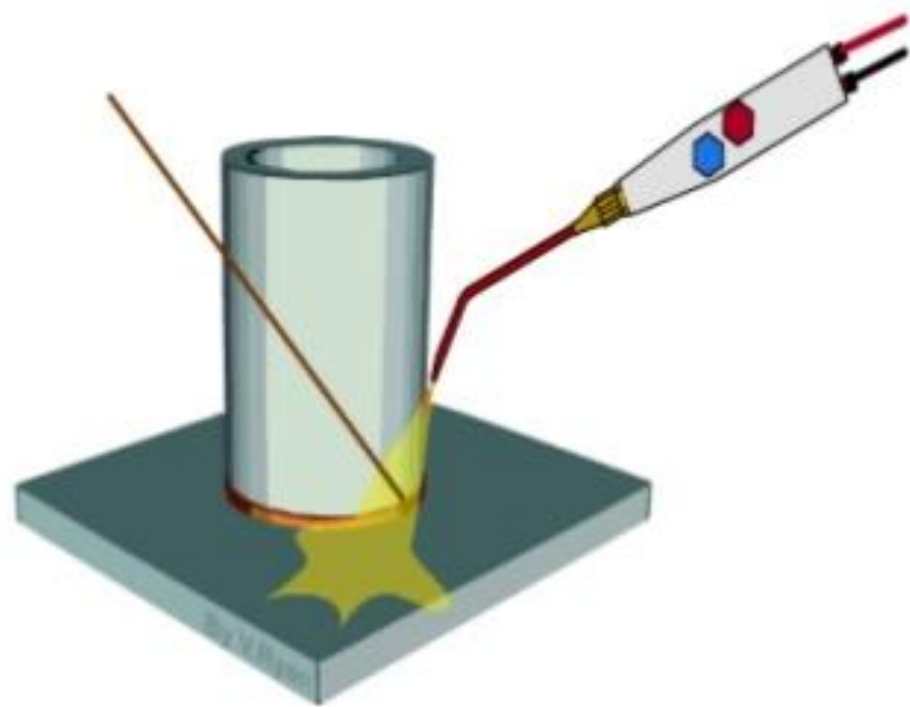
Brazing Methods:

- **Torch Brazing:-**

flux is applied to the part surfaces and a torch is used to focus flame against the work at the joint. A reducing flame is used to prevent the oxidation.

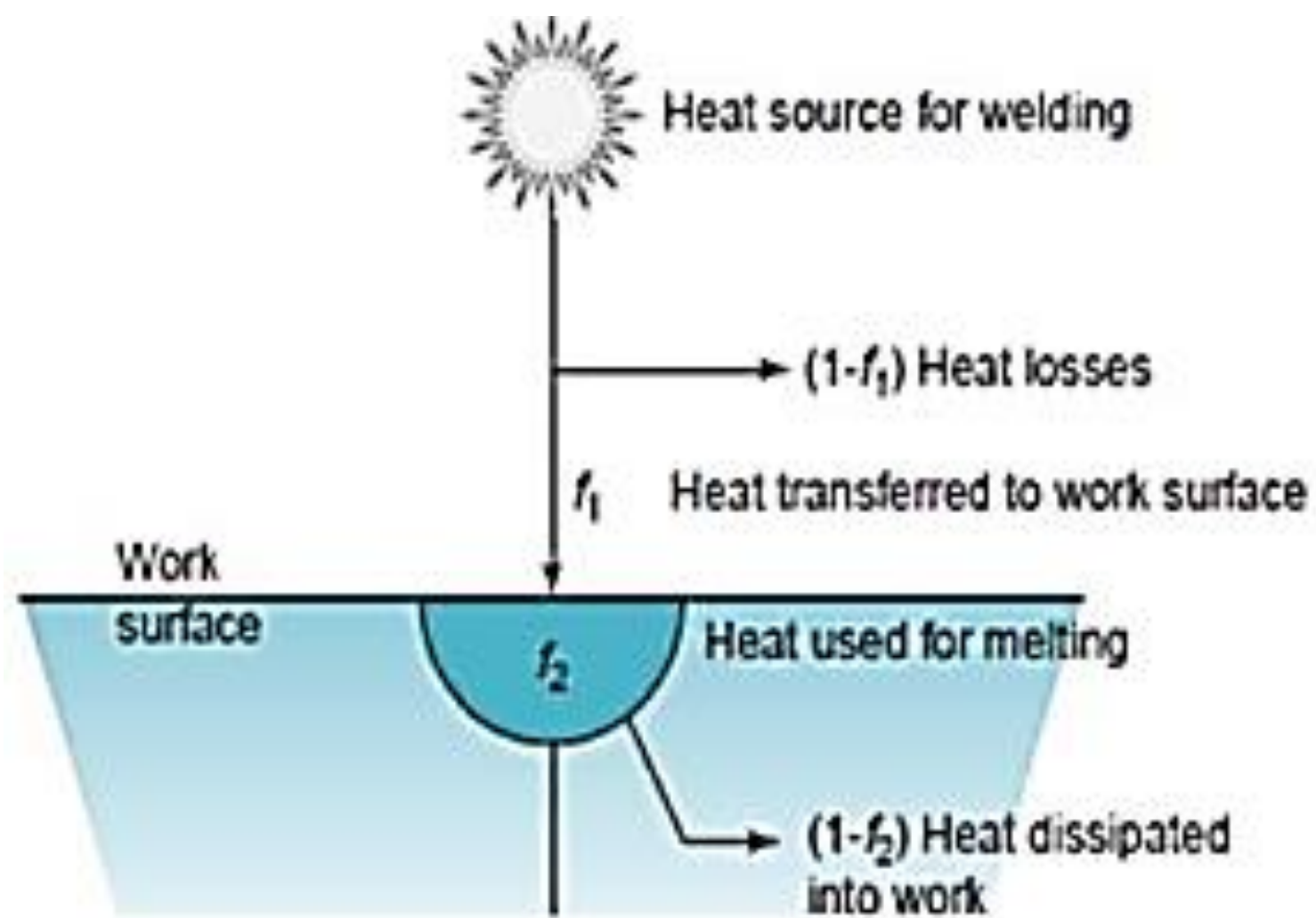
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BRAZING



	Soldering	Brazing	Welding
1	These are weakest joint out of three. Not meant to bear the load. Use to make electrical contacts generally.	These are stronger than soldering but weaker than welding. These can be used to bear the load upto some extent.	These are the strongest joints used to bear the load. Strength of a welded joint may be more than the strength of base metal.
2	Temperature requirement is upto 450°C.	It may go to 600°C in brazing.	Temperature required is upto 3800°C, of welding zone.
3	No need to heat the workpieces.	Workpieces are heated but below their melting point.	Workpiece to be joined need to be heated till their melting point.

	Soldering	Brazing	Welding
4	No change in mechanical properties after joining.	May change in mechanical properties of joint but it is almost negligible.	Mechanical properties of base metal may change at the joint due to heating and cooling.
5	Cost involved and skill requirements are very low.	Cost involved and skill required are in between the other two.	High cost is involved and high skill level is required.
6	No heat treatment is required.	No heat treatment is required after brazing.	Heat treatment is generally required to eliminate undesirable effects of welding.
7	Preheating of workpieces before soldering is good for making good quality joint.	Preheating is desirable to make strong joint as brazing is carried out at relatively low temperature.	No preheating of workpiece is required before welding as it is carried out at high temperature.

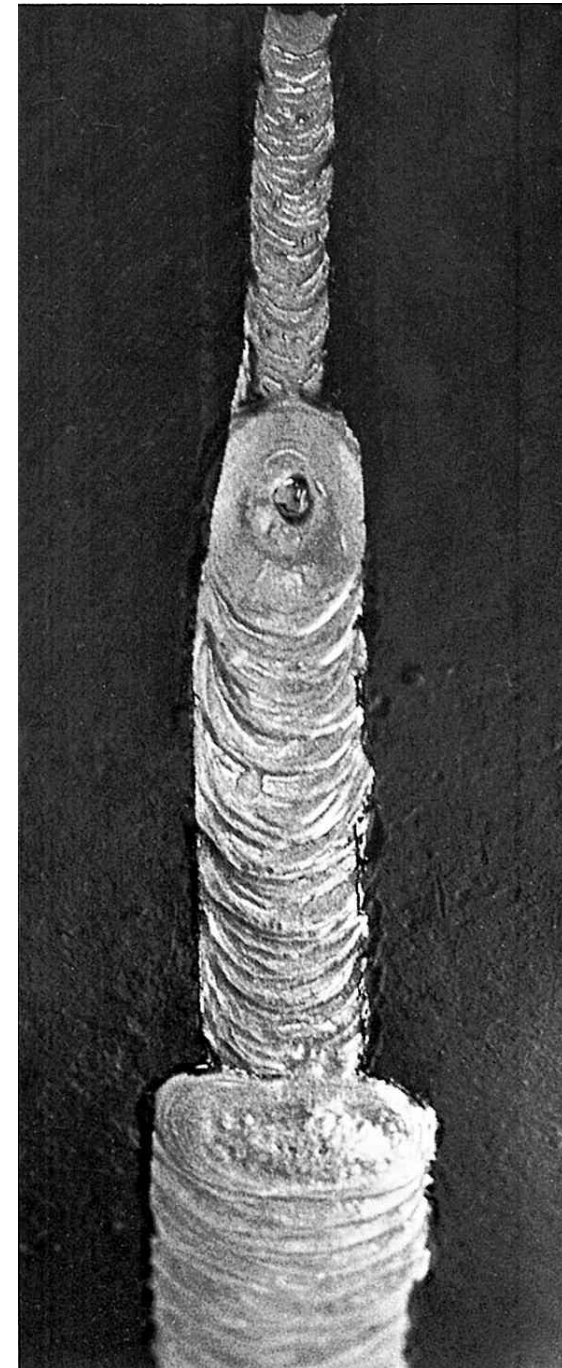


TYPES OF FLAMES

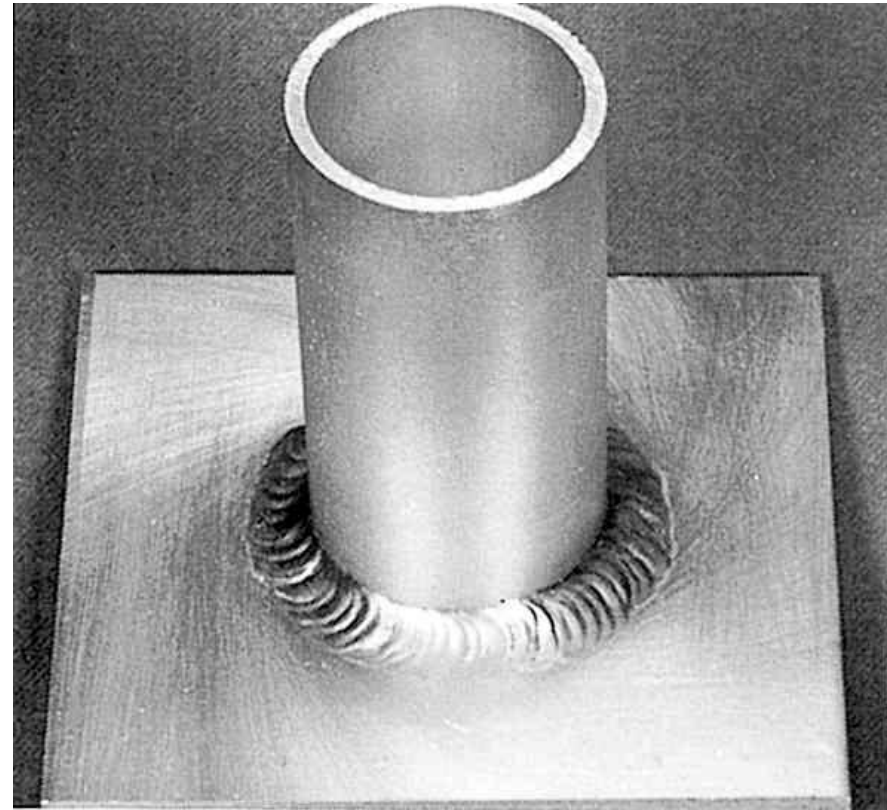
- Oxygen is turned on, flame immediately changes into a long white inner area (Feather) surrounded by a transparent blue envelope is called **Carburizing flame** (3000°C)
- Addition of little more oxygen give a bright whitish cone surrounded by the transparent blue envelope is called **Neutral flame** (It has a balance of fuel gas and oxygen) (3200°C)
- Used for welding steels, aluminium, copper and cast iron
- If more oxygen is added, the cone becomes darker and more pointed, while the envelope becomes shorter and more fierce is called **Oxidizing flame**
- Has the highest temperature about 3400°C
- Used for welding brass and brazing operation

Multipass Welds

Ability to make multipass welds such as this one, on plate and pipe, led to growth of industry. Welds are sound and have uniform appearance.



- Patent issued in 1930 to Hobart and Devers for use of electric arc within inert gas atmosphere
- Tungsten electrode replace magnesium procedure Patent issue in 1942
- Linde Company developed gas tungsten arc welding (GTAW)
 - Also called tungsten inert gas (TIG) process or HELIARC



An aluminum weld made using the TIG process. The welding of aluminum is no longer a problem and can be done with the same ease as that of steel.

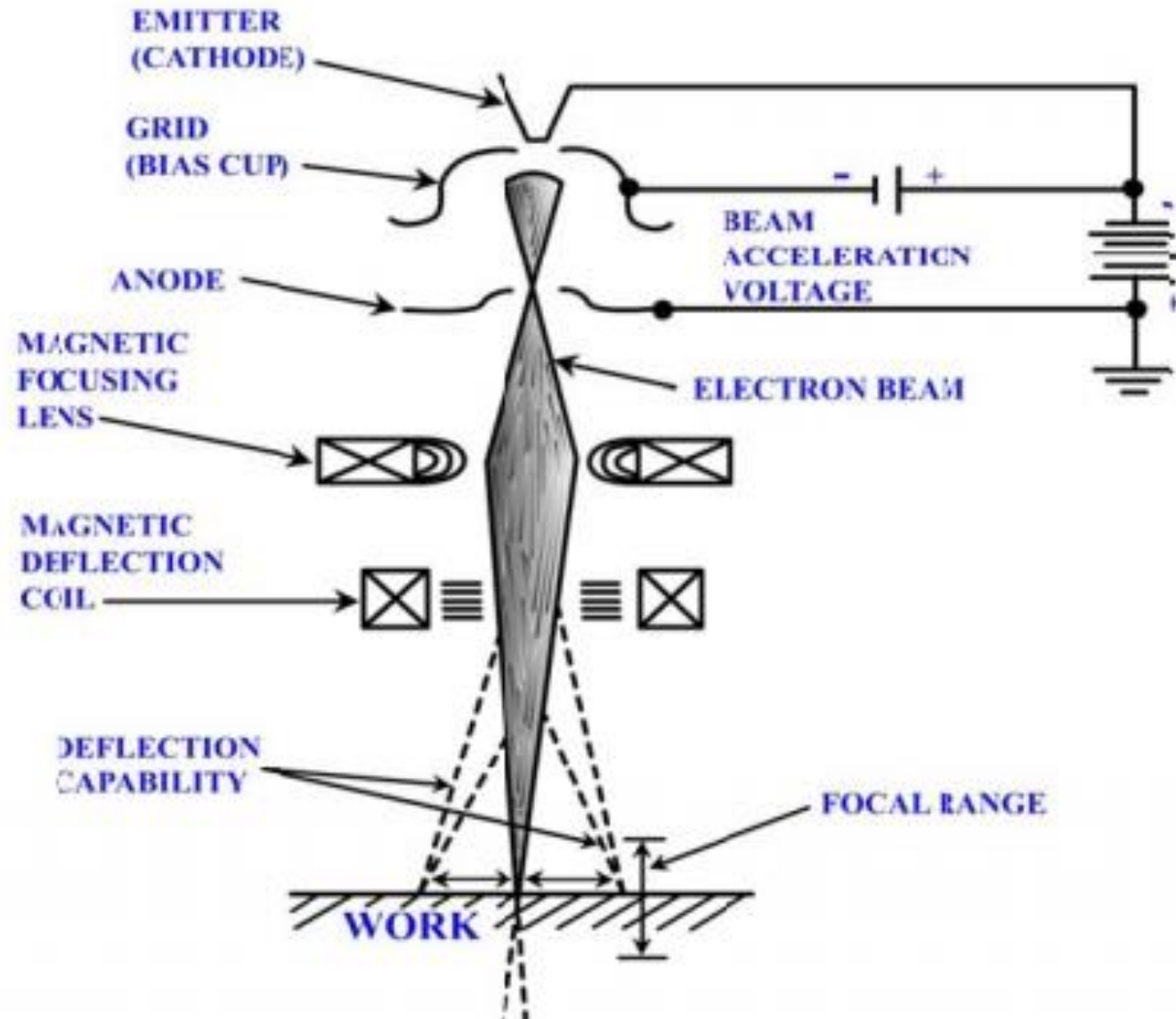
HIGH ENERGY BEAM WELDING

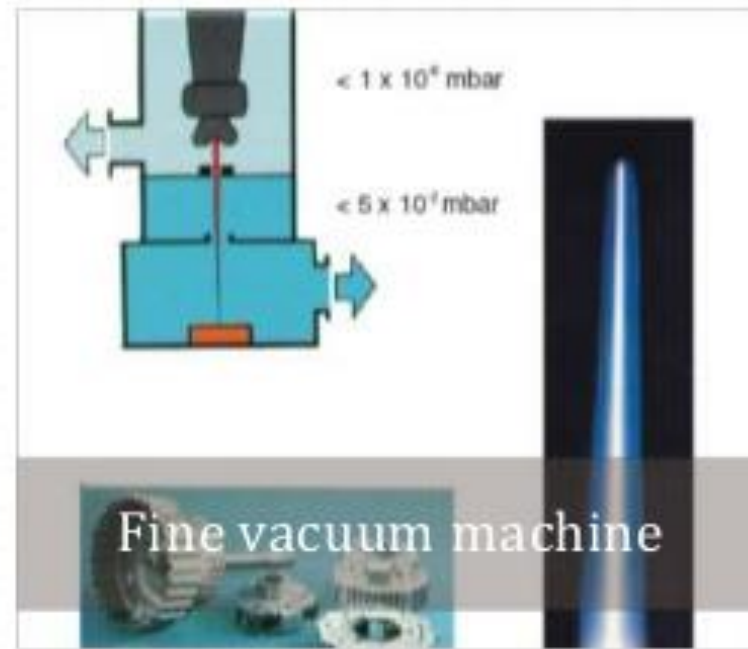
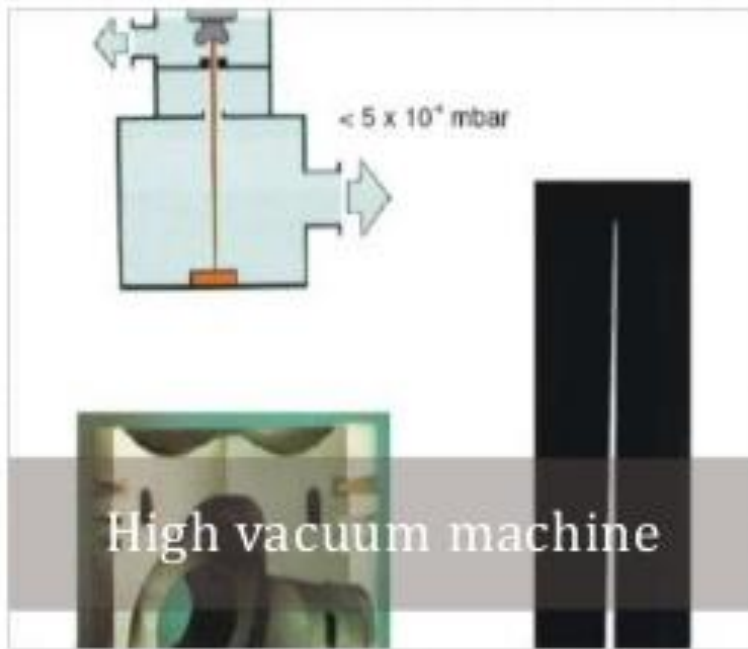
- ELECTRON BEAM WELDING
- LASER BEAM WELDING

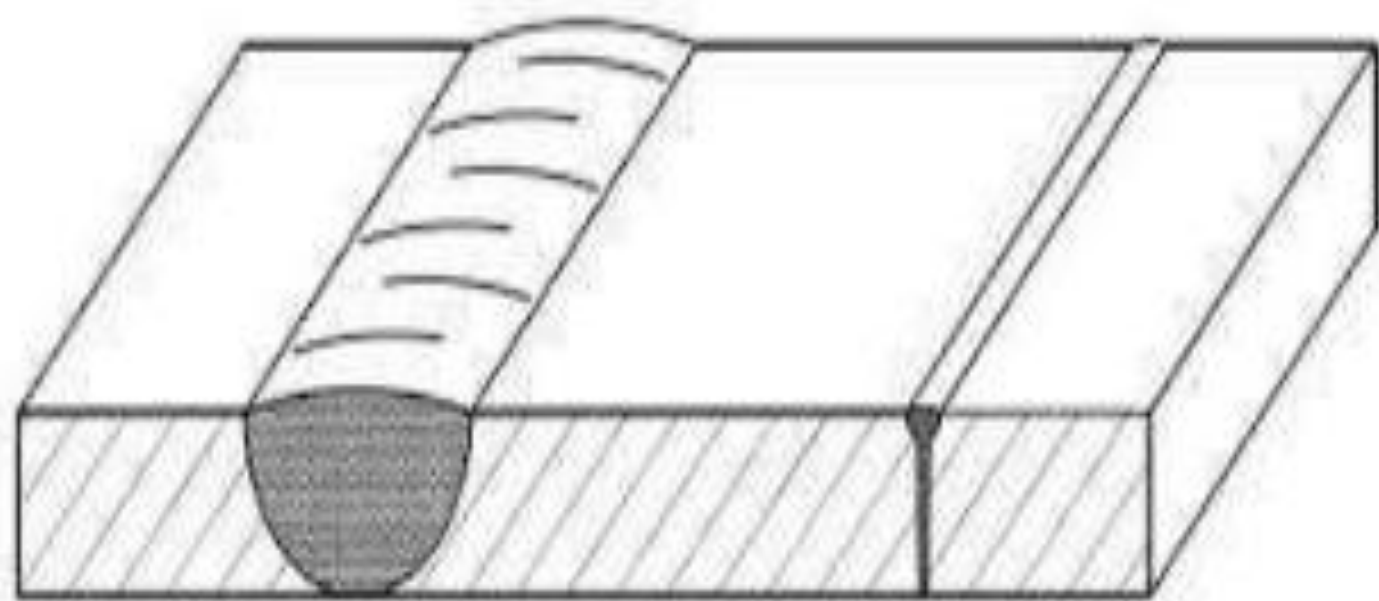
ELECTRON BEAM WELDING

EBW set up

- a) Electron gun,
- b) Power supply,
- c) Vacuum Chamber,
- d) Work piece handling device





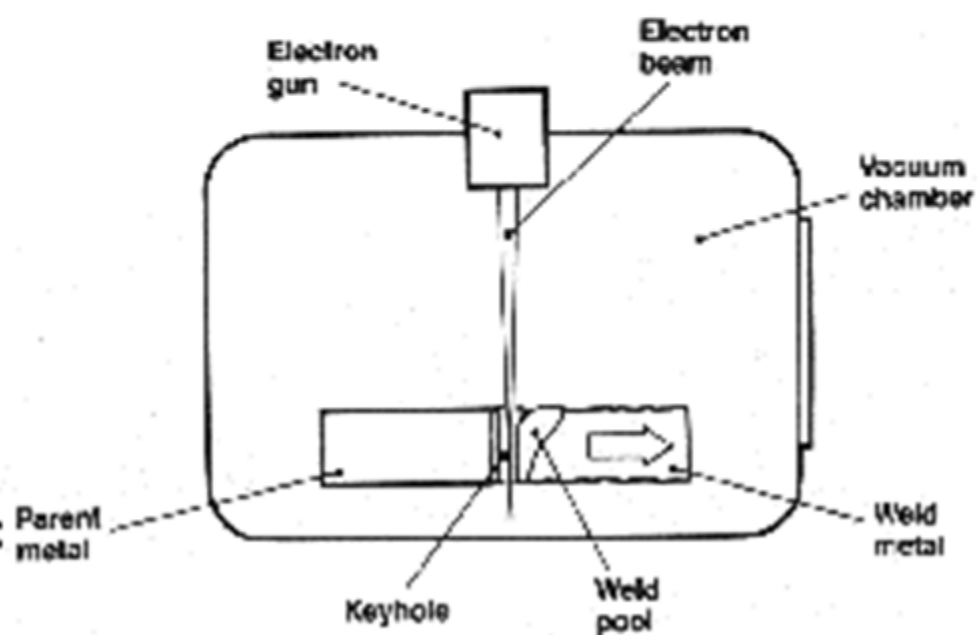


CONVENTIONAL WELD

ELECTRON BEAM WELD

Electron Beam Welding

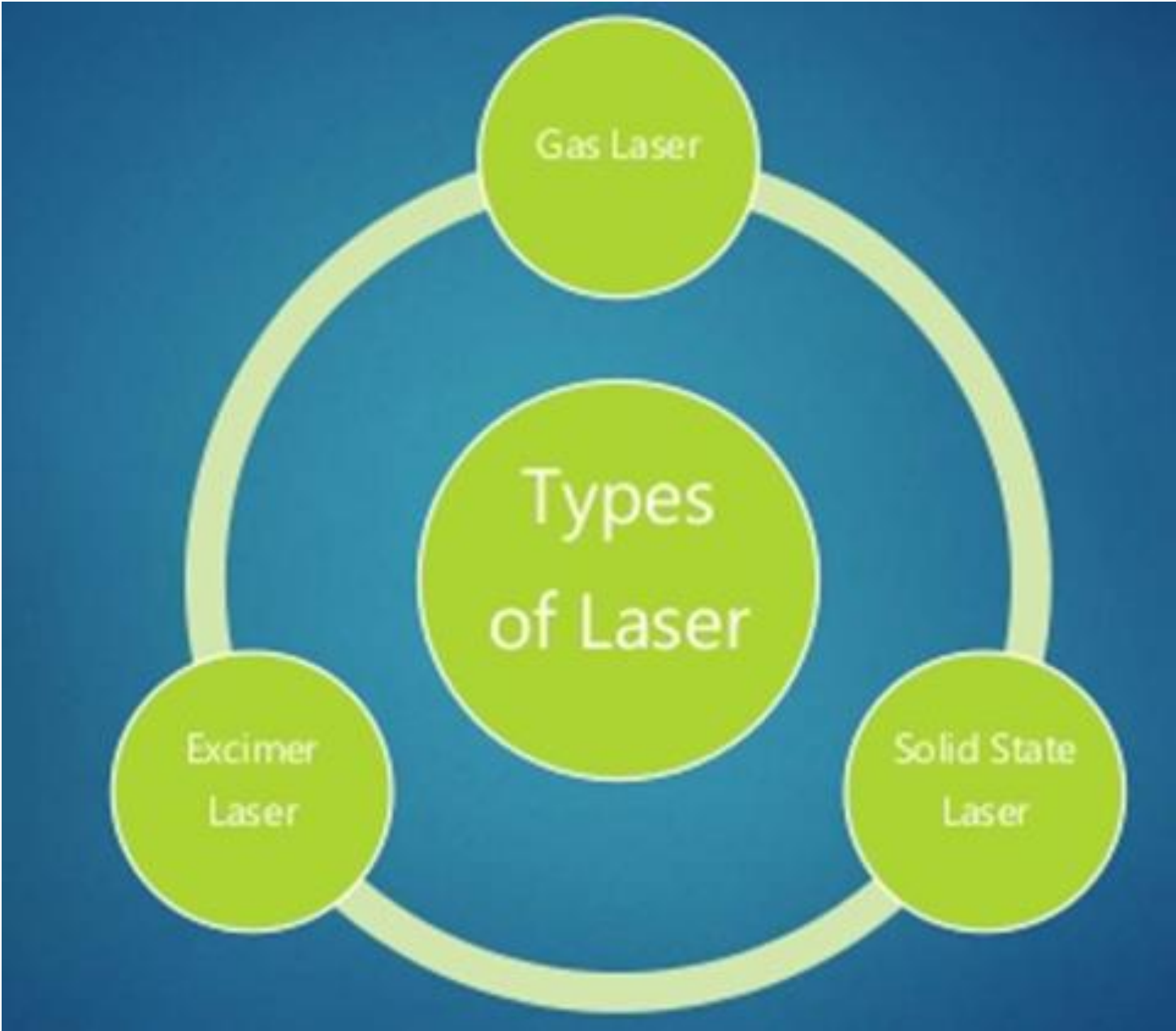
- Heat source
 - concentrated beam of high energy electrons
 - 30-200kV
 - 0.1mA to 1A
- System requires a vacuum chamber
 - electron range in air is normally only a few mm



Laser welding



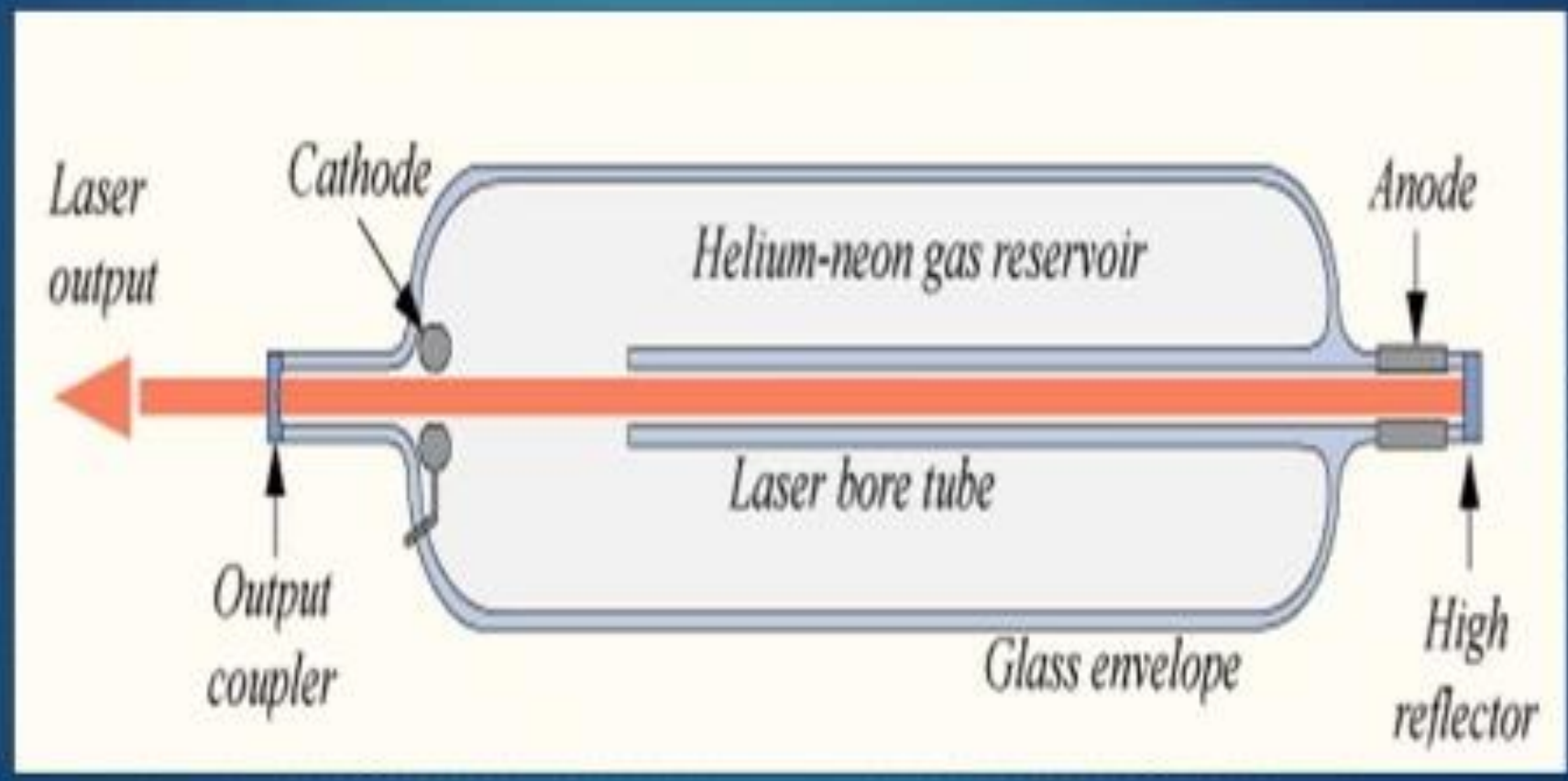
- Laser welding is a commercial process used to weld a wide range of materials. The beam is focused towards the joint which causes the materials to change from solid to liquid state. Upon cooling it returns to a solid state.



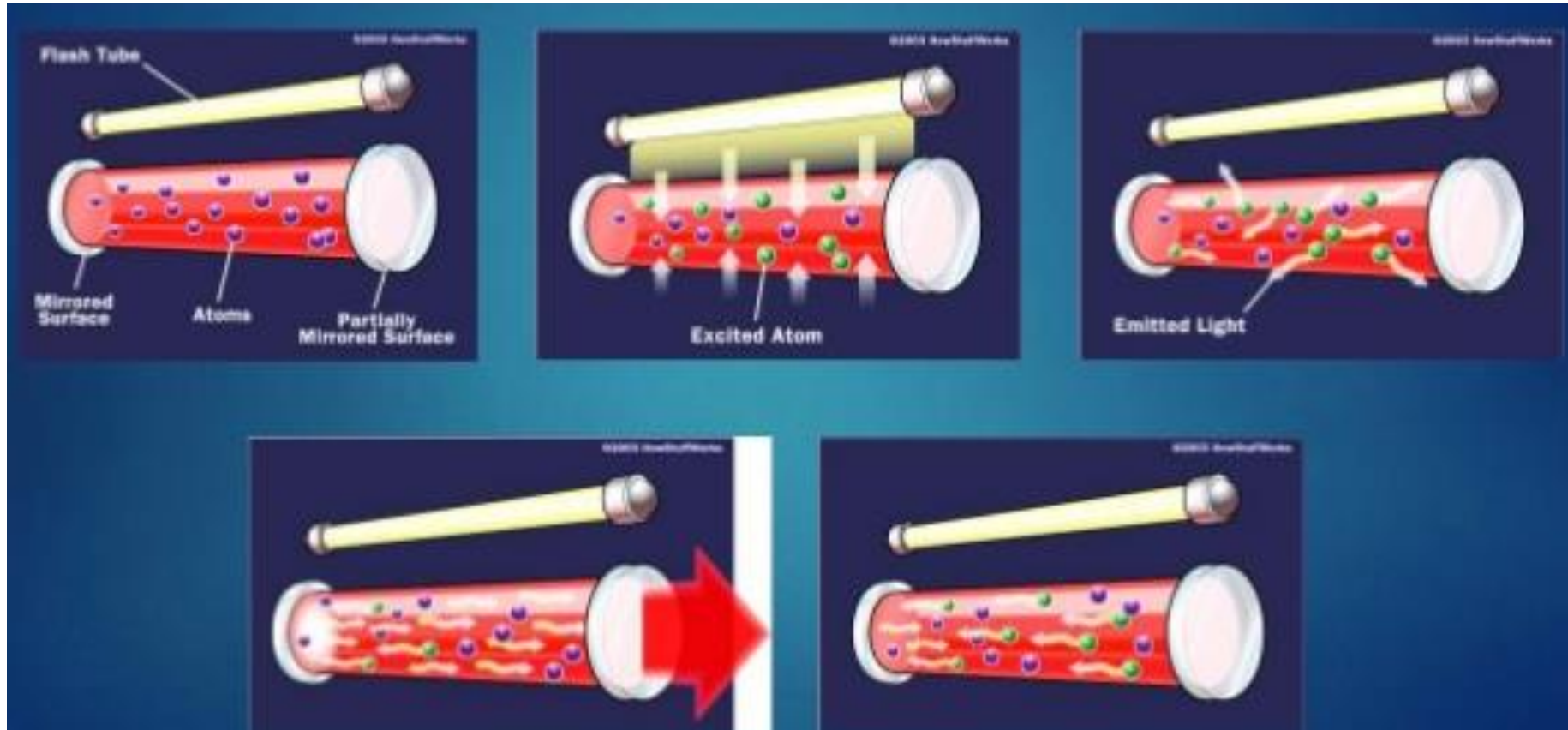
Gas Laser

- ◆ Electric current is discharged through a gas to produce a coherent light
- ◆ Operate on the principle of converting electric energy into laser light output
- ◆ Gas acts as pumping medium to attain the necessary population inversion
- ◆ Common gas laser are CO₂ Gas Laser, He-Ne Gas Laser

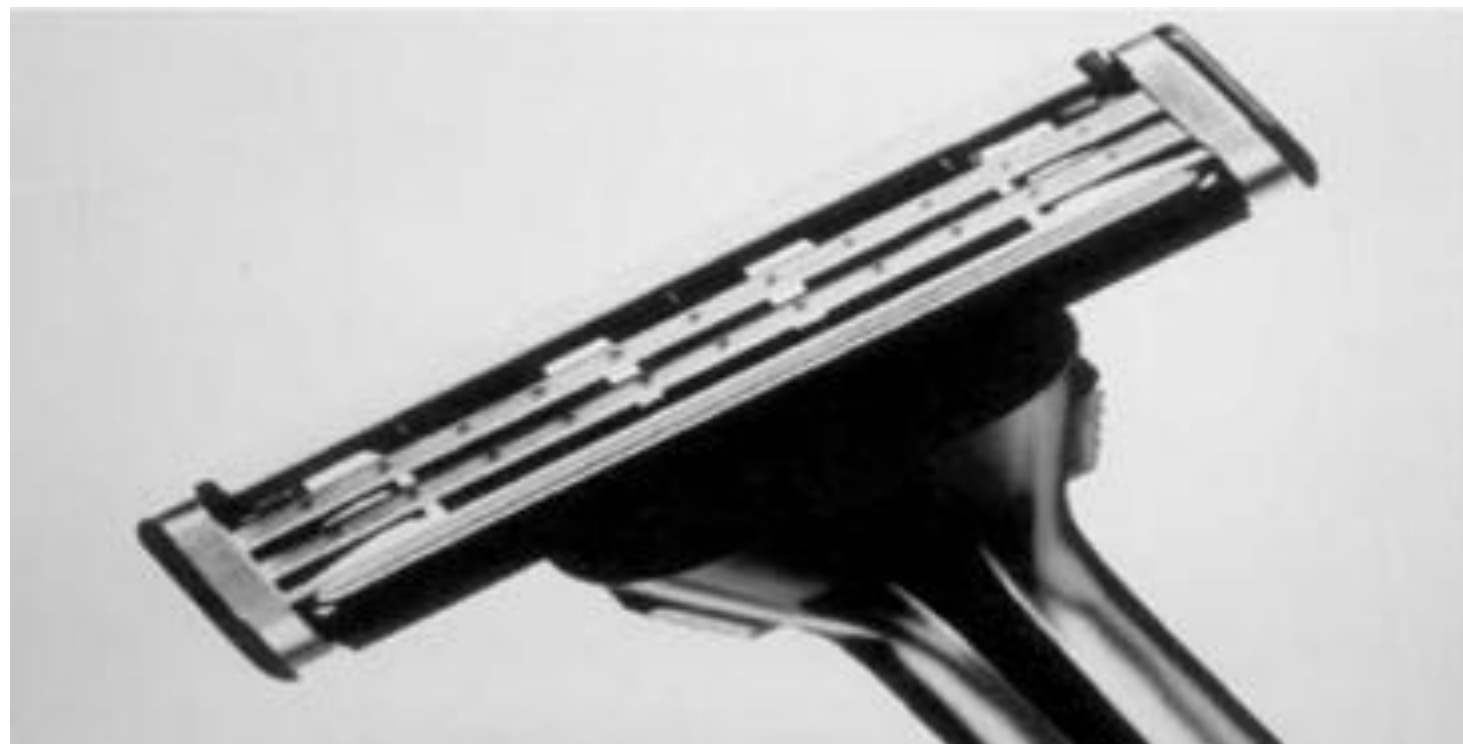
He-Ne Gas Laser



RUBY LASER



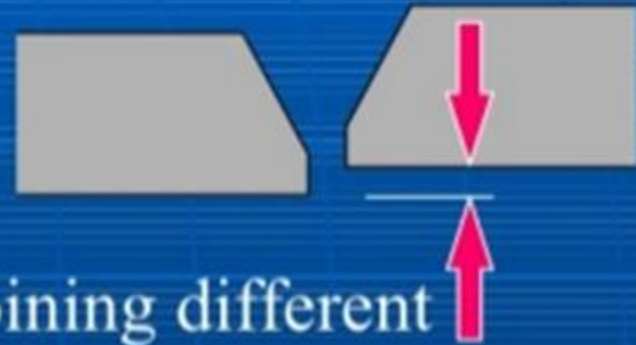
LASER WELDED RAZOR BLADE



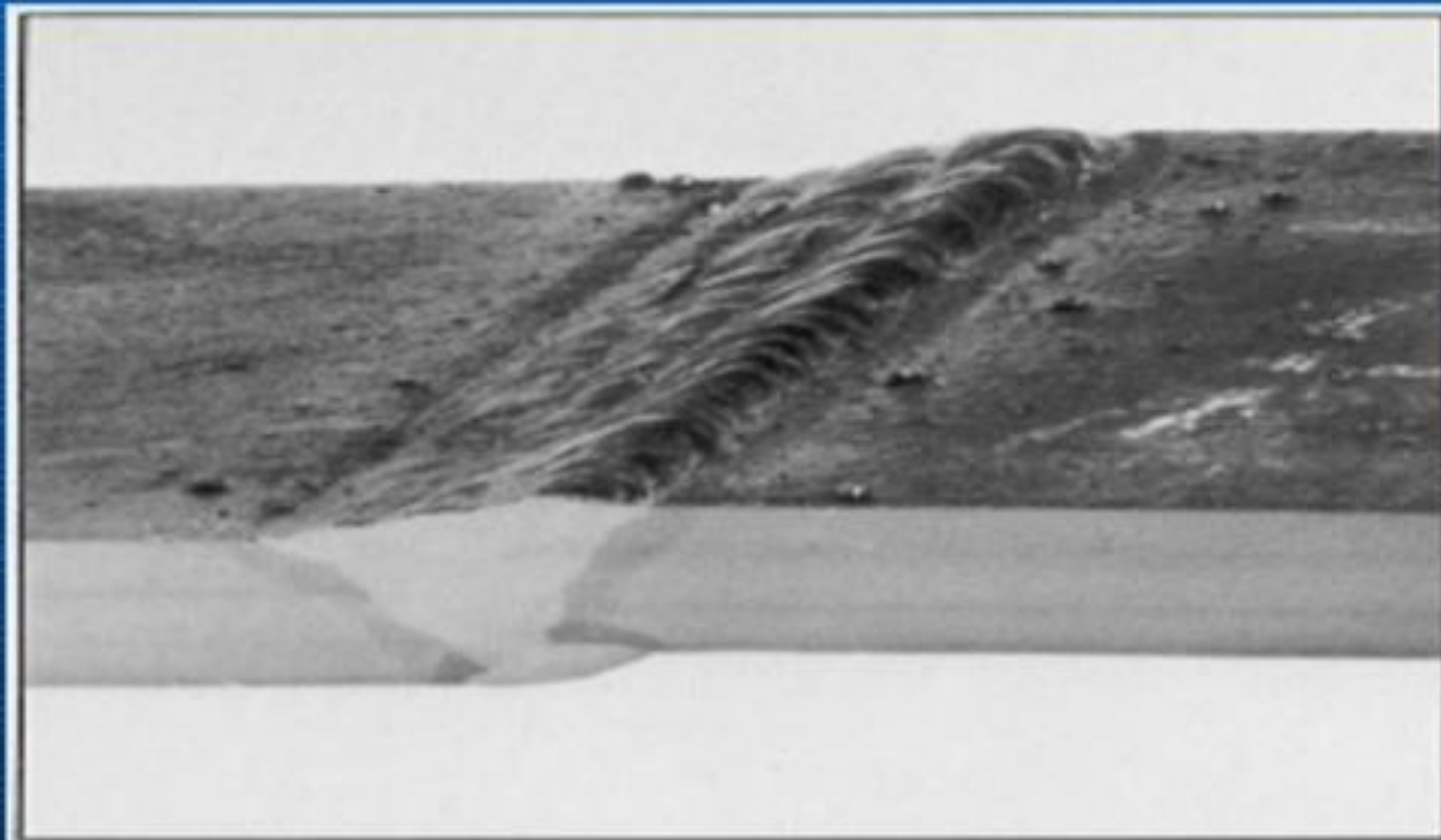
WELDING DEFECTS

Misalignment (hi-lo)

- **Definition:** Amount a joint is out of alignment at the root
- **Cause:** Carelessness. Also due to joining different thicknesses (transition thickness)



Misalignment

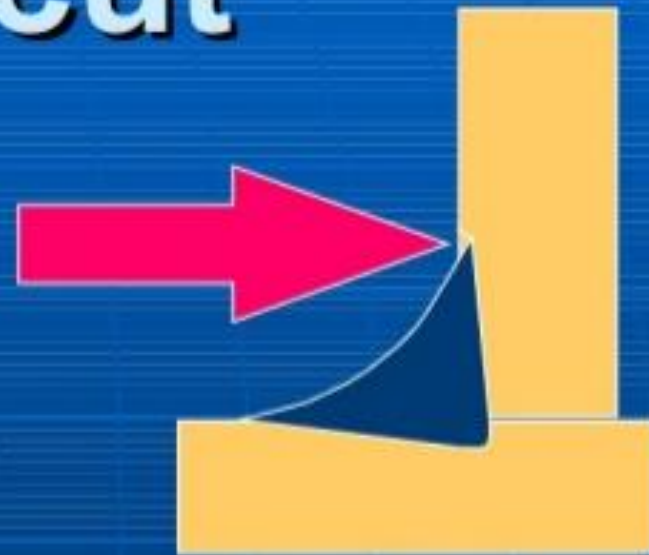


50mm

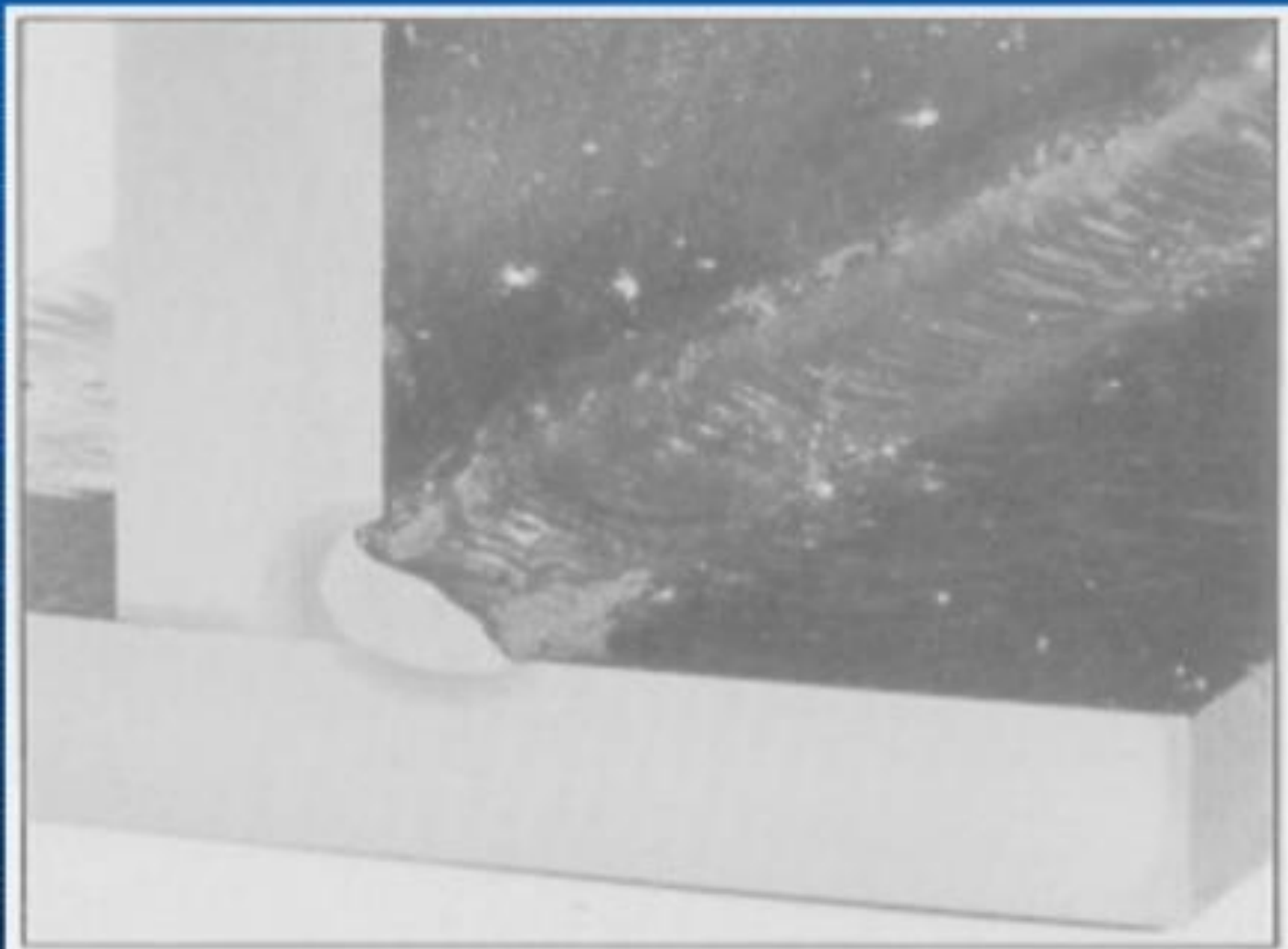
Undercut

Definition: A groove cut at the toe of the weld and left unfilled.

Cause: High amperage, electrode angle, long arc length, rust



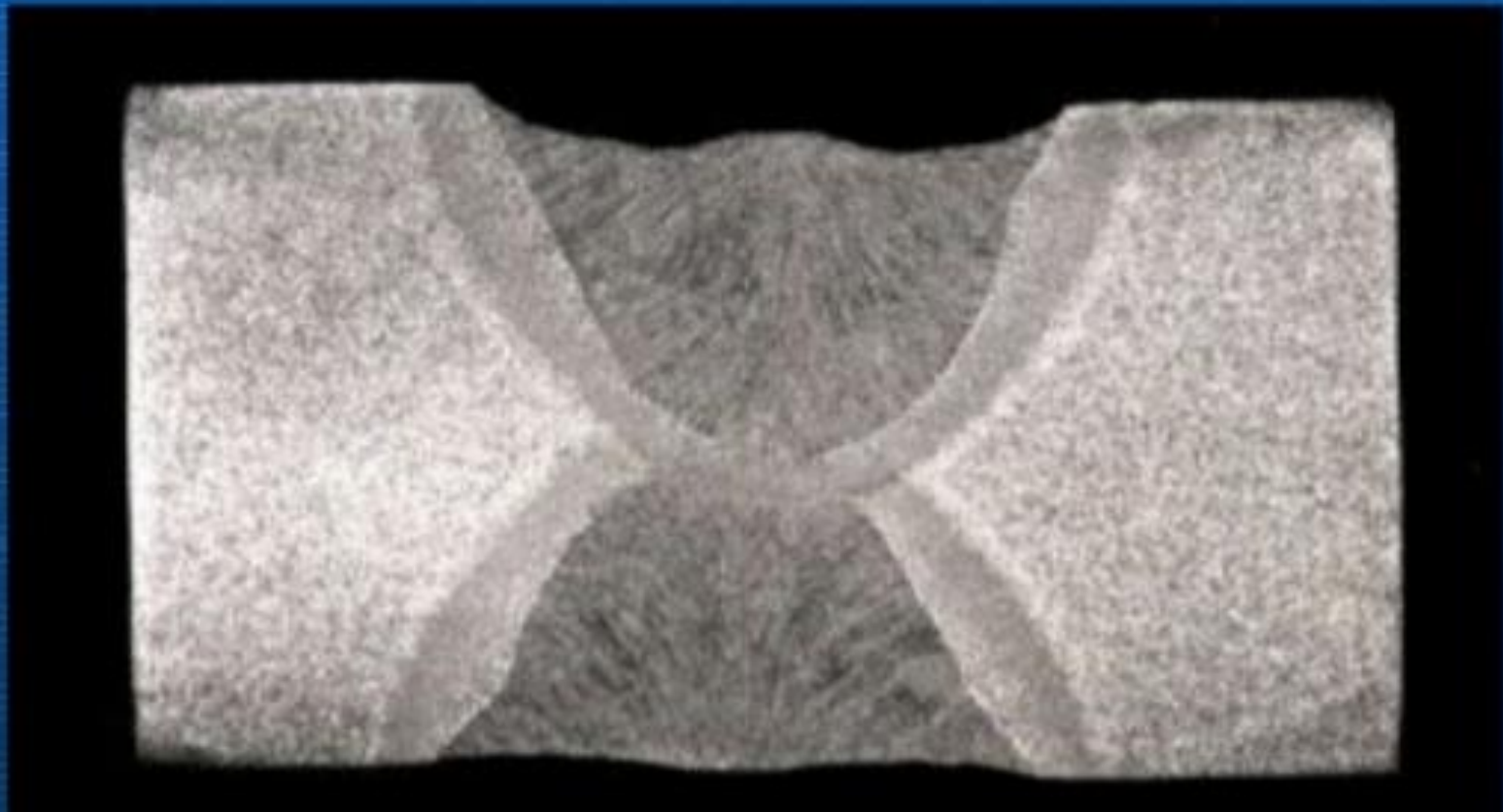
Under Cut



Insufficient Fill or Under fill

- Definition: The weld surface is below the adjacent surfaces of the base metal
- Cause: Improper welding techniques

Under fill



Excessive Concavity or Convexity

- **Definition:** Concavity or convexity of a fillet weld which exceeds the specified allowable limits
- **Cause:** Amperage and travel speed

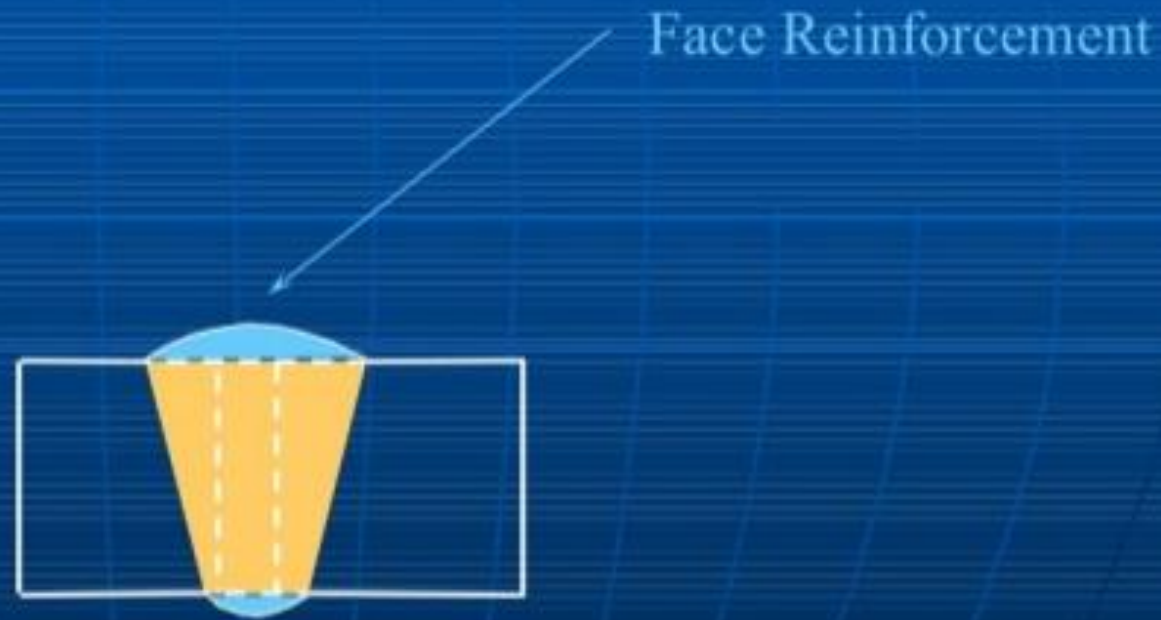
Root Concavity



Reinforcement

The amount of a groove weld which extends beyond the surface of the plate

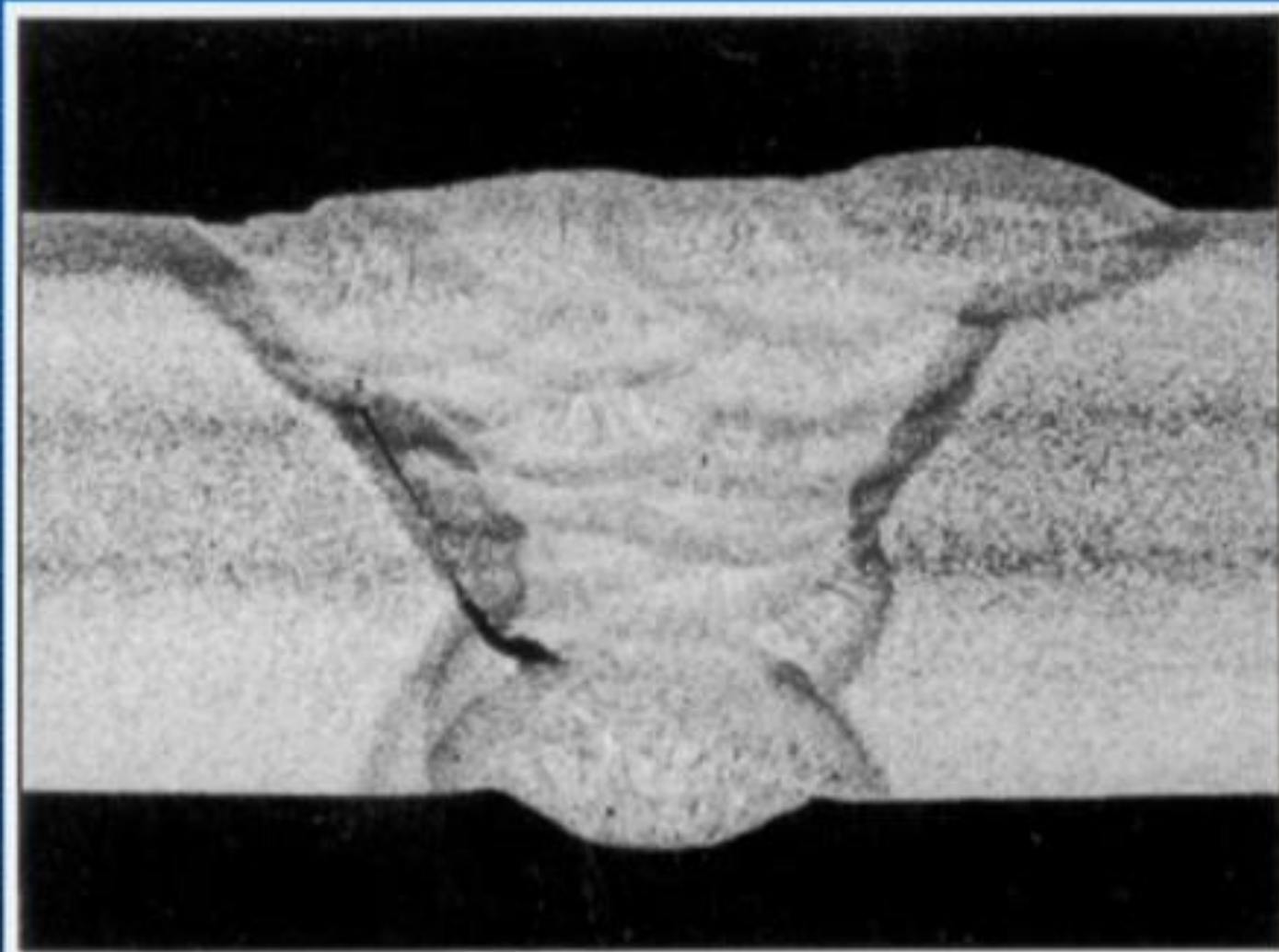
- Excessive
- Insufficient
- Improper contour



Excessive Penetration



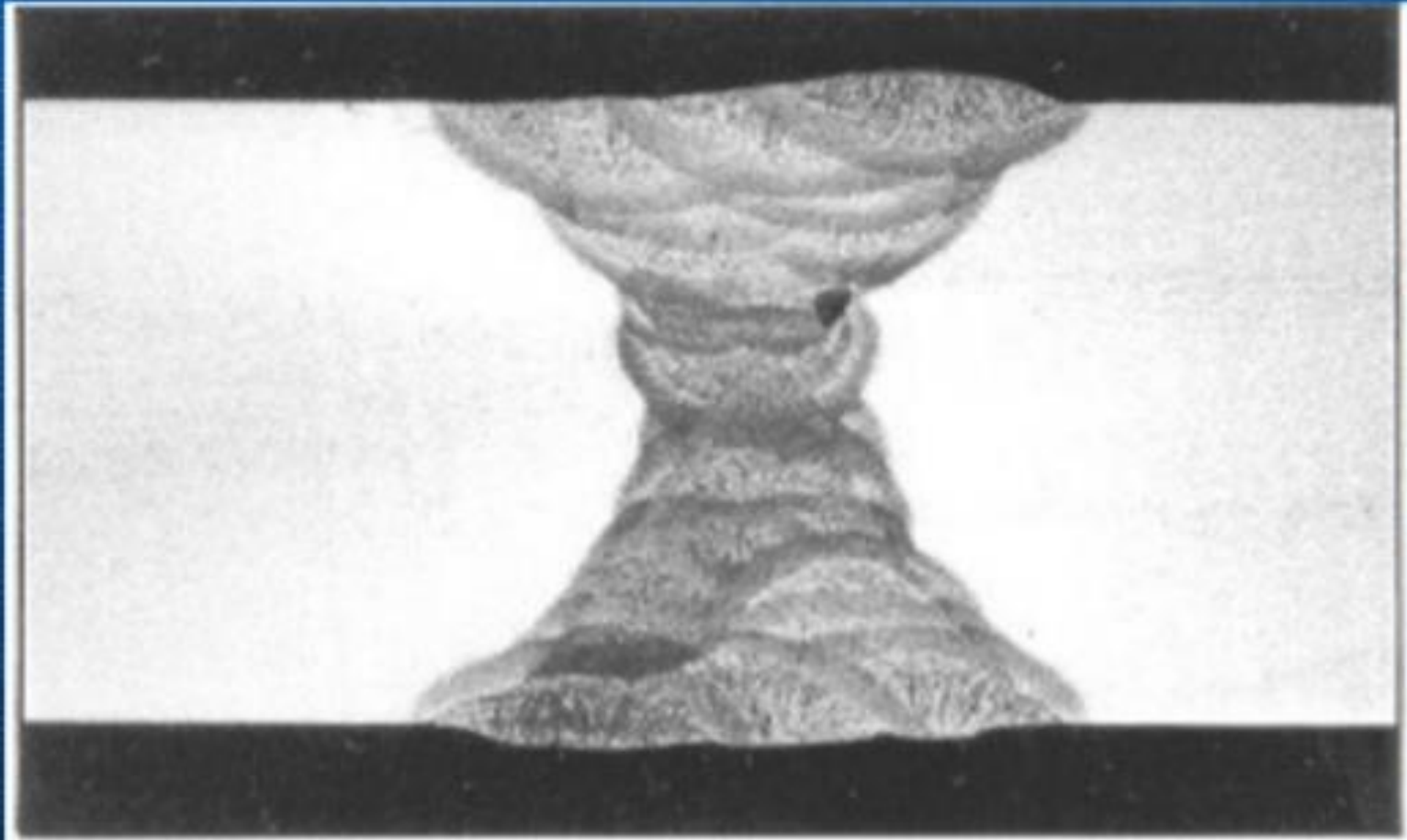
Lack of Side Wall Fusion



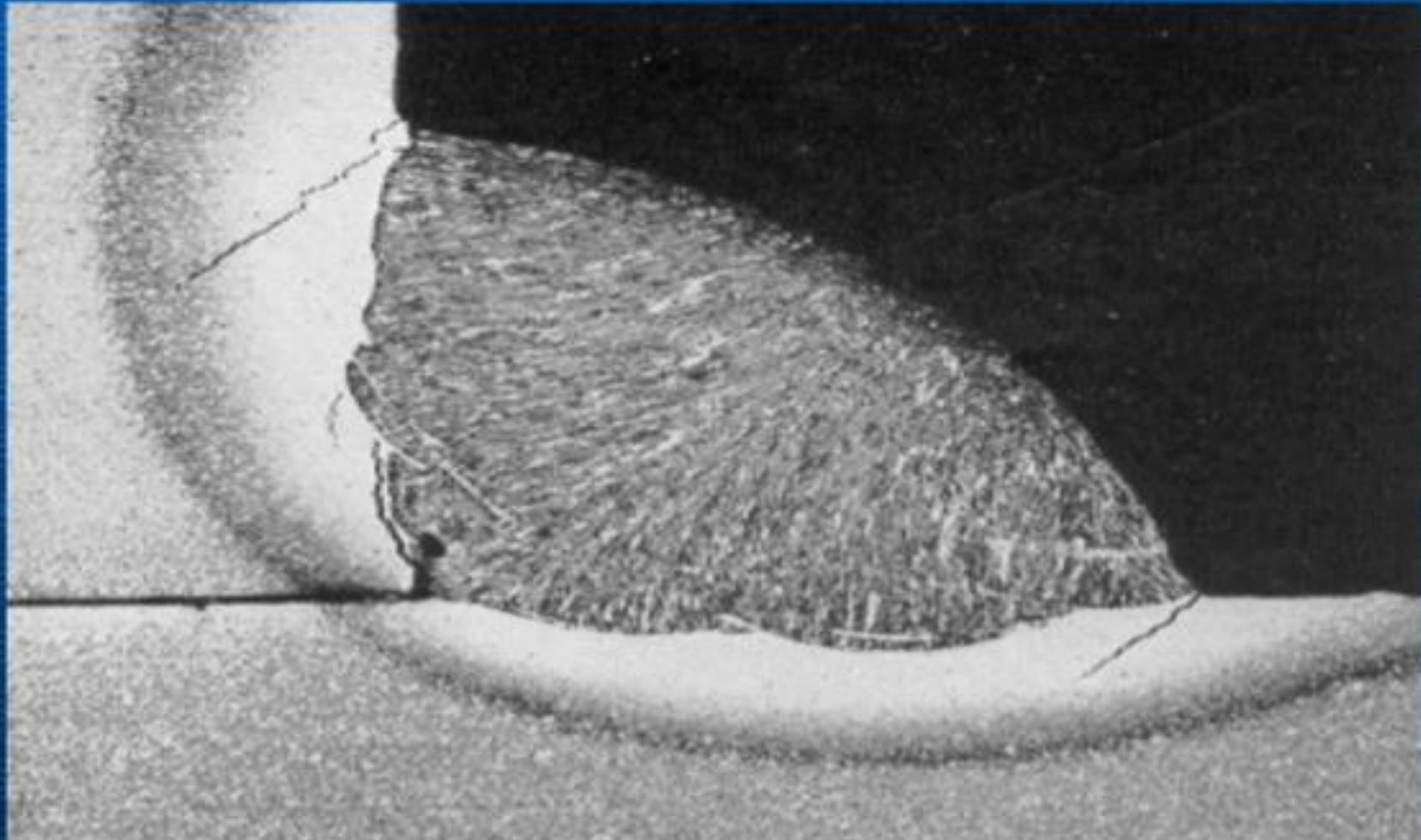
Arc Strike



Slag Inclusion



Toe Crack



Root Crack

