



Welding

Module 19.2.1

Prepared by:

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Hard Soldering

- Hard soldering is a general term for *silver soldering and brazing*.
- *These are very* similar thermal joining processes to soft soldering in as much that the parent metal does not become fused or molten and that the filler alloy has to have a lower melting temperature range than the metals being joined.



Module 19.2.1

Explain the basic principles of hard soldering and braze welding.

Principles: joint types and materials joined, solders, fluxes, heating equipment, applications, safety precautions



Hard Soldering



- The term ' **brazing** ' is derived from the fact that the filler material (spelter) is a brass alloy of copper and zinc and a typical spelter containing **40% copper** and **60% zinc** melts at about 850°C to produce a strong and malleable joint. This is very much higher than the temperatures required when soft-soldering.
- Brazing is defined as a process of joining metals in which the molten filler material is drawn into the gap between the closely adjacent surfaces of the metals being joined by capillary attraction.

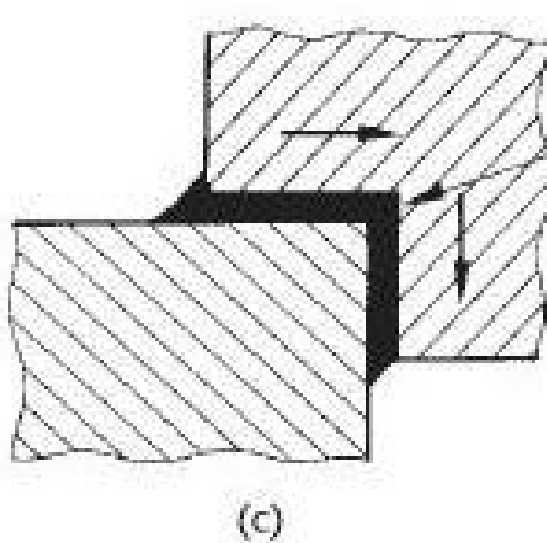
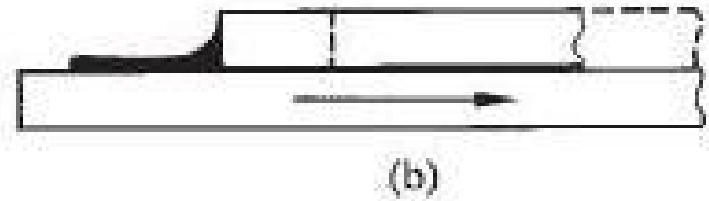
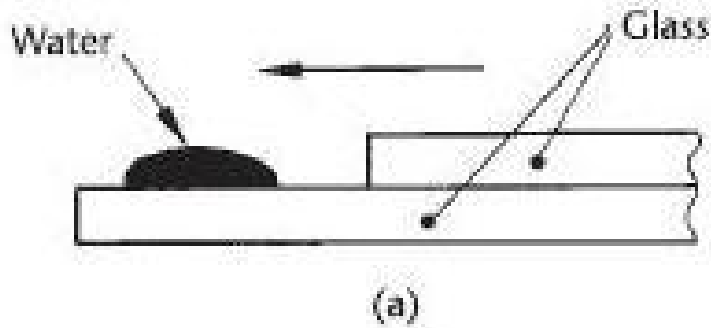


Principles of Brazing

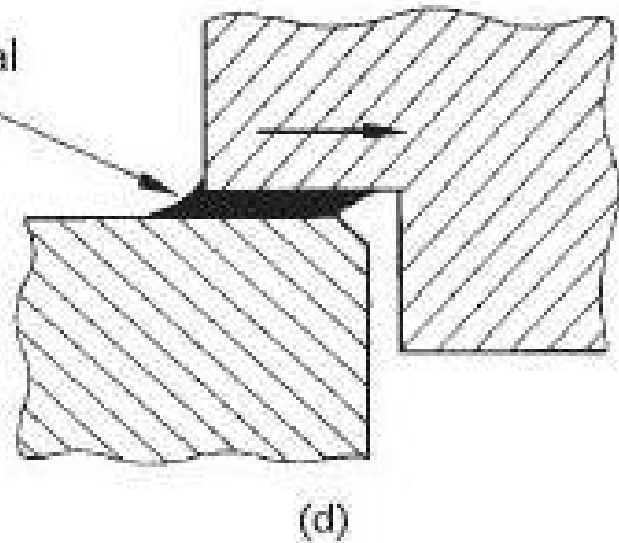


- The selection of a suitable filler alloy which has a melting range that is appreciably lower than that of the parent metals being joined – but substantially higher than that used for soft soldering.
- The thorough cleanliness of the surfaces being joined. Previously soft-soldered joints cannot be remade by hard soldering.
- The complete removal of the oxide film from the surfaces of the parent metal and the filler material by a suitable flux.
- The complete ' **wetting** ' of the joint surfaces by the molten brazing alloy.

Capillary Action



Filler metal

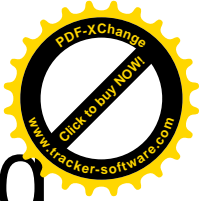




Metals suitable for Hard Soldering

The following common metals and their alloys can be joined by hard soldering processes:

- Copper and copper-based alloys.
- Low, medium, and high carbon steels.
- Alloy steels including stainless steels.
- Malleable cast iron and wrought iron.
- Nickel-based alloys.
- Aluminium and certain aluminium alloys.



Metals suitable for Hard Soldering

- Metals and alloys of dissimilar compositions can be hard-soldered (brazed or silver-soldered) together, for example: copper to brass; copper to steel; brass to steel; cast iron to mild steel; and mild steel to stainless steel.



Filler Materials



Brazing filler alloys maybe classified into:

- Silver Solders
- Brazing alloys containing phosphorus
- Brazing brasses or 'spelters'



Silver Solder

- More expensive due to the high percentage of precious metal **silver**
- Produce strong & Ductile joints at much lower temperature than other filler metal
- Low processing temperature therefore little thermal effects on parent metal
- Borax or flux based upon boric acid are not suitable to used with silver solder as these flux are not sufficiently fluid at the processing temperature of silver solder



Brazing alloys containing phosphorus



- Composed of silver, phosphorus & copper or just copper & phosphorus
- Usually referred as self fluxing brazing alloys as they have capability to braze copper component in air without the need of flux however for copper based alloys suitable flux is needed
- Only effective when used in oxidizing atmosphere and should only be used with copper and copper alloys otherwise a brittle and weak joint will be produced



Brazing brasses or 'spelters



- Generally known as brazing spelters and uses **borax** as flux
- Processing temperature are relatively higher than other two filler metal
- Produces high tensile strength joints and suitable for producing high strength joints between ferrous components



Heat Sources for Brazing



Heat sources for Brazing are:

- Flame brazing (torch)
- Furnace Brazing
- Dip Brazing
- Electric induction brazing
- Electric resistance brazing

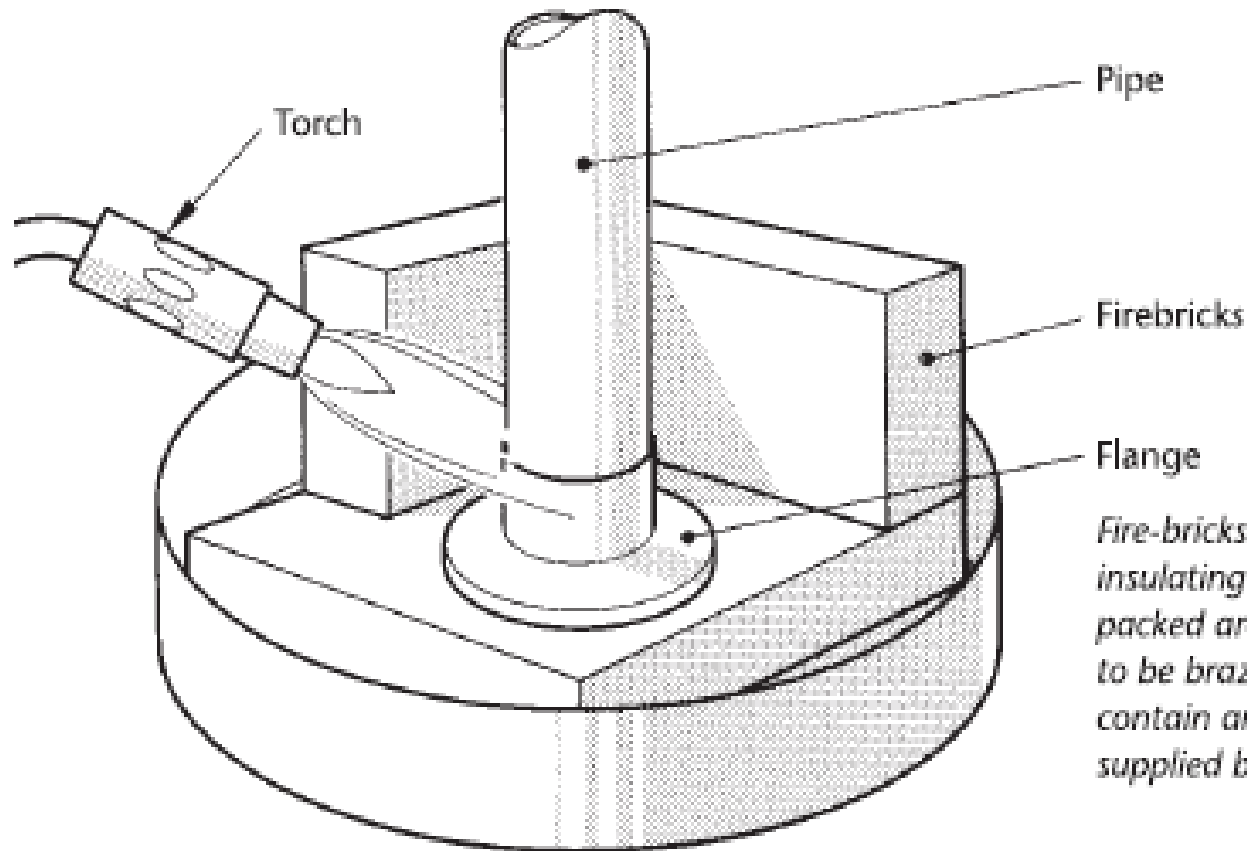


Flame brazing (torch)



- Most versatile (Gas welding torch normally used for flame)
- Used in batch production for large or small assembly
- Spelter can be used in two ways
 - Granules of spelter is boiled with borax and a paste is formed which is then applied in the heated joint area, spelter melts and flows by capillary action
 - Tip of spelter is heated and dip I flux which is adhered to it then applied to the joint area which is also fluxed.

Flame brazing (torch)



Fire-bricks or other suitable insulating materials are packed around the component to be brazed. This helps to contain and reflect the heat supplied by the torch.

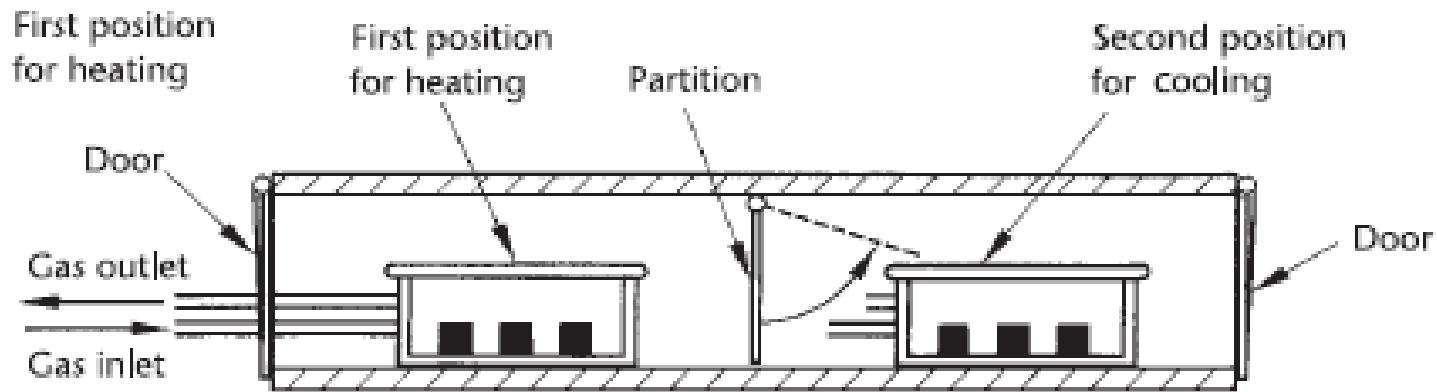


Furnace Brazing

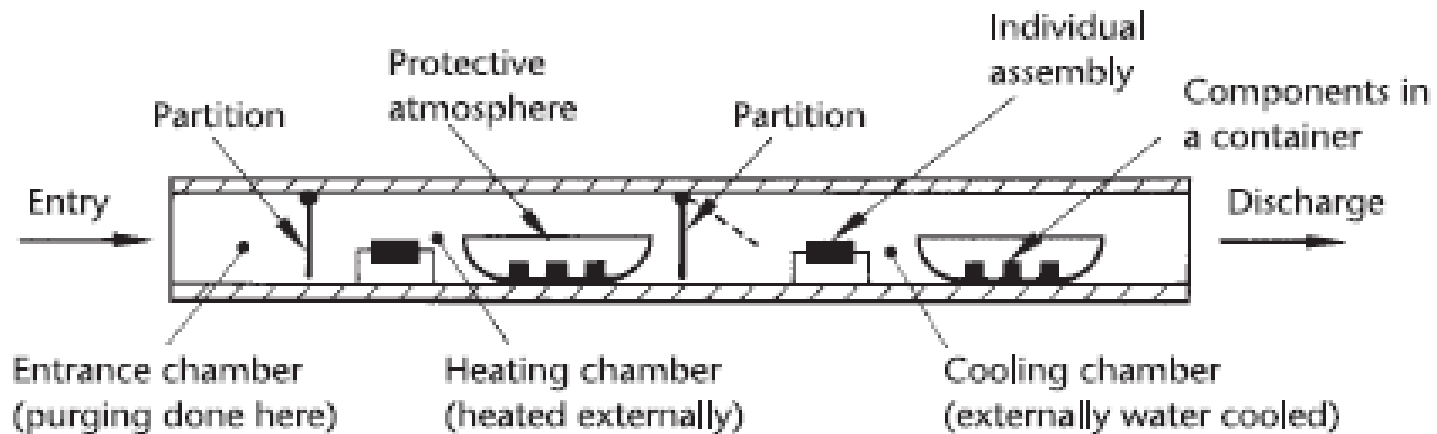


- Mainly used when controlled atmosphere is required & when components to be joined is design so that they can be pre assembled or hold them in position during brazing
- Heat source may be gas oil in a muffle type furnace

Furnace Brazing



Schematic layout of batch brazing in a sealed container

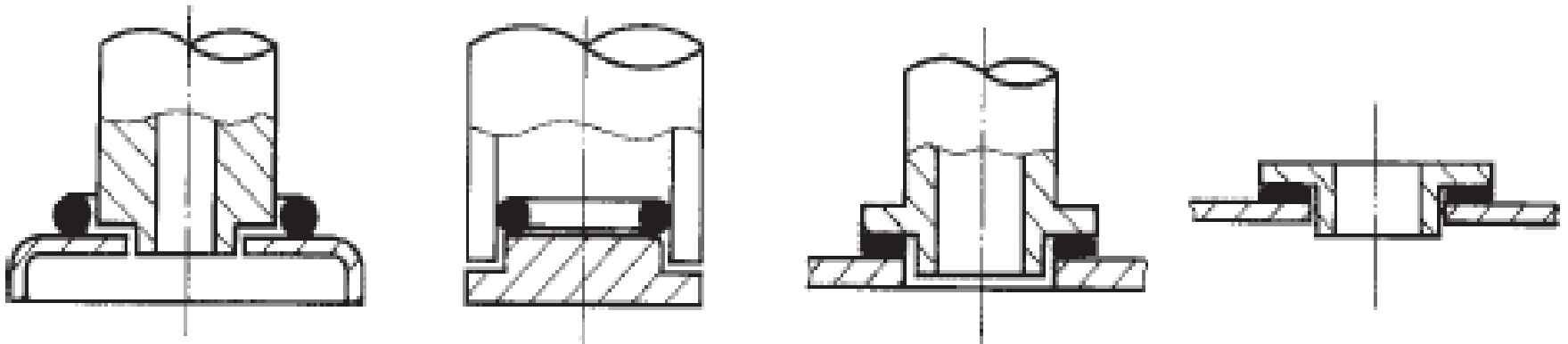


Schematic layout of continuous brazing furnace

Individual assemblies or components for batch brazing (in trays) are passed through the furnace on a conveyor system. Inert or reducing atmospheres can be used to protect the work from oxidation.



Furnace Brazing



Filler metal for furnace brazing is used in the form of pre-placements. The components to be brazed are assembled with the filler alloy in the required position and fluxed if necessary. Pre-placed brazing alloy inserts are available in a variety of forms, such as wire rings, bent wire shapes, washers and foils.



Dip Brazing



- Dip brazing can be defined in two ways
 - Molten filler metal dip brazing
 - Flux bath dip brazing
- Molten filler metal dip brazing
 - Component to be joined assembled and submerged in the bath of molten filler metal
 - Flux is floated on the surface to exclude the air
 - The parts should be raised & lowered several times through the molten flux into the molten brazing alloy to ensure penetration of flux & brazing alloy in the clearance



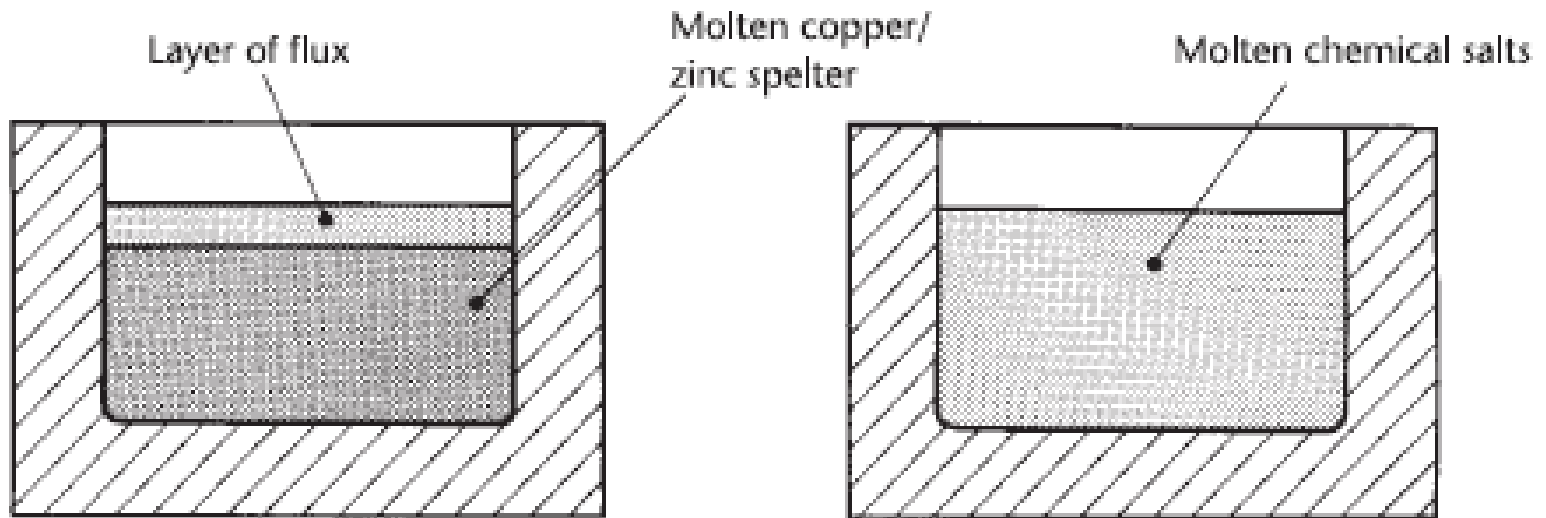
Dip Brazing



- Flux bath dip brazing
 - Also called salt bath dip heating & mainly used for aluminum components using spelters as brazing alloy
 - Molten salt is contained in salt bath
 - It enables the parts to be joined heated more rapidly than in furnace because of the greater heat conductivity of the liquid medium in the bath
 - Salt used is carefully chosen for their melting characteristics and ability to have a fluxing action



Dip Brazing



Dip brazing bath

The brazing bath is heated externally.

Salt bath

Baths are usually fitted with an insulated lid or cover to prevent heat loss.



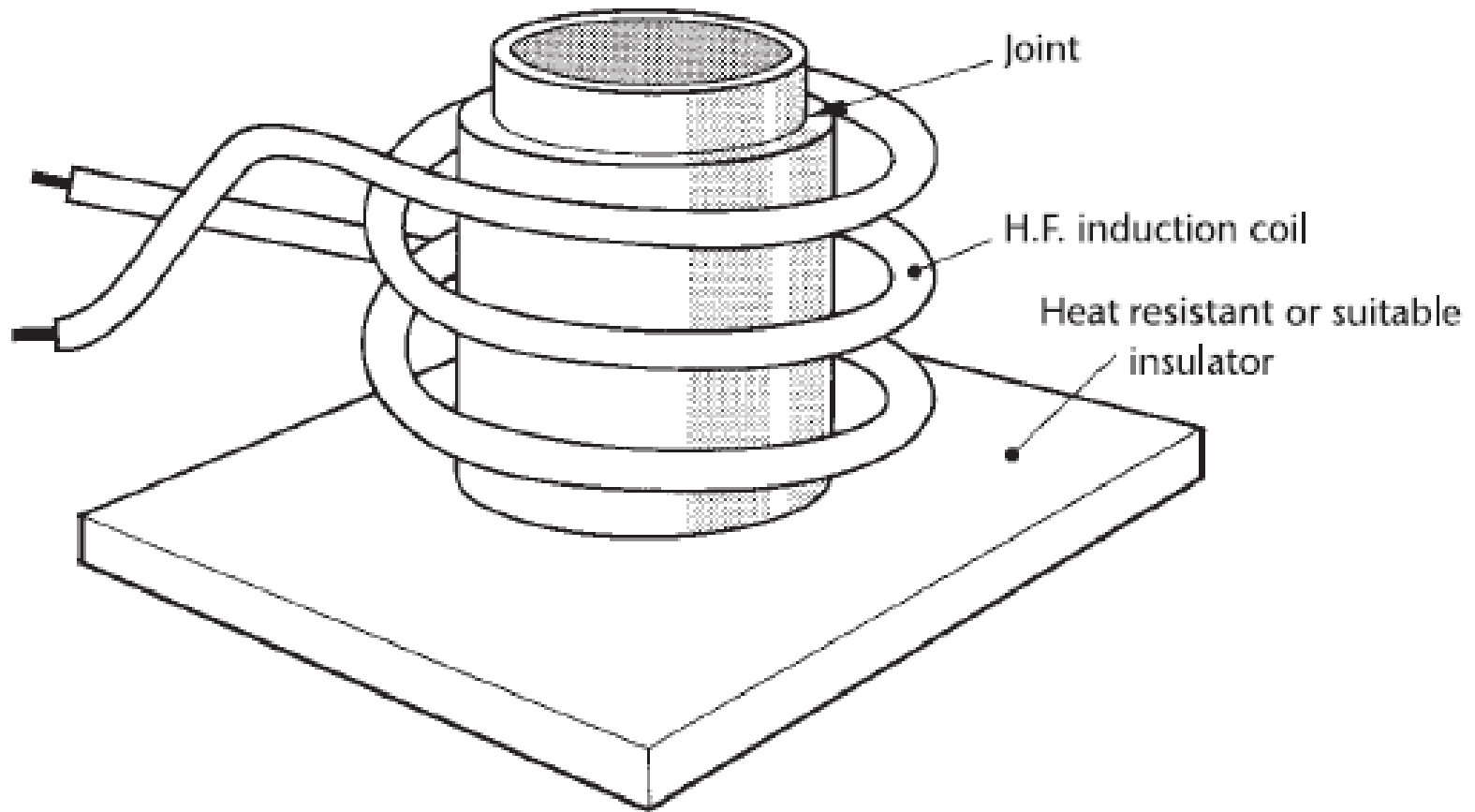
Electric induction brazing



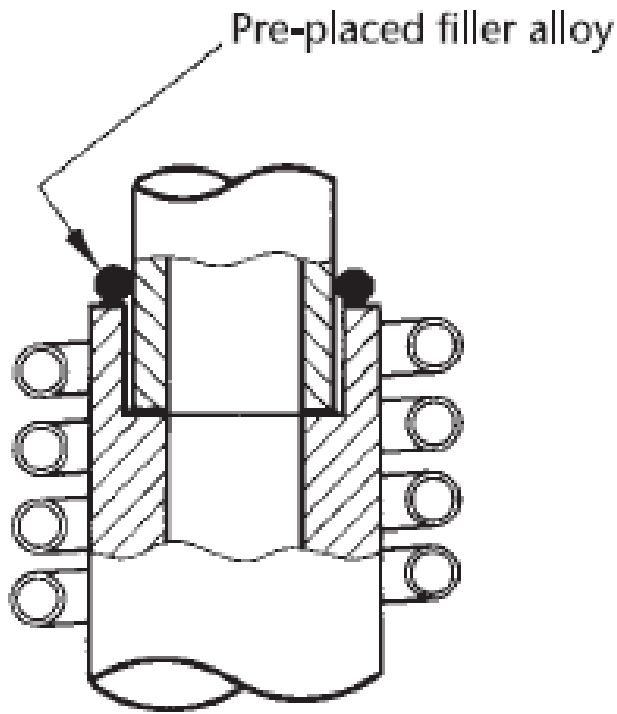
- Induction heating is used to braze part that are self jiggling
- The assembly to be brazed is placed in magnetic field of a solenoid carrying a high frequency AC current
- The heat required for brazing is generated within the joint material itself



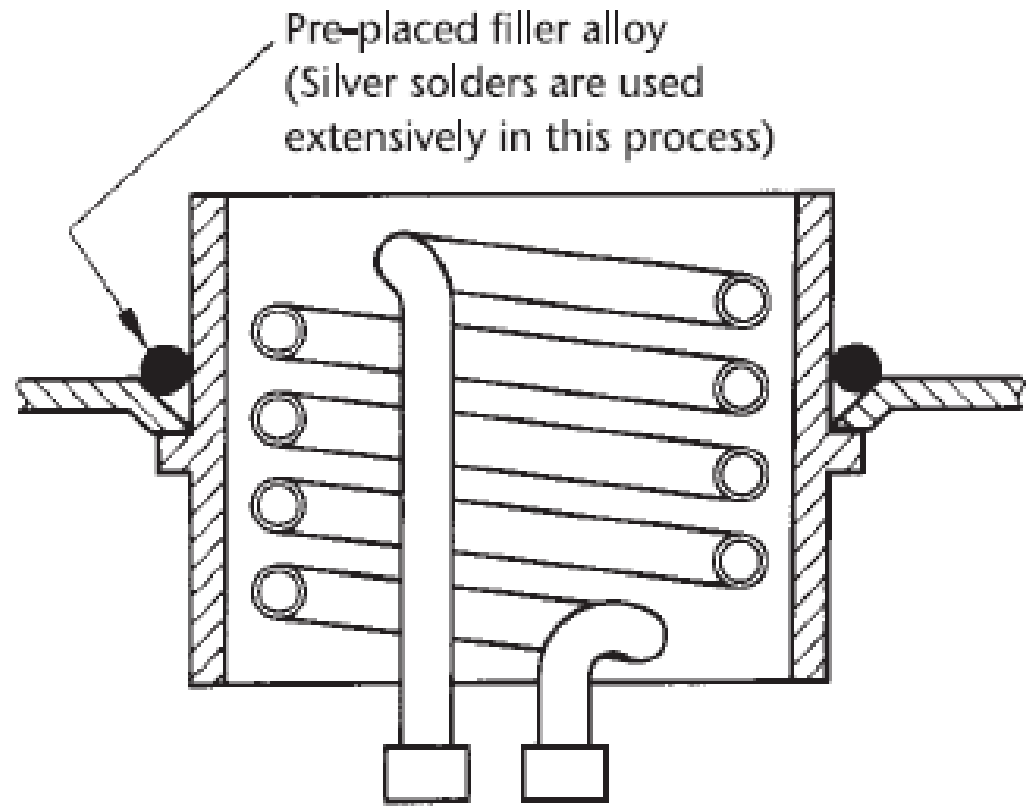
Electric induction brazing



Electric induction brazing



External coil



Internal coil



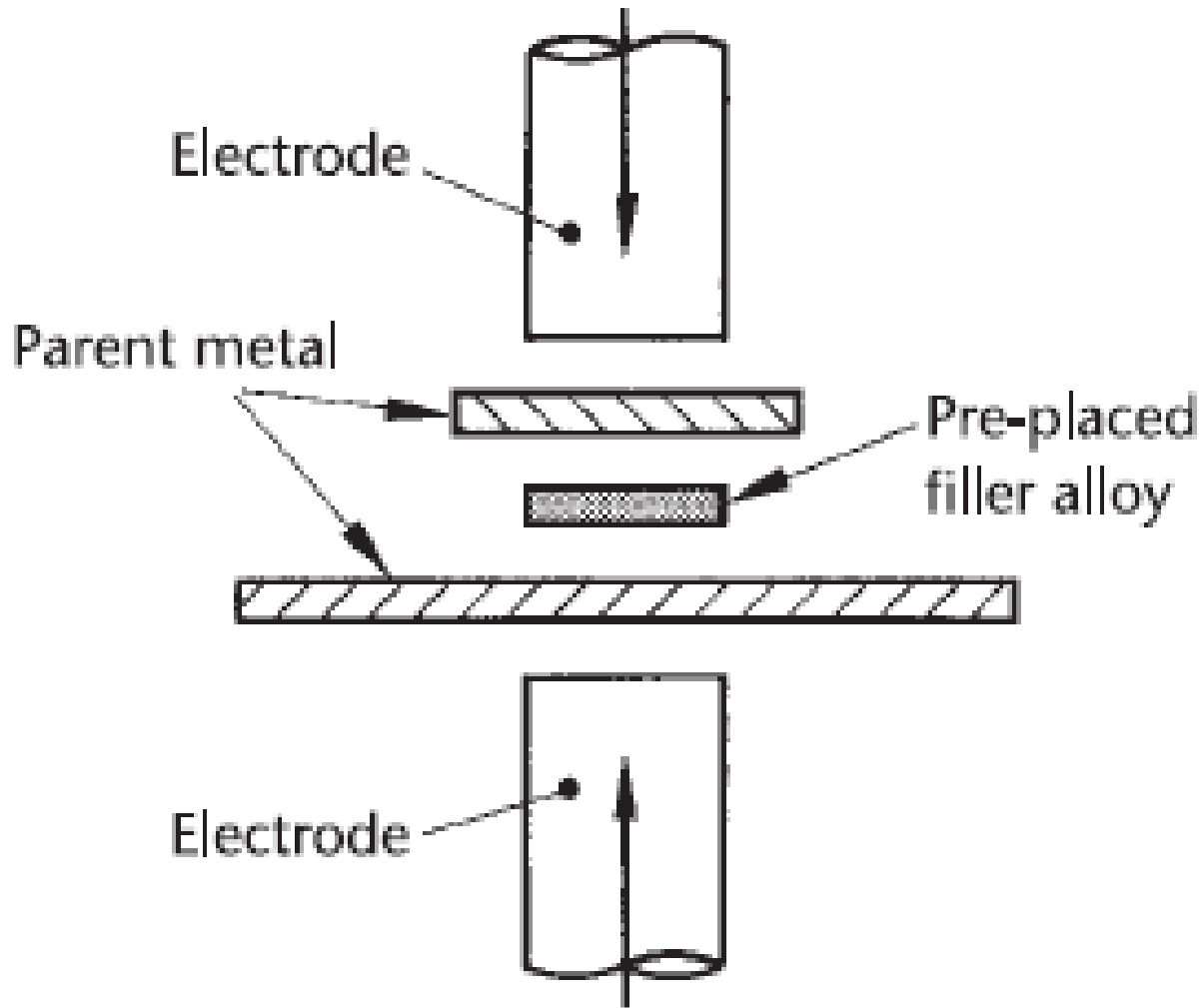
Electric resistance brazing



- In this process the heat required for brazing is generated by the passage of high value electric current through the joint material at low voltage
- The resistance by the joint material in current flow and carbon electrodes are responsible for the heat generated
- No jigs required as the carbon electrode hold the pieces itself



Electric resistance brazing





Types of Brazed joints

There are two basic types of brazed joint, namely the **lap joint** and the **butt joint**.

However, there are many combinations and variations of these joints designed to meet specific requirements.

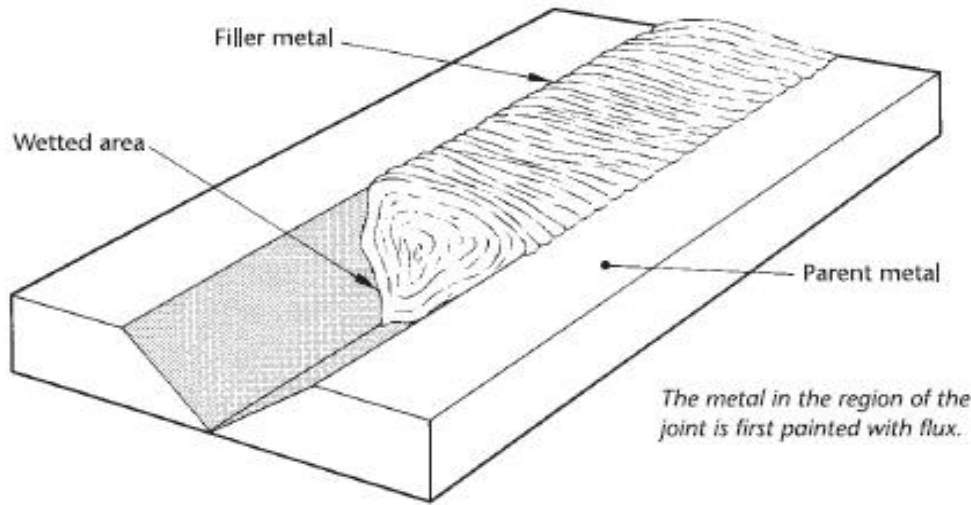
The factors affecting the strength of hard soldered joints are similar to those that apply to soft soldering but, since the mechanical strength of the filler materials (brazing alloys) is very much greater than that for soft solders, the overall joint strength is very much higher.



Braze Welding

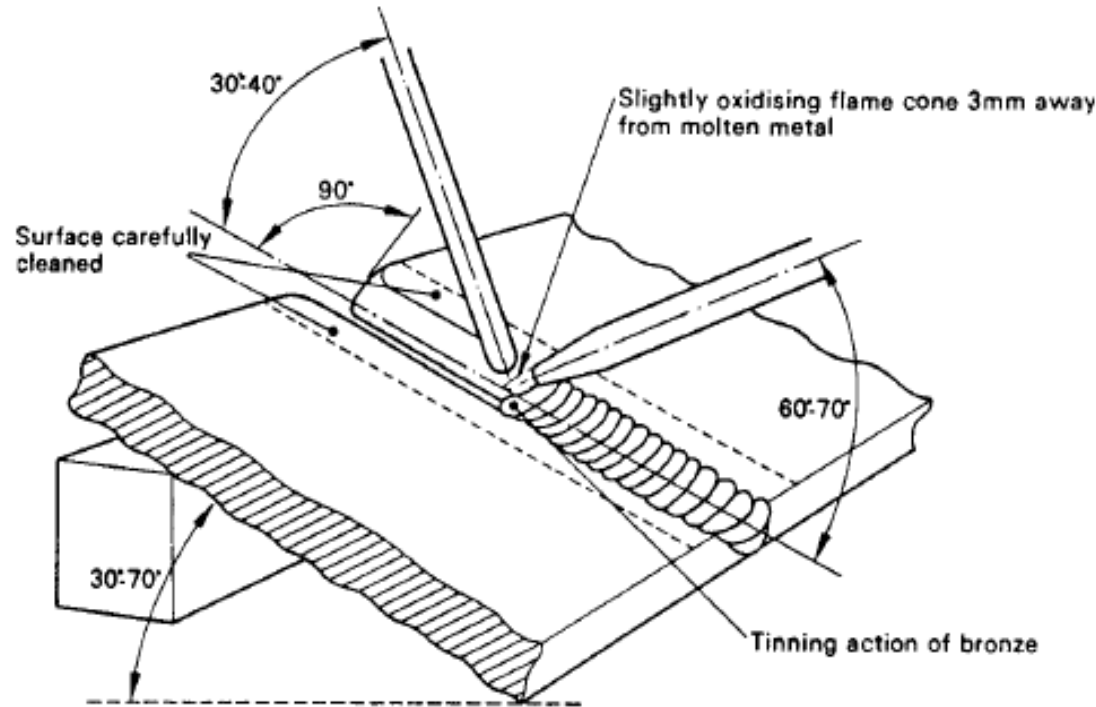
- Braze-welding can be used to join similar or dissimilar metals by using a filler material with a lower melting temperature range than the parent metals being joined.
- When brazing , the filler material is drawn into a close-fitting joint by capillary attraction. When braze welding the joint gap is not so closely fitting, there is no capillary penetration and a relatively large quantity of filler material is used.

Braze Welding



The metal in the region of the joint is first painted with flux.

Figure 10.22 The wetting action in braze welding





Braze Welding

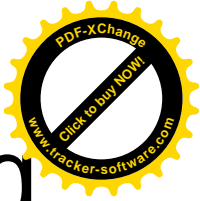
- In braze-welding as distinct from fusion welding the melting temperature range of the filler material is lower than that of the parent materials being joined.
- As a result of this, the process of braze-welding requires a lower temperature than that required for full fusion welding which, in turn, results in less distortion and oxidation of the parent metals. When braze-welding, the work-piece must be thoroughly clean and free from scale, oil/grease, paint, metal plating or any other surface contaminant.



Flux (Braze Welding)



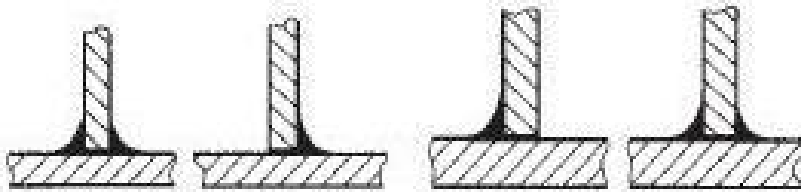
- The flux should become completely molten at a temperature at least 50°C below the melting point of the filler material and retain its activity at a temperature at least 50°C above the melting temperature of the filler material.
- Fluxes of the borax type are suitable when braze-welding.
- A paste or a powdered flux worked into a paste with water can be more thoroughly and evenly spread than a dry flux in powder form.
- If a powder flux is used the tip of filler rod should be heated and dipped into the flux powder in order to pick up a ' tuft ' of flux.



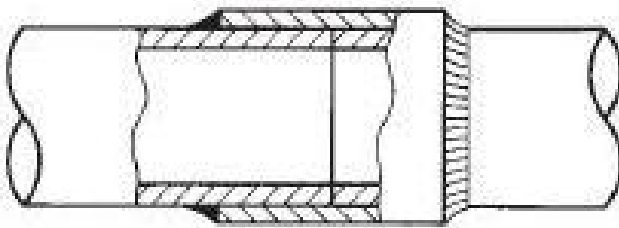
Metals suitable for Braze Welding

- Cast Iron
- Copper
- Galvanized Mild Steel
- Malleable Cast Iron
- Mild Steel
- A Combination of any two of the above

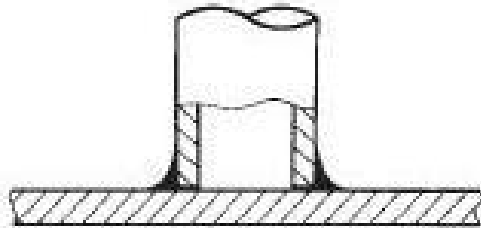
Applications



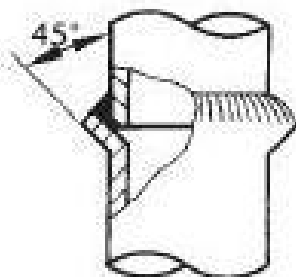
Examples of 'Tee fillet' joints in mild steel.



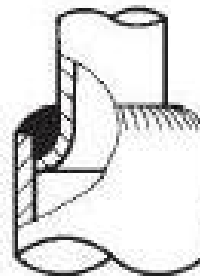
*Sleeve joint for mild steel pipes
The mating surfaces of the pipes should be accurately machined. The sleeve and the pipes should be a close fit.*



Tube plate joint for mild steel assemblies



(a)



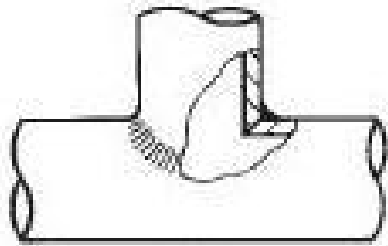
(b)

(a) *Bell type butt joint*

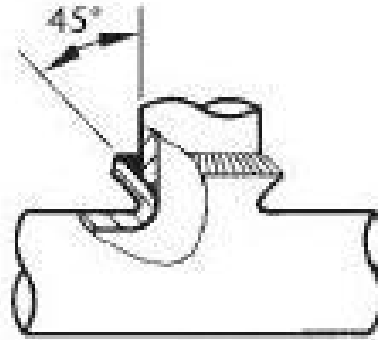
(b) *Diminishing joint*

The end of the smaller pipe is belled out to fit into the large pipe.

Applications



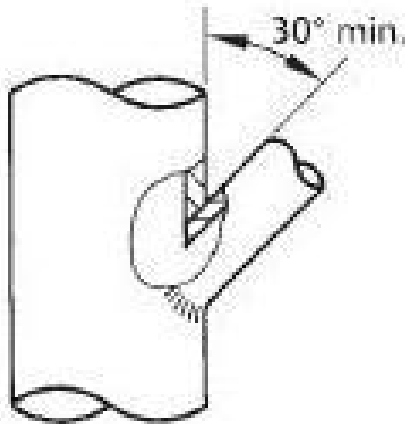
(c)



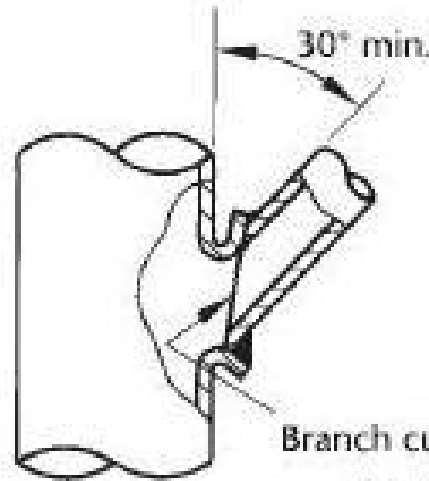
(d)

(c) *Branch tee joint*
Suitable for small pipes of equal and unequal diameters.

(d) *Bell type tee joint*
Suitable for all diameters and thickness of pipes.



(e)



(f)

(e) *Stub branch joint*

(f) *Short bell branch joint*

Branch cut at angle

Braze welded joints in copper pipes



Welding

Module 19.2.2

Prepared by:

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Module 19.2.2

Describe the methods used to protect the weld pool from atmospheric contamination during welding.

Protection: oxy-fuel gas, manual metal arc



Weld Pool



- The pool of the molten metal that is created by the heat of the welding torch.

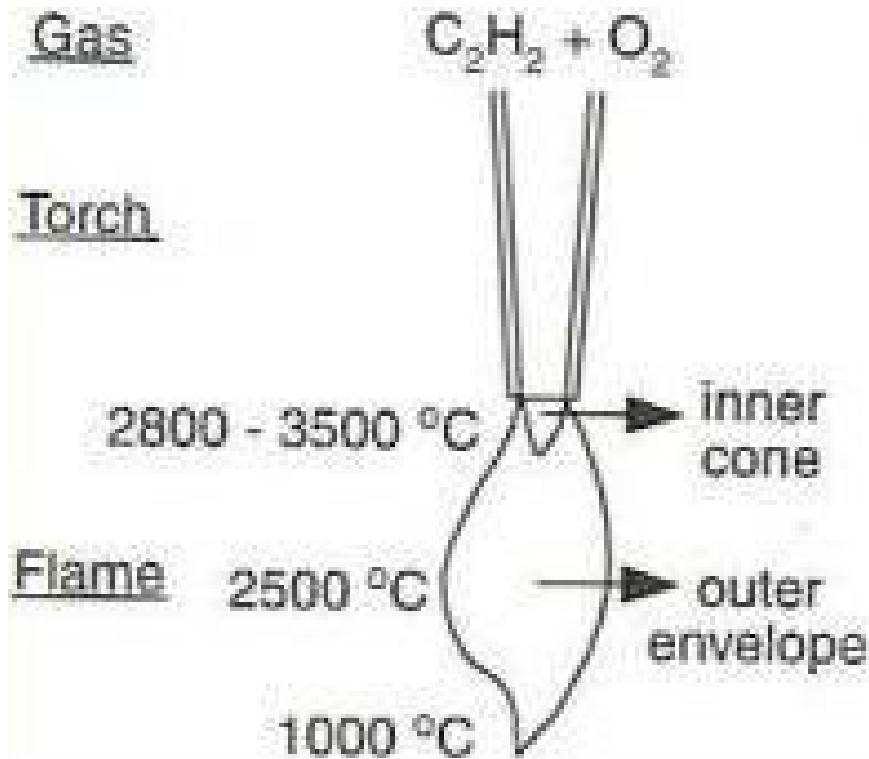


Protection of Weld Pool

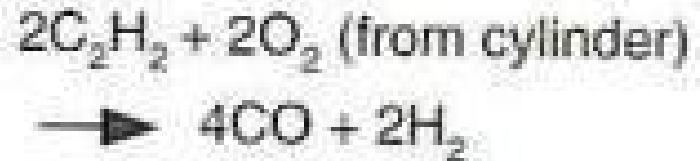


- The weld pool needs to be protected from atmospheric contamination.
- Oxygen and nitrogen along with other impurities present in the atmosphere can effect the quality of the weld if the weld pool is not properly protected.

Oxy-Fuel Gas Welding



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



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





Oxy-Fuel Gas Welding



For the ferrous metal welding the flux should be borax, sodium silicate, sodium carbonate, sodium bicarbonate, it gives best result. The borax forms compounds with the iron oxide, when the carbonate is the cleanser and it promotes fluidity of the molten metal.



Oxy-Fuel Gas Welding



- The secondary combustion is also called the protection envelope since CO and H_2 here consume the O_2 entering from surrounding air, thereby protecting the weld from oxidation.



Manual Metal Arc Welding

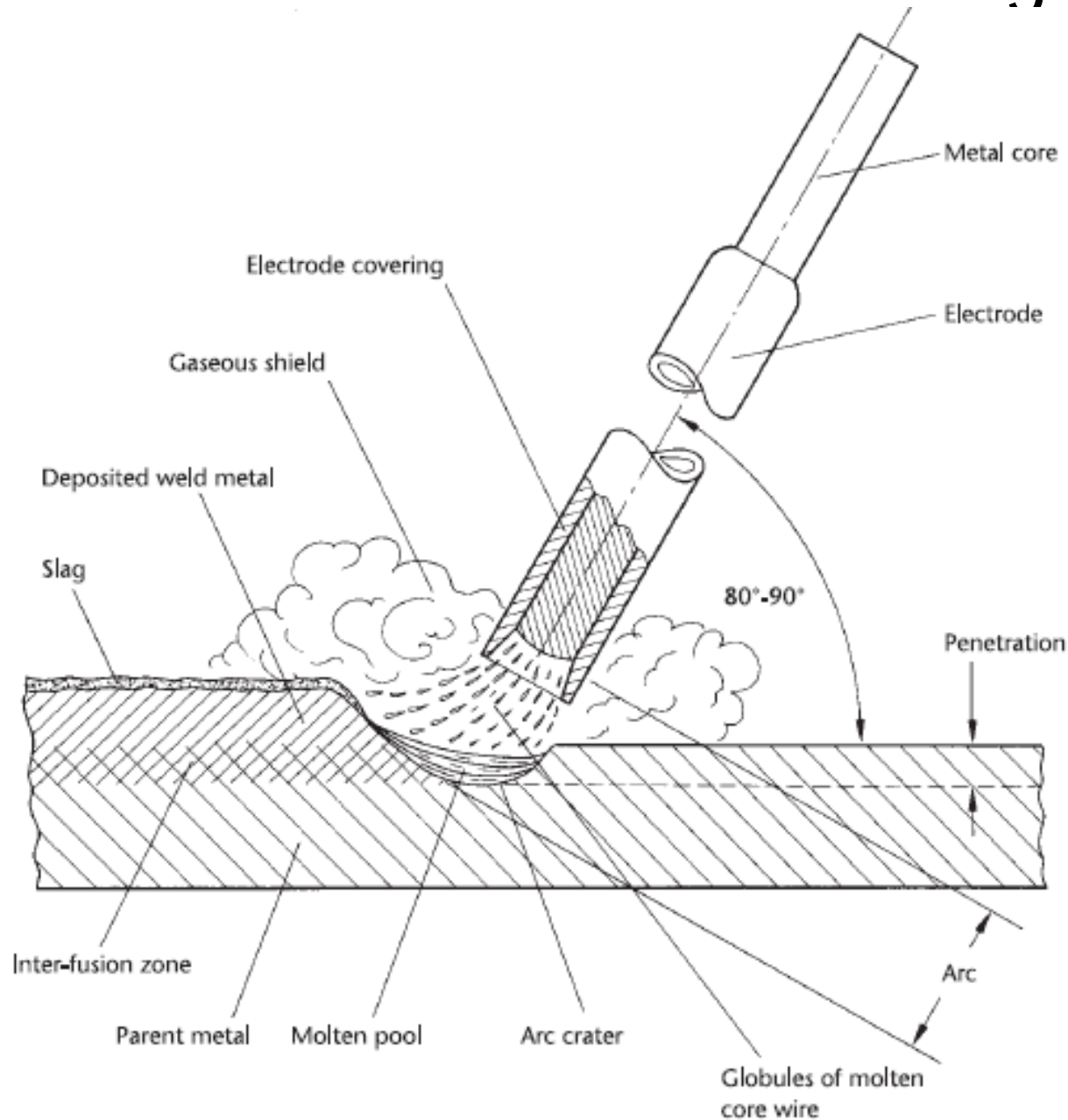


- A flux prevents the oxidation of molten metal. The flux (material) is fusible and non metallic. During welding, flux chemically reacts with the oxides and a slag is formed that floats to and covers the top of the molten puddle of metal and thus helps keep out atmospheric oxygen and other gases



Manual Metal Arc Welding

AMAI





Manual Metal Arc Welding



- SMAW flux coatings includes
 - Addition of elements which produce slag
 - Addition of deoxidizer
 - Addition of elements for reducing moisture content
 - Addition of alloying elements
 - Binders



Manual Metal Arc Welding



Shielding Gases:

Mixture of H_2 , CO , H_2O and CO_2



Manual Metal Arc Welding



Protection:

The gaseous shield protects the molten metal from air.



Manual Metal Arc Welding



Protection:

- Cellulose-type electrode $(C_6H_{10}O_5)_x$ – providing gas mixture of H_2 , CO , H_2O and CO_2 .
- Limestone-type electrode $(CaCO_3)$ – low in hydrogen and it is used for welding metals that are susceptible to hydrogen cracking such as high-strength steels.



Manual Metal Arc Welding



De-oxidation:

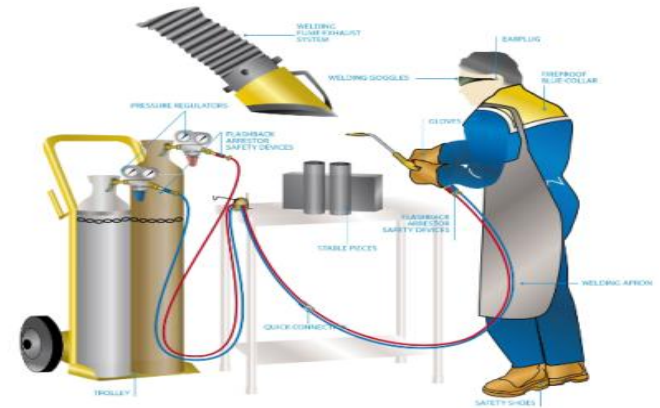
Deoxidizers and fluxing agents are used to deoxidize and cleanse the weld metal. The solid slag also protects the weld metal from oxidation.

WELDING

Module 19.2.3

Describe oxy-fuel gas welding and ancillary equipment. Equipment: blow pipes, cylinders, filler metals and fluxes, pressure gauges, regulators, gas economizer, hose, connectors, protectors, safety devices, thread identification; hose, pipeline and cylinder colors, manifold system

Correct and safe oxygas welding station





Blow pipes



- Flexible hoses
- Colored black for oxygen & red for acetylene
- They have seamless rubber or rubber compound lining inside that is chemically resistant to the normal welding gases.
- Care must be taken to avoid:
 - Trolleys to run over them
 - Dropping heavy weight on them
 - Welding flame to come into contact with hoses



Cylinders

- Can be identified by shape & color coding
- High pressure cylinders are tall & narrow
- Low pressure cylinders are shorter
- As per **BS-349** Acetylene are painted maroon & oxygen are painted black
- Acetylene can only be stored safely if dissolve under pressure in Acetone
- Acetylene cylinder must always be used & stored upright
- Cylinders must always be stored in well ventilated area
- They must be protected from welding flame, direct sunlight, wet and frost on an open site



Filler metal

- Bare metal wire is usually used in oxy fuel welding
- Often coated to avoid rusting or scaling
- Different diameter of wire according to the required type of joint is used





Flux

- Fluxes are usually in powder form.
- These fluxes are often applied by sticking the hot filler metal rod in the flux
- Sufficient flux will adhere to the rod to provide proper fluxing action as the filler rod is melted in the flame.
- Welding rods with a covering of flux are also available
- The melting point of a flux must be lower than that of either the metal or the oxides formed, so that it will be liquid. The ideal flux has exactly the right fluidity when the welding temperature has been reached

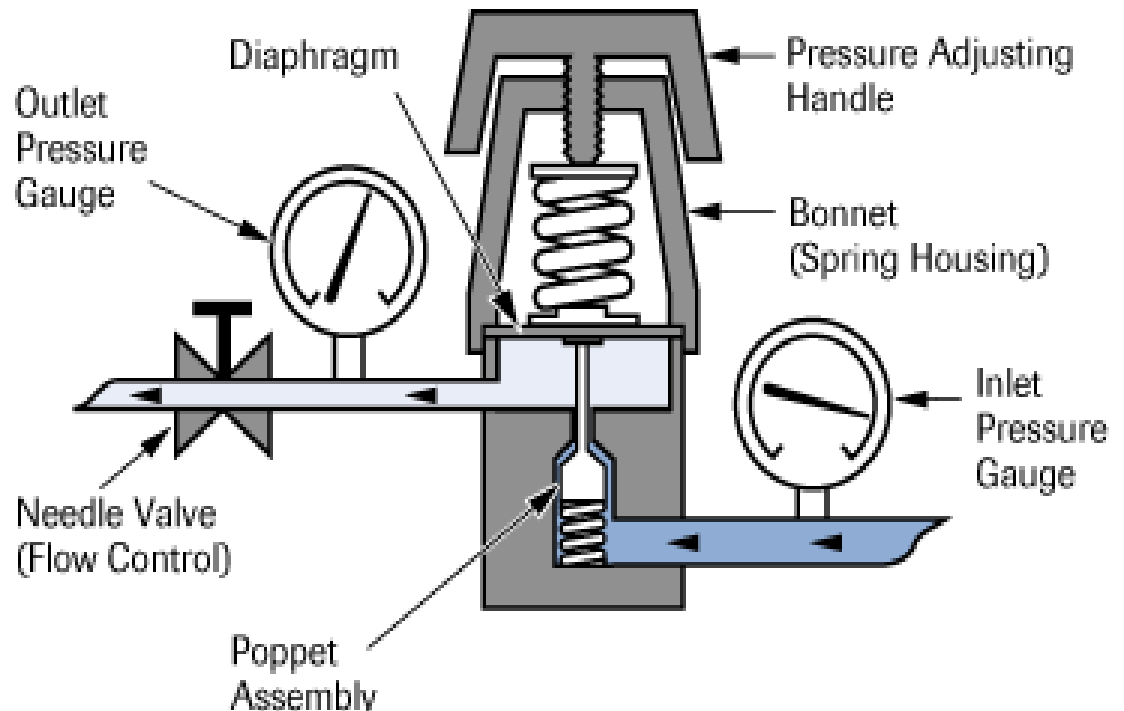


Pressure gauges & Regulators

- The regulator is used to control pressure from the tanks to the required pressure in the hose
- Two types of regulators are there
 - Single stage regulator
 - Two stage regulator

Single stage regulator

- Single-stage pressure regulators reduce the cylinder pressure to the delivery or outlet pressure in one step.

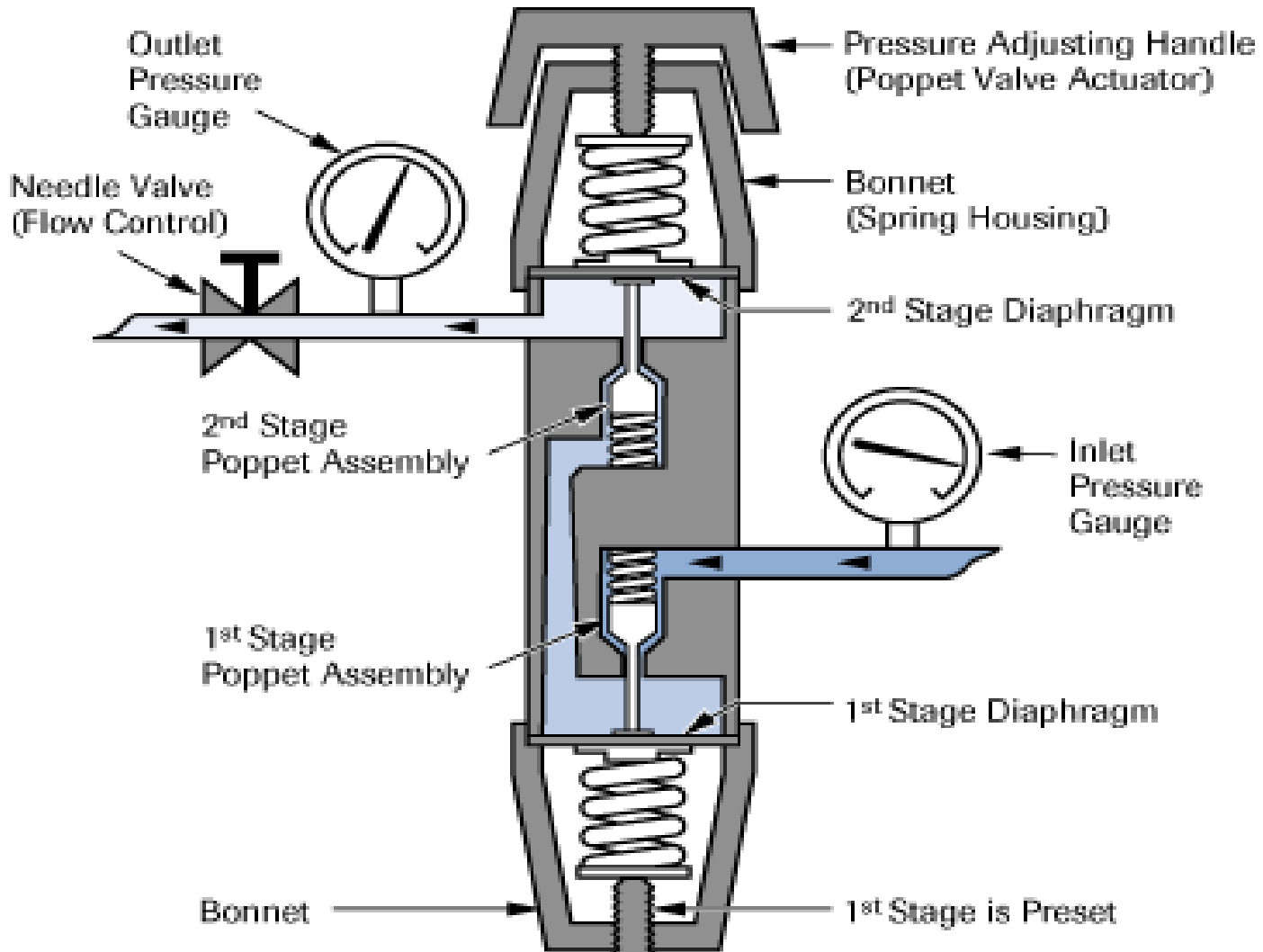


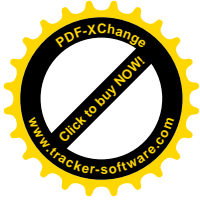


Two stage regulator

- The difference is that the total pressure decrease takes place in two steps instead of one, On the high-pressure side the pressure is reduced from cylinder pressure to intermediate pressure. On the low-pressure side the pressure is reduced from intermediate pressure to working pressure
- Because of the two-stage pressure control, the working pressure is held constant and pressure adjustments during welding operations are not required

Two stage regulator





Gas economizer

- It is used for saving Oxygen, fuel gas time and torch wears. It discontinues automatically the supply of oxygen and fuel gas to the torch when the torch is placed on the hook during the intervals between operations.
- The flame does not require re-setting on resuming operations. When the torch is unhooked, the full gas flow supply is released and the previous mixing ratio maintained.
- Absolutely necessary whenever work involves frequent temporary stoppages, this device is ideally suited to repetitive work on production lines, where efficiency, productivity and economy in gas consumption are needed.



Gas economizer





Safety devices

Check valve

- A check valve lets gas flow in one direction only. Not to be confused with a flashback arrestor, a check valve is not designed to block a shock wave. The pressure wave could occur while the ball is so far from the inlet that the pressure wave gets past before the ball reaches its off position. A check valve is usually a chamber containing a ball that is pressed against one end by a spring: gas flow one way pushes the ball out of the way, and no flow or flow the other way lets the spring push the ball into the inlet, blocking it.

Flash back arrester

- A flashback arrestor or flame arrestor is a device most commonly used in oxy-fuel welding and cutting to stop the flame from burning back up into the equipment and causing damage or explosions

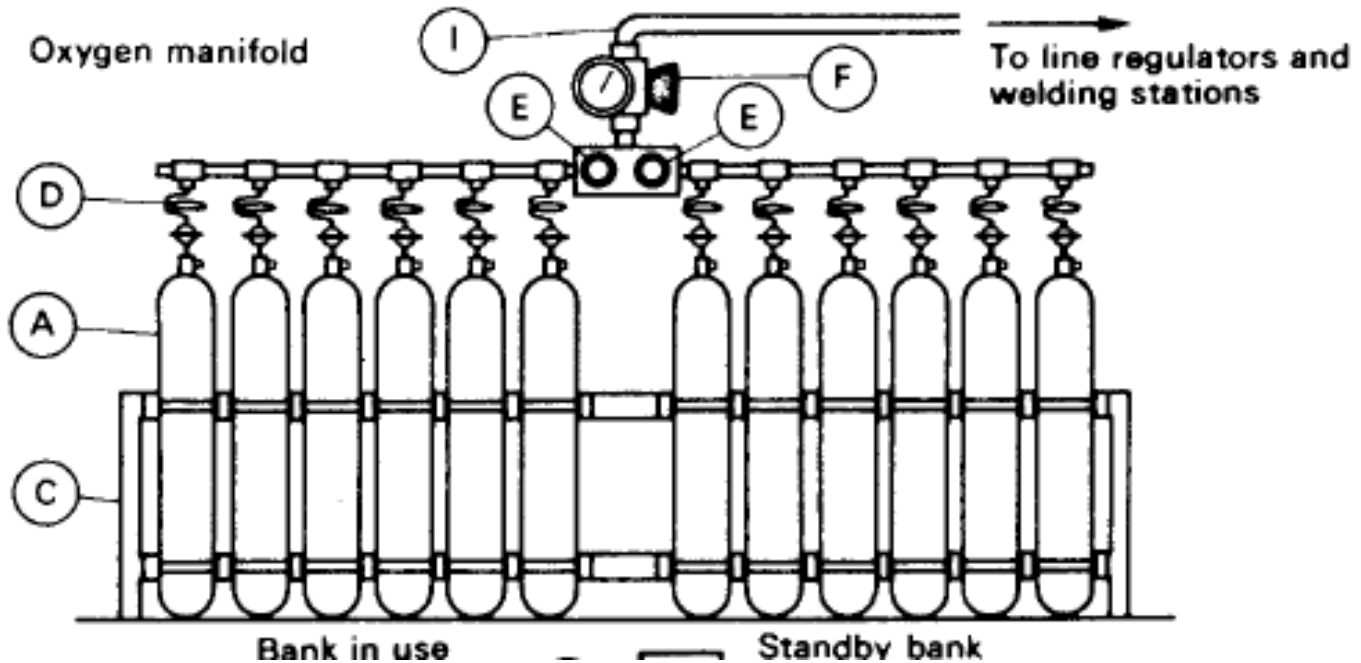




Manifold system

- In an industry where considerable gas welding is done and at several places or where rate of gas consumption is high, it is much advantageous to use a manifold system.
- In a manifold system, instead of having gas cylinders at each place of work, they are assembled at one centralised position in specially designed racks and connected by a manifold. The gas is then distributed by means of a pipeline to different workplaces.
- The manifold distributes welding gases at a reduced pressure. There are separate manifolds for oxygen and acetylene gas supplies. A manifold system for acetylene, an oxygen manifold system differs from it in the following ways:
 - There is no anti flashback device in an oxygen manifold system.
 - Oxygen supply line is a copper pipe whereas acetylene supply line is a steel pipe.
 - An oxygen pressure regulator is used in an oxygen manifold system

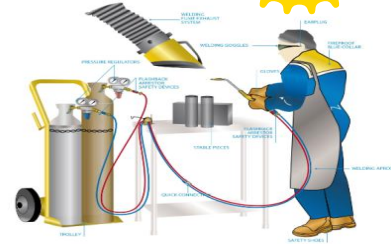
Manifold system



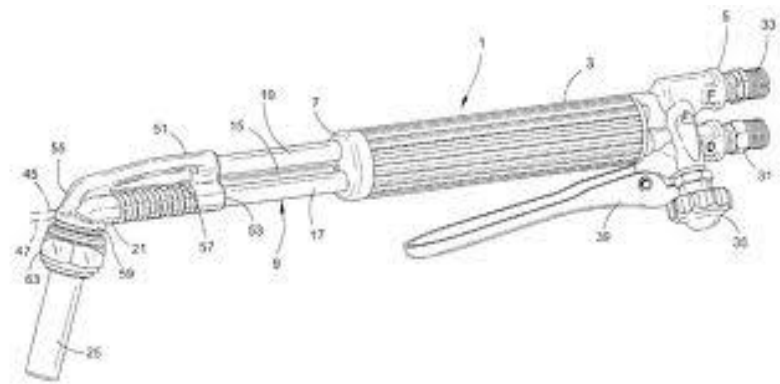


Torches

Correct and safe oxygas welding s



- Torches
 - Gas Welding
 - Gas Cutting





Welding

Module 19.2.4

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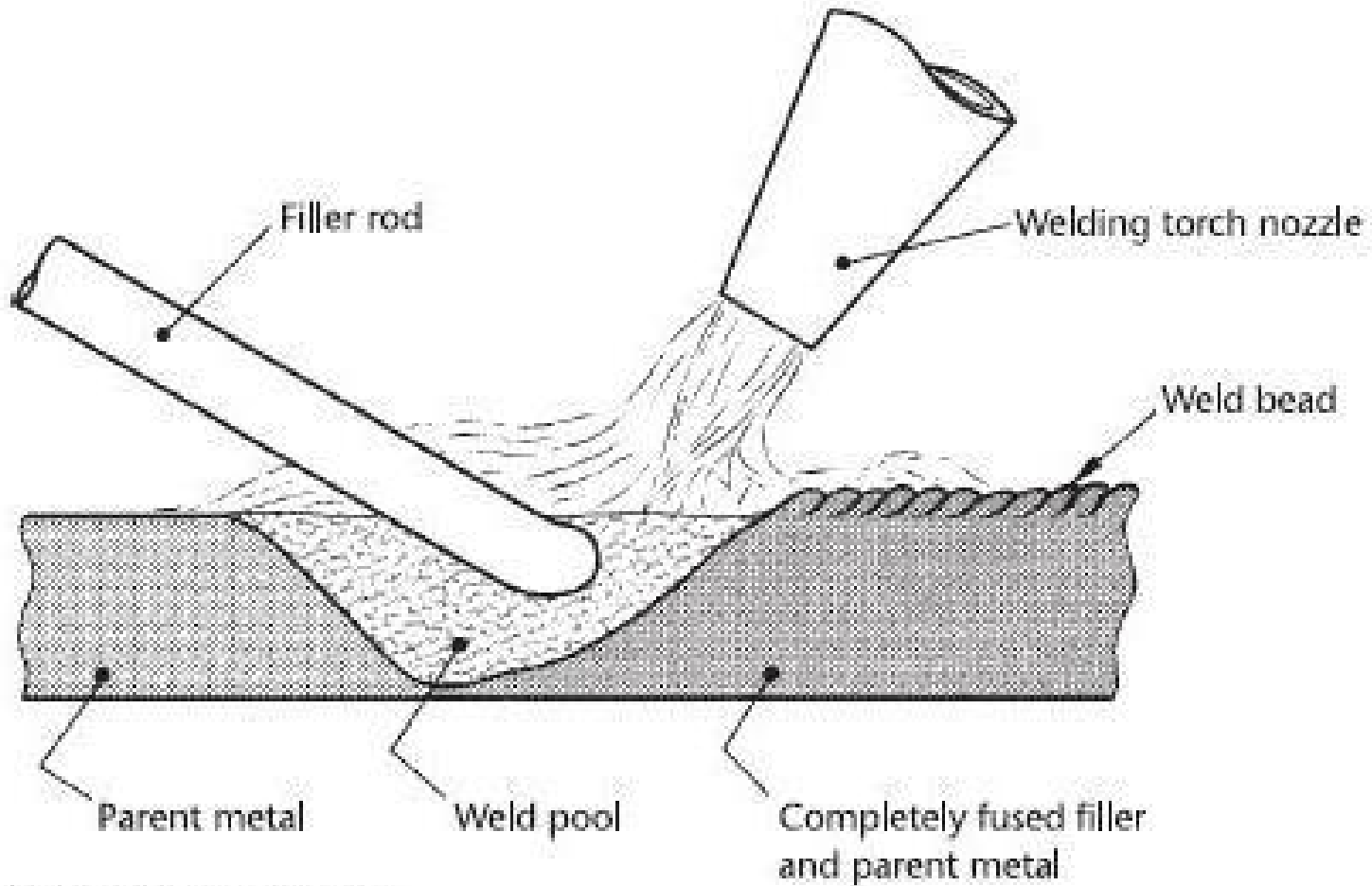
Module 19.2.4

Describe the oxy–fuel gas welding process.

Process: setting up the equipment, leak testing, oxy-fuel gas mixing, flame adjustment (including oxidizing, neutral and carburizing flames), melting parent and filler metals, fusion and solidification, shutting down procedure



The Process



(a) Oxy-acetylene welding



The Process

An oxy-fuel gas flame provides the heat required at a high enough temperature to melt most engineering materials in common use. The fuel-gas most widely used is acetylene and the process is then referred to as oxy-acetylene welding.

Acetylene is the most economical gas to use in conjunction with commercially pure oxygen supplied from high-pressure cylinders to give a flame with a maximum temperature of **3200°C**.



Setting up equipment



1. Attaching pressure-reducing regulators
 - a) Chain acetylene and oxygen cylinders in an upright position so they cannot be knocked or fall over.
 - a) Remove the protective caps from the oxygen and acetylene cylinders.
 - a) “Crack” the cylinder valves by opening the valve quickly, about one fourth turn, then close it immediately. This will clear the valve outlet of accumulated dust and dirt.



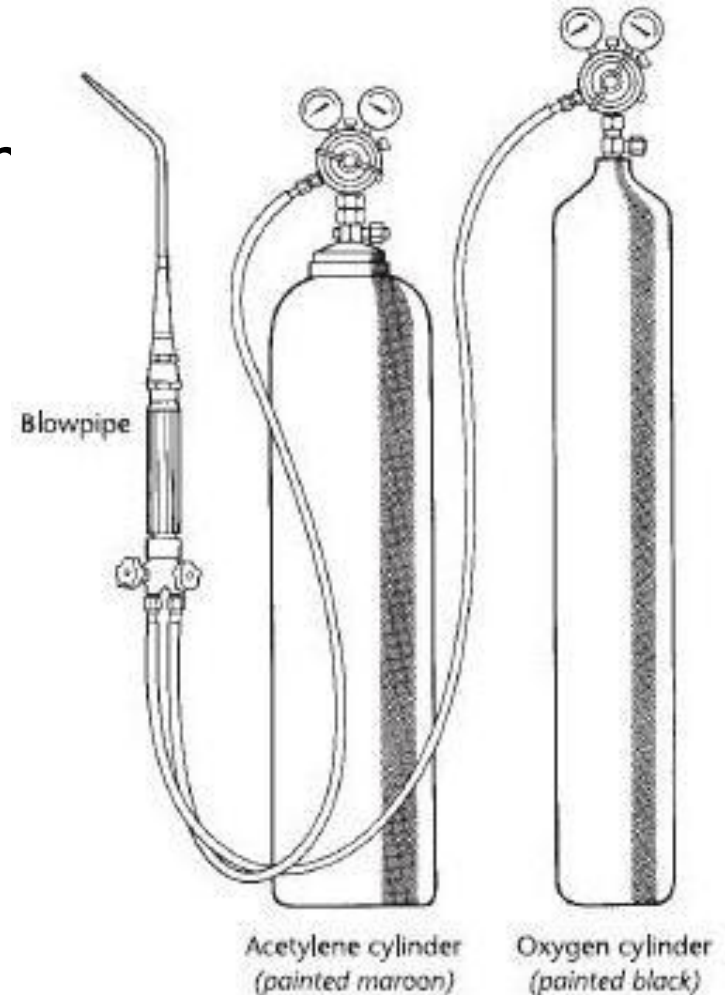
Setting up equipment



- d) Connect the oxygen regulator to the oxygen cylinder and the acetylene regulator to the acetylene cylinder; tighten securely.
- e) Turn the pressure-adjusting screw of each regulator to the left (counter-clockwise) until it rotates freely.
- f) Open the oxygen tank valve fully to prevent leaking around the valve stem. The oxygen tank valve is a double seated valve.
- g) Open each cylinder valve slowly. Always leave the wrench in place on the acetylene cylinder valve while the valve is open. Open the acetylene cylinder valve 3/4 of a turn to allow for fast turn-off if the need arises.

Setting up equipment

2. Connecting Gas supplies to torch
3. Adjusting operation pressures
4. Lighting and adjusting the flame





Leak Testing

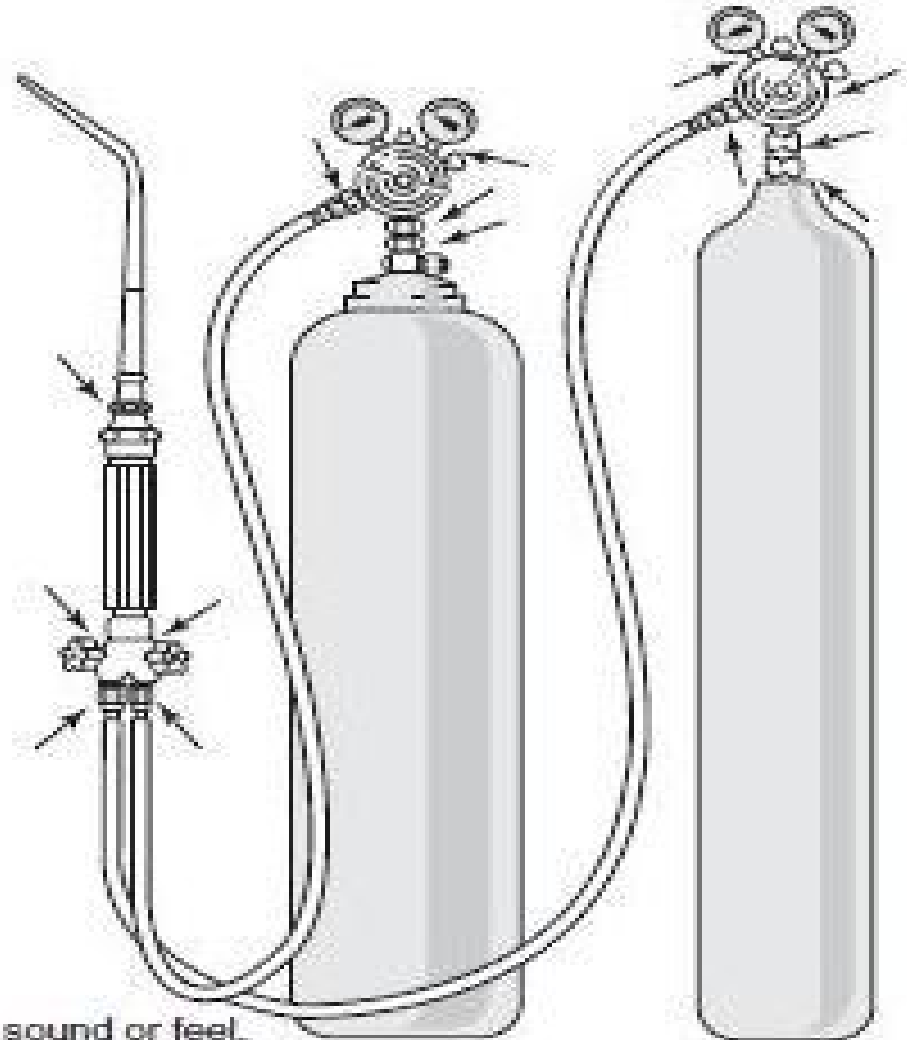
Never search for gas leaks with a flame. Oxygen is odorless and, whilst it does not burn, it speeds up the combustion process violently. Acetylene has an unmistakable, strong, garlic-like smell and can be readily ignited by a spark or even a piece of red-hot metal. The correct procedure for pressure testing is as follows:

1. Open the control valves on the torch.
2. Release the pressure-adjusting control on the regulators.
3. Open cylinder valves to turn on the gas.
4. Set the working pressure by adjusting the regulator controls.
5. Having established the correct pressure for each gas, close the control valves on the torch.
6. The system is now ready for leak testing as shown in next slide.

Leak Testing

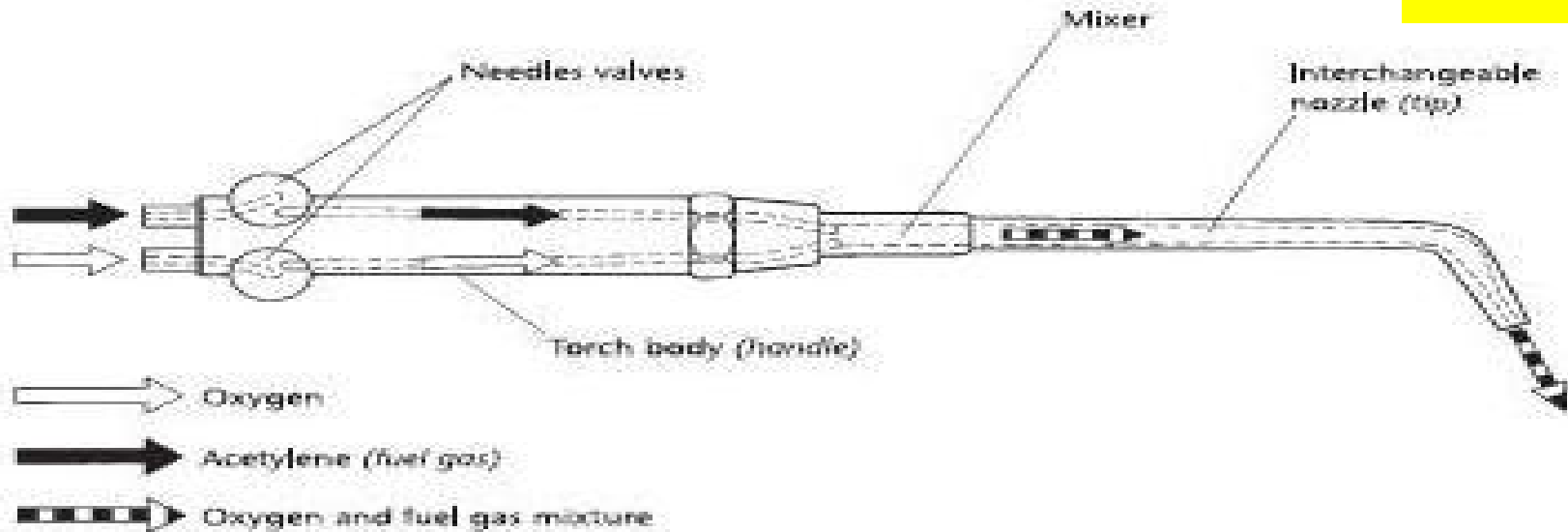


→ Places where leaks may occur

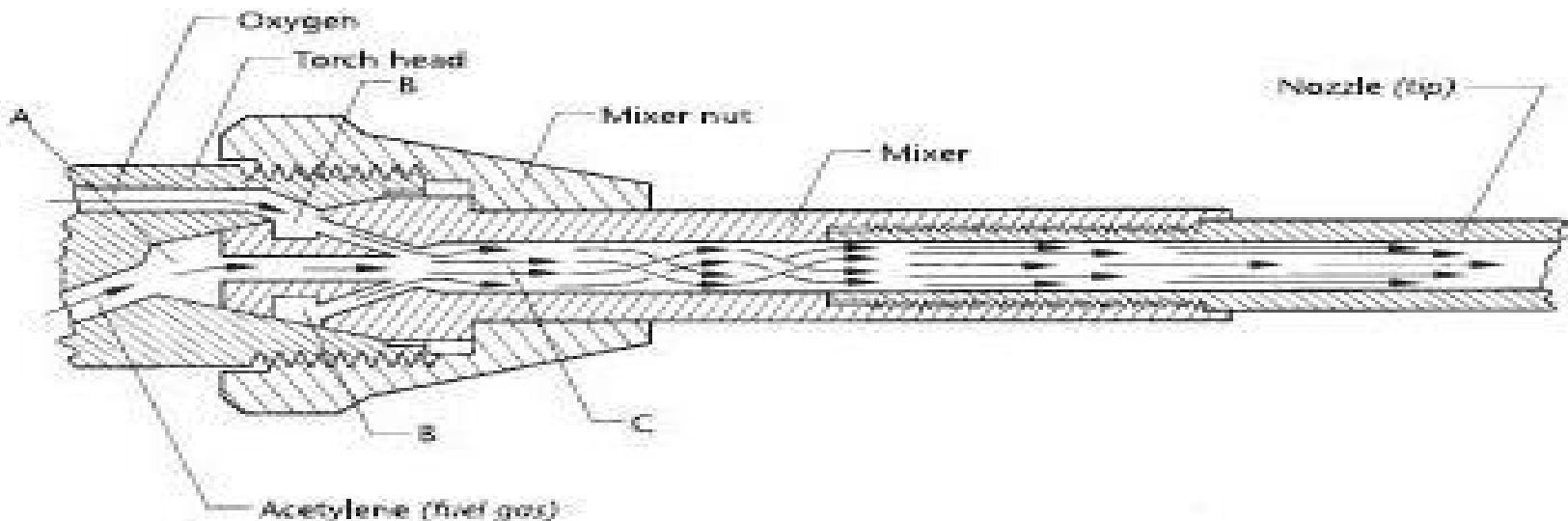


Escaping gases can be detected by sound or feel, or smell in the cases of ACETYLENE

Oxy-Fuel Gas Mixing



(a) High-pressure welding torch

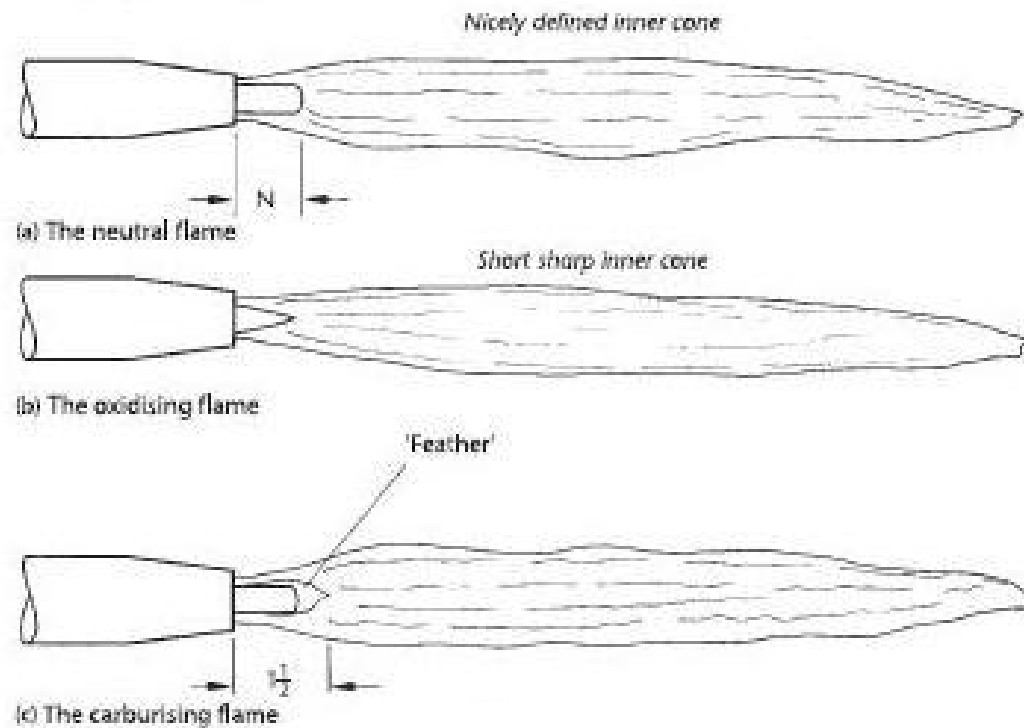


Flame Adjustment

The welding flame is produced by burning approximately equal volumes of **acetylene** and **oxygen** mixture at the nozzle of the welding torch.

There are THREE types of flames:

- a) Neutral Flame
- b) Oxidizing Flame
- c) Carburizing Flame





Flame Adjustment



❖ Neutral Flame:

For most welding applications the neutral flame condition is used. This is produced when approximately equal volumes of oxygen and acetylene are mixed in the welding torch. It is called a neutral flame because it does not cause any chemical change in the metals being joined.

❖ Oxidizing Flame:

The flame is first set to the neutral condition and the acetylene supply is slightly *reduced by the welding torch control valve*. The oxidizing flame is recognized by the shorter and sharply pointed inner cone and by a noisier (roaring) combustion process.

The oxidizing flame gives the highest temperature providing the oxygen: acetylene ratio does not exceed **1.5:1**.



Flame Adjustment



❖ Carburizing (Reducing) Flame:

When a reducing flame is required, the flame is first set to the neutral condition and the acetylene supply is slightly increased by the control valve on the welding torch. This flame is recognized by the ' feather ' of incandescent carbon particles between the inner cone and the outer envelope. A reducing flame is used for carburizing (surface-hardening) ferrous metals and when ' flame brazing ' aluminium and its alloys.



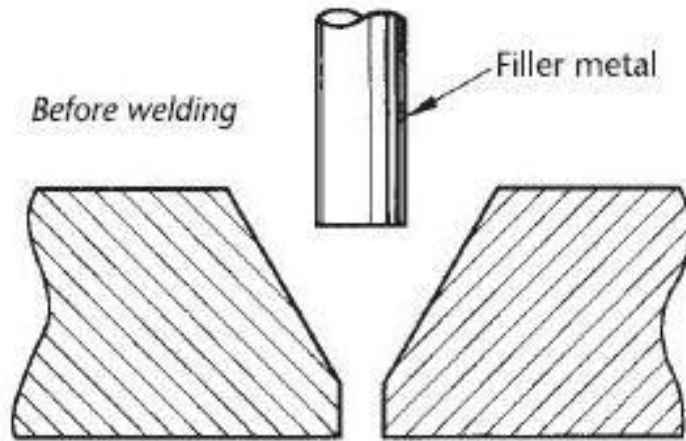
Fusion & Solidification



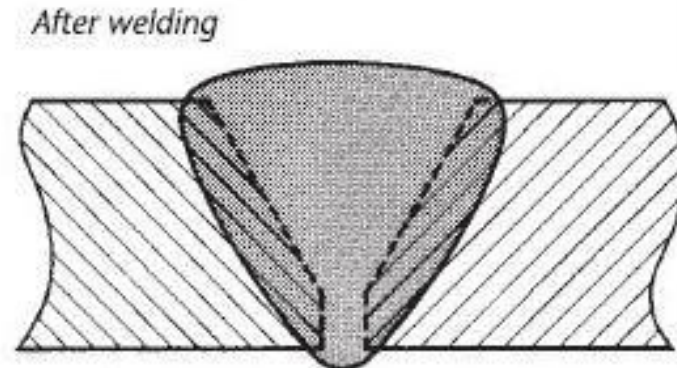
- ✓ Full fusion welding, as the name implies, is a thermal joining process in which the edges of the parent metal to be joined are melted and caused to fuse together with or without the use of a filler material.
- ✓ The basic principle of fusion welding outlines two typical joint configurations: one using a separate filler rod and the other self-supplying and not needing a filler rod.
- ✓ The filler rod is a thin steel rod or wire of similar composition to the parent metals being joined.
- ✓ Filler rods are usually copper plated so that they do not rust.



Fusion & Solidification



SINGLE VEE BUTT requires extra metal.



The edges of vee are melted and fused together with the molten filler metal.



Shutting Down



1. First close the acetylene torch valve, then close the oxygen valve. Closing the acetylene valve first reduces the chance of allowing unburned fuel gas to escape and be ignited accidentally.
2. Close both cylinder valves, then open the acetylene and oxygen valves on the torch body, one at a time. Allow the gas in each line to escape and see the line pressures go to zero on the regulator gauge.
3. Close the acetylene and oxygen torch valves after the gas in each line has been released. This is to prevent the reverse flow of gas into an opposite line.
4. Release the line pressure-adjusting screws on the acetylene and oxygen regulators.



Welding

Module 19.2.5

Prepared by:

Syed Farwad



Module 19.2.1

Describe the oxy–fuel gas cutting process.

Process: exothermic reaction (i.e. metals cut, limitations), lighting, adjusting and extinguishing the flame, factors influencing the quality of cut, applications, freehand cutting (i.e. cutting from an edge of plate, inside from the edge, sections, round bar), guided hand cutting (i.e. bevel cutting, circle cutting guides, spade or wheel guides)

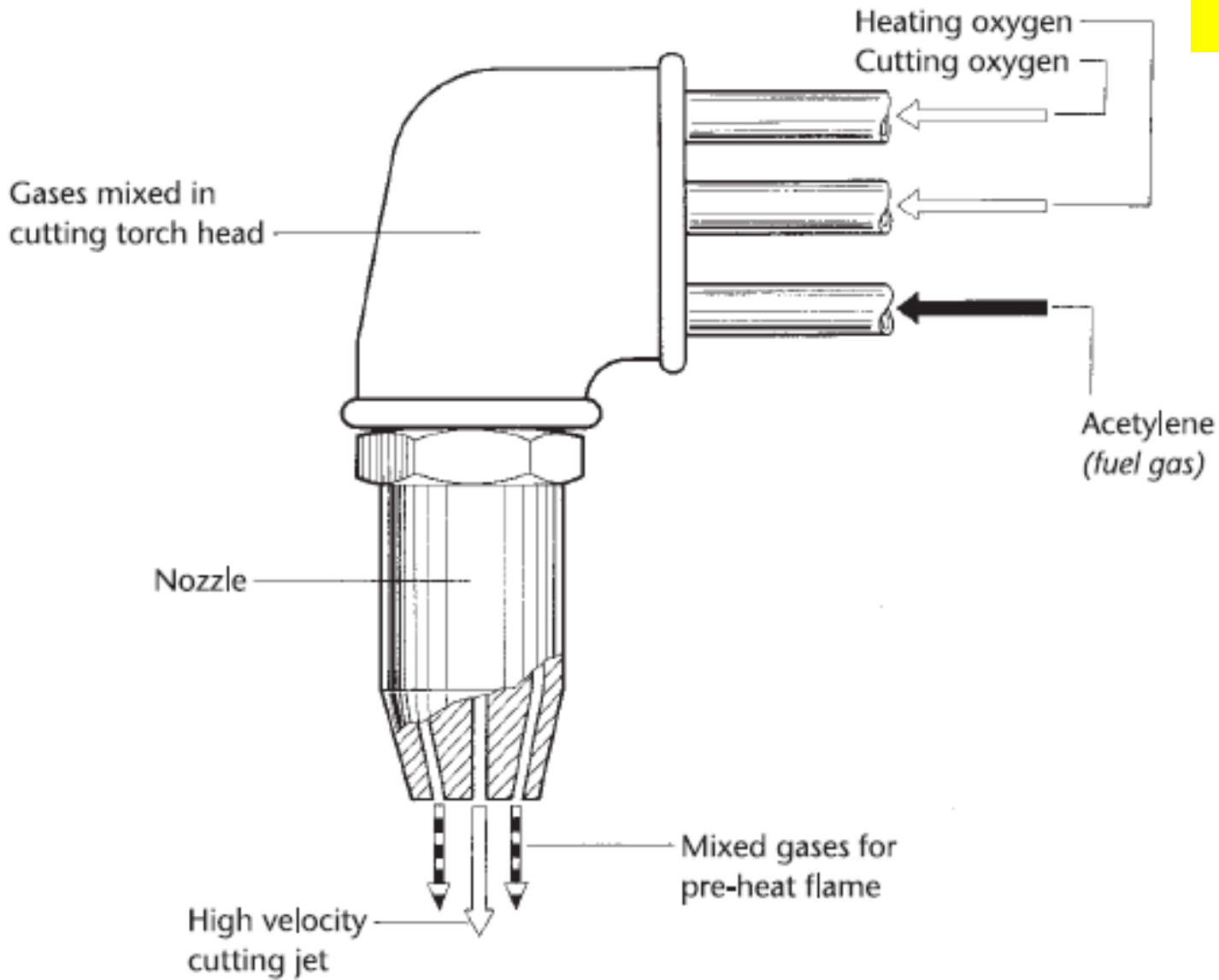


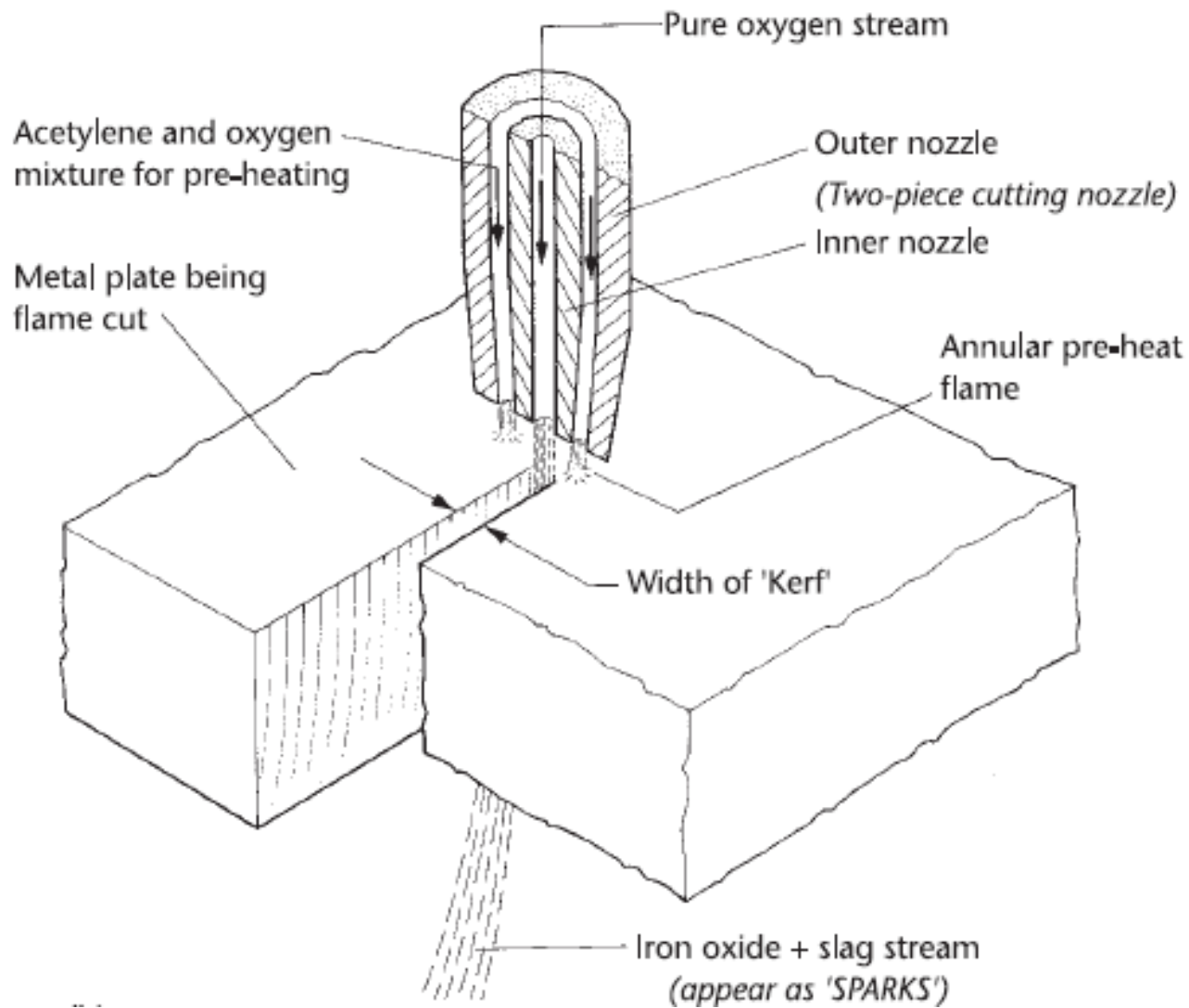
Applications

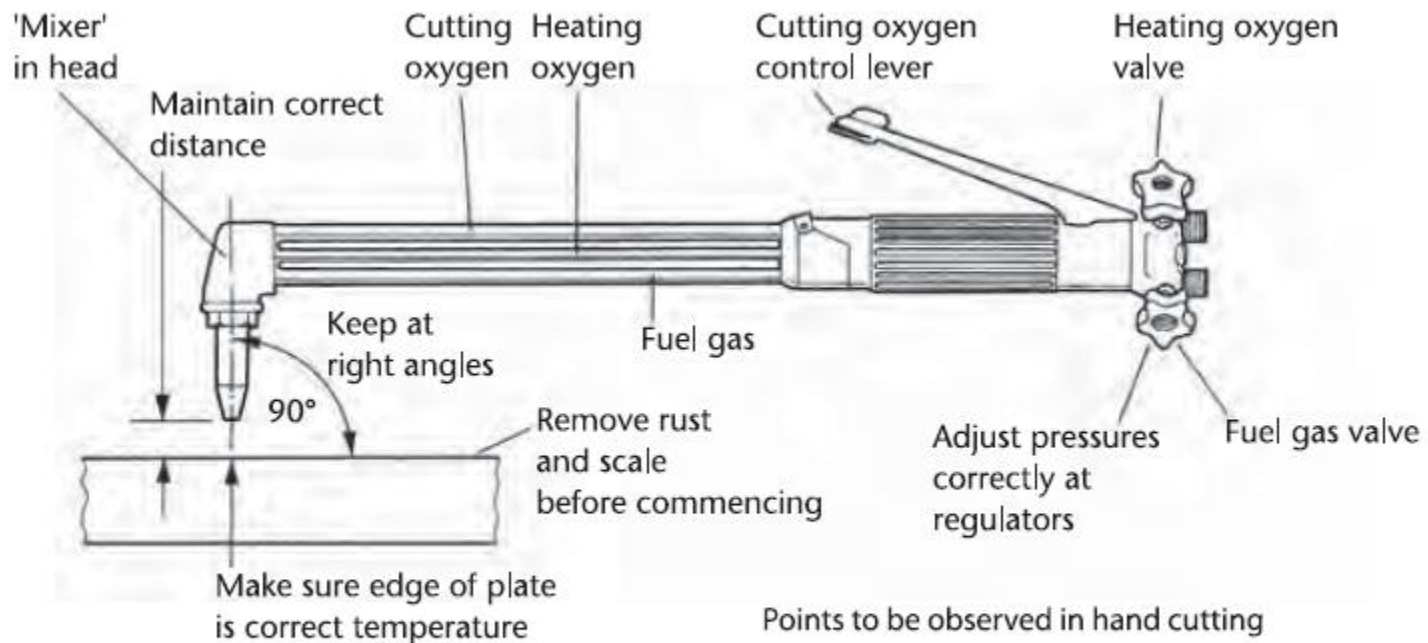


Flame-cutting is used for cutting thick plate and structural sections. It can only be used for cutting ferrous metals since the process depends upon a chemical reaction between the hot steel and a stream of high-pressure oxygen.

Despite its appearance a set of flame-cutting equipment is *not the same as welding equipment although* it looks similar.







(a)

The size of the torch used depends upon whether it is for light duty or heavy continuous cutting and the volume of oxygen used is much greater than that of fuel gas (measured in LITRES PER HOUR)



Exothermic Reaction



A chemical reaction that generates heat.



Process

A typical cutting provides a ring of flames to preheat the metal being cut to **870–900°C (red heat)**. When the metal reaches this ignition temperature, a powerful jet of pure oxygen is released into the centre of the preheated area. This initiates an ***exothermic reaction*** *between the hot steel and the oxygen jet*. The steel immediately below the oxygen jet is converted into *metal oxides or slag*. *These oxides are blown away by the jet of oxygen in a shower of sparks*. If the jet is not powerful enough or the speed of cutting is too quick the slag will solidify in the cut and the cut will not be achieved. This oxidizing reaction helps to heat up the metal being cut and the process becomes continuous. The cutting torch is then moved forward along the line of the cut.



Lighting & Adjusting Flame



- a. Open the acetylene torch valve about one-fourth turn.
- b. Immediately light the flame with a friction lighter. **NEVER USE A MATCH OR FLAMMABLE LIGHTER.**
- c. Adjust the acetylene flow, by turning the torch acetylene valve, until the flame just starts to produce black smoke around its edges; then increase acetylene flow just enough to get rid of the black smoke. Another method is to open the acetylene valve until the flame leave the end of the tip then reduce the acetylene flow until the flame comes back to the tip.
- d. Open the oxygen torch valve slowly until the desired flame is obtained. The point at which the feather and the inner cone come together is the neutral flame. The carburizing flame is the flame reached before reaching the neutral flame. An oxidizing flame is one which has excess oxygen beyond the neutral flame.



Shutting Down



1. First close the acetylene torch valve, then close the oxygen valve. Closing the acetylene valve first reduces the chance of allowing unburned fuel gas to escape and be ignited accidentally.
2. Close both cylinder valves, then open the acetylene and oxygen valves on the torch body, one at a time. Allow the gas in each line to escape and see the line pressures go to zero on the regulator gauge.
3. Close the acetylene and oxygen torch valves after the gas in each line has been released. This is to prevent the reverse flow of gas into an opposite line.
4. Release the line pressure-adjusting screws on the acetylene and oxygen regulators.



Freehand Cutting



It takes a fair amount of skill to maintain a constant rate of travel over the work. The general quality of cut produced with a hand-held cutting torch is therefore usually inferior to the quality of cut made with a correctly adjusted cutting machine.

Cutting guides can help to keep the torch on the correct line of cut. A roller attachment can be used to maintain the correct nozzle-to-work distance.

Stack cutting can be used to cut more than one plate at once, if the same shape is required



Guided Cutting

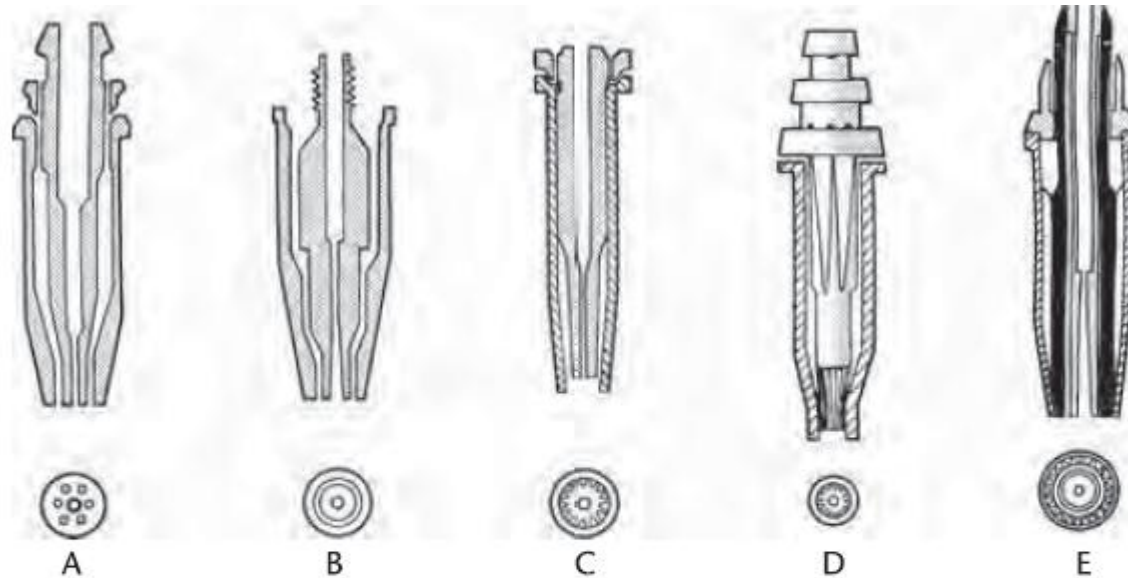
Below are some useful attachments which, when fitted to the hand-held cutting torch, ensure a steady rate of travel and enable the operator to execute straight lines, bevels and circles with relative ease.

- Single cutting support
- Circle cutting device (small diameter)
- Circle cutting device (large diameter)



Constituents of steel that affect oxygen cutting

Alloying element	Range for good cutting	Comments
Carbon	up to 0.25%	Above 0.25% carbon preheating over a wide area of 250–300°C may be necessary
Manganese	up to 14%	Cutting is difficult above 14% and will need extra pre-heat
Chromium	up to 1.5%, but cutting speeds will be lower	Chromium at 1.5% to 5% requires extra pre-heat. Above 5% process is not recommended
Nickel	up to 3%	Between 3% and 7% requires additional pre-heat. Above 7% process not recommended
Molybdenum	up to 1.5%	Molybdenum at 1.5% to 5% requires extra pre-heat. Above 5% process is not recommended

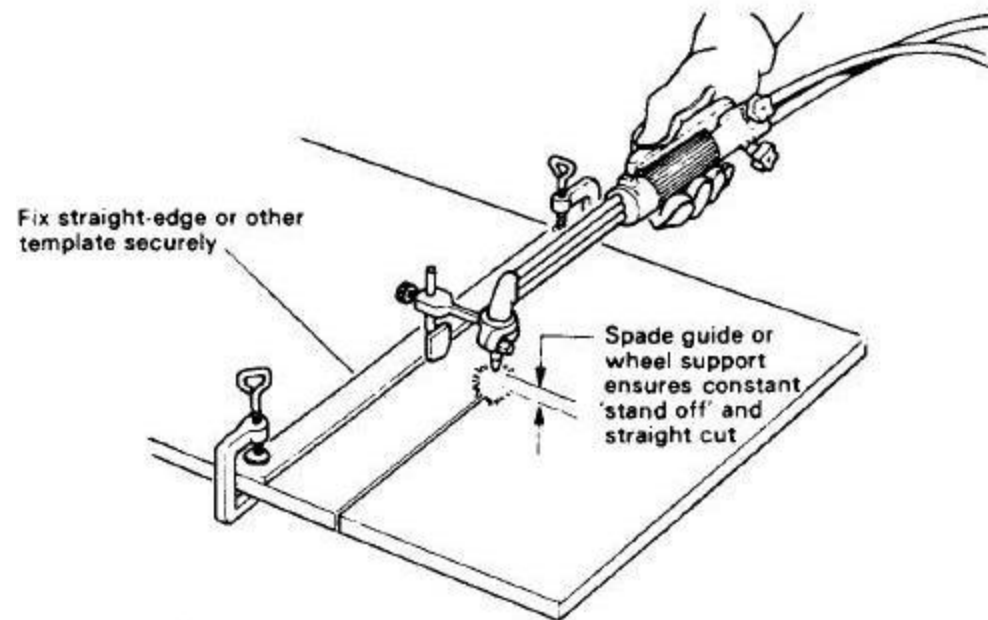


- A One-piece ACETYLENE cutting nozzle – parallel bore, 3 – 9 pre-heat holes, no skirt
- B Two-piece ACETYLENE cutting nozzle – venturi bore, pre-heat annulus, no skirt
- C Two-piece NATURAL GAS nozzle – venturi bore, pre-heat flutes, long skirt
- D Two-piece PROPANE nozzle – parallel bore, pre-heat slots, long skirt
- E Two-piece PROPANE nozzle – parallel bore, pre-heat flutes, long skirt, oxygen curtain



Single cutting support

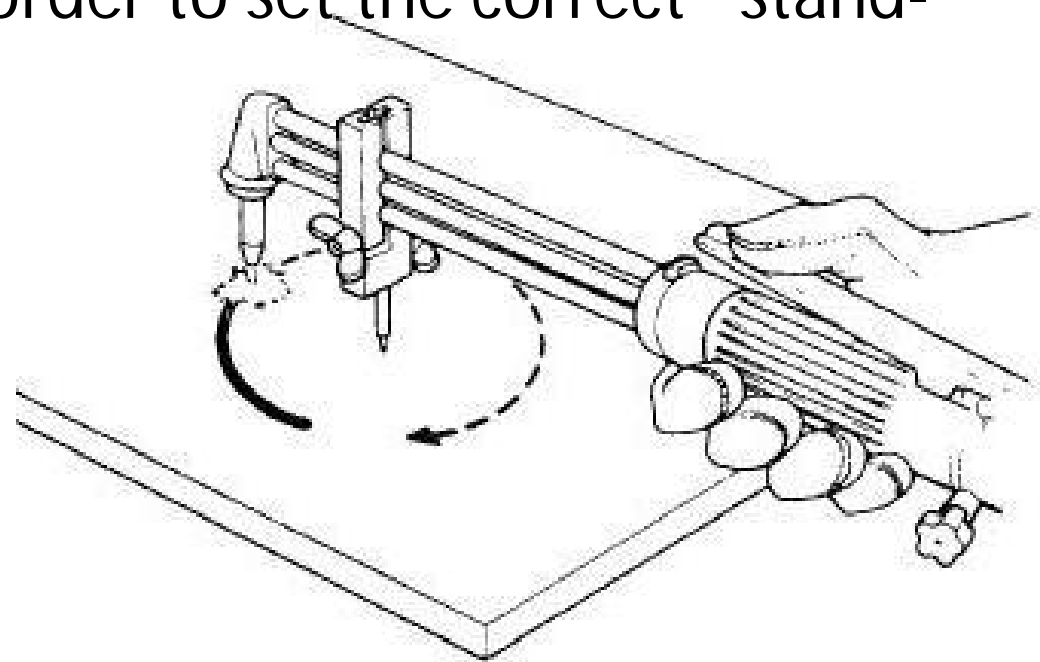
This simple device may either be a ' spade-type ' support or a single ' roller guide ' which can be adjusted vertically to give the correct ' stand-off '. Figure shows a single roller guide supporting the cutting torch at the correct height above the work and guiding it by means of a straight-edge clamped to the work-piece.





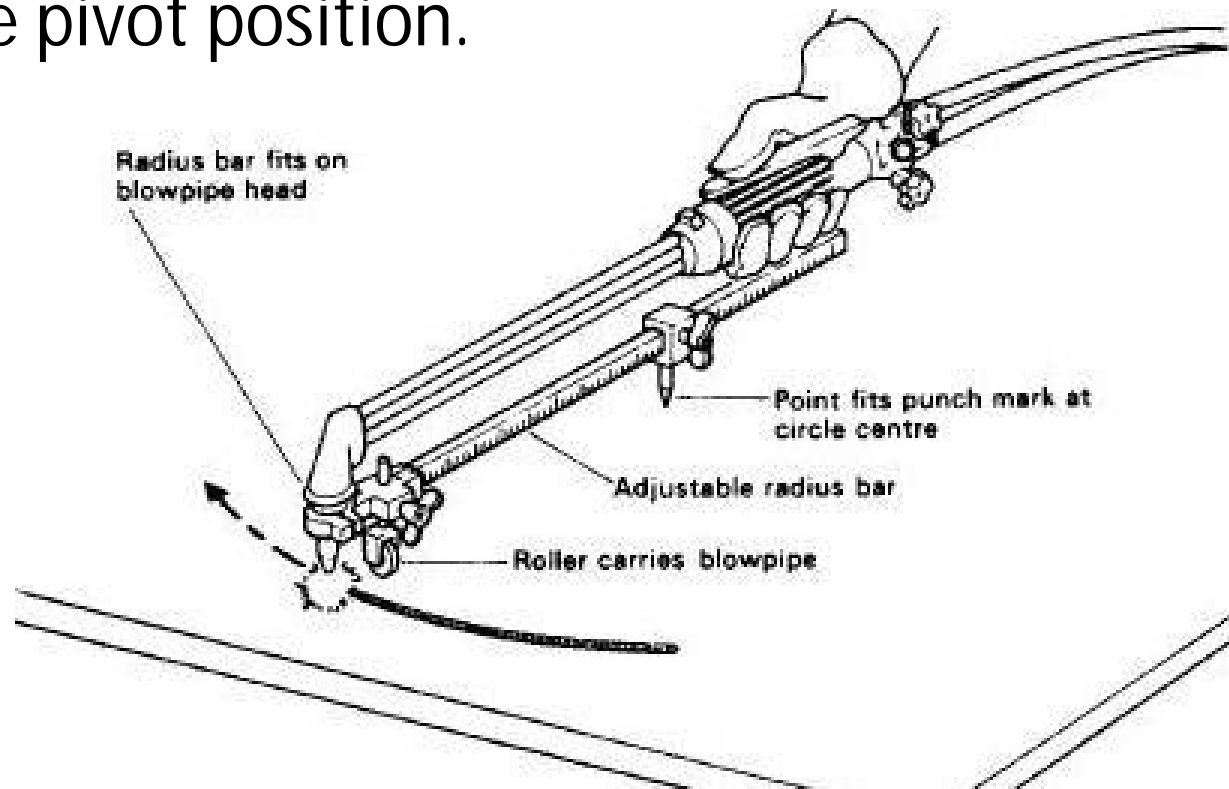
Circle Cutting Device (small diameter)

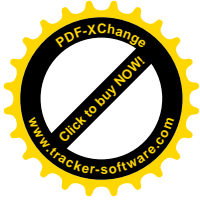
This is simply a pivot which is attached to the shank of the torch at the required distance from the nozzle according to the radius required. The point of the pivot is located in a centre punch mark as shown in Figure. Vertical adjustment is provided in order to set the correct 'stand-off'.



Circle Cutting Device (large diameter)

An example of a large-circle cutting attachment is shown in below Figure. This is similar to the small-diameter-circle cutting device except that it has a graduated radius bar to facilitate setting the pivot position.





Welding

Module 19.2.6

Prepared by:

Syed Fawwad

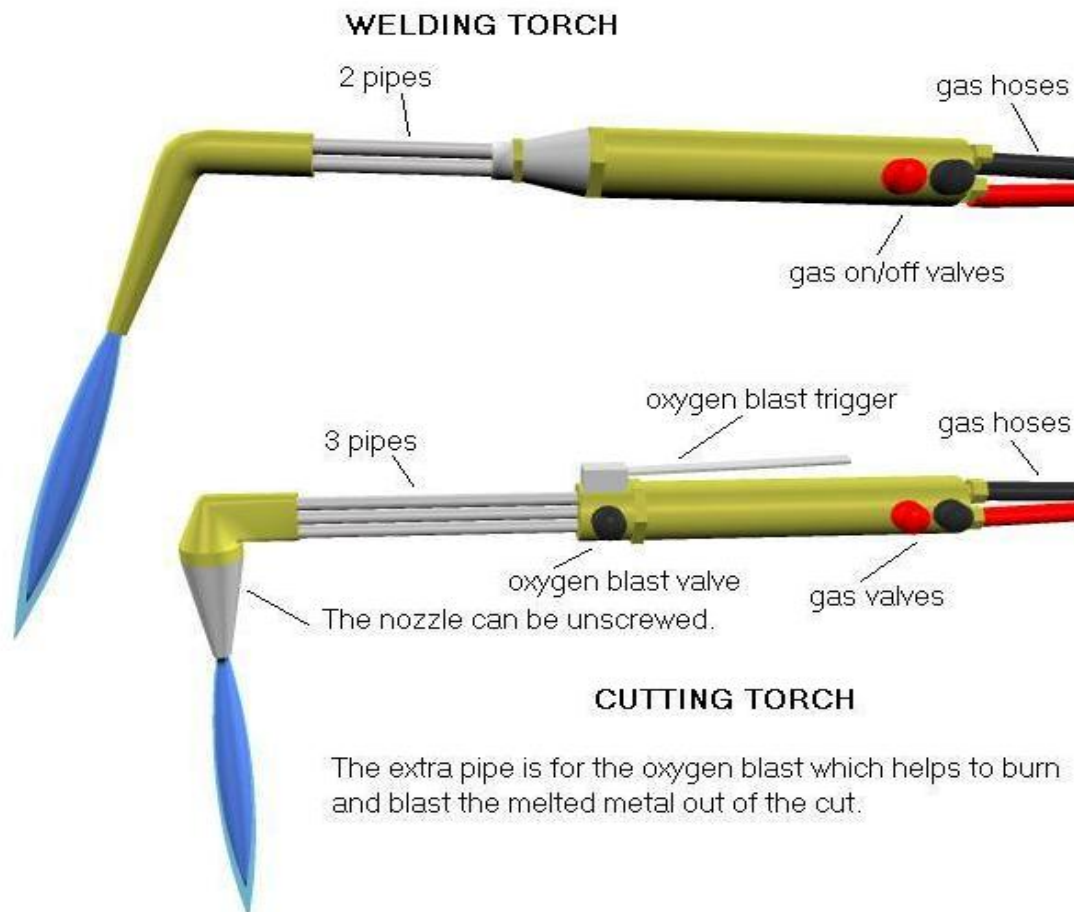


Module Objective

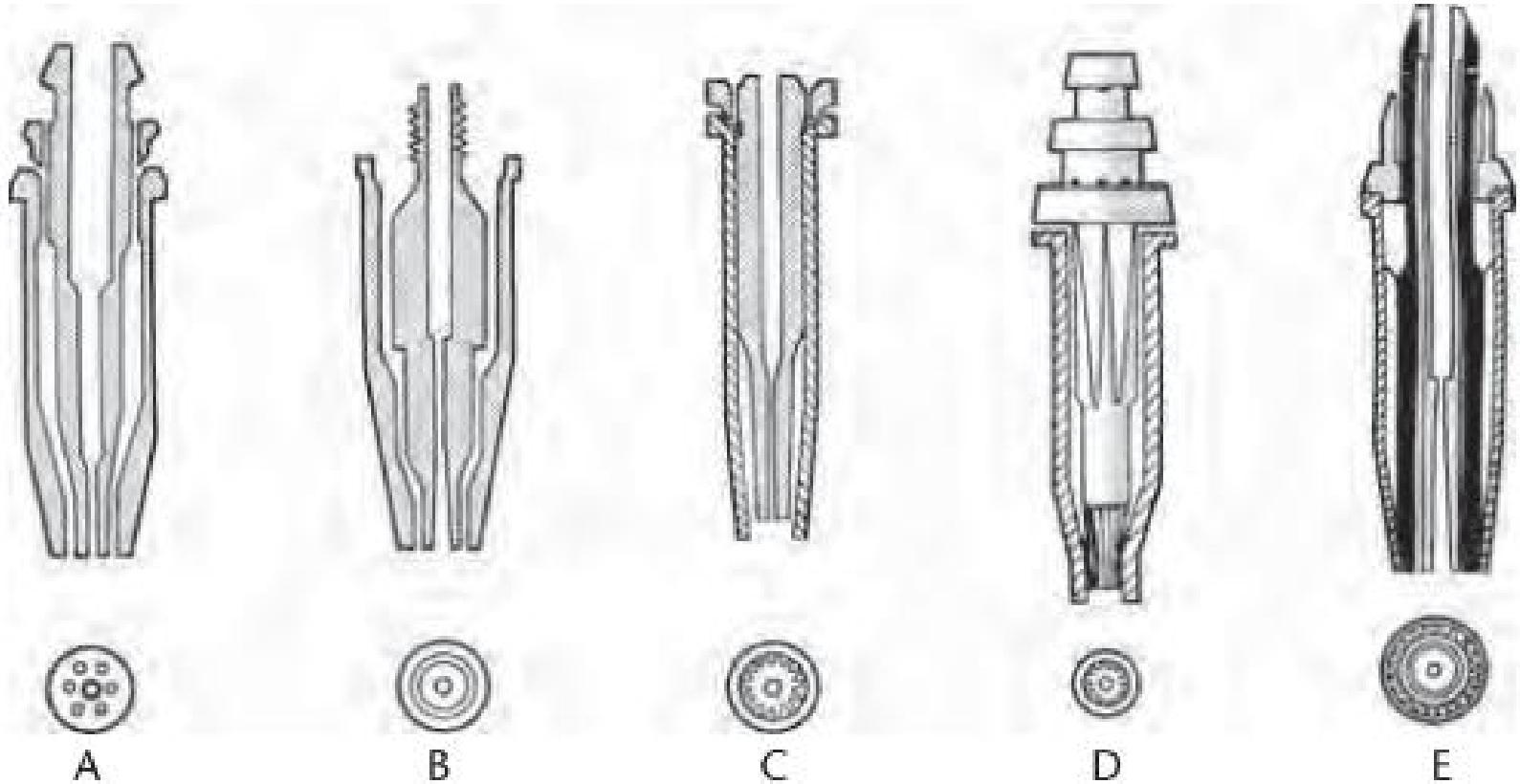
- Describe the oxy-fuel gas cutting and ancillary equipment.
 - Equipment: blow pipes (e.g. arrangements of the mixing of oxygen and fuel gas), construction and application of typical cutting nozzles, hoses (e.g. connections, safety devices, identification), pressure gauges and regulators, gases (e.g. acetylene, propane, hydrogen, oxygen) flame temperature, relative cutting speed, operating costs, cylinder identification

Blow pipes

- Cutting torch is also referred as blow pipe inside which the mixing of two gases takes place.



Construction of nozzles



- A One-piece ACETYLENE cutting nozzle – parallel bore, 3 – 9 pre-heat holes, no skirt
- B Two-piece ACETYLENE cutting nozzle – venturi bore, pre-heat annulus, no skirt
- C Two-piece NATURAL GAS nozzle – venturi bore, pre-heat flutes, long skirt
- D Two-piece PROPANE nozzle – parallel bore, pre-heat slots, long skirt
- E Two-piece PROPANE nozzle – parallel bore, pre-heat flutes, long skirt, oxygen curtain



- Hoses, safety devices, pressure gauges & regulators have already been done in previous module..





Fuel Gases

- Although the ignition temperature is dependent on the composition of the steel being cut, the choice of fuel gas has an effect on how quickly the flame will raise the material to the ignition temperature.
- The higher flame temperature of oxy-acetylene (3160°C) compared with oxy-propane (2828°C) will mean that if oxy-acetylene is used then cutting would commence sooner than for oxy-propane. The thicker the material being cut, the more pronounced this effect becomes. However, acetylene is more costly than propane.



Cont'd

- Various fuel gases such as acetylene, propane, mixed gases (MAPP) and natural gas may be used in conjunction with oxygen for cutting
- Characteristics of fuel gases used when oxygen cutting

	Acetylene C ₂ H ₂	Propane C ₃ H ₈	MAPP C ₃ H ₄
Ratio fuel to oxygen	1:1.1	1:3.75	1:2.5
Max. flame temperature (°C)	3160	2828	2976
Heat distribution to primary flame (kJ/m ³)	18890	10433	15445
Heat distribution to secondary flame (kJ/m ³)	39882	85325	56431
Calorific value of flame (kJ/m ³)	54772	95758	71876



Acetylene

- Highest flame temperature so preheat time is shorter of any of the fuel gas
- Heating area is localized which prevents against distortion
- Acetylene also tends to produce cuts with much smaller and less pronounced drag lines on the surface.

- Propane

- Propane is cheaper than acetylene and easier to transport
- Propane does not burn as hot as acetylene in its inner cone, and so it is rarely used
- The main advantage of propane is that most of its heat energy is concentrated in the outer or secondary envelope of the flame
- it does mean that it is less sensitive to the distance between the end of the nozzle and the work piece



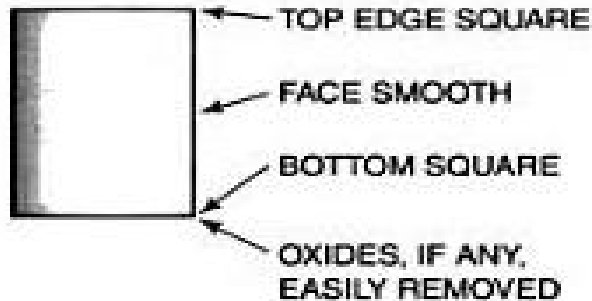
MAPP



- As MAPP is a mixture of several fuel gases including propane and methyl acetylene it combines the properties of both gases
 - One niche area where MAPP is widely used is underwater cutting, where its stability allows for a greater outlet pressure than would be safe with acetylene alone.
 - Acetylene cannot be used below about 10 m of water, whereas MAPP can be used at much greater operational depths
- Natural Gas
 - Easily available in bulk supply
 - Cheapest fuel gas and also requires the least amount of oxygen
 - Natural gas has the lowest flame temperature (2786°C) and the lowest calorific value of all the fuel gases

Effect of different parameters

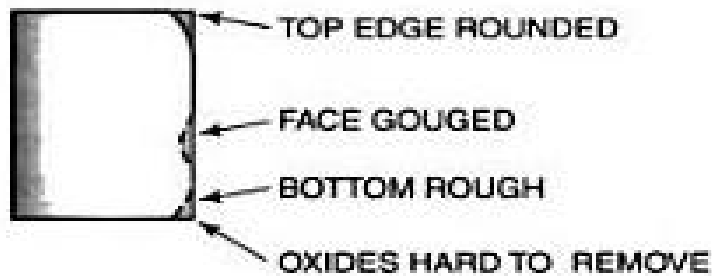
CORRECT CUT



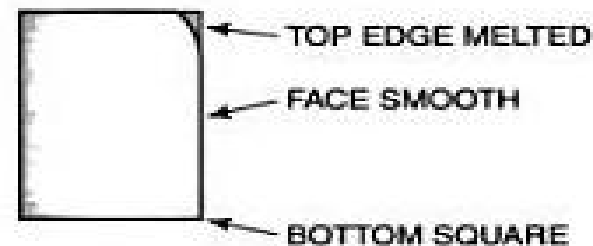
PREHEAT FLAMES TOO HIGH ABOVE THE SURFACE



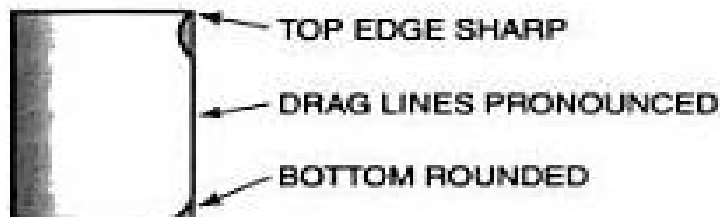
TRAVEL SPEED TOO SLOW



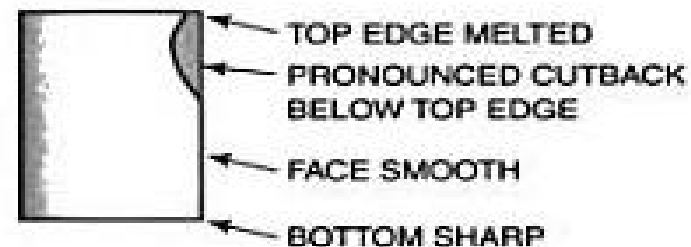
PREHEAT FLAMES TOO CLOSE TO THE SURFACE



TRAVEL SPEED TOO FAST



CUTTING OXYGEN PRESSURE TOO HIGH





Welding

Module 19.2.7

*Prepared By:
Syed Fawwad AShraf*



Module objective

- Describe potential safety hazards associated with oxy-fuel gas welding and cutting. State precautions which should be taken.
 - Potential hazards: protective clothing and equipment, fire risks, adequate ventilation, working in confined spaces (ie ventilation, fumes, fire, explosive risk), precautions in the use of compressed gas cylinders (ie storage in well ventilated area, correct identification of gases (BS colour coding), careful handling and transportation, security/anchorage of cylinders in use, located away from sources of heat and arc welding equipment, oxygen cylinder free of oil and grease, procedure to be taken in the event of cylinder overheating, backfire or flashback



Safety

- Oxyacetylene welding/cutting is not difficult, but there are a good number of subtle safety points that should be learned such as:
- More than 1/7 the capacity of the cylinder should not be used per hour. This causes the acetone inside the acetylene cylinder to come out of the cylinder and contaminate the hose and possibly the torch.
- Acetylene is dangerous above 15 psi pressure. It is unstable and explosively decomposes.
- Proper ventilation when welding will help to avoid large chemical exposure.



Potential hazards

- Some of the main potential hazards includes
 - Particulate and gaseous fumes.
 - Burns caused by the high levels of heat produced by the process.
 - Burns caused by metal ejected from the process.
 - Potential asphyxiation if work is carried out in a confined space.
 - Oxygen enrichment in a confined space.
 - Fire hazards due to the flammability of the fuel gases employed.



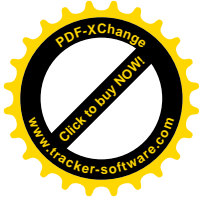
Production of fumes



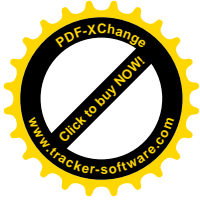
- The main safety issue when oxygen cutting is the production of fumes; especially when cutting paint-coated or galvanized surfaces. Zinc fumes can cause metal fume fever
- Therefore, it is necessary to ensure there is an adequate fume extraction in operation
- Adequate ventilation. Ventilate as needed to prevent harmful accumulations of fumes and smoke that may be produced by welding cutting. Consult for detailed ventilation requirements.
- NEVER USE OXYGEN TO VENTILATE THE WORK AREA.
- Lead-, Cadmium-, Zinc-, Mercury and Beryllium-bearing and similar materials, when welded (or cut) may produce harmful concentrations of toxic fumes. Adequate local exhaust ventilation must be used, or each person in the area as well as the operator must wear an air-supplied respirators



Burns



- Due to the high flame temperature hazard of burn is always there. To prevent burns we should use:
 - Wear Protective clothing – gauntlet gloves, hat, and high safety toe shoes. Keep shirt collar and pocket flaps buttoned and wear cuffless trousers to prevent entry of sparks and slag.
 - Do not wear oily or greasy clothing while welding or cutting. They are readily ignited by sparks.
 - Wear safety goggles or glasses
 - Hot metal such as welding rod, electrode stubs and work pieces should never be handled without gloves



Working in confined space

- Work in a confined space only while it's being ventilated, or when wearing an air-supplied respirator. Do NOT use oxygen for ventilation
- Gas leaks in a confined space, shut OFF gas supply at source and remove the welding and cutting equipment to avoid accidental release of gases into the space should down stream valves be opened inadvertently or closed improperly.
- A person must be present outside when working in confined spaces.



Prevention from fire & explosion



- Keep equipment clean and operable, free of oil, grease, and (in electrical parts) of metallic particles that can cause short circuits
- If combustibles are in area, do NOT weld or cut. Move the work, if practical, to an area free of combustibles. Avoid paint spray rooms, dip tanks, storage areas, ventilators
- Explosive atmospheres. Never weld or cut where the air may contain flammable dust, gas, or liquid vapors (such as gasoline)
- Never connect a regulator to a cylinder containing gas other than that for which the regulator was designed.



Cylinder safety

- Cylinders must be handled carefully to prevent leaks and damages to their walls, valves, or safety devices
- Prohibited use. Never use a cylinder or its contents for other than its intended use
- Secure from falling. Always chain or secure cylinders upright when a regulator (and hose) are connected to it.
- Passageways and work areas. Keep cylinders clear of areas where they may be struck or knocked over.
- Transporting cylinders. With a crane, use a secure support such as a platform or cradle designed for the purpose. Do NOT lift cylinders off the ground by their valves or caps, or by chains, slings, or magnets



Back fire

- A backfire is a loud noise produced by the explosion of gases at the cutting or welding tip usually following a minor flashback of the flame, extinguishment, and re-ignition at the tip. Repeated backfire can cause tip to overheat and eventually cause a sustained flashback. Causes are:
 - Bringing tip too close to work or touching it.
 - Foreign particles entering tip and impeding gas flow.
 - Overheated tip, such as caused by working in corners.
 - Trying to operate with incorrect or too low a gas flow



Back fire remedy

- If torch does not stay lit, close oxygen gas and fuel gas valves in that order. Relight fuel gas with spark lighter only, NOT MATCHES OR CIGARETTE LIGHTER, and, NOT over hot work. If stable flame is not obtained by adding oxygen, close torch valves, check tip cleanliness and regulator settings, purge, and relight



Flash back



- A flashback is a burning back of the flame into the tip, or into or through the torch. It is also called a sustained burning in tip or torch. A flash back can be caused by faulty or misused equipment. If it doesn't cause fire or hose rupture, then it may produce a hissing or squealing due to burning inside torch or tip (usually at the mixer). Examples of faulty or misused equipment are:
 - Failure to purge.
 - Incorrect pressures.
 - Distorted or loose tips or adapter seats.
 - damaged hoses.
 - Clogged tip or torch orifices.
 - Overheated tip or torch



To stop flash back



- Do NOT touch any parts of the tip, mixer, or extension that may be hot
- When squealing sound is heard: the internal combustion must be extinguished immediately by shutting off torch fuel gas and oxygen valves in that order. Wait a MOMENT, OR UNTIL NO SQUEALING (loud noise) is heard on reopening fuel gas valve, then relight.
- When squealing is not heard (and flashback is indicated by flow of hot gases from tip): flame is inside the torch. Immediately shut off cylinder valves and wait. After five minutes, if torch, regulator, and cylinder are cool, disconnect equipment and inspect torch and regulator for inner damage.



Welding

Module 19.2.8

*Prepared By:
Syed Fawwad AShraf*

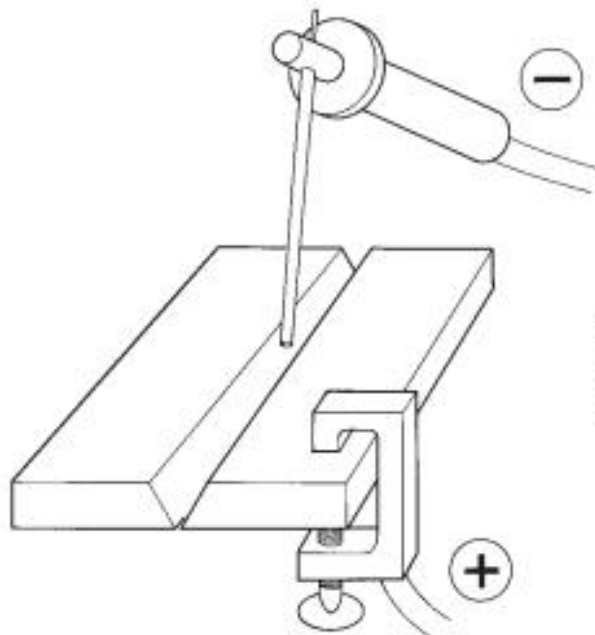


Welding with DC supply

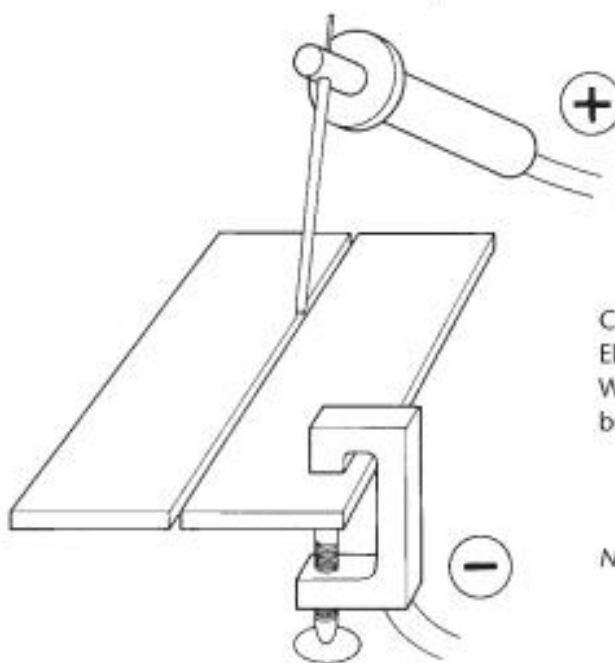


- With a direct current the electron current always flows in the same direction . This causes the positive pole to become hotter than the negative pole. In fact, two thirds of the heat is generated at the positive pole and only one third of the heat is generated at the negative pole.
- This is very important when welding since it enables the welding operative to vary the heat according to the job in hand
- The polarity of the electrode is most important when welding with d.c. and the manufacturer's recommendations must be adhered to rigidly. In order to prevent confusion, electrodes that are only to be connected to the positive side of the supply are termed 'electrode positive

Polarity in DC supply



Connections to heavy-gauge work pieces
Electrode NEGATIVE
Workpiece POSITIVE to concentrate the heat into the parent metal



Connections to light-gauge work pieces
Electrode POSITIVE
Workpiece NEGATIVE to prevent burning a hole

Note: Some coated electrodes can only be connected to the positive pole



Source of DC supply

- Engine driven generators
- Electrically driven generators
- Rectifiers (converts AC to DC)



Welding with AC Supply

- With alternating current (a.c.) the electron current is changing in magnitude and direction 50 times per second in the UK and, therefore, there are no positive and negative sides of the supply
- therefore the electrodes for use with alternating current do not have a specific polarity and the same amount of heat is produced at the electrode and at the joint



Source of AC supply

- Alternators
- Transformers
 - Primary winding (high voltage)
 - Secondary winding (low voltage)



Welding current & voltage values



- There are three voltage conditions that the operator should be familiar with when arc-welding.
 - The *open circuit voltage* or electromotive force (emf). This is the maximum voltage available from the welding set under zero current conditions. This is approximately 40 to 100 volts.
 - The *striking voltage*. This is the voltage necessary to strike the arc, and its magnitude will depend upon the welding equipment and the type of electrode being used.
 - The *welding or arc voltage*. This is the electrical potential that produces the welding current once the arc has been struck. It is the lowest of the three voltages (approximately 10 to 50 volts) and is the lowest value that will maintain a stable arc.



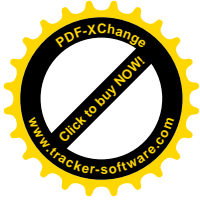
Voltage & Current Meters

- Ammeter
 - It is the device which is used to measure welding current
 - It is always connected in series with the circuit
- Voltmeter
 - It is used to measure potential difference or voltage across the terminals
 - It is always connected in parallel with the circuit



Welding

Module 19.2.9



Module objective

- Identify manual metal arc welding equipment and state reasons for use.
 - Equipment and uses: welding lead and electrode holder, welding return cable and clamp, welding earth, isolator switches, electrodes (i.e. types, functions of flux coating, storage), head screens, chipping hammer, wire brush



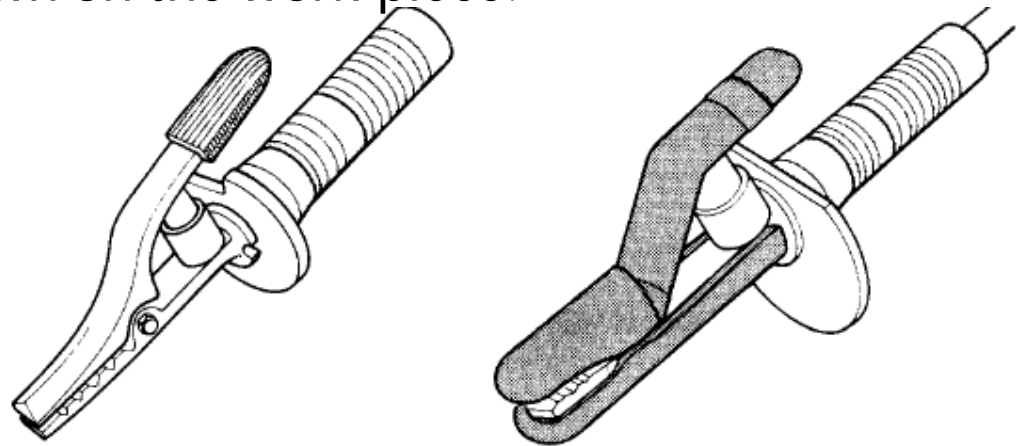
Welding lead

- This is a heavy duty flexible cable capable of carrying the maximum output current for the set to which it is connected. This may be as much as 500 amperes. It connects the welding set to the electrode holder.



Electrode Holder

- These should be soundly connected to the welding lead and have adequate rating for the maximum welding current in order to prevent heating up and becoming too hot to handle. Electrode holders may be partially insulated or fully insulated
- The protective guard (disc) of the partially insulated type of holder not only protects the welder's hands but also prevents short circuits should the holder be laid down on the work-piece.



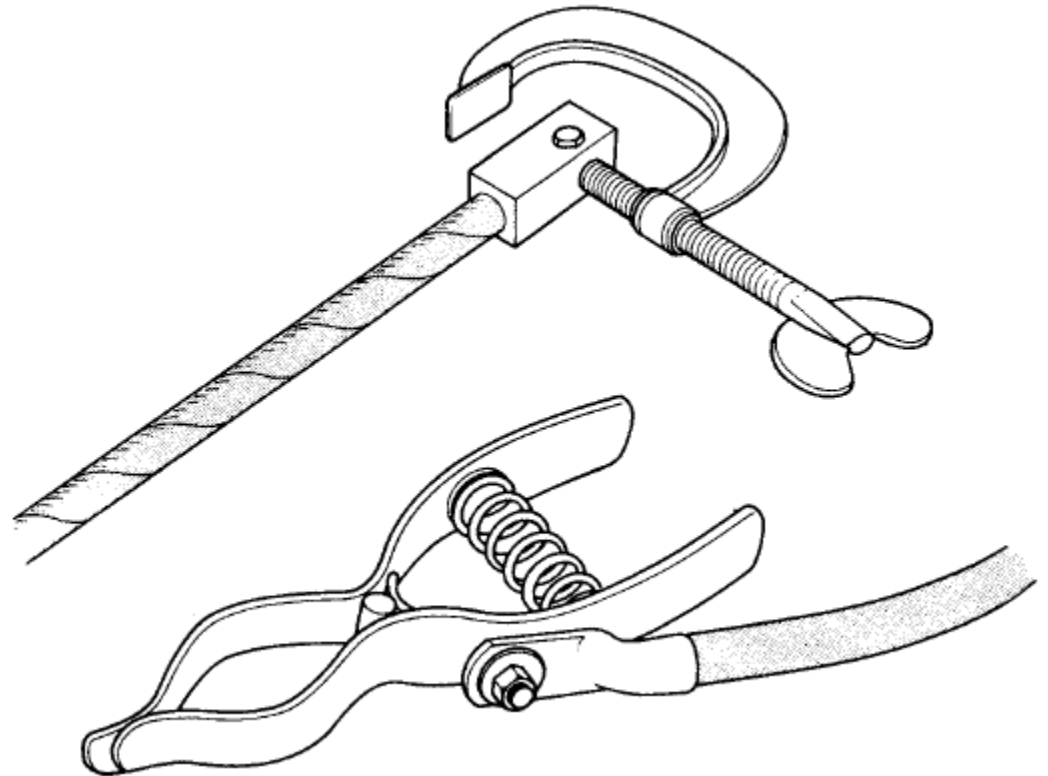
(a) Partially insulated type; (b) Fully insulated



Welding return cable & clamp



- This is a heavy duty cable of the same type and capacity as the welding lead. It carries the return current from the work-piece back to the welding set, thus completing the external welding circuit. It is connected to the work piece by means of screw or spring clamps





Welding Earth



- This is necessary on all welding circuits to maintain the work piece and any other associated equipment and structures connected to it at earth potential

Welding Earth

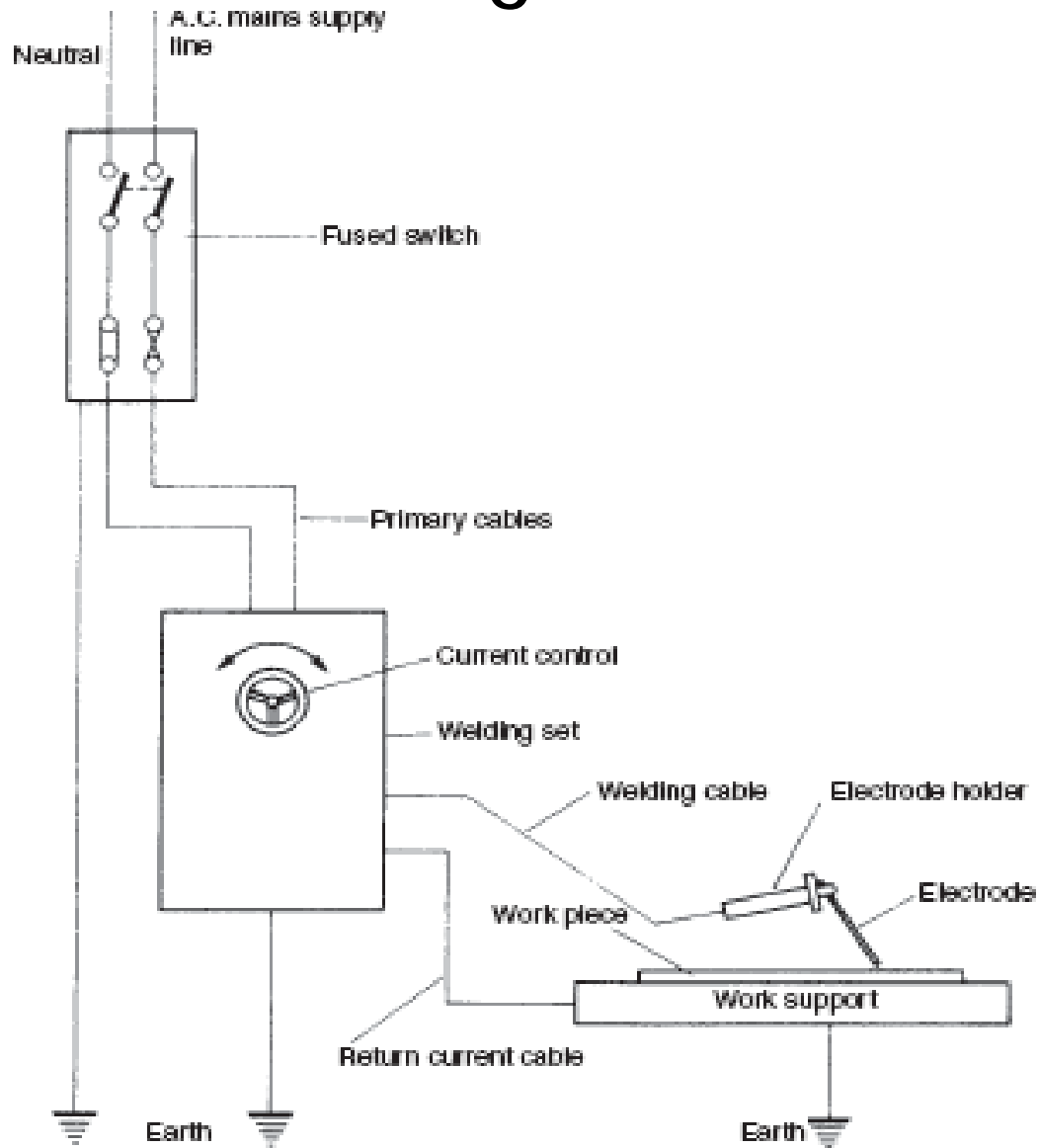


Figure 1.45 Manual metal-arc welding circuit diagram



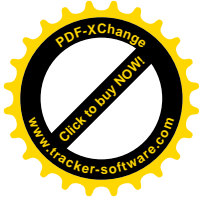
Isolator Switch

- A switch intended for isolating an electric circuit from the source of power





Electrodes



- Most electrodes used in the manual arc-welding process are *coated electrodes*
- The coated electrode consists of a wire core of suitable composition surrounded by a concentric covering of a flux
- Flux will melt uniformly along with the core wire to form a partly vaporized and partly molten shield around the arc stream.
- The liquid slag that is produced performs three important functions
 - It protects the solidifying weld metal from atmospheric contamination
 - It prevents the weld metal cooling too rapidly
 - It controls the contour of the completed weld.



Electrode coatings



- Coated electrodes are the subject of British Standard 499. It classifies electrodes according to:
 - Their mechanical properties.
 - The composition and type of coating.
 - Their operating conditions





British Standard 499



- According to the British Standard 499.
E 46 3 INi B 5 4 H5
- The first letter ' E ' indicates the product or process being used.
- The number 46 indicates the strength and elongation properties of the electrode material.
- The number 3 indicates the impact strength of the electrode material.
- The letters ' INi ' indicate the chemical composition of the electrode material.
- The letter ' B ' indicates the flux covering (this will be discussed later in this section)



Now let's consider the optional section (5 to H5 inclusive)

- The number 5 indicates the amount of weld metal deposited per electrodes and the type of welding current needed.
- The number 4 indicates the welding position.
- Finally ' H5 ' which indicates the hydrogen content of the weld metal



There are three types of electrode coatings available

- *Rutile (code R)*, which would be used to coat an electrode for general-purpose welding. The residual slag is easy to remove. This may be subdivided into RR (a thick coating), RC (a rutile cellulosic coating), RA (a rutile acid coating), and RB (a rutile basic coating)
- *Cellulosic (code C)* is an electrode coating containing cellulose. This produces a forceful arc with deep weld penetration.
- *Basic (code B)* is an electrode coating that ensures a very low hydrogen content in the weld metal and is used where a high-strength weld is required



American (AWS) Standard



E 7018

E : Electrode for manual metal electric arc welding

70 : 70 stands for tensile strength multiply by 1000

1 : this digits indicates the position

1 for all positions

2 only for horizontal & flat

3 flat only

8: this digit describe the current type & flux coating

Details: see next slide





- 0 High cellulose sodium (Cellulosic)DC+
- 1 High cellulose potassium AC or DC+ or DC-
- 2 High titania sodium (Rutile) AC or DC-
- 3 High titania potassium (Rutile) AC or DC+
- 4 Iron powder titania (Rutile) AC or DC- or DC+
- 5 Low hydrogen sodium DC+
- 6 Low hydrogen potassium (Basic) AC or DC+
- 7 Iron powder iron oxide AC or DC+ or DC-
- 8 Iron powder low hydrogen (Basic)AC or DC+



Head screen

- For all arc-welding operations it is essential to protect the welder's head, face and eyes from ultra-violet radiation, heat (infra-red radiation), spatter and hot slag
- To protect from these either a helmet (visor) or a hand shield must be used



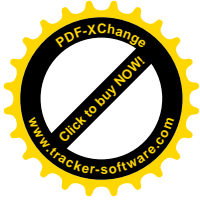
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Chipping Hammer

- To remove the slag from the top of the weld bead chipping hammer is used.





Wire brush

- Wire brush is used to remove any residual particles of slag or dust particles after chipping it gives more finishing to the weld bead





Welding

Module 19.2.10

By : S. Fawwad



Module objective

- Describe the manual metal arc welding process.
 - Process: arc voltage and amperage settings, method of striking the arc, breaking and restriking, melting parent and filler metals, fusion and solidification, control of liquid metal and slag

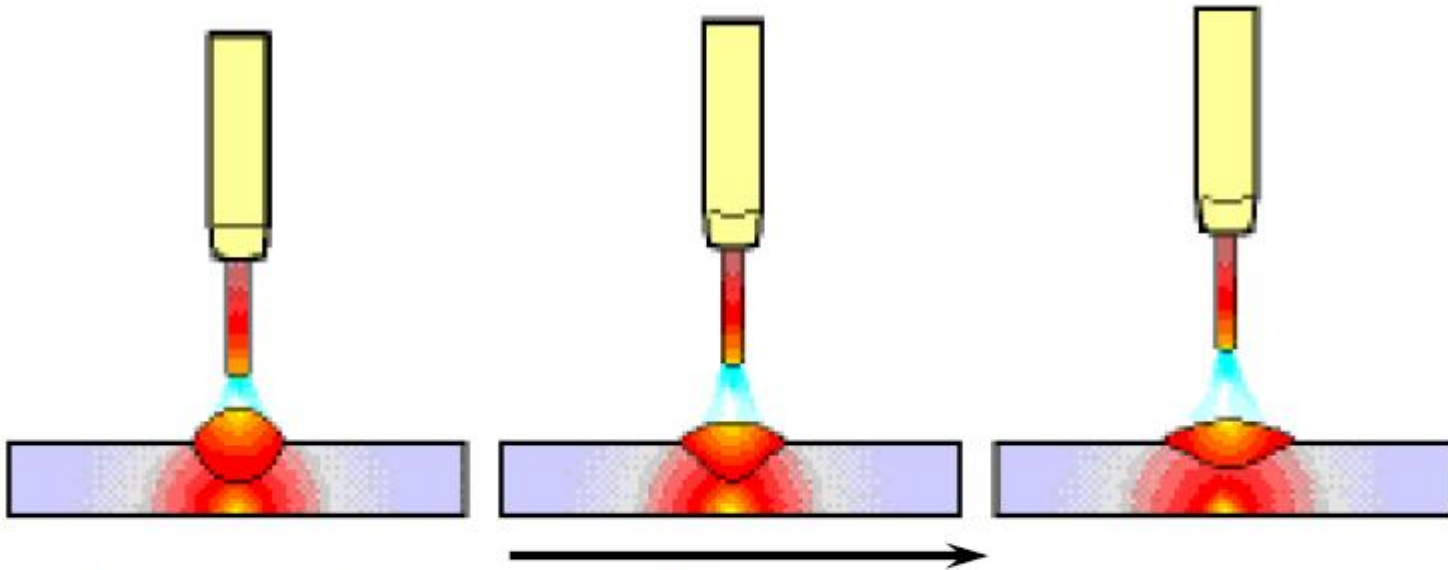


Arc voltage & amperage settings



- In arc welding, the voltage is directly related to the length of the arc (greater the arc length will increase the voltage and decrease the current hence heat in the region will decrease)
- The current is related to the amount of heat input
- Voltage output is typically 20 to 50 volts during welding (*Three different voltages already been described in previous module*)
- In welding we require low voltage values and high current Voltage output is typically **20 to 50 volts** during welding Typical currents are **50 to 500 amps**, depending on the size of weld required

Arc voltage & amperage settings



- Increasing arc voltage
- Reduced penetration, increased width
- Excessive voltage can cause porosity, spatter and undercut



Current Setting

- The current values for most basic dia of electrodes and a rule of thumb to calculate is given in following formulae

Minimum current = $D \times 25$ (approx)

Maximum current = $D \times 40$ (approx)

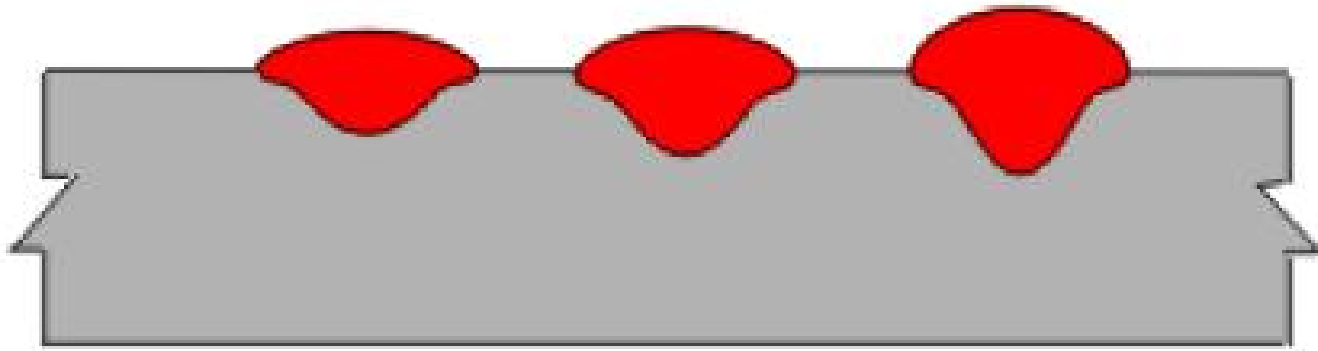
D = diameter of the electrode

- For root welding, vertical up & over head welding, operator should use the lower limit
- For fillet welding in the horizontal & flat positions and also for vertical down welding the amperage is set near to the upper limit

Diameter	2.0	2.5	3.25	4.0	5.0	6.0
Length	250/300	350	350/450	350/450	450	450
Amperage	40-80	50-100	90-150	120-200	180-270	220-360



Current Setting

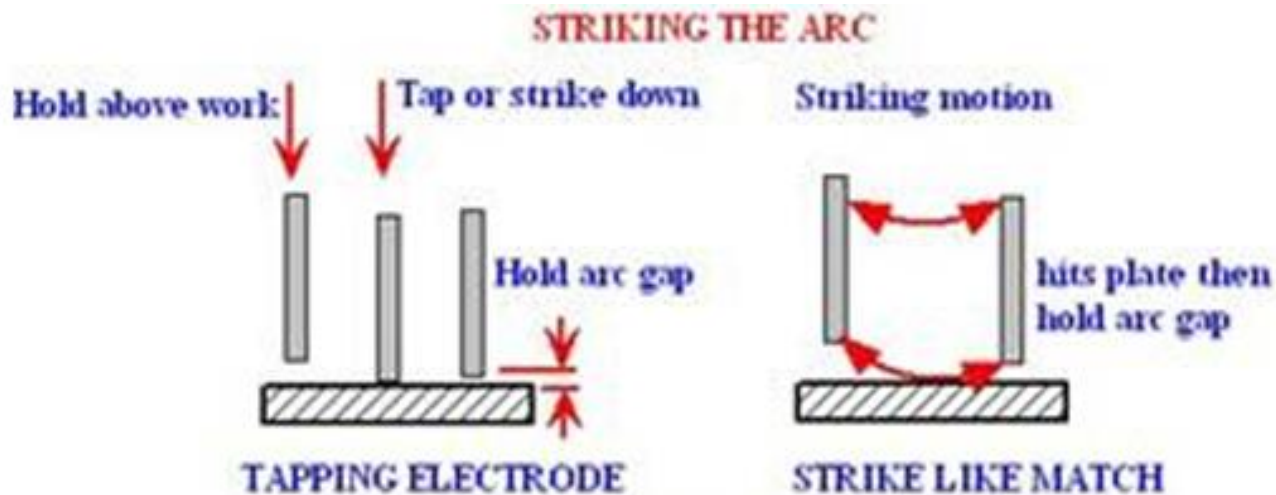


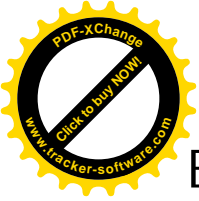
- **Increasing welding current**
- **Increase in depth and width**
- **Increase in deposition rate**



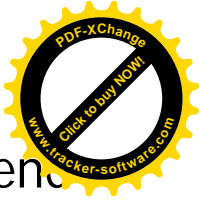
Striking the arc

- Before welding can commence it is necessary to *strike the arc to do this, the electrode* must first touch the work briefly and then be withdrawn to the correct arc distance.
- There are two methods for striking the arc
 - Scratching motion
 - Up & down / Tapping motion





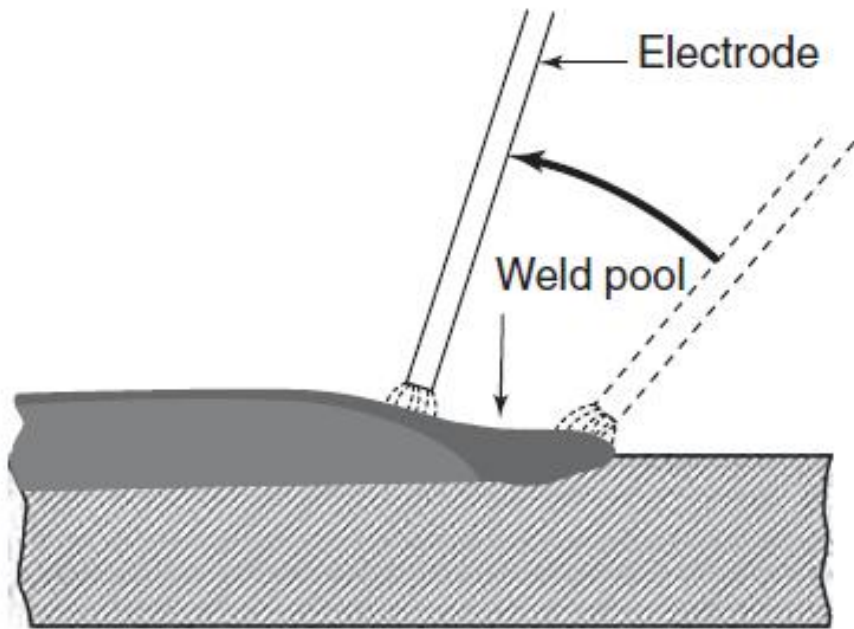
Breaking & re striking



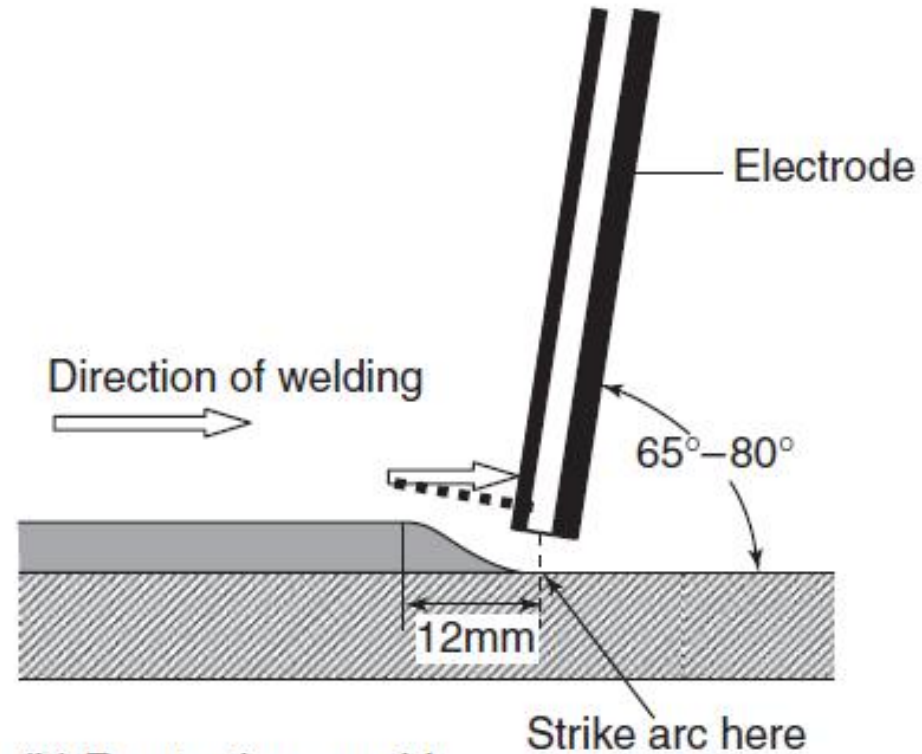
Breaking/stopping requires practice to prevent metal being lost at the end of the weld

- This is not only unsightly but could result in the weld breaking as a result of fatigue failure at later
- To prevent loss of metal the weld crater should be built up at the end of the weld as shown in Figure
- Re-starting is necessary after stopping to change an electrode
- The skill required here is not only in striking the arc in the correct place but also in joining up with the existing weld.
- Re-strike the arc with the new electrode at the edge of the existing weld crater and move the electrode quickly back over the crater as shown in figure then resume welding in the correct direction of travel at the normal welding speed.

Breaking & re striking



(a) Building up the weld crater before stopping



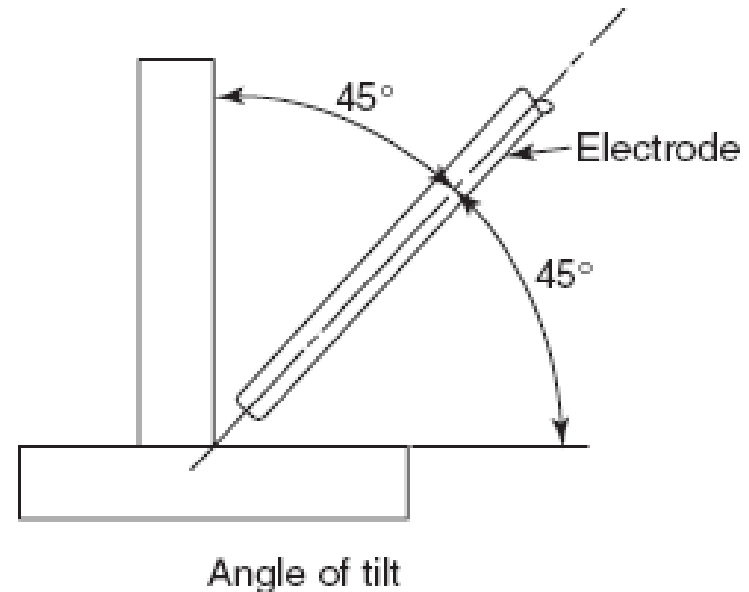
(b) Re-starting a weld



Electrode angles



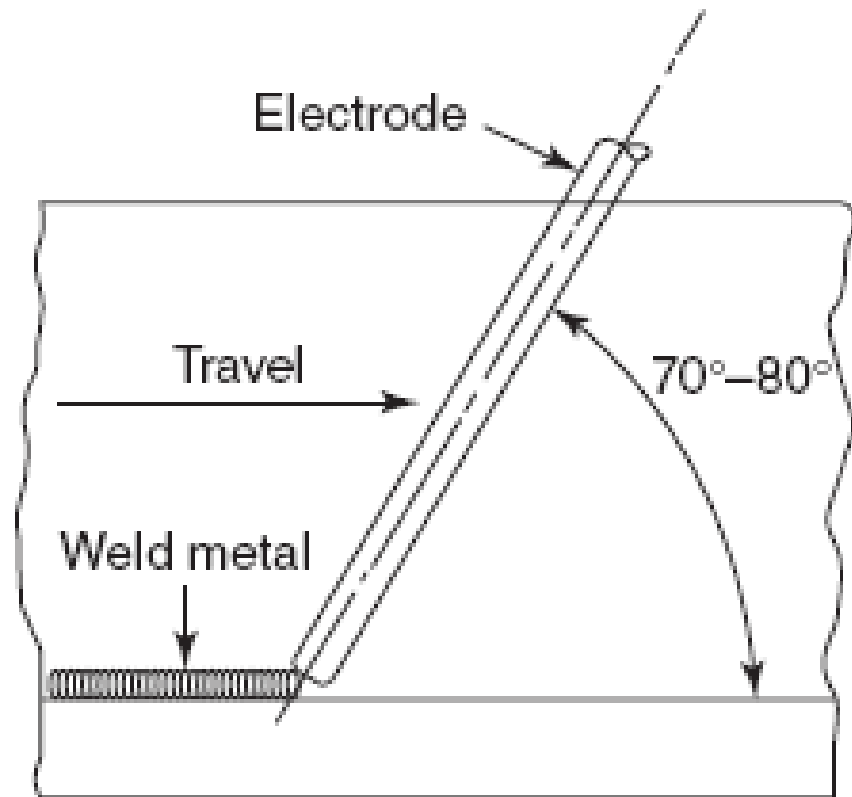
- There are two types of angles considered in welding
 - Tilt angle
 - Slope angle
- Tilt angle
 - Tilt angle is the angle between the electrode and the work in a plane perpendicular to the direction of electrode travel along the joint.





Slope angle

- The *slope angle* is the angle between the electrode and the work in a plane parallel to the joint.

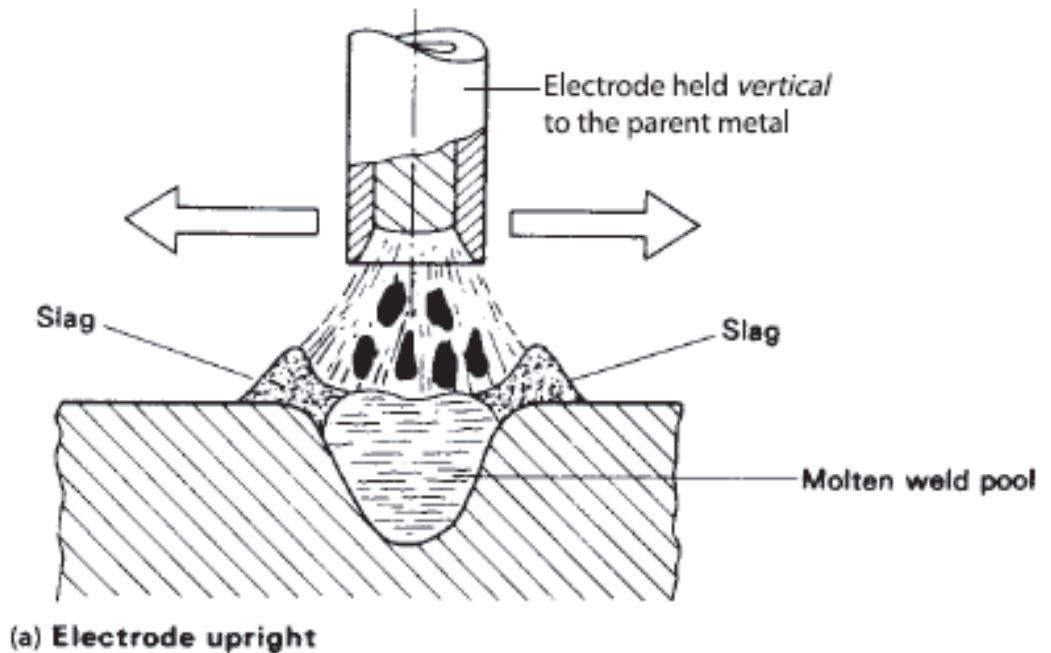


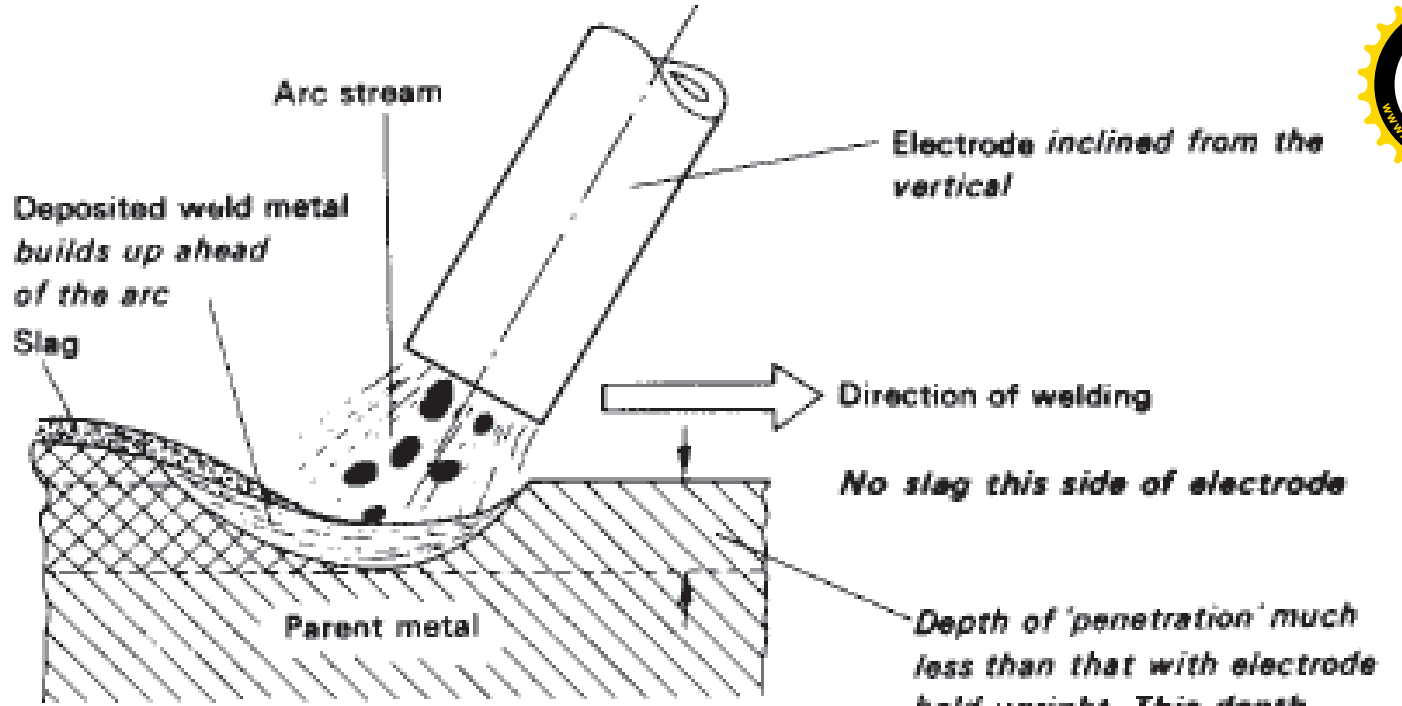
Angle of slope



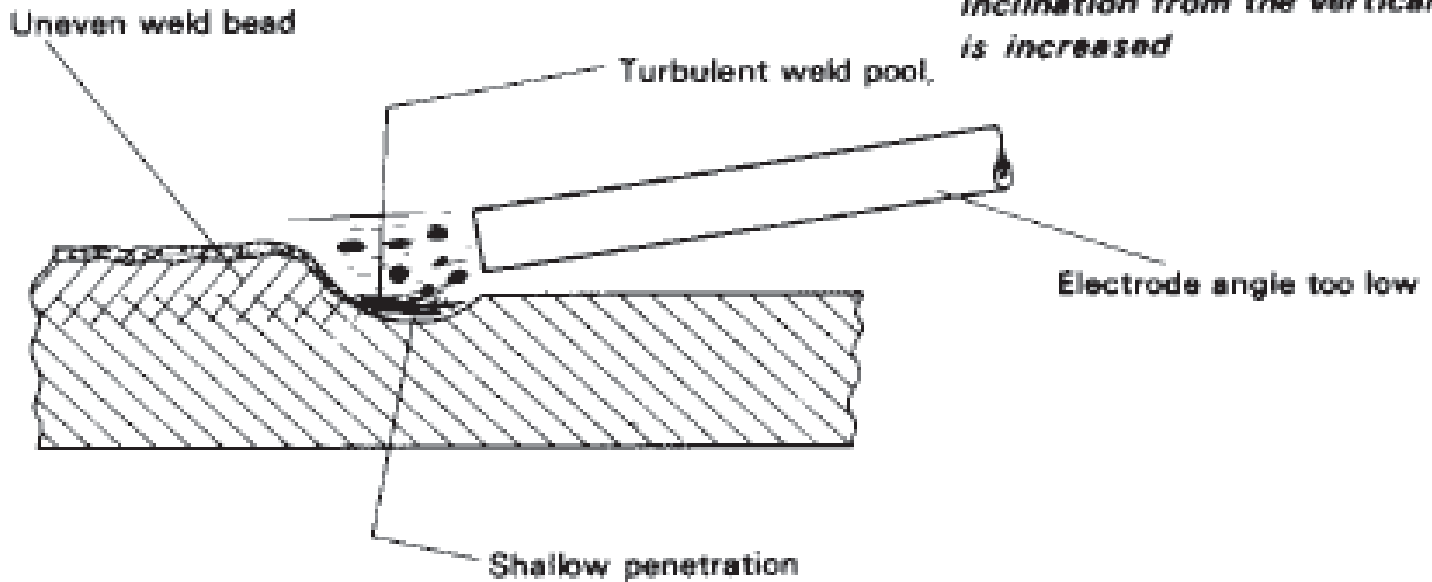
The nearer the slope angle approaches the vertical, the greater will be the depth of penetration

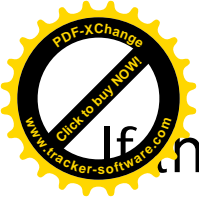
- In this position the force of the arc stream tends to drive the molten metal from the edge of the weld pool and the chance of undercutting increases
- Further, with the electrode in the upright position, the slag will build up and surround the weld metal deposited



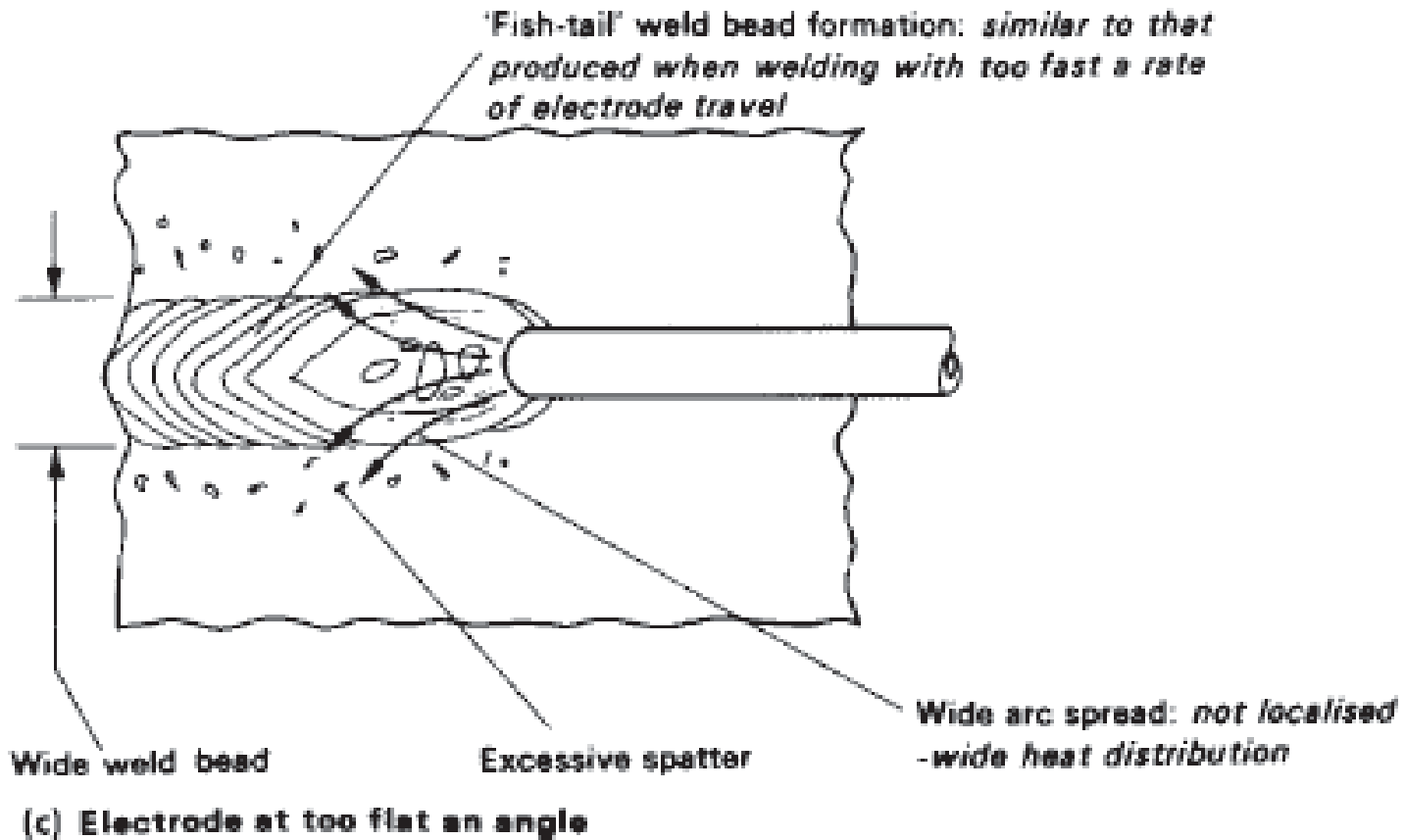


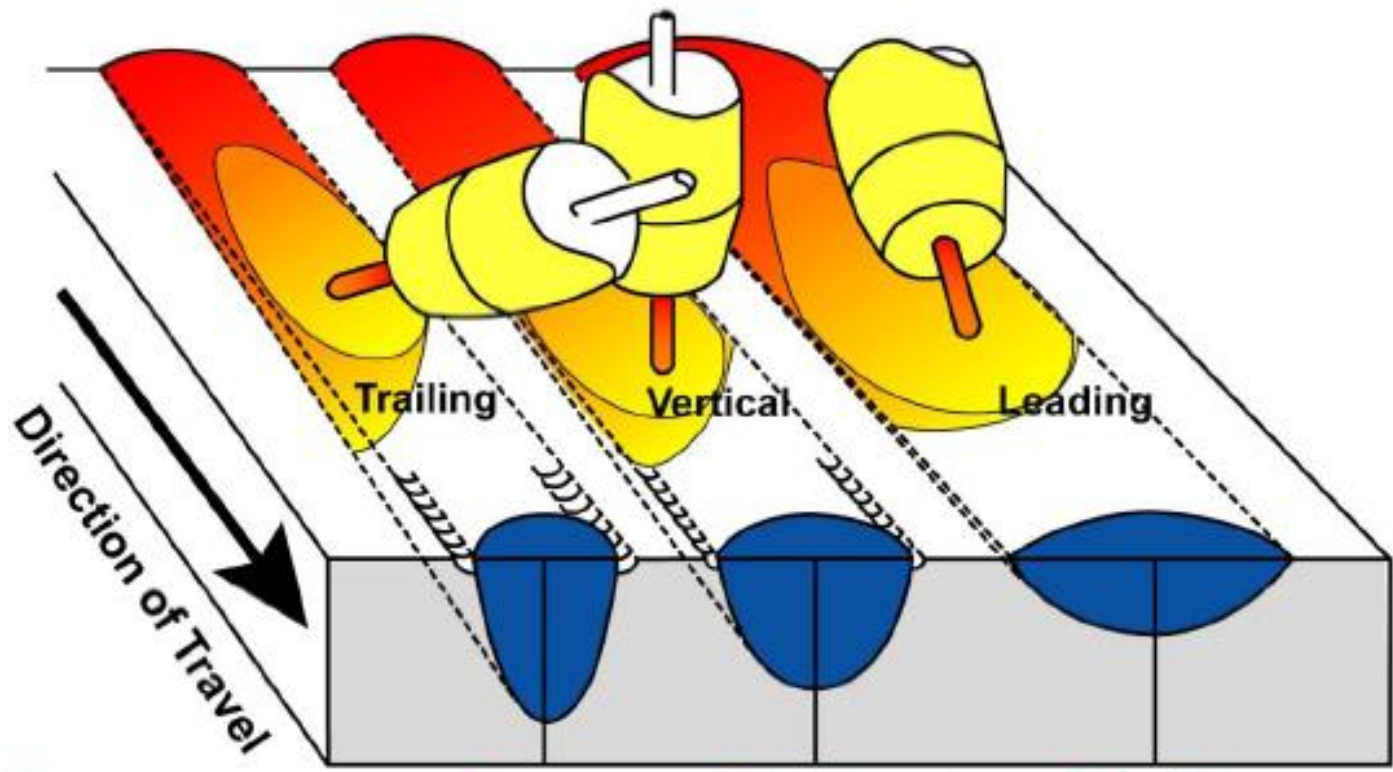
(b) Electrode inclined at correct angle





If the angle of inclination is too low, there will be lack of penetration, resulting in a weak weld. This will also be accompanied by excessive spatter and a poor 'fish-tail' weld profile.





Penetration

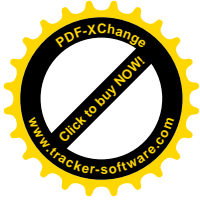
Deep Moderate Shallow

Excess weld metal

Maximum Moderate Minimum

Undercut

Severe Moderate Minimum



Fusion & solidification

- Fusion
 - During welding the parent metal and filler metal both melts and form a pool of weld metal and mix with each other this process is called fusion
- Solidification
 - The process of returning back of fused liquid metal into solid state is called solidification.



Welding

Module 19.2.11

Prepared by:

Syed Fawwad

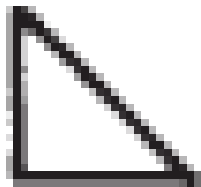
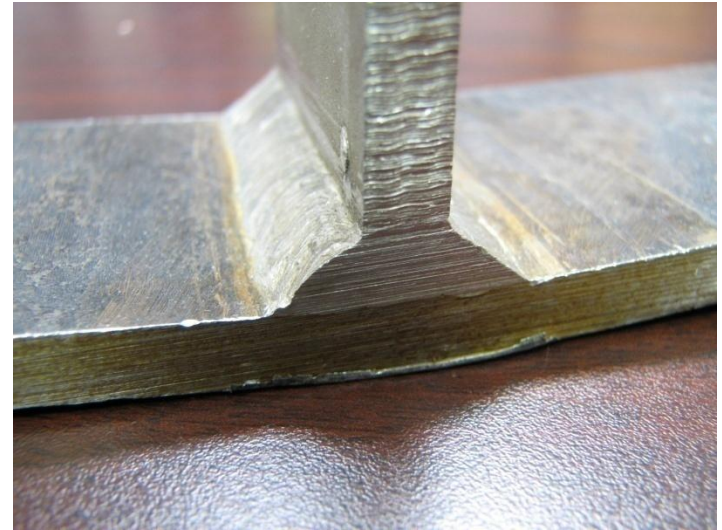
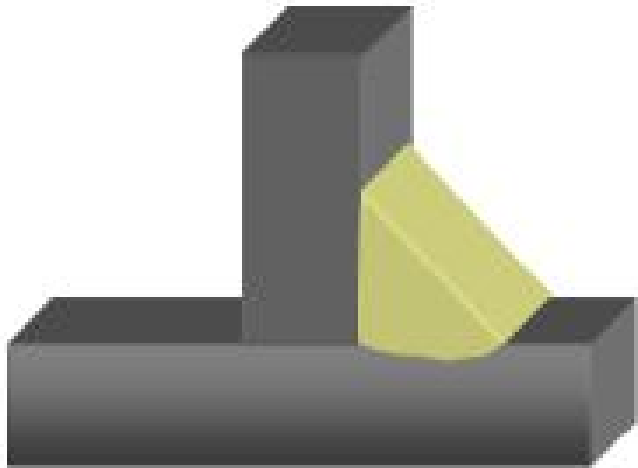


Module objective

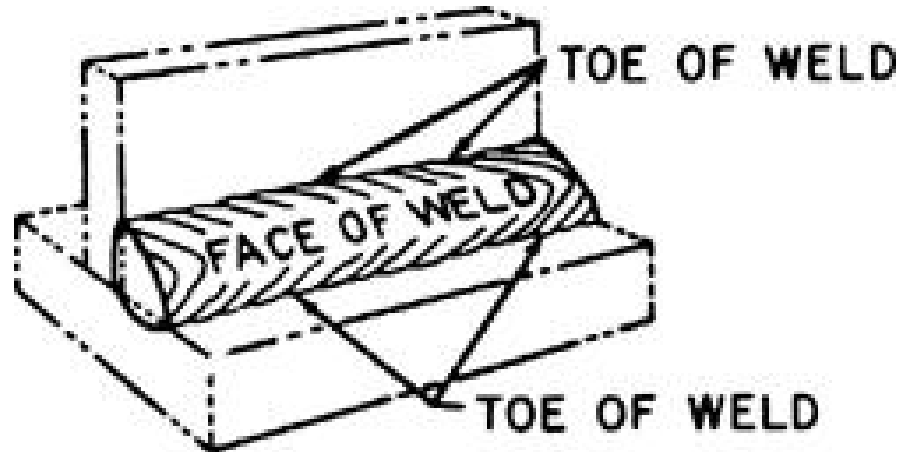
- Identify oxy-fuel gas and manual metal arc joint types.
 - Joint types: fillet, lap, square butt, single and double-V butts, single and double-U butts, single and double-bevel butts, open outside corner



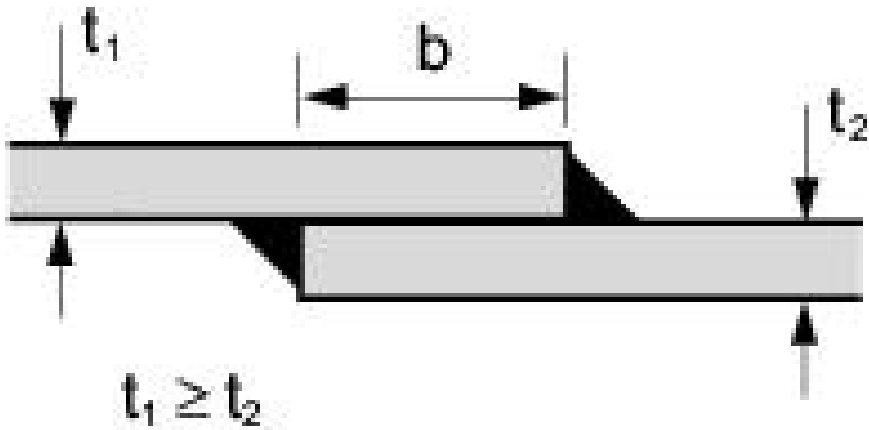
Fillet Weld



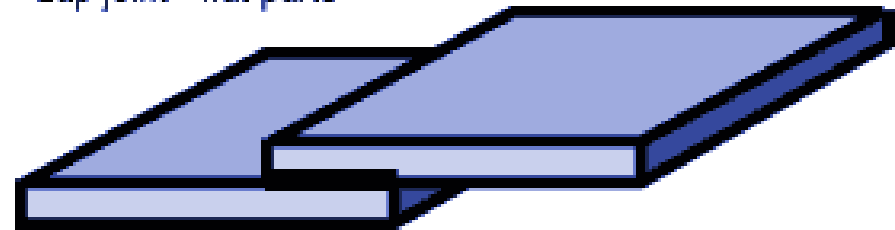
Symbol of fillet weld



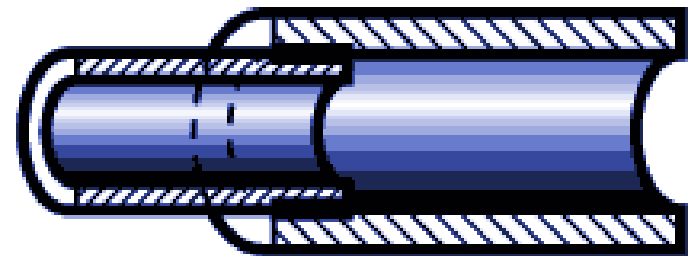
Lap Joint



Lap joint - flat parts

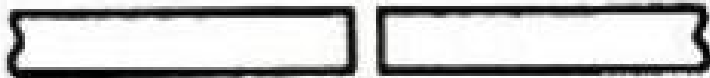


Lap joint - tubular parts (cutaway)

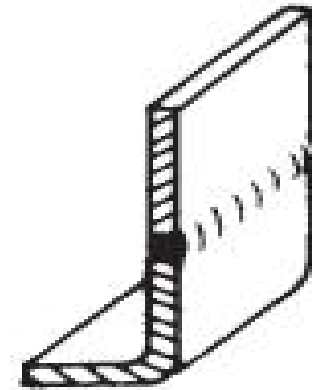
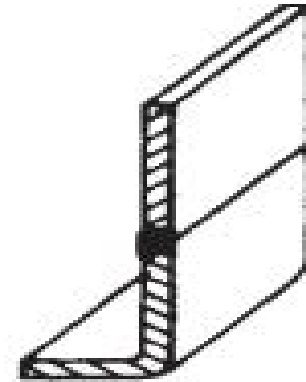




Square Butt



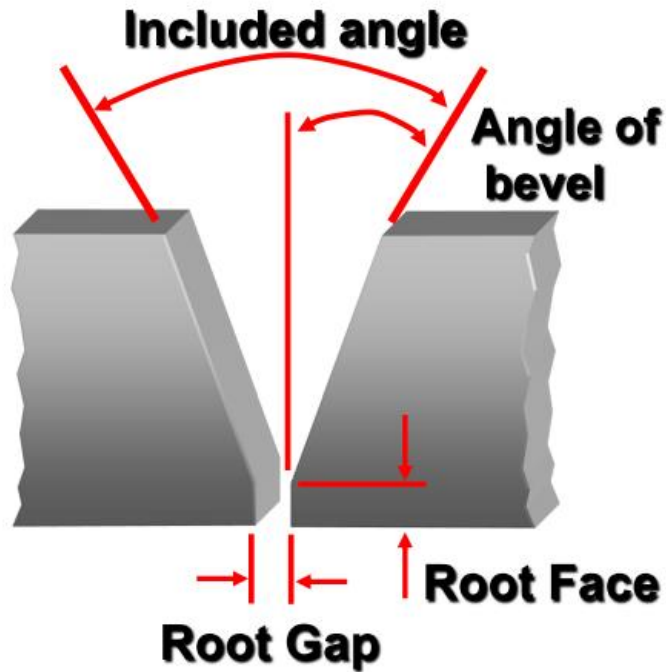
Square



Symbol of square butt weld



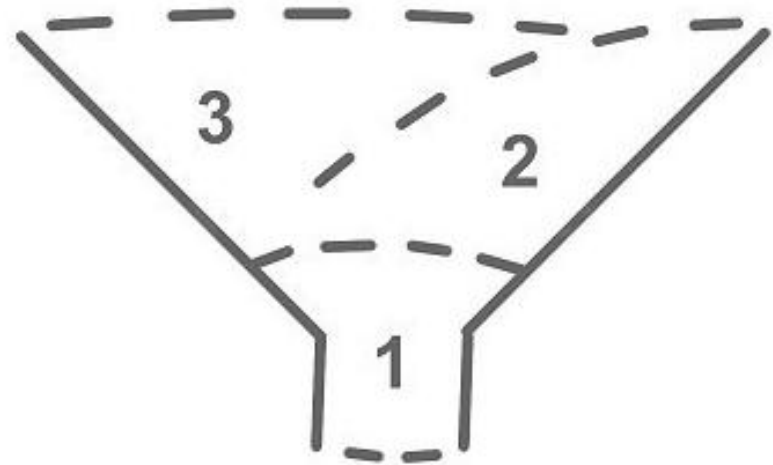
Single and double V butt joint



Single-V Butt



Double-Vee





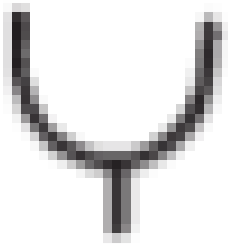
Single and double U butt joint



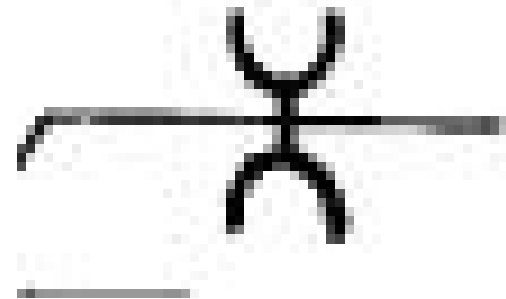
Single-U



Double-U



Symbol of square butt weld



Symbol of square butt weld



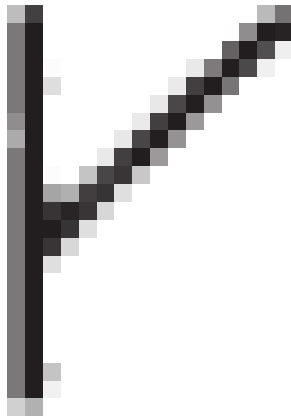
Single and double Bevel butt joint



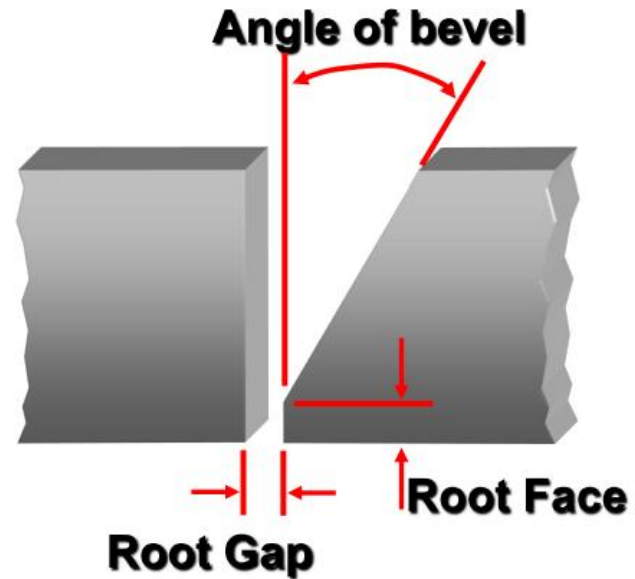
Single Bevel



Double-Bevel



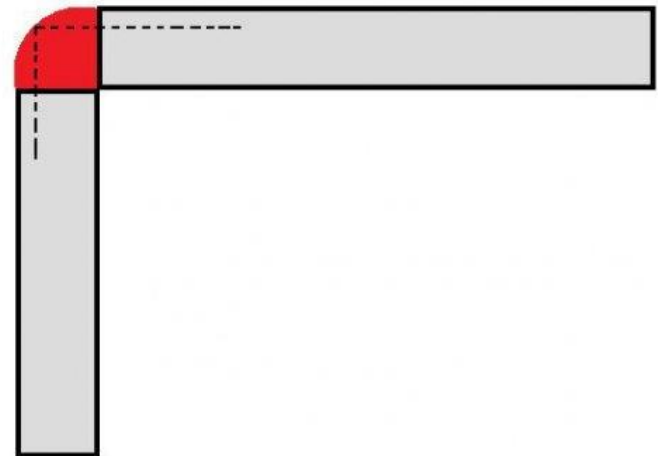
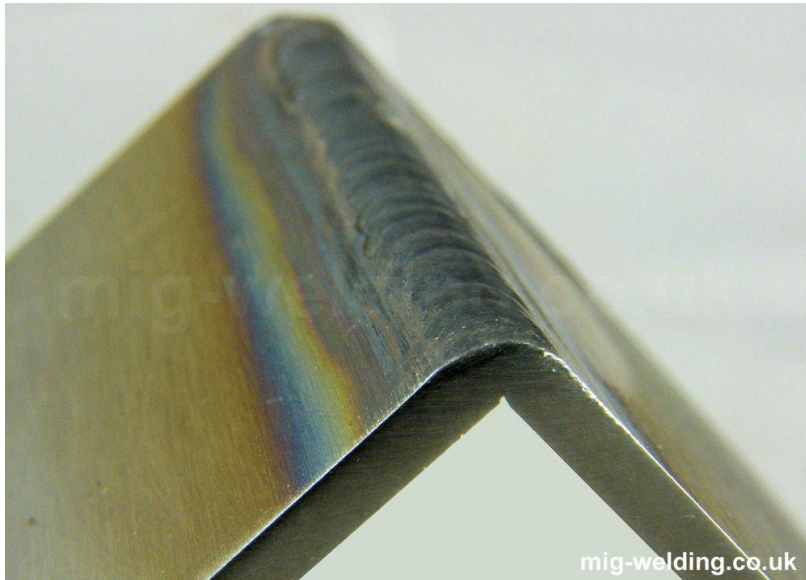
Symbol of single bevel butt



Single Bevel Butt



Open outside corner joint





Welding

Module 19.2.12

Prepared by:

Syed Fawwad



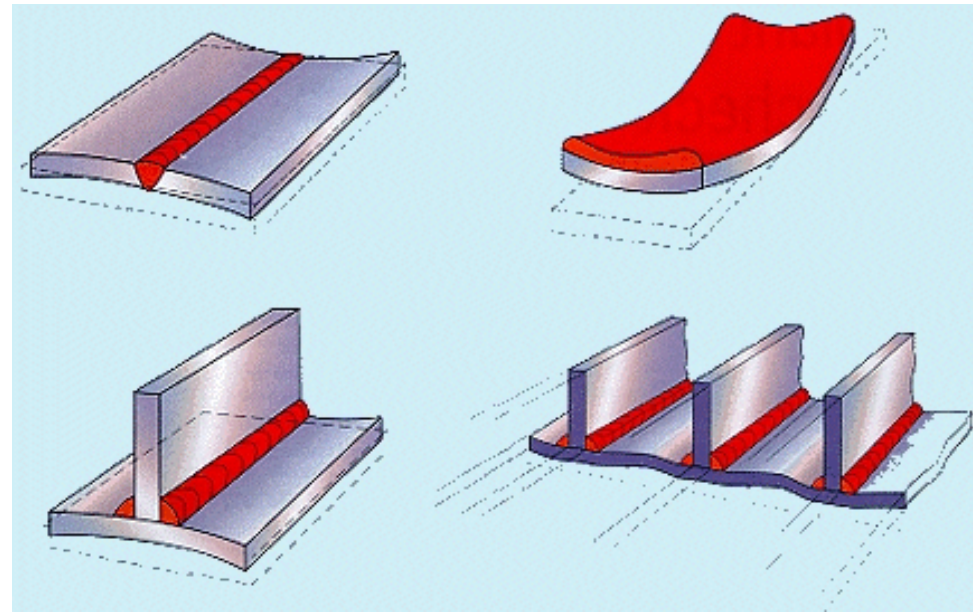
Module objective

- Describe the causes and control of distortion.
 - Distortion: types of distortion, methods of control (i.e. presetting, welding sequences, backing bars and strips, tack welding, restraint, jigs and fixtures, pre and post heating, chills), residual stress



Distortion in welding

- Because welding involves highly localized heating of joint edges to fuse the material, non-uniform stresses (both compressive and tensile) are set up in the component because of expansion and contraction of the heated material. This causes distortion in the structure





Types of distortion

- Longitudinal shrinkage
- Transverse shrinkage
- Angular distortion
- Bowing and dishing
- Buckling
- Twisting

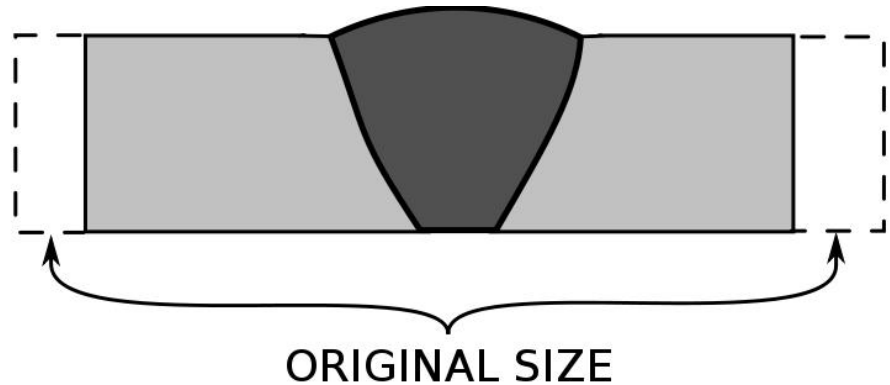
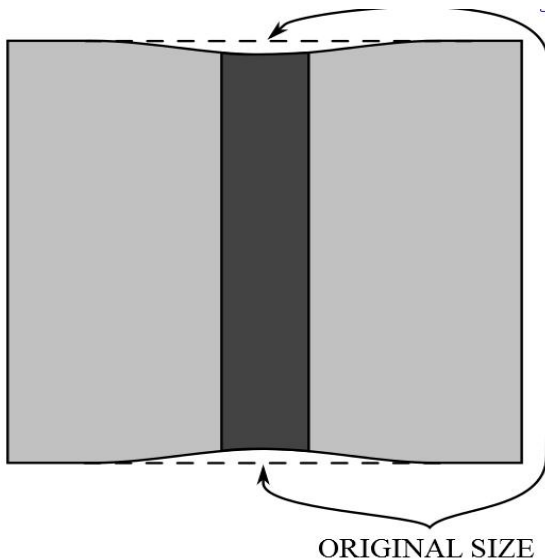


Longitudinal shrinkage

- Shrinkage stresses leading to a shortening of the member along the principal axis of the welded joint

- Transverse shrinkage

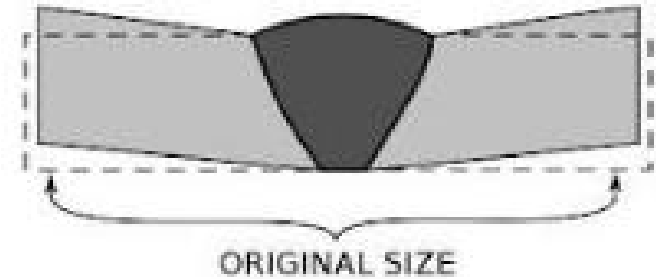
- Shrinkage stresses leading to a shortening of the member across the toes of the welded joint





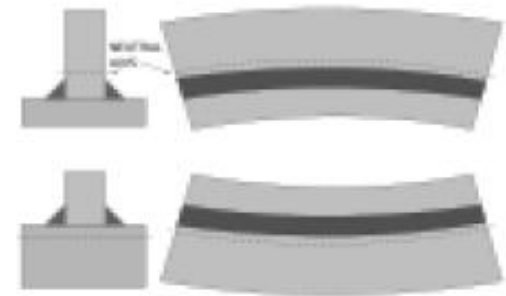
Angular distortion

- Weld zone transverse shrinkage stresses not in the plane of the neutral axis leading to rotation of one member with respect to an adjacent member.

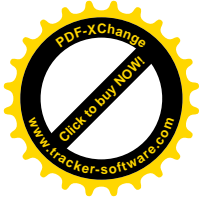


- **Bowing and dishing**

- Shrinkage of edges or surfaces where the distortion is not coincident with the neutral axis of the member leading to bowing or dishing due to asymmetric shortening



Neutral axis distortion



- Buckling
 - Similar to bowing and dishing but more pronounced localized deformations as seen on larger structures or thinner or less restrained sections.
- Twisting
 - Seen in slender structures with shear deformation at welded joints. Box sections and fabricated beams and columns can twist.



Method of controlling distortion

- Pre setting
- Welding sequences
- Backing bars and strips
- Tack welding, restraint, jigs and fixtures
- Pre and post heating

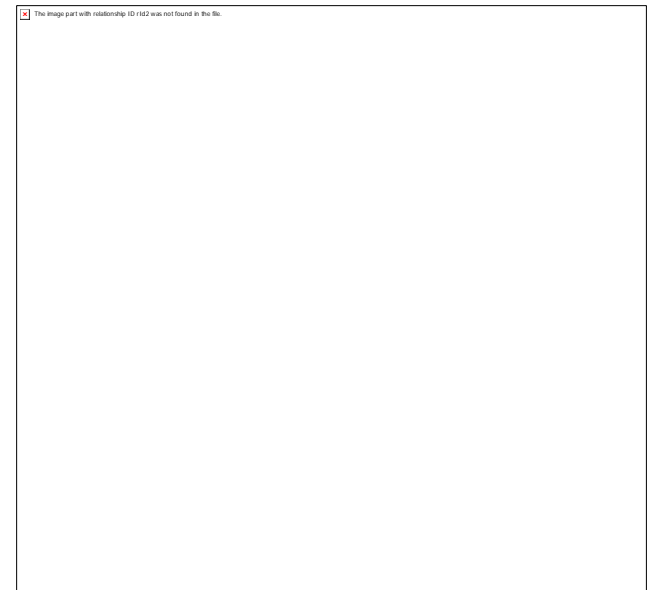




Pre setting



- The parts are pre-set and left free to move during welding .In practice, the parts are pre-set by a pre-determined amount so that distortion occurring during welding is used to achieve overall alignment and dimensional control.
- Unfortunately, as it is difficult to predict the amount of pre-setting needed to accommodate shrinkage, a number of trial welds will be required
- Pre-setting is a technique more suitable for simple components or assemblies.



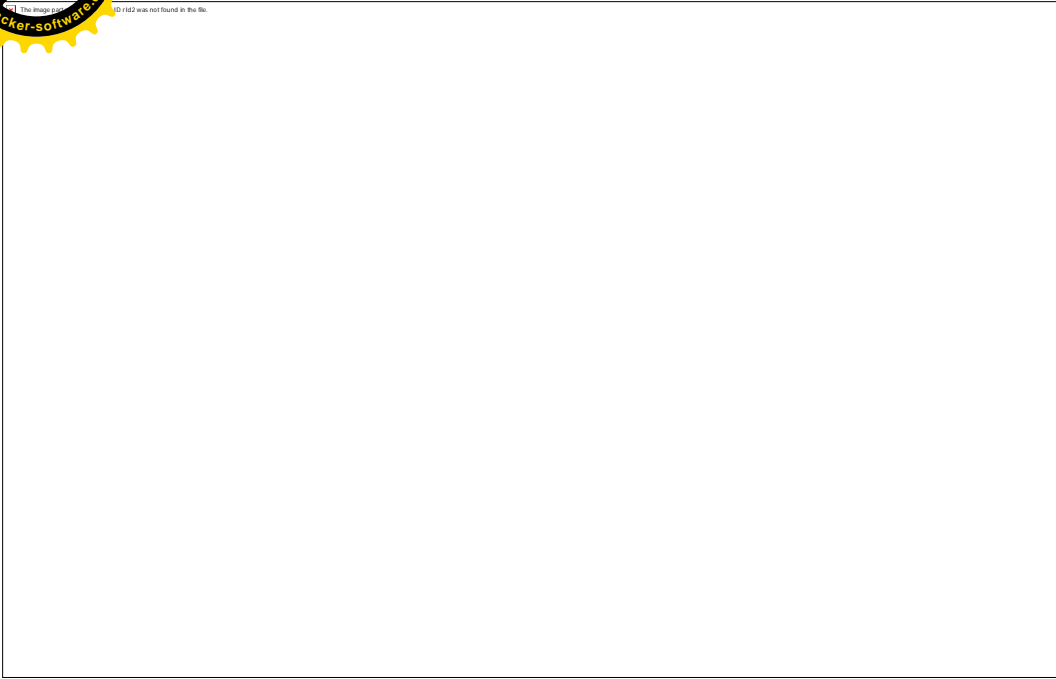
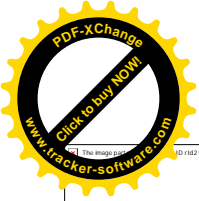


Welding sequences

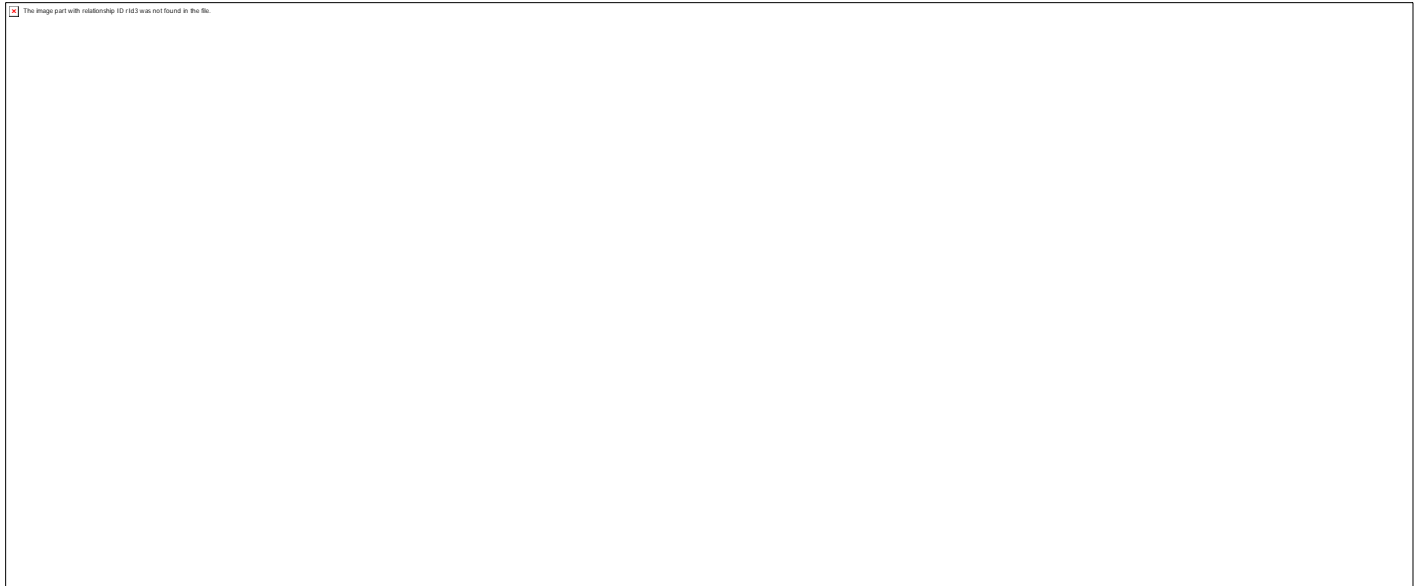


- The sequence, or direction, of welding is important and should be towards the free end of the joint. For long welds, the whole of the weld is not completed in one direction. Short runs, for example using the back-step or skip welding technique, are very effective in distortion control
- *Back-step welding* involves depositing short adjacent weld lengths in the opposite direction to the general progression.
- *Skip welding* is laying short weld lengths in a predetermined, evenly spaced, sequence along the seam. Weld lengths and the spaces between them are generally equal to the natural run-out length of one electrode.

Welding sequences

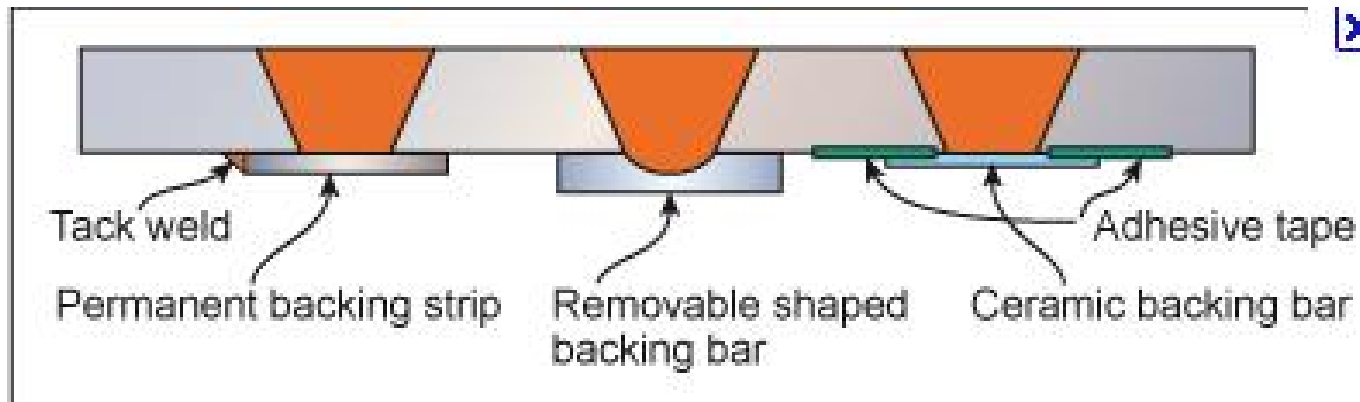


- a) Back step welding
- b) Skip welding



Backing bars & Strips

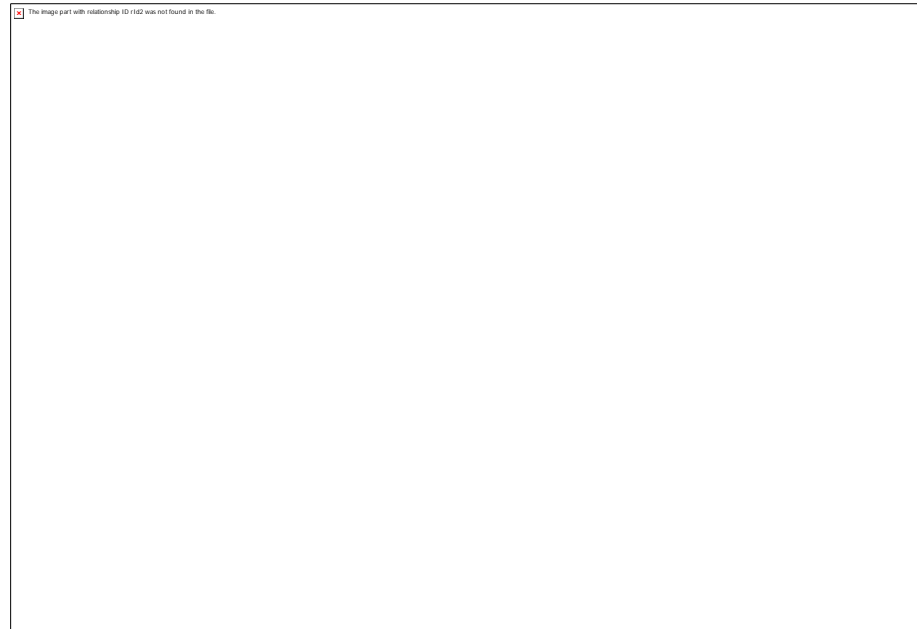
- The purpose of the backing bar or strip is to support the root pass where conditions make the control of the bead difficult. Conventionally, a backing bar is temporary and can be lifted away as soon as the weld has been completed.
- Place a backing bar, generally made of aluminum or copper, behind the surface to be welded. A backing bar will absorb heat, thus lessening the warping effect that heat can have on metal.





Tack welding

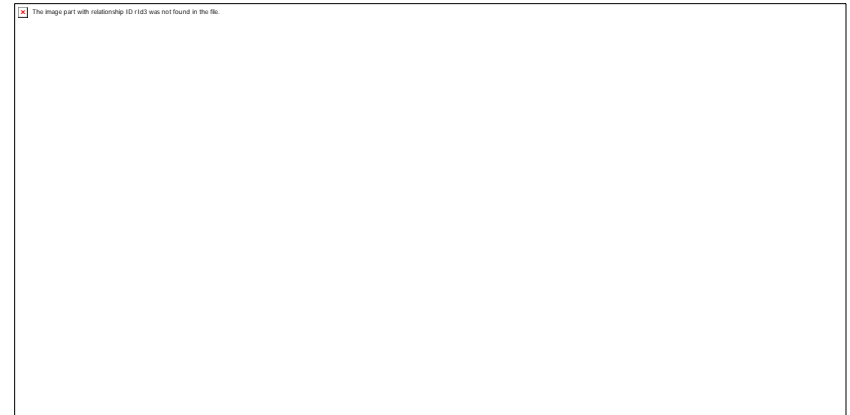
- Tack welds are ideal for setting and maintaining the joint gap but can also be used to resist transverse shrinkage. To be effective, thought should be given to the number of tack welds.
- The tack welding sequence is important to maintain a uniform root gap along the length of the joint. Three alternative tack welding sequences are shown.





Use of Restraint

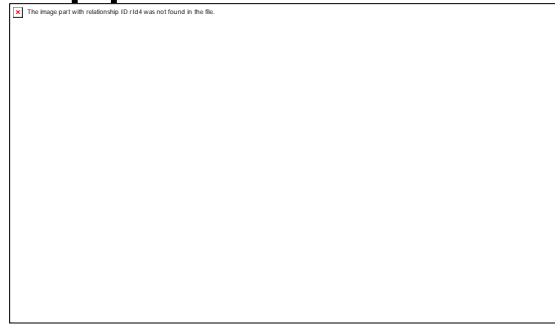
- Because of the difficulty in applying pre-setting and pre-bending, restraint is the more widely practiced technique. The basic principle is that the parts are placed in position and held under restraint to minimize any movement during welding
- Welding with restraint will generate additional residual stresses in the weld which may cause cracking. When welding susceptible materials, a suitable welding sequence and the use of preheating will reduce this risk.



Use of Restraint

- The restraint can be applied as following ways

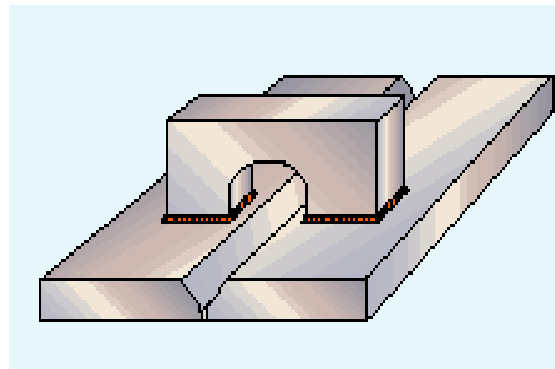
- Jigs & fixture



- Flexible clamp



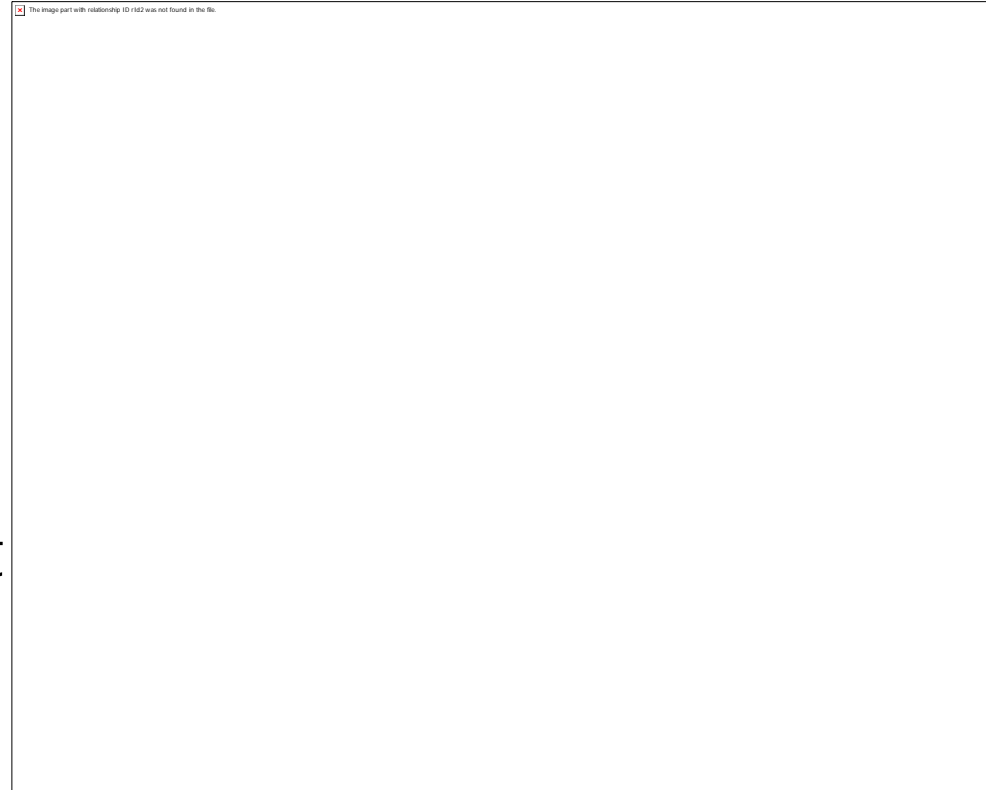
- Strong back





Use of Restraint

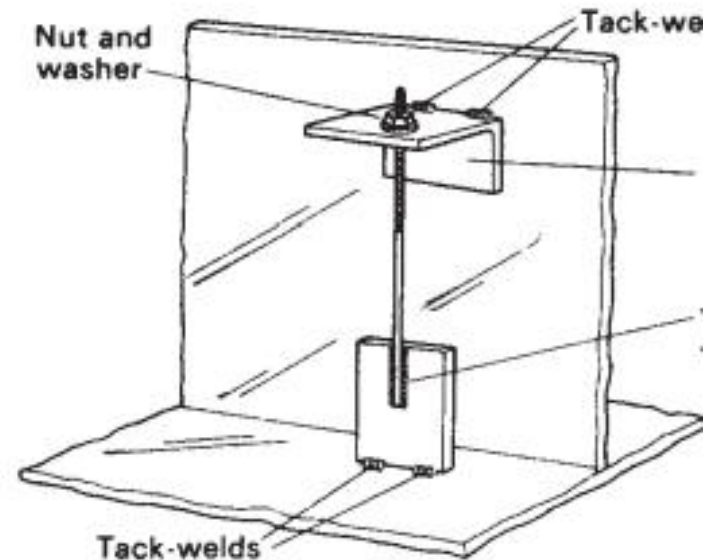
- Spider
 - Large cylindrical vessels are often constructed from two or more sections of roll-formed plate . During welding to ensure proper alignment and to hold the roll together spider is used





Use of Restraint

- Cleats
 - Angle cleats are used to push or pull (draw) the plate edges together when assembling long and circular weld seams





Pre & Post heating

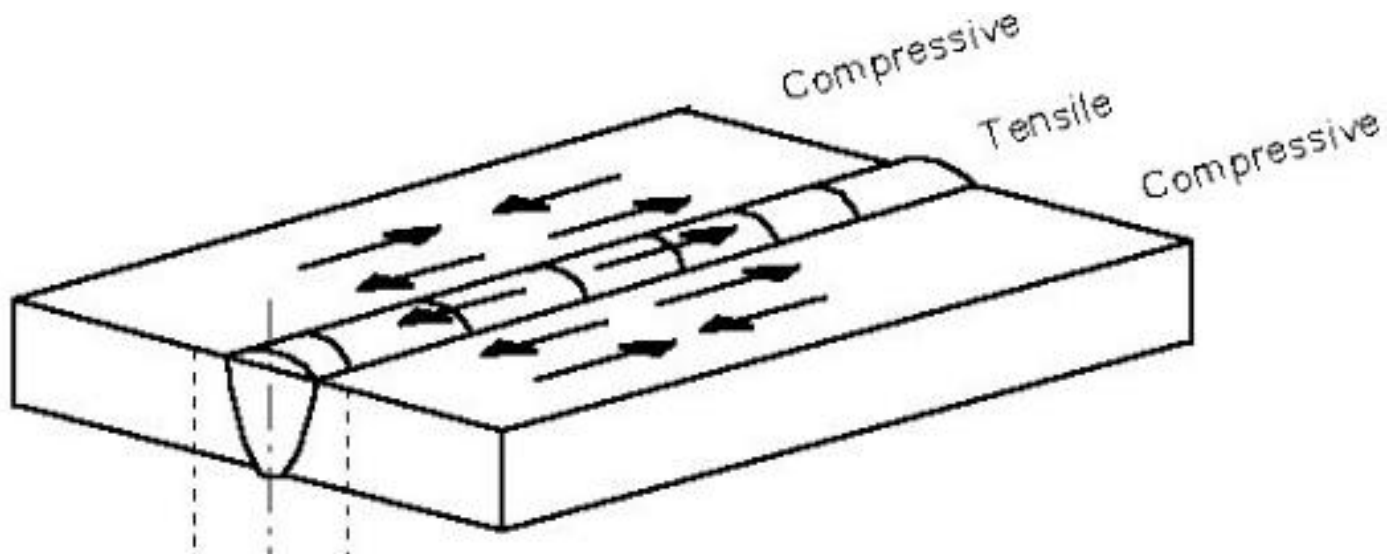


- Preheating Is the application of heat before welding it helps to reduce cracking ,hardness, distortion and stresses.
- It slower the cooling rate and resulting more ductile weld and uniform temperature of the structure.
- It can be done with the torch or by using an oven



Residual stresses

- As the molten pool solidifies and shrinks, it begins to exert shrinkage stresses on the surrounding weld metal and heat-affected zone. This surrounded heat affected zone resist against this contraction this is called residual stresses





Welding

Module 19.2.11

Prepared by:

Syed Fawwad



Module objective

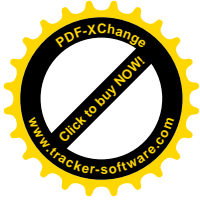
- Describe methods of inspecting and testing welds.
 - Inspecting and testing: destructive (ie nick break test, bend tests, macro etching), non-destructive (ie visual, dye penetrant, magnetic particle inspection, ultrasonic examination, radiographic examination)





Destructive testing

- In general, the term destructive testing is used to describe an evaluation process of a weld by a technique that destroys the test specimen or destroys its ability to function in its design application. The destructive testing technique should, therefore, be used with some form of partial sampling, rather than complete sampling



Destructive testing

- Nick break test
- Bend test
- Macro Etching



Nick Break Test

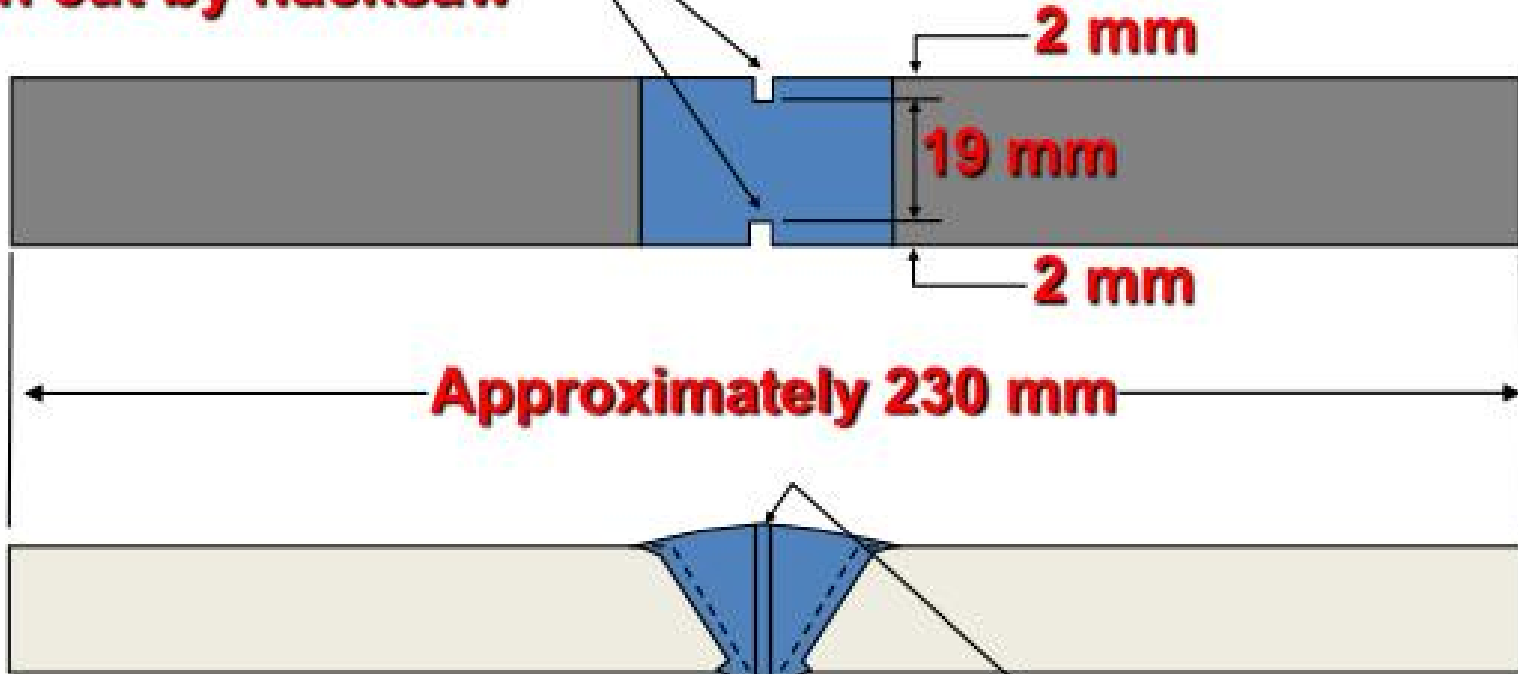


- Object of test:
 - To permit evaluation of any weld defects across the fracture surface of a butt weld.
 - Specimens are cut transverse to the weld
 - A saw cut approximately 2mm in depth is applied along the welds root and cap
 - Fracture is usually made by striking the specimen with a single hammer blow
 - Visual inspection for defects



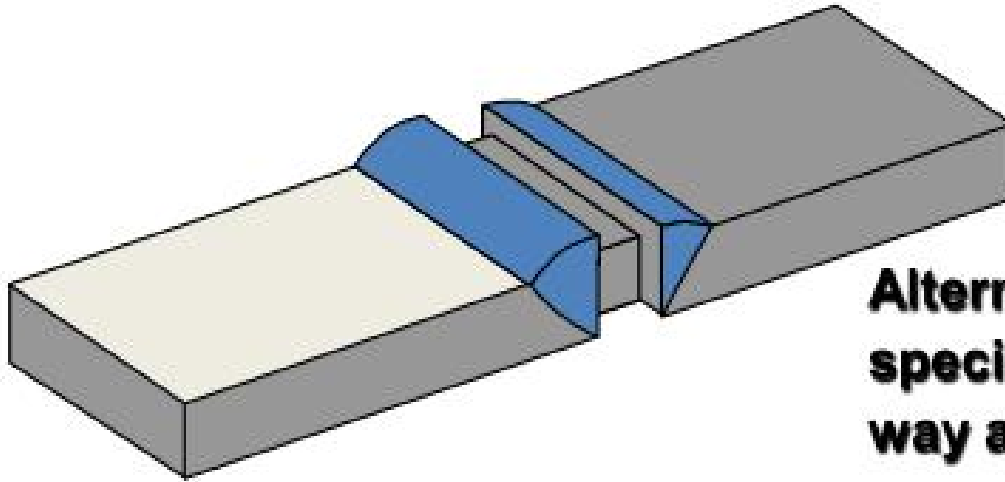
Nick Break Test

Notch cut by hacksaw

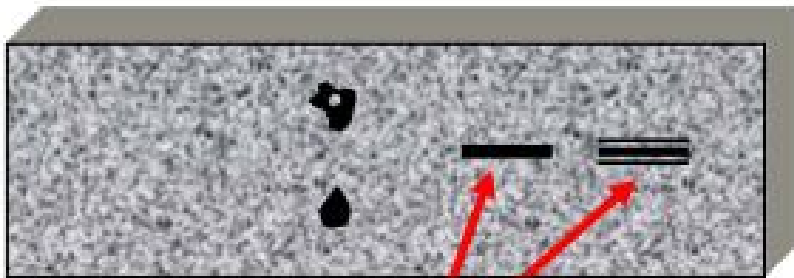


**Weld reinforcement
may or may not be
removed**

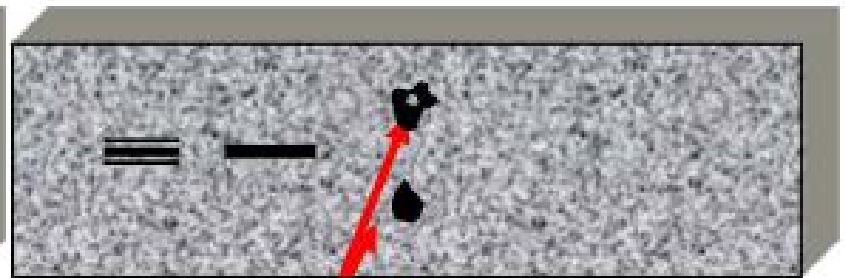
Nick Break Test



Alternative nick-break test specimen, notch applied all way around the specimen



Lack of root penetration or fusion



Inclusions on fracture line



- A nick break test involves breaking the weld joint to examine the fractured surfaces for internal defects such as:

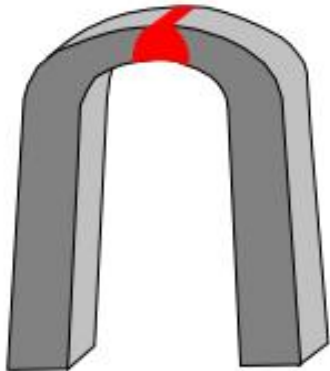
Gas pockets

Slag inclusions

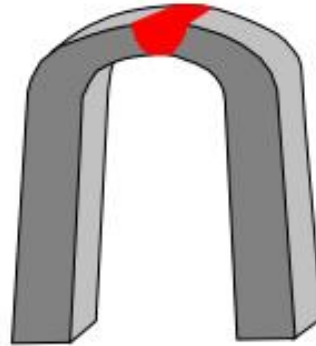
Porosity.

Bend test

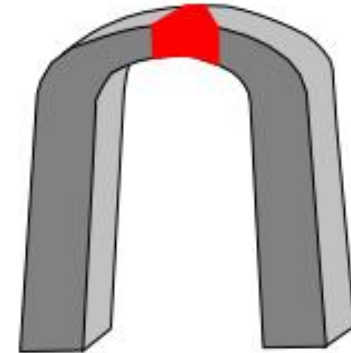
- Object of test:
 - To determine the soundness of the weld zone. Bend testing can also be used to give an assessment of weld zone ductility.
 - There are three ways to perform a bend test:



Root bend



Face bend

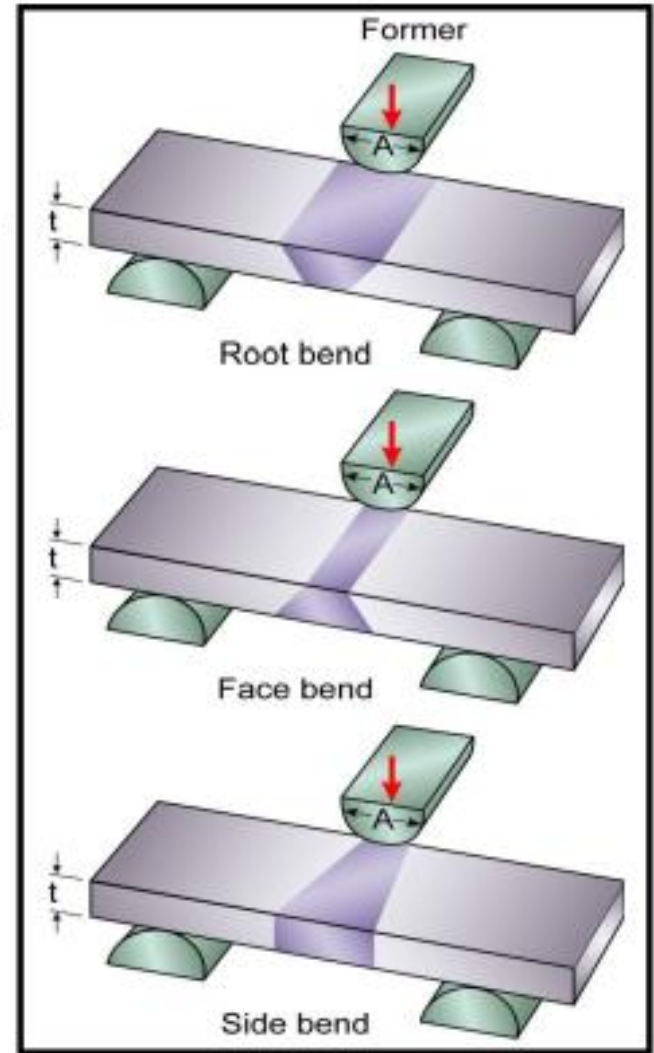
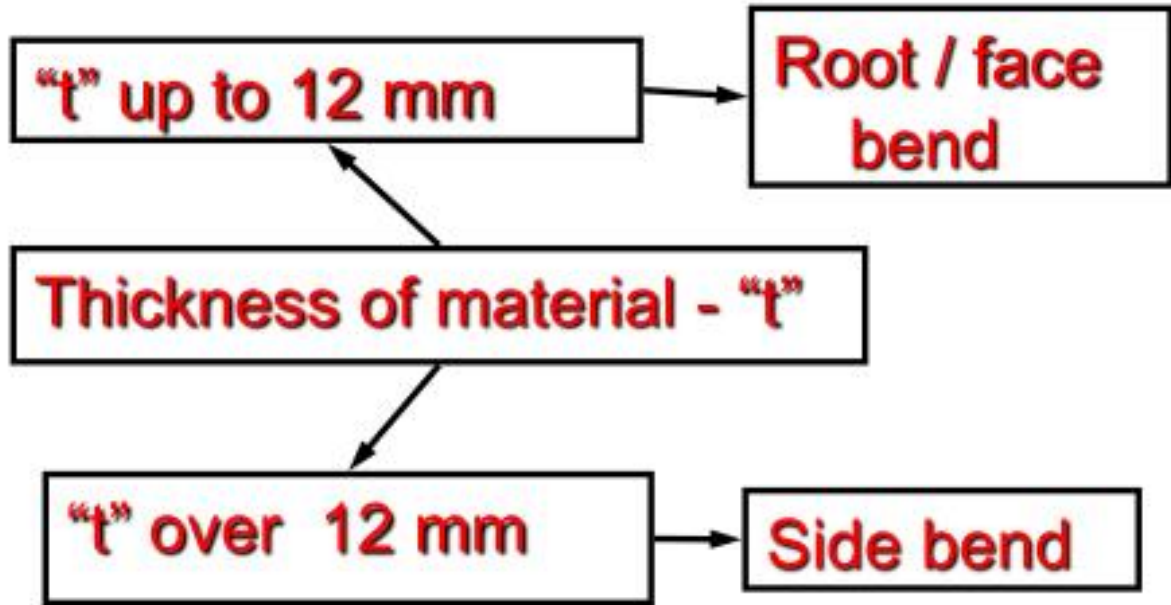


Side bend

Side bend tests are normally carried out on welds over 12mm in thickness

Bend test

Types of bend test for welds (acc. BS EN 910):

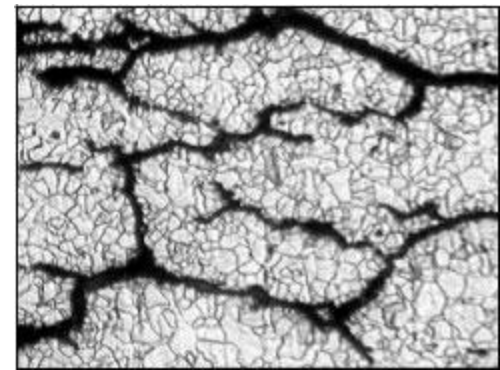


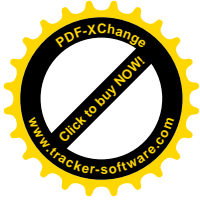


Macro etching



- This method of testing typically involves the removal of small samples of the welded joint
- These samples are polished across their cross-section and then etched using some type of mild acid mixture
- The acid etch provides a clear visual appearance of the internal structure of the weld
- Such items as depth of penetration, lack of fusion, inadequate root penetration, internal porosity, cracking and inclusions can be detected during inspection of the etched sample





ETCHING REAGENTS

- These are acids used to show up different structures in metals
- For steels the most common is "1-2 % nitric acid in distilled water or alcohol.
- Aluminium uses a solution of 10-20%caustic soda in water



Non Destructive testing



- Non destructive testing involves the inspection of weld at several places without breaking or bending the structure
- Five basic Non destructive testing are:
 - Visual Inspection
 - Dye Penetrate
 - Magnetic particle Inspection
 - Ultrasonic testing
 - Radiographic testing`





Visual Inspection

- The most common & cost effective method
- It must take place prior to, during and after welding
- Highly dependant on the experience & skills of the inspector





Visual Inspection



- It can be used to detect these defects:
 - Cracks
 - Porosity
 - Unfilled crater
 - Poorly formed beads
 - Misalignment

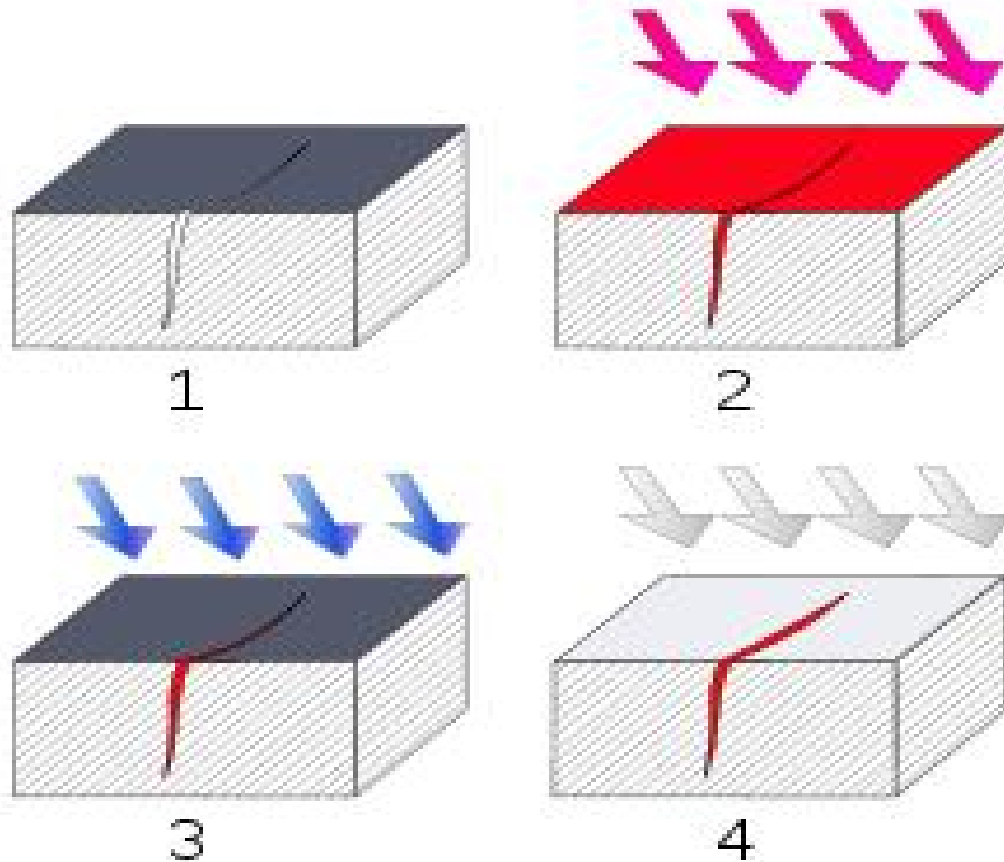


Dye Penetrant/ Liquid Penetrant test



- Liquid penetrant inspection is often referred to as an extension of the visual inspection method
- Two types of penetrating liquids are used - fluorescent and visible dye
- With fluorescent penetrant inspection, a highly fluorescent liquid with good penetrating qualities is applied to the surface of the part to be examined
- Capillary action draws the liquid into the surface openings, and the excess is then removed
- A "developer" is used to draw the penetrant to the surface, and the resulting indication is viewed by ultraviolet (black) light.
- The high contrast between the fluorescent material and the object makes it possible to detect minute traces of penetrant that indicate surface defects

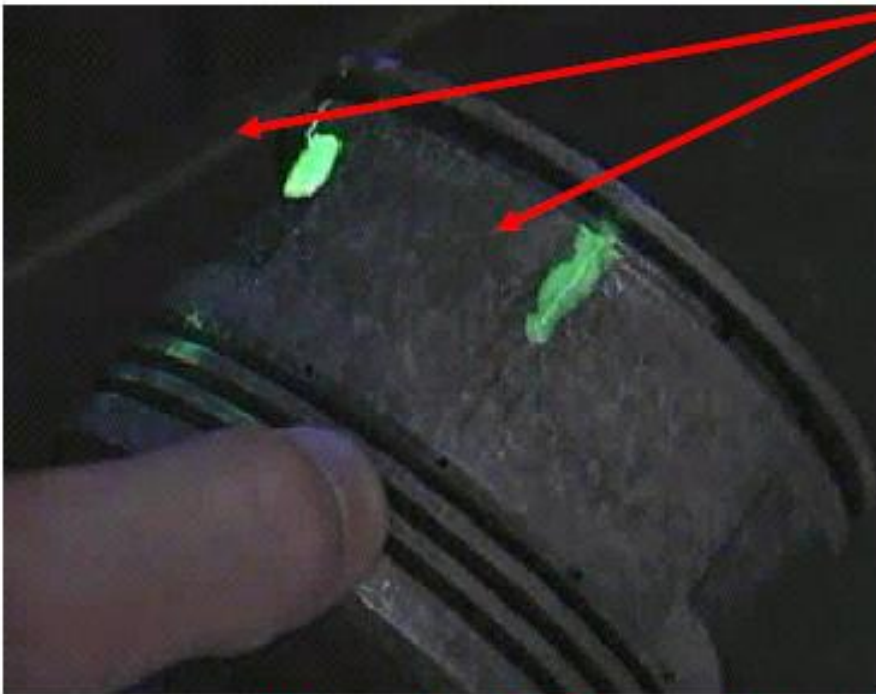
Dye Penetrate test



1. Section of material with a surface-breaking crack that is not visible to the naked eye.
2. Penetrant is applied to the surface.
3. Excess penetrant is removed.
4. Developer is applied, rendering the crack visible.

Dye Penetrate test

Fluorescent Penetrant



Bleed out viewed under a UV-A light source



Bleed out viewed under white light

Colour contrast Penetrant



Dye Penetrate test

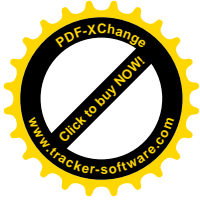


Advantages

- Simple to use
- Inexpensive
- Quick results
- Can be used on any non-porous material
- Portability
- Low operator skill required

Disadvantages

- Surface breaking defect only
- little indication of depths
- Penetrant may contaminate component
- Surface preparation critical
- Post cleaning required
- Potentially hazardous chemicals
- Can not test unlimited times
- Temperature dependant



Dye Penetrate test

- Excellent for locating leaks in weldments
- Can detect surface flaws/defects only
- Easy to use
- Low cost



Magnetic particle inspection



Main features:

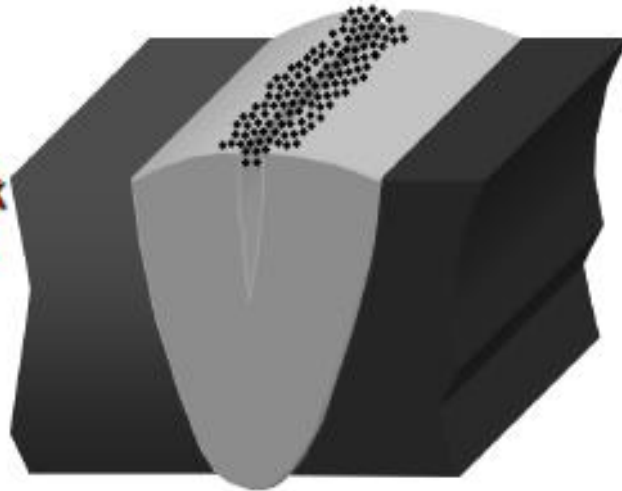
- Surface and slight sub-surface detection
- Relies on magnetization of component being tested
- Only Ferro-magnetic materials can be tested
- A magnetic field is introduced into a specimen being tested
- Methods of applying a magnetic field, yoke, permanent magnet, prods and flexible cables.
- Fine particles of iron powder are applied to the test area
- Any defect which interrupts the magnetic field, will create a leakage field, which attracts the particles



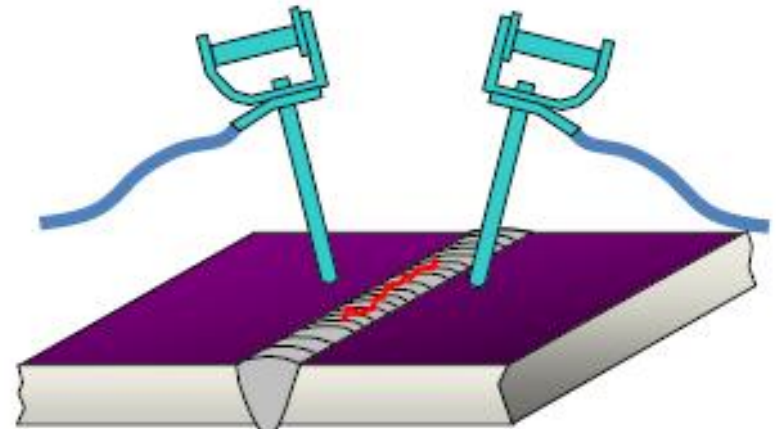
Magnetic particle inspection



Collection of ink particles due to leakage field



Electro-magnet (yoke) DC or AC



Prods DC or AC



Magnetic particle inspection



- *Typical sequence of operations to inspect a weld*
 - Clean area to be tested
 - Apply contrast paint
 - Apply magnetism to the component
 - Apply ferro-magnetic ink to the component during magnetising
 - Interpret the test area
 - Post clean and de-magnetise if required



Magnetic particle inspection



- Advantages

- Simple to use
- Inexpensive
- Rapid results
- Little surface preparation required
- Possible to inspect through thin coatings



Magnetic particle inspection



- **Disadvantages**

- Surface or slight sub-surface detection only
- Magnetic materials only
- No indication of defects depths
- Only suitable for linear defects
- Detection is required in two directions



Ultrasonic Examination



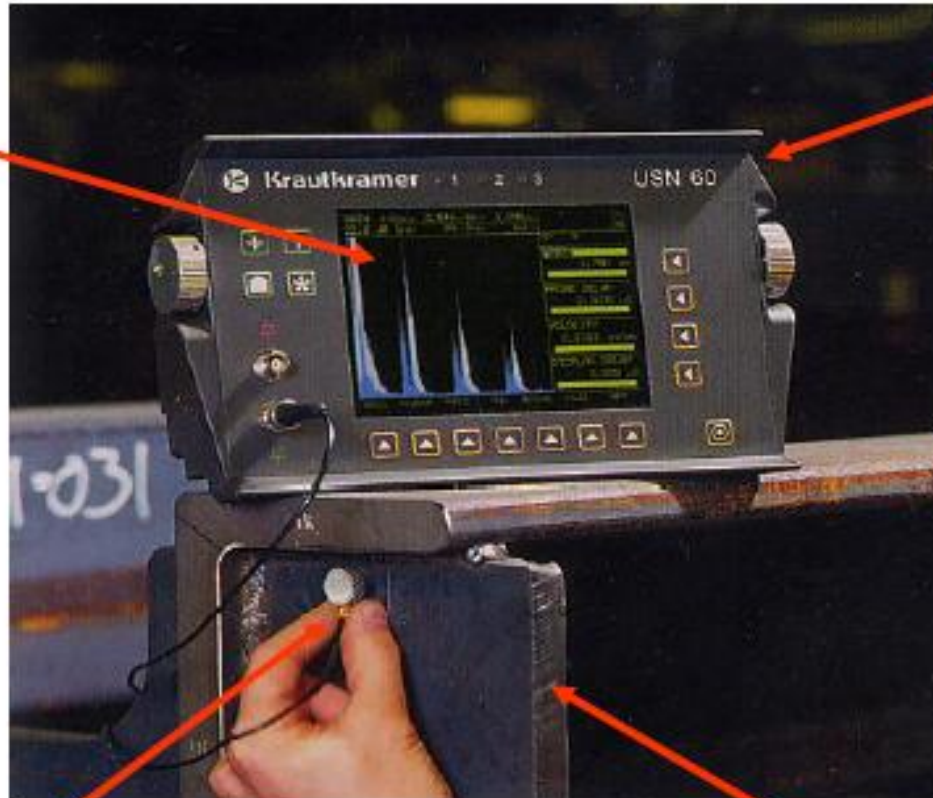
- *Main Features:*
 - Surface and sub-surface detection
 - This detection method uses high frequency sound waves
 - A probe is used which contains a piezo electric crystal to transmit and receive ultrasonic pulses and display the signals on a cathode ray tube or digital display
 - The actual display relates to the time taken for the ultrasonic pulses to travel the distance to the interface and back
 - An interface could be the back of a plate material or a defect



Ultrasonic Examination

**Pulse echo signals
A scan
Display**

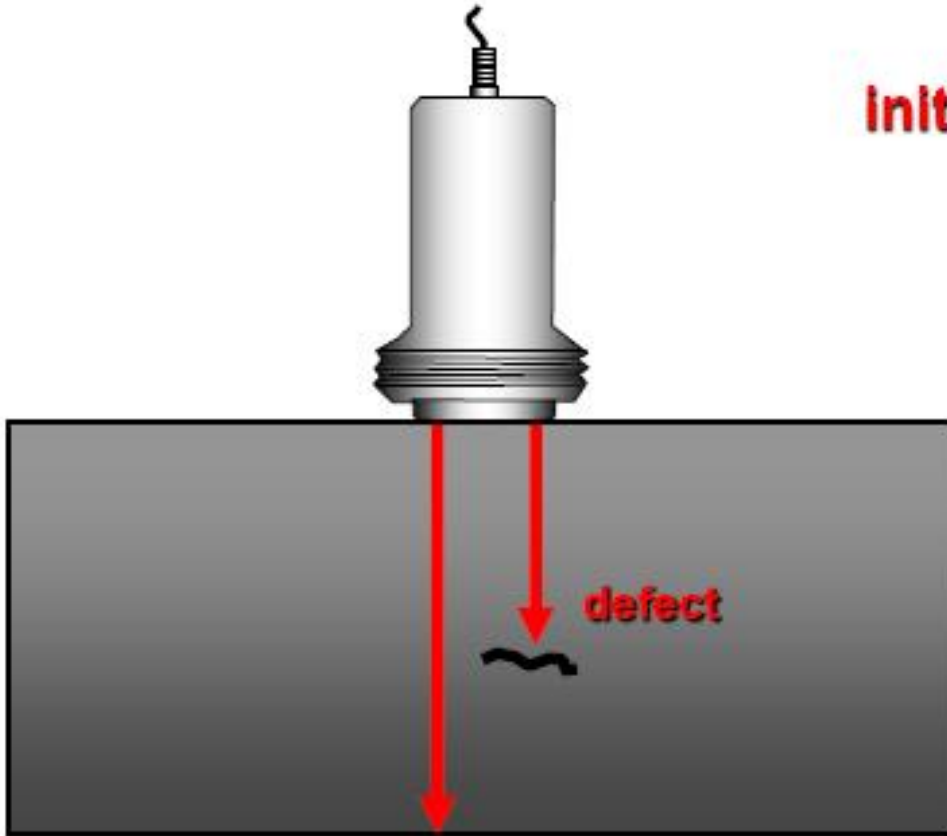
**Digital
UT Set,**



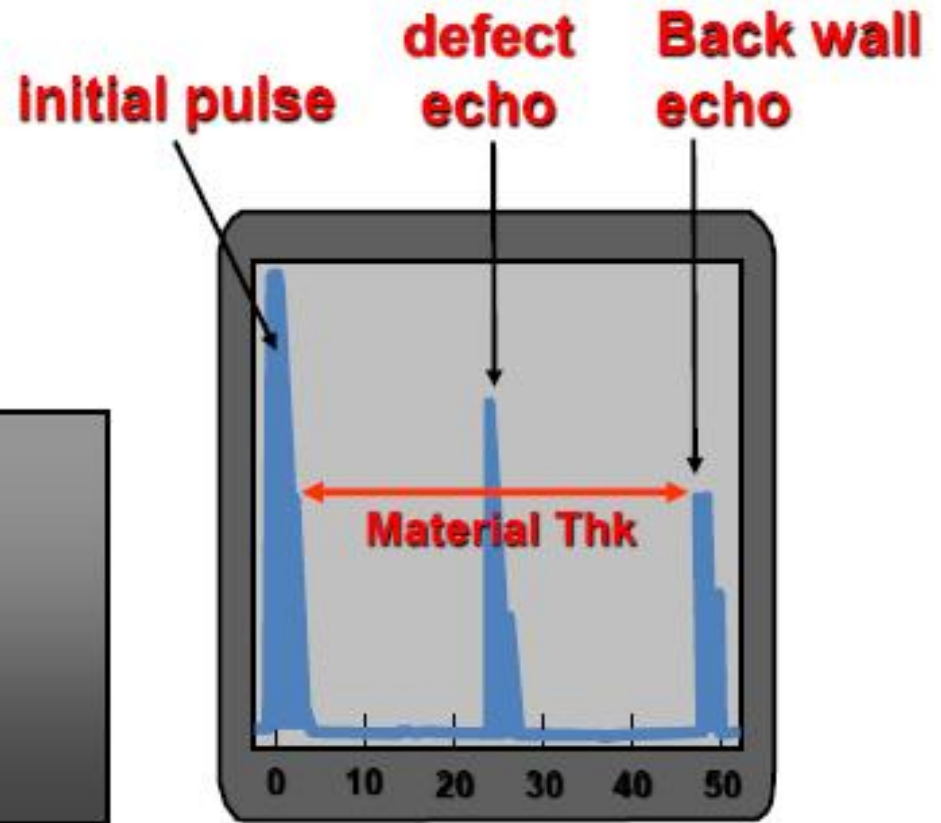
Compression probe

checking the material Thickness

Ultrasonic Examination



Compression Probe

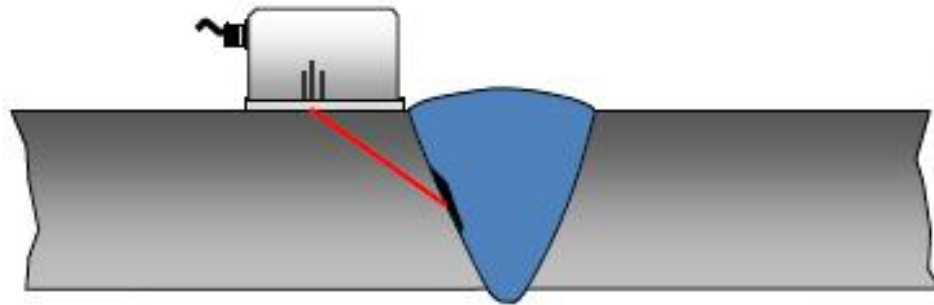


CRT Display

Ultrasonic Examination



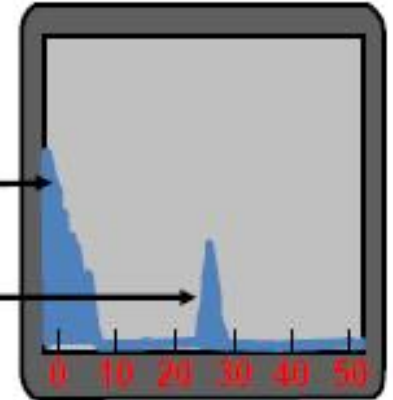
Ultrasonic Examination



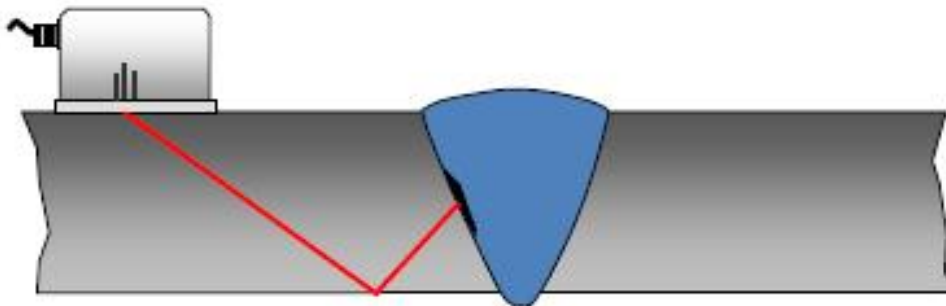
1/2 Skip

initial pulse

defect echo



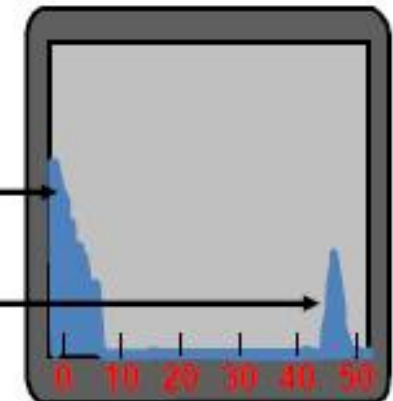
CRT Display



Full Skip

initial pulse

defect echo



CRT Display



Ultrasonic Examination



- **Advantages**
- Rapid results
- Both surface and sub-surface detection
- Safe
- Capable of measuring the depth of defects
- May be battery powered
- Portable



Ultrasonic Examination



- **Disadvantages :**
- Trained and skilled operator required
- Requires high operator skill
- Good surface finish required
- Defect identification
- No permanent record
- Calibration Required



Radiographic Examination



- *The principles of radiography*
 - X or Gamma radiation is imposed upon a test object
 - Radiation is transmitted to varying degrees dependant upon the density of the material through which it is travelling
 - Thinner areas and materials of a less density show as darker areas on the radiograph
 - Thicker areas and materials of a greater density show as lighter areas on a radiograph
 - Applicable to metals, on-metals and composites



Radiographic Examination



X – Rays

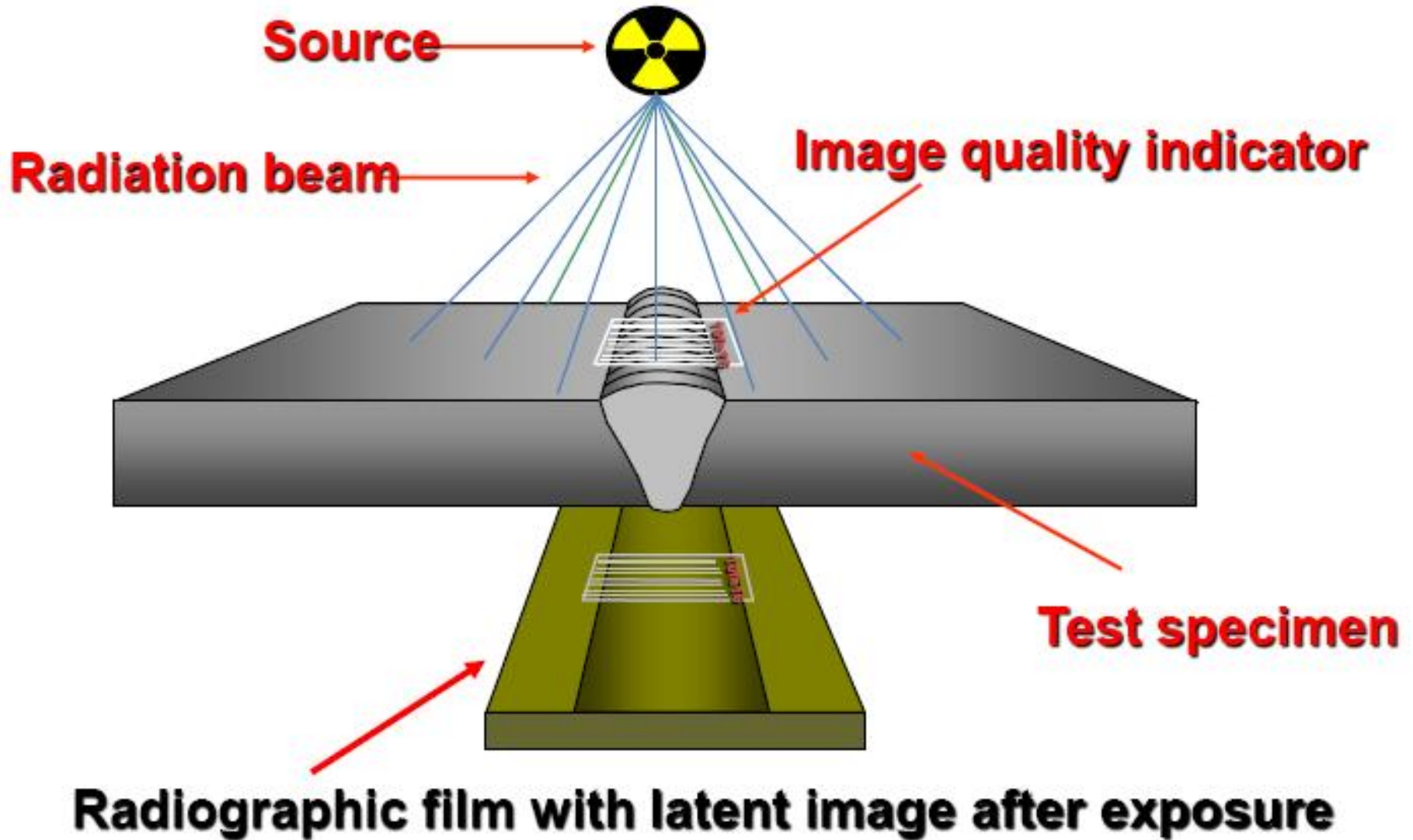
Electrically generated



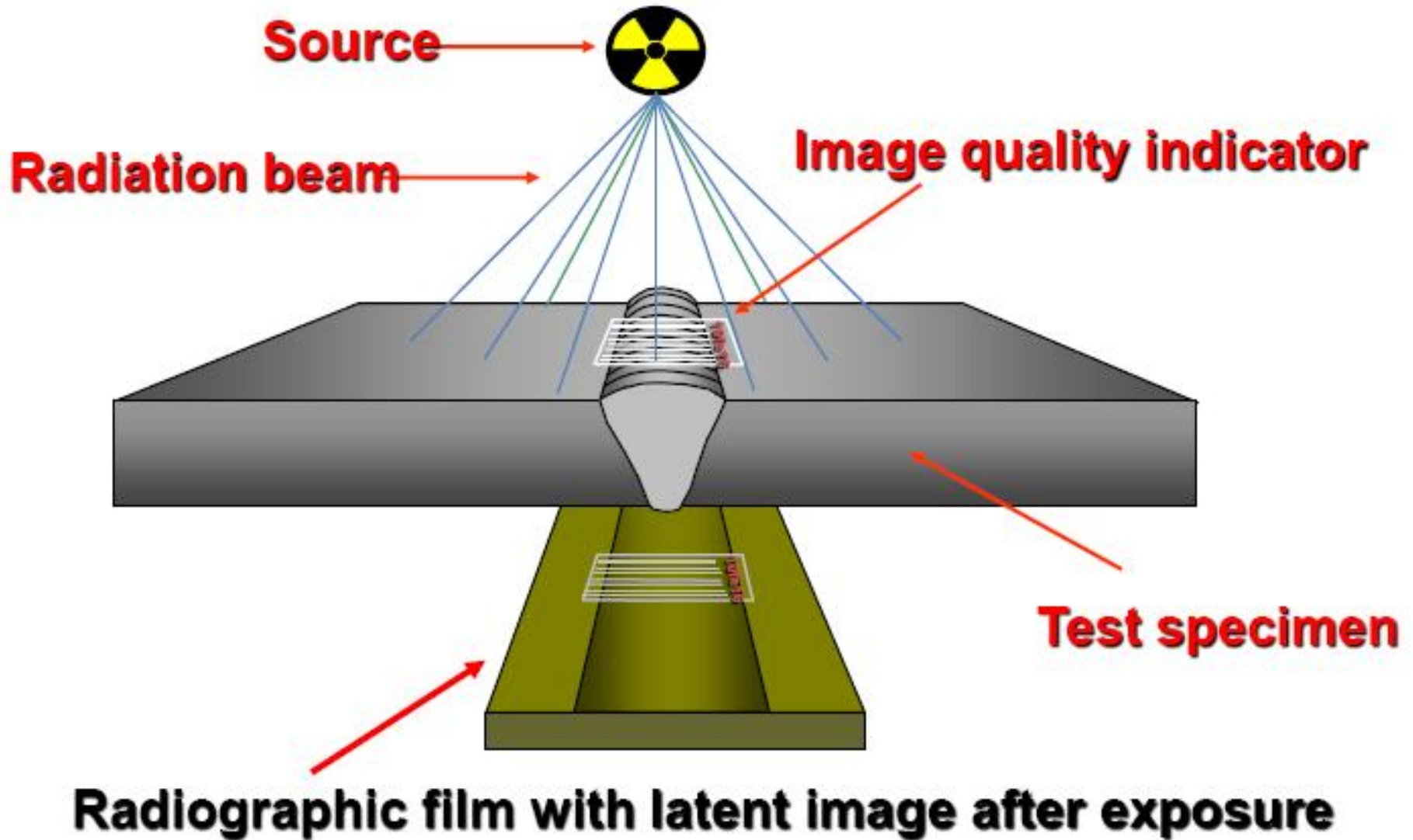
Gamma Rays

**Generated by the decay
of unstable atoms**

Radiographic Examination



Radiographic Examination





Radiographic Techniques



Single Wall Single Image (SWSI)

- film inside, source outside

Single Wall Single Image (SWSI) panoramic

- film outside, source inside (internal exposure)

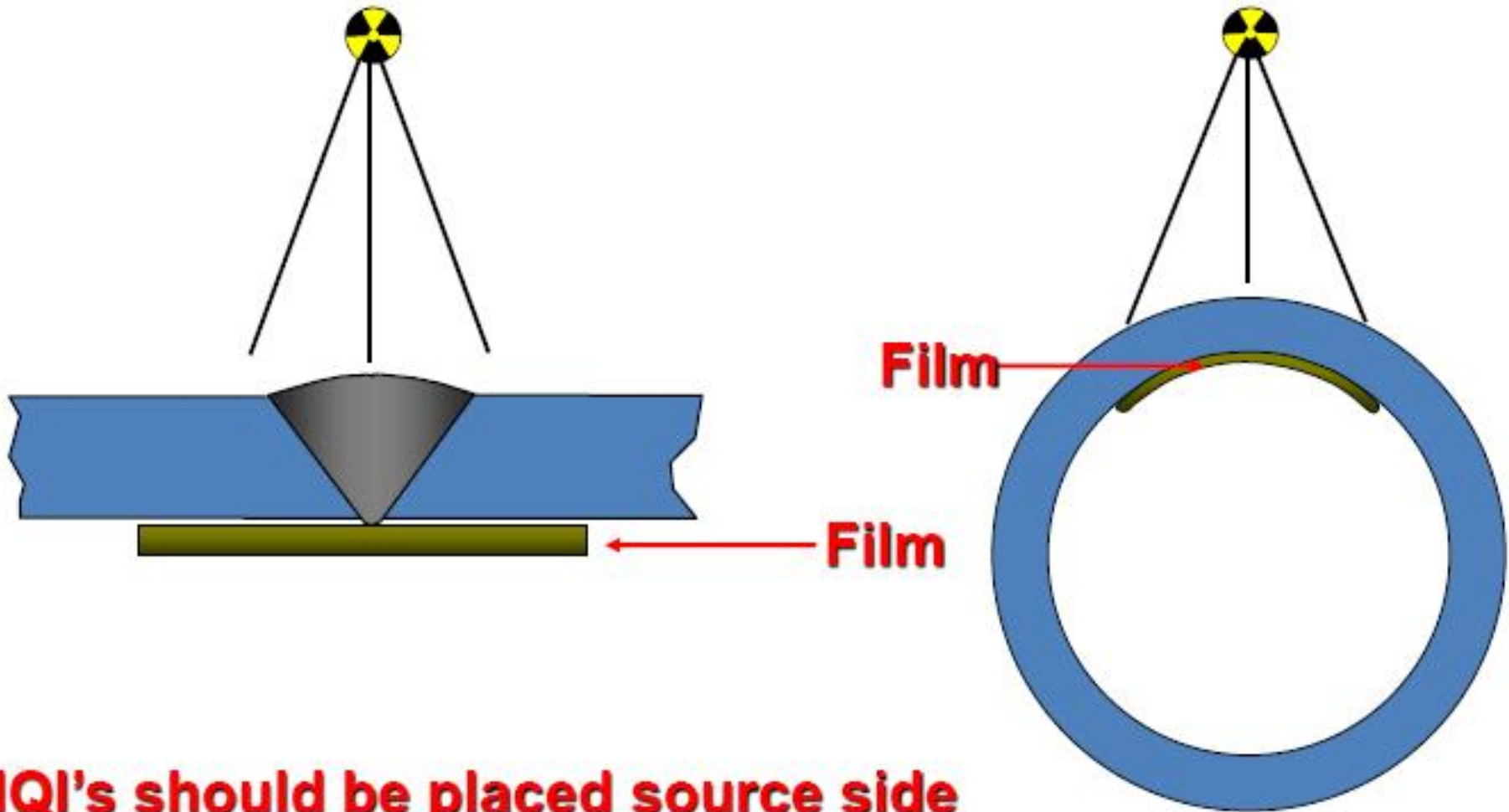
Double Wall Single Image (DWSI)

- film outside, source outside (external exposure)

Double Wall Double Image (DWDI)

- film outside, source outside (elliptical exposure)

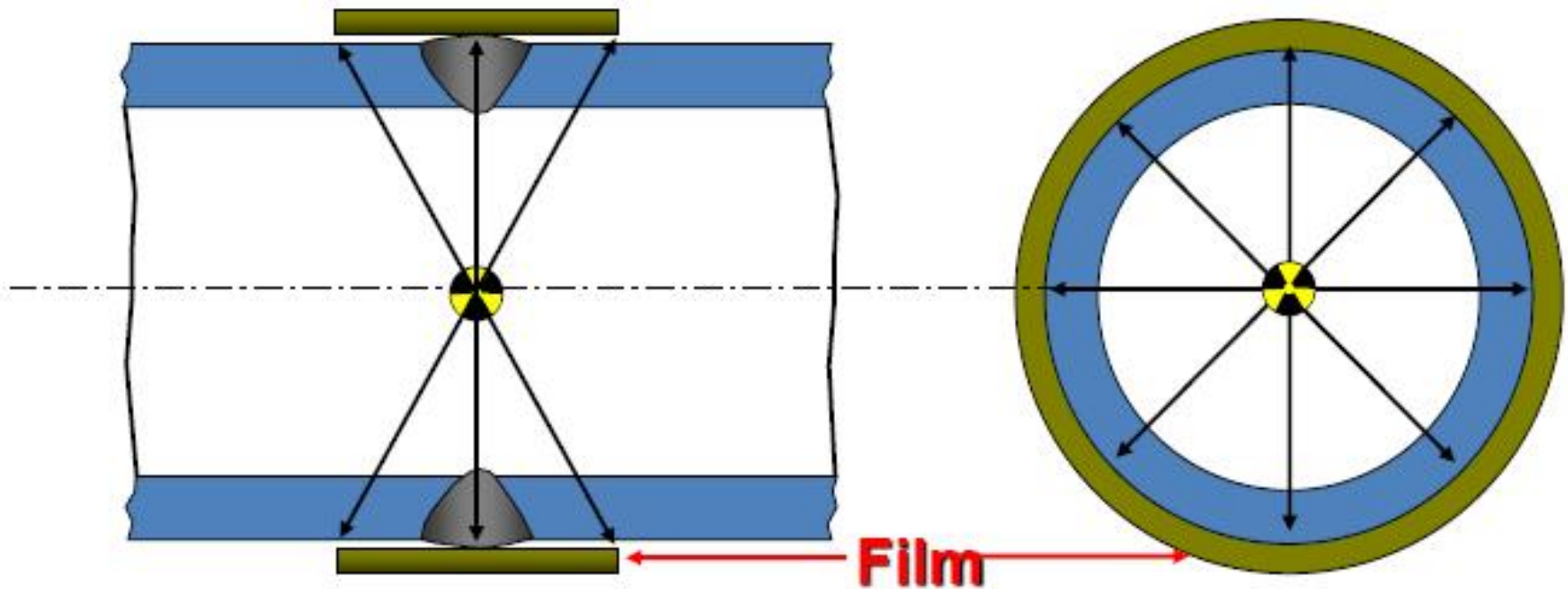
Single Wall Single Image (SWSI)



IQI's should be placed source side



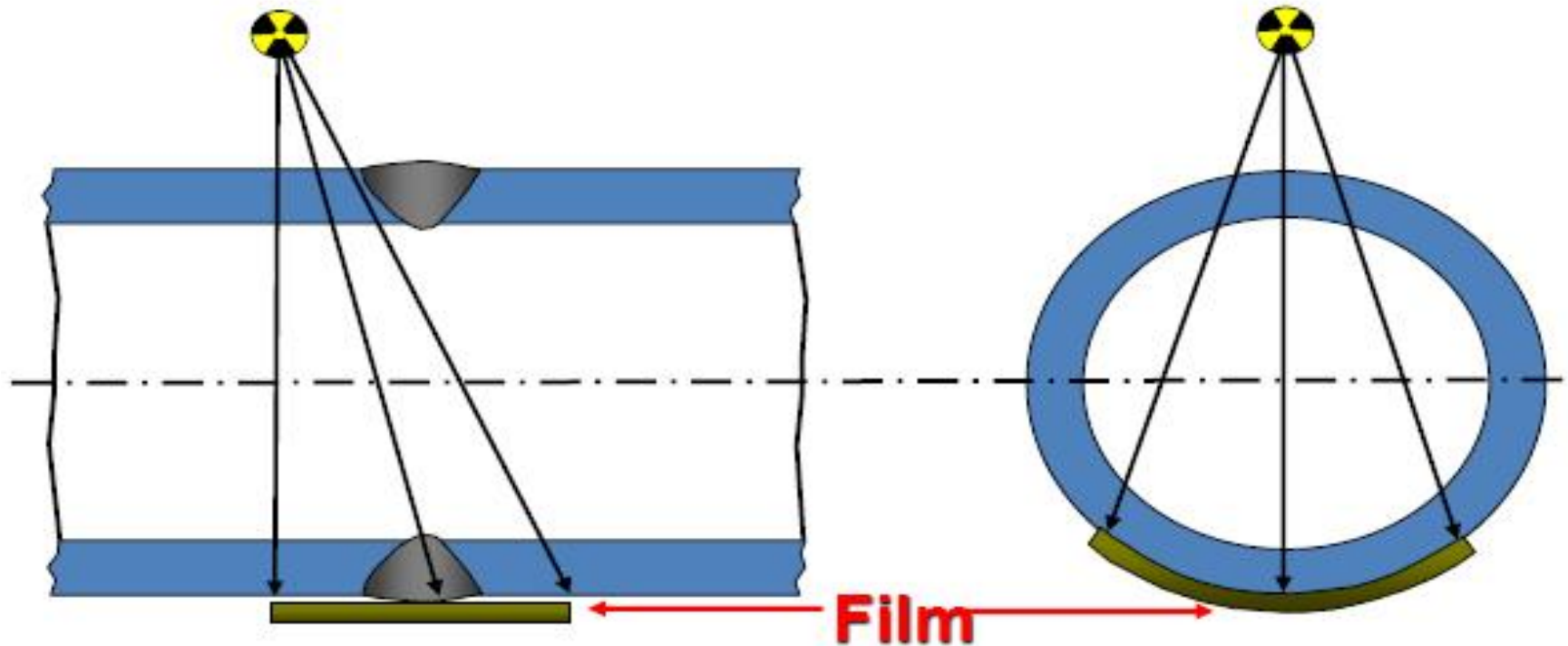
Single Wall Single Image Panoramic



- **IQI's are placed on the film side**
- **Source inside film outside (single exposure)**



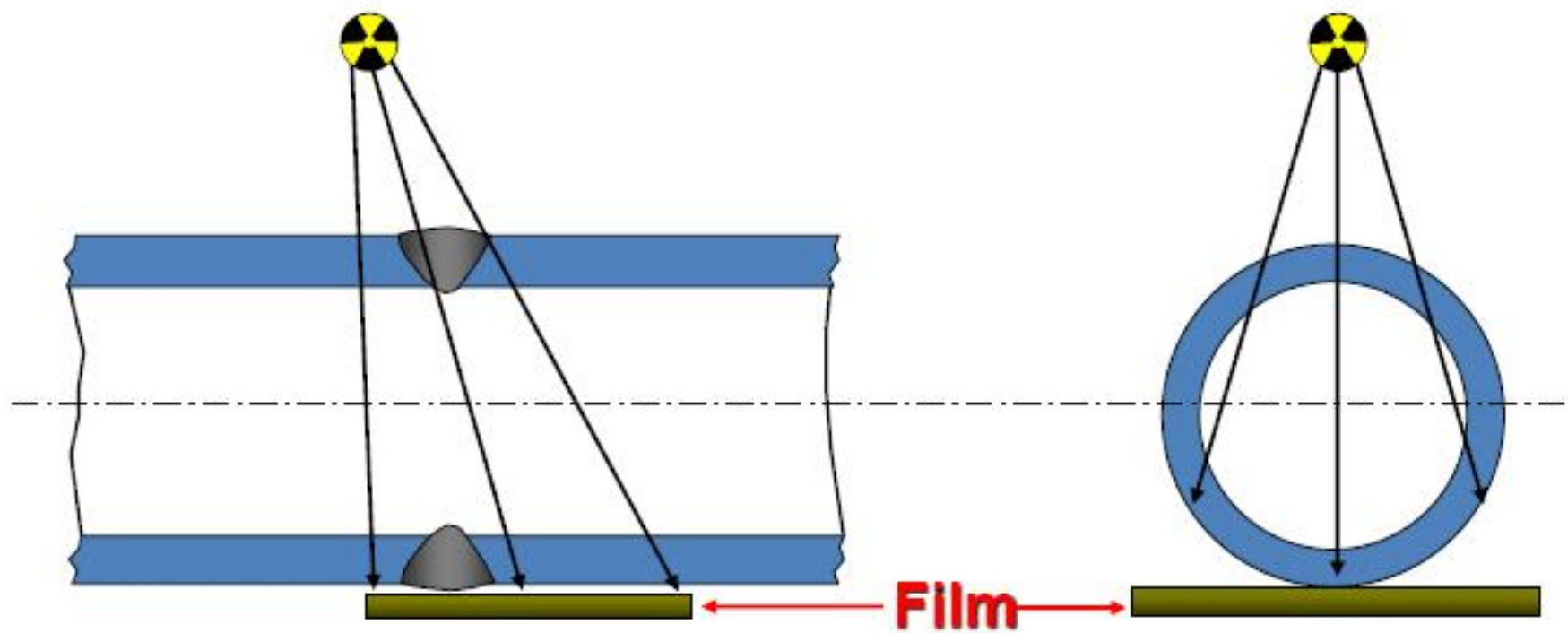
Double Wall Single Image (DWSI)



- **IQI's are placed on the film side**
- **Source outside film outside (multiple exposure)**
- **This technique is intended for pipe diameters over 100mm**



Double Wall Double Image (DWDI)



- IQI's are placed on the source or film side
- Source outside film outside (multiple exposure)
- A minimum of two exposures
- This technique is intended for pipe diameters less than 100mm



Radiographic Examination



- *Advantages*

- Permanent record
- Little surface preparation
- Defect identification
- No material type limitation
- Not so reliant upon operator skill
- Thin materials

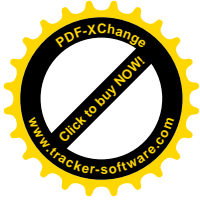


Radiographic Examination



- *Disadvantages*

- Expensive consumables
- Bulky equipment
- Harmful radiation
- Defect require significant depth in relation to the radiation beam (not good for planar defects)
- Slow results
- Very little indication of depths
- Access to both sides required



Welding

Module 19.2.14

Prepared by:

Syed Fawwad



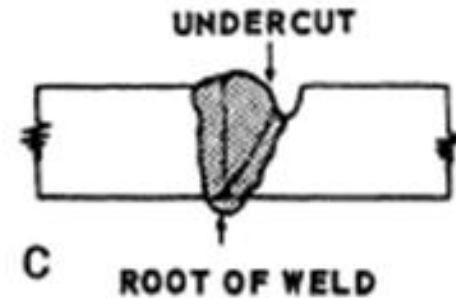
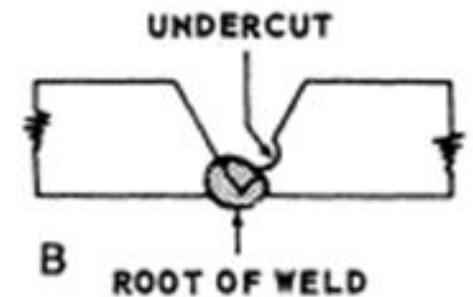
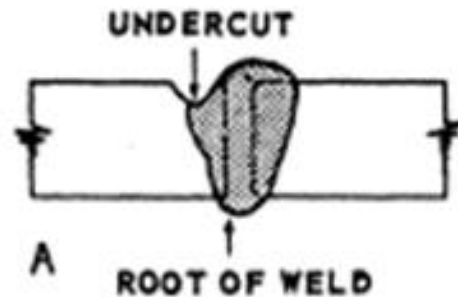
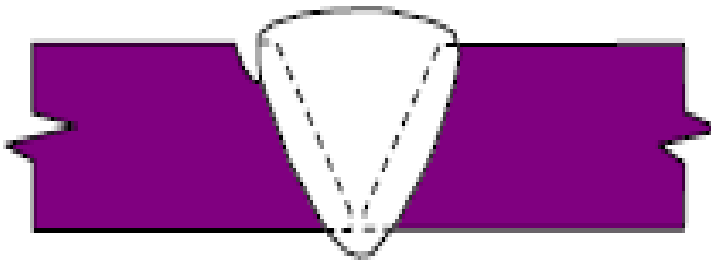
Module objective

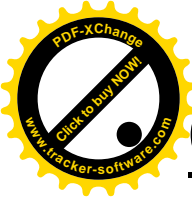
- Identify weld defects and state possible causes.
 - Weld defects: undercut, cracking, overlap, incomplete penetration, slag inclusions, lack of side wall fusion, porosity, poor weld appearance, excessive spatter



Undercut

- Undercut is a defect that appears as a groove in the parent metal directly along the edges of the weld. It is most common in lap fillet welds, but can also be encountered in fillet and butt joints.





Causes of undercut

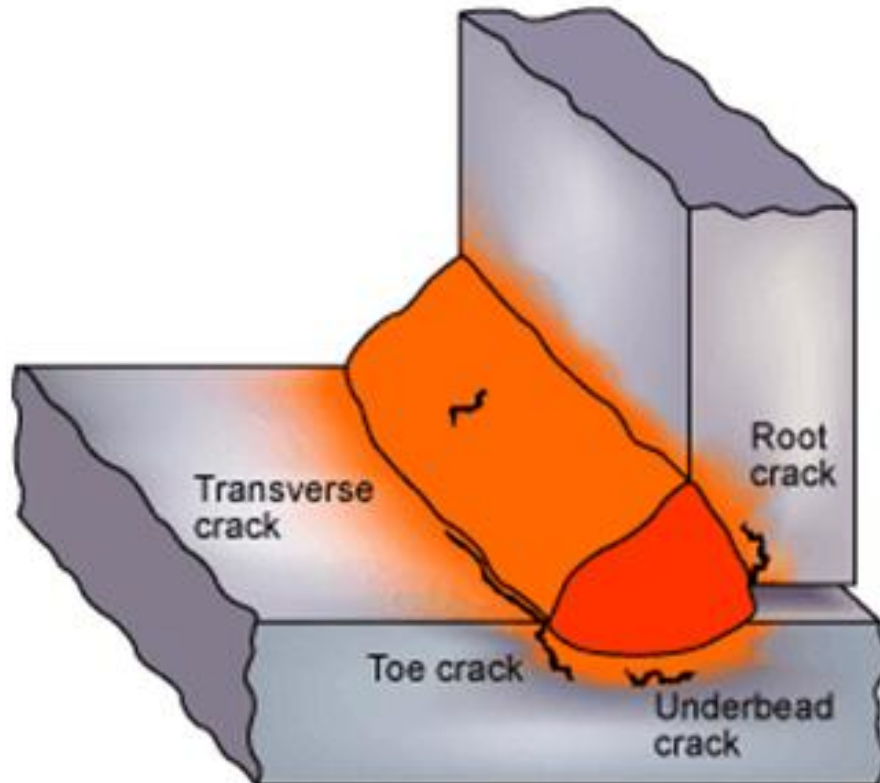
- Excessive welding speed
- Excessive current for the size of the electrode
- Incorrect electrode angles
- Incorrect type of electrode
- Excessive weaving of the electrode

- Remedies for undercut

- Set welding current according to required specifications
- Control the speed of welding properly
- Adopt correct welding procedure

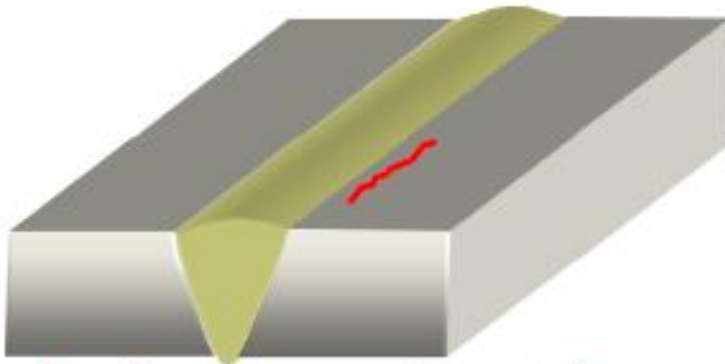
Cracking

- Cracks are discontinuities presenting fracture.

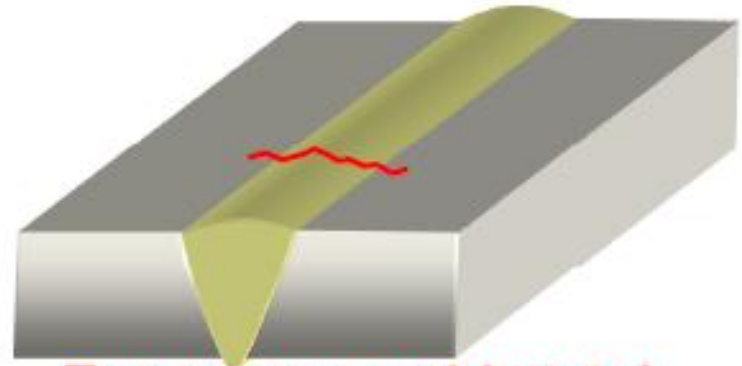




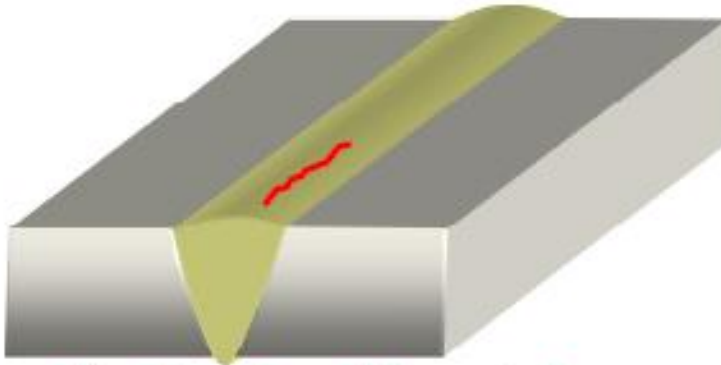
Types of crack



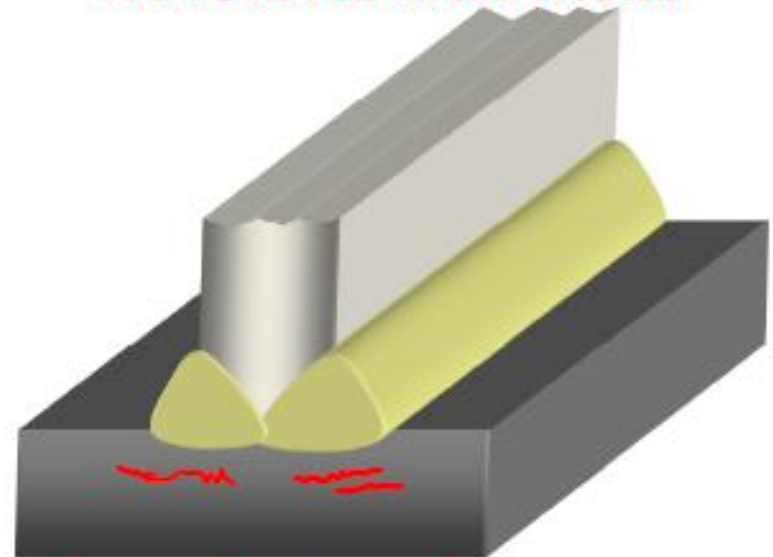
Longitudinal parent metal



Transverse weld metal



Longitudinal weld metal



Lamellar tearing



Causes of cracks

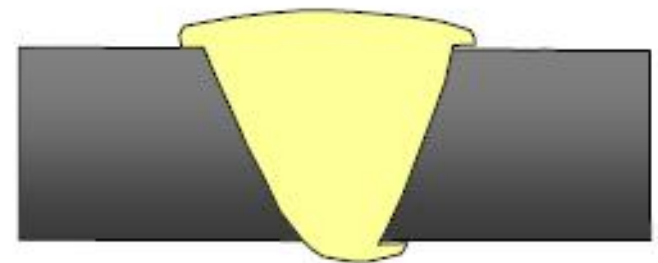
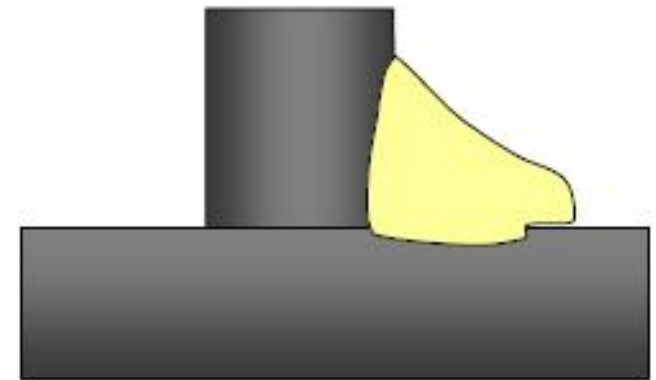
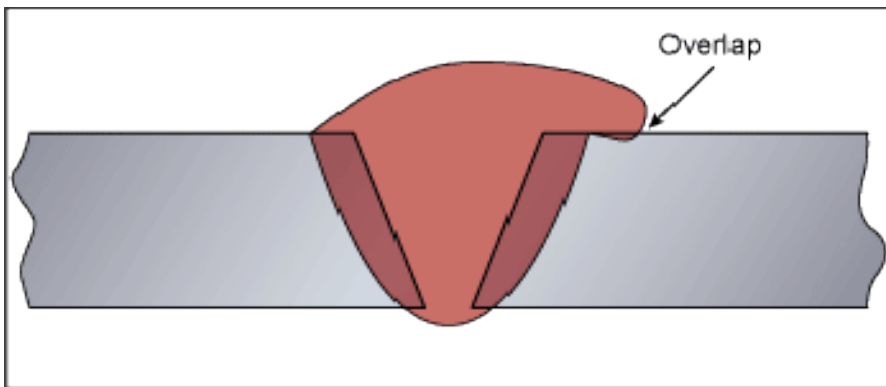
- Poor ductility of base metal.
- Hardenability, high Sand Carbon percentage of base metal.
- Concave weld bead.
- Fast arc travel speed.
- Electrode with high H₂ content.

- Remedies for cracking

- Use preheating
- Relieve residual stresses.
- Minimize shrinkage stresses, Using back step or block welding sequences
- Use proper electrode

Overlap

- This is an imperfection at a toe or root of a weld caused by metal flowing on to the surface of the parent metal without fusing to it.





Causes of Overlap

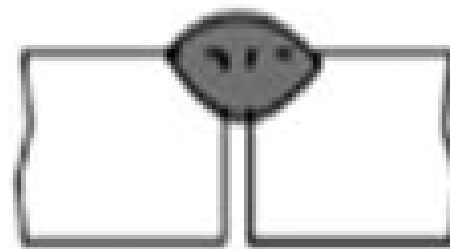
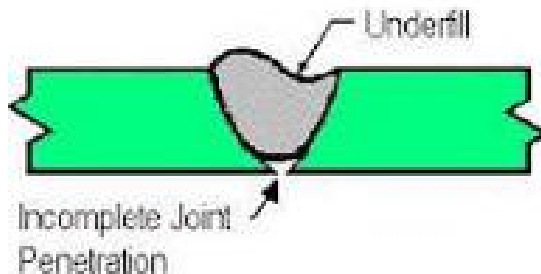
- Poor handling of electrode or welding gun
- Too cold a welding conditions (current and voltage too low)
- Large weld pool

- Remedies for Overlap

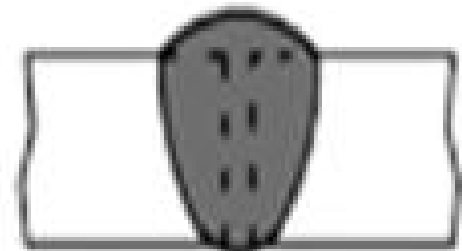
- Welder skill level should be acceptable
- Reduction in weld pool size (obtained by reducing current or increasing travel speed)
- Adequate cleaning of the parent plate

Incomplete penetration

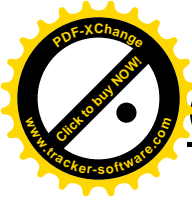
- This type of defect is found in any of three ways
 - When the weld bead does not penetrate the entire thickness of the base plate
 - When two opposing weld beads do not interpenetrate.
 - When the weld bead does not penetrate the toe of a fillet weld but only bridges across it



Lack of Penetration



Good Penetration

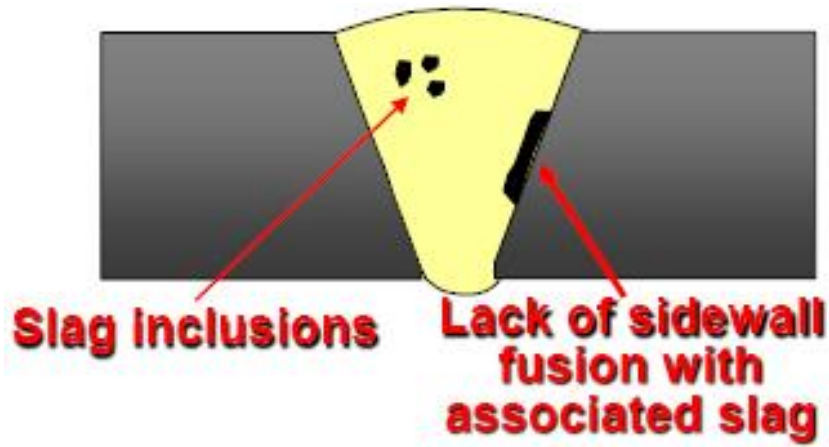


Causes of incomplete penetration

- Improper joints types
 - Too large root face
 - Root gap too small
 - Less arc current.
 - Faster arc travel speed.
 - Too large electrode diameter.
 - Longer arc length.
-
- Remedies for incomplete penetration
 - Increase welding current
 - Reduce welding speed
 - The arc must be kept on the leading edge of the weld puddle
 - Use correct electrode diameter
 - Electrode should be in the centre of the joint.

Slag Inclusion

- Slag inclusions are defined as a non-metallic inclusion caused by some welding process





Causes of slag inclusions

- Excessive hydrogen, nitrogen, or oxygen in welding atmosphere
- High solidification rate
- Dirty base metal
- Improper arc length, welding current, or electrode manipulation
- Excessive moisture in electrode covering

- Remedies for slag inclusions

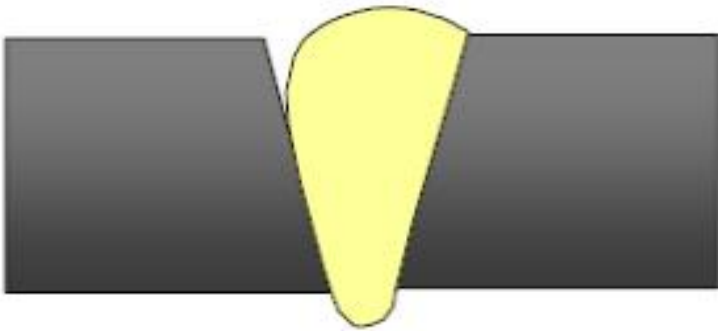
- Increase shielding gas flow
- Use low-hydrogen welding process
- Use preheat or increase heat input
- Change welding conditions and techniques



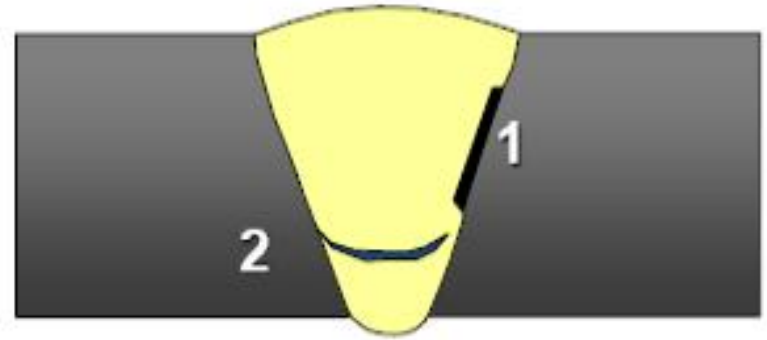
Lack of side wall fusion



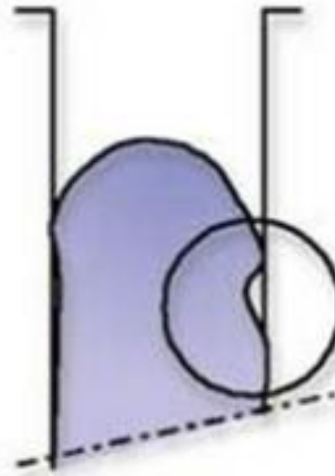
- It is lack of union between weld metal and parent metal at the fusion faces on the sloping sides of the weld preparation



**Incomplete filled groove +
Lack of sidewall fusion**



**1. Lack of sidewall fusion
2. Lack of inter-run fusion**





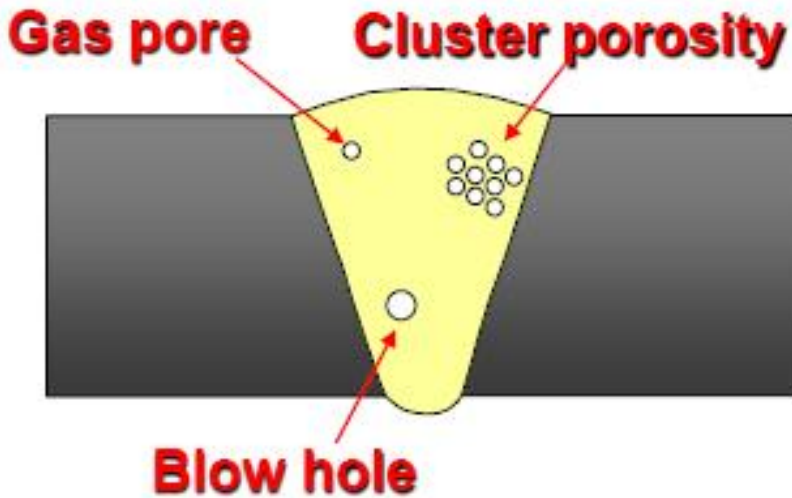
Causes of lack of side wall fusion

- Too narrow a joint preparation
 - Incorrect welding parameter settings (welding current, welding speed etc.)
 - Poor welder technique
-
- Remedies for lack of side wall fusion
 - Use a sufficiently wide joint preparation
 - Select welding parameters (high current level, short arc length, not too high a welding speed) to promote penetration into the joint side wall without causing flooding
 - Ensure the electrode/gun angle and manipulation technique provide adequate side wall fusion



Porosity

- Porosity in welding is a result of dissolved gases or gases released during the welding process, being trapped in the metal when there is insufficient time to escape prior to solidification





Causes of Porosity

- Excessively long or short arc length
- Welding current too high
- Insufficient or moist shielding gas
- Travel speed too fast
- Base metal covered with oil, grease, moisture etc.
- Wet, unclean or damaged electrodes

- Remedies for Porosity

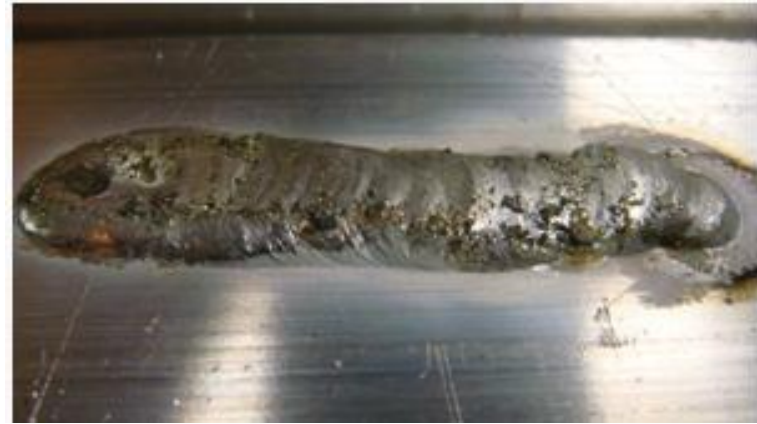
- Change welding parameters (current, travel speed, arc length) and technique.
- Use preheating. Warm up work piece.
- Provide proper gas shielding
- Clean surface and previous weld bead



Poor weld appearance



- Poor welding appearance is a common welding defect. While this is not harmful from a structural point of view, it affects the quality from the finished appearance of the weld





Causes of poor welding appearance

- Failure to clean finished weld deposit
- Improper joint preparation
- Poor welding technique
- Failure to set current properly or improper electrode manipulation

• Remedies for poor welding appearance

- Remove all slag, flux and spatter from weld bead and the adjacent base metal
- Use proper joint preparation. Get the best fit possible
- Use the proper technique for the electrode you have selected. If the electrode is deposited with a weave, keep the motion uniform. Travel along the joint at a constant rate.
- Do not use excessive welding currents



Excessive spatter

- Spatters are the small metal particles which are thrown out of the arc during welding and get deposited on the base metal around the weld bead along its length. Excessive spatter can result in low-quality stick and MIG welds, make your welding area messy, and cause visibility problems





Causes of excessive spatter

- Excessive arc current
- Longer arcs
- Damp electrodes
- Electrodes being coated with improper flux ingredients
- Bubbles of gas becoming entrapped in the molten globule of metal
- Remedies for excessive spatter
 - Cut down on spatter by adjusting your voltage
 - Keep your welding surface free from contamination.
 - Make sure your shielding gas is not affected by air circulation.
 - Make sure cabling is secure and on clean surfaces
 - Find the Right Torch Angle



Thank you