

ARC WELDING PROCESS AND PRINCIPLE

Metal arc welding:

Manual metal arc welding –

This is a group of processes in which heat required for fusion is generated by the electric arc formed between a metallic electrode & the base metal. The electrode is consumed in the arc & provides the filler metal for the joint. The electric arc is an ideal source of welding heat. The extremely high arc temperature of over 5000°C permits it to supply a large amount heat to a small area. Hence the melting in the base metal is restricted to a narrow zone. Among the arc processes, **manual metal arc** is the most common, versatile and inexpensive one and account for 60% of the total welding in advanced countries and over 90% of the total welding in India. It is a manual process, and hence depends on the skill and experience of the welder. It makes use of a flux –coated electrode having a core of solid wire (diameter 6.3-1.6mm, length 450-250mm). It needs a power source, either a transformer supplying AC or generator/ rectifier supplying DC.

The process is suitable for the entire range of plate thickness, and for almost all-commercial metals and alloys. It is used for joining as well as for surfacing (rebuilding). It can be used in all welding positions. It is well suited for site welding (Fig-1).

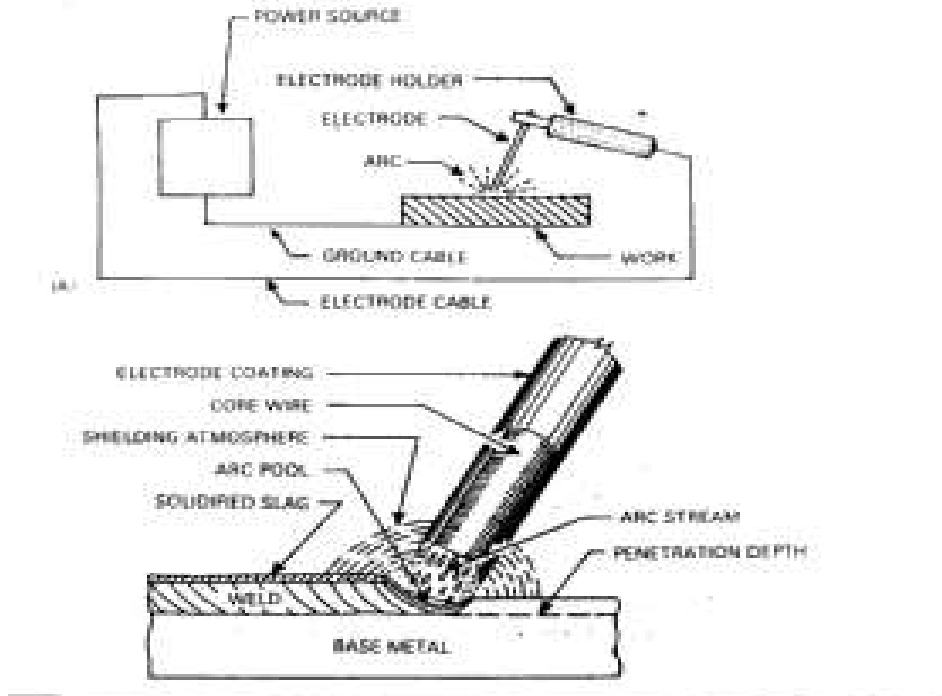


Fig 1: Manual Metal Arc Welding (a) welding circuit (b) welding arc in action

Submerged-Arc Welding –

This is mostly used as a fully- automatic process, and sometimes as a semiautomatic process. The electrode is a continuous metallic wire (solid or flux cored) in the form of a spool or a coil. It is fed automatically into the arc at a constant speed. The arc is covered with a layer of dry granular flux fed into the welding groove, which performs the same functions as the coating of a manual electrode. The arc is created between the continuous wire lowered through the flux and the base plate. The arc remains covered by the flux, hence the name. As the arcing continues either the welding or the welding head moves, feeding the flux ahead of flux from a hopper. The arc length is automatically controlled. The power source can be a transformer (AC) or a generator/rectifier (DC). It is generally of high capacity, say 750 or more, even up to 3,000amps.

In semiautomatic welding, the operator guides the flexible welding head along the groove. In doing so he controls the speed of travel and the line of travel. Controlling the line is difficult, because the arc is submerged. Hence this version is usually restricted to fillet weld and grooved butt weld.

In fully- automatic welding, the welding head is mounted on a trolley, which travels along the joint. Alternately, the welding head is stationary, and the joint moves under it. This process gives very high productivity and excellent weld quality.

It is generally applied on mild steel, high tensile steels, and stainless steels. It is ideal for heavy thickness. For thin sections, weld backing is necessary to avoid burn-through. It is commonly used for fabrication of plate girders, pressure vessels, pipes and penstocks, for surfacing & strip cladding. In strip cladding, the electrode is in the form a strip, usually 1.6mm X75mm wide (Fig-2).

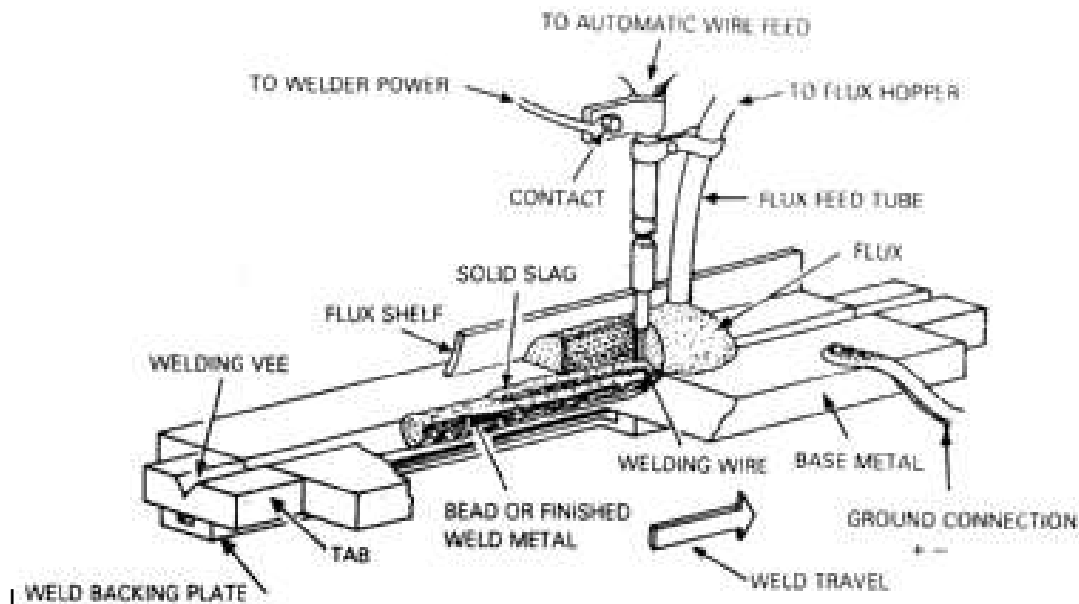


FIG 2: Diagrammatic sketch of Submerged Arc Welding (SAW)

MIG Welding:

MIG (Metal–Inert-Gas Welding) is also known as GMAW (Gas–Metal-Arc Welding). In this process, coalescence is achieved by an electric arc formed between the work piece and a continuous consumable solid wire electrode, which is fed through a gun at controlled speeds. Inert gas flows through coaxial passage in the gun and forms a blanket over the weld puddle to protect it from atmospheric contamination.

The welding can be semiautomatic or fully mechanised. In semiautomatic version, the welder concerns himself only with gun-to-work distance, gun manipulation, welding speed. Wire feed rates, electrical settings, and gas flow is pre-set. When the equipment is completely mechanised, all of these variables and welding functions performed automatically without the need for a welder.

The power source is a rectifier or motor generator giving DC. DCRP (Direct Current Reverse Polarity i.e. electrode to positive terminal and job to negative terminal) is used, as it gives better melting, deeper penetration and better cleaning action.

MIG is a versatile process, and is gradually replacing manual metal-arc and TIG welding. Most metals can be easily welded including aluminum, carbon steels, low alloy steels, stainless steels, nickel, copper, magnesium, titanium, and zirconium. However, for carbon steels and low alloy steels, MAG or CO₂ welding is preferred, because it avoids the use of expensive argon gas (Fig-3).

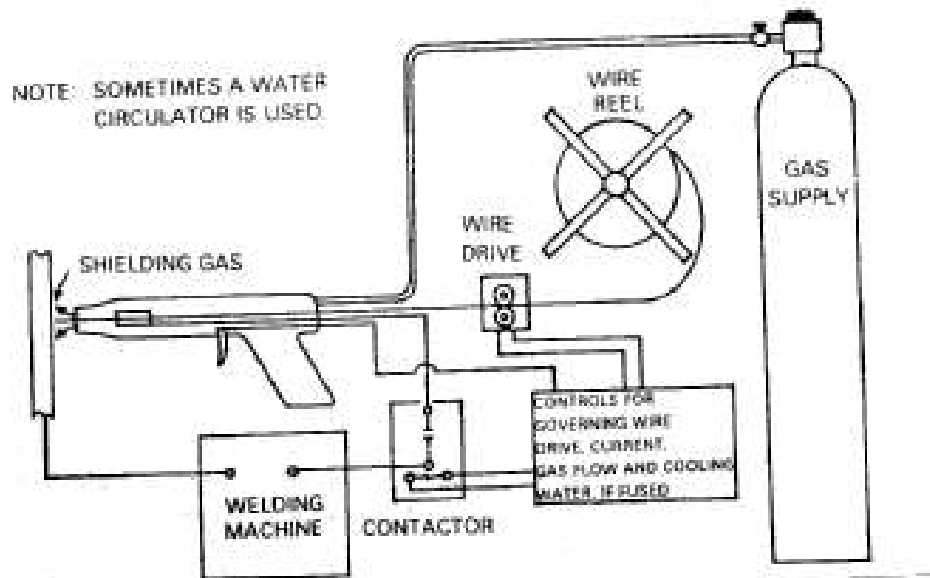


Fig 3: Schematic diagram of MIG/MAG (CO₂) Welding

MAG (CO₂) Welding:

MAG stands for metal active-gas arc welding. This is a variation of MIG welding, in which identical equipment is used but chemically active gas mixture or carbon dioxide replaces the inert argon gas. However, the CO₂ gas tends to form Dry Ice while coming out from high pressure cylinder. To prevent choking, one tubular heating arrangement is kept just at the outlet, through which the gas is passed. The term gas-metal-arc welding (GMAW) is also applied to the MAG (CO₂) process. CO₂ welding is gradually replacing MMAW in the

TIG Welding:

TIG (Tungsten-Inert-Gas) welding is also termed as GTAW (Gas-Tungsten-Arc Welding). In this process, an arc is struck between a non-consumable tungsten electrode and the base metal. The inert argon or helium or argon-helium mixture shields the arc. A filler wire may or may not be used. When it is used, the welder feeds it externally into the arc in the form of rod or strip. The welder also has to control the arc length and arc travel speed. An AC power source is used for welding aluminum & its alloys, while a DC source is used for other metals. This is an ideal process for welding non-ferrous metals and stainless steels of limited thickness. TIG is also preferred for depositing the root pass in the pressure piping, where welding from inside is not possible (Fig-5).

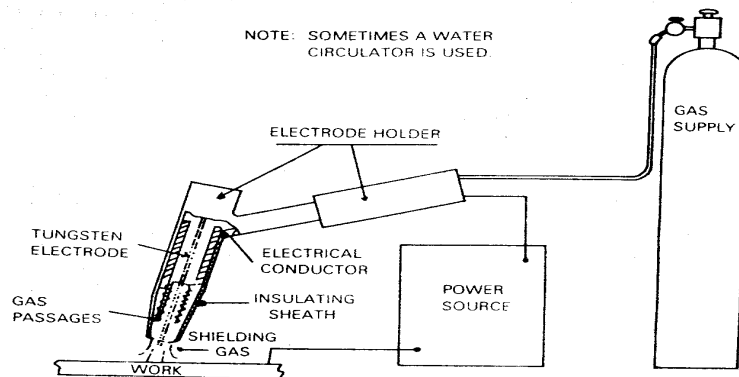


Fig-5 SCHEMATIC DIAGRAM OF TIG WELDING

Arc Spot Welding:

In this process, coalescence at the overlapping surfaces is produced in one spot by heating with an electric arc between an electrode and the work. The weld is made without preparing a hole in either member. Filler metal or shielding gas or flux may or may not be used. The arc is produced by using either of the carbon arcs, TIG, MIG processes. Arc spot welding by MAG (CO₂) process is widely used today, for which the equipment is provided with the necessary controls to achieve consistent spot-welds. While

electric resistance spot welding requires access from both sides of the overlapping plates, arc spot welding can be from one side only (Fig-6).

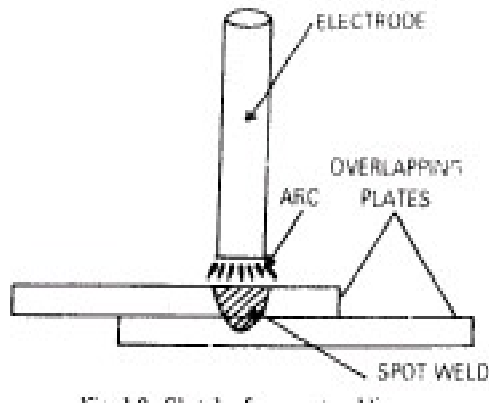


Fig 6: Schematic diagram of Arc Spot Welding

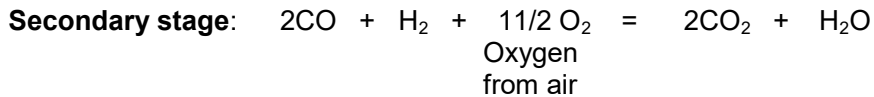
Gas Welding:

In this process, the melting of the base metal is achieved by means of a gas flame, which derives its intense heat from the combustion of a fuel with oxygen. The most commonly used fuel is acetylene, and hydrogen is sometime used. Hence appropriate term of this process is oxy fuel or oxyacetylene welding. Filler metal may or may not be used.

The oxyacetylene process depends on the chemical reaction, which occurs in two stages:



The primary combustion provides the actual flame for welding, with temperature up to $3,000^{\circ}C$ in the inner cone.



This secondary combustion occurs at the outer portion of the flame. It protects the molten puddle from attack by air and helps to preheat the base metal.

Equipment for oxyacetylene welding consists of oxygen and acetylene cylinders, pressure regulators that reduce the high cylinder gas pressure to the required working pressure, a torch where the two gases are mixed, and hoses, which connect the regulators to the torch. Gas welding has limited application for industrial production purposes, because it is much slower than arc welding process. It is used considerably more for general maintenance work including thin sheet welding, hard-facing, welding metals of low melting points (especially non-ferrous metals) and performing such operations as brazing, soldering and thermal spraying (Fig-7).

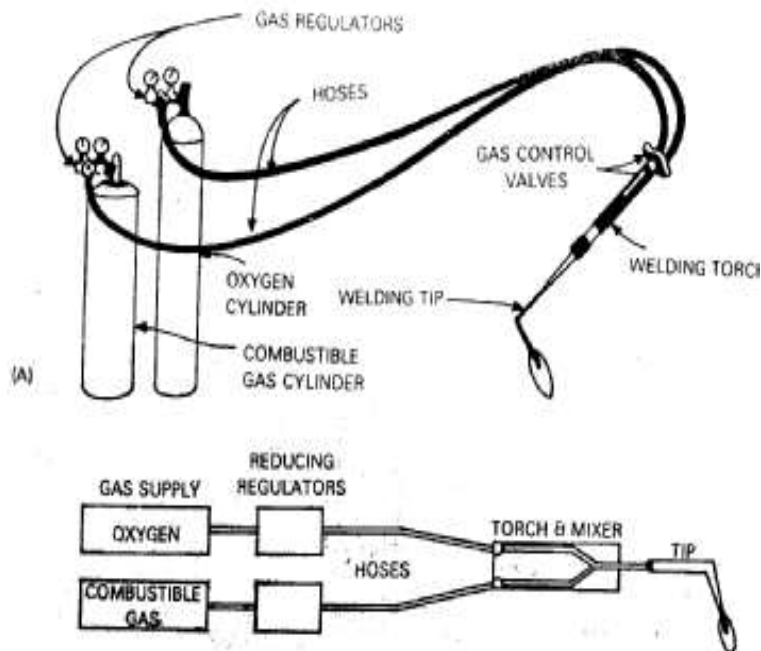
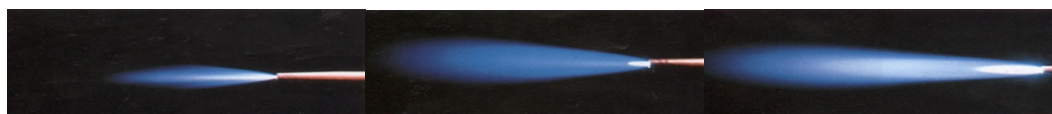


Fig-7:Oxyfuel welding: (a) Schematic diagram of the process
 (b) Sketch of the welding torch



Neutral flame

Oxidizing flame

Carburizing flame

Fig 8: Different flames produced by controlling the gas flow

Plasma Welding:

Plasma is considered the fourth state of matter, the other three being solid, liquid, and gas. Plasma is a gas, which has partially dissociated into positive ions, and negative electrons. Plasma is formed when an electric discharge takes place in a gas, and also in an electric arc (the blinding light of an arc comes from the plasma). In normal arc welding processes, moving gas streams easily blows the plasma away. But in plasma processes which are listed below, the plasma is contained and used effectively:

- Plasma arc welding.
- Micro-plasma arc welding.
- Plasma-MIG welding.
- Plasma arc cutting.
- Plasma spraying.

In all these processes, based on DC supply, a specially designed torch, which is a modification of the TIG torch, concentrates the plasma energy and ensures its most efficient utilization for welding, cutting, and spraying. The tip of the tungsten electrode (DC negative) is located within the torch nozzle, while the nozzle has a small opening, which constricts the arc. As gas (usually argon or air) is fed through the arc, it becomes heated to the plasma temperature range (30,000⁰ to the 60,000⁰F). The plasma tail-flame comes out of the torch nozzle as a jet of tremendous velocity.

The plasma-arc is of two types: transferred arc and non- transferred arc. In the former, the arc is formed between the electrode and the work piece. In the latter, the arc is formed between the electrode and the constricting orifice inside the torch.

Plasma arc welding is an extension of TIG welding. The main difference as explained above is the constriction of the arc column, resulting in much higher heat transfer rate. The torch is further modified to provide an outer sheath of cool gas around the central plasma core. When the plasma jet strikes the metal, it cuts entirely through the work piece producing a small hole, which is carried along the weld seam. During this cutting action, the molten metal in front of the arc flows around the arc column, then gets drawn together immediately behind the hole by surface tension forces and reforms as a weld bead. Butt welds of 12.5 mm or larger thickness are possible in a single pass without edge preparation or filler metals. The process can weld Carbon Steels, Stainless Steels, Copper, Brass, Aluminium, Titanium, Monel, and Inconel (Fig-10).

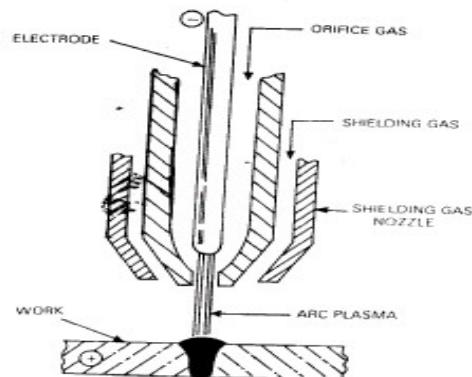


Fig 10: Sketch of Plasma Welding

Plasma MIG welding is an extension of plasma arc welding in which the non-consumable tungsten electrode is replaced by a consumable continuously fed metallic electrode.

DEFINATIONS OF WELDING TERMS

AC OR ALTERNATIVE CURRENT : In this kind of electricity in which polarity of the current changes its directions from positive to negative and negative to positive 50 times in a second.

DC OR DIRECT CURRENT: Electric current which flows only in one direction.

: Output of welding sets can be ac, dc or both ac/ dc.

ARC VOLTAGE: The voltage across the welding arc is known as arc voltage.

ARC LENGTH: The distance from the end of the electrode to the point where the arc makes contact with work surface.

OPEN CIRCUIT VOLTAGE: The voltage between the output terminals of the welding machine when no current is flowing in the circuit. (When the welding set is on but electrode is not in contact with the job.

BASE WELD: The metal to be welded, brazed, soldered or cut.

FLUX: A fusible material or gas used to dissolve and / or prevent the formations of oxides, nitrides or other undesirable inclusions formed in the weld metal.

WELD: A localized merger of metal or non metal produced either by heating the material to welding temperature, with or without the application of pressure, and with or without the use of filler material

BEVEL: An angular type of edge preparations. (Like hypotenuse of a right angle triangle).

FILLET WELD: A weld of approximately triangular cross section joining two surfaces approximately at right angle to each other.

GROOVE WELD: A weld made between two members to be joined. The standard types of groove weld are as follows. Double – v, double – u, double – j, single v, u, single j etc.

ROOT OF WELD: The points, as shown in cross section at which the bottom of the weld intersects the base metal surfaces.

ROOT OPENING: The separation between the members to be joined, at the root of the joint

FACE OF THE WELD: The exposed surfaces of a weld

WELD TOE: The junction of the weld face and base metal

THROAT OF FILLET WELD: Shortest distance from the root of the fillet weld to the face

WELD REINFORCEMENT: It is added to ensure that the net throat of weld is not less than that of plate welded. In fatigue or under vibrations the weld joint has a higher strength

PENETRATION: The distance, the fusion zone extends below the surfaces of the part or parts being welded. (Weld metal which reaches in the base metal).

HEAT AFFECTED ZONE: The portion of the base metal which has not been melted, but the structure properties of which have been altered by the heat of welding or cutting.

CRATER: A depression at the terminations of the weld.

POSITION OF WELDING: Flat, horizontal, vertical and over head.

POST HEATING: Heat applied to the work after welding or cutting.

PRE – HEATING: The heat applied to the work prior to welding or cutting.

REVERSED POLARITY: The arrangement of arc welding leads where in the work is the negative pole and the electrode is the positive pole in the arc circuit.

STRAIGHT POLARITY: The arrangement of arc welding leads where in the work is positive pole and the electrode is negative pole of the circuit.

TACK WELD: A weld generally of short lengths made to hold parts to be welded in proper alignment before full welding.

ARC BLOW: The deflection of an electric of an electric arc from its normal path because of magnetic forces.

BACKFIRE: The momentary recession of the flame into the torch tip following by immediately reappearance or complete extinguishment of the flame.

BEADING (PARALLEL BEADS): A Technique of depositing weld metal without oscillation of the electrode, which generally results in a relatively narrow pass.

BRAZE: A Weld wherein coalescence is produced by heating to suitable temperatures above 800°f. And by using a nonferrous filler metal, having a melting point below that of the base metals. The filler metal is distributed between the closely fitted surfaces of the joint by capillary attraction.

CAPILLARY ATTRACTION: The phenomenon by which adhesion between the molten filler metal and the base metals, together with surface tension of the molten filler metal distributed the filler metal between the properly fitted surfaces of the joint to be brazed.

CYLINDER (BOTTLE): A Portable steel container for storage of a compressed gas.

DEPOSITION RATE: The weight of metal deposited in a unit of time.

DEPTH OF FUSION: The distance that fusion extends into the base metal from the surface melted during welding.

ELECTRODE: A Metal arc welding: filler metal in the form of a wire or rod, either bare or covered, through which current is conducted between the electrode holder and the arc.

FILLET GLASS (LENS) : A glass , usually colored , used in goggles , helmets, and hand shields to exclude harmful light rays .

FLASH BACK: A recession of the flame into or back of the mixing chamber of the torch.

INCOMPLETE FUSION: Fusion which is less than complete.

KERF: The space from which metal has been removed by a cutting process.

MANUAL WELDING: Welding wherein the entire welding operations is performed and controlled by hand.

METAL ELECTRODE: A filler or non – filler metal electrode, used in arc welding, consisting of a metal wire, with or without a covering or coating.

NEUTRAL FLAME: A gas – welding flame where in the portion used is neither oxidizing nor reducing.

OXIDIZING FLAME: A gas welding flame wherein the portion used has an oxidizing effect.

OXY – ACETYLENE CUTTING : An oxygen – cutting process wherein the severing of metals is effected by means of the chemical reaction of oxygen with the base metal at elevated temperatures, the necessary temperatures, being maintained by means of gas flames obtained from the combustion of acetylene with oxygen.

PEENING: Mechanical working of metal by means of hammer blows.

RADIOGRAPHY: The use of radiant energy in the form of X – Rays or gamma rays for the nondestructive examinations of opaque objects, which yields a graphical record of their soundness on sensitized films.

REGULATOR : A Device for controlling the delivery of gas at some substantially constant pressure regardless of variation in the higher pressure at the source.

ROOT FACE (SHOULDER) : The portion of the prepared edge of a part to be joined by a groove weld, which has not been beveled or grooved.

SEAM WELDING : A resistance – welding process wherein coalescence is produced by heat obtain from resistance to the flow of electric current through the work parts held together under pressure by circular electrodes. The resulting weld is a series of overlapping spot welds made progressively along a joint by rotating the electrodes.

SIZE OF WELD:

- A. FILLET WELD: The size of a fillet weld is the leg length of the largest inscribed isosceles right triangle.
- B. GROOVE WELD: The size of a groove weld is the depth of the groove. Where the fusion materially exceeds the groove depth, the size of the weld is the depth of the groove plus the depth of fusion.

SLAG INCLUSION: Non metallic solid material entrapped in weld metal or between weld metal and base metal.

SPATTER: In arc and gas welding the metal particles expelled during welding and which do not form a part of the weld.

STRAIGHT POLARITY (ELECTRODE) : The arrangement of direct current arc – welding leads wherein the work is the positive pole and the electrode is the negative pole of the welding arc.

STRESS – RELIEF HEAT TREATMENT: Uniformly heating of a structure or portion thereof to a sufficient temperature, below the critical range to relieve the major portion of the residual stresses, followed by uniform cooling.

STRING BEAD: A type of weld bead made without transverse oscillations.

SUBMERGED ARC WELDING : An arc – welding process wherein welding process coalescence is produced by heating with an arc or arcs between a bare metal electrode or electrodes and the work. The welding is shielded by a blanket of granular, fusible on the work. Pressure is not used and filler metal is obtained from the electrode and sometimes from a supplementary welding rod.

WELDABILITY: The capacity of a metal to be welded under the fabrication conditions imposed into a specific, suitable designed structure and to perform satisfactorily in the intended service.

ELECTRICAL ASPECTS OF WELDING

INTRODUCTION:

Selection of a welding process is determined primarily by the characteristics of the joint, the materials involved their shape and thickness, and joint design. Additionally, production requirements, such as rate and quality, must also be considered. Only after the process has been determined can the proper power supply and accessory equipment be chosen. The process is the primary factor in their selection.

The various arc-welding processes require special electric power of relatively low voltage and high current and sustain an arc capable of making a good weld. The machines designed to deliver such electric power are known as "POWER SOURCE FOR ARC WELDING".

Many types of Power Sources are available to suit the various arc-welding processes, and they can be classified in several ways. A simple classification based on the consideration of design, rating and applications is as under:

S. No.	Method of classification	Features
1	Type of Basic Design	<ul style="list-style-type: none"> • Rotating Type <ul style="list-style-type: none"> ➤ Motor Driven Generator ➤ Engine Driven Generator • Static Type <ul style="list-style-type: none"> ➤ Transformer ➤ Rectifier / Inverter
2.	Method of Current Control	Field control, Variable Reactor, Tap-changer switch, saturable core reactor Electronic Control with feedback (Thyristor control, IGBT control, etc)
3	Type of Output Current	Constant Current (CC), Constant Voltage (CV) & Combination of both
4	Type of Static Characteristics (volt-ampere Curve)	Constant Current (CC), Constant Voltage (CV) & Combination of both
5	Rated Current & Duty Cycle	To deliver Current at specified duty – cycle (60%, 100%, etc) and range of welding current.
6	Suitability for process	MMAW, MIG/CO ₂ , GTAW or TIG, SAW etc
7	Type of Cooling	NA(Natural Air), FA(Forced Air),ON (Oil Cooled Natural) & OF(Oil Cooled Forced)

SELECTION FACTORS FOR POWER SOURCES:

The following main factors influence the selection of power source:

- Available power – AC or DC, single-phase, 3 – phase, etc. Where no power is available, a diesel driven generator may be used.
- Available floor space
- Location of operation – whether in the plant or in the field
- Earthing arrangement.
- Required output
- Duty cycle and efficiency
- Personnel available for maintenance & repair
- Initial costs and running cost.
- Type of electrodes to be used and metals to be welded
- Type of work (Heavy Versus Light)

DC sets often offer control of both voltage and current and choice of polarity. AC sets in multi operator transformer form are more economical to buy and operate, especially if power factor correction is applied.

A transformer occupies less floor area as compared to a Motor Generator set. A diesel driven generator set occupies the maximum floor area. Costs associated with Motor Generator sets are more than those for transformers.

DC POWER SOURCE:

Generator Sets:

- A DC welding generator produces direct current in either straight or reverse polarity. The polarity selected for welding depends upon the kind of electrode used & the material to be welded.
- A DC generator is powered by an electric motor or a diesel engine. Diesel operated generator sets are suitable for out door application or other areas where power is not available.
- The current supplied by a DC generator is created by an armature rotating in a magnetic field. An electric motor or an engine rotates the armature. The current drawn off for welding use by commutator. Polarity switches on most machines provide reversed or straight polarity.
- Generators are designed to rotate at a speed of 1500, 1800 or 3600 rpm to give optimum current values.
- Generator supplies voltage usually in the range from 15 to 45 volts across the arc. The open circuit voltage is between 50 and 100 volts. Current output will vary depending upon the type of unit. A typical value is 200 to 600 Amps.
- A generator is designed such that it will compensate for any change in the arc column voltage, thus ensuring a stabilized arc. Three V – I characteristics used in arc welding.

Advantages of Generator Sets:

- Straight and reverse polarities can be employed
- Welding can be carried out in all positions
- Nearly all ferrous & non ferrous metals can be welded
- Diesel driven generator form a self contained unit
- Generator output is not affected by normal variations in power line voltage.
- DC is most universal in application; it can be used in all welding operations.

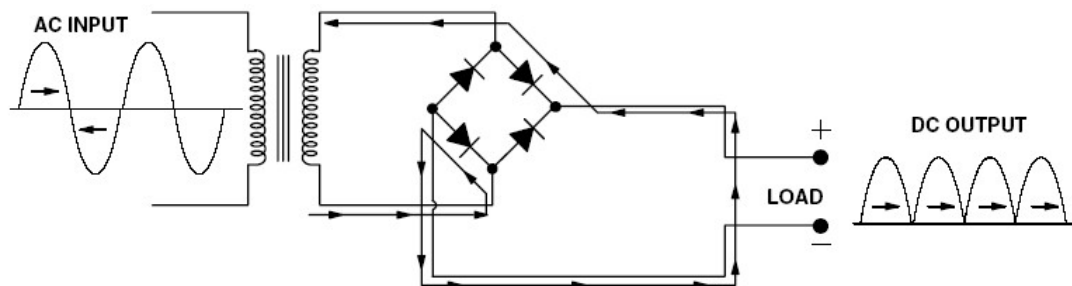
Disadvantages of Generator Sets:

- Higher initial cost
- Higher maintenance cost
- Noisy machine operation

Rectifier:

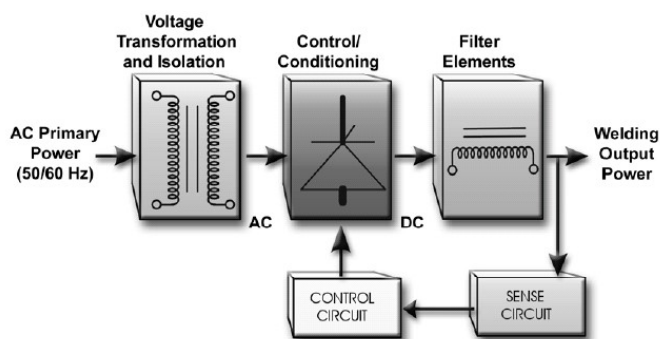
Rectifiers are the devices that change alternating current into direct current. They permit or allow the passage of current in one direction only through the circuit.

The AC/DC and DC static welding power source usually incorporate both a Transformer and a Rectifier. The Transformer – Rectifier type arc welding source has a stabilizer to improve the arc stability.



The full wave Bridge Rectifier (full output)

Thyrstor (SCR) can also be used as Rectifier and has a capability to control welding power by altering the welding current or voltage waveform. Because the output characteristics are controlled electronically, automatic line voltage compensation is easily accomplished. This allows welding power to be precisely set and held at that value even if the input line voltage varies.



Block diagram for Solid state Control for DC Power Welding Source

AC POWER SOURCE:

Welding Transformer:

A welding transformer changes high voltage, low amperage power to the low voltage high amperage welding power. It is the least expensive, lightest and smallest welding machine. It takes power directly from the mains and transforms it to the voltage/current required for welding. It is a normal frequency machine.

Since AC passes through zero twice in every cycle, it means that there are two periods in every cycle when the welding current is zero, during which the arc would extinguish and make continuous welding difficult. This difficulty is removed by

- Building in automatic arc stabilization in welder winding
- Development of electrode coatings that produce a more complete ionization in the arc stream and keep the arc igniting as the current passes through zero.

A Welding Transformer has the following main parts:

- The frame structure
- The cooling system
- The primary circuit
- The transformer core
- The secondary circuit

- The current control mechanism

The transformer is housed in a steel tank, which has external tubes. The tank is filled with transformer oil to cool the transformer core & winding by convection. The transformer-laminated core is made up of high quality silicon steel. The primary and secondary circuits are windings around the core. The primary winding/circuit is connected to the power source. The secondary circuit is connected to the electrode holder through which welding arc current flows.

The output or welding current of the transformer can be adjusted/controlled by either Reactor adjustment or Reactance adjustment.

- Reactor adjustment – Control adjustment may be made by tapping the reactor coil, moving an iron bar within the reactor coil with direct current.
- Reactance adjustment – Altering the position of the primary & secondary coils relative to one another (coil adjustment), Moving iron bar between primary and secondary coils (movable core adjustment)

Those transformers that employ reactance adjustment for current control don't have reactors in their secondary circuit.

Electrical Characteristics:

Transformer for shielded metal arc welding has generally constant current volt – amp characteristics.

Application of Welding Transformer

- A transformer with secondary current ratings of 200 to 500 Amps is often used.
- Transformers are used for flux shielded metal arc welding.
- It producing welding on heavy gauge steel.

Advantages of Transformer:

- It is least expensive, lightest and smallest machine.
- Operation is noiseless
- Overall efficiency is high
- It provides forceful arc
- Work piece doesn't get magnetized.

Disadvantages of Transformer:

- Polarity cannot be changed
- Starting of arc is difficult.

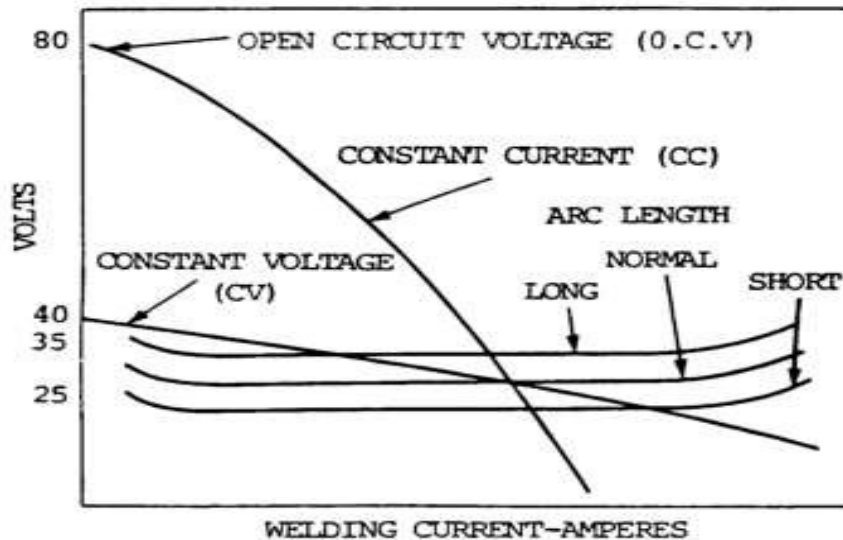
BASIC FEATURES OF ARC WELDING POWER SOURCE:

Static Characteristics Curves:

These curves show the relation between load voltage & load current under various load conditions. Hence it is called "Volt-Amp (V-A) curves.

Procedure: A pure resistive load (usually water load) is connected across the output terminals of the power source. The load is gradually varied from the minimum or no load condition to the maximum or short circuit condition. The voltage across the load and the current passing through the load are accurately measured. The graph showing load voltage versus Load current is then plotted to obtain the static characteristic curve.

The typical curves obtained various types of power sources are shown below:



.Fig1: Characteristic curves for welding power source

It is seen that some curves are "drooping" type, while the others are of relatively "flat" type.

1. Drooping or Constant Current ---

In drooping characteristics as the arc length increases, arc voltage rises and the current decreases and vice versa. Machine with drooping characteristics is used for standard shielded arc welding.

2. Constant Voltage –

It is preferred for semi automatic MIG or automatic welding process, because they maintain a preset voltage regardless of the amount of current being drawn from the machine.

3. Rising Arc Voltage –

In rising arc Voltage characteristics, as the current increases, voltage also increases. Fully automatic welding process use rising voltage characteristics.

OTHER EQUIPMENTS REQUIRED FOR ARC WELDING

- **Welding Cables:**

The welding current is conducted from the power source through the electrode holder, the arc and back to the welding power source by means of insulated copper and aluminium cables.

Two cables are needed for welding purpose. One, known as Electrode lead joins holder or electrode to the welding power source and the other, known as Ground lead connects job with power source or welding machine.

Welding cables or leads are well insulated by suitable insulating materials and are to be checked periodically for any break in insulation. These are flexible stranded insulated cables. But earthing cable may not be flexible one.

Size of cables is depending upon the welding machine stated in amperes and the length of the cable. The recommended sizes of welding cables are as under:

Distance from welding machine in meter	300 Ampere Welder		400 Ampere Welder	
	Copper mm ²	Aluminium mm ²	Copper mm ²	Aluminium mm ²
15	35	50	50	70
20	50	70	70	95
30	70	95	95	120

Single core welding cable of copper conductor (As per IS 2641:1964)

Nominal HWC in Ampere	Number/Diameter of Wire in mm	Nominal area in mm ²
100	509 / 0.2	16
150	796 / 0.2	25
250	1114 / 0.2	35
400	1591 / 0.2	50
600	2228 / 0.2	70
900	1344 / 0.2	95

Power requirement:

Power requirement of the welding sets is on account of continuous HWC & varies with the sizes of the electrodes:

Continuous HWC in ampere	Power		Electrode size in mm
	KVA	KW	
150	12	06	2 – 4
200	17	7.5	2 – 4
250	21	9.5	2.5 – 5
300	25	11.5	3.3 – 6
400	35	20	3.2 – 8
500	50	28	3.2 -- 10

Power Factor Improvement in AC welding set:

Power Factor is an important electrical characteristic of a power source, which is calculated as:

Power factor = KW / KVA

Where KVA is an apparent power drawn from the supply line and KW is actual power used to produce the rated load.

Example – If the voltage reading and current reading on primary side are 240V & 30 Amps. Respectively and the actual watts registered are 5040, then

$$\text{Power factor} = 5040 / 240 \times 30 = 0.7$$

Low Power factor means unnecessary wastage & less efficient utilization of power. IS: 4559 has specified that machine must have a minimum Power factor of 0.8 at 50% of Continuous Hand Welding Current.

The power factor of a welding transformer is improved by connecting a Capacitor across the primary winding. The values of Capacitor are in KVAR. Recommended values of Capacitor are with respect to the Continues Hand Welding Current are as under.

Continuous HWC in Ampere	Recommended rating of Capacitor in KVAR
100	04
200	05
250	06
300	08
400	10
600	14

Connection of leads –

For the welding to be proper, all parts of the electrical circuit must have perfect electrical connections with one another. The ground lead may be connected to the work piece by a variety of methods such as bolted – Clamped, ground clamp etc.

The electrode lead is connected to the welding machine with a suitable Lug. These lugs are made a cast copper alloy and may be covered with a fiber insulation layer. Lugs are attached to the welding cables by soldering or mechanical methods such as crimping. Cable connectors are fittings specially designed for joining 2 or more lengths of welding cables to obtain a long cable. Cable connectors can be easily connected or disconnected.

SPECIFICATION DETAILS OF WELDING MACHINE:

- **Duty Cycle:** It is the ratio of time during which the machine is loaded to the total time elapsed during one welding cycle with the machine is remain energized. 60% duty cycle means that a machine is loaded for 3 minutes in a cycle of 5 minutes. Duty cycle is 100% for automatic, 60%for continuous DC Hand Welding, 55% for AC welding.
- **Maximum Hand Welding Current:** It is the maximum current, which a machine can deliver without exceeding the permissible temperature rise. It is 1.3 times the rated current.
- **Minimum Hand Welding Current:** It is the minimum current that a machine can deliver. It should be 20% of the rated current.
- **Open Circuit Voltage:** It is a voltage with secondary open circuit. It should be 30 to 60 volts minimum.
- **Welding Load Voltage:** It is the voltage of secondary with specified current flowing through the welding circuit. $V = 20 + 0.4 \times I = 44$ volts, where V is the welding load voltage and I welding load current.

- **Rated Current:** Welding machine is rated at current and duty cycle corresponding to the maximum continuous welding current. It should be 150,200,300,400,500,600,900 amps.

Trouble Shooting chart and remedial actions:

Defects	Cause	Remedy
High or low output	Incorrect link connection primary Voltage	Check and change
Erratic welding current	Loose welding connection	Check and tightened
Low current	Loose welding connection Long cable used	Tightened Set current level at higher level
Set Over loading	Input connection wrong Duty cycle exceed Blower not working	Check and changed Duty cycle follow Check and attended
Set vibrates and more noise	Transformer core loose	Tightened the core clamp
Pilot lamp not glowing	Bulb fuse Line fuse blown off	Changed replaced

Maintenance of Welding Transformer –

- Place the welding (Transformer) set in a clean and well-ventilated place.
- Ensure at least 60-cm distance between 2sets or a set and wall to get free circulation of air on all sides.
- Check and tighten all connections regularly to expel dirt etc.
- Installed proper earths and returns current lead with low resistance path is to be ensured. Preferably Aluminium cable is used for this purpose.
- Blowing the set with air pressure regularly to expel dust & dirt.
- Use proper and good quality accessories.
- Transformer oil should be checked/tested for Dielectric and acidity once in a year

Equipments required for metal arc welding-

- Arc welding power source – AC or DC type
- Welding cables
- Electrode holder
- Earth clamp
- Welding electrodes
- Safety items like helmets, hand shield, protective clothes and gloves.
- Chipping hammers & wire brush

Is Welding Dangerous?

Compared to other industrial jobs, welding is fairly dangerous. However, the occupational and health hazards of welding can be avoided with:

- Proper equipment
- Safe materials,
- A few common sense measures

Risks associated with welding include:

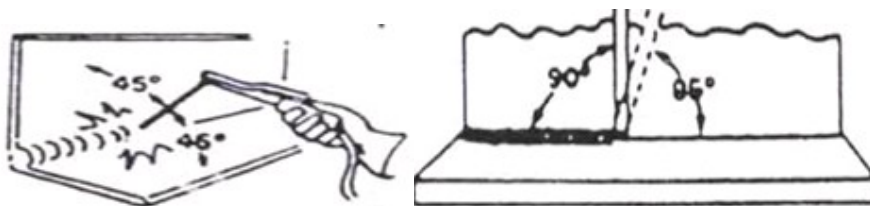
- Asphyxiation due to dangerous inhalants
- Skin and eye damage due to ultraviolet light
- Electrical or chemical fires
- Long-term negative effects from fumes

Sparks and Arcs are the most dangerous aspects of welding because they call attention to themselves, but they are only one risk. The brightness of the sparks, with their strong Ultra Violet light, can cause cancer in unprotected eyes and skin. Yet there is a wide range of equipment, such as auto-darkening helmets and thick gloves, to reduce your exposure. Also, sparks are not usually hot, yet general precautions should be taken to keep wood or other combustible material out of the range of the welder's arc. Setting heated metal on a flammable surface is more likely to start a fire.

ESSENTIALS FOR PROPER WELDING

1. **Correct electrode size** -- The correct choice of electrode size involves consideration of a variety of factors:
 - Type
 - Position
 - Preparation of joint
 - Ability to carry high current without injury to the weld metal / loss of deposition efficiency
 - Ability to maintain its original properties after welding
2. **Correct current** –
 - Too much of current Electrode melts too fast causing molten large / irregular
 - Too low of current Electrode not gets enough heat to melt the base metal and molten pool will be small, will pile up, look irregular.
3. **Correct arc length or voltage** ---
 - If the arc is too long or voltage too high the metal melts off the electrode is large globules which wobble from side to side as the arc wavers, giving a wide, spattered and irregular bead-with poor fusion between original metal and deposited metal.
 - If the arc is too short, or voltage too low, there is not enough heat to melt the base metal properly and the electrode quite often sticks to the work, giving a high, uneven bead, having irregular ripples with poor fusion.
4. **Correct travel speed** ---
 - When your speed is too fast your pool does not last long enough, impurities an gas locked in.
 - The bead in narrow and ripples pointed. When speed is too slow the metal piles up, the bead is high and wide with a rather straight ripple.
5. **Correct electrode angle** –

The electrode angle is of particular importance in fillet welding and deep groove welding. when making a fillet weld, the electrode should be held so that it bisects the angle between the plates (as shown at right) and is perpendicular to the line of weld, if under cut occurs in the vertical member, lower the angle of the arc and direct the arc toward the vertical member.



Safety Requirement –

- Inspect the cables periodically for looseness at the joints, defects due to wear, or other damage. Defective or loose cables are a fire hazard. Defective electrode holders should be replaced and connections to the holder should be tightened.
- Welding generators should be located or shielded so that dust, water, or other foreign matter will not enter the electrical windings or the bearings.
- Disconnect switches should be used with all power sources so that they can be disconnected from the main lines for maintenance.
- Do not operate the polarity switch while the machine is operating under welding current load. Consequent arcing at the switch will damage the contact surfaces and the flash may burn the person operating the switch.
- Do not operate the rotary switch for current settings while the machine is operating under welding current load. Severe burning of the switch contact surfaces will result. Operate the rotary switch while the machine is idling.

WELDING TRANSFORMER CONTROLLER

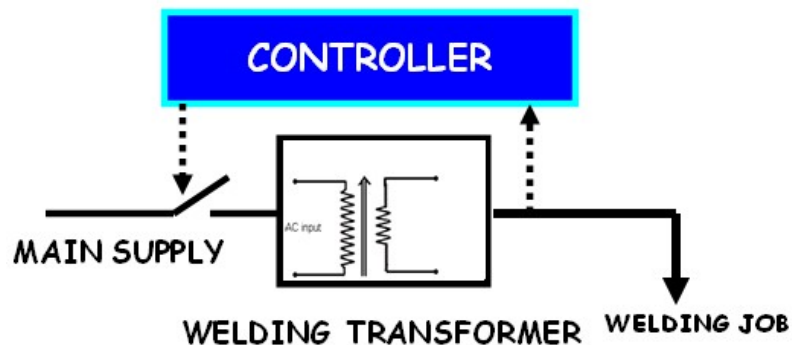
MAIN FEATURES:

- > It does not affect quality of the welding
- > Easy to installed & use
- > Improves system Power Factor
- > Reduces Maintenance & Increase the life of M/C
- > Auto / Manual Option & Compact
- > Recover the cost in less than 06 months

WELDING TRANSFORMER CONTROLLER is a new concept in Electricity Saving for Arc Welding Transformer

- The welder keeps the Transformer “ON” from morning to evening but the actual welding process is carried out only for a fraction of total “ON” time.
- Transformer consumes a minimum current called “NLC” even while the welding process is not carried ON.
- The “NLC” is observed as 04 to 08 Amperes (depending upon the capacity & efficiency of the Transformer)
- This consumption without any output, is wastage & intended to be saved by using WTC (Welding Transformer Controller)

Simplified Circuit:



WELDING TRANSFORMER CONTROLLER switch OFF the Transformer when welding process is not carried out for 30 Seconds.

- To start the welding, the welder touches the electrode to JOB, which shorts the secondary of welding transformer.
- This is sensed by the controller's in built electronic circuitry and remains ready for switching “ON” the contactor to energize primary of the welding transformer.

- Actual “Switching ON” takes place only after the touch break to avoid short circuiting of the transformer.
- While welder continues welding, the controller senses the process and keeps the primary energized.
- Controller has inbuilt timer that switch OFF the contractor if there is no welding for 30 Second.

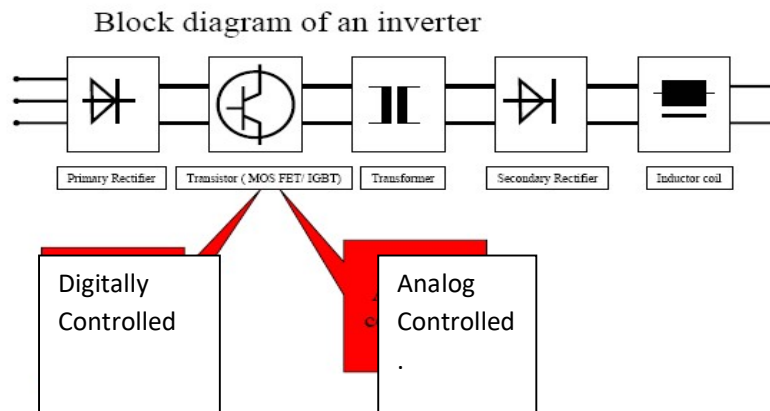
SYENERGY WELDING POWER

It is Micro-processor controller based Weld Power Source that are highly integrated in this system

Typical features:

- ❑ The welding power source and the Micro-processor controller communicate through a fast *Device net* bus.
- ❑ All programming is through the Micro-processor *Teach Pendant*. One window in the Teach Pendant is called *Schedule Manager*. This is where *schedules* for the power source are programmed. A schedule contains all data for the power source performance.

Full Digital Welding Power Source



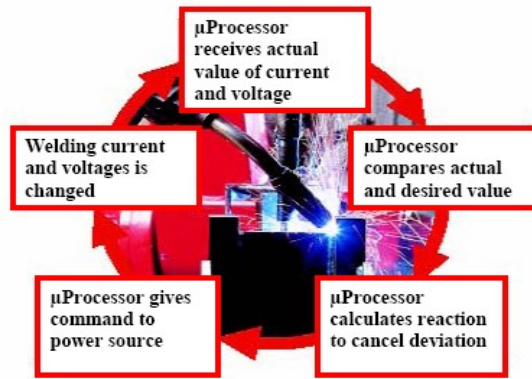
User demands

- ❑ Highest demand on welding performance and quality
- ❑ 100 % repeatability
- ❑ Easy to operate
- ❑ Synergic adjustment - one knob use
- ❑ Prevention of faulty operation
- ❑ Easy service

Transferred to a welding power sources

- ❑ The welding process is stored digitally on the DSP(Digital Signal Processor)
- ❑ That means the arc itself is specified by software ; rather than by inflexible hardware
- ❑ Functions and characteristics of the welding machine are no longer sensitive for ageing and wear out.

The functional principle



Main Process Tasks

- **Welding tasks that the robot controller performs from the program sequence without co-operation with the power source:**
 - All gas timersp
 - Some optional start functions (restart motion, scrape start motion, Motion delay time and heat time/distance)
 - Weld speed
 - Weaving parameters
 - Weld delay distance
 - Cool and fill time (for the robot controlled crater fill)

The advantages of a digital power source

- 100% repeatability
- Insensitive for input voltage fluctuation
- Insensitive for temperature thrift
- Less electronic components required
- Insensitive for ageing
- Easy maintenance due to plug and play PCB's , no trimming necessary
- High flexibility , customized functions can be achieved by
- software without changing hardware

The benefits for the operator

- Easiest setting due to synergic function= one knob use
- Full synergic operation = the operator just recalls the parameters which are stored in the database, according to the present task
- Special synergic lines for uncommon materials can be uploaded , customized for individual requirements

Hazards of Welding

Welding is a high risk and labor intensive activity. It exposes workers to a number of hazards that may be detrimental to health and can have both acute and chronic effects. Welding related accidents can also be fatal.

- Electrical shock hazard.
- Fires and explosive hazard – welding sparks when comes in contact with combustible or flammable materials (10 meters on a horizontal direction from the work area)
- Hazards in Confined Space – Dangerous concentrations of toxic fumes and gases could lead to unconscious or death from suffocation, high concentrations of some fumes and gases can also be very explosive.

**WELDING PROCEDURE FOR JOINING VARIOUS TYPE OF STAINLESS STEELS
WITH MILD STEEL AND CORTEN STEELS
(Based on RDSO PROCEDURE NO. MC – 97)**

INTRODUCTION:

During fabrication of railway carriage & wagons, the use of carbon steels in rolled; forged & cast conditions were prevalent till last decade, which are prone to corrosion. Over the last few years, IR is switching over progressively to SS and Corten steel for manufacturing super structures and trough floors of railway carriages & wagons to get better service life and aesthetics. In this process of change, various types of **similar and dissimilar joints between Stainless steels, Carbon steels and Corten steel** are encountered. Welding of SS and dissimilar metals is definitely a tricky job and if close control over the process and procedure is not exercised, the basic objectives may get defeated. Keeping this in view, detailed guideline for joining SS with SS and other type of carbon and corten steels has been issued by **RDSO** vide **Procedure No. MC-97**. Salient features of MC-97 are reproduced here.

1. MATERIAL:

There are various types of stainless steels of different grades used in IR. The most commonly used stainless steels are:

- i) AISI – 301, 304 (Austenitic) and other similar steels.
- ii) AISI-409M & 3Cr12 grade of IRSM-44(Ferritic)

S. No	Class of Steel	Composition				Application
		C%	Cr %	Ni %	Ti%	
1	301 (Austenitic)	0.15	16-18	6-8	-	Trough floor, inside panelling, vendor compartment deck sheet, drivers cabin etc. of EMU
2	304 (Austenitic)	0.08	18-20	8-12	-	Roof and trough floor of LHB Coach, trough floor, roof and side panel above window of all SS EMU, Break pipe of EMU.
3	409M (Ferritic)	0.08	10.5-11.75	-	6 X %C	Side wall & End wall of LHB coach, side wall below window of EMU, Under-frame & Side panel below window of SS EMU
4	3Cr12 of IRSM-44 (Ferritic)	0.03	10.8- 12.5	-	0.75 (Max)	Side wall, Extension, Side Sill and Centre Sill of BOXN CR wagon.

Table 1: Application & Chemical composition of commonly used SS in IR

Other steels are:

- i) Corten steel to IRS: M-41
- ii) Structural steel to IS: 2062 in different grades including copper bearing and other carbon steels.

2. WELDING PROCESS:

A. For joining of Stainless steel together:

TIG, MIG/MAG or SMAW process shall be used. The process TIG & MIG/MAG is considered beneficial in fabrication of carriages & wagons where as during their repair MMAW & MIG/MAG process may be convenient & beneficial.

B. For joining of Corten steel together –

MIG/MAG, MMAW & SAW process shall be used. The process SAW & MIG/MAG is considered beneficial in fabrication of carriages & wagons whereas during their repair MMAW & MIG/MAG process may be convenient & beneficial.

C. For joining of structural and other carbon steels –

MIG/MAG, MMAW & SAW process shall be used. The process SAW & MIG/MAG are considered beneficial in fabrication of carriages & wagons where as during their repair MMAW & MIG/MAG process may be convenient & beneficial.

D. For combination joints between stainless steels with Carbon/Corten steels-

MIG/MAG & MMAW process shall be used for both fabrication & repair work.

3. WELDING CONSUMABLES:

A. For joining of AISI 301, AISI 304 & other similar steels together:

- i) MMAW electrodes approved under **class M1 as per IRS: M-28-02** shall be used.
- ii) MIG/MAG welding filler wires approved under **class VI as per IRS: M46-03** shall be used.

B. For joining Gr. 409M or 3Cr12 grade of IRS: M-44 & equivalent and combination joint with A. above:

- i) MMAW electrodes approved under **class M2 as per IRS: M-28-02** shall be used.
- ii) MIG/MAG welding filler wires approved under **class VI as per IRS: M46-03** shall be used.

C. For joining all types of SS under A. & B. with Carbon steel/Corten steel:

- i) MMAW electrodes approved under **class M4 as per IRS: M-28-02** shall be used.
- ii) MIG/MAG welding filler wires approved under **class VII as per IRS: M46-03** shall be used.

4. WELDING PROCEDURE:

Any welding activity may be subdivided into three sub-activities, i) Activity prior to welding ii) activity during welding & iii) Activity after welding. Some **DOs and DON'Ts at different stages for welding SS with SS or Corten/Carbon steels** are detailed below:

a) Prior to Welding:

- i) The area about 15 mm from each side of the area to be welded shall be properly cleaned.
- ii) The area to be welded shall be free from dust, dirt, grease, oil, paints etc. Any non-corrosive and suitable organic solvent (Kerosene oil, Benzene etc) can be used for removing grease, oil & paints.
- ii) **Chlorine based solvents shall not be used.**
- iii) Stainless steel wire brushes should be used to remove tenacious layer of Chromium oxide for better strength of joint.

b) During Welding:

- i) The welding parameter in the machine shall be set as per commendation of manufacturer.
- ii) If welding is carried out by MMAW process, connect the electrode with positive terminal of welding equipment (DC+) when welding with DC.
- iii) Use 70 OCV (min) transformers while welding with AC.
- iv) Keep the welding current on lower side (as possible) of the range as recommended by the manufacturer of the consumables.
- v) Maintain short arc length to minimize the loss of alloying elements during welding.

- vi) Put stringer beads, weaving shall not be more than two times of the diameter of electrode used.
- vii) Use small diameter electrode according to thickness of base metal to minimize heat input.
- viii) De-slag each run properly by using stainless steel brushes and chisels.

c) After Welding:

- i) The stainless steels are susceptible to corrosion if the surface is rough. To avoid the corrosion, surface should be made smooth & polished. It is therefore, necessary to finish the stainless steel joint by grinding & subsequent polishing using fine grinder.
- ii) Mild steel & corten steels both are anodic to the stainless steels, hence any small portion of Mild steel & corten steel in contact with stainless steel will corrode severely in short time. Proper & quick corrosion protection is therefore, required in these locations.

Special features of Joining SS with Corten/Carbon Steel:

Dissimilar metal joints are common in fabrications of carriage & wagons on Indian Railways. The welding of dissimilar metals is little more troublesome than welding of carbon structural steels together or stainless steels together. The difference in physical properties Like Thermal Conductivity, Melting Point, Coefficient for Thermal Expansion etc. creates special problems during welding. Dilution of the deposited filler material with either of two base materials leads the variety of problems. **During welding of dissimilar metals, following general points will be helpful:**

- i) Minimum heat input shall be provided to joint, so that diffusion can be restricted and dilution is minimized. To achieve this, low welding current and small diameter electrodes shall be preferred.
- ii) Proper filler material compatible with both the joining steels is to be used.
- iii) Dilution must be reduced as low as possible. Dilution depends on the welding process, process variables and penetration. Hence, proper welding process shall be used with proper setting of process variables (Current, Voltage, Travel speed, Polarity etc.).
- iv) When using gas metal arc welding (MIG/MAG) reduced current density is to be employed, so that only dip transfer of metal occurs.
- v) The problem of dilution and formation of inter-metallic phases can be minimized by buttering one or both joint faces with a layer of compatible material.

General Precautions for all type of welding involving SS:

- i) MMAW electrodes of diameter 2.5 mm/3.15 mm/4.0 mm shall be used depending upon the thickness of plate.
- ii) For continuous wires the diameter of wire shall preferably be 0.8 mm/ 1.2 mm.
- iii) Electrodes are to be re - dried before use to about 150°C for at least one hour or as recommended by the manufacturers.
- iv) Always use stainless steel brushes during welding of stainless steels.
- v) The heat conductivity of stainless steels is about 50% of that of mild steel. This will increase the localized heating of work piece. To reduce the effect of localized heating, usage of current in the lower side of the recommended range will be helpful.
- vi) Because of lower Melting Point, melting rate of stainless steel electrodes is higher than mild steel electrodes. This is another reason to use low current for welding of stainless steel components.
- vii) The thermal expansion of stainless steels is about 50% more than that of mild steel. This will increase the chance of warping & buckling of the component. Thus suitable fixture must be used while welding of stainless steels.

- viii) The electrical resistance of stainless steel is 6 to 12 times more than that of mild steels. This may create problem of overheating in electrodes. To avoid this use low welding current & small length electrodes.

5. EDGE PREPERATION:

- i) No edge preparation is required when welding up to thickness 3/16"(5 mm approx.).
- ii) For higher thickness between 3/16" to 1/2" (5-12 mm approx.) bevel preparation is necessary.
- iii) For joining of plates of unequal cross section in butt joints, taper shall be given to thicker part to reduce thickness equal to thinner part at the end. The slope i.e. $\tan \theta$ of taper should lie between 1 in 6 to 1 in 4 (see Fig.1) below.

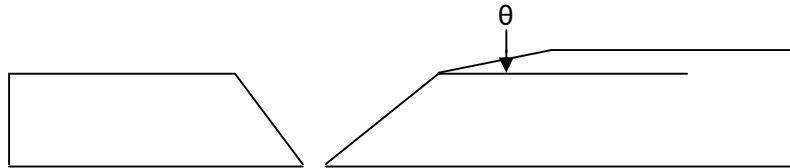


Fig.1 Butt joint of unequal cross section

6. CUTTING OF STAINLESS STEELS:

For cutting of stainless steels plasma cutting or machine cutting shall be used. Manual metal arc cutting followed by grinding may also be used in case plasma arc cutting facility is not available.

WELDING OF STAINLESS STEEL

INTRODUCTION:

Stainless steel is gradually penetrating Indian Railways inventory replacing mild steel & Corten steel. Until recently, the use of stainless steel was limited to some specific components used in Diesel locomotive for high temperature services such as exhaust manifold, turbo super charger, exhaust pipe, bellow etc. Now, with the introduction LHB coaches, BOXNCR wagons etc. use of stainless steel is increasing day by day. Panels of EMU coaches below window level, trough floor etc. are now being made from stainless steel. All SS EMU coaches are on the anvil & prototype is under manufacture. Therefore an understanding of cutting & welding of stainless steel for manufacture & maintenance of the above items is felt very much necessary.

RECENT USAGE OF STAINLESS STEEL IN RAILWAYS

S No	Class of Steel	Composition				Application
		C%	Cr %	Ni %	Others	
3	301 (Austenitic)	0.15	16-18	6-8	-	Trough floor, inside panelling, vendor compartment deck sheet, drivers cabin etc. of EMU
2	304 (Austenitic)	0.08	18-20	8-12	-	Roof and trough floor of LHB Coach, trough floor, roof and side panel above window of all SS EMU, Break pipe of EMU.
1	409M (Ferritic)	0.08	10.5-11.75	-	Ti- 6 X C	Side wall & End wall of LHB coach, side wall below window of EMU, Under-frame & Side panel below window of SS EMU
4	M- 44 (Ferritic)	0.03	10.8- 12.5	-	Ti- 0.75 (Max)	Side wall, Extension, Side Sill and Centre Sill of BOXN CR wagon.

Various Types of Stainless Steel:

Chromium is a metal that possess good corrosion property due to formation of continuous & impervious oxide film. Fortunately, this property is conferred upon its solid solution to iron and the steel become stainless when percentage of chromium in the solid solution is about 12% min.

There are three types of stainless steel, Ferritic, Martensitic & Austenitic based on the microstructure. The first two are also called straight chromium steel. Addition of nickel makes the steel more ductile and resistant to acids & at the same time makes the steel austenitic at room temperature.

Ferritic Stainless steel contains very low Carbon & about 11-30% Chromium. As the name implies, the micro structure contains ferrite & hence magnetic the steel possess good ductility & do not response to heat treatment as no change in phase takes place during heating or cooling. That is why this is very much prone to grain growth when heated above 950°C. It has very good corrosion resistance property & suitable for low temperature use.

Martensitic Stainless Steel contains 11-18% Chromium & comparatively higher amount of Carbon (Normally 0.2% but even 1.2% in some grades). These steels are hardened by heat treatment, contain martensite in the micro structure and find extensive usage because of their ability to resist wear, oxidation & corrosion.

Austenitic stainless steels generally contain 18-30% Chromium & 5-20% Nickel and are by far the most important group with respect to tonnage & application. A great many varieties of Austenetic SS with varying composition & properties are available. The microstructure contains mainly austenite and hence non-magnetic. Sometimes ferrite may also be present in smaller amount. This steel possesses highest corrosion resistance of all the steel and some grades have greatest strength & scale resistance at higher temperature.

IS 9511 covers various grades of Ferrite, Martensitic & Austentic stainless steel plates, sheets & strips for common use.