

Principles of selected joining and assembling process

Welding

- Welding is a process for joining two similar or dissimilar metal by fusion.
- It joins different metals/alloys with or without application of heat, with or without pressure and with or without filler metal
- A range of **welding processes have been developed** so far using single or a combination above factors namely heat, pressure and filler.
- The fusion of metal takes place by means of heat.

Principles of selected joining and assembling process

Heat flow in welding

Welding heat sources

Electrical sources

- Arc welding
- Resistance welding
- Electroslag

Heat intensity $\sim 10^6$ - 10^8 Wm⁻²

Chemical sources

- Oxyfuel gas welding
- Thermit welding

Heat intensity $\sim 10^6$ - 10^8 Wm⁻²

High energy sources

- Laser beam welding
- Electron beam welding

Heat intensity $\sim 10^{10}$ - 10^{12} Wm⁻²

Mechanical sources

Friction (stir) welding

Heat intensity $\sim 10^4$ - 10^6 Wm⁻²

- Ultrasonic welding (15-75 KHz)
- Explosion welding (EXW)

Other sources

Diffusion welding

- 
- So that heat may be generated either from combustion of gases, electric arc, electric resistance or by chemical reaction.
 - Welding provides a permanent joint.
 - Most of the metals and alloys can be welded by one type of welding process or the other
 - To compare this ease in welding term 'weldability' is often used.
 - The weldability may be defined as property of a metal which indicates the ease with which it can be welded with other similar or dissimilar metals.

FIVE ESSENTIALS IN WELDING

- Quality
- Conforms with the standard,
- customer satisfaction,
- good appearance,
- reliable,
- durable,
- accurate

Correct Materials

1. Material – electrode properties and characteristics should match with the base metal,

Example : Cast iron base = cast iron base

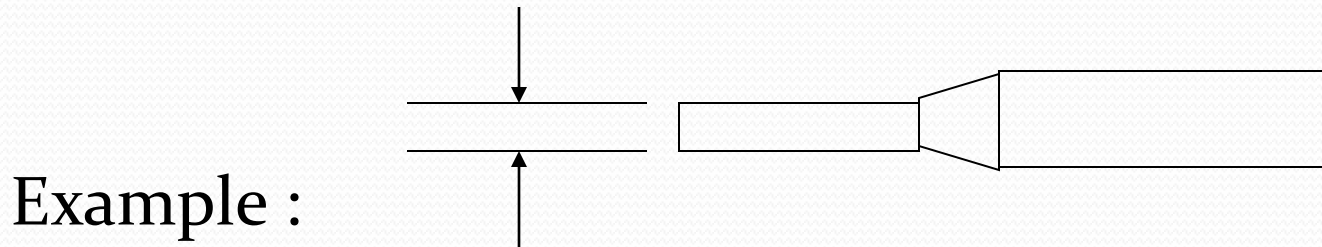
Stainless steel = stainless steel

Aluminum = aluminum

Mild steel = mild steel

Correct Current

Set-up of current depends upon the core size of the electrode



$1/8 \text{ } \varnothing = 80 - 130 \text{ amperes}$

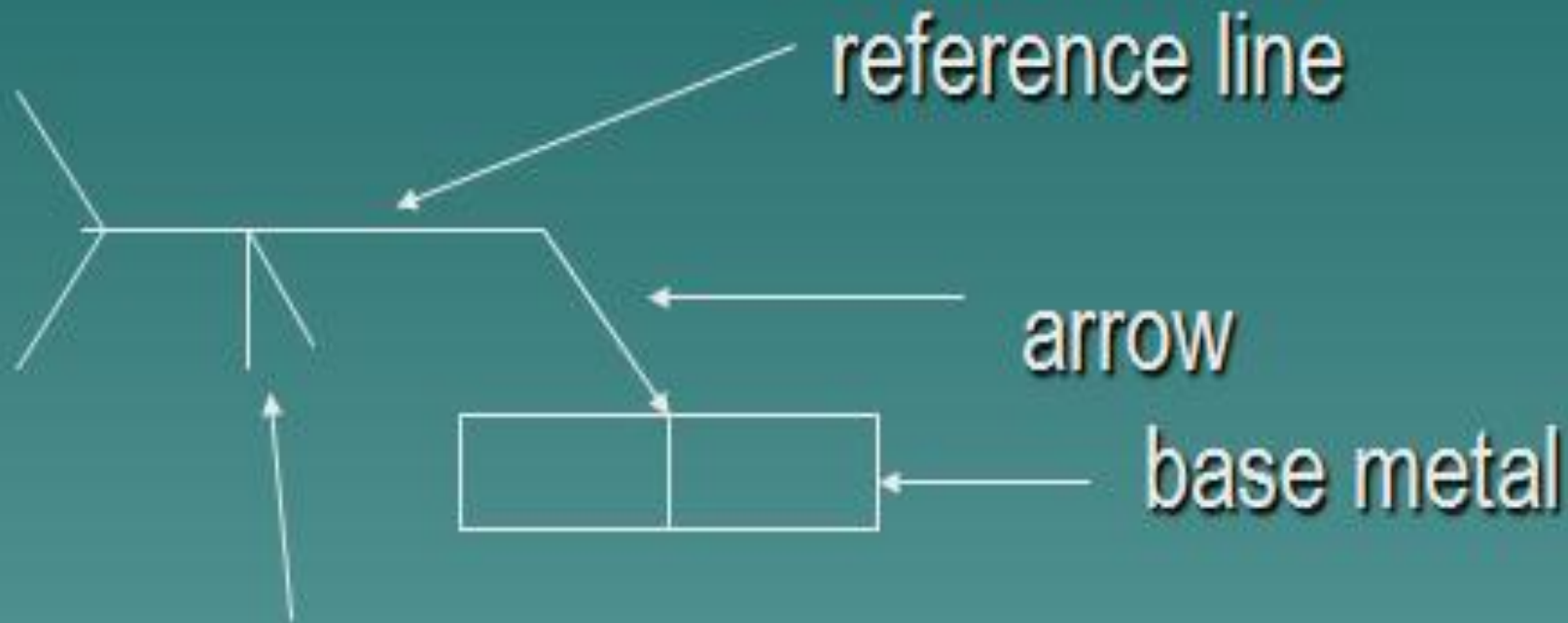
$80 + 130 = 210 / 2 = 105 \text{ amperes start-}$
up current

Welding symbols

- Engineering drawings use standard series of symbols to define welds and weld position.
- These symbols have been established by the American Welding Standards 1969 and will be shown on all engineering drawings on which welds are indicated.
- In your work, you maybe required work from these drawings, therefore you should understand the use and meaning of these symbols.

- 
- Welder should know how to read welding blueprint so that welding most common repairs and construction will be easier to understand.
 - The blueprint can either be rough drawn or well design plan.
 - Both written direction and welding symbols maybe included on the blueprint to tell the welder what type of joint preparation, weld bead and other techniques are to be used for each weld.

- An arc welding symbol consist of three parts



basic symbol

The basic symbol also indicates the type of weld (butt, fillet, etc.).

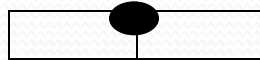
Welding symbols

Form of weld

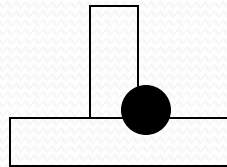
Sectional
Representation

Symbol

Bead



Fillet

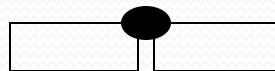


General butt

full penetration butt, weld by a
welding procedure to be agreed



Square butt



Single V butt



Form of weld

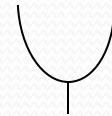
Sectional Representation

Symbol

Single bevel butt



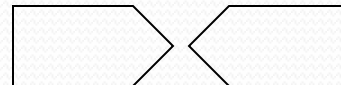
Single U butt



Single J butt



Double V butt

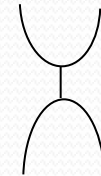
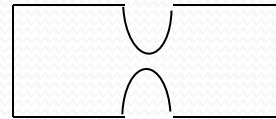


Form of weld

Sectional
Representation

Symbol

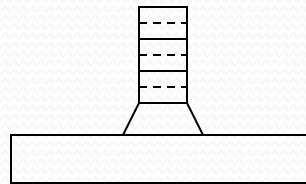
Double U butt



Plug or slot



Stud

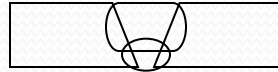


Surfacing

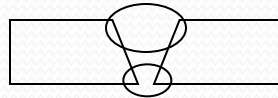


Finish symbols

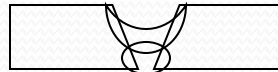
Flush



Convex



Concave



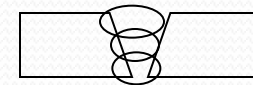
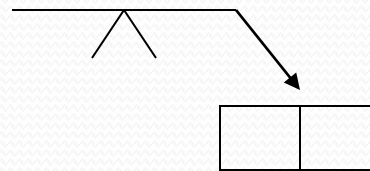
Step by step explanation of AWS welding symbols

Elements

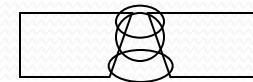
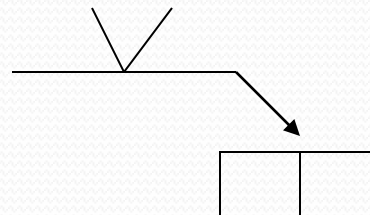
Symbol

Sectional
Representation

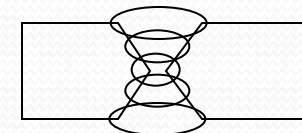
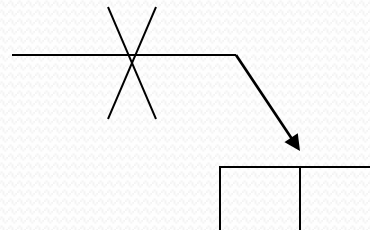
Arrow side



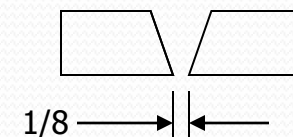
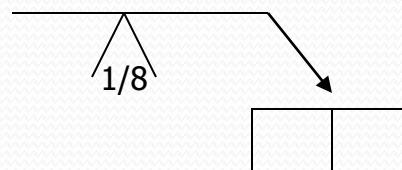
Other side



Both sides



Root gap



Elements

Symbol

Sectional
Representation

Groove angle

Contour symbol

Flat

Convex

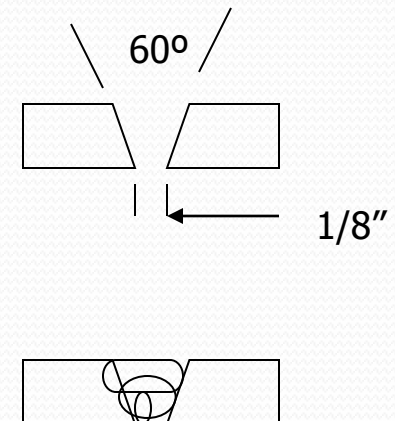
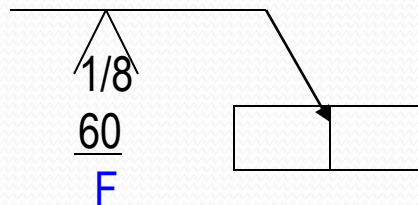
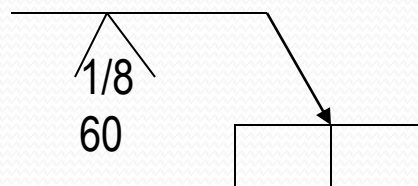
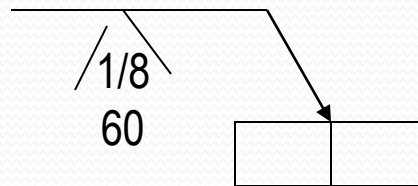
Concave

Finish symbol

F – filing

G – grinding

M – machining



Elements

Symbol

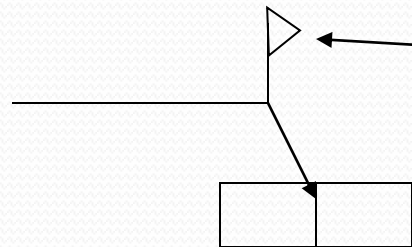
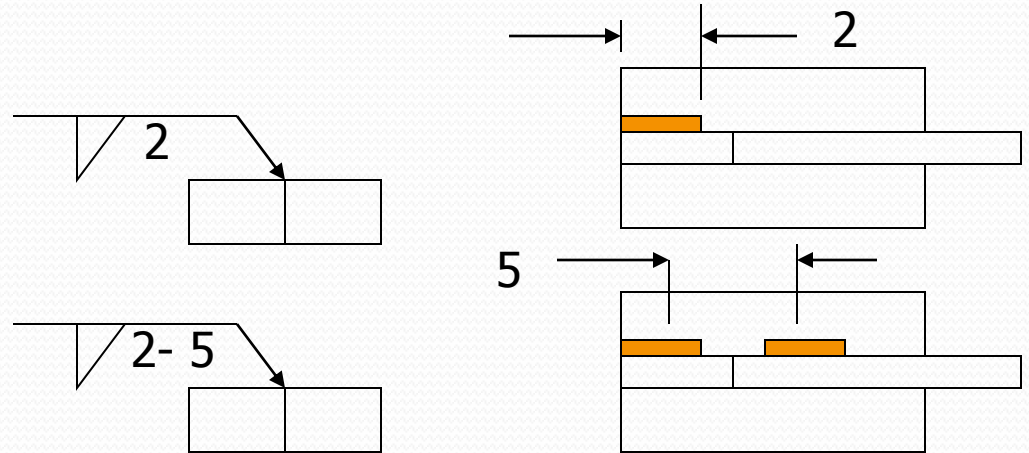
Sectional
Representation

Length of weld

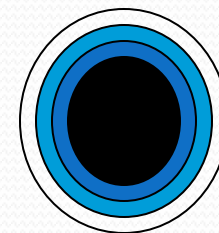
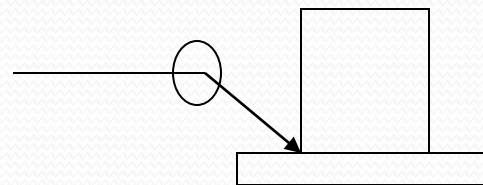
Pitch of weld

Field weld symbol

Weld all around



Signifies that part
to be weld will
done in **jobsite**

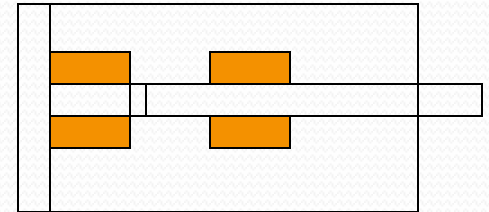
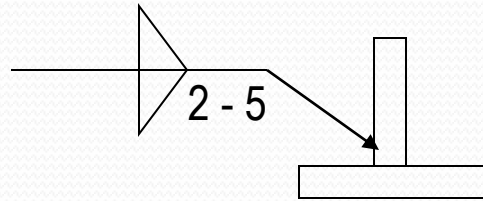


Elements

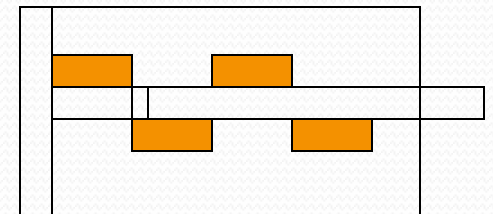
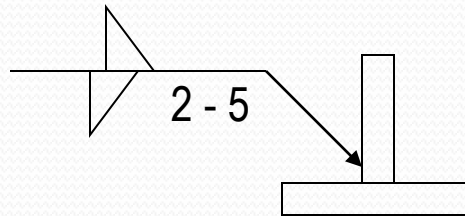
Symbol

Sectional
Representation

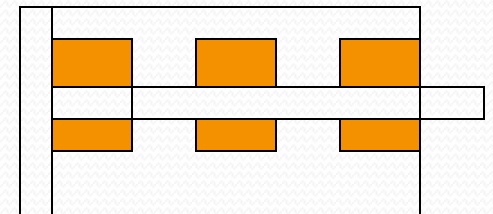
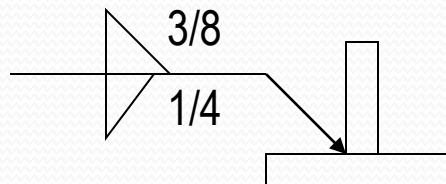
Chain intermittent
Fillet weld symbol



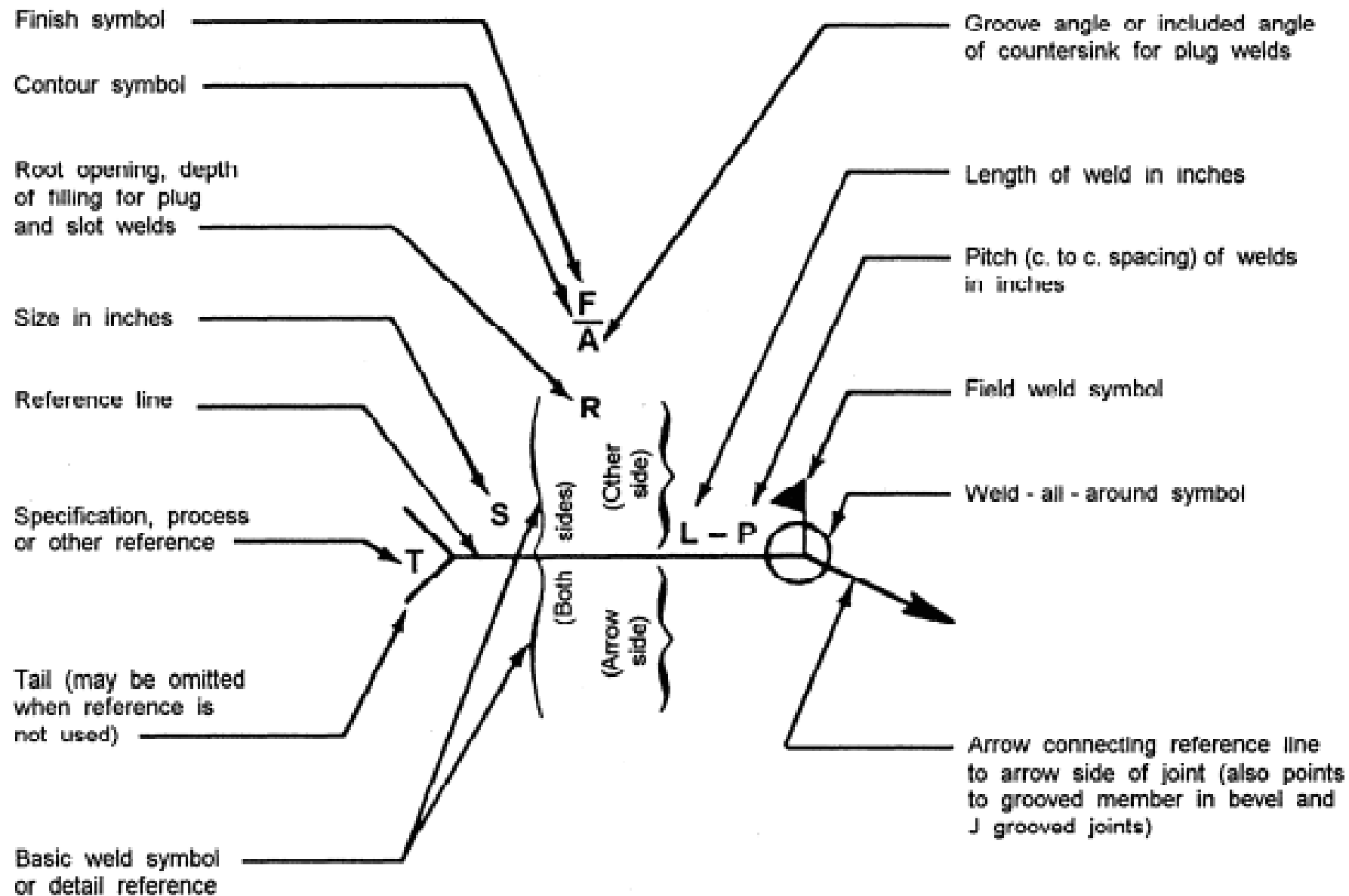
Staggered intermittent
Fillet weld symbol



Unequal double
Fillet weld symbol



STANDARD LOCATION OF ELEMENTS OF A WELDING SYMBOL

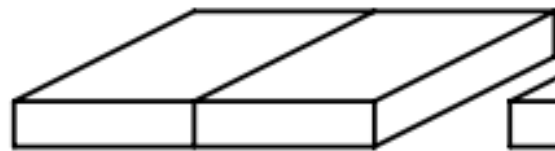


TERMINOLOGICAL ELEMENTS OF WELDING PROCESS

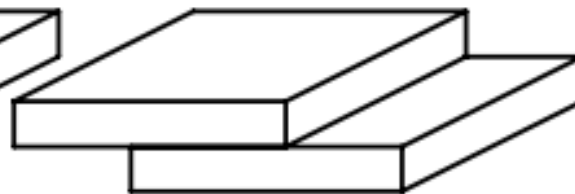
➤ To become a skilled welder, you first need to learn the technical vocabulary '(language) of welding.

Welding joints

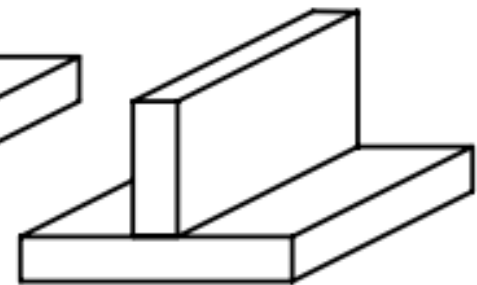
- The common Welding joints are
 - lap joint
 - butt joint
 - **tee, corner, and edge**



(a) butt joint

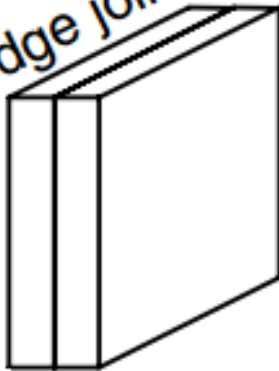


(b) lap joint

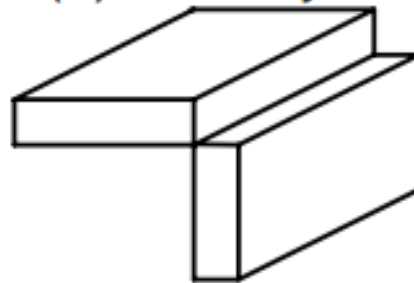


(c) T-joint

(d) edge joint



(e) corner joint



Five basic types of weld joint designs.

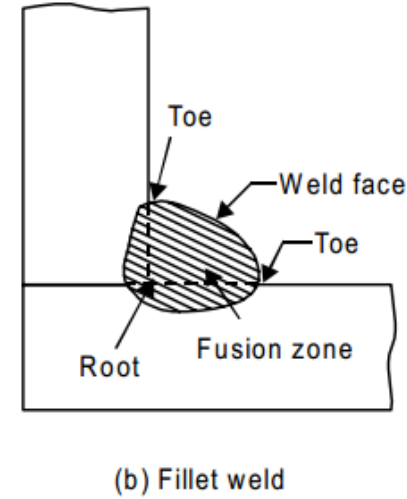
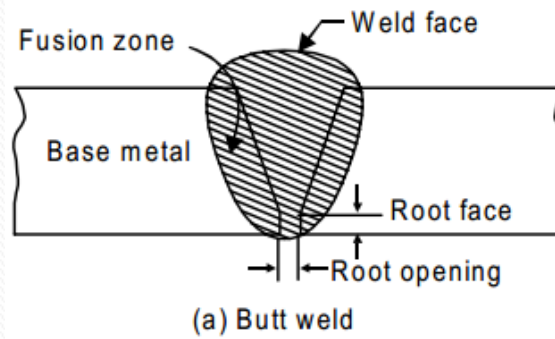


Fig. 2.1 Terminological elements of welding process

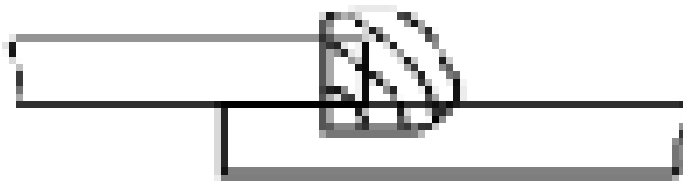
- The **weld face** is the exposed surface of a weld on the side from which the weld was made.
- The **toe** is the junction between the face of the weld and the base metal.
- The **root** of a weld includes the points at which the back of the weld intersects the base metal surfaces.

Lap weld joint

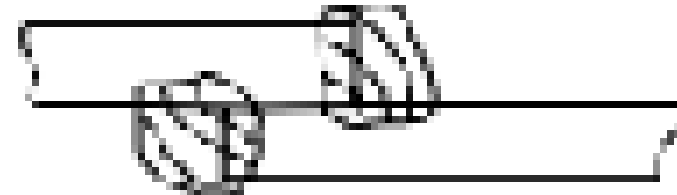
single-Lap Joint:-This joint, made by overlapping the edges of the plate, is not recommended for most work.

- The single lap has very little resistance to bending.
- It can be used satisfactorily for joining two cylinders that fit inside one another.

Double-Lap Joint: This is stronger than the single-lap joint but has the disadvantage that it requires twice as much single lap welding.



Single lap

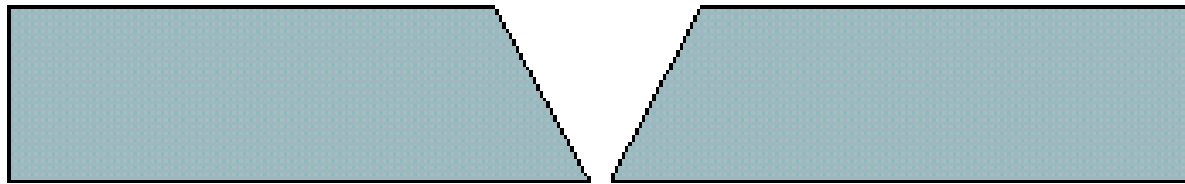


Double lap

Butt weld joint

Single-Vee Butt Weld

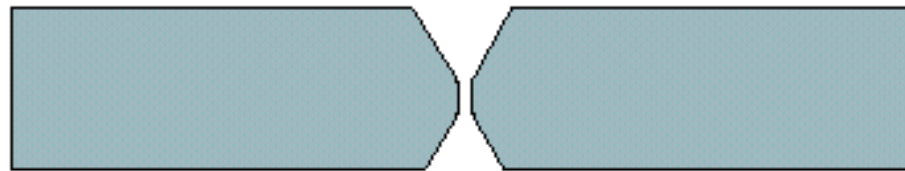
- It is used for plates **up to 15.8 mm thick**.
- The angle of the vee depends upon the technique being used, the **plates being spaced** approximately **3.2 mm**.
- This joint is **strong in loads with tension forces but weak in loads that bend** at the weld root.



Single V butt joint.

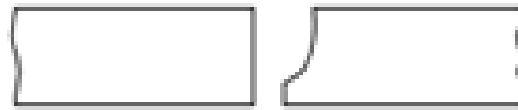
Double-Vee Butt Weld

- It is used for plates **over 13 mm thick** when the welding can be performed on both sides of the plate, **excellent for all load conditions**,
- The **top vee** angle is either **60° or 80°**, while the **bottom angle is 80°**, depending on the technique being used.

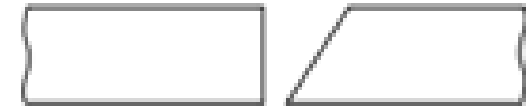


Double V butt joint.

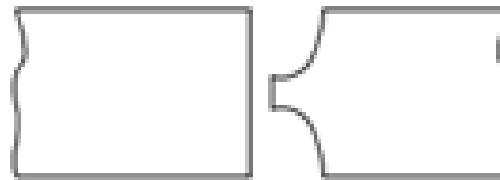
Edge preparations: For welding the edges of joining surfaces of metals are prepared first.



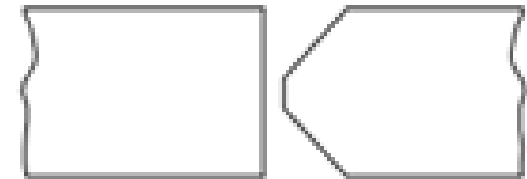
Single - J



Single bevel



Double - J



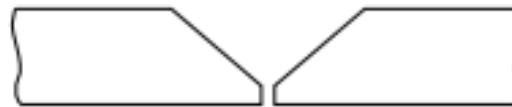
Double bevel



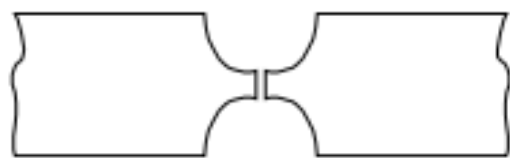
Straight



Single - U



Single - V



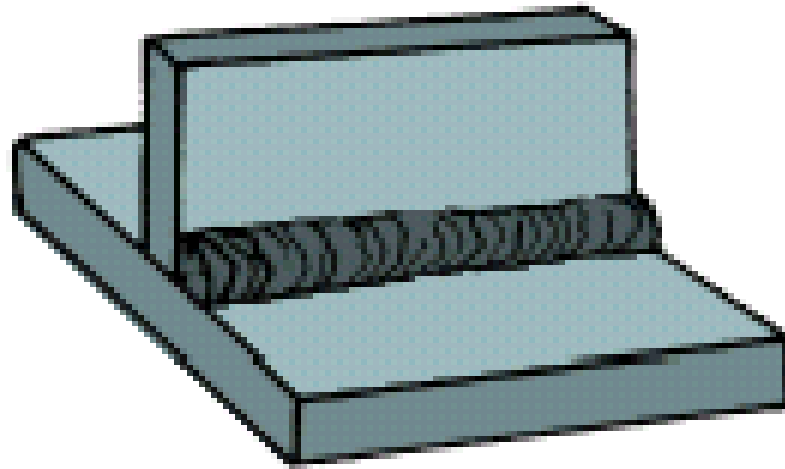
Double - U



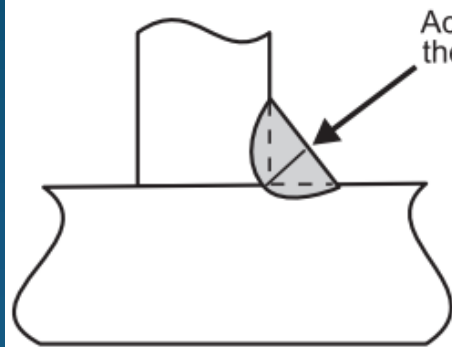
Double - V

Fig. Butt welding joints edge preparations

- The other types of joints are the **tee, corner, and edge**.
- A tee weld is a type of fillet weld.
- The ***fillet weld*** has **two surfaces at right angles**, and the **bead is triangular in shape**.

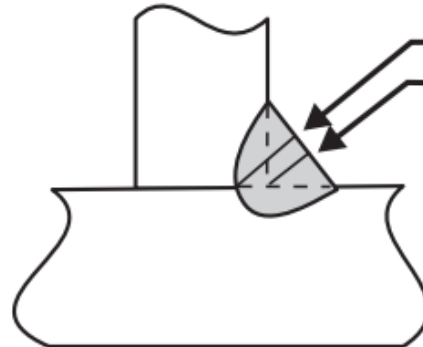


Tee (Fillet) Joint



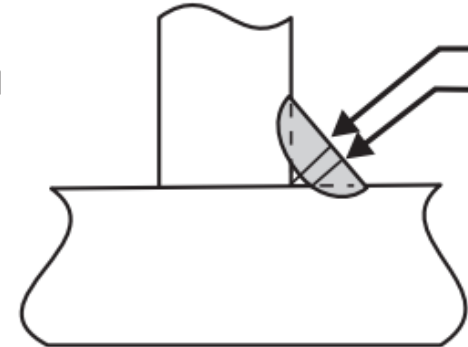
Actual and
theoretical
throat

Acceptable -
through fusion to
the root.



Actual
Theoretical

Acceptable, but no design
credit given for increased
throat.

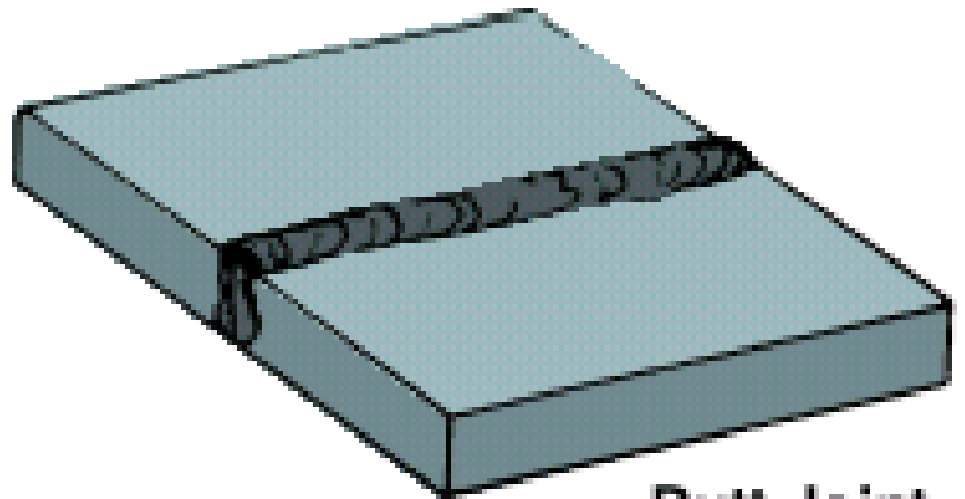


Theoretical
Actual

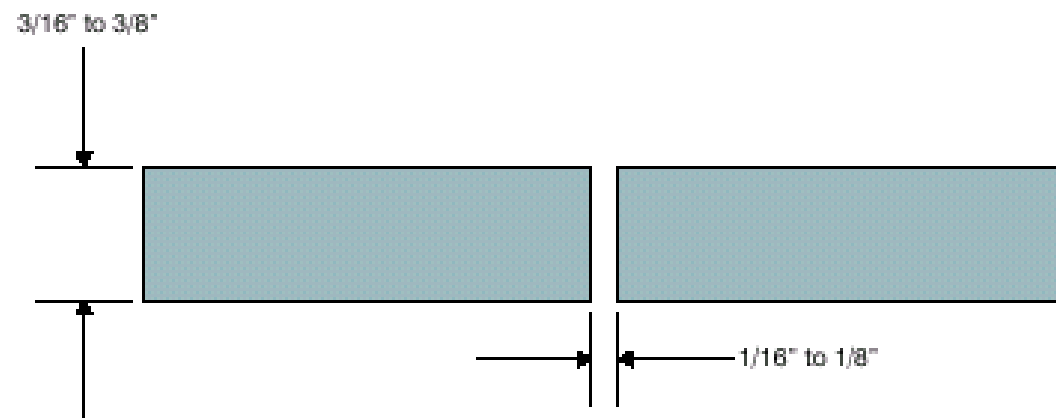
Unacceptable, weld
lacks fusion to the root

Fillet weld requirements

- The square butt joint is used on **metal sections no thicker than $\frac{3}{16}$ inch.**
- This joint is **strong in tension loads but not good for repeated loads and impact forces.**



Butt Joint



Square butt joint with a $\frac{1}{16}$ " to $\frac{1}{8}$ " root gap.

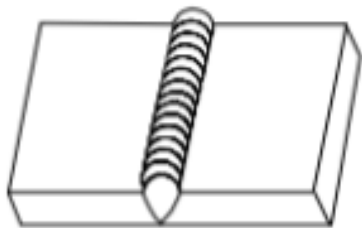
Welding Positions

➤ There are **four types of welding positions**, which are given as:

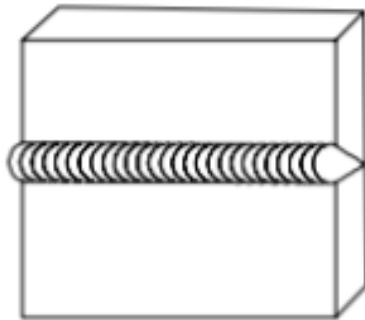
1. **Flat** or down hand position
2. **Horizontal** position
3. **Vertical** position
4. **Overhead** position

Flat or Down hand Welding Position

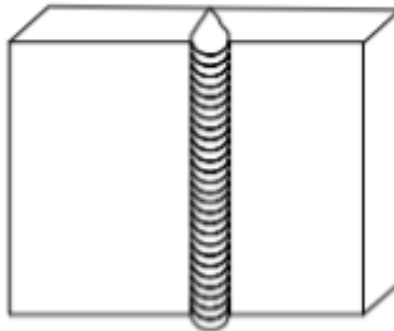
➤ The flat position or down hand position is one in which the welding is performed from the upper side of the joint and the face of the weld **is approximately** horizontal.



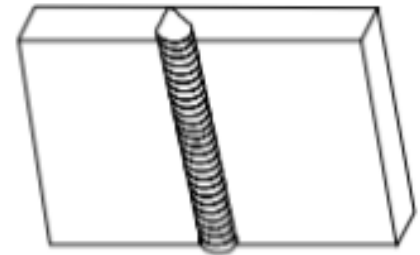
Flat



Horizontal



Vertical

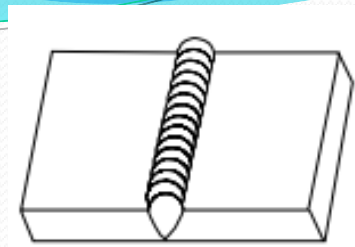


Over head

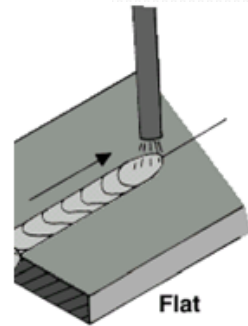
Kinds of welding positions

➤ This(**flat**) is the simplest and the **most convenient** position for welding.

➤ Using this technique, excellent welded joints at a fast speed with minimum risk of fatigue to the welders can be obtained.



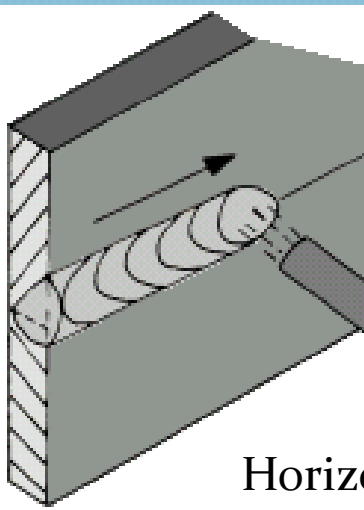
Flat



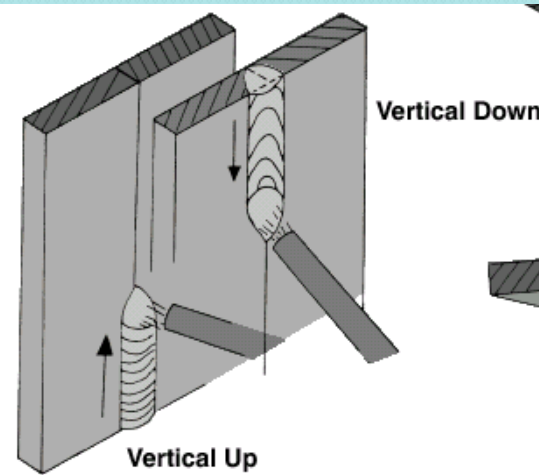
Horizontal Welding Position: In horizontal position, the **plane of the work piece is vertical and the deposited weld head is horizontal.**

➤ The **metal deposition rate** in horizontal welding is **next to that achieved in flat** or down hand welding position.

➤ This position of welding is most commonly **used in welding vessels and reservoirs.**



Horizontal Welding

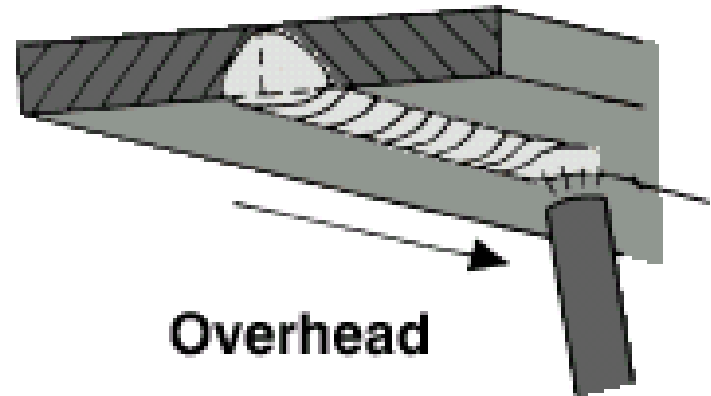


Vertical Welding Position: In vertical position, the plane of the work piece is vertical and the weld is deposited upon a vertical surface.

- It is difficult to produce satisfactory welds in this position due to the effect of the force of gravity on the molten metal.
- The welder must constantly control the metal so that it does not run or drop from the weld.

In overhead position, the plane of the work piece is horizontal.

- But the **welding** is carried out from the **under side**.
- The electrode is held with its welding end upward.
- **more difficult to weld than the vertical position.**



The joints produced by welding are:

- permanent
- strong, usually matching the strength of the components,
- leak tight,
- reproducible,
- readily inspected by non-destructive techniques.

Welding can be used:

- in the workshop
 - on site
- for
- sheet
 - plate
 - pipe
 - sections

ADVANTAGES AND DISADVANTAGES OF WELDING

Advantages

- ✓ Welding is more economical and is much faster process as compared to other processes (riveting, bolting, casting etc.)
- ✓ Welding, if properly controlled results permanent joints having strength equal or sometimes more than base metal.
- ✓ Large number of metals and alloys both similar and dissimilar can be joined by welding.
- ✓ General welding equipment is not very costly.
- ✓ Portable welding equipments can be easily made available.
- ✓ Welding permits considerable freedom in design.



Disadvantages

It results in residual stresses and distortion of the work pieces.

- ✓ Welded joint needs stress relieving and heat treatment.
- ✓ Welding gives out harmful radiations (light), fumes and spatter.
- ✓ Jigs, and fixtures may also be needed to hold and position the parts to be welded.
- ✓ Edges preparation of the welding jobs are required before welding
- ✓ Skilled welder is required for production of good welding
- ✓ Heat during welding produces metallurgical changes as the structure of the welded
- ✓ joint is not same as that of the parent metal

Classification of welding processes

- Welding processes can be classified on the basis of following technological criteria:
- Welding with or without filler material
- Source of heat for welding i.e., fire, flame, arc, etc.
- interaction i.e., liquid / liquid (fusion welding) or solid/solid (solid state welding) e.t.c

Classification of welding processes:

(I). Arc welding

- Shield Metal arc welding (SMAW)
- Submerged Arc Welding (SAW)
- Gas Tungsten Arc Welding (GTAW)
- Gas Metal Arc Welding (GMAW)
- Flux Cored Arc Welding (FCAW)

(ii). Oxy-Fuel Gas Welding

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

(iii). Resistance Welding

- Spot
- Seam
- Projection

iv) Solid State Welding(**no filler & no melting**)

- ✓ Friction
- ✓ Ultrasonic
- ✓ Diffusion
- ✓ Radiant Energy Welding Processes
 - ✓ Electron-beam welding
 - ✓ Laser beam welding

(vi) Other allied Processes

- ✓ Brazing
- ✓ Soldering

Fusion welding Types

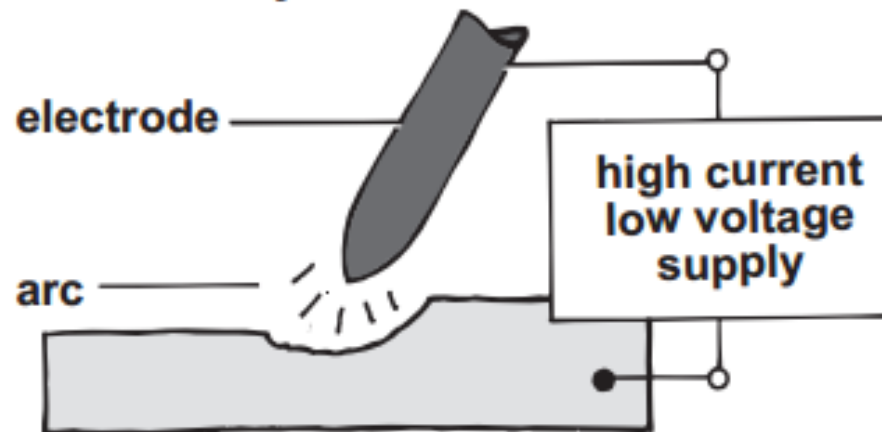
- **Gas welding**
 - Oxyacetylene welding
- **Arc welding**
 - Shielded metal arc welding (SMAW)
 - Gas-tungsten arc welding (GTAW=TIG)
 - Gas-metal arc welding (GMAW=MIG)
 - Flux-core arc welding (FCAW)
 - Plasma arc welding (PAW)
 - Submerged arc welding (SAW)
 - Electro slag welding (ESW)

Fusion welding

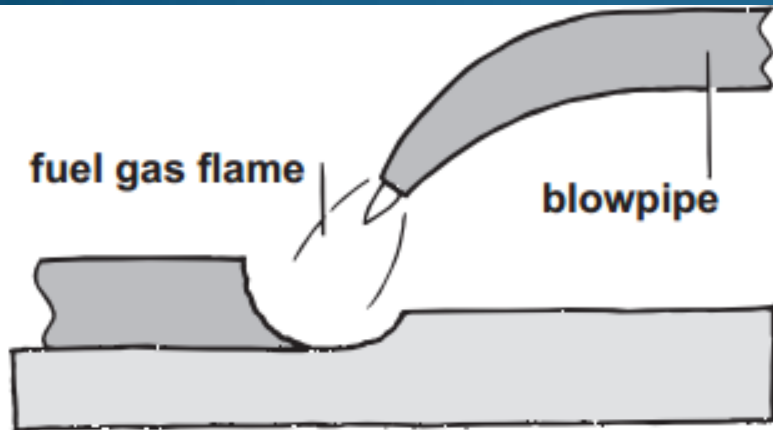
The most widely used welding processes rely on fusion of the components at the joint line.

In fusion welding, a heat source melts the metal to form a bridge between the components.

Two widely used heat sources are:



Electric arc

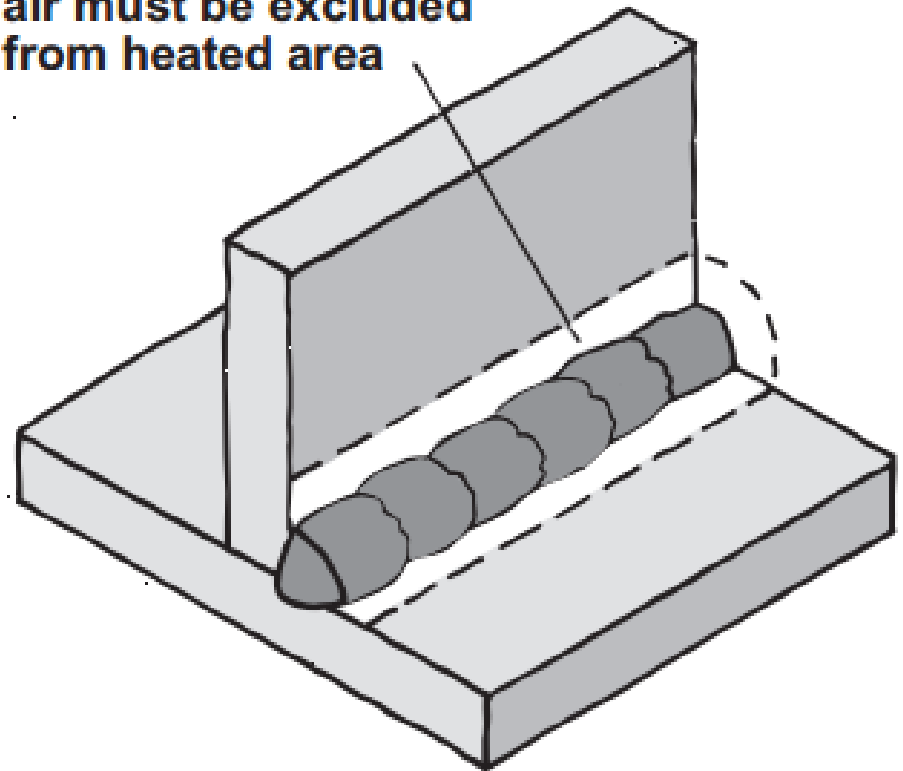


Gas flame

The molten metal must be protected from the atmosphere - absorption of oxygen and nitrogen leads to a poor quality weld.

Air in the weld area can be replaced by a gas which does not contaminate the metal, or the weld can be covered with a flux.

air must be excluded from heated area



Which process?

A large number of welding processes and techniques are available. No process is universally best. Each has its own special attributes and must be matched to the application.

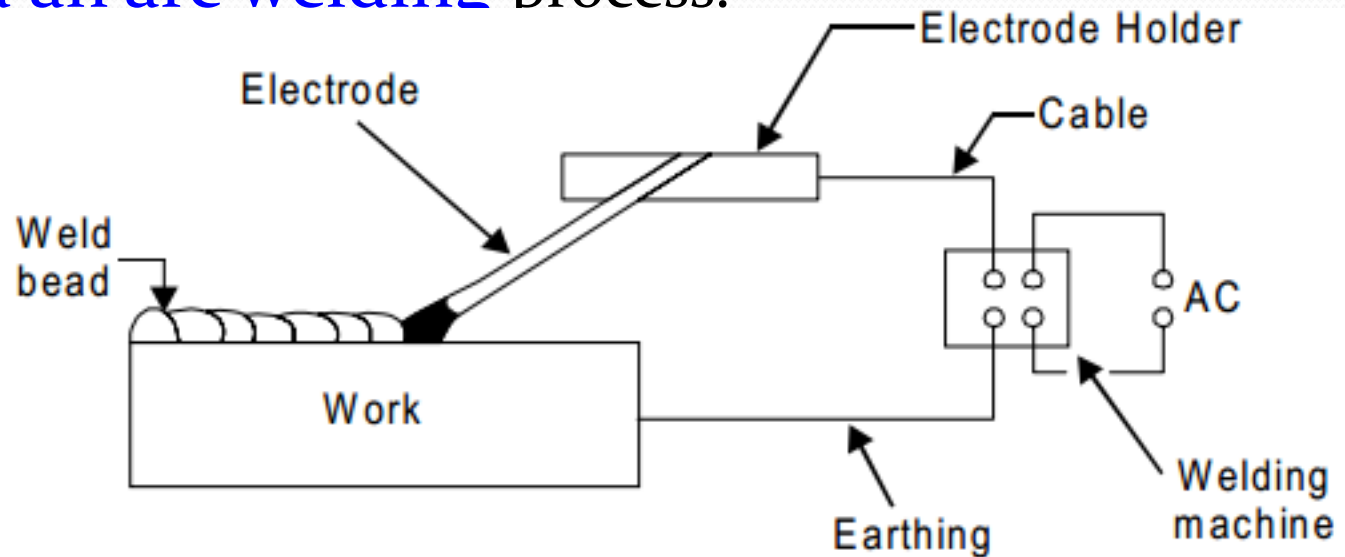
Choosing the most suitable process requires consideration of a number of factors.

Factors in choosing welding process:

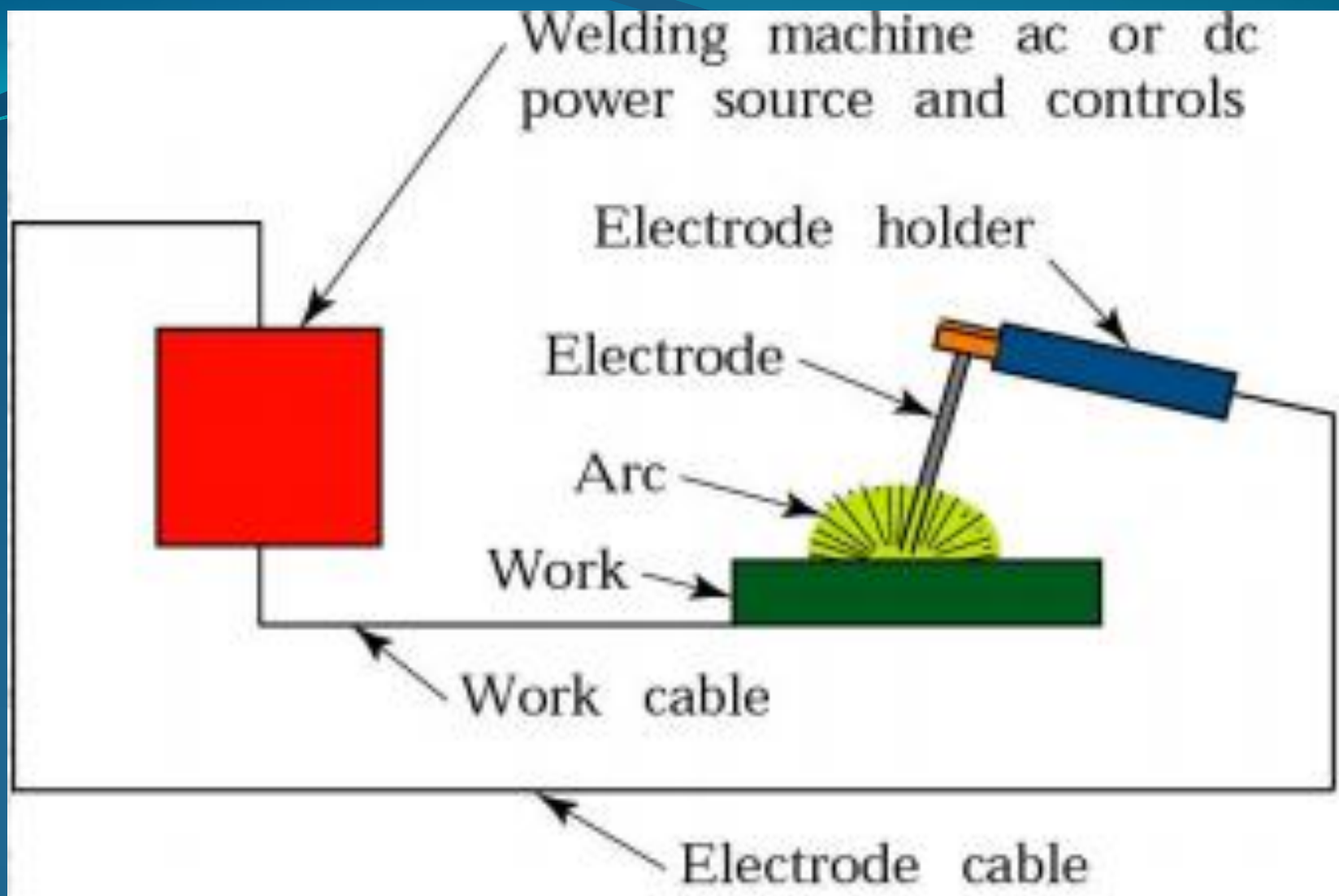
- type of metal
- type of joint
- production constraints
- equipment availability
- labour availability
- health, safety and the environment
- costs of consumables
- labour costs
- material thickness

I. ARC WELDING PROCESSES

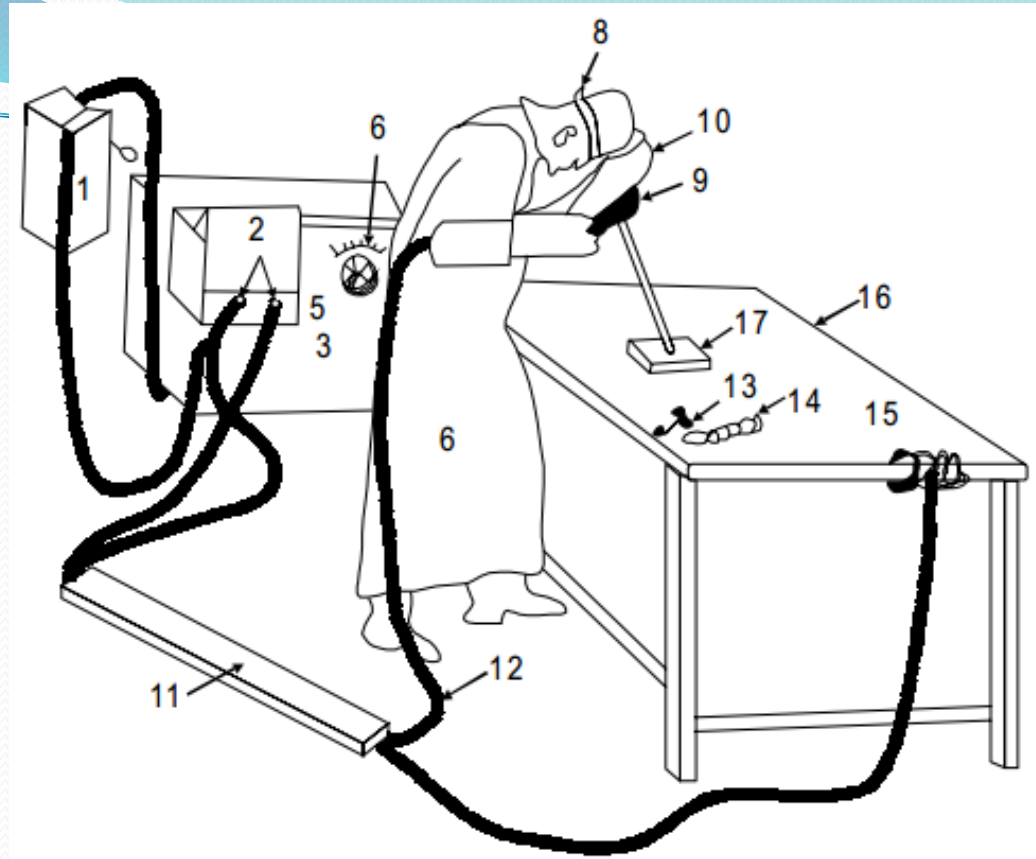
- The process, in which an electric arc between an electrode and a work piece or between two electrodes is utilized to weld base metals, is called an arc welding process.



- Most of these processes use some shielding gas while others employ coatings or fluxes to prevent the weld pool contamination from the surrounding atmosphere.



Schematic illustration of the shielded metal-arc welding operations (also known as stick welding, because the electrode is in the shape of a stick).



- (1) Switch box.
- (2) Secondary terminals.
- (3) Welding machine.
- (4) Current reading scale.
- (5) Current regulating hand wheel.
- (6) Leather apron.

- (7) Asbestos hand gloves.
- (8) Protective glasses strap.
- (9) Electrode holder.
- (10) Hand shield.
- (11) Channel for cable protection.
- (12) Welding cable.

- (13) Chipping hammer.
- (14) Wire brush.
- (15) Earth clamp.
- (16) Welding table (metallic).
- (17) Job.

Arc welding process setup

A. Arc Welding Equipment

- Few of the important components of arc welding setup are
 1. Arc welding power source: Both direct current (DC) and alternating current (AC) are used for electric arc welding, each having its particular applications.
- DC welding supply is usually obtained from generators driven by electric motor or if no electricity is available by internal combustion engines.
- For AC welding supply, transformers are predominantly used for almost all arc where Welding where mains electricity supply is available.

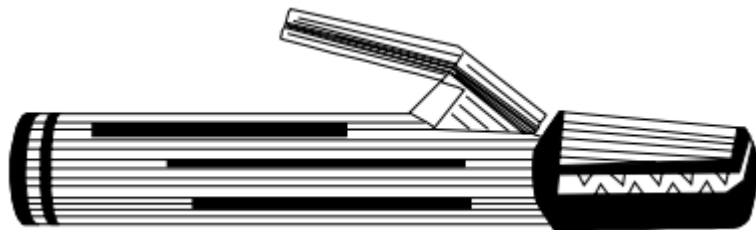
2. **Welding cables:** Welding cables are required for conduction of current from the power source through the electrode holder, the arc, the work piece and back to the welding power source.

➤ These are insulated copper or aluminum cables.

3. **Electrode holder:** Electrode holder is used for holding the electrode manually and conducting current to it.

➤ These are usually matched to the size of the lead, which in turn matched to the amperage output of the arc welder.

➤ Electrode holders are available in sizes that range from 150 to 500 Amps.



4. **Welding Electrodes**: An electrode is a piece of wire or a rod of a metal or alloy, with or without coatings.

- An arc is set up between electrode and work piece.
- Welding electrodes are classified into following types-

(i) **Consumable** Electrodes

(a) **Bare** Electrodes

(b) **Coated** Electrodes

(ii) **Non-consumable** Electrodes

(a) Carbon or **Graphite** Electrodes

(b) **Tungsten** Electrodes

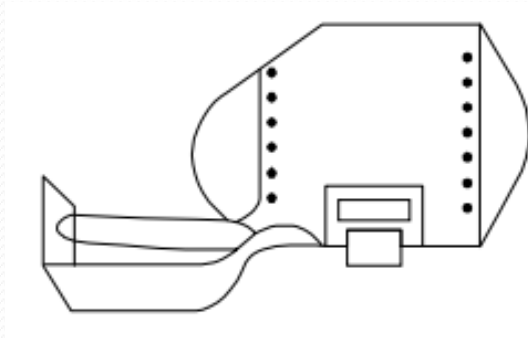
- Consumable electrode is made of different metals and their alloys.
- The end of this electrode starts melting when arc is struck between the electrode and work piece.
- Bare electrodes consist of a metal or alloy wire without any flux coating on them.
- Coated electrodes have flux coating which starts melting as soon as an electric arc is struck. This coating on melting performs many functions like prevention of joint from atmospheric contamination, arc stabilizers etc

- Non-consumable electrodes are made up of high melting point materials like carbon, pure tungsten or alloy tungsten etc.
- These electrodes do not melt away during welding.

Electrode Diameter

- Position of welding may affect size of electrode
- Small diameters recommended for vertical and overhead positions
- Welding thin material
 - Wires with diameters: 0.023/0.025, 0.030, 0.035"
- Medium thick materials
 - Wires with diameters: 0.045" or 1/16"
- Heavy materials
 - Wire with diameter: 1/8"

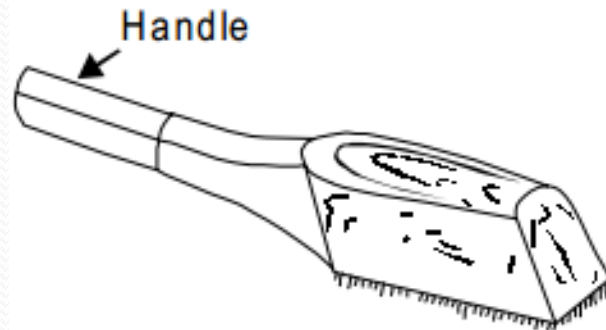
5. Hand Screen; Hand screen used for protection of eyes and supervision of weld bead.



6. Chipping hammer; Chipping Hammer is used to remove the slag by striking.

7. Wire brush; Wire brush is used to clean the surface to be weld.

Protective clothing; as apron to keep away the exposure of direct heat.



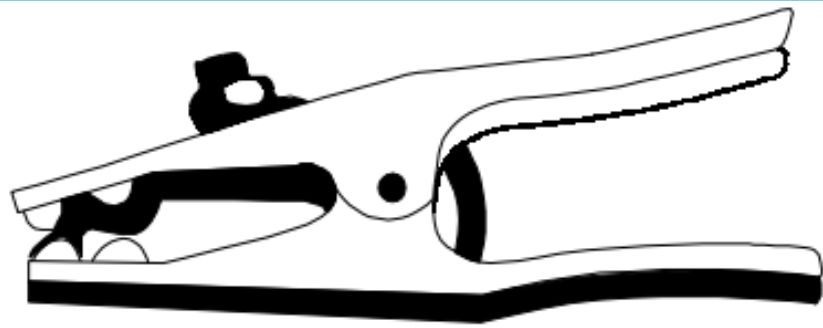


Fig. 17.11 Earth clamp

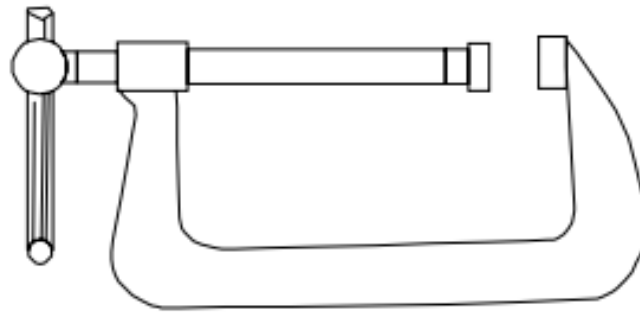


Fig. 17.15 C-clamp

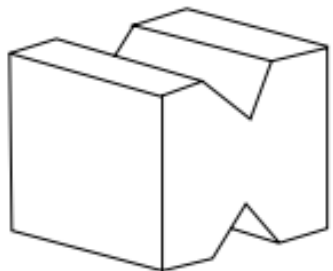


Fig. 17.16 V-block

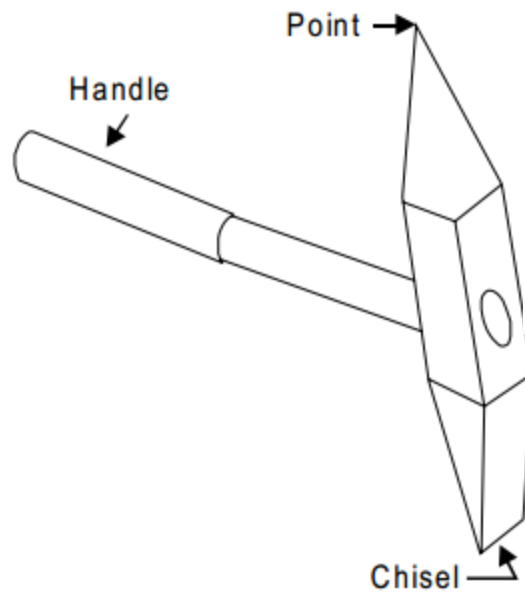


Fig. 17.13 Chipping and hammer



Scriber

Fig. 17.17 Scriber

B. Arc Welding Procedures ,Striking the arc

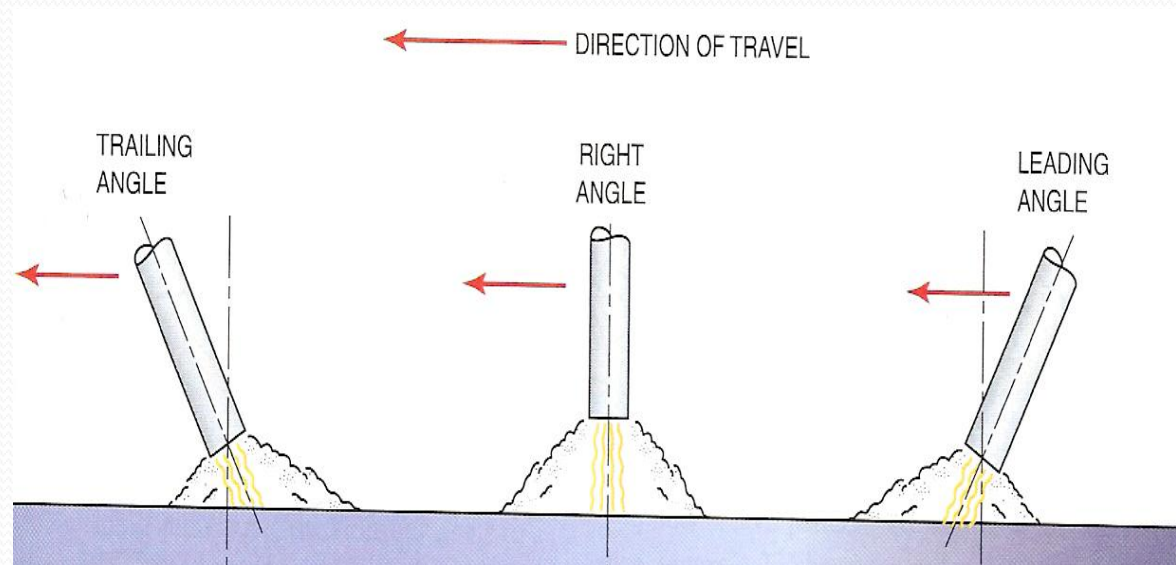
All welding processes in which heat for melting the faying surfaces is provided after establishing an arc either between the base plate and an electrode or between electrode & nozzle are grouped under arc welding processes

1. Before striking the metal should be located for operator access, free of dirt, oil, and rust.
2. Set proper machine amperage for the electrode and material.
3. Position electrode tip about $\frac{1}{4}$ " above material.
4. Drop welding helmet,
5. Strike arc by quickly lowering, touching, and then lifting the electrode.

Electrode angle – the electrode should be held 20 degrees from vertical away **from the direction of travel**.

Arc length – rule of thumb; the distance between the work piece and the electrode **should equal the diameter of the filler metal**

Movement - the proper movement depends on many factors and comes with practice.



Speed

When the electrode is moving at a constant rate the weld material forms uniformly spaced rings behind the weld puddle.

Amperage setting

❖ The shape of molten pool indicates amperage setting.

→ Long narrow rings indicate *amperage is too low*,

→ rings that are *slightly wider than* long indicates correct amperage setting.

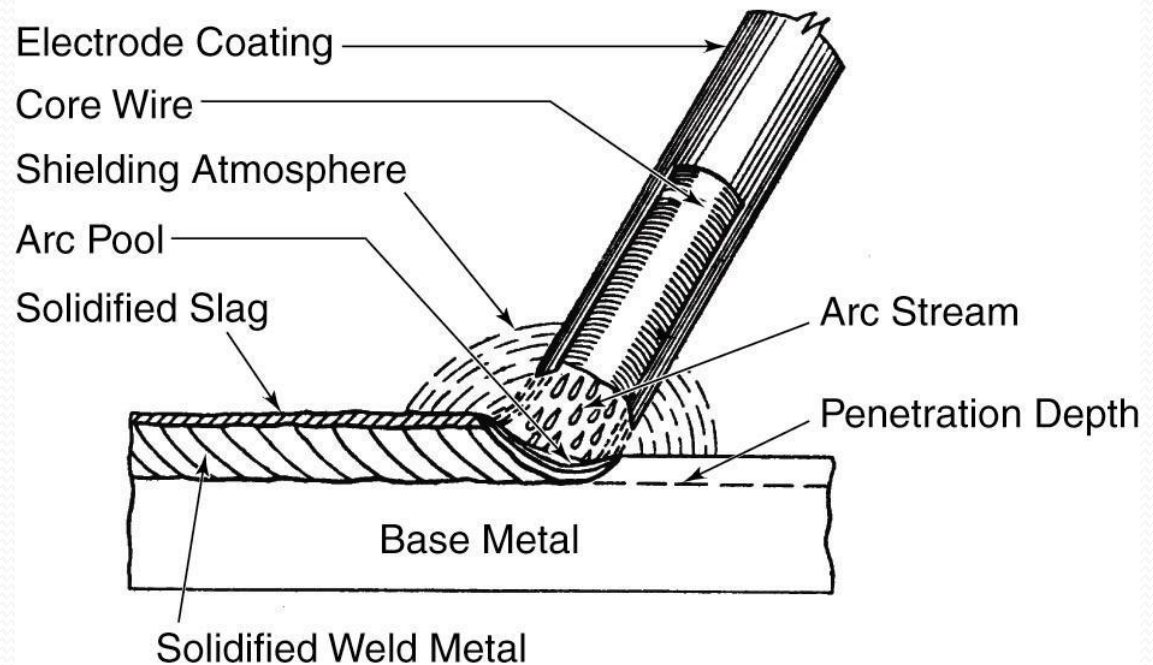
The various arc welding processes are:

- Shielded Metal-Arc Welding (**SMAW**)
- Gas Metal Arc Welding (**GMAW**)
- Gas Tungsten Arc Welding (**GTAW**)
- Flux Cored Arc Welding (**FCAW**)
- Submerged Arc Welding (**SAW**)

II. Shielded Metal-Arc Welding (SMAW) or Manual metal arc welding (MMAW)

- Shielded metal arc welding (SMAW) is a commonly used arc welding process manually carried by welder.
- It is an arc welding process in which heat for welding is produced through an electric arc set up between a flux coated electrode and the work piece.

- The flux coating of electrode decomposes due to arc heat and serves many functions, like weld metal protection, arc stability etc
- Inner core of the electrode supply the filler material for making a weld.



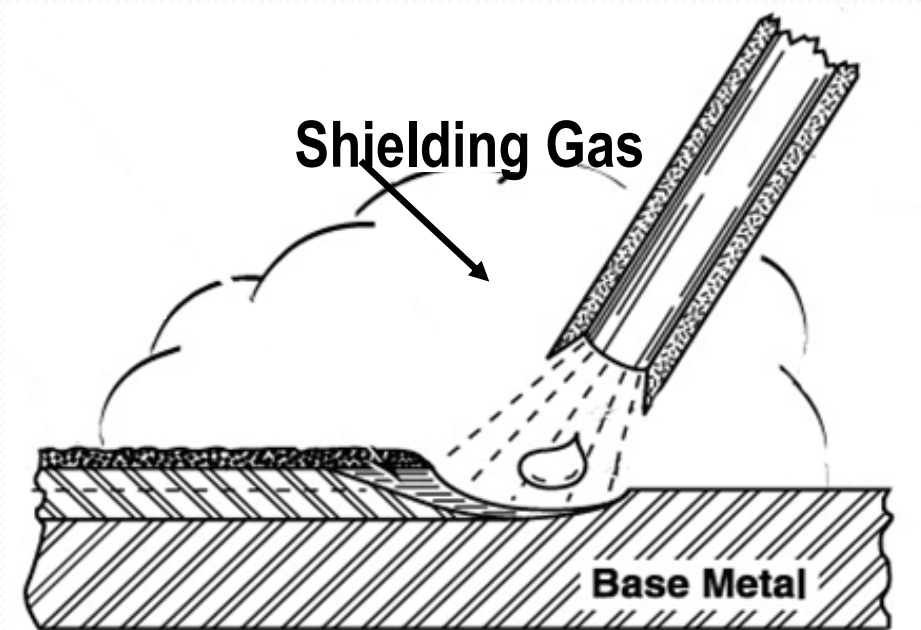
- Combustion and decomposition of electrode creates gaseous shield to
 - Protects electrode tip, weld puddle, arc, and highly heated work from atmospheric contamination
 - Additional shielding provided by covering of molten slag (flux)

Weld Puddle

- The weld is initiated by tapping [striking] the tip of the electrode against the work piece which initiates an electric arc.
- As the core rod, flux coating, and work pieces heat up and melt, they form a pool of molten material called a **WELD PUDDLE**
- The weld puddle is what a welder watches and manipulates while welding.



Shielding Gas



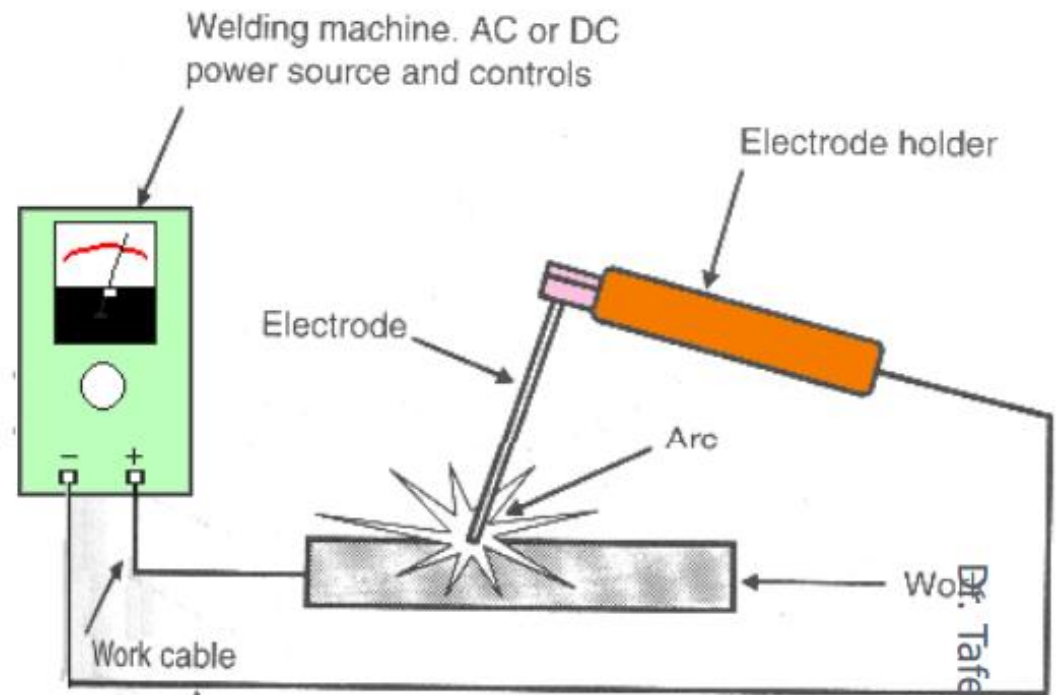
The shielding gas protects the molten puddle from the atmosphere while stabilizing the arc

- A shielding gas is formed when the flux coating melts.
- This protects the weld puddle from the atmosphere preventing contamination during the molten state

Solidified Weld Metal

- As the molten weld puddle solidifies, it forms a joint or connection between two pieces of base material
- While it done properly on steel, it results in a weld stronger than the surrounding base metal





➤ it is only suitable for manual operation.

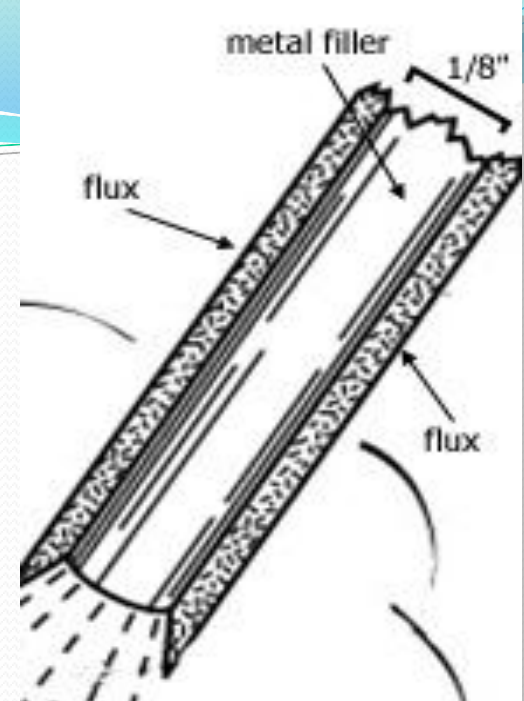
A. The Electrode

- **Is a consumable** - it gets melted during the welding process
- Is composed of **two parts**
 - **Core Rod** (Metal Filler)
 - *Carries welding current
 - *Becomes part of the weld
 - **Flux Coating**
 - ***Produces a shielding gas**
 - ***Can provide additional filler**
 - ***Forms a slag**

↔ Electrodes can be :

→ **Straight** polarity (**electrode -ve**) DCSP
Work Piece is +ve

→ **Reverse** polarity (**electrode +ve**) DCRP
Work Piece is -ve



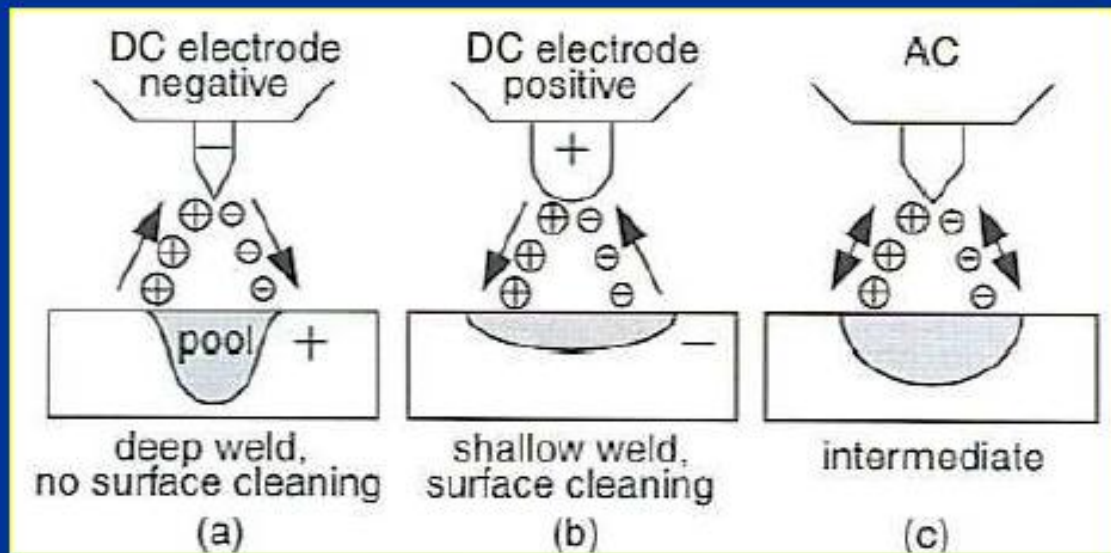
Polarity

There are three different types of current used in arc welding

1) Direct-Current Electrode Negative (DCEN)

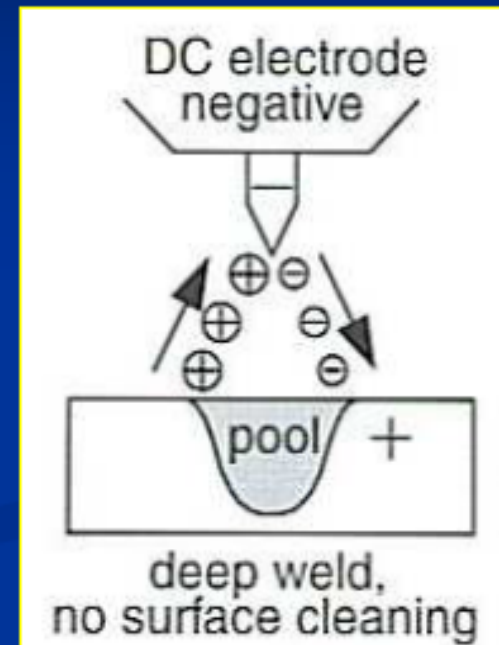
2) Direct-Current Electrode Positive (DCEP)

3) Alternating current (AC)



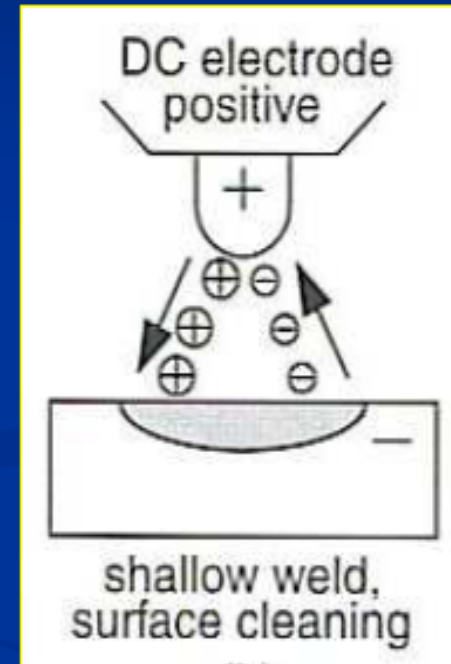
Direct-Current Electrode Negative (DCEN)

- Also called **straight polarity**.
- Electrons are emitted from the **negative tungsten electrode** and accelerated while travelling through the arc.
- Most commonly used in **GTAW**.
- Relatively **narrow and deep weld pool** is produced due to high energy.
- **DCEN in GMAW** makes the **arc unstable** and causes **excessive spatter**, large droplet size of metal and the arcs forces the droplets away from the workpiece. → This is due to a low rate of electron emission from the negative electrode.



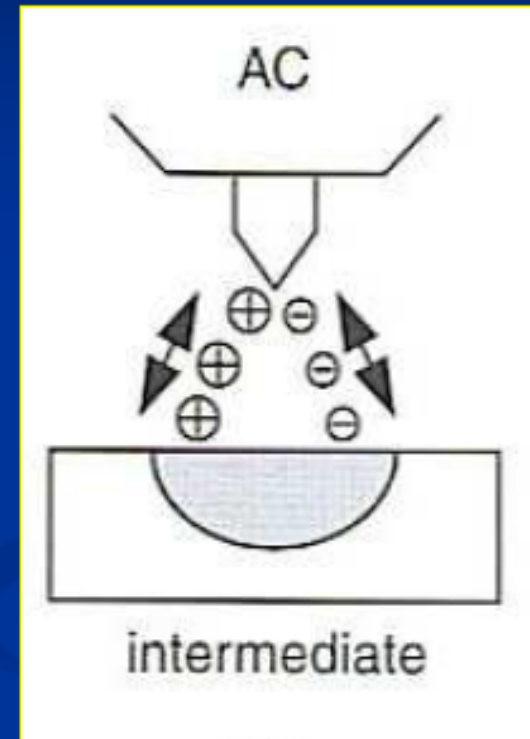
Direct-Current Electrode Positive (DCEP)

- Also called **reverse polarity**.
- The electrode is connected to the positive terminal of the power source, therefore the **heating affect** is now at the **tungsten electrode** rather than the workpiece. → **shallow weld** → for welding thin sheets.
- At low current in **Ar**, the size of the droplet ~ the size of the electrode → Globular transfer.
- The **droplet size** is inversely proportional to the **current** and the droplets are released at the rate of a few per second.
- At above the critical current → the droplets are released at the rate of hundreds per second (**spray mode**).
- Positive ions **clean off** the oxide surface.



Alternating Current (AC)

- Reasonably **good penetration and oxide cleaning action** can be both obtained.
- Often used for welding **aluminium alloys**.



DCEN(electrode negative)

- current flow from electrode to base metal
- high melting of electrode and deposit filler metal at faster rate
- low melting of base metal/shallow penetration
- commonly used to weld thin metal

DCEP(electrode positive)

- current flow from base metal to electrode
- deep penetration

AC

- Generally operate at 60 cycle per second
- AC flow in *one direction for 1/120 of a second* then reverses its direction for 1/120 of a second
- Produce *medium depth* of penetration
- Most DC arc welding m/c are DCEP. Because DCEP produce deep penetration than DCEN

- A **wide variety of electrodes are available** to enable the welder to do many different jobs.
- Choosing the **correct electrode** for the application is the first step in producing a **high quality weld**.
- Electrode wire is made up of pure metals or metal alloys

electrode size

→ Available in d/t length and diameter

→ (9", 12", 14", and 18" → length

→ diameter of electrode ($1/16"$ → $1/8"$ → $1/4"$)

($5/64"$ → $5/32"$ → $5/16"$)

($3/32"$ → $3/16"$ → $3/8"$)

AWS Classification of SMAW Electrodes

E70XX

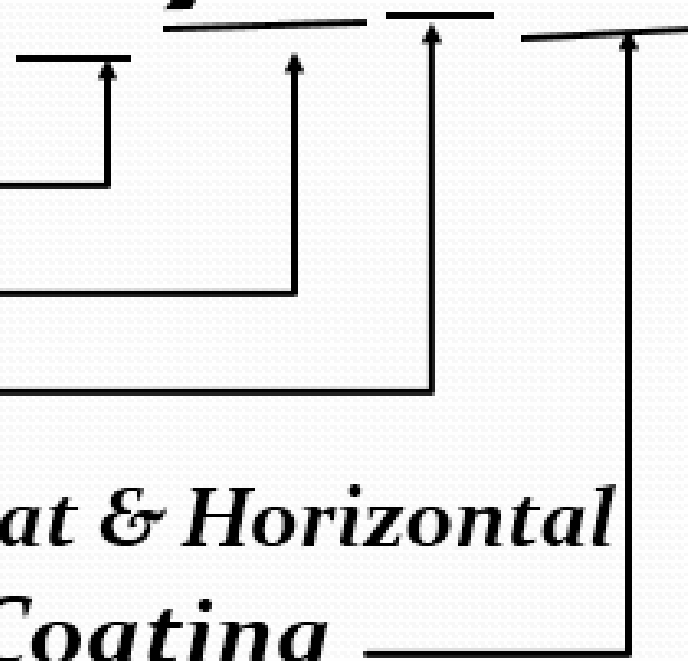
Electrode _____

Tensile in Ksi _____

Welding Position: _____

1 = All Position, 2 = Flat & Horizontal

Type of Current and Coating _____



→ The diameter of electrode wire determine the amount of amperage required to melt it.

→ $1/8$ " diameter electrode requires 90A-120A

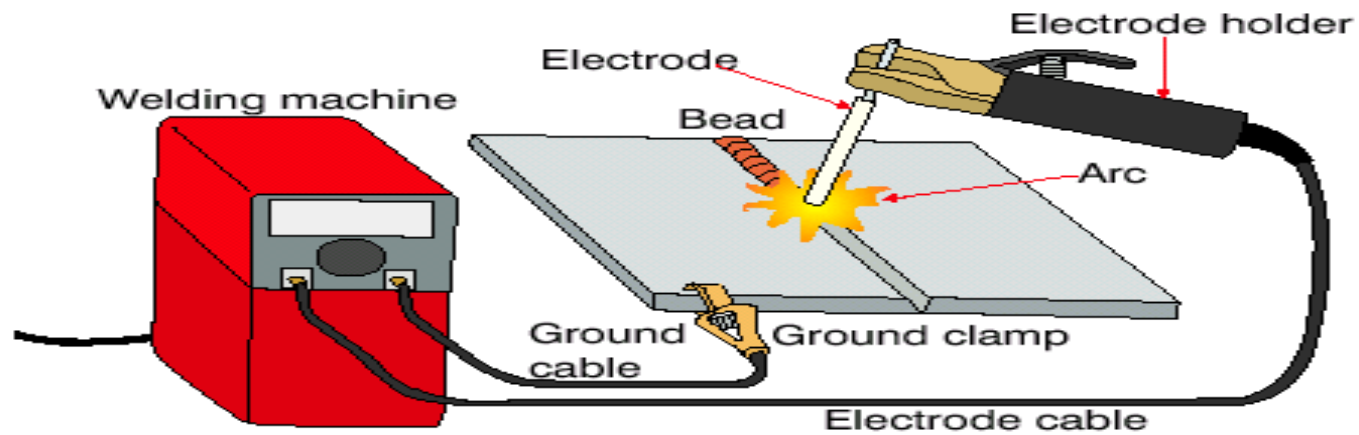
→ Add 40A to 90A for each $1/32$ " of diameter above $1/8$ "

Electrode Angle

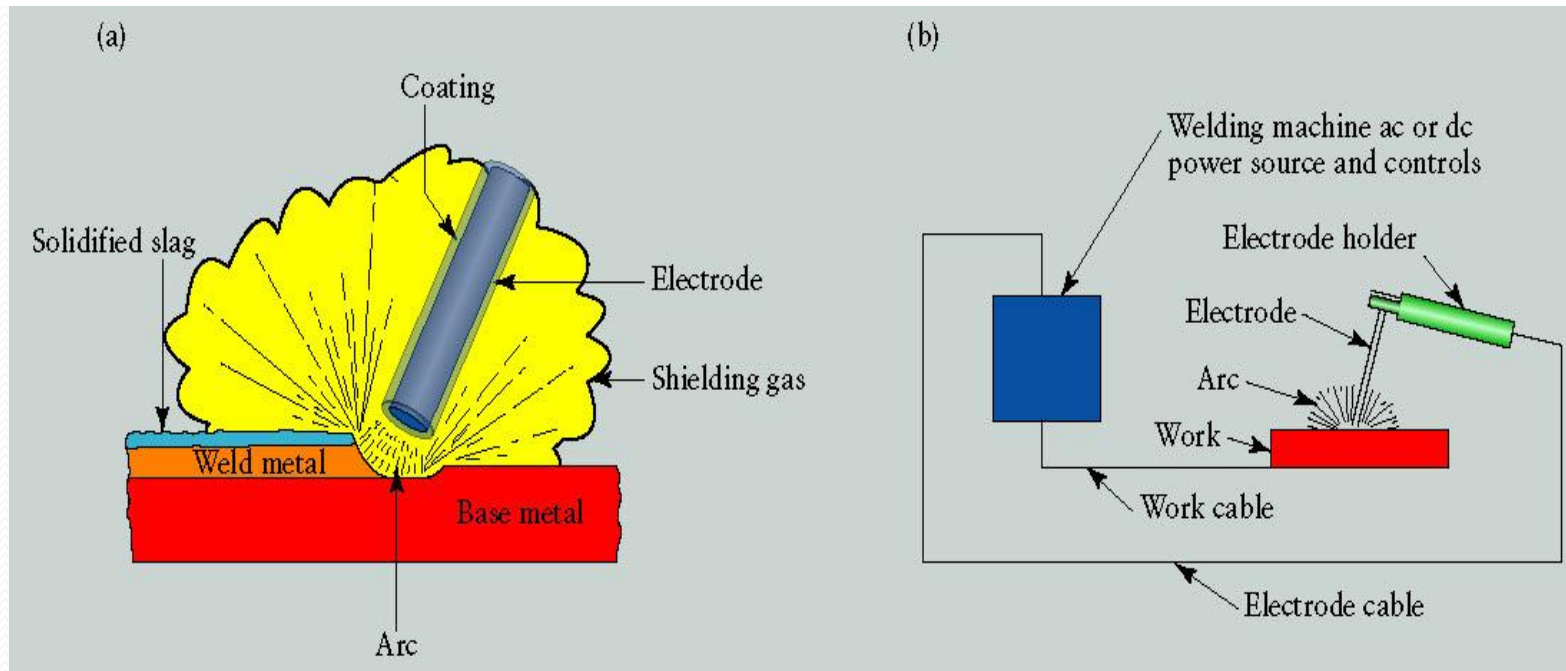
- The correct angle of the electrode will depend on the type of weld that is to be completed.
- Hold the electrode at 5 to 20 degrees in the direction of travel.
- Speed of travel: It should produce a bead that is 1.5 to 2 times the diameter of the bare end of the electrode.

Electrodes are covered with flux. The flux provides four important functions.

- a. Flux protects the molten metal from the atmosphere.
- b. The flux-covering burns in the intense heat of the arc, forming a blanket or shield of gas around the bead. Air contains oxygen and nitrogen which would combine with the metal to cause it to be brittle and weak.
- c. Flux mixes with the weld metal, floating the impurities to the top in the form of slag. Slag covers the bead to protect it from the air and slow the rate of solidification and cooling.
- d. Flux stabilizes the arc. After the arc is started, current flows across the gap between the end of the electrode and the work.



(Courtesy, Interstate Publishers, Inc.)



Slag

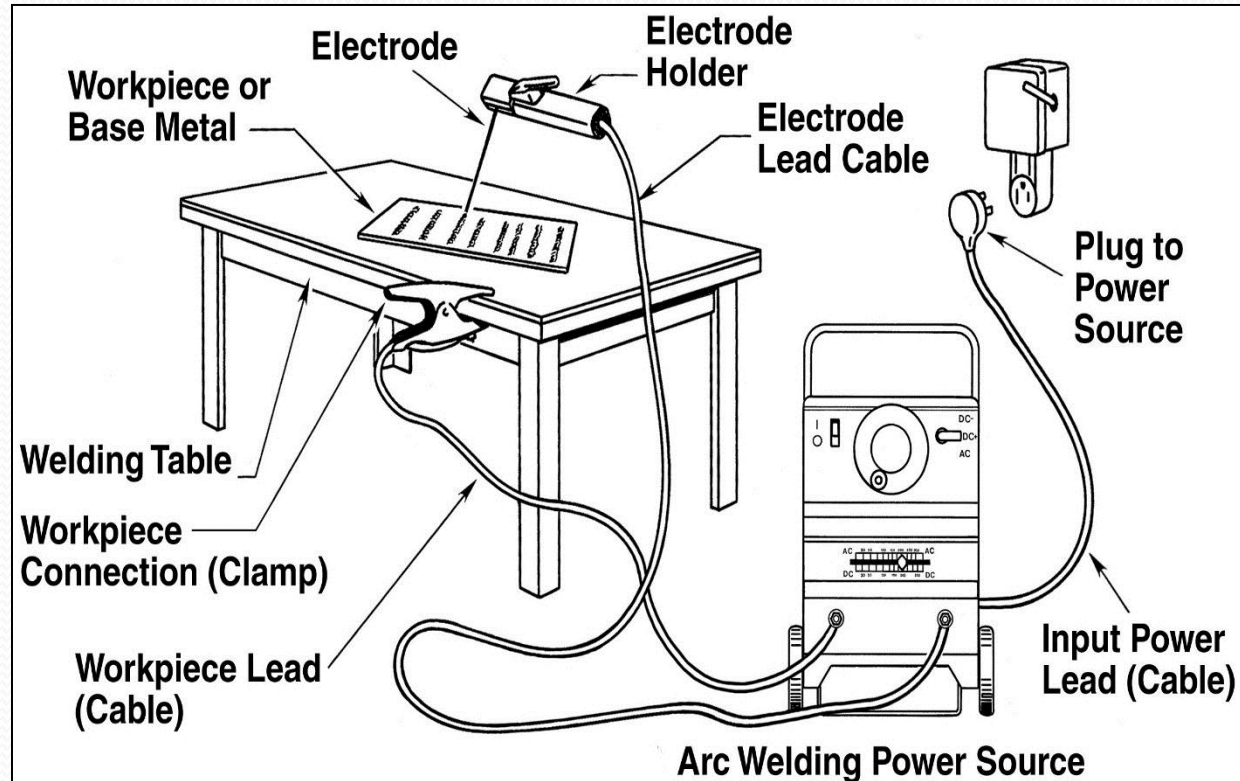
- is a combination of the flux coating and impurities from the base metal **that float to the surface of the weld.**
- Slag **quickly solidifies** to form a solid coating
- The slag also **slows the cooling rate of the weld**
- The slag can be **chipped away and cleaned with a wire brush when hard.**



This welder chips the slag off of a weld during the repair of railroad tracks

B. SMAW equipments:

- A welding machine DC or AC or both
- Two cables- one for work and one for electrode
- Electrode holder
- Electrode
- Protective shield
- Gloves
- Wire brush
- Chipping hammer
- Goggles
- Clamp
- Helmet



C. OTHER ACCESSORIES

- ventilation
- arc welding helmet and lenses
- Working table
- Fire extinguisher
- Fume exhausting system
- Opaque/ filtered transparent plastic screen.

SMAW

Advantages

- Most efficient way to join metals
- Lowest-cost joining method
- Affords lighter weight through better utilization of materials
- Joins all commercial metals
- Provides design flexibility

Limitations

- Manually applied, therefore high labor cost.
- Need high energy causing danger
- Not convenient for disassembly.
- Defects are hard to detect defects at joints.

SMAW Applications

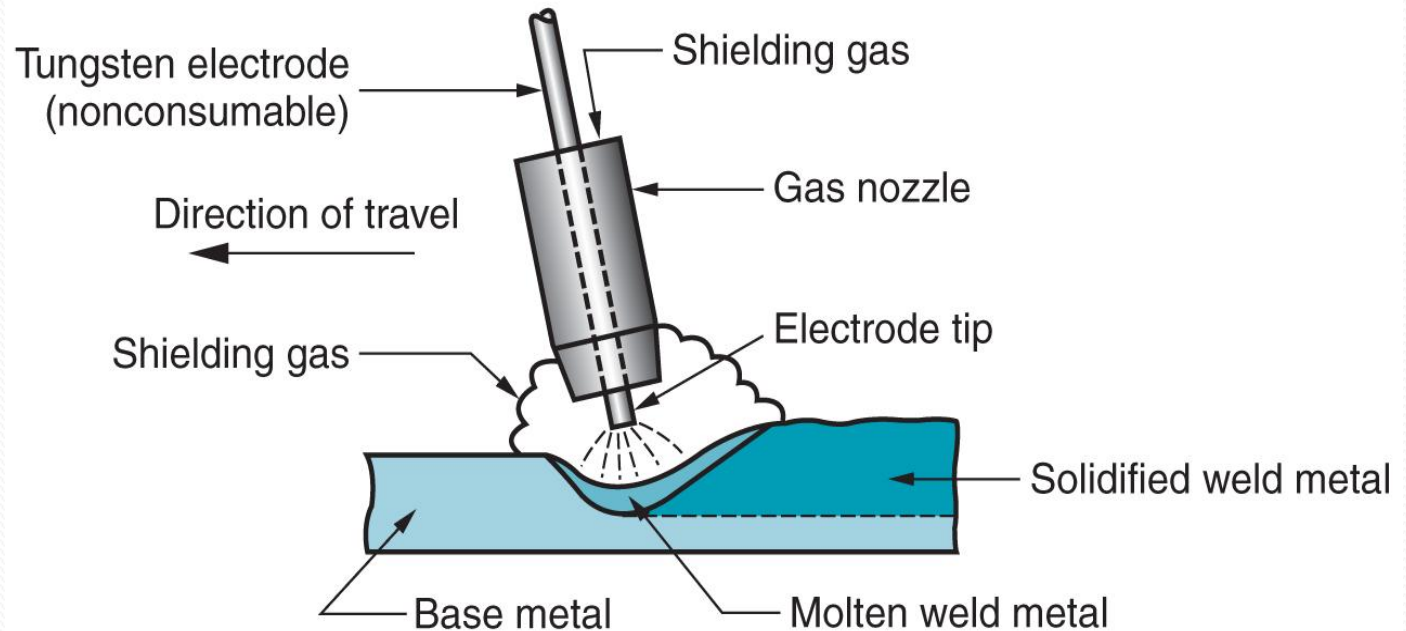
- ❑ Used for steels, stainless steels, cast irons, and certain nonferrous alloys.
- ❑ Not used or rarely used for copper alloys, and titanium.
- ❑ Can be used in windy weather.
- ❑ Can be used on dirty metals (i.e. painted or rusted surfaces).
- ❑ Good for repair work.
- ❑ Makes thick welds.

The process finds applications in

- (a) Building and Bridge construction
- (b) Automotive and aircraft industry, etc.
- (c) Air receiver, tank, boiler and pressure vessel fabrication
- (d) Ship building
- (e) Pipes and
- (f) Penstock joining

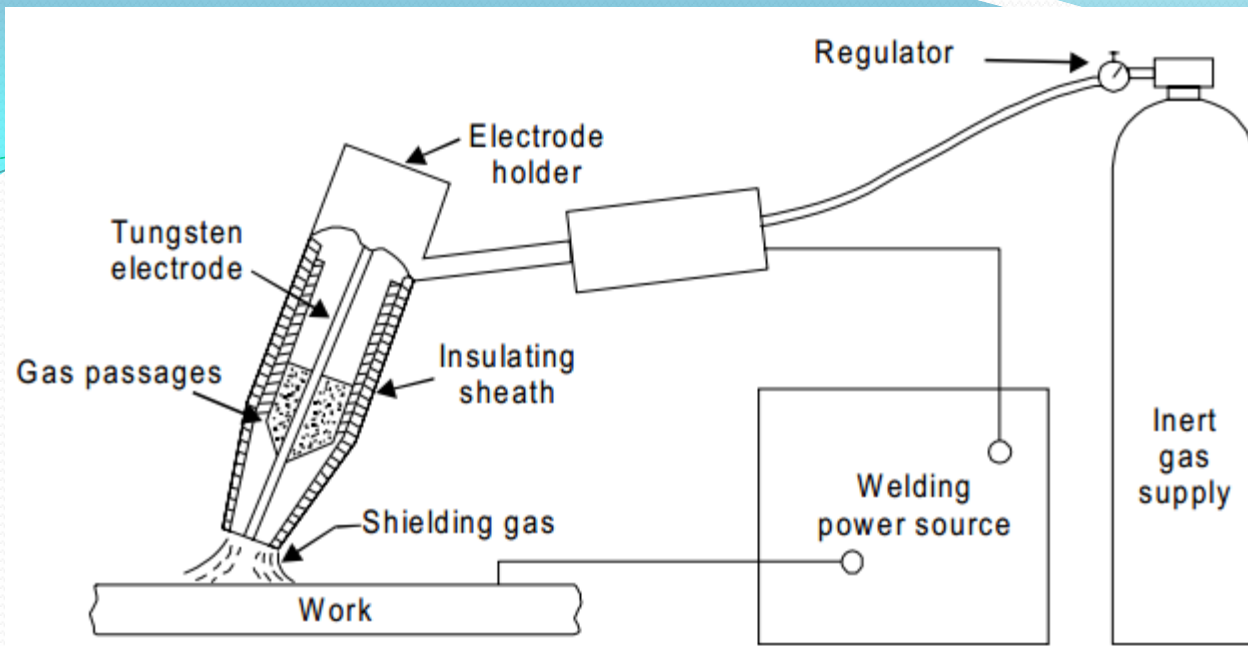
III. Gas Tungsten Arc Welding (GTAW) or Tungsten Inert Gas (TIG) Welding

- In this process a non-consumable tungsten electrode is used with an envelope of inert shielding gas around it.
- The shielding gas protects the tungsten electrode and the molten metal weld pool from the atmospheric contamination.



TIG (tungsten inert gas)

- The shielding gases generally used are **argon, helium** or their mixtures.
- gas tungsten arc welding (GTAW) can be used to **weld all types of metals.**
- In this process the **arc is formed between a pointed tungsten electrode and the work piece** in an inert atmosphere of argon or helium.
- GTAW has played a major role in the acceptance of **aluminum for high quality welding and structural applications.**
- a constant and stable arc gap is maintained at a constant current level.



The filler metals are similar to the metals to be welded, and flux is not used.

Figure Tungsten inert gas welding setup

Electrode materials

- The electrode material may be tungsten, or tungsten alloy (thoriated tungsten or zirconiated tungsten).
- Alloy-tungsten electrodes possess higher current carrying capacity, produce a steadier arc as compared to pure tungsten electrodes and high resistance to contamination.

Electric power source

- Both AC and DC power source can be used for TIG welding.
- DC is preferred for welding of copper, copper alloys, nickel and stainless steel whereas
- DC reverse polarity (DCRP) or AC is used for welding aluminum, magnesium or their alloys.
- DCRP removes oxide film on magnesium and aluminum.
- GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques.

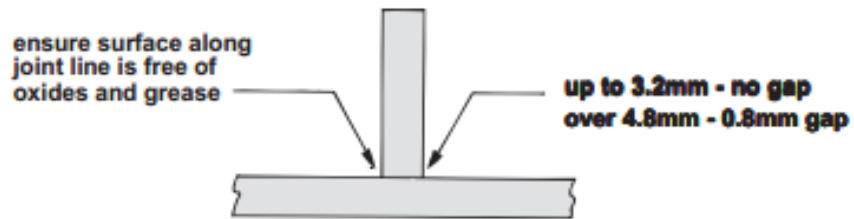
Inert gases

The following inert gases are generally used in TIG welding:

1. Argon
 2. Helium
 3. Argon-helium mixtures
 4. Argon-hydrogen mixtures
- i.e Ar, He ,mixture of(Ar-He)& (Ar-H)

Typical conditions for TIG welding

T Joints - fillet welded



Metal thickness mm	Electrode diameter mm	Filler rod diameter mm	Welding current A	Shielding gas flow l/min
Aluminium — alternating current — zirconiated electrode				
1.6	2.4	1.6	60 – 80	5
3.2	3.2	2.4	130 – 160	6
4.8	3.2 or 4.0	3.2	195 – 230	7
6.0	4.0 or 4.8	4.8	260 – 295	10
Stainless steel — direct current — thoriated electrode				
1.6	1.6	1.6	50 – 70	5
3.2	2.4	2.4	85 – 105	5
4.8	2.4	3.2	120 – 145	6
6.0	3.2	4.0	165 – 180	7
Carbon steel — direct current — thoriated electrode				
1.6	1.6	1.6	50 – 70	5
3.2	1.6 or 2.4	2.4	90 – 120	5
4.8	2.4	3.2	135 – 175	6
6.0	3.2	4.8	170 – 200	7

GTAW Applications

1. Used to weld ferrous and various non-ferrous and metals.
2. Can weld various dissimilar metals together.
3. Good for fabrications such as aircraft or race car frames.
4. Applications: aluminum and stainless steel mostly.
5. Used for welding thinner metal parts (not as thick as MIG).
6. Metal must be very clean to start weld.

Advantages

- Superior quality welds, generally free from spatter, porosity, or other defects
- Precise control of arc and fusion characteristics
- Weld almost all metals
- Used with or without filler wire
- Easily automated
- Used in all positions
- Intricate geometries weldable

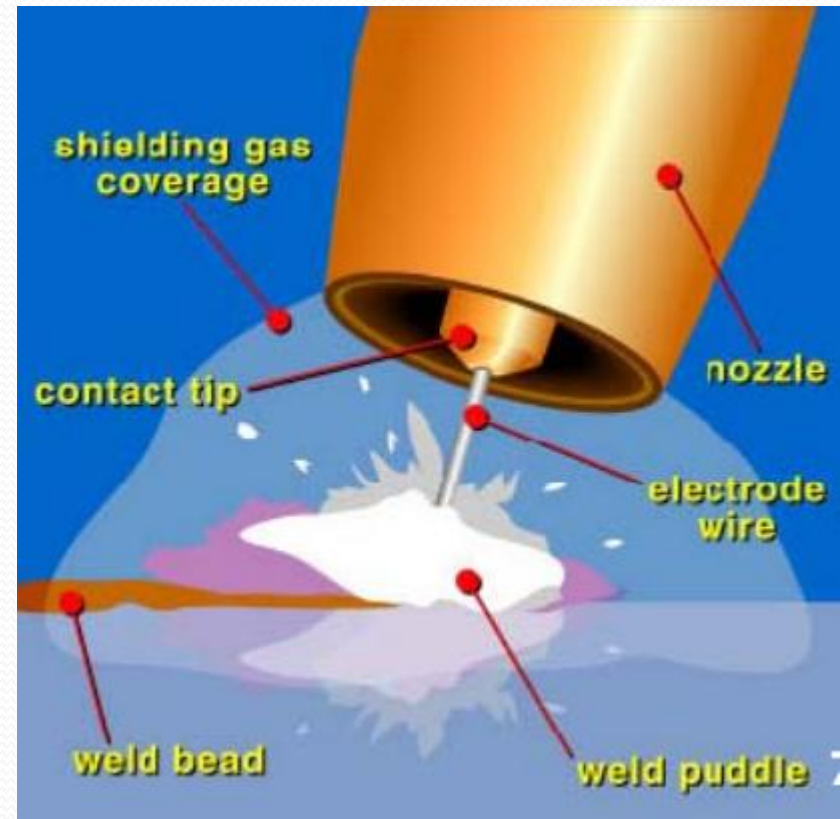
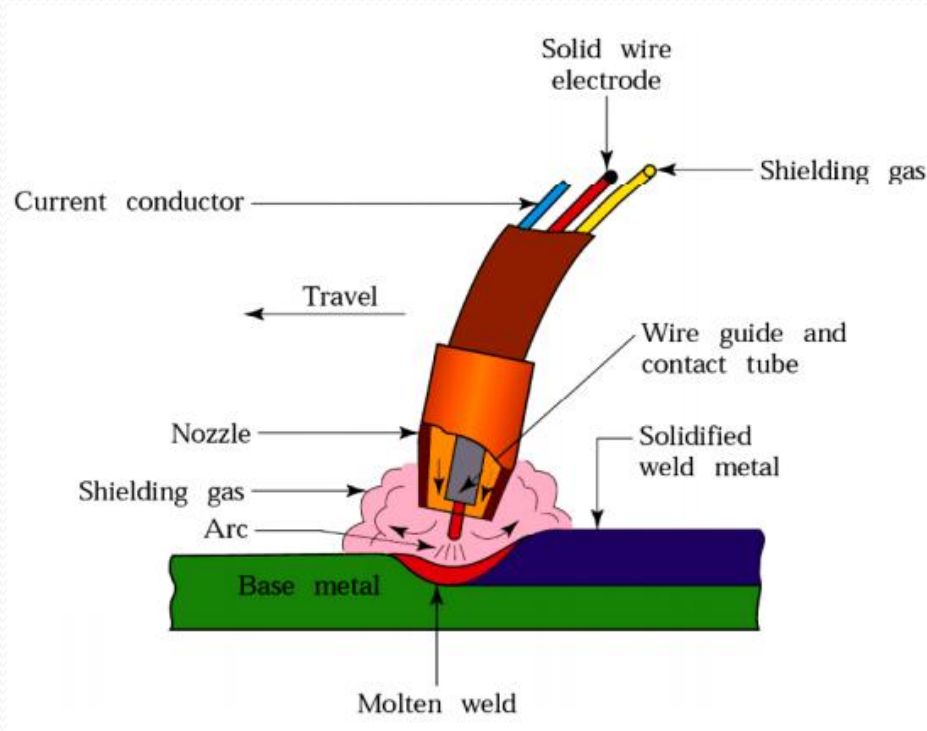
Disadvantages

- Less economical than consumable electrode processes for sections thicker than 3/8 inch
- Lowest deposition rate of all arc processes
- Tungsten inclusions
- Higher operator skill Required
- Sensitive to defects

IV. Gas Metal ARC Welding (GMAW)

- In this process, a bare wire electrode ,(consumable)is used and a shielding gas is fed around the arc and weld pool.
- This gas prevents contamination of the electrode and weld pool by air. Also known as Metal Inert Gas (MIG).
- Sometimes referred to as semiautomatic arc welding
- It was developed for production welding
- More difficult than SMAW to switch sizes of metal and types of metal.
- GMAW is best process for welding thin steel, When thicker sheets are to be welded, the filler metal requirement makes GTAW difficult to use.

- The weld area is shielded by an external source such as argon, helium, carbon dioxide, or various other gas mixtures.





Gas Metal Arc Welding (GMAW) including MIG and MAG (i.e Metal Inert Gas and Metal Active Gas MAG welding)

- (MIG)-Argon or helium gas is used for shielding .
- ✓ This process is generally used for non-ferrous metals.
- MAG (metal-active gas) welding - Carbon dioxide (usually mixed with argon) is used for shielding.
- ✓ This process is generally used for carbon and carbon-manganese steels.

- 
- Usually operates on direct current electrode positive (DCEP) or direct current reverse polarity (DCRP).
 - A wire is used as an electrode and a welding arc is struck between the electrode and the base metal.
 - The electrode melts and becomes part of the weld.
 - The process is controlled by a constant voltage, which is set by the welder.

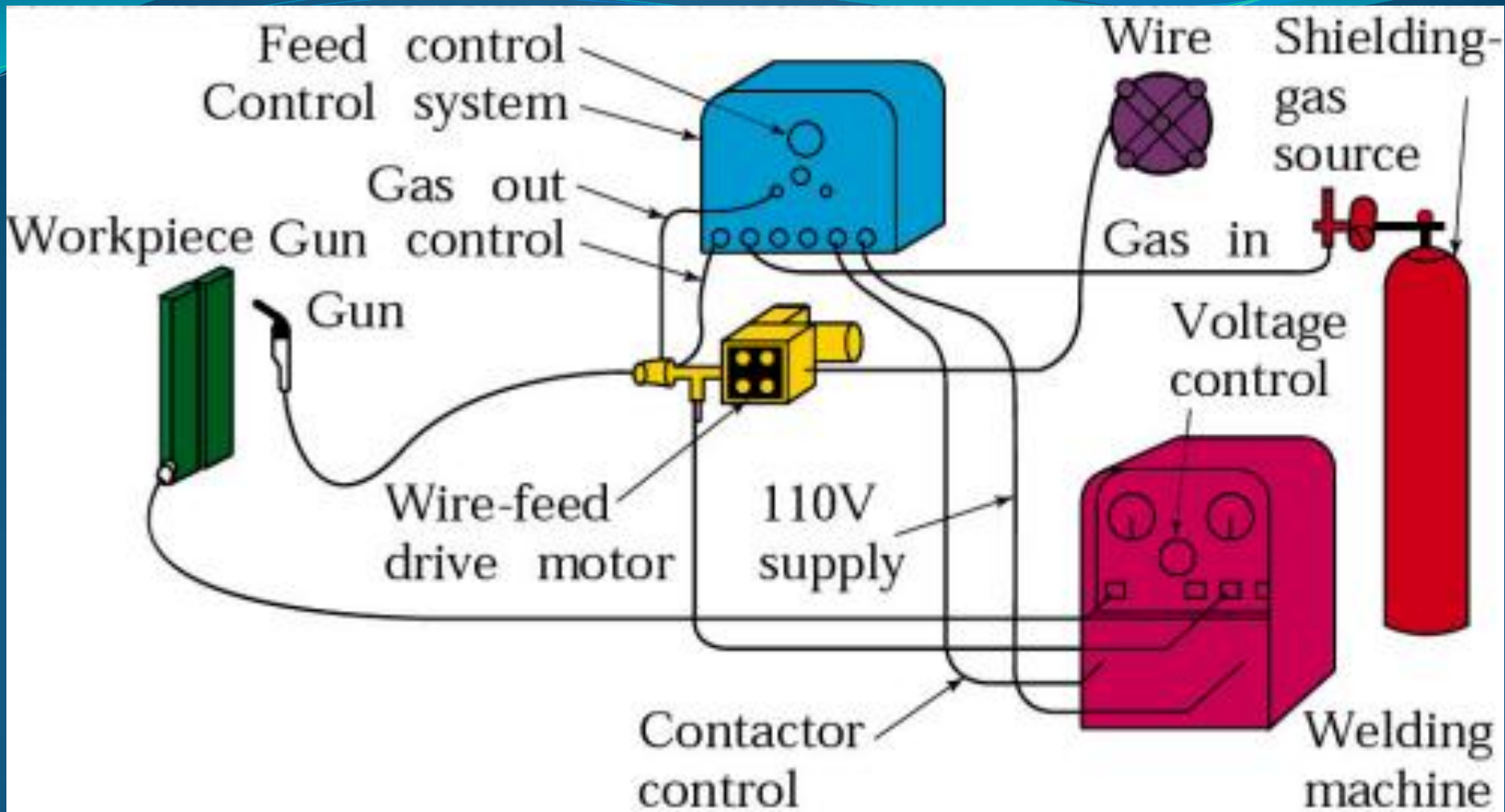
GMAW Process

- A continuous wire electrode from a spool or coil pushed by the wire feeder through a flexible conduit to the welding gun.
- The wire exits the welding gun through the contact tip.
- A constant potential power supply supplies the current for an electrical arc that is hot enough to melt the base metal and the electrode.

The wire melts and combines with the molten base metal to form a weld.

Shielding is provided by an inert gas supplied by a cylinder. Gas flow is controlled by a solenoid valve and is delivered to the nozzle on the gun.

- The power supplies are always of the constant voltage type only.
- The current from the welding machine is changed by the rate of feeding of the electrode wire.
- Normally DC arc welding machines are used for GMAW with electrode positive (DCRP).
- The DCRP increases the metal deposition rate and also provides for a stable arc and smooth electrode metal transfer.



Basic equipment used in gas metal-arc welding operations. Source: American Welding Society

MIG/MAG welding principles

Gas shielded metal arc welding is a semi-automatic process which is suitable for both manual and mechanised operation.

It is known by a variety of names:

- MIG - Metal Inert Gas
- MAG - Metal Active Gas
- CO₂ - carbon dioxide

A low voltage (18–40V), high current (60–500A) arc between the end of a wire electrode and the work provides the heat needed for the welding operation. The arc and the weld are protected from atmospheric contamination by a gas shield.

The shielding gas can be:

- pure argon
- argon mixed with small amounts of other gases
- helium or
- carbon dioxide

according to the metal being welded.

Operation

An electric motor feeds the wire into the arc and the power source keeps the arc length at a preset value leaving the welder to concentrate on ensuring complete fusion of the joint.

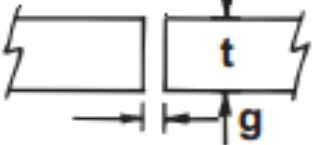
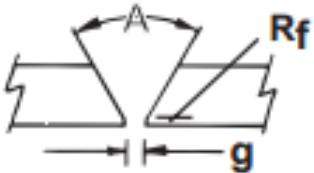
MIG/MAG welding of plate

Spray transfer can be used for butt joints in the flat position and for T-joints in both flat, horizontal and vertical positions. All vertical and overhead welding needs a low current technique — dip or pulse transfer.

Up to 3mm thickness, the edges of the plate can be cut square.

A single or double bevel is used for greater thicknesses.

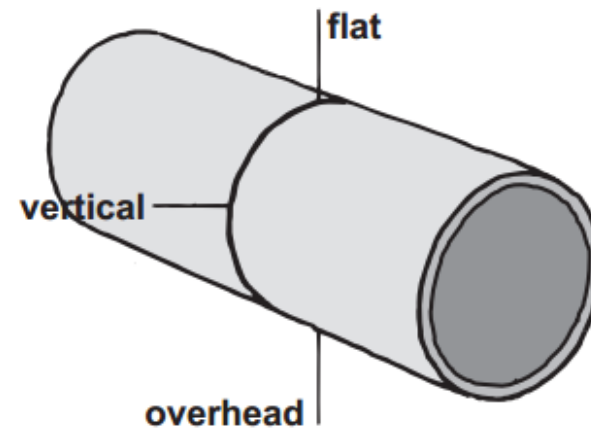
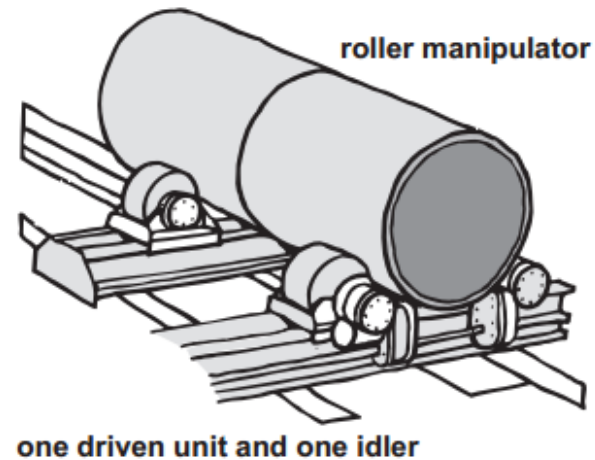
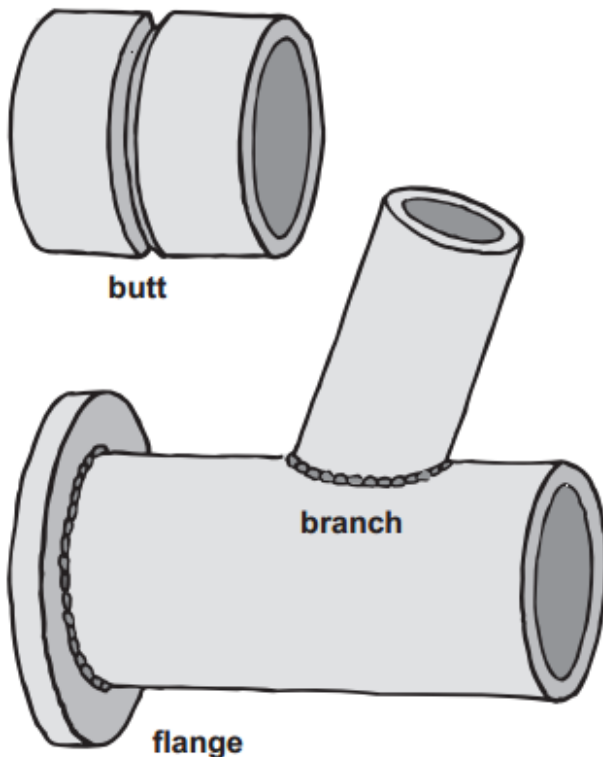
The dimensions of the edge preparation depend on thickness and type of material.

Type	Thickness	Low carbon steel and stainless steel	Aluminium
Square edge 	Up to 6mm	$g = \frac{1}{2}t$	$g = \frac{1}{2}t$
Single V 	6mm to 18mm	$A = 60^\circ$ $Rf = 1.5\text{mm max}$ $g = 1\text{mm max}$	$A = 65-70^\circ$ $Rf = 1.5\text{mm max}$ $g = 1.5\text{mm max}$
Double V 	Above 18mm	$A = 50^\circ$ $Rf = 1 \text{ to } 2\text{mm}$ $g = \text{nil}$	$A = 80-90^\circ$ $Rf = 1.5\text{mm max}$ $g = 1.0\text{mm max}$

Pipe and tube joints

There are three main types of welded joint used in pipework.

- butt
- branch
- flange



Before welding, the pipes can be clamped or tack welded to maintain alignment.

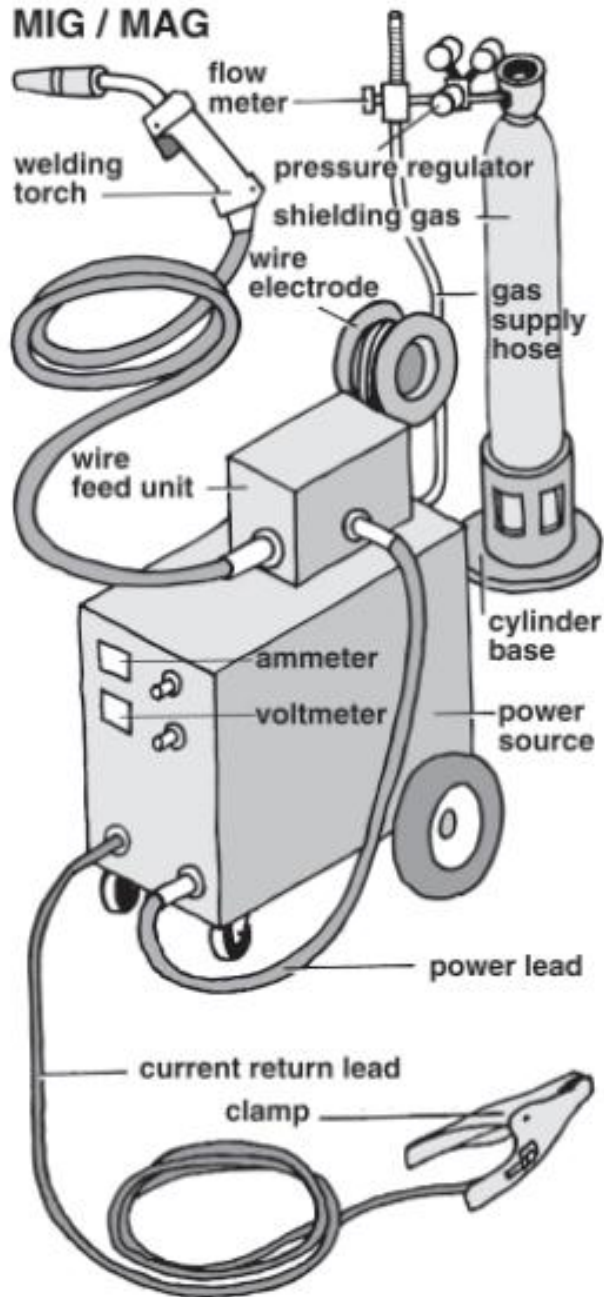
GMAW Advantages over SMAW

1. Continuous welding because of continuous wire electrode.
Sticks must be periodically changed in SMAW.
2. Higher deposition rates.
3. Eliminates problem of slag removal.
4. Can be readily automated.
5. Has better control to make cleaner & narrower welds than SMAW.

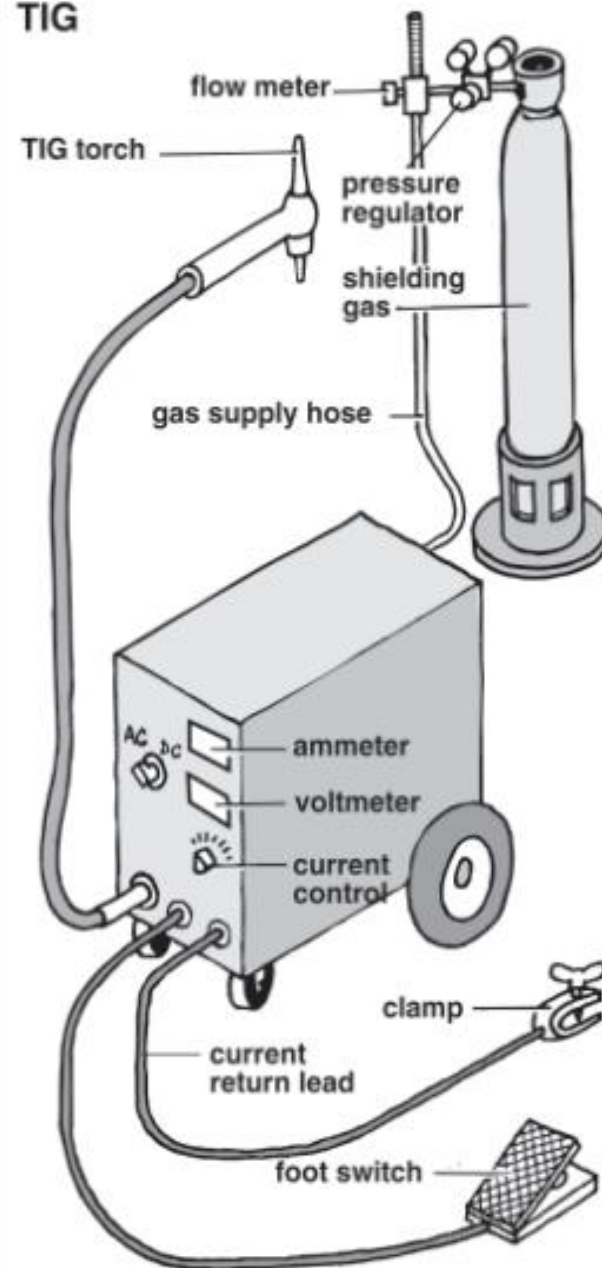
GMAW Applications

1. Used to weld ferrous and various non-ferrous and metals.
2. Good for fabrications such as frames and farm equipment.
3. Can weld thicker metal (not as thick as SMAW).
4. Metal must be clean to start weld.

MIG / MAG



TIG



Weld metal protection in different techniques

GTAW

- The cleanest arc welding process due to inert gases used.
- Special gas-filled box can be used.
- Stable arc.

GMAW

- Very clean but not as clean as **GTAW** due to unstable arc with consumable electrodes.
- **CO₂** is sometimes used as shielding gas in which it can decompose to give **O** at high temperature.

SMAW

- Weld pool protection is not effective as in **GTAW** or **GMAW** because the gas flow is not well directed to the weld pool. → Higher **O** and **N** levels.
- Decomposition of slag is possible → increase **O** level.

Self-shielded arc welding

- Used for strong nitride formers such as **Al, Ti, Zr**.

SAW

- Oxygen level varies depending on the composition of the flux. Acidic flux (containing **SiO₂**) gives high **O** level.



General Characteristics of Fusion Welding Processes

Joining process	Operation	Advantage	Skill level required	Welding position	Current type	Distortion*	Cost of equipment
Shielded metal-arc	Manual	Portable and flexible	High	All	ac, dc	1 to 2	Low
Submerged arc	Automatic	High deposition	Low to medium	Flat and horizontal	ac, dc	1 to 2	Medium
Gas metal-arc	Semiautomatic or automatic	Most metals	Low to high	All	dc	2 to 3	Medium to high
Gas tungsten-arc	Manual or automatic	Most metals	Low to high	All	ac, dc	2 to 3	Medium
Flux-cored arc	Semiautomatic or automatic	High deposition	Low to high	All	dc	1 to 3	Medium
Oxyfuel	Manual	Portable and flexible	High	All	—	2 to 4	Low
Electron-beam, Laser-beam	Semiautomatic or automatic	Most metals	Medium to high	All	—	3 to 5	High

Safety Recommendations for ARC Welding

1. The body or the frame of the welding machine shall be efficiently earthed.
2. Welding arc in addition to being a source of infra-red and ultra-violet light also; consequently the operator must use either helmet or a hand-shield fitted with a special filter glass to protect eyes
3. Excess ultra-violet light can cause an effect similar to sunburn on the skin of the welder
4. The welder's body and clothing are protected from radiation and burns caused by sparks and flying globules of molten metal with the help of the following.

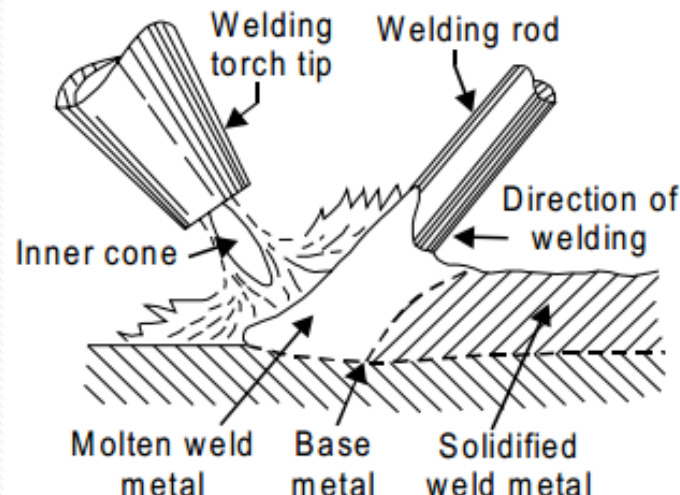
5. **Gloves** protect the **hands** of a welder.
6. **Leather or asbestos apron** is very useful to protect **welder's clothes** and his trunk and thighs while seated he is doing welding.
7. **For overhead welding**, some form of **protection for the head** is required.
 - 8. **Leather skull cap** or peaked cap will do the needful.
9. **Leather jackets** and **leather leggings** are also available as clothes **for body protection**.
10. **Welding equipment shall be inspected periodically and maintained** in safe working order at all times.
11. Arc welding machines should be of suitable quality.
12. **All parts of welding set** shall be suitably **enclosed and protected**.

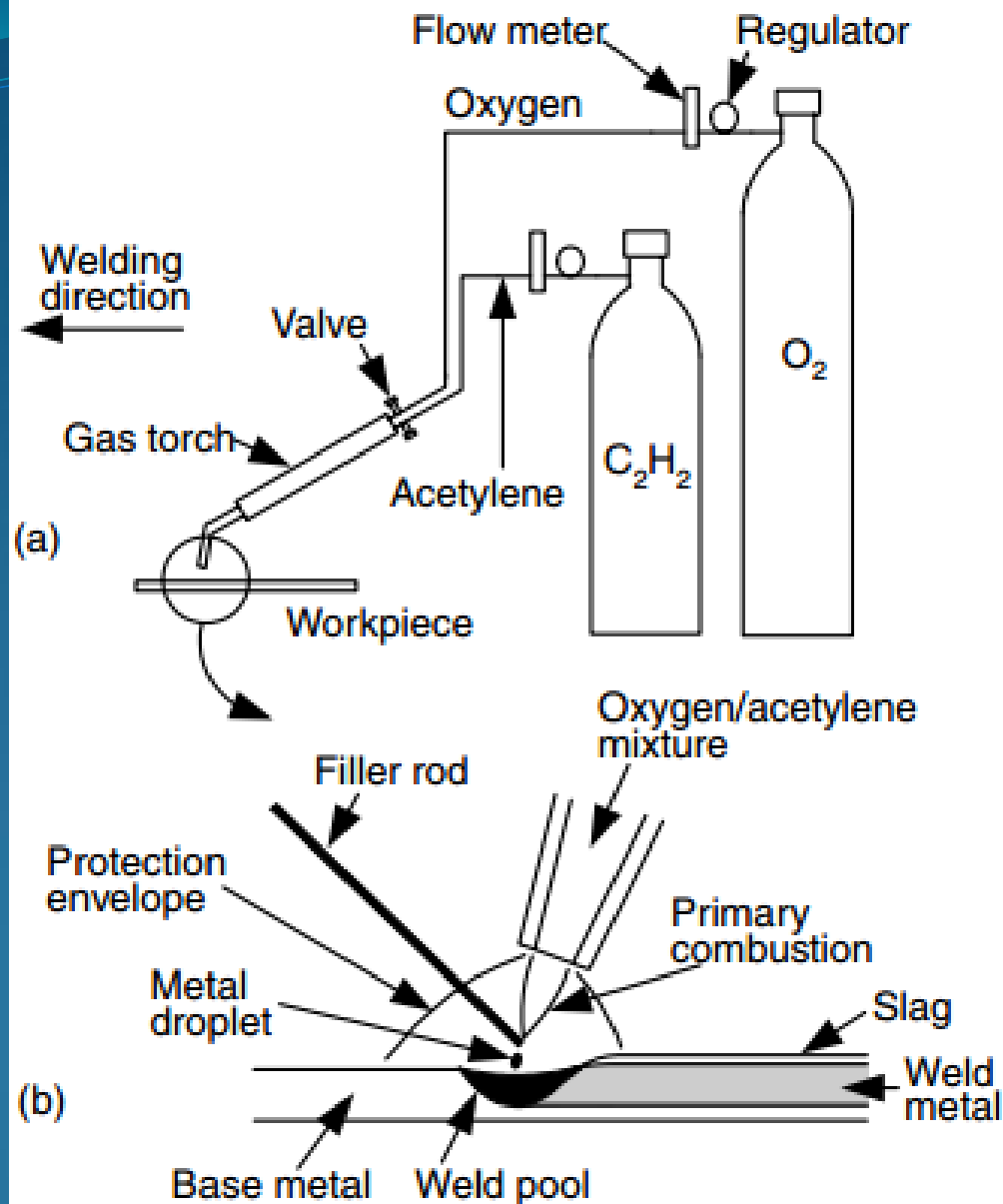
18. At or near each welding machine, a disconnecting switch shall
19. Control apparatus provided with the welding machine shall enclose except for the operating wheels, levers, etc.
20. Transformer windings be suction or compressed-air cleaned periodically.
21. Before undertaking any maintenance work on welding machine disconnects them from the main supply.
22. As regards other arc welding equipment, electrode holders should be soundly connected to the welding lead
23. They should be of adequate rating for the maximum welding current to prevent them from heating up and be coming too hot to handle.

- 
27. The welding cable should be free from repair or splices up to a minimum distance of three metres from the electrode holder.
 28. Fully insulated cable connectors of capacity at least equivalent to that of the cable shall be used to connect two cables together.
 29. Welding cables shall be kept dry and free from grease and oil to avoid premature breakdown of insulation.
 30. Arc welding machines should be properly ground (earthed).
 31. Construction of arc welding machines should be such that they can operate satisfactorily even under conditions of saltish or moist air as in coastal areas, dust,

GAS WELDING PROCESSES

- A fusion welding process which joins metals, using the heat of combustion of an oxygen /air and fuel gas (i.e. acetylene, hydrogen propane or butane) mixture is usually referred as 'gas welding'.
- The intense heat (flame) thus produced melts and fuses together the edges of the parts to be welded, generally with the addition of a filler metal.





Oxyacetylene welding: (a) overall process; (b) welding area enlarged.

- The fuel gas generally employed is acetylene; however gases other than acetylene can also be used though with lower flame temperature.
- Oxy-acetylene flame is the most versatile and hottest of all the flames produced by the combination of oxygen and other fuel gases such as Hydrogen, Propane, Butane, Natural gas etc., may be used for some welding and brazing applications.

❖ **some of the processes are:**

- Oxyfuel gas welding
- Oxy-acetylene welding
- Oxy-hydrogen welding and Pressure gas welding are some.

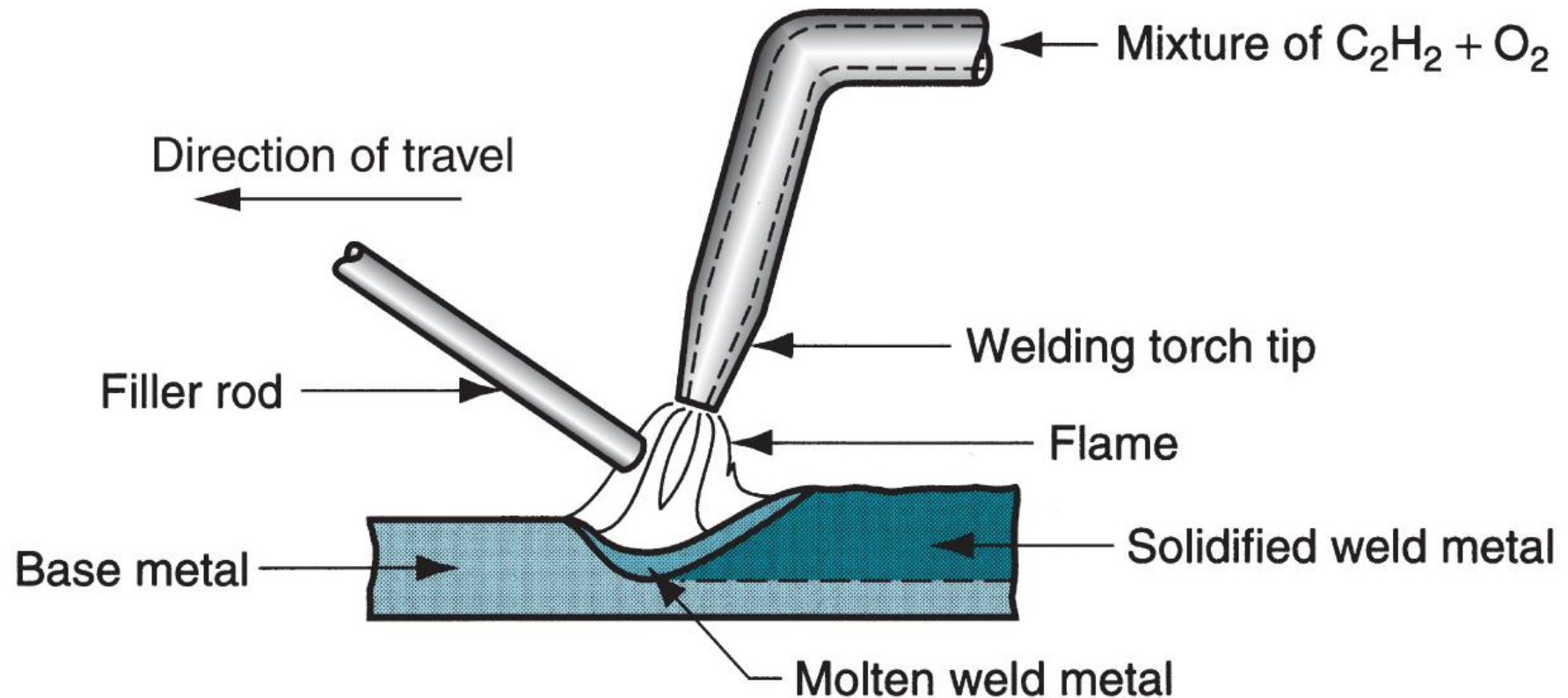
OXYFUEL GAS WELDING/OFW

- Oxyfuel gas welding (OFW) is a general term used to describe any welding process that uses a fuel gas combined with oxygen to produce a flame.
- The most common gas welding process uses acetylene fuel, is known as oxyacetylene welding and is used typically for structural sheet-metal fabrication and automotive bodies and various other repair work.

Oxy Acetylene Welding

- In this process, acetylene is mixed with oxygen in correct proportions in the welding torch and ignited(explode)
- The flame resulting at the tip of the torch is sufficiently hot to melt and join the parent metal.
- The oxy-acetylene flame reaches a temperature of about 3300°C and thus can melt most of the ferrous and non-ferrous metals in common use.
- A filler metal rod or welding rod is generally added to the molten metal pool to build up the seam slightly for greater strength.

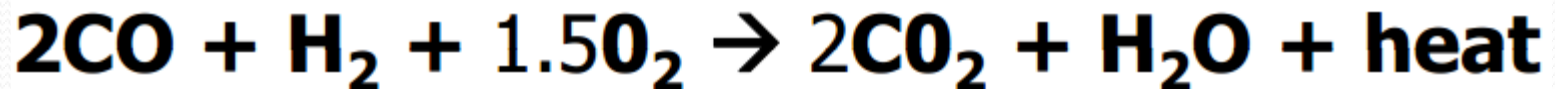
- Filler metal is sometimes added
- Composition must be similar to base metal
- Filler rod often coated with *flux* to clean surfaces and prevent oxidation



- The heat is generated in accordance with the following chemical reactions .
- The primary combustion process, which occurs in the inner core of the flame, is



- This reaction dissociates the acetylene into carbon monoxide and hydrogen and produces about 1/3 of the total heat generated in the flame.
- The second reaction is:



which results in burning of the hydrogen and combustion of the carbon monoxide, producing about 2/3 of the total heat.

Gas



Torch

2800 - 3500 °C

inner
cone

Flame

2500 °C

outer
envelope

1000 °C

Primary combustion in inner
cone (2/3 total heat) :



Secondary combustion in outer
envelope (1/3 total heat) :



Chemical reactions and temperature distribution in a neutral oxyacetylene
flame.

- 
- The **temperatures** developed in the flame as a **result of these reactions** can reach **3300 °C** (6000 °F).
 - The reaction of hydrogen with oxygen produces water vapour.

TYPES OF FLAMES

- The proportions of **acetylene and oxygen in the gas mixture** are an important factor in oxy fuel gas welding.
- **At a ratio of 1 : 1**, that is, when there is no excess oxygen, it is considered to be a **neutral flame**.

Torch tip Inner cone Outer envelope



Neutral flame



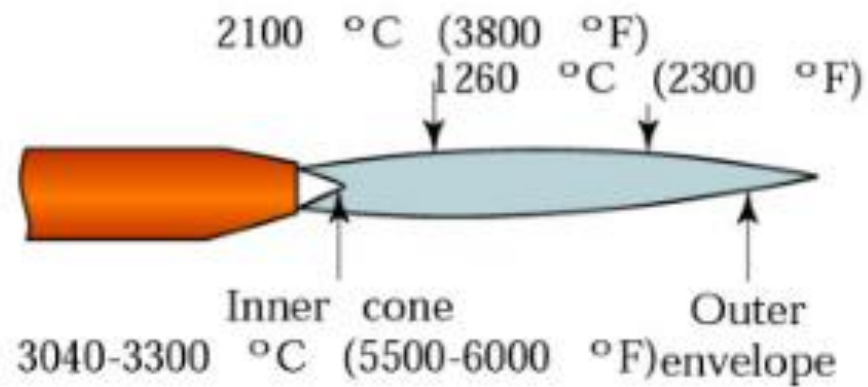
Oxidizing flame
(Excessive oxygen)



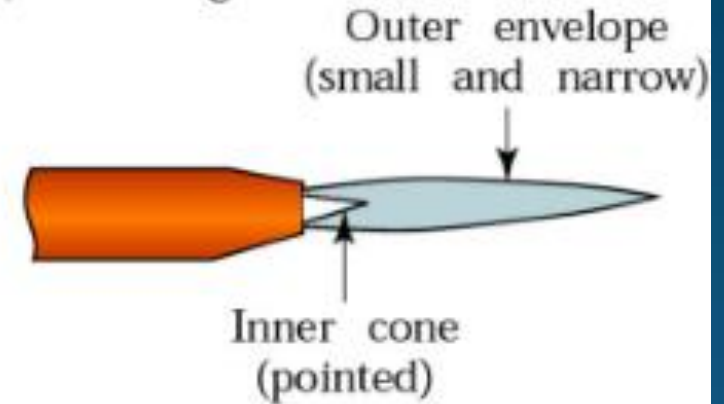
Carburising flame
(Excessive acetylene)

Gas welding flames

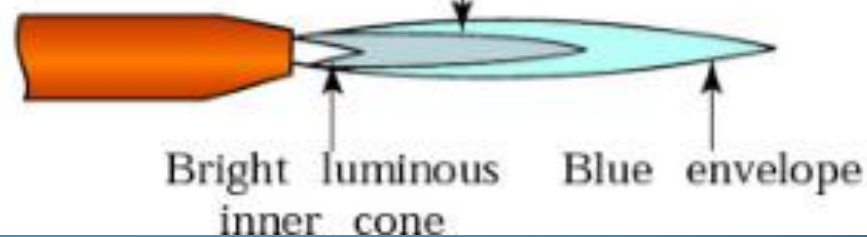
(a) Neutral flame

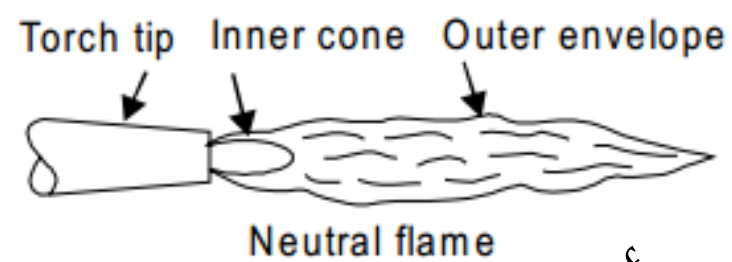


(b) Oxidizing flame

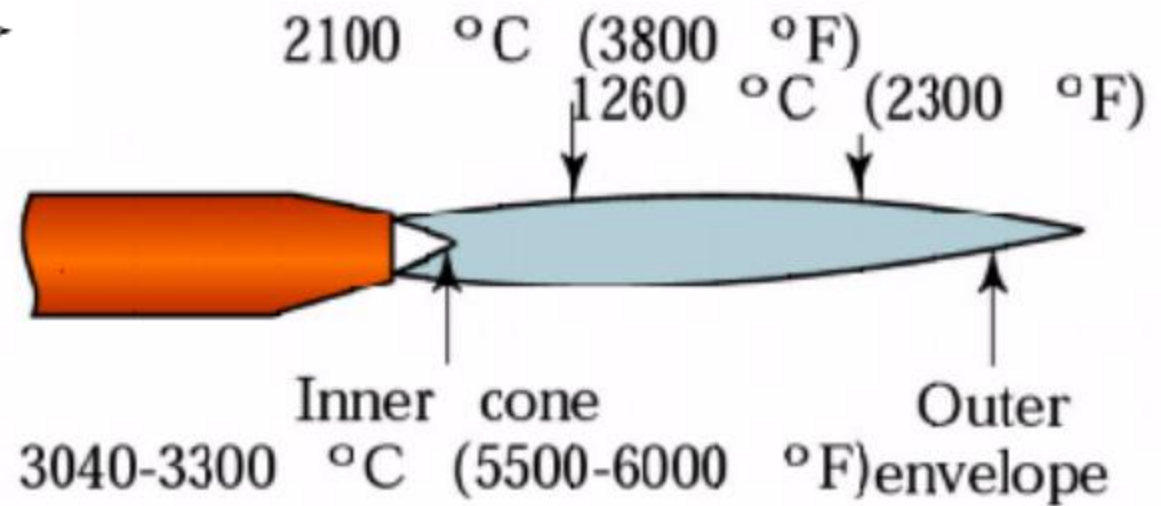


(c) Carburizing (reducing) flame
Acetylene feather

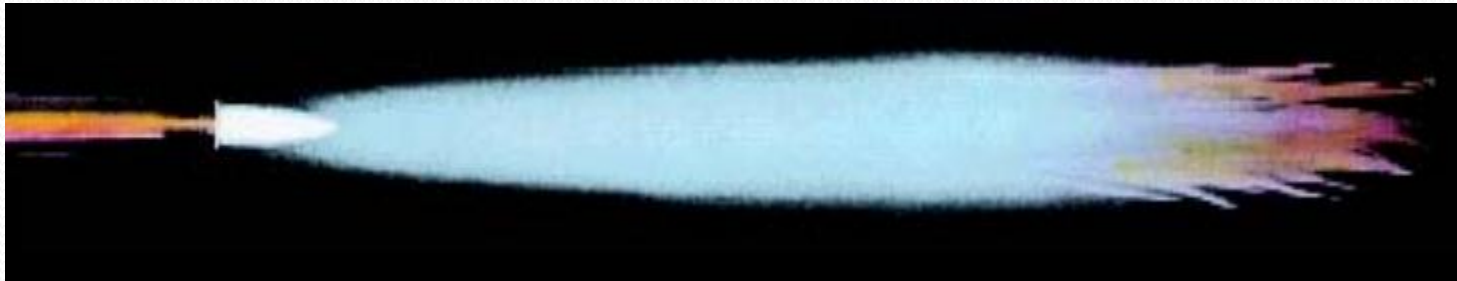




➤ The temperature of the neutral flame is of the order of about 5900°F (3260°C)



a) Neutral Flame



➤ It has a clear, well defined inner cone, indicating that the combustion is complete.



➤ The inner cone is light blue in color. It is surrounded by an outer flame envelope, produced by the combination of oxygen in the air and superheated carbon monoxide and hydrogen gases from the inner cone.

➤ This envelope is Usually a much darker blue than the inner cone.

➤ A neutral flame is named so because it affects no chemical change on the molten metal and, therefore will not oxidize or carburize the metal.

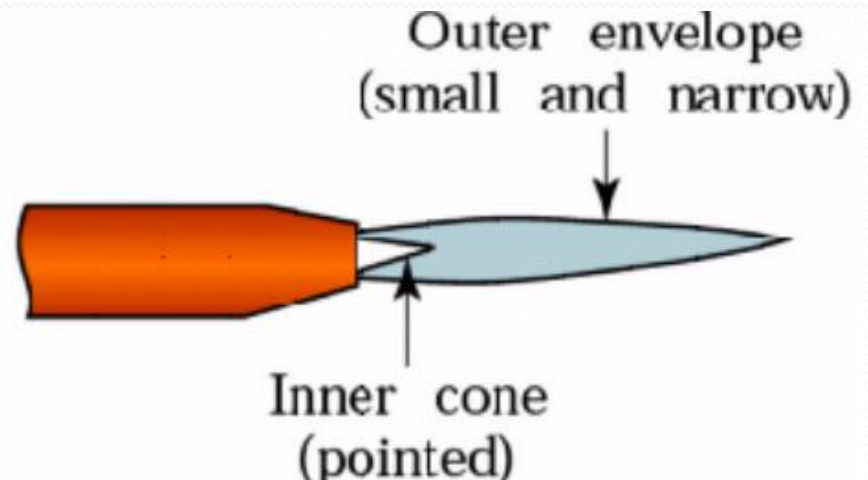
➤ The neutral flame is commonly used for the welding of mild steel, stainless steel, cast Iron, copper, and aluminum

- With a greater oxygen supply, it becomes an oxidizing flame.
- But the excess oxygen especially at high temperatures tends to combine with many metals to form hard, brittle, low strength oxides. Moreover, an excess of oxygen causes the weld bead and the surrounding area to have a scummy or dirty appearance



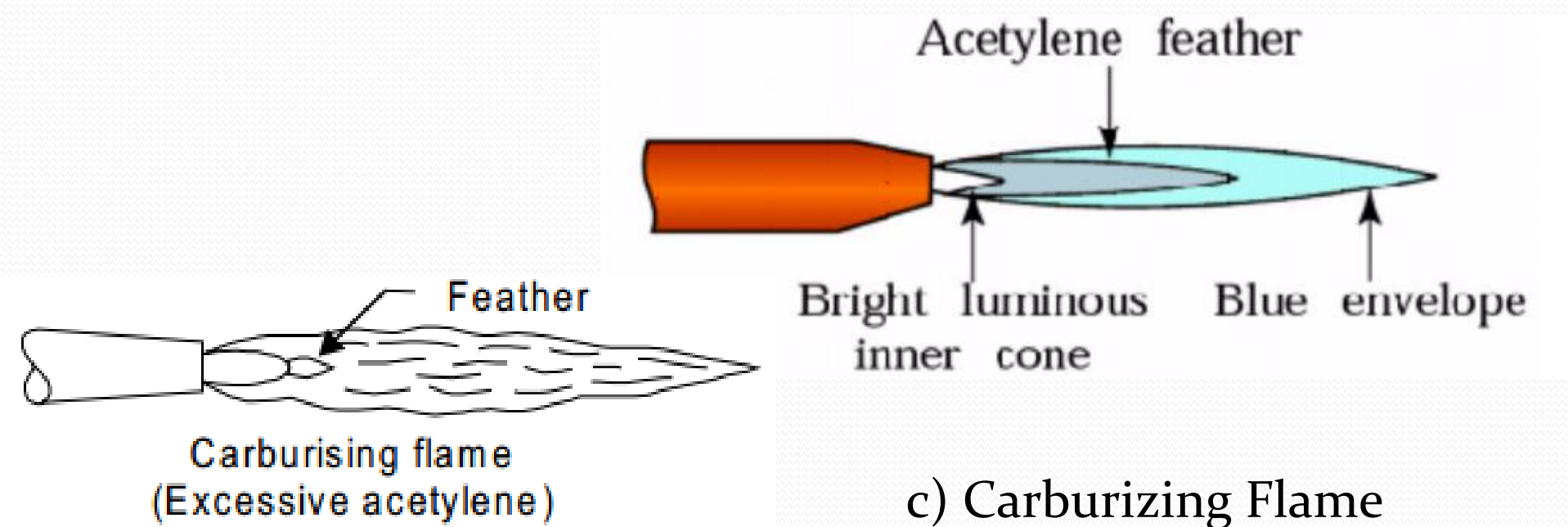
Oxidizing flame
(Excessive oxygen)

b) Oxidizing Flame



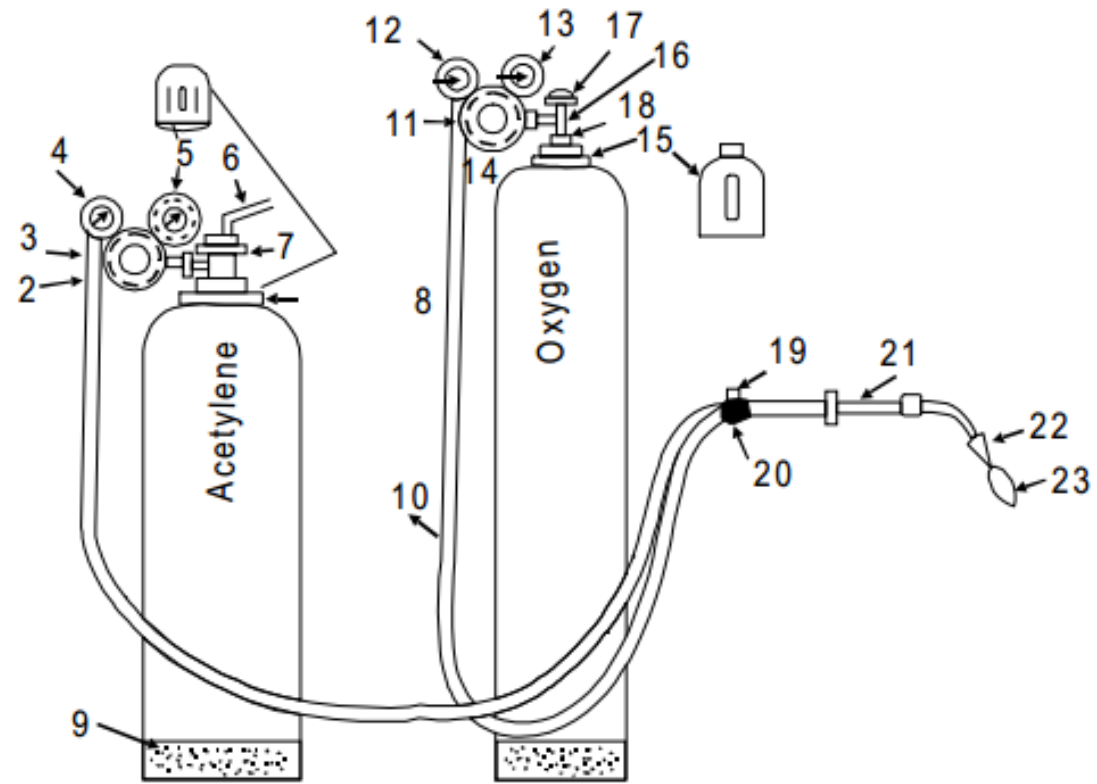
- 
- An oxidizing flame can be recognized by the small cone, which is shorter, much bluer in color and more pointed than that of the neutral flame.
 - It is the hottest flame (temperature as high as 6300°F) produced by any oxy-fuel gas source.
 - But the excess oxygen especially at high temperatures tends to combine with many metals to form hard, brittle, low strength oxides.
 - A slightly oxidizing flame is helpful when welding
 - (i) Copper-base metals
 - (ii)(ii) Zinc-base metals and
 - (iii)(iii) A few types of ferrous metals such as manganese steel and cast iron

- If the supply of oxygen is lowered, it becomes a reducing or carburizing flame.
- The temperature of a reducing, or excess-acetylene, flame is lower.
- Hence it is suitable for applications requiring low heat, such as brazing, soldering, and flame hardening.



- The outer flame envelope is longer than that of the neutral flame and is usually much brighter in color.
- With iron and steel, carburizing flame produces very hard, brittle substance known as iron carbide.
- A carburizing-flame is used in the welding of lead and for carburizing (surface hardening) purpose.
- It is used for welding with low alloy steel rods and for welding those metals, (e.g., non-ferrous) that do not tend to absorb carbon. This flame is very well used for welding high carbon steel.

oxy acetylene welding set up



1. Acetylene hose
2. Adjusting screw
3. Acetylene regulator
4. Regulator outlet pressure gauge
5. Cylinder pressure gauge
6. Valve wrench
7. Acetylene cylinder valve
8. Cylinder cap

9. Fusible plugs
10. Oxygen hose
11. Oxygen regulator
12. Regulator outlet pressure gauge
13. Cylinder pressure gauge
14. Cylinder cap
15. Oxygen cylinder valve
16. Oxygen cylinder valve

17. Hand wheel
18. Bursting disc
19. Acetylene valve
20. Oxygen valve
21. Welding torch
22. Torch tip
23. Flame

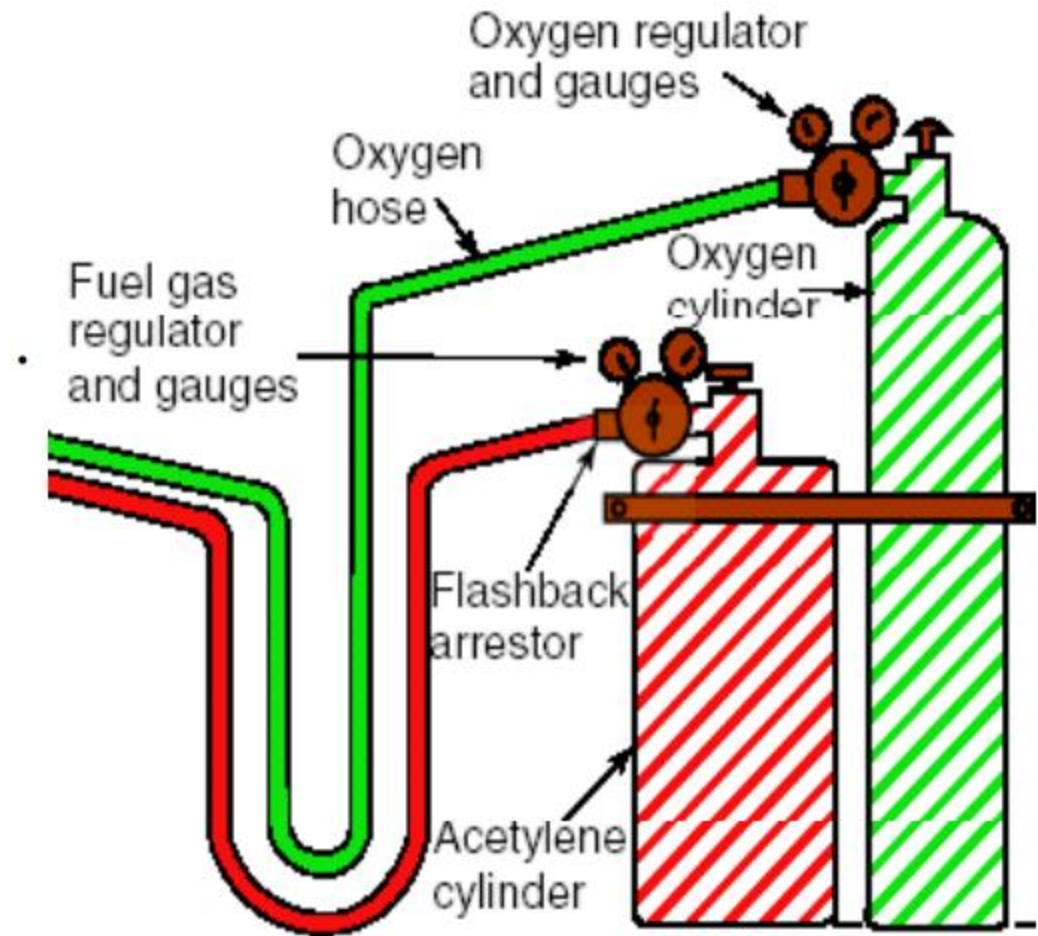
- 
- Acetylene and oxygen gas is stored in compressed gas cylinders. These gas cylinders differ widely in capacity, design and color code. However, in most of the countries, the standard size of these cylinders is 6 to 7 m³ and is painted black for oxygen and maroon for acetylene.
 - An acetylene cylinder is filled with some absorptive material, which is saturated with a chemical solvent acetone.
 - Acetone has the ability to absorb a large volume of acetylene and release it as the pressure falls.

- 
- If large quantities of acetylene gas are being consumed, it is much cheaper to generate the gas at the place of use with the help of acetylene gas generators.
 - Acetylene gas is generated by carbide-to-water method.
 - Oxygen gas cylinders are usually equipped with about 40 litres of oxygen.

➤ oxygen and acetylene cylinders have different threads so hoses cannot be connected to the wrong cylinders.

➤ **Acetylene** hoses are red in color with left hand thread.

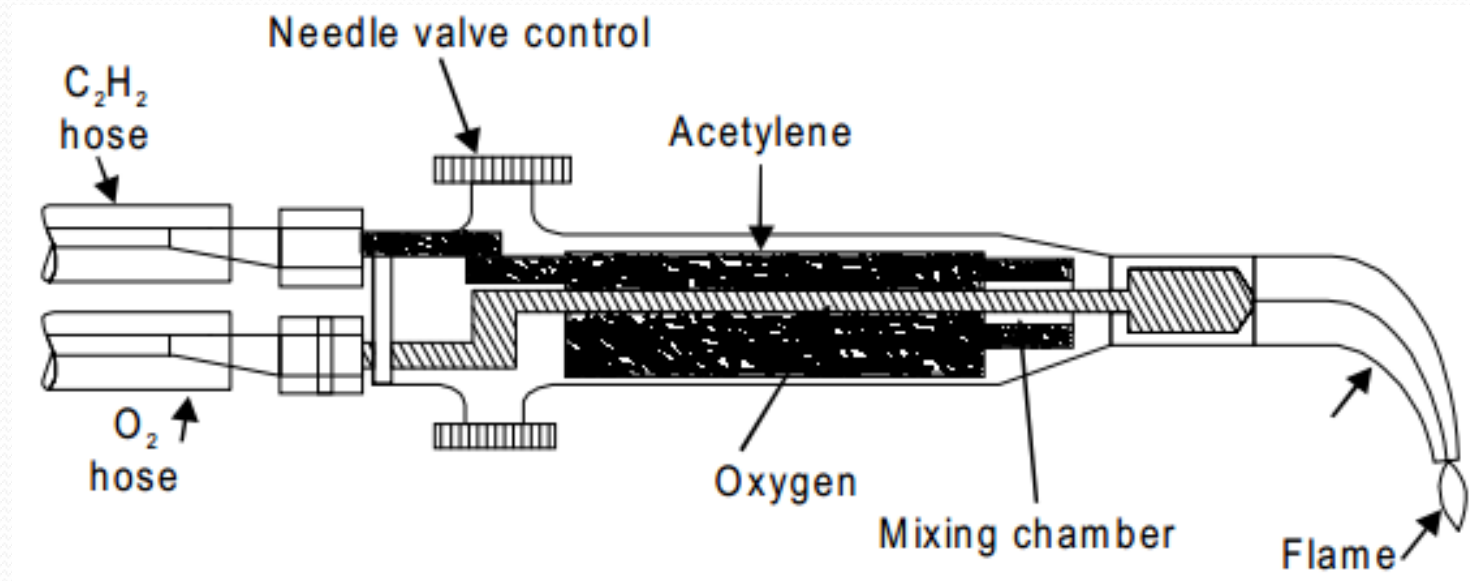
➤ **Oxygen** hoses are green in color and have right hand thread.



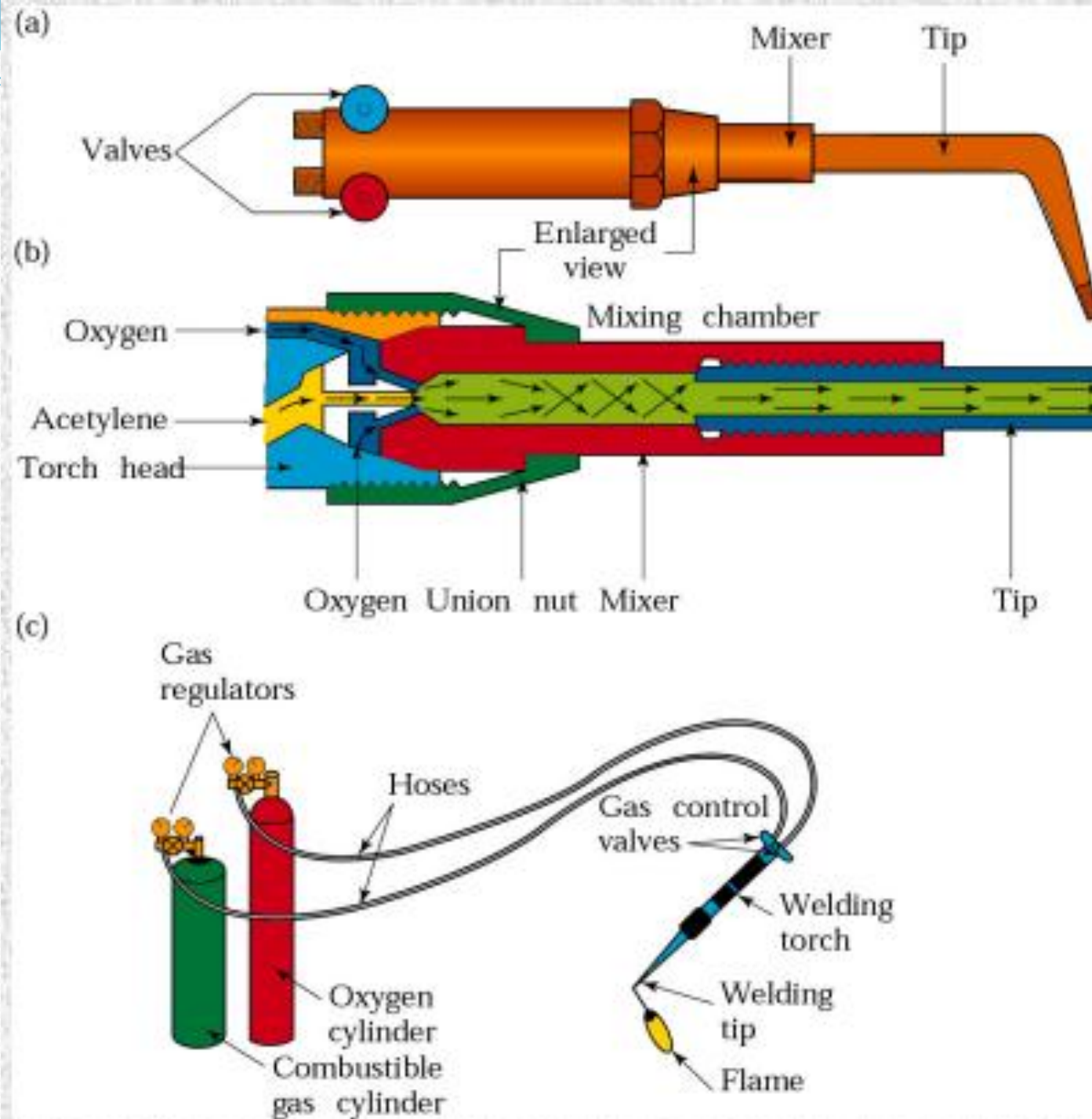
Gas pressure regulators: they are employed for regulating the supply of acetylene and oxygen gas from cylinders

- The cylinder and hose connections have left-handed threads on the acetylene regulator while these are right handed on the oxygen regulator.

Welding torch: It is a tool for mixing oxygen and acetylene in correct proportion and burning the mixture at the end of a tip.



- (a) General view of blow torch
- (b) cross-section of a torch used in oxyacetylene welding
- (c) Basic equipment used in oxy fuel-gas welding



Torch tips: It is the portion of the welding apparatus through which the gases pass just prior to their ignition and burning.

Hose pipes: The hose pipes are used for the supply of gases from the pressure regulators.

➤ The most common method of hose pipe fitting both oxygen and acetylene gas is the reinforced rubber hose pipe.

Fluxes: Fluxes are used in gas welding to remove the oxide film and to maintain a clean surface.

➤ These are usually employed for gas welding of aluminium, stainless steel, cast iron, brass and silicon bronze.

➤ They are available in the market in the form of dry powder, paste, or thick solutions

CHECKVALVES & FLASHBACKARRESTORS

- Check valves allow gas flow in one direction only.
- Flash back arrestors are designed to eliminate the Possibility of an explosion at the cylinder.
- Combination Check valves/ Flashback Valves can be placed at the torch or regulator.

Goggles: These are fitted with colored lenses and are used to protect the eyes from harmful heat and ultraviolet and infrared rays.

Gloves: These are required to protect the hands from any injury due to the heat of welding process.

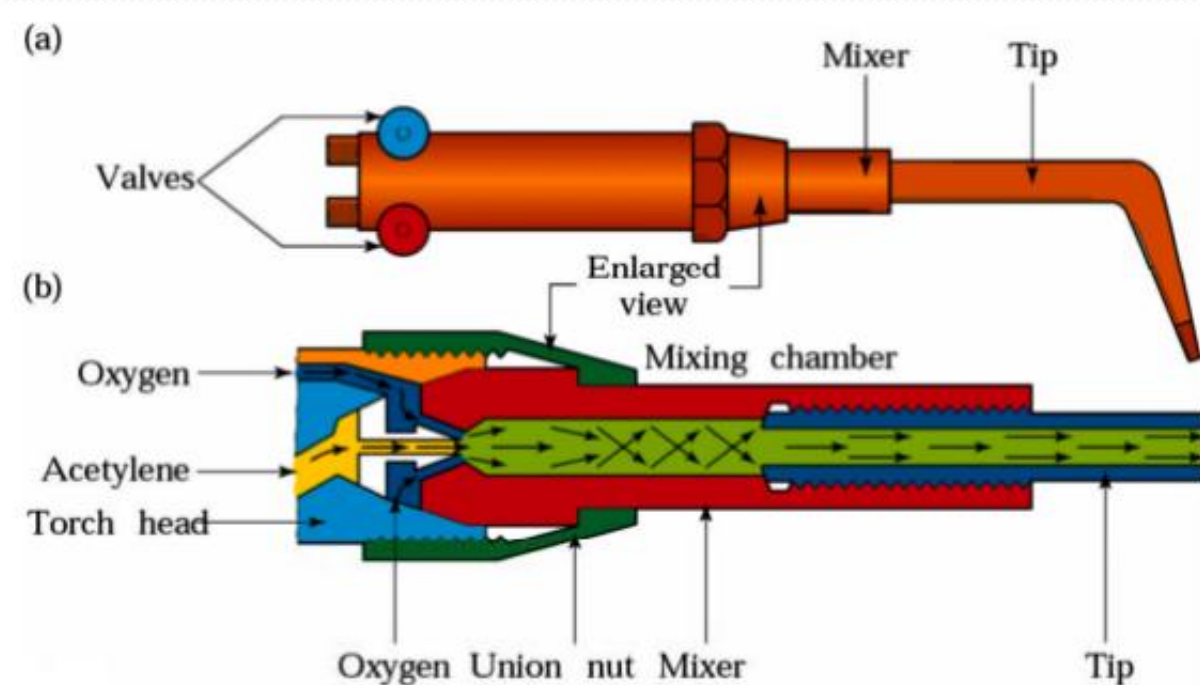
Spark-lighter: It is used for frequent igniting the welding torch.

Filler rods: Gas welding can be done with or without using filler rod. When welding with the filler rod, it should be held at approximately 90 degree to the welding tip.

Fluxes: Fluxes are used in gas welding to remove the oxide film and to maintain a clean surface, employed for gas welding of Aluminum, stainless steel, cast iron, brass and silicon bronze. They are available in the market in the form of dry powder, paste, or thick solutions

GASWELDING PROCEDURES

- Open and light acetylene first, then open and adjust oxygen to a neutral flame.
- When finished, close valves, bleed the lines, neatly coil hoses and replace equipment



Oxyacetylene Gas Welding Applications

- ❑ Suitable for low quantity production and repair jobs
- ❑ Used for welding thinner parts



general safety Recommendations of gas welding, are given below.

1. Never hang a torch with its hose on regulators or cylinder valves.
2. During working, if the welding tip becomes overheated it may be cooled by plunging the torch into water; close the acetylene valve but leave a little oxygen flowing.
3. Always use the correct pressure regulators for a gas. Acetylene pressure regulator should never be used with any other gas.
4. Do not move the cylinder by holding the pressure regulator and also handle pressure regulators carefully.
5. Use pressure regulator only at pressures for which it is intended.

- 
6. Open cylinder valves slowly to avoid straining the mechanism of pressure regulator.
 7. Never use oil, grease or lubricant of any kind on regulator connections.
 8. For repairs, calibrations and adjustments purposes, the pressure regulators should be sent to the supplier.
 9. Do cracking before connecting pressure regulator to the gas cylinder.

- 
10. Inspect union nuts and connections on regulators before use to detect faulty seats which may cause leakage of gas when the regulators are attached to the cylinder valves.
 11. Hose connections shall be well fittings and clamped properly otherwise securely fastened to these connections in such a manner as to withstand without leakage a pressure twice as great as the maximum delivery pressure of the pressure regulators provided on the system.

- 
12. Protect the hose from flying sparks, hot slag, hot work piece and open flame. If dirt goes into hose, blow through (with oxygen, not acetylene) before coupling to torch or regulator.
 13. Store hose on a reel (an automobile wheel) when not in use.
 14. Never allow the hose to come into contact with oil or grease; these deteriorate the rubber and constitute a hazard with oxygen.
 15. Use the correct color hose for oxygen (green/black) and acetylene (red) and never use oxygen hose for acetylene or vice versa.
 16. Always protect hose from being trampled on or run over. Avoid tangle and kinks(sharp twist). Never leave the hose so that it can be tripped over

RESISTANCE WELDING

- The metal parts to be joined are heated by their resistance to the flow of an electrical current.
- Usually this is the only source of heat, but a few of the welding operations combine resistance heating with arc heating, and possibly with combustion of metal in the arc.
- The process applies to practically all metals and most combinations of pure metals and those alloys, which have only a limited plastic range, are welded by heating the parts to fusion (melting).



➤ Some alloys, however, may be welded without fusion; instead, the parts are heated to a plastic state at which the applied pressure causes their crystalline structures to grow together.

➤ The welding of dissimilar metals may be accomplished by melting both metals frequently:

- only the metal with the lower melting point is melted, and
- an alloy bond is formed at the surface of the unmelted metal.

- In resistance welding processes no fluxes are employed, the filler metal is rarely used and the joints are usually of the lap type.
- The amount of heat generated in the work piece depend on the following factors:
 - (1) Magnitude of the current,
 - (2) Resistance of the current conducting path, and
- Mathematically

Where H =heat generated in joules

I = current in Amp.

R = resistance in ohms

t = time of current flow in seconds.

$$\begin{aligned} H &= IVt \\ &= I(IR)t \\ &= I^2Rt \end{aligned}$$

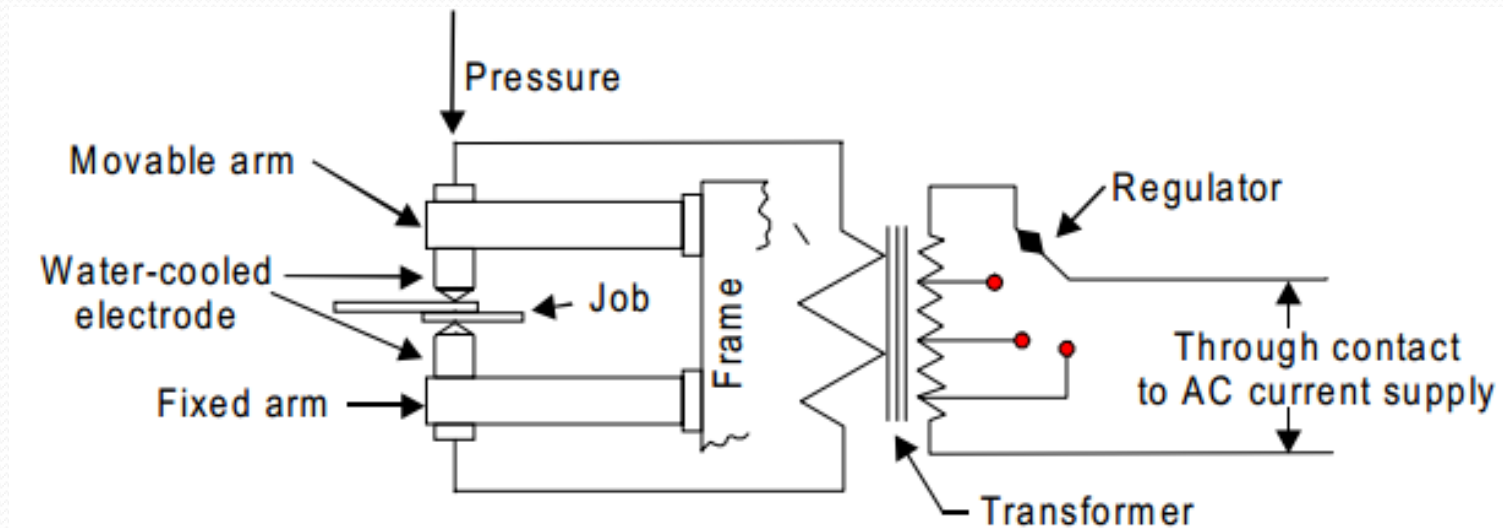


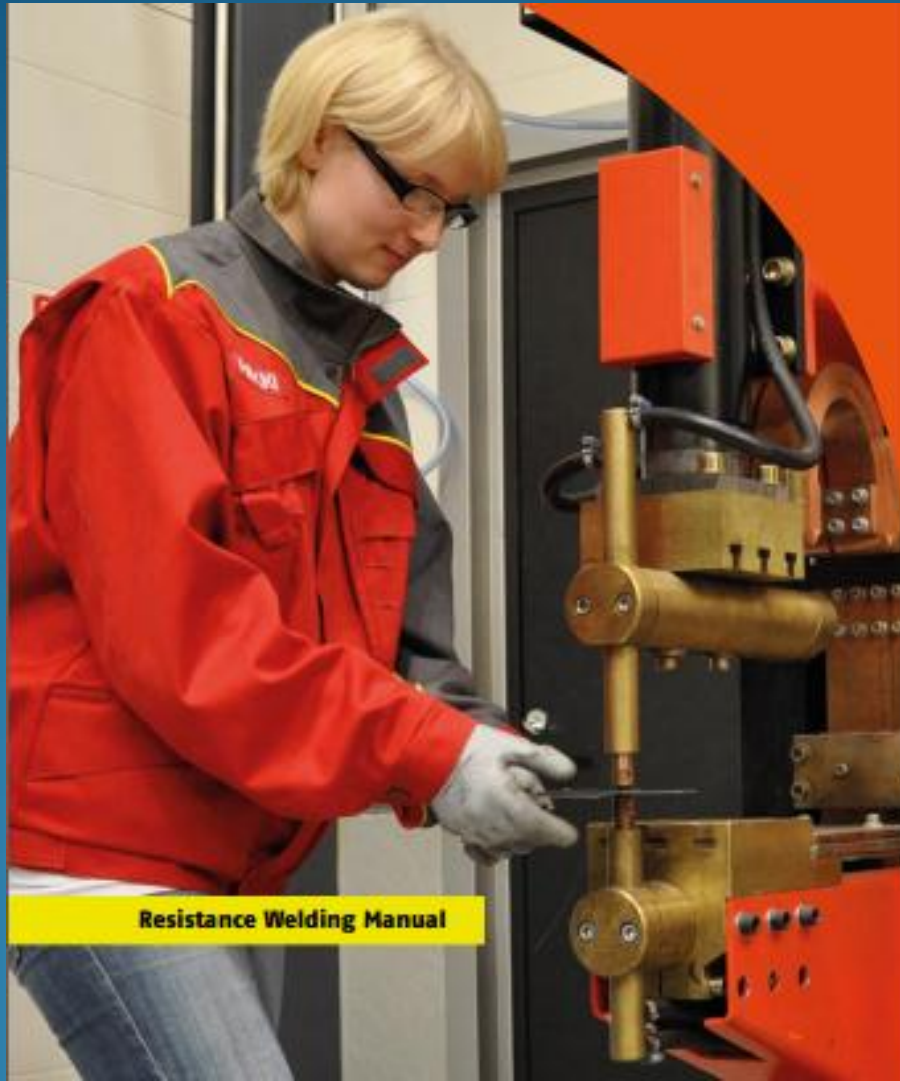
Some of the resistance welding includes

- Spot Welding
- Seam Welding
- Projection Welding

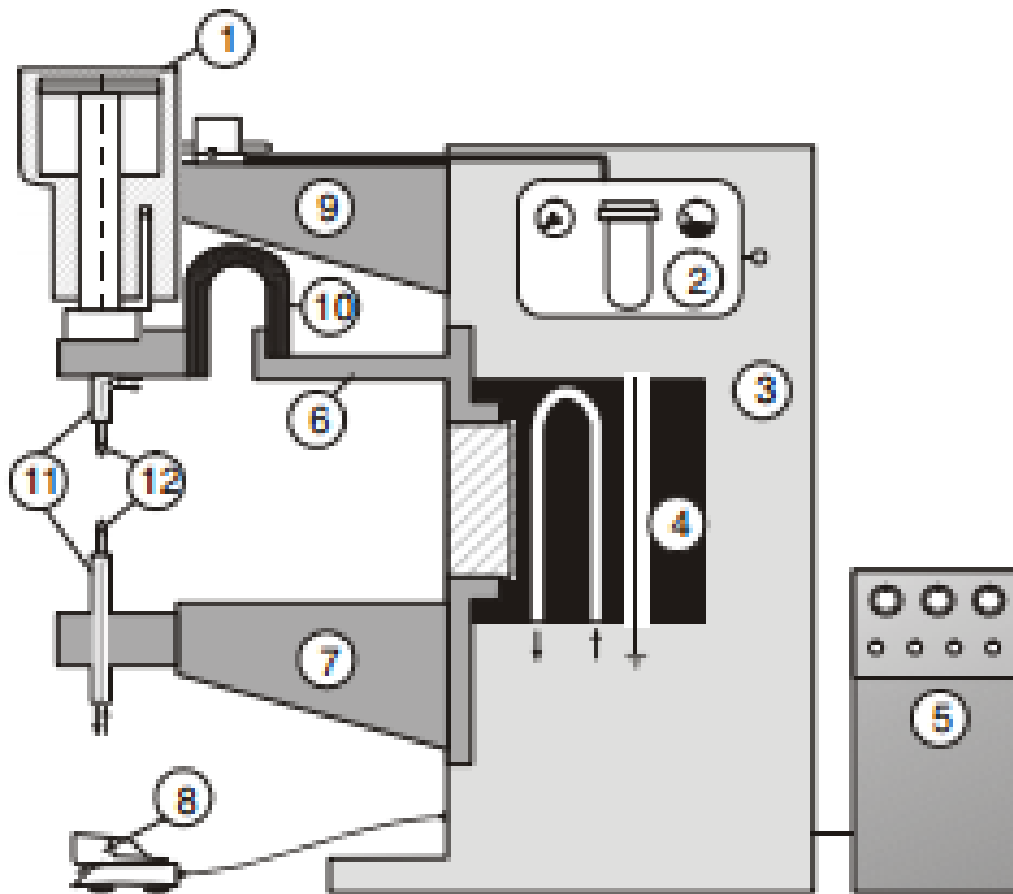
Spot Welding

- In this process overlapping sheets are joined by local fusion at one or more spots, by the concentration of current flowing between two electrodes.
- This is the most widely used resistance welding process.



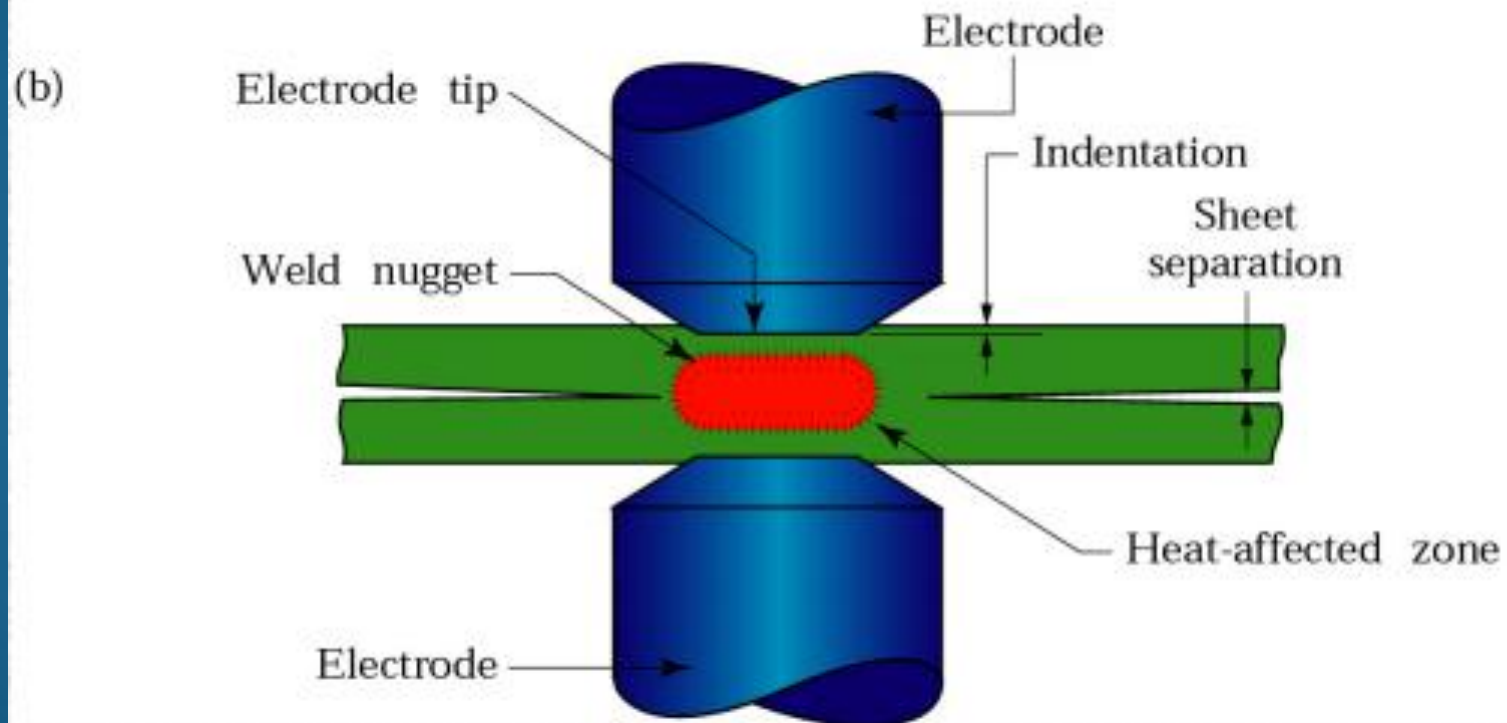
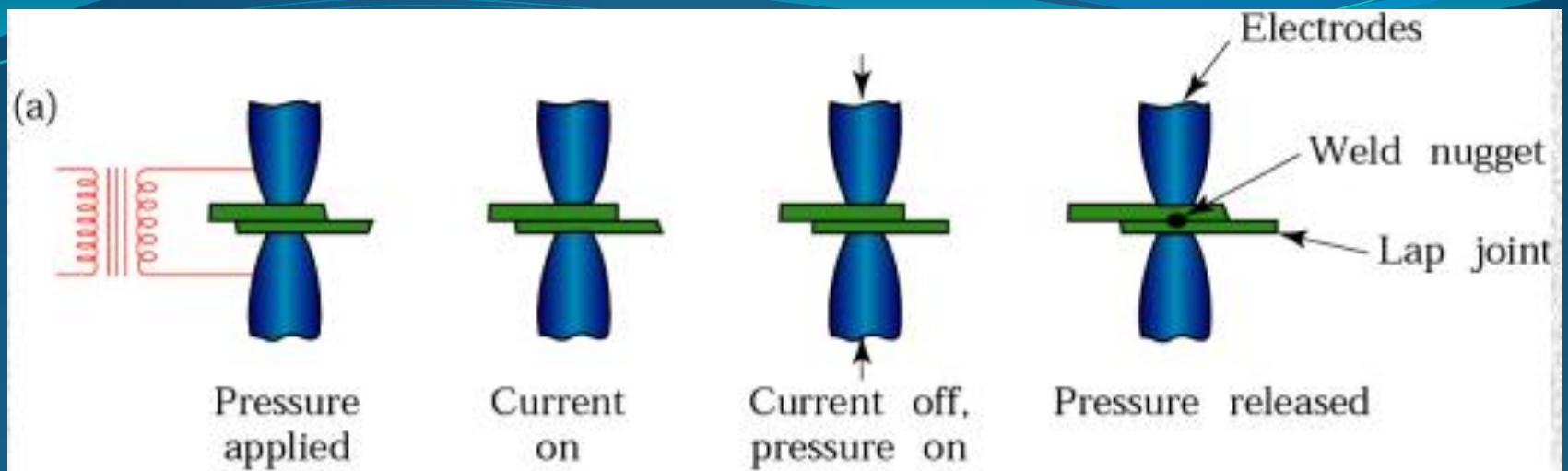


Resistance Welding Manual



1. electrode force cylinder
- 2 .pneumatic equipment
3. machine tool frame
4. welding transformer
- 5 .power control unit
- 6 .current conductor
7. lower arm
8. foot switch
9. top arm
- 10 .electrical power supply cable
11. water cooled electrode holder
12. electrode

Schematic Assembly of Spot Welding Machine

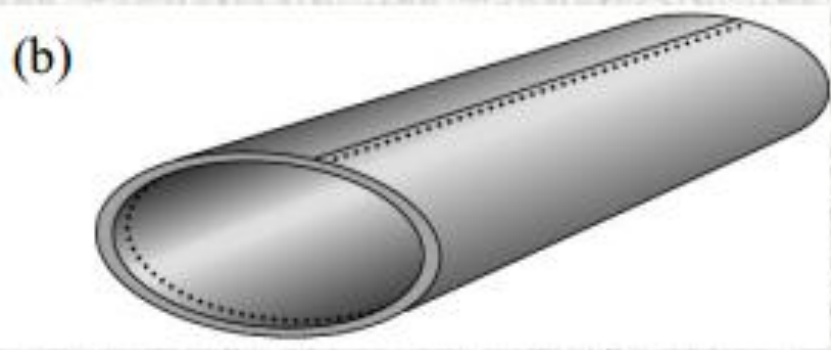


(a) Sequence in resistance spot welding.

(b) Cross-section of a spot weld, showing the weld nugget and the indentation of the electrode on the sheet surfaces.

This is one of the most commonly used process in sheet metal fabrication and in automotive-body assembly

Examples of Spot Welding



(a) and (b) Spot welded cookware and muffler

- 
- It essentially consists of two electrodes, out of which one is fixed.
 - The other electrode is fixed to a rocker arm (to provide mechanical advantage) for transmitting the mechanical force from a pneumatic cylinder.
 - The other possibility is that of a pneumatic or hydraulic cylinder being directly connected to the electrode without any rocker arm. For welding large assemblies such as car bodies, portable spot welding machines are used.

Spot welding electrodes

Spot welding electrodes are made of materials which have

- (1) Higher electrical and thermal resistivities, and
- (2) Sufficient strength to withstand high pressure at elevated temperatures.

➤ **Copper base alloys** such as copper beryllium and copper tungsten are commonly used materials for spot welding electrodes.

ADVANTAGES AND DISADVANTAGES OF WELDING

Advantages

1. **Welding** is more **economical** and is much faster process as compared to **other processes** (riveting, bolting, casting etc.)
Welding, if properly controlled results **permanent joints** having **strength equal or sometimes more than base metal**.
3. Large number of metals and alloys **both similar and dissimilar** can be joined by welding.
4. General welding **equipment** is not very costly.
5. **Portable welding equipment** can be easily made available.
6. Welding permits considerable **freedom in design**.
7. Welding can **join welding jobs** through spots,



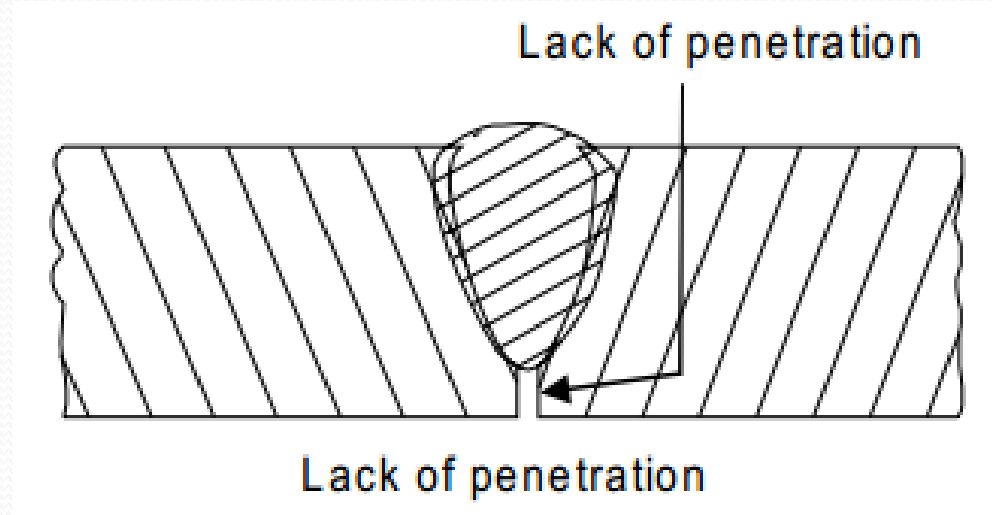
Disadvantages

1. It results in residual stresses and distortion of the work pieces.
2. Welded joint needs stress relieving and heat treatment.
3. Welding gives out harmful radiations (light), fumes and spatter.
4. Jigs, and fixtures may also be needed to hold and position the parts to be welded
5. Edges preparation of the welding jobs are required before welding
6. Skilled welder is required for production of good welding
7. Heat during welding produces metallurgical changes as the structure of the welded joint is not same as that of the parent metal.

WELDING DEFECTS

➤ **Lack of Penetration**:-It is the failure of the filler metal to penetrate into the joint. It is due to

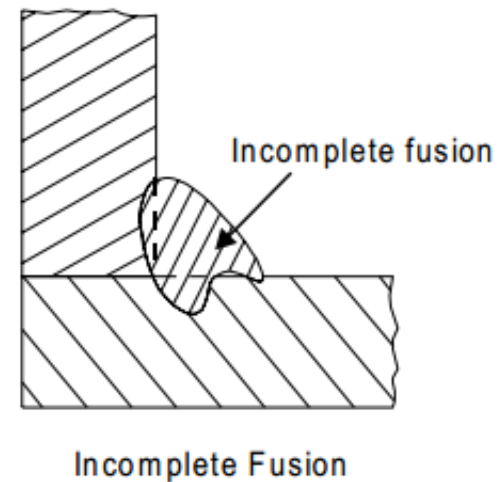
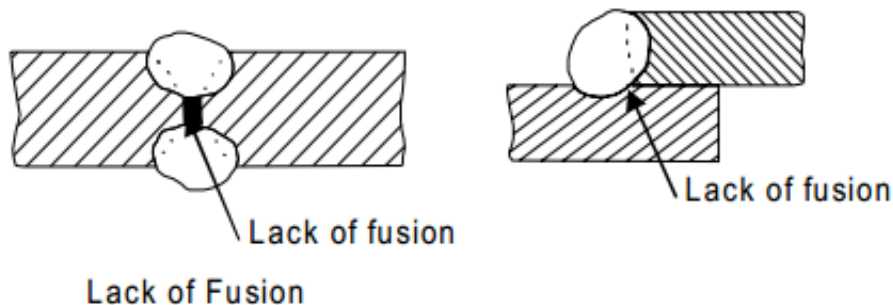
- ✓ Inadequate de-slagging
- ✓ Incorrect edge penetration
- ✓ Incorrect welding technique.



✓

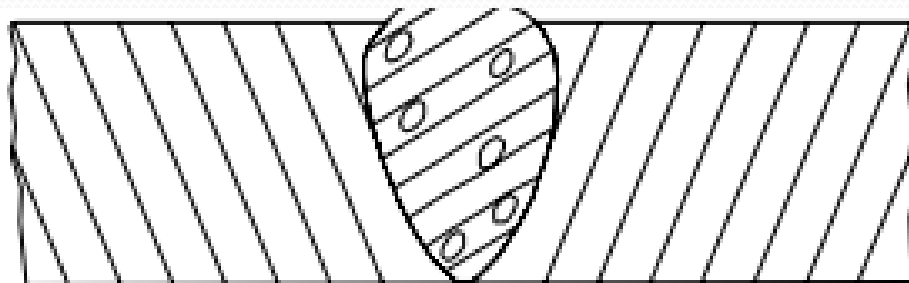
✓ **Lack of Fusion** :- Lack of fusion is the failure of the filler metal to fuse with the parent metal. It is due to

- ✓ Too fast a travel
- ✓ Incorrect welding technique
- ✓ Insufficient heat



➤ Porosity :- It is a group of small holes throughout the weld metal. It is caused by the trapping of gas during the welding process, due to

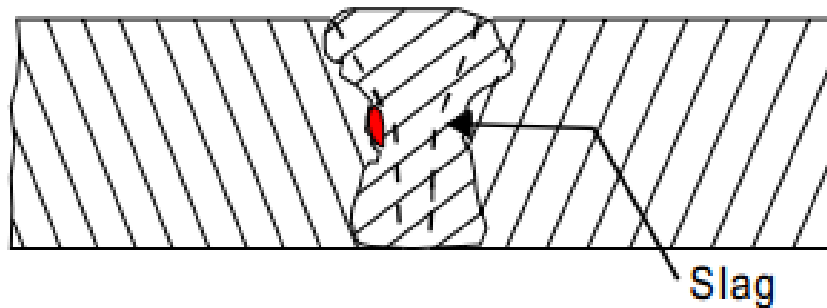
- Chemicals in the metal
- Dampness
- Too rapid cooling of the weld



Porosity

Slag Inclusion :-It is the entrapment of slag or other impurities in the weld. It is caused by

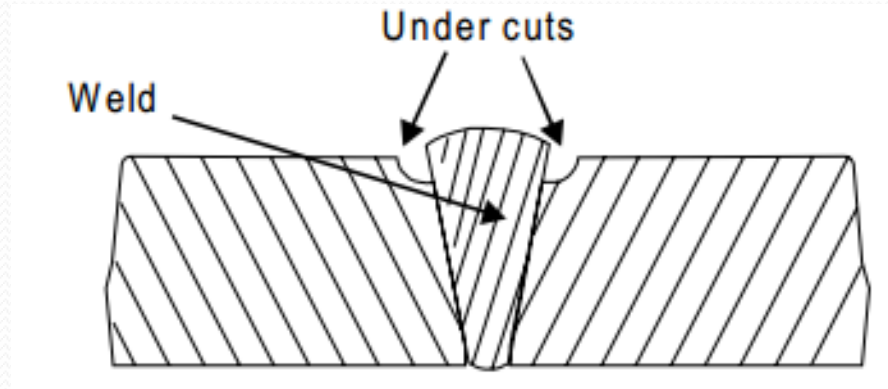
- ✓ Slag from previous runs not being cleaned away,
- ✓ Insufficient cleaning and preparation of the base metal before welding commences.



Slag Inclusion

Undercuts:- These are grooves or slots along the edges of the weld caused by

- ✓ Too fast a travel
- ✓ Bad welding technique
- ✓ Too great a heat build-up.



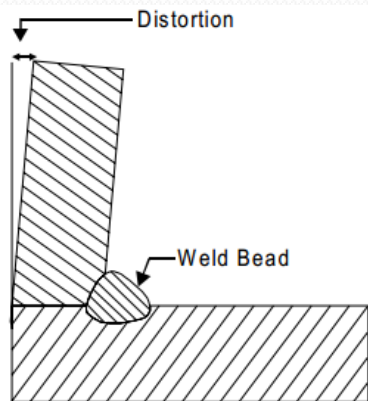
Cracking

It is the formation of cracks either in the weld metal or in the parent metal. It is due to

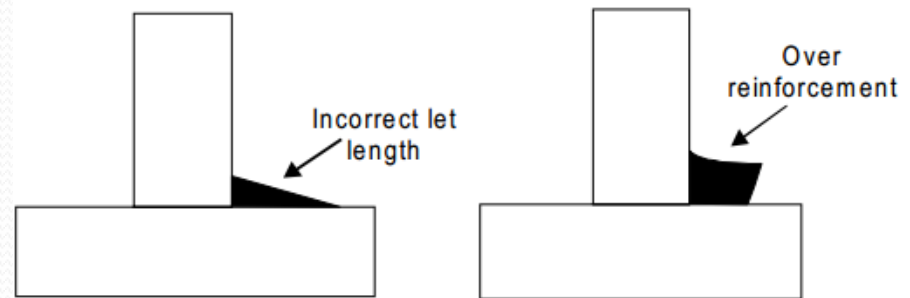
- (a) Unsuitable parent metals used in the weld
- (b) Bad welding technique.

Distortion :Distortion is due to high cooling rate, small diameter electrode, poor clamping and slow arc travel speed.

Poor Weld Bead Appearance : If the width of weld bead deposited is not uniform or straight, then the weld bead is termed as poor. It is due to improper arc length, improper welding technique, damaged electrode coating and poor electrode and earthing connections. It can be reduced by taking into considerations the above factors.



Distorted T Joint



Poor Weld Bead Appearance

Brazing

- brazing is a process of joining metals without melting the base metal.
- Filler material used for brazing has liquidus temperature above 450°C and below the solidus temperature of the base metal.
- The filler metal is drawn into the joint by means of capillary action (entering of fluid into tightly fitted surfaces).
- It then interacts with a thin layer of the base metal (known as wetting) and is then cooled quickly. This forms a sealed joint.

- 
- Almost all metals can be joined by brazing except aluminum and magnesium which cannot easily be joined by brazing
 - Brazed joints are generally stronger than the individual filler metals that have been used to make them.
 - This is because of the geometry of the joint and the metallurgical bonding that occurs.

Methods of Brazing

Torch Brazing:-Heat is produced, generally, by burning a mixture of oxy-acetylene gas, as in the gas welding.

➤A carbonizing flame is suitable for this purpose as it produces sufficiently high temperature needed for brazing.

Furnace Brazing:-It is suitable for brazing large number of small or medium parts.

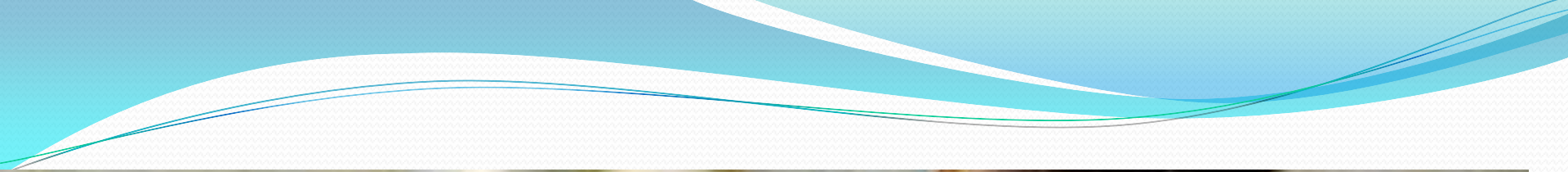
➤Usually brazing filler metal in the granular or powder form or as strips is placed at the joint, and then the assembly is placed in the furnace and heated.

Soldering

- Soldering is a process in which two or more metals are joined together by melting and flowing a filler metal into the joint, the filler metal having a relatively low melting point.

Soft soldering is characterized by the melting point of the filler metal, which is below 400 °C.

- The filler metal used in the process is called solder.
- Soldering is distinguished from brazing as the filler metal used has a lower melting point.
- Soldering is normally done by melting the solder with a soldering iron and applying it to the two metals that are going to be joined together.



Advantages of soldering

- Low power is required;
- Low process temperature;
- No thermal distortions and residual stresses in the joint parts;
- Microstructure is not affected by heat;
- Easily automated process;
- Dissimilar materials may be joined;
- High variety of materials may be joined;
- Thin wall parts may be joined;
- Moderate skill of the operator is required.

Disadvantages of soldering

- Careful removal of the flux residuals is required in order to prevent corrosion;
- Large sections cannot be joined;
- Fluxes may contain toxic components;
- Soldering joints can not be used in high temperature applications;
- Low strength of joints.

Advantages of brazing

- It's easy to learn.
- You can join virtually any dissimilar metals.
- The bond line can be very neat in appearance.
- Joint strength is strong enough for most non-heavy-duty use applications

Disadvantages of brazing

- A badly brazed joint looks similar to a good joint, and can have a VERY low strength.
- The metal used to bond the two parts may be different in color than the parts being bonded. This may or may not be a problem..
- Since the filler material (typically bronze) melts at a relatively low temperature,
 - brazed parts may not be put in an environment which exceeds the melting point of the filler metal.

End of chapter two!!

**Thank you for
your attention**

