WELDING: Introduction

- Welding which is the process of joining two metallic components for the desired purpose
- The process of joining may also take place by other means of riveting or by fastening nut and bolts
- process of joining two similar or dissimilar metallic components
- with the application of heat,
- with or without the application of pressure
- and with or without the use of filler metal.

- Normally in welding operation joining of metal pieces is done by raising their temperature to the fusion point so that they form a sort of pool of molten metal at the ends to the joined

- the pool is supplemented with a filler metal (wire or rod) which normally has almost same compositions as that of the work pieces

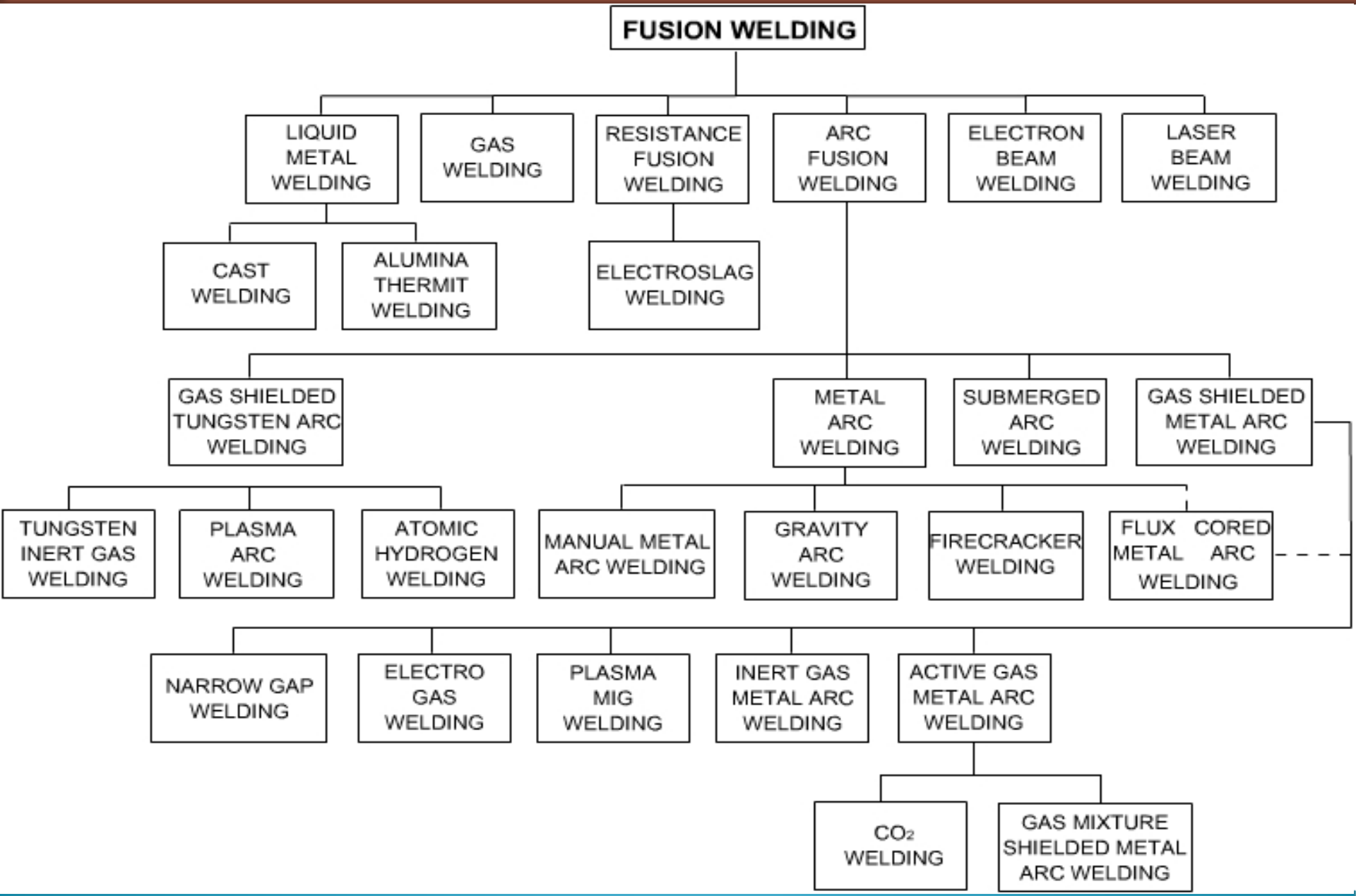
Welding processes can be classified based on following criteria;

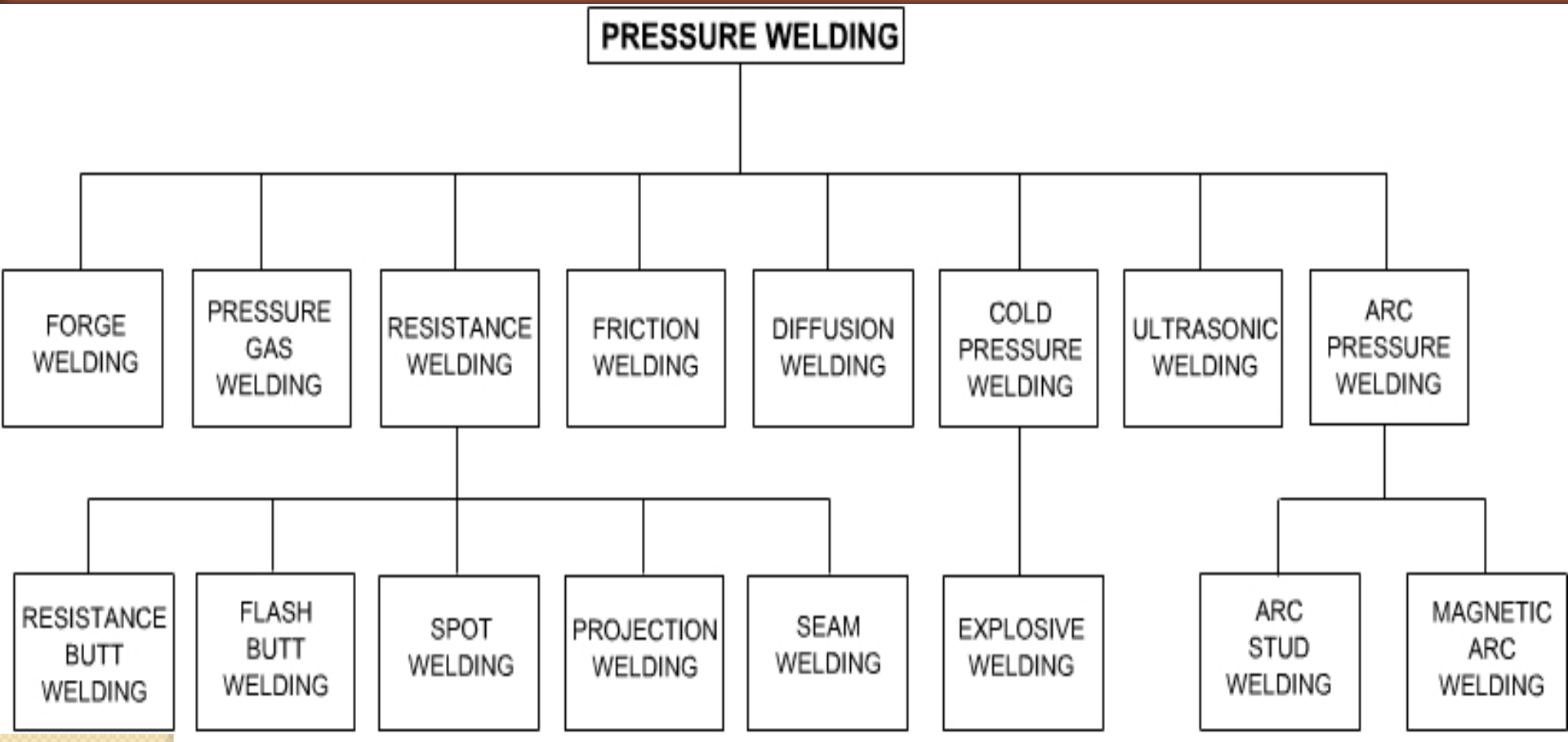
- Welding with or without filler material.
- Source of energy of welding.
- Arc and Non-arc welding.
- Fusion and Pressure welding
- Various sources of energies are used such as chemical, electrical, light, sound, mechanical energies

Classification of Welding Processes

It can be classified as fusion welding or pressure welding depending upon on the application of heat

- If application of heat is not required, it is called pressure welding.
- In case of fusion welding it can classified low temperature welding and high temperature welding low temperature welding like soldering and brazing
- Fusion welding can also be classified on the basis of method of heat generation like gas welding, electric arc welding, resistance welding, thermit welding, etc.
- On the basis of the type of joint produced it can be categorized as butt welding, seam welding, spot welding, lap joint welding, etc.


FUSION WELDING
LIQUID METAL WELDING
GAS WELDING
RESISTANCE FUSION WELDING
ARC FUSION WELDING
ELECTRON BEAM WELDING
LASER BEAM WELDING
CAST WELDING
ALUMINA THERMIT WELDING
ELECTROSLAG WELDING
GAS SHIELDED TUNGSTEN ARC WELDING
METAL ARC WELDING
SUBMERGED ARC WELDING
GAS SHIELDED METAL ARC WELDING
TUNGSTEN INERT GAS WELDING
PLASMA ARC WELDING
ATOMIC HYDROGEN WELDING
MANUAL METAL ARC WELDING
GRAVITY ARC WELDING
FIRECRACKER WELDING
FLUX CORED METAL ARC WELDING
NARROW GAP WELDING
ELECTRO GAS WELDING
PLASMA MIG WELDING
INERT GAS METAL ARC WELDING
ACTIVE GAS METAL ARC WELDING
CO_2 WELDING
GAS MIXTURE SHIELDED METAL ARC WELDING


PRESSURE WELDING
FORGE WELDING
PRESSURE GAS WELDING
RESISTANCE WELDING
FRICTION WELDING
DIFFUSION WELDING
COLD PRESSURE WELDING
ULTRASONIC WELDING
ARC PRESSURE WELDING
RESISTANCE BUTT WELDING
FLASH BUTT WELDING
SPOT WELDING
PROJECTION WELDING
SEAM WELDING
EXPLOSIVE WELDING
ARC STUD WELDING
MAGNETIC ARC WELDING

Gas Welding

- It is a fusion welding in which strong gas **flame** is used to generate **heat** and raise
- temperature of metal pieces localized at the place where joint is to be made.
- In this welding **metal pieces to be joined** are heated
- The metal thus melted starts **flowing** along the edges where joint is to be made.
- A filler metal **may also** be added to the flowing molten metal to fill up the cavity at the edges
- The cavity filled with molten metal is allowed to solidify to get the strong joint.
- Different **combinations of gases** can be used to obtain a heating flame.
- The popular gas combinations is oxygen-acetylene mixture. Different mixing **proportions** of two gases in a mixture can generate different types of flames with different characteristics

Oxy-Acetylene Welding

- Oxy-acetylene welding can used for welding of wide range of **metals** and **alloys**
- Acetylene mixed with oxygen when burnt under a controlled environment produces large amount of heat giving higher temperature rise.
- This burning also produces carbon dioxide which helps in preventing **oxidation of metals** being welded.
- Highest temperature that can be produced by this welding is 3200oC.
- The chemical reaction involved in burning of acetylene is

$$2C_2H_2 + 5O_2 = 4CO_2 + 2H_2O + Heat$$

Tools and Equipment

(a) Gas cylinders (two)

(b) Hose pipes and valves

(c) Cylinder pressure gauge

(d) Outlet pressure gauge

(e) Pressure regulators

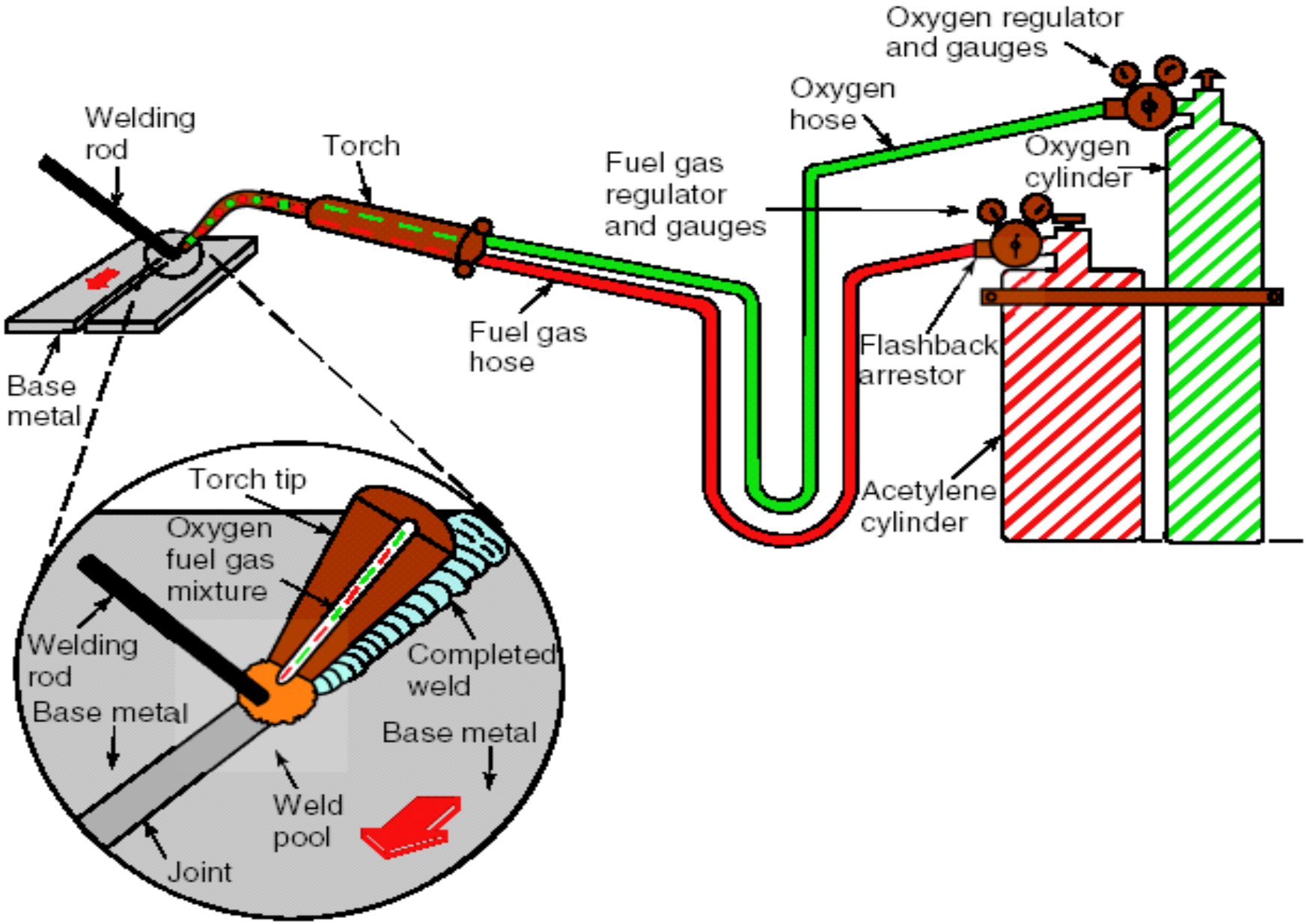
(f) Blow pipe or torch and spark lights

(g) Welding screens

(h) Goggles, screens, gloves and apron

(i) Wire brush, trolley, chipping hammer.

Oxy-Acetylene Welding



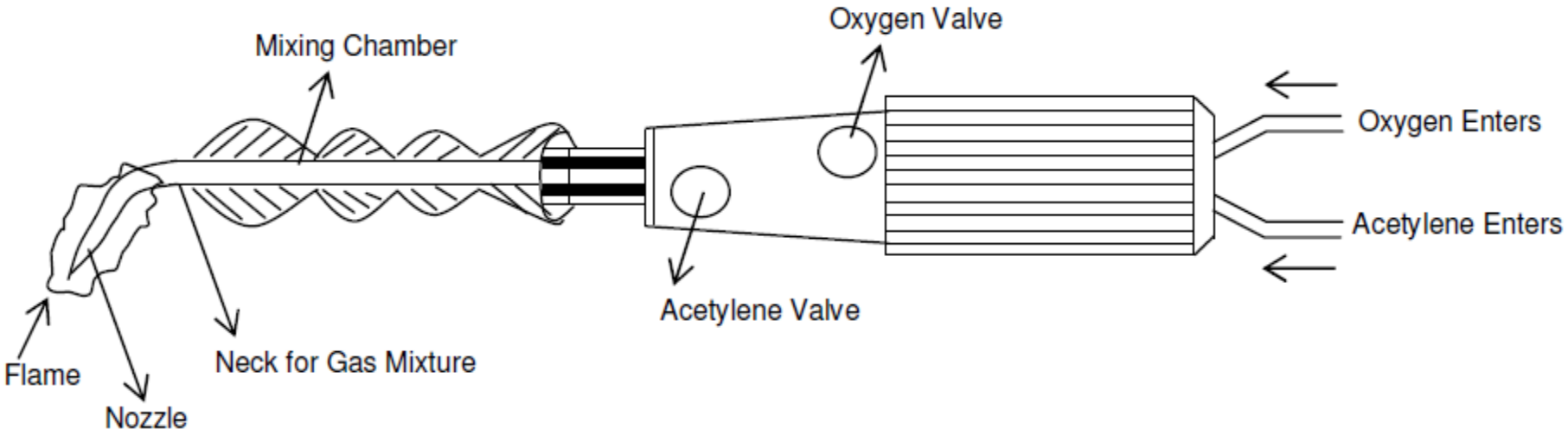
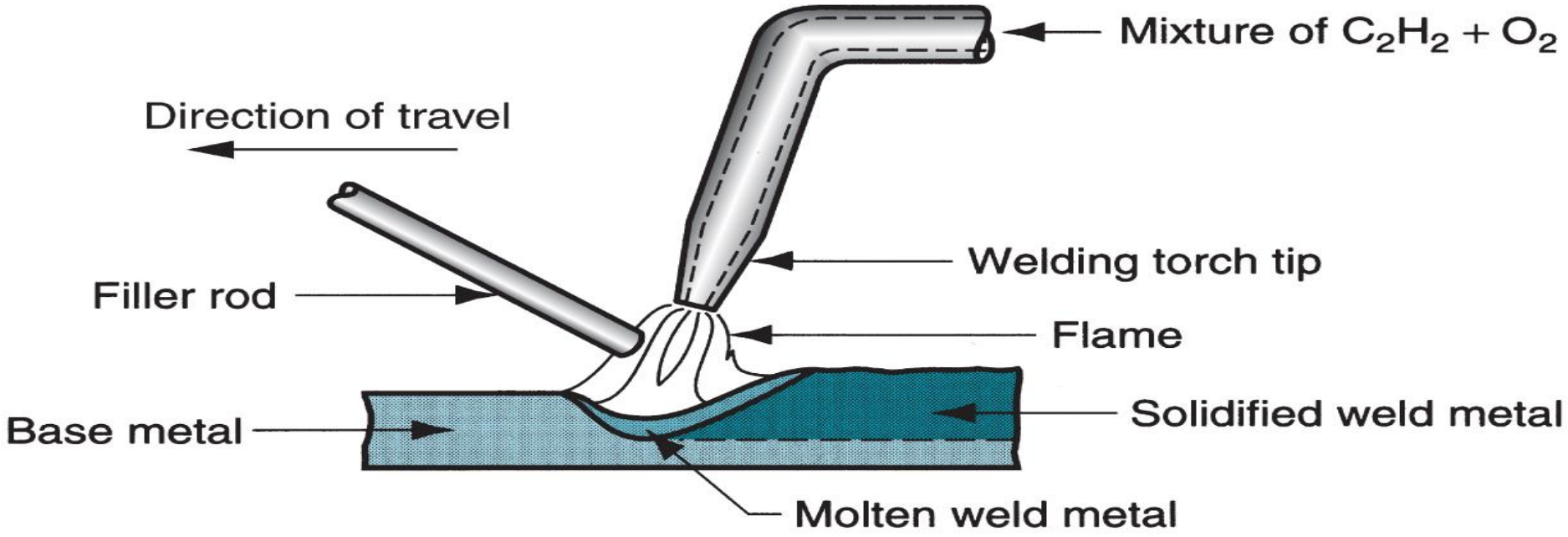


Figure 5.3 : Blow Pipe Used in Gas Welding



Consumables:

- (a) Oxygen gas
- (b) Acetylene gas
- (c) Filler metal (rod or wire)
- (d) Fluxes.

Welding Rods:

- Filler metal is typically in the form of rod,
- 90 mm long and diameter ranging from 1.6 mm to 9.5 mm
- Composition of filler metal must be **same as that of base metal**
- One is coated welding rods, which have coating of **flux**
- Others are bare welding rods having **no coating** of flux

Flux:

- Flux is used to prevent **oxidation** of hot metal.
- It converts the **oxides and nitrides to** slag that can be removed from welding zone easily.
- Formation of oxides and nitrides make weldment weak.
- Different fluxes are used for welding of different metals.
- For the welding of copper and its alloy sodium nitrate, sodium carbonates are used as flux.
- For welding of aluminium or its alloy chloride of sodium, potassium, lithium or barium are used.

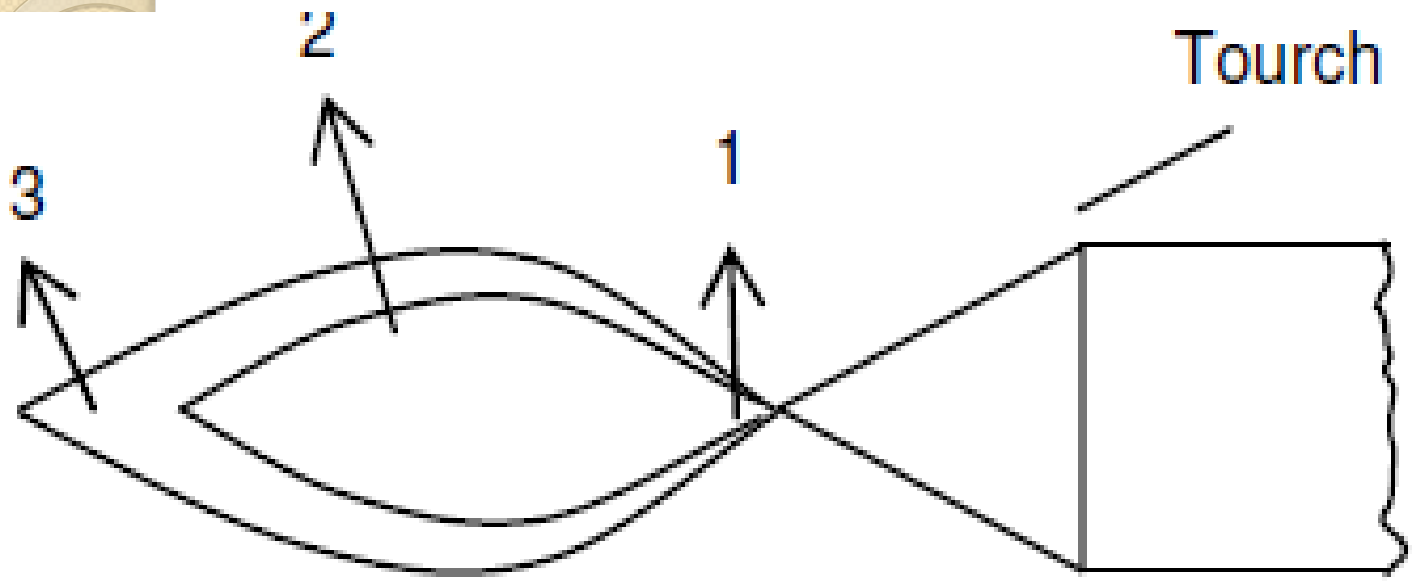
FLAME FORMATION AND ITS DIFFERENT TYPES

- Flame is established by burning (controlled) of the two gases mixture at the outlet of blow pipe or torch.
- The proportion of gasses in the mixture is controlled by controlling the **flow rate** of each of the two gasses
- Here, it should be clear that burning of acetylene generates heat and oxygen only supports
- Zone ‘1’ is very near to the outlet of torch, where oxygen reacts with acetylene and burning of two gases takes place.
- Zone ‘2’ produces carbon monoxide and hydrogen in ratio 2 : 1 by volume.

  This zone gives the highest temperature of the flame
- Zone ‘3’ is the outermost zone of the flame. Temperature of this zone is comparatively low.

On the basis of supply proportion of acetylene and oxygen, flames can be divided into three categories,

1. neutral flame,
2. carburizing flame (**excess acetylene**)
3. oxidizing flame (**excess oxygen**)



.1 : Establishment of Flame in Oxy-acetylene Welding

1. Neutral Flame

- The neutral flame is used for most gas-welding applications
- has roughly equal amounts of acetylene and oxygen.

  can be recognized by a light blue inner flame cone with a darker blue outer flame
- very little or **no chemical reaction** in the molten metal.
- In fact, the neutral flame actually acts as a gas shield to protect the weld pool from

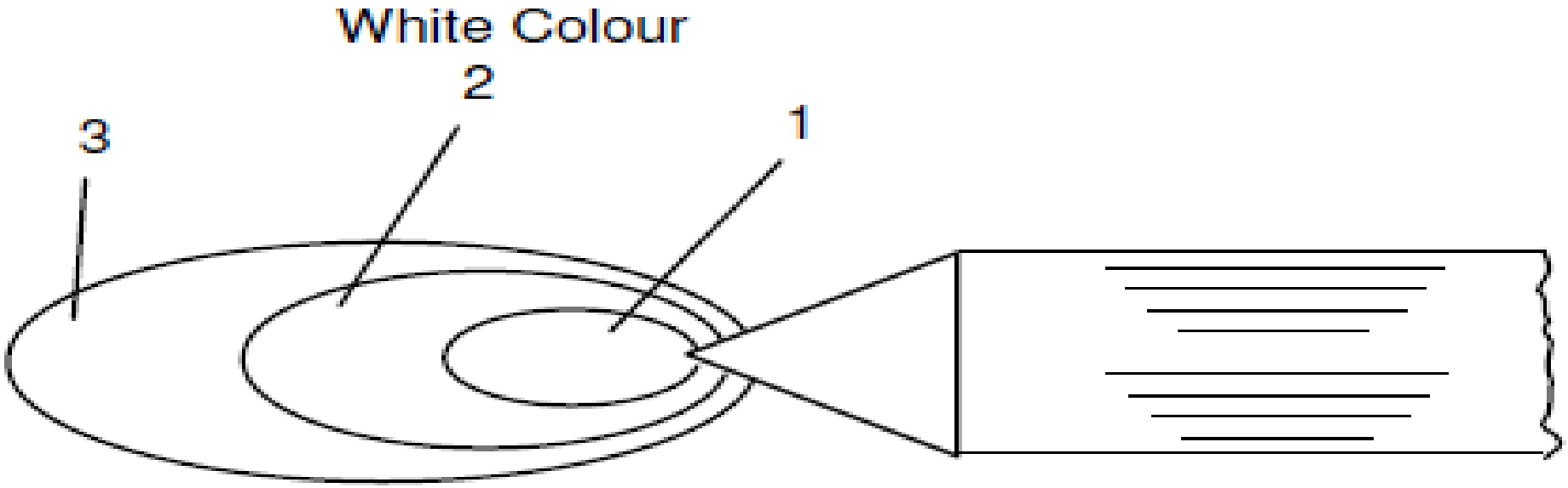
  chemical reactions with the atmosphere
- It is used for welding mild and stainless steel, cast iron, aluminium, and copper.

  In this flame none of two gasses is supplied in excess.

2. Carburizing Flame

- This flame is obtained when excess of acetylene is supplied
- It is white in colour due to excess acetylene
- Larger the excess of acetylene larger will be its length.
- it does **not** completely burn up the carbon and because the unconsumed carbon is **forced into the metal**.
- It is used for welding high-carbon steel and other metals that do not readily absorb carbon.
- Its temperature generation range is 3100oC to 3300oC.

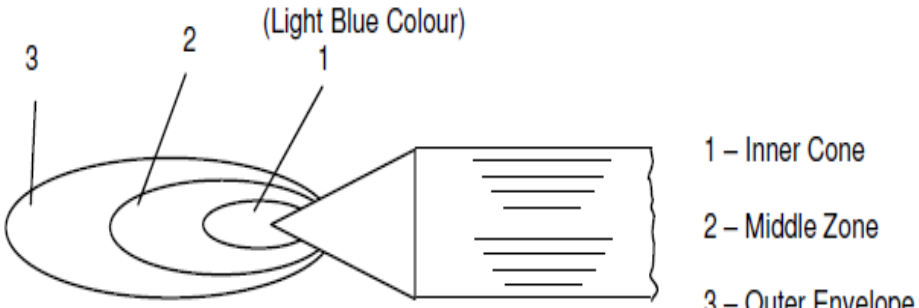
2. Carburizing Flame



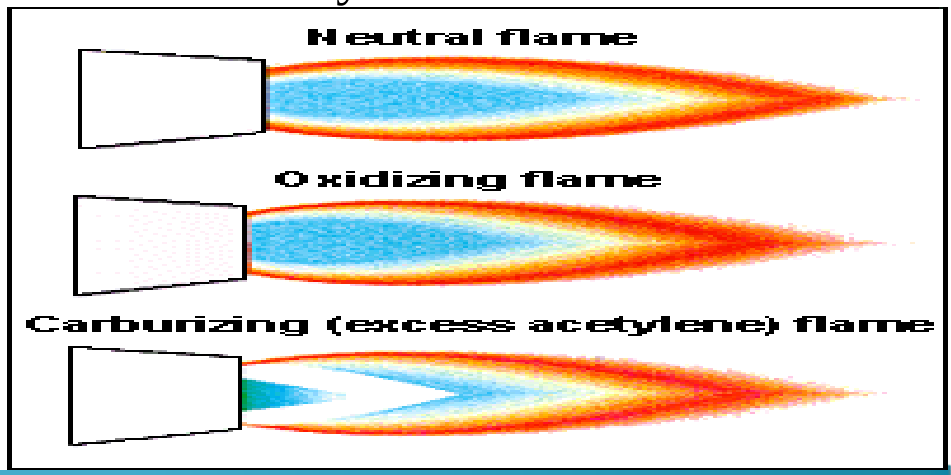
Carburizing or Reducing Flame

3. Oxidizing Flame

- This flame as an **excess of oxygen** over that required for a neutral flame
- The ratio O2 : C2H2 = 1.15 to 1.50
- To have this flame set carburizing flame first convert it to neutral flame and than reduce the supply of acetylene to get oxidizing flame.
- Its inner cone is relatively shorter and excess oxygen turns the flame to **light blue** colour. It is used for metals which are not oxidized readily like brasses and bronzes.

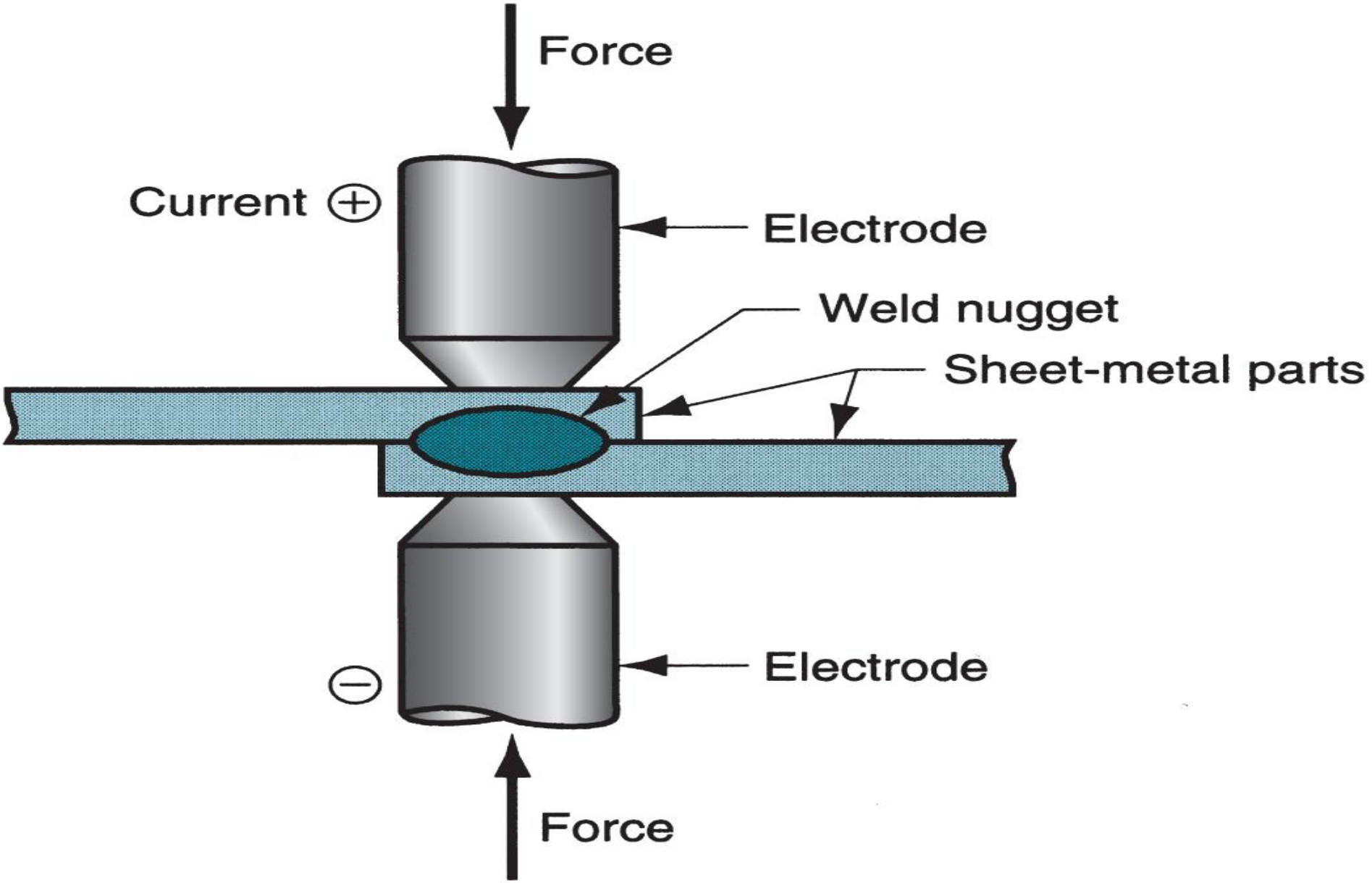


Oxidizing Fame



Resistance Welding

- Resistant welding is also one of the fusion welding technique that utilize heat and pressure to make the welded joint.
- Required heat is generated at the junction due to flowing current through it and resistance offered.
- It consists of work piece to be welded, two opposing electrodes, a mechanism to apply pressure to squeeze the work pieces, AC power supply to maintain the current, a circuit breaker with times to stop the flowing current after a pre-set time.


Force
Current ⊕
Electrode
Weld nugget
Sheet-metal parts
⊖
Electrode
Force

Depending upon the joint to be make, resistance welding can be divided into different categories :

(a) Spot welding,

(b) Seam welding,

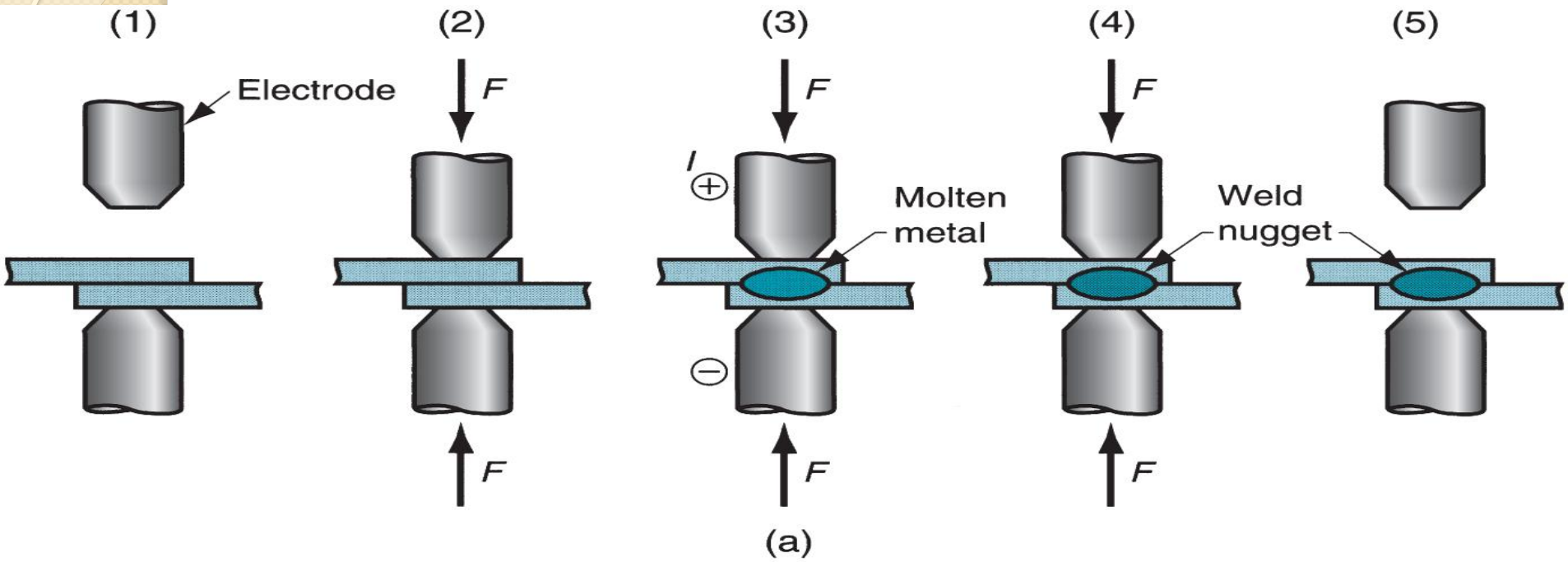
(c) Projection welding, and

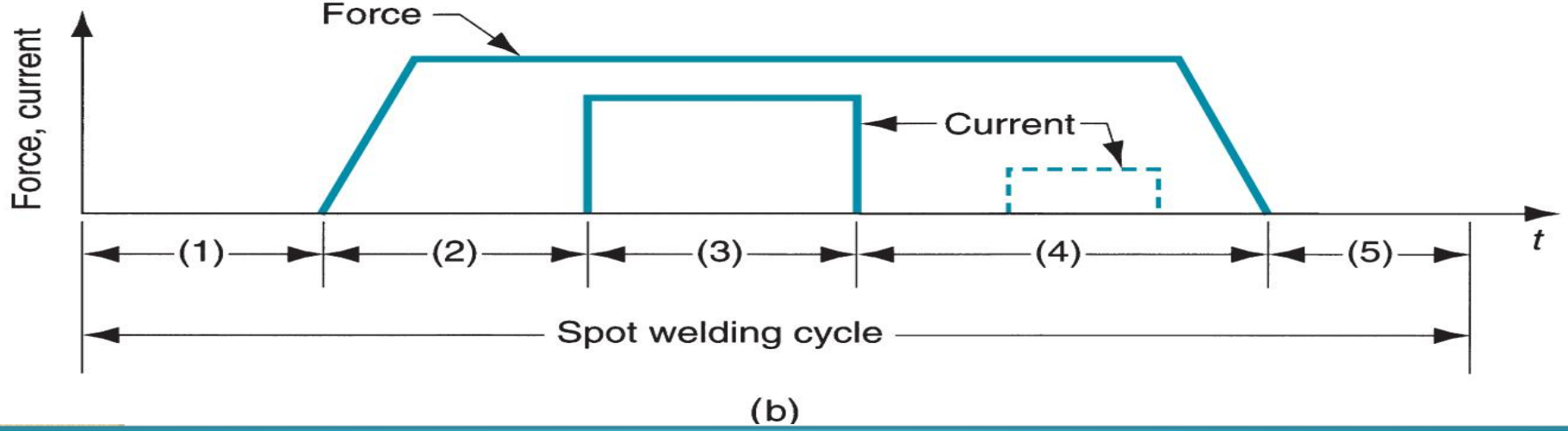
(d) Precision welding

(a) Spot Welding:

- It is widely used in mass production of automobiles
- and other products made of sheet metal
- There are approximately 10,000 individual spot welds in a single car body.
- Strength of a spot weld is equal to the strength of metal of work piece

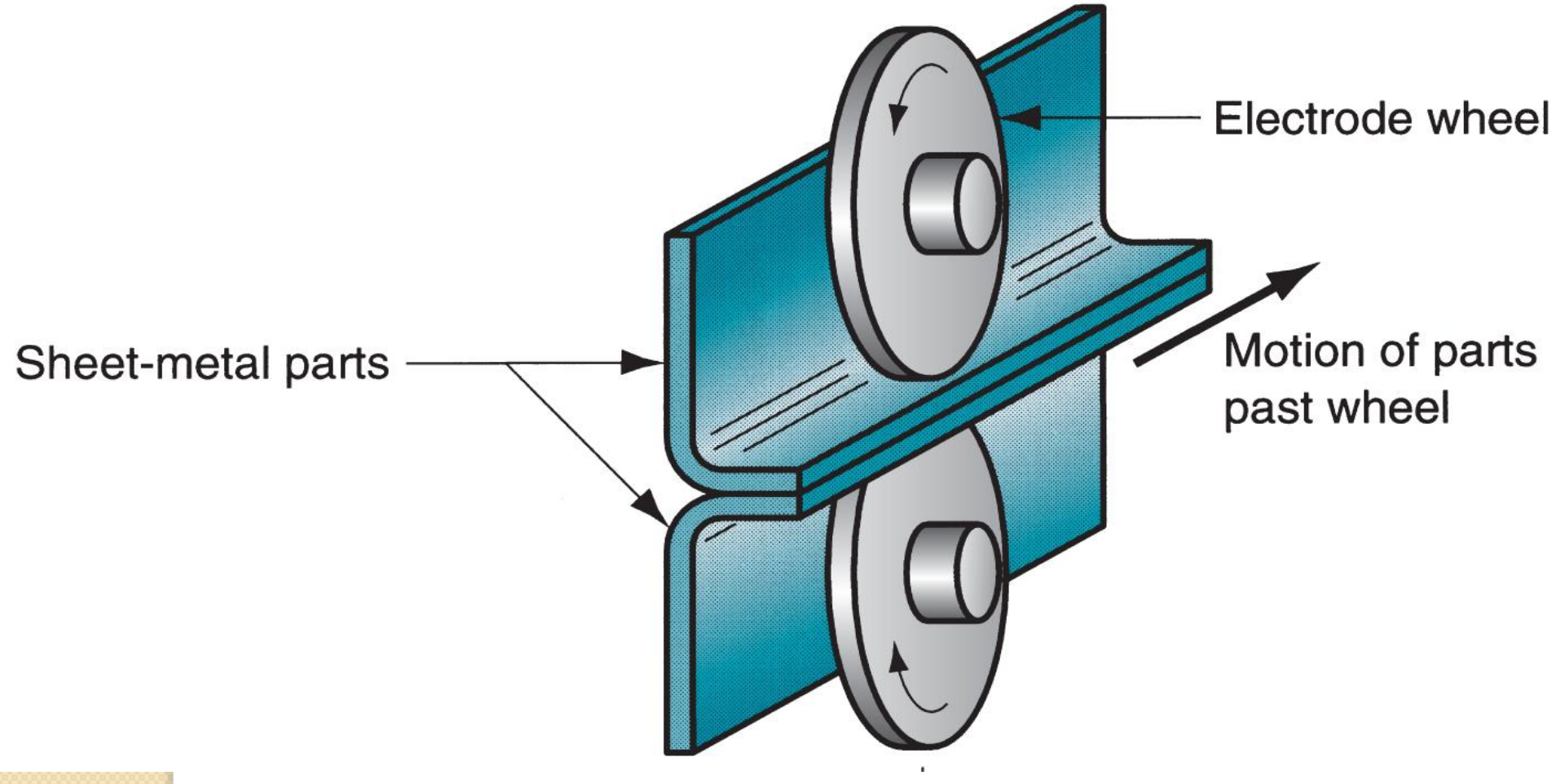
Spot Welding Cycle





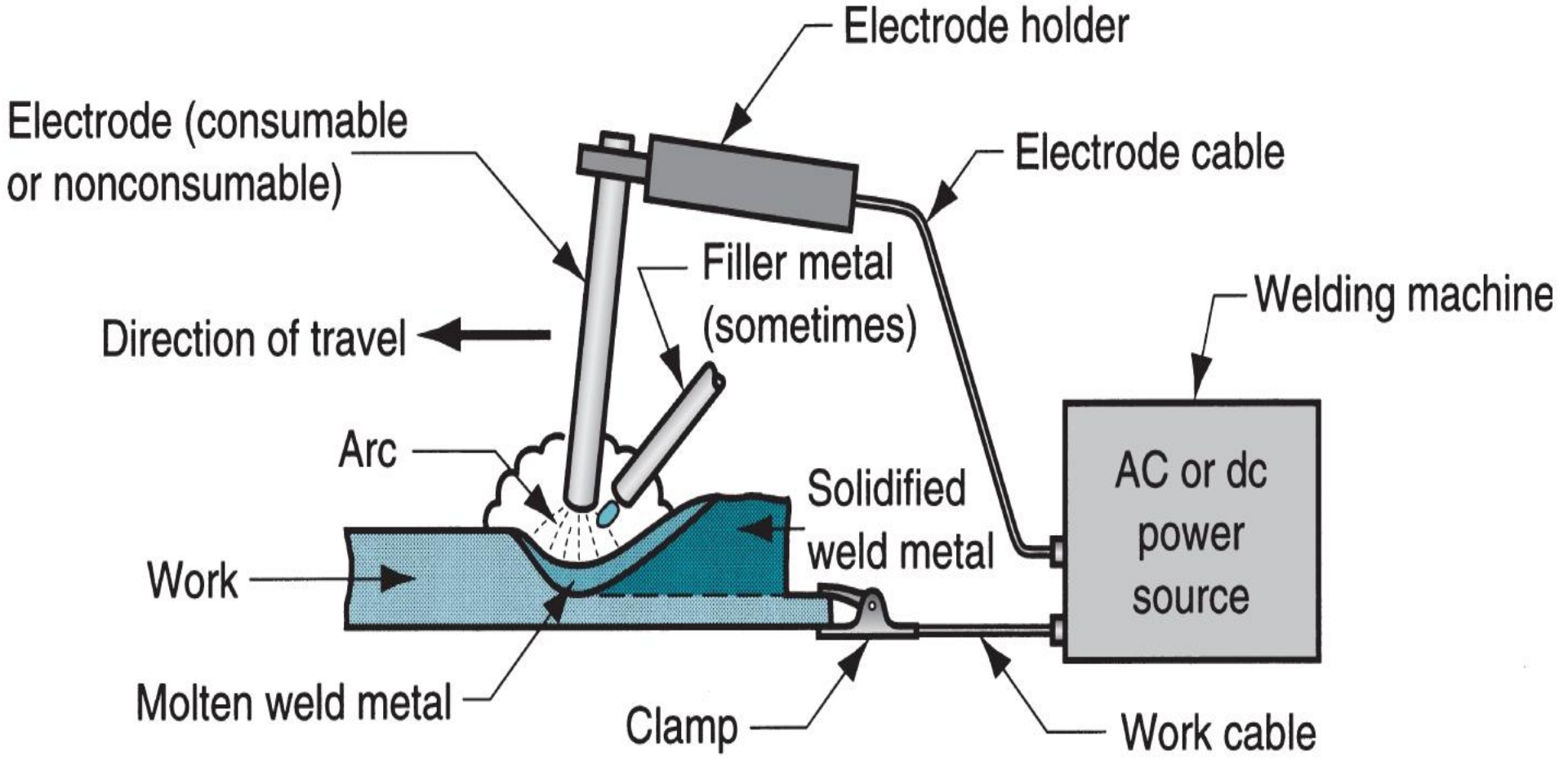
(b) Resistance Seam Welding

- In this case rotating wheels are used as welding electrodes.
- It is like **making a continuous series of spot welds** along the lap joint.
- This process produces air tight and leak proof joint.
- The lap joint to be made is allowed to pass through between rotating electrodes.
- These electrodes press the work piece and fuse it to make a continuous lap joint.
- This welding is used in production of gasoline tanks, automobiles.
- welding flash\Seam welding.swf


Electrode wheel
Sheet-metal parts
Motion of parts
past wheel

Arc Welding

- is one of the **fusion** welding processes in which coalescence
- of the metal is achieved by the heat from an electric arc between an electrode and work piece.
- Electric arc is generated when electrode is brought into contact with the work and is then quickly separated by a short distance approximately 2 mm
- The circuit operates at **low voltage and high current** so arc is established in the gap due to thermo ionic emission from electrode (Cathode) to work piece (Anode).
- This arc produces at temperature of the order of 5500oC or higher.
- In this way a pool of molten metal consisting of work piece metal and filler metal is formed in the welding zone.
- Movement of the electrode relative to work piece is accomplished by either manually or by mechanical means.



Welding flashback welding 2.3wt

ARC WELDING EQUIPMENT

YouTube - Arc Welding How It works.FLV

Facilitator Equipment

(a) Power source (welding machine)

(b) Electrode holder

(c) Work table

(d) Cables (for connection)

(e) Finishing devices like chipping, hammer, wire brush, etc.

Consumable Equipment

(a) Electrode

(b) Flux

(c) Work piece

(d) Filler metal

Protecting Equipment

(a) Welding shields

(b) Goggles

(c) Screens

- **Power Source**
- Both AC (Alternative Current) and DC (Direct Current) can be used for welding.
- AC machines are recommended for ferrous metal and DC machines are
- recommended for other metals for better result
- Main constituent of welding machine is transformer which convert the supply to low voltage and high current.
- For AC welding power is required at 80 to 110 volt and 50 to 80 ampere
- In case of DC welding power is required at 8 to 25 volts and 50 ampere.
- Polarity is also are significant factor.

Straight Polarity:

- Electrode is made negative pole and work piece is made positive pole. It is also called as electrode negative

Reversed Polarity:

- Electrode is made positive pole and work piece is made negative pole.
- It is called electrode positive too.
- As we know that two third of the total heat is generated at positive pole and only one third at negative pole.
- Polarity is decided according to the requirement of heat at either pole.

Welding Electrodes:

- Two types of welding electrodes are generally used.
- Consumable electrodes and non-consumable electrodes
- Consumable electrodes can further be classified into two categories coated and bare electrodes
- Bare electrodes are simple rods mode of filler metal with no coating over them
- In case of coated electrode flux is required additionally
- Coated electrodes are used in case of gas shielded welding processes (MIG and UIG)

Non-consumable Electrodes

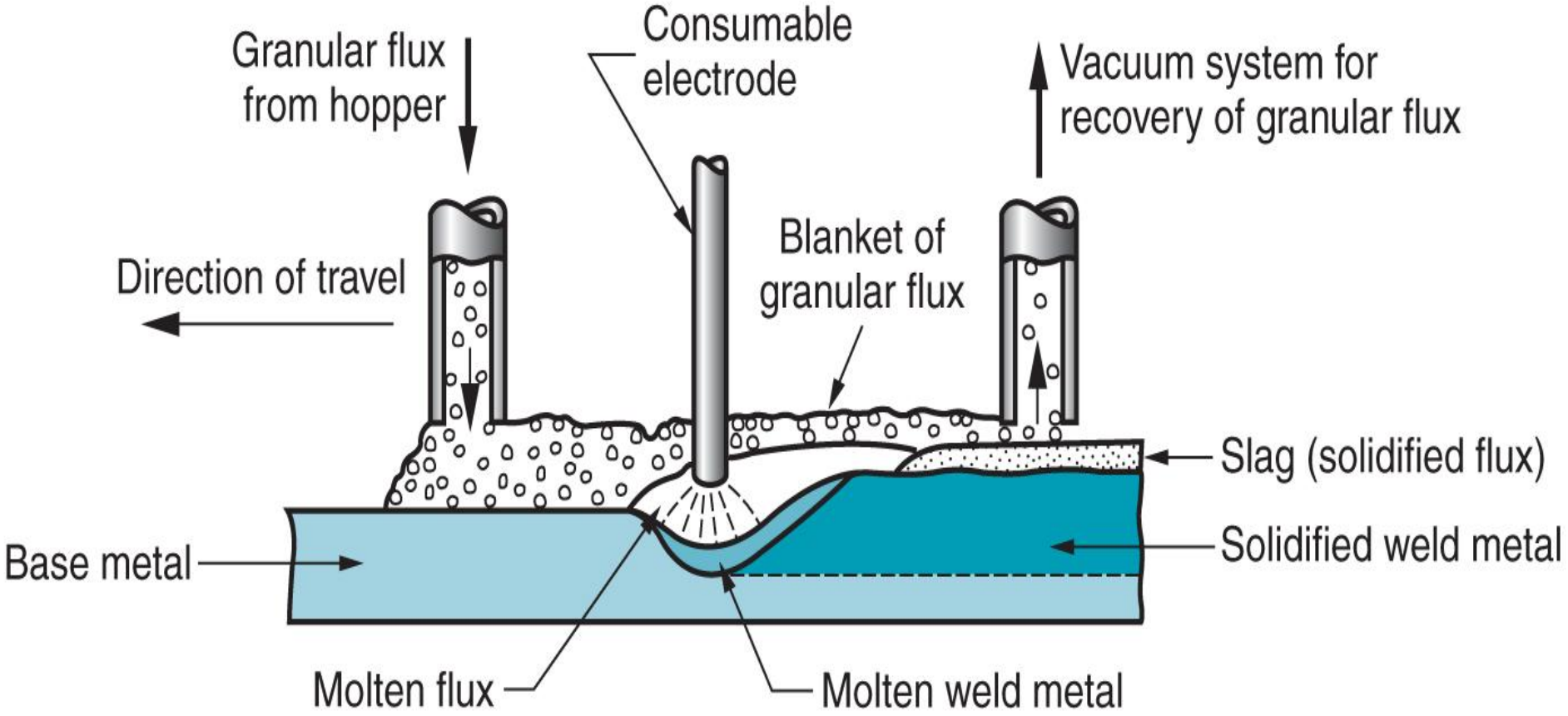
- They are made of tungsten or carbon
- These do not melt in the process of
- welding and so called non-consumable electrodes
- Their depletion rate is very low.
- In case of non-consumable electrodes metal and flux is supplied additionally

Coated Consumable Electrodes

- These are the most popular arc welding electrodes.
- No additional filler metal and flux are required.
- In general these electrodes have core of mild steel and coating over them of flux material.
- It develops a reducing atmosphere and prevents oxidation, forms separable slag from metal impurities, establishes ac providing necessary alloying elements to the weld pool.
- The common ingredients act as flux which help in slag formation are asbestos, mica, silica, fluorspar, stealite, titanium dioxide, iron oxide, metal carbonates, etc.

1. Submerged Arc Welding

- This is first arc welding technique to be automated.
- Submerged arc welding uses continuous consumable electrode of the shape of a bare wire
- The established arc is shielded by a cover of granular flux.
- The electrode wire is fed continuously and automatically from a roll into the welding zone
- The flux is introduced in to the joint slightly ahead of the weld arch by gravity from a hopper
- blanket of granular flux completely submerges the welding zone preventing sparks, spatter and radiations.
- The portion of the flux near to the arc is melted, forming slag, after mixing with molten metal



welding flash\Twin Arc SAW.swf

Applications of Submerged Arc Welding

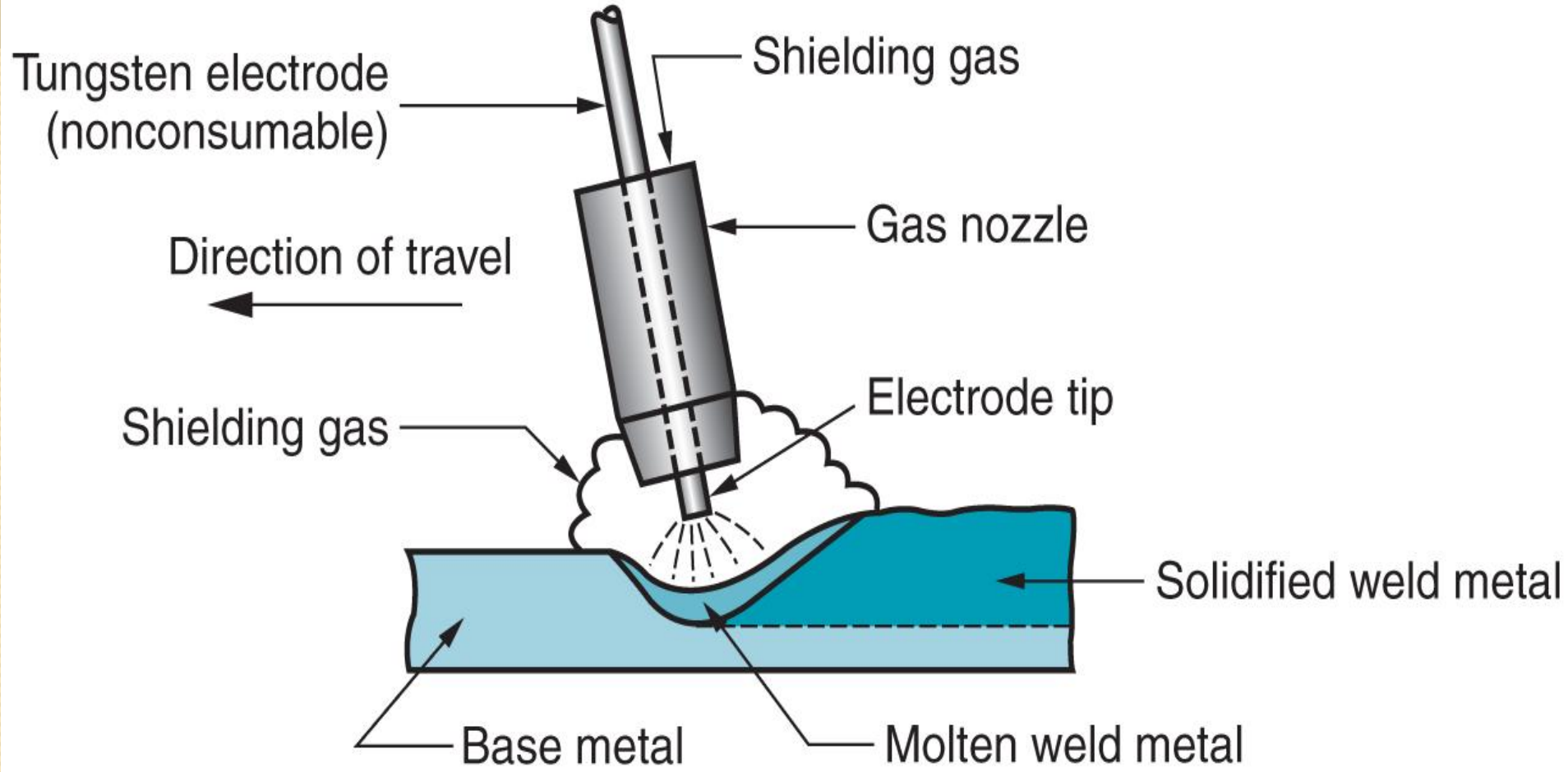
- steel fabrication, structural shapes, longitudinal and
- circumferential seams of large diameter pipes, welding pressure vessels, welding of heavy machinery, etc.

- In any type of welding we require **flux** to avoid oxidation of weldment to maintain proper **strength** of the joint.
- In this regard, to keep the atmospheric air away from the welding pool, inert gases like argon, helium, carbon dioxide, are used for surrounding the arc to keep atmosphere away.
- It not only results in production of sound weld but also enables welding of such metals which are otherwise difficult to weld.

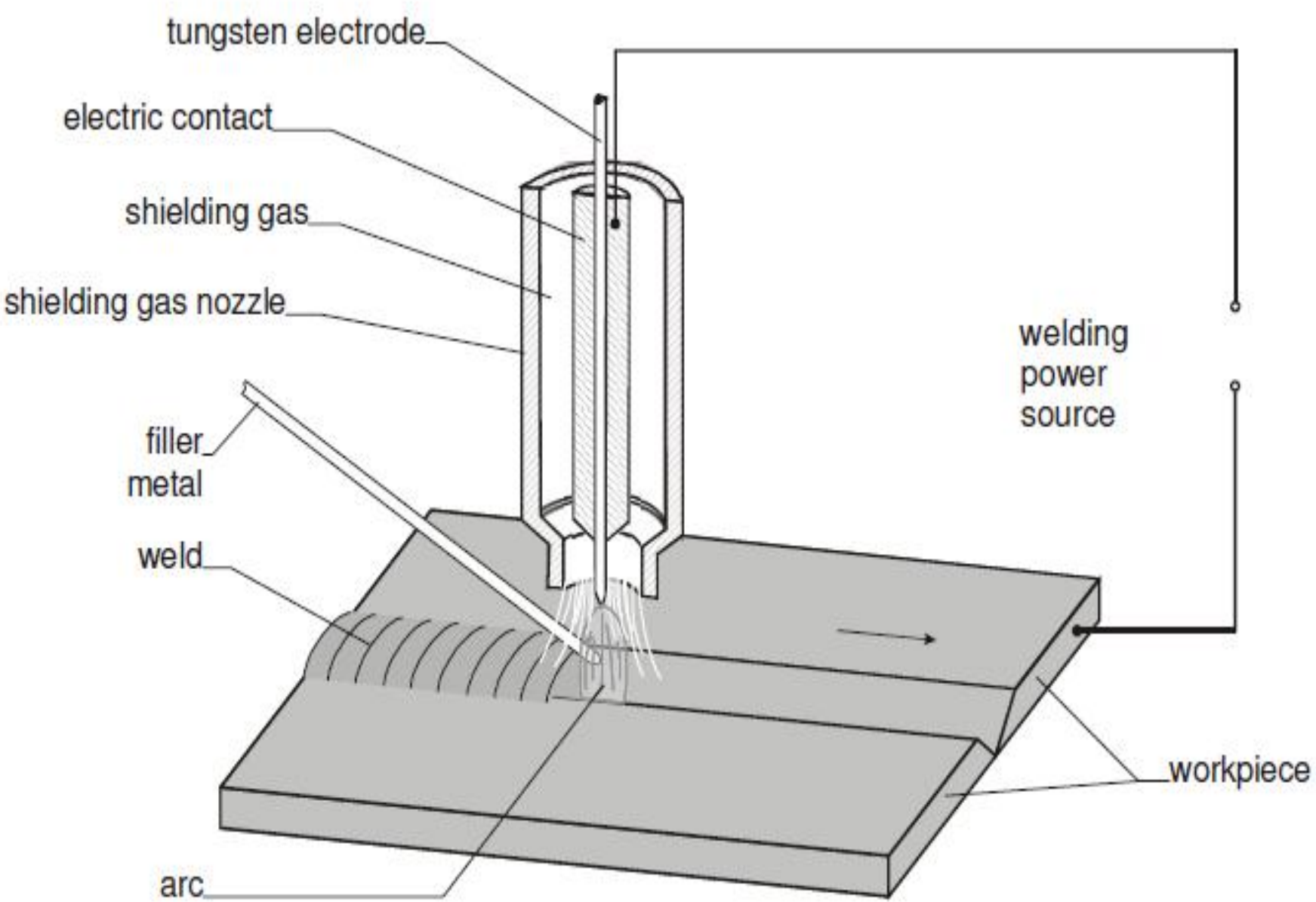
TIG Welding

- This is similar to arc welding.
- Additionally it requires a cylinder of inert gas, valve, pressure regulator and hose pipe with sprayer to spray inert gas in the welding pool.
- A non-consumable tungsten electrode is used to establish arc.
- Sometimes inert gas sprayer is also mounted in the electrode holder.
- As per the requirement additional filler metal can be provided from the outside to make up the joint.
- This is suitable for welding of most of the metal and alloys except lead and zinc due to their very low melting point.

TIG Welding


Tungsten electrode
(nonconsumable)
Shielding gas
Gas nozzle
Direction of travel
Shielding gas
Electrode tip
Solidified weld metal
Base metal
Molten weld metal

TIG Welding


tungsten electrode
electric contact
shielding gas
shielding gas nozzle
filler metal
weld
arc
welding power source
workpiece

MIG Welding

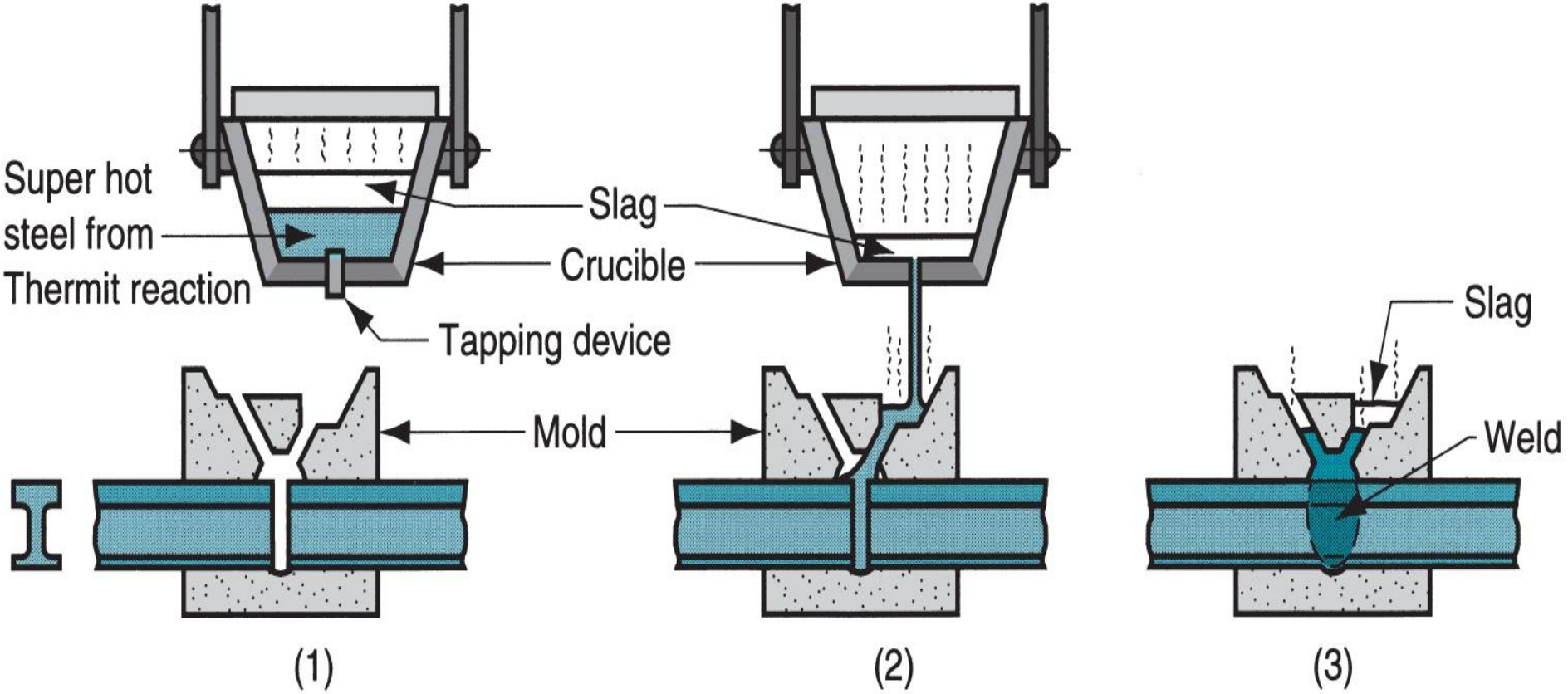
- This is similar to TIG welding
- At the place of non-consumable tungsten electrode, a consumable metal electrode is used in the form of continuously fed metal wire.
- The electrode wire and inert gas are fed through welding gun
- This is used for the welding of carbon steel, low alloys steel, stainless steel and alloys of the metal exhibiting resistance to heat.

Thermit Welding (TW) (exothermic bonding)

- process for joining two electrical conductors.
- A mixture of Aluminium powder and iron oxide that produces an exothermic reaction when ignited.
- heat is produced by superheated molten metal from the **chemical reaction** of thermit.
- Following reaction takes place:

$$8AL + 3F3_3O_4 \longrightarrow \underset{\text{Molten Filler Metal}}{9Fe} + 4Al_2O_3(slag) + heat$$

- Thermit welding has applications in joining of rail road rails, repair of cracks in castings.

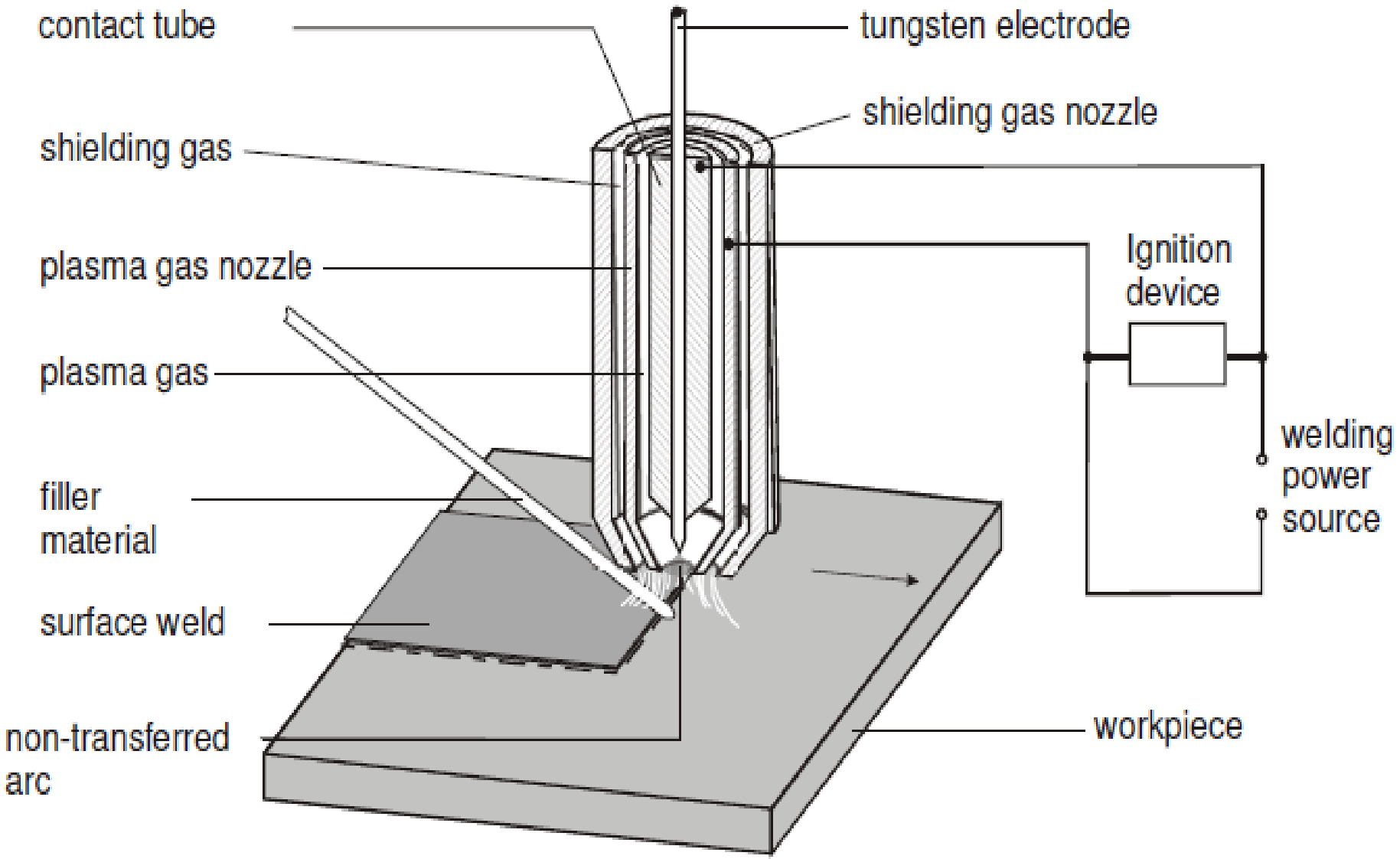


- (1) Thermit ignited; (2) crucible tapped, superheated metal flows into mold; (3) metal solidifies to produce weld joint

Laser Beam Welding

- is a fusion welding process in which coalescence is
- achieved by the energy of a highly concentrated coherent light beam focused on the joint to be welded
- LASER stands for *Light Amplification by Stimulated Emission of Radiation*.
- In this case spray of inert gas is used for shielding the weld pool.
- LBW is used for deeply penetrated narrow joint
- The weldment formation is
- very accurate, highly focused and very precise so it is recommends to join the small parts.

Plasma Arc Welding

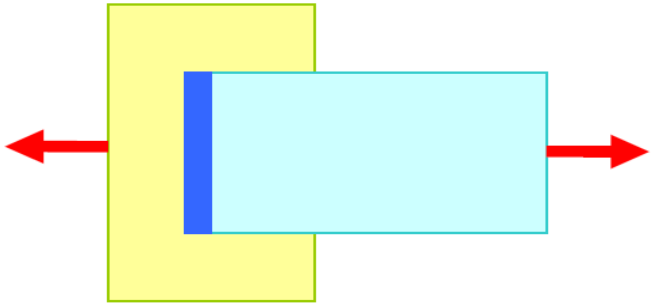


Types of Weld Joints

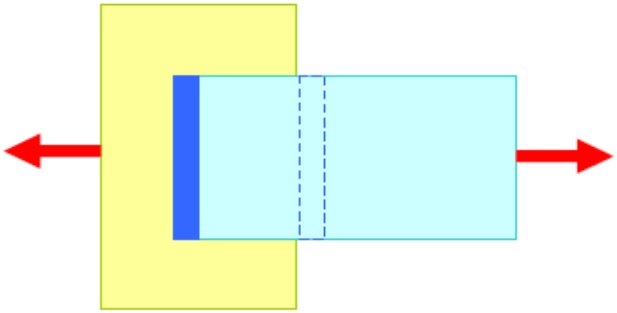
There are five basic types of weld joints:

- Butt joint.
- T-joint.
- Lap joint.
- Corner joint.
- Edge joint.

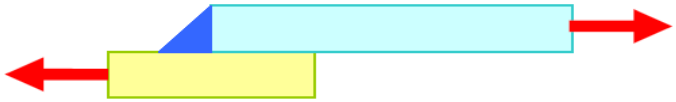
- *Lap or fillet joint*: obtained by overlapping the plates and welding their edges.
- The fillet joints may be single transverse fillet, double transverse fillet or parallel fillet joints

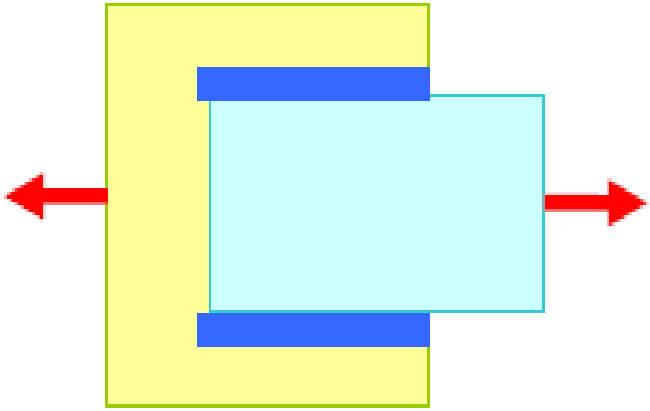


Single transverse lap joint

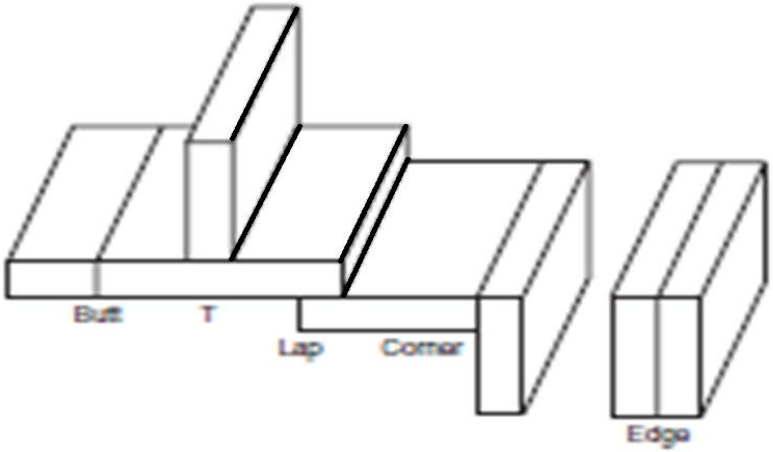


Double transverse lap joint





Parallel lap joint



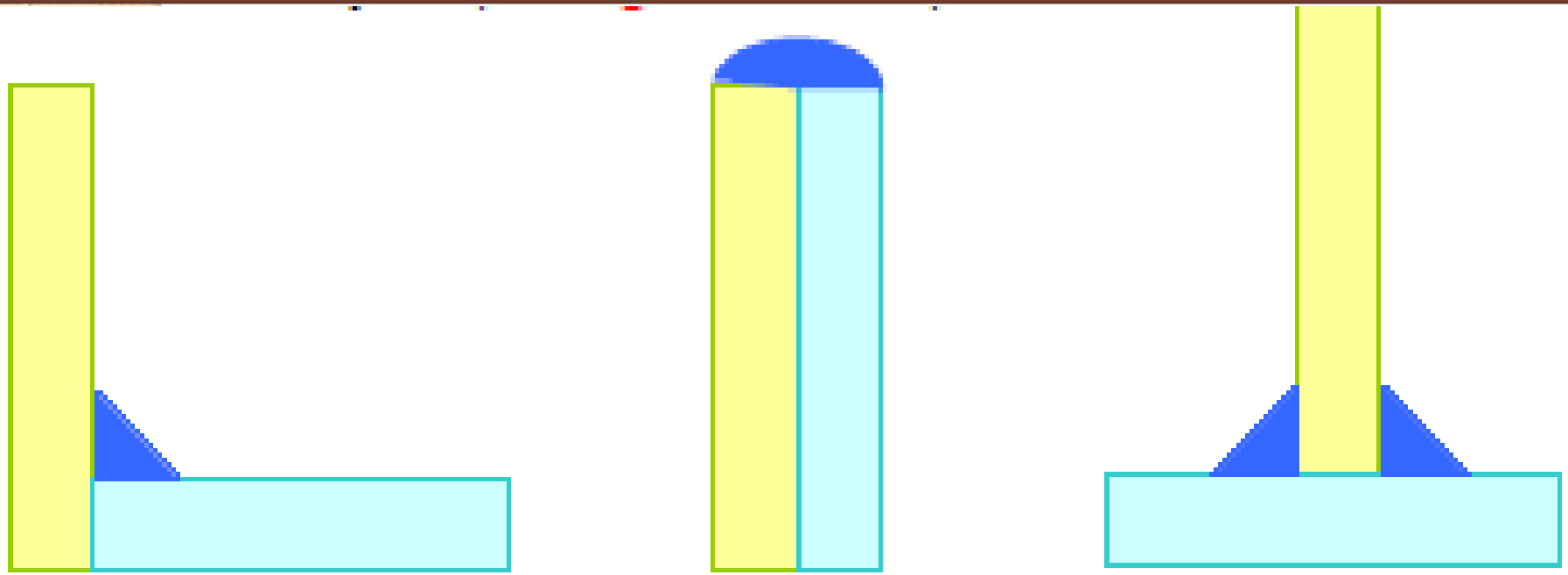
Butt joints: formed by placing the plates edge to edge and welding them. Grooves are sometimes cut (for thick plates) on the edges before welding.

According to the shape of the grooves, the butt joints may be of different types, e.g.,

- Square butt joint
- Single V-butt joint, double V-butt joint
- Single U-butt joint, double U-butt joint
- Single J-butt joint, double J-butt joint
- Single bevel-butt joint, double bevel butt joint

These are schematically shown in figure 10.3.2.

Figure 10.3.2: Different types of butt joints



(a) Corner joint (b) Edge joint (c) T - joint

- Compared to other type of joints, the welded joint has higher efficiency. An efficiency > 95 % is easily possible.
- Since the added material is minimum, the joint has lighter weight
- It is less expensive.
- Forming a joint in difficult locations is possible through welding.
- Forming a joint in difficult locations is possible through welding.

WELDING DEFECTS

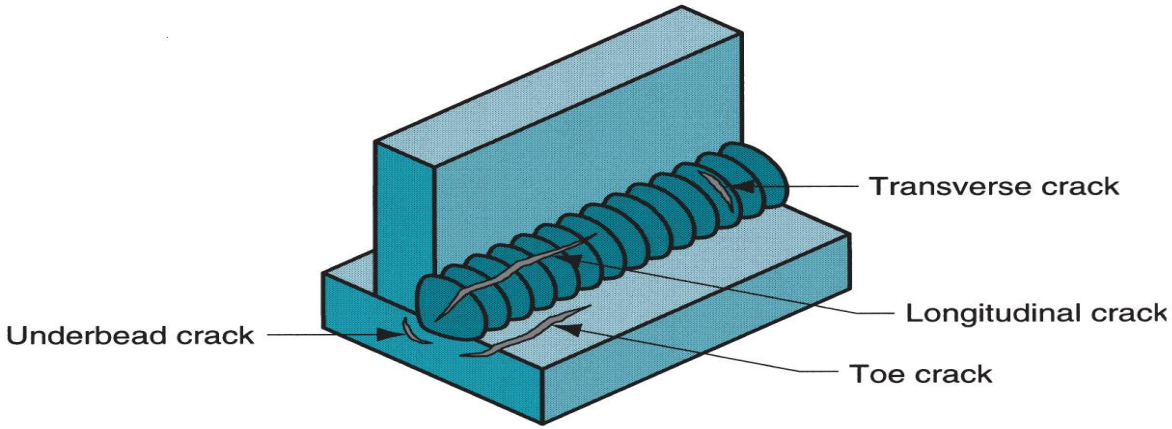
In case of welding, we apply heat to the work pieces to join them together then these are allowed to coal down till room temperature. This process may incorporate some defects to the weldment.

1. Residual Stresses and Warpage:

- Rapid heating and then uncontrolled cooling result in uneven expansion and contraction in the work piece and weldment.
- This causes development of residual stresses in the weldment.
- Sometimes wrong selection of filler metal and welding technique may also be the cause of residual stress and warpage.

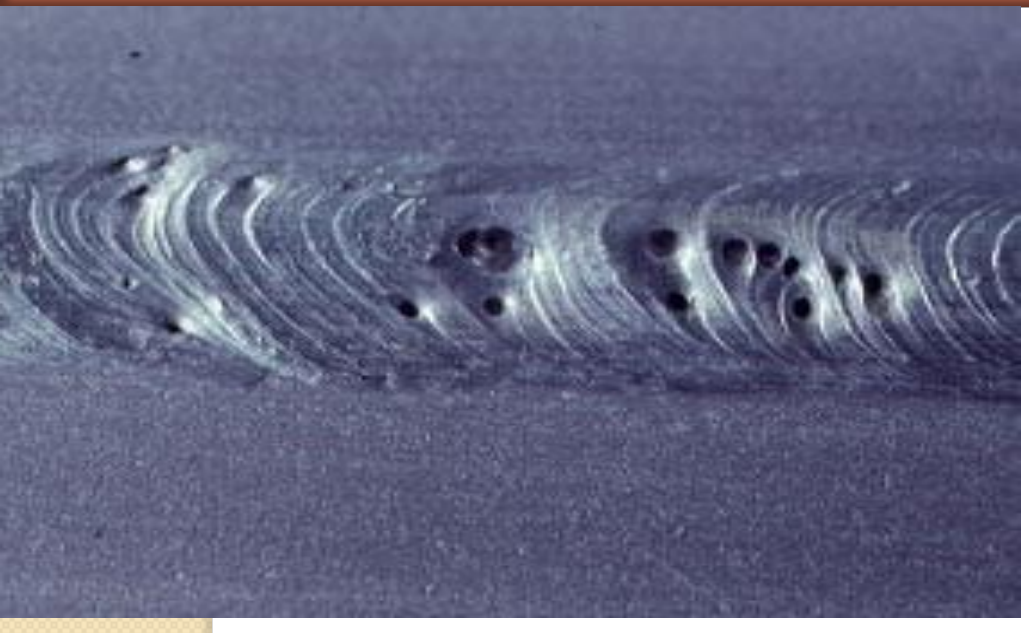
2. Cracks

- This is a serious welding defect appears as fracture type interruptions in the weld
- Crack works as a point of stress concentration so reduce the strength of the joint



3. Cavities or Porosity

- Porosity consists of small voids in weld metal formed by gases entrapped during solidification.
- Shape of the voids may be spherical holes or elongated holes.



4. Solid Inclusions

- This is the entrapped non-metallic solid material
- It may be the inclusion of slag generated in a welding process.

Applications of welding

- Flanges welded to shafts and axles.
- Crank shafts
- Heavy hydraulic turbine shafts
- Large gears, pulleys, flywheels
- Gear housing
- Machine frames and bases
- Housing and mill-stands.
- Pressure vessels, steel structures