Welding

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Welding is an efficient and economical means of joining two or more metal pieces permnently.

Welding is a process of making permnent joint by establishing interatomic bonds between two or more pieces of metals by applying heat or heat and pressure.

Welding process may be classified according to source of heat input and state of metal at the joint.

Pressure Welding	Fusion welding
1. It requires heat and pressure	1. It requires only heat.
2. Joint area is heated to plastic state	2. Joint area is heated to fusion (or) molten state.
3. It requires low temperature	3. It requires high temperature
4. Composition and Structure is not much affected.	4. Composition and Structure is affected
5. It doesn't require filler Material.	5. It requires filler Material.

Advantages and limitations:

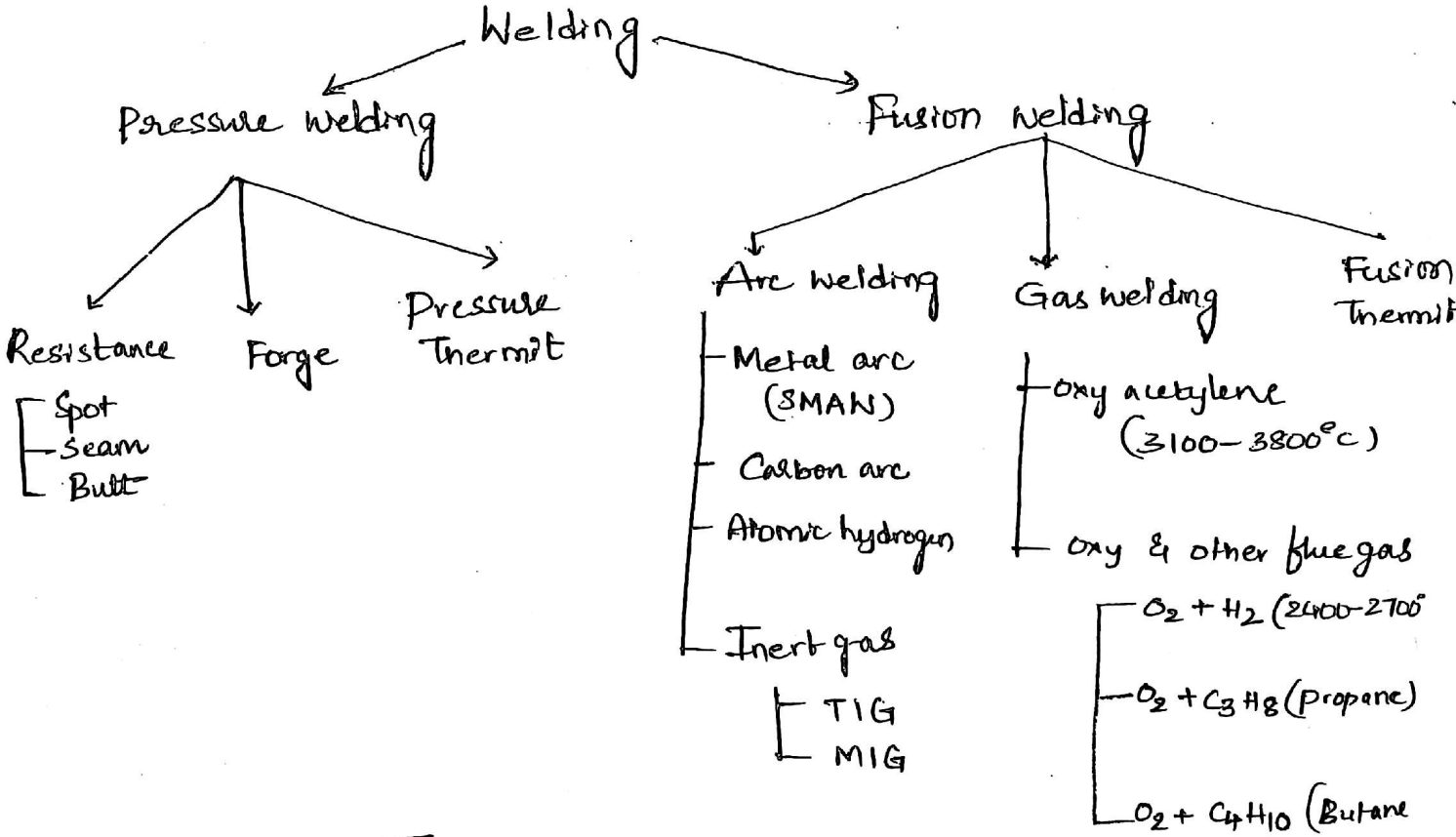
Welding is the most widely adopted method of fabrication and is also used as a means of repairing broken parts.

Advantages:

1. A welded joint is as strong as the base metal.
2. Welding equipment is not costly and easily portable.
3. Welding provides considerable freedom in design.
4. A large no.of metals and non-metals can be welded and is also suitable for dissimilar metals.
5. 'Weldments' (Welding products) are lighter and stronger.
6. Joints are easier to inspect.

Disadvantages:

1. Welding requires skilled operator.
2. Welding results in residual stresses and distorsion of the workpiece. Therefore it needs heat treatment to relieve internal stresses.
3. Welding requires edge prepation, use of jigs & fixtures.
4. Welding gives out harmful radiation and fumes.
5. The structure of welded joint is not same as base metal.



Types of welding processes

Accessories required in arc welding :

1. Electrodes

It conveys welding current to workpiece Generally Material is Same as workpiece

2. Electrode holder

Clamping device for holding electrode

3. Cables & leads :

Copper wires which are insulated one used to connect power source to electrode, work piece

4. Safety devices

a. Face shields
b. Hand gloves
c. Aprons
d. Safety goggles
e. Skull caps
f. Safety boots

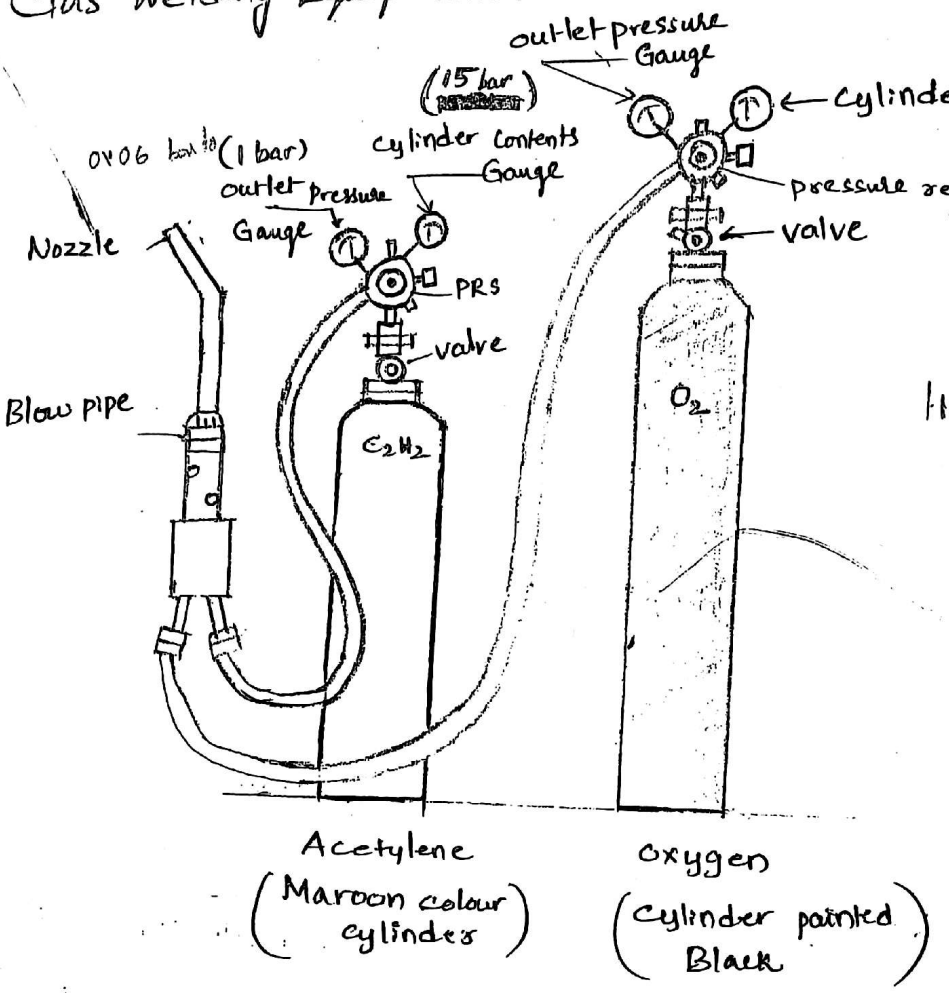
5. Tools :

1. Chipping Hammer
2. Brushes
3. Tongs
4. Welding fixtures

Gas Welding :

In Gas welding the heat required to melt the metal & filler rod is produced by gas flame. Different gas compositions can be used for producing hot flame. However, oxygen and acetylene mixture is most commonly used, Acetylene (C_2H_2) produces higher temperature (in range of 3200°C) than other gases like H_2, propane (C_3H_8), Butane (C_4H_{10}), coal gas etc (which produce temperature in the range of < 2500°C).

Gas welding Equipment:



Equipment requires in gas welding includes Cylinders for Compressed gases, regulators, blow pipes, Nozzles, Hose and Hose fittings.

Cylinders: The oxygen cylinder is painted black and is made of steel.

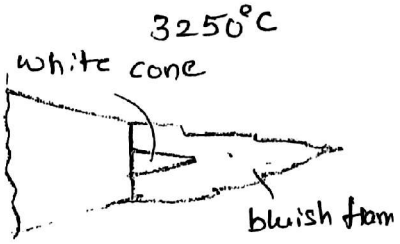
Acetylene Cylinder is painted Maroon and is made of Steel.

To avoid potentially lethal situations, C_2H_2 Cylinders have left hand threads and Oxygen Cylinders have Right hand threads. This safety precaution also applies to all valves, connectors and regulators.

A neutral flame is obtained when equal amounts of oxygen & acetylene are mixed and burnt in a torch.

$$C_2H_2 + O_2 \longrightarrow 2CO + H_2$$

The flame is recognized by two sharply defined zones, the inner white cone flame and the outer blue flame envelope.



Neutral flame

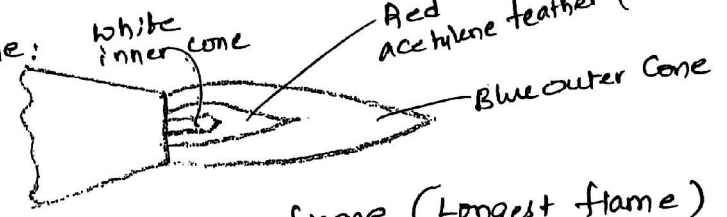
The reaction of equal amounts of O_2 & C_2H_2 produces carbon monoxide and Hydrogen reacts with the oxygen from surrounding air which is supplied.

$$2CO + O_2 \longrightarrow 2CO_2$$

$$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O \text{ (vapour)}$$

During actual welding the outer envelope spreads over the surface of the work and serves as a protective shield from the ordinary atmosphere. Also heat developed is not concentrated in the outer envelope, so it contributes only to preheat work material for welding. Neutral flame has no tendency to react with material to be welded. So, it is used to weld low carbon steel, stainless steel, cast Iron, Copper, Aluminium, Magnesium etc.

Carburising flame: Reducing flame:



Carburising flame (Longest flame)

A carburising flame is obtained when excess of acetylene is supplied than theoretically required. $O_2 : C_2H_2 = 0.85$ to 0.95.

The inner cone which is not sharply defined. It has outer envelope as for the neutral flame. The third zone surrounds the inner cone and extends in to the outer envelope. It is Red in colour and is called "excess "acetylene feather". Its length is an indication of excess acetylene.

carburising flame is used to weld stellate, High carbon steel, Cemented carbides.

Oxy acetylene flame:

In an oxyacetylene flame oxygen and acetylene are mixed and burnt to release heat.

$$C_2H_2 + 2.5O_2 \longrightarrow 2CO_2 + H_2O + 1284.57 \text{ KJ/mol.}$$

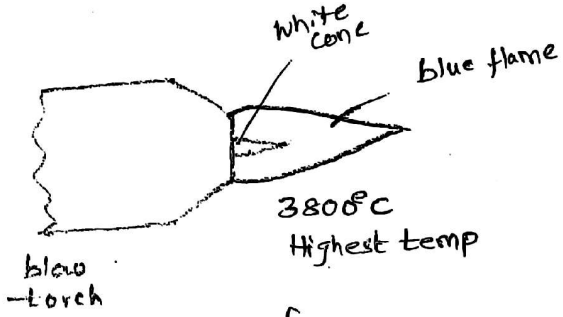
The complete combustion of acetylene in an atmosphere of oxygen is represented by above reaction.

Depending on the metal to be welded and the type of filler material used in welding the flame can be set to (i) oxidising (ii) neutral (iii) Carburising or reducing flame.

Oxidising flame:

This flame requires excess of oxygen over that required for neutral flame. $O_2 : C_2H_2 = 1.15$ to 1.5.

To obtain an oxidising flame the flame first set to the neutral condition. Then the acetylene valve is turned down gradually to reduce the amount of acetylene giving an excess amount of oxygen.



Oxydising flame
(Shortest length)

The flame resembles the neutral flame except that it acquires a light blue tint and the inner cone is slightly shorter & more pointed than in a neutral flame. An oxidising flame burns with a harsh sound and the outer envelope is short and narrow.

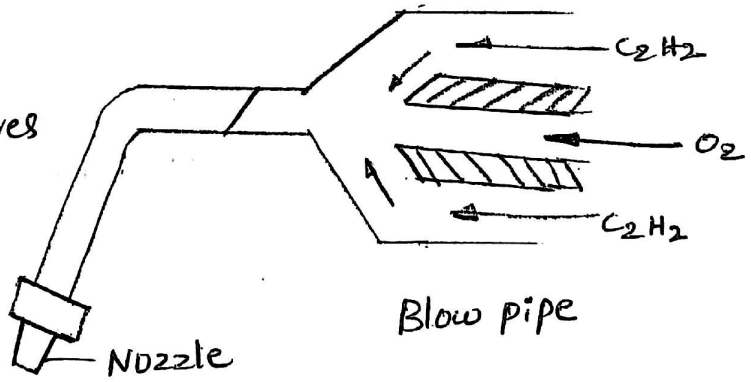
Oxidising flame is used for brass, bronze, gold.

Pressure Regulators: A pressure regulator located on the top of both O_2 & C_2H_2 cylinders, serves to reduce the high cylinder pressure of the gas to a suitable working value at the blow pipe and to maintain a constant pressure.

3. Pressure gauges: Each gas cylinder is provided with two pressure gauges. One gauge indicates the pressure of the gas inside the cylinder and the other indicates the pressure of the gas supplied to the blow pipe.

4. Blow pipe:

The blow pipe or welding torch serves to mix the gases in proper proportions & to deliver the mixture to the nozzle tip where it is burned.



5. Nozzle or Tip:

The Nozzle is a device screwed to the end of blow pipe. It is used to permit the flow of oxyacetylene gas mixture from the mixing chamber of blow pipe to the tip of nozzle to facilitate burning.

6. Hose and Hose fittings: The hose connects the outlet of pressure reducing valve and the blow pipe. Rubber tube is used for flexibility. Blue colour for oxygen and Red colour for acetylene. Hose fittings [illegible] ends of hoses for attachments.

The temperature of the arc is about 3600°C which can melt the metal and filler material together so that they all fuse into one solid piece of metal. The temperature of the arc at the center is 6500°C. Only 60-70% heat is utilized in arc welding to heat up and melt the metal and the remaining is dissipated in to Surroundings.

This process is used primarily to weld iron and steel but aluminum, nickel and Copper can also be welded.

Applications: Arc welding is used extensively in the Construction of steel Structures, fabrication of pressure vessels, ships, joints in a pipe work, Construction and Repair of machine parts.

Classification:

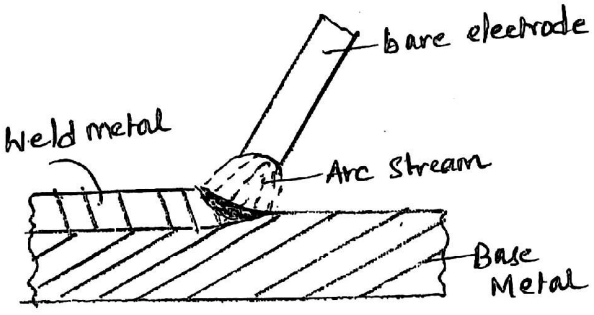
Arc welding is classified in to two types.

They are 1. Metal arc welding [Manual Metal Arc welding] MMA

2. Shielded metal arc welding (SMAW)

Manual Metal arc welding: (MMAW)

It is the most Common type of arc welding. Because of manual operation it is also called Manual Metal Arc welding. The Composition of electrode is Same as base metal and the electrode is a consumable metal electrode (filler rod). The arc is struck by Scratching the tip of electrode on the parent metal. As the

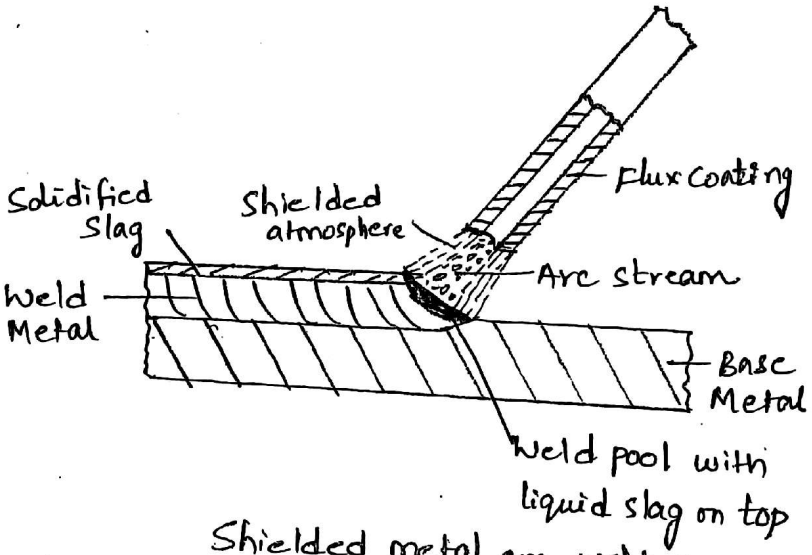


MMAW

As the electrode tip makes the contact the current flows and is drawn away an arc is formed across the gap. The feeding of electrode should be controlled properly to maintain constant gap 2to4mm. Because bare electrode is used the joint formed is weak and brittle. This is due to absorption of oxygen and nitrogen from the atmosphere.

Shielded Metal arc welding : (SMAW)

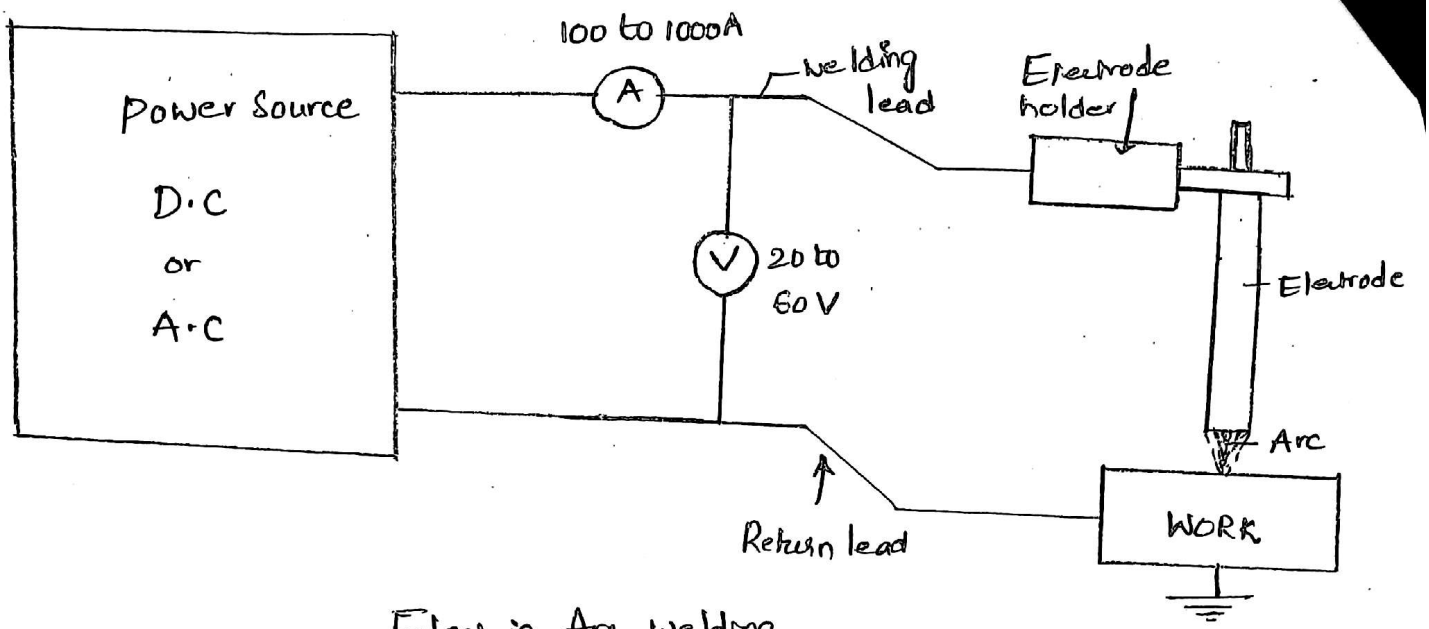
To overcome the difficulties of metal arc welding Coated electrodes are used. Flux Coating on the electrode also melts and provides a gaseous shield around the arc which protects the molten pool from atmospheric Contaminations. Electrode melts & provides filler material for weld.



Shielded metal arc welding

Metal arc welding using Coated electrode that provides shielding of weld pool from atmospheric Contaminations is called Shielded metal arc welding (SMAW).

Electric arc welding equipment:



Electric Arc welding

Power Source: Power Source provides welding Current. Both D.C and A.C equipment are employed in arc welding. D.C arc welding machines are D.C generators driven by an electric motor. A.C Welding machines are transformers for stepping down the main Supply high voltage to low voltage (20 to 60V) and high ampere (100 to 1000A) Suitable for arc welding. The two power Sources are discussed below.

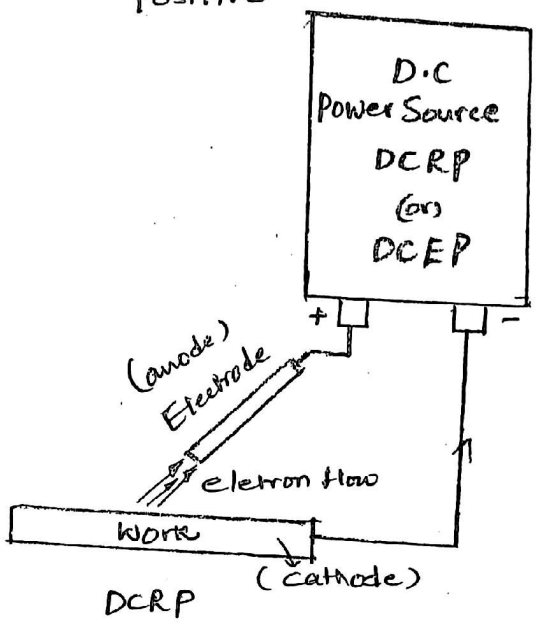
D.C power Source:

In D.C Supply, the electrons flow in one direction only, which is called polarity. The polarity can be changed by simply reversing the cables at the terminals i.e, from electrode to work and vice-versa. This fact can be utilized for obtaining desired penetration of the base metal.

DCRP: Direct Current Reverse polarity (or) DCEP: Direct Current electrode positive

DCRP

Arc penetration



DCRP

In D.C reverse polarity the electrode is connected to positive terminal and the work is connected to negative terminal of power source. The electrons flow from workpiece which tend to clean it. But the heat flow is towards electrode making its consumption faster and so limiting the current that can be put through the electrode. This System is preffered in welding thin sections such as automobile bodies and non-ferrous metals to prevent the melting or burning of holes in the metal, Since only about 37% of arc energy is liberated at the work Surface. Because this System has inherent ability to Scour oxide film from the Surface of work, it is Very useful for welding aluminium and magnesium whose oxide is very hard and brittle. A wide bead and cleaner work surface are the characteristics of this System.

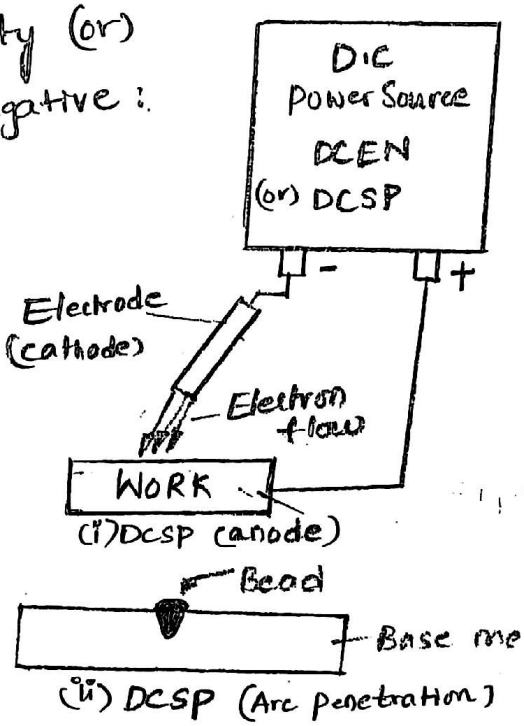
Ac arc penetration

(iii) A.C power Source:

In Alternate Current welding the polarity is changing at the rate of 50 c/s, half of the arc energy is liberated at the work Surface and half at the electrode. Thus, the penetration of the heat zone in the base metal is approximately in the mid way between two D.C types.

The electrons move from the negative terminal to positive terminal of an arc, striking it at a great speed. Due to this about 63% of arc energy goes to the anode surface and about 37% is liberated at the cathode surface.

(i) DCSP : Direct Current Straight polarity (or) DCEN: Direct Current electrode Negative :



In D.C Straight polarity electrode is Connected to the negative terminal of Power source, where as Work Connected to positive terminal.

Therefore 63% of arc energy is liberated at Work (anode), is heated much faster than electrode.

This is useful in welding massive pieces (thick Sections) because it puts heat where it needed. Its advantages are deeper penetration, the narrowest heat effected zone, the fastest travel speed, less electrode Consumption and least distortion because faster heat input into the work. We can use light and medium coated electrodes as they require less amount of heat for melting. This System is preffered on all metals except for aluminum, magnesium, copper and beryllium.

Liquid Solid State bonding (LSSB)

In LSSB the joint is made by distributing molten filler material between closely fitted surfaces of the parts, without melting the base metal.

It is classified into two types. They are Brazing & Soldering. The difference between the two depends upon the melting point of the filler material.

When the filler material Melts below 427°C & also below the solidus of the base metal, the process is called Soldering.

When the filler material melts above 427°C & also below the solidus of the base metal, the process is called Brazing.

In these processes the molten metal is drawn to various parts of the joint by capillary action. Since the molten metal is distributed in the closely spaced joint by capillary action, the strength of brazed or soldered joint is markedly affected by the width of gap between the parts to be joined together.

In brazing steel parts with copper or Silver fillers, the optimum gap width ranges from 0.03 to 0.15 mm. In soldering with a tin-lead solder it is from 0.05 to 0.2 mm.

It should be understood that the strength of soldered / Brazed joint increases upon a certain gap between the two joining surfaces beyond which it decreases.

Soldering: (Soft Soldering)

In soldering two parts are joined by the use of a molten filler material whose melting point is below 427°C and is always less than melting point of the base metals.

The filler material is an alloy of lead and tin (solder). The percentage of lead increases the melting point of solder.

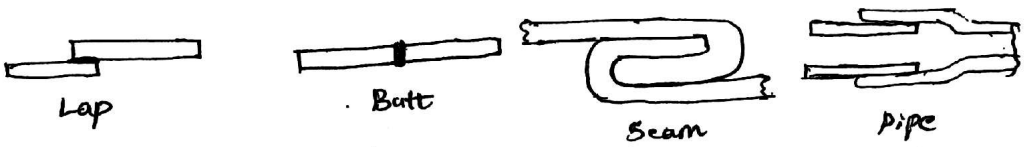
Fillers: The composition of most widely used solders:

	Tin %	lead %	Melting temp (°C)	Applications
1. Soft solder	63	37	184	sheet metal components
2. Medium solder	50	50	204	Tinmans solder used for general workshop.
3. Electrician solder	42	58	220	Electrical components
4. plumber solder	30	70	250	plumbing work.

Steps in Soldering process:

1) Surface preparation which involves fitting the surfaces to each other, cleaning them mechanically and chemically and covering the cleaned surfaces with a flux. The clearance for a joint is about 0.05 to 0.2mm

2) After this soldering proper is done. Commonly used soldering joints are Lap, butt, seam and pipe joints.



The fluxes used in soldering are:

Corrosive flux: The flux must be washed off after soldering to prevent corrosion.

They are Zinc chloride [For brass & Most of Metals] For steel] Mixtures of Zinc chloride & Aluminum chloride.

Non corrosive flux :

These are essential for electrical connections where corrosion create local high resistance and even loss of Conduction.

They are rosin, rosin + alcohol } (Electrical work)

Talloo [for lead]

Lead being toxic has adverse effects on the environment. Due to this lead free solders are being developed & are now in wider use. They are being used in connection with supplying drinking water & other applications.

Ex:

1. Tin - silver (Sn 96.5 / Ag 3.5)
2. Tin - Bismuth (Sn 42 / Bi 58)
3. Tin - zinc alloys
4. cadmium-silver
5. zinc - aluminum etc.

The strength of soldered joint ranges from 0.3 to 1 N/mm^2. Soldered joints are weaker than brazed joints for which strength ranges from 3 to 4.5 N/mm^2.

Brazing:

Brazing is a process of joining two metal pieces by the use of molten filler material whose temperature is above 427°C but usually less than melting point of the base metals.

The term brazing implies use of brass as the filler material. The filler material is called 'Spelter'.

Steps in Brazing:

1. The surfaces to be joined are cleaned and fitted closely together.
2. A flux is applied to all surfaces where the filler material has to flow.
3. After that, the joint is heated to the proper brazing temperature. Solid filler material may be preplaced on the metal pieces and thus melted as the metal pieces are heated.

Filler material	Composition (%)	Melting point (°C)	Applications
Copper alloys [Spelter Brazing brass]	Cu-60, Zn-40	900	Steel, Cu alloys Ni alloys
Aluminium alloys	Al-86, Si-10, Cu-4%	600	Aluminium alloys
Silver alloys	Ag-34, Cu-25, Zn-20 Cd-21	700	Used for most of common metals
Nickel alloys	Ni-74, Cr-14, Si-5, B-3,	1100	Nickel & cobalt

In general brazing metals of higher melting point gives higher strength. The brazing metals are based on Ag, Cu & Ni are also called "Hard solders".

Fluxes: Commonly used fluxes are borates, fluorides, Chlorides, borax and boric acid.

Applications: Brazing is very suitable for joining dissimilar metals together. It is used for cycle and motor cycle frames, heat exchangers & throw away tool tips.

Comparisons between welding, Brazing and Soldering

Welding	Brazing	Soldering
1. permanent fastening	1. Permanent	1. Permanent
2. Base metal is heated to molten state (or) plastic state.	2. Only filler material is heated to molten state > 427°C but base metal is not heated to molten (or) plastic state.	2. Only filler material is heated to molten state < 427°C but base metal is not heated to molten (or) plastic state.
3. Strong bonding is developed b/c two materials are fused together.	3. Spelter (Cu + Zn) melts & forms the bond. brazing gives stronger joint than soldering.	3. Solder melts and forms the bond. Weak joint compared to welding & brazing.
4. Require very high temp than brazing & soldering	4. > 427°C	4. < 427°C