Principles of arc welding brief description classification and applications

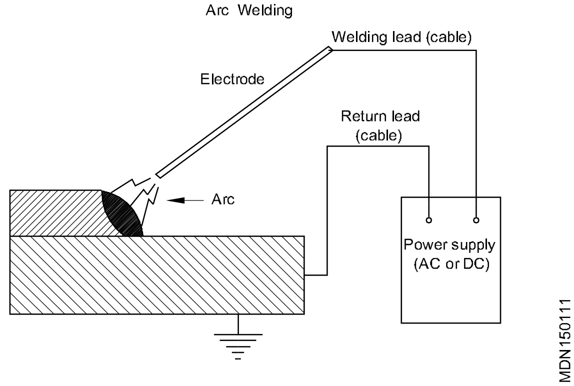
Objectives: At the end of this lesson you shall be able to
- **state the principle of arc welding**
- **state the clasification of arc welding**
- **state the application of arc welding**

Arc welding is a welding process, in which heat is generated by an electric arc struck between an electrode and the work piece.

Electric arc is luminous electrical discharge between two electrodes through ionized gas.

- Power supply (AC or DC)
- Welding electrode
- Welding leads (electric cables) connecting the electrode and work piece to the power supply.
- Electric arc between the electrode and work piece closes the electric circuit. The arc temperature may reach 10000°F (5500°C), which is sufficient for fusion the work piece edges and joining them.

Fig 1



Arc Welding

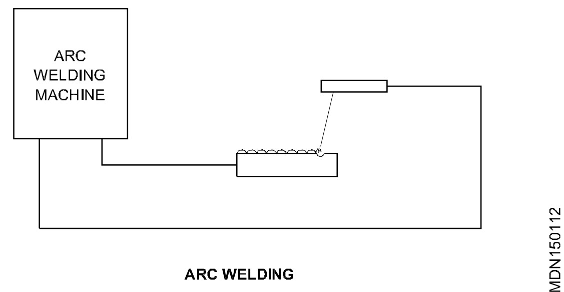
Classification and applications of Arc welding

- Shield metal arc welding
- Carbon arc welding
- Tungsten inert gas arc welding
- Gas metal arc welding
- Atomic Hydrogen are welding
- Submerged arc welding
- Electro slag welding
- Plasma arc welding

Shielded Metal arc welding (Fig 1,2): This is an arc welding process in which the welding heat is obtained from an arc, formed between a metallic (consumable) electrode and welding job.

The metal electrode itself melts and acts as a filler metal.

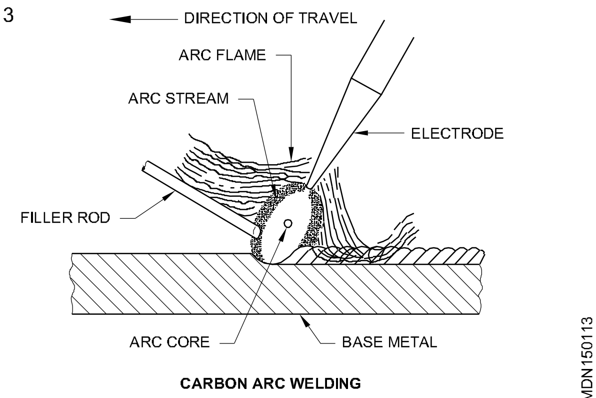
Fig 2



ARC WELDING

Carbon arc welding (Fig 3): Here the arc is formed between a carbon electrode (non-consumable) and the welding job.

Fig 3

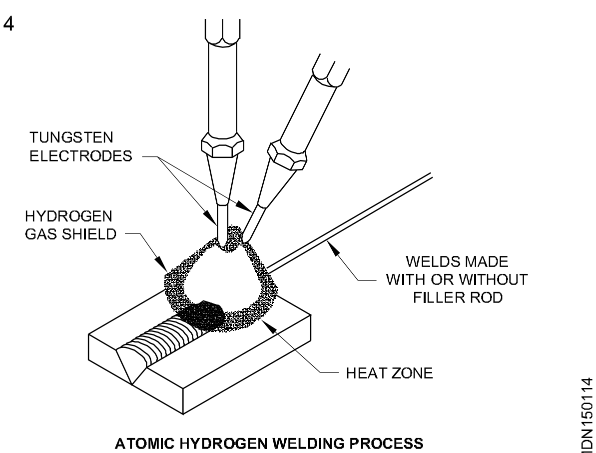


CARBON ARC WELDING

A separate filler rod is used since the carbon electrode is a non-metal and will not melt.

Atomic hydrogen arc welding (Fig 4): In this process the arc is formed between two tungsten electrodes in an atmosphere of hydrogen gas.

Fig 4



ATOMIC HYDROGEN WELDING PROCESS

The welding job remains out of the welding circuit.

A separate filler rod is used to add the filler metal.

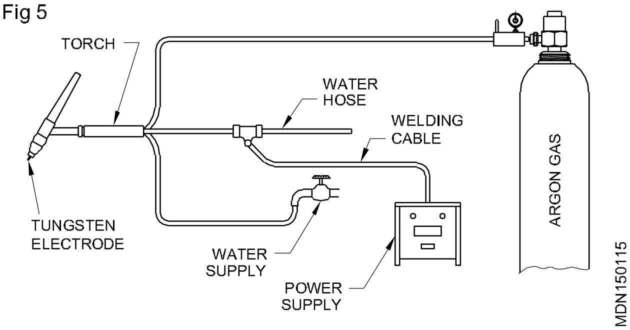
Tungsten inert gas arc welding (TIG) (Fig 5): In this case the arc is formed between the tungsten electrodes (non-consumable) and the welding job in an atmosphere of an inert gas (argon or helium).

A separate filler rod is used to add the filler metal.

This process is also called gas tungsten arc welding (GTAW) process.

Gas metal arc welding (GMAW) or Metal inert gas arc welding (MIG) (Fig 6): In this process the arc is formed between a continuous, automatically fed, metallic consumable electrode and welding job in an atmosphere of inert gas, and hence this is called metal inert gas arc welding (MIG) process.

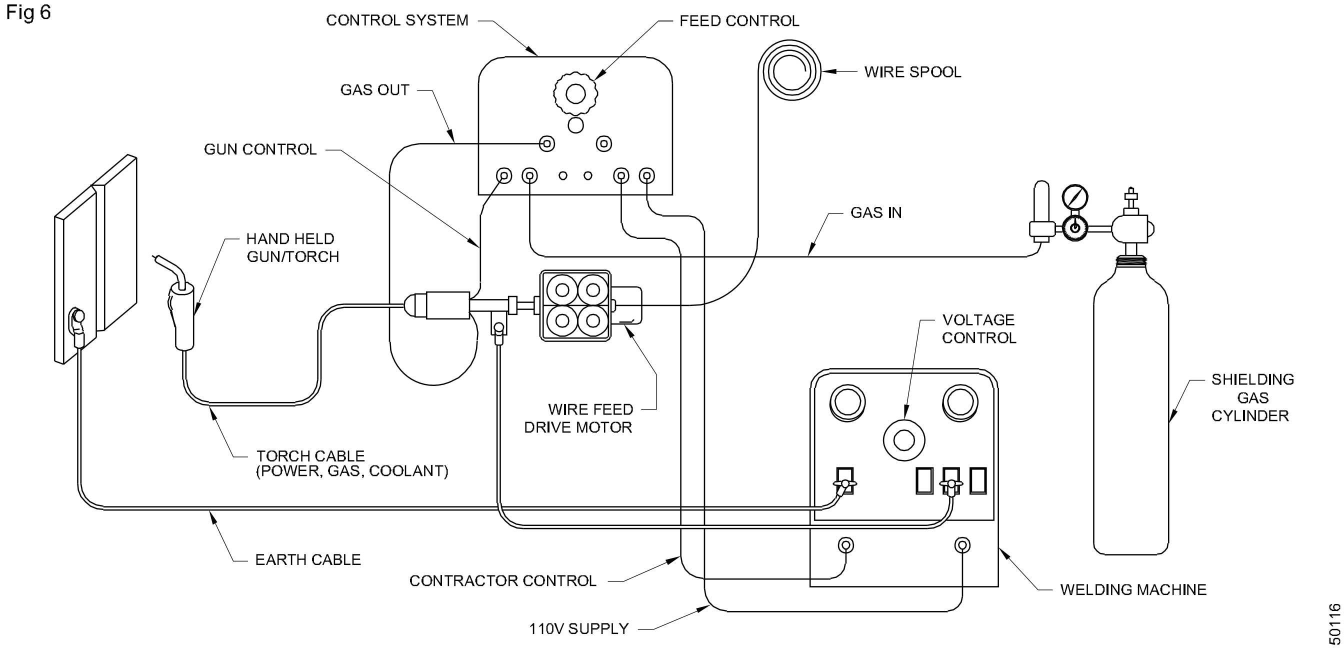
Fig 5



When the inert gas is replaced by carbon dioxide then it is called CO_2 arc welding or metal active gas (MAG) arc welding.

The common name for this process is gas metal arc welding (GMAW).

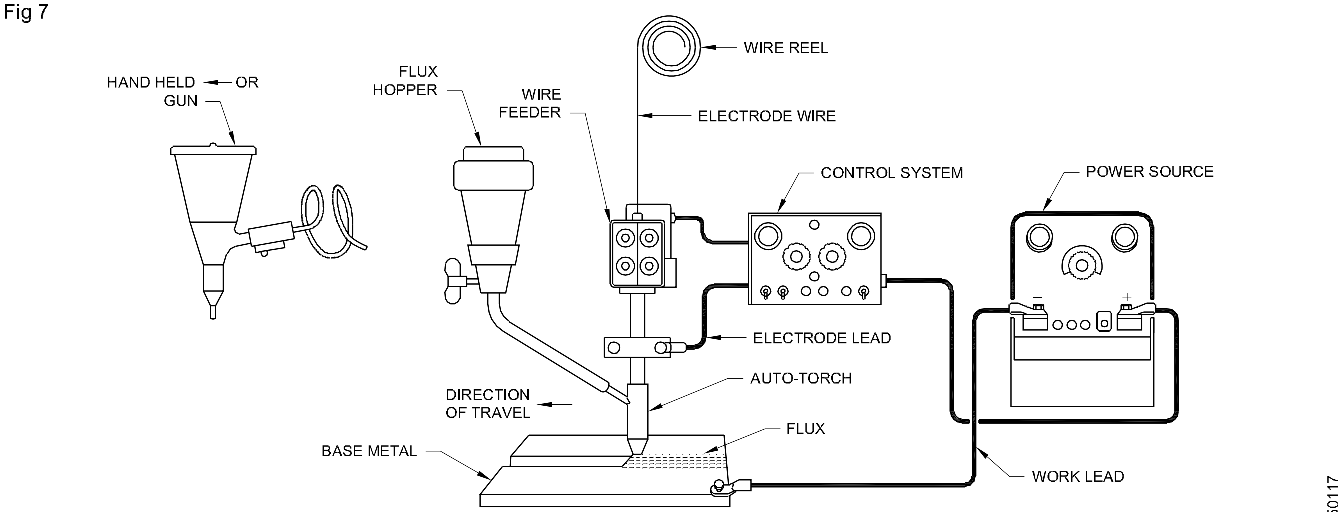
Fig 6



BLOCK DIAGRAM (GMAW/MIG)

Submerged arc welding (Fig 7): Here the arc is formed between a continuous, automatically fed, metallic consumable electrode and the welding job under a heap of powdered/granulated flux.

Fig 7



SUBMERGED ARC WELDING

The arc is totally submerged in the flux (invisible).

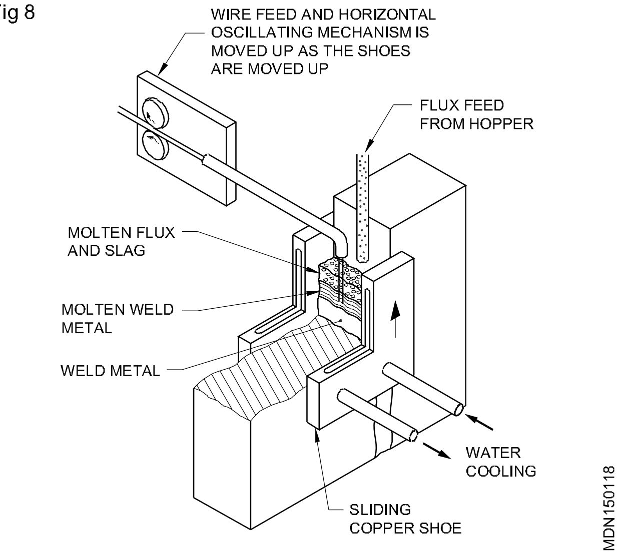
Electro-slag welding (Fig 8): The arc is formed between a continuous, automatically fed, metallic consumable electrode and the welding job under a thick pool of molten flux (slag).

This automatic process requires special equipment and is used only in vertical position for the welding of heavy thick plates.

Plasma arc welding: In this process the arc is formed between a tungsten electrode and the welding job in an atmosphere of plasma-forming gas-nitrogen, hydrogen and argon.

A separate filler rod is used to add the filler metal in the joint, if necessary. But normally no filler rod is used.

Fig 8



Arc-Welding machines

Objectives : At the end of this lesson you shall be able to
- **state the function of arc-welding machines**
- **name the different types of arc-welding machines.**

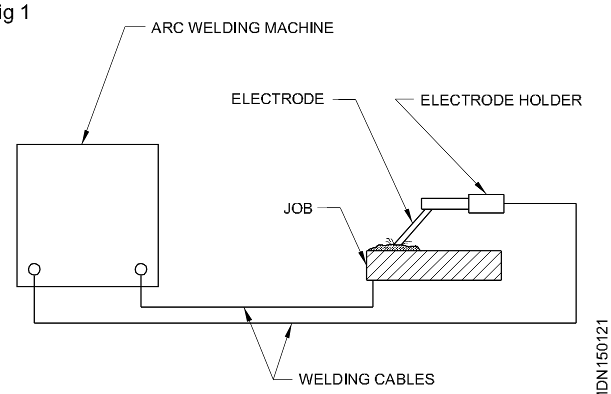
In the arc-welding process, the source of heat is electricity (high ampere low voltage). This heat is supplied by the arc-welding machine which is the power source.

Function (Fig 1)

The equipment is used to

- Provide A.C. or D.C. supply for arc welding
- Change the high voltage of main supply (A.C.) to low voltage, heavy current (A.C. or D.C.) suitable for arc welding
- Control and adjust the required supply of current during arc welding

Fig 1



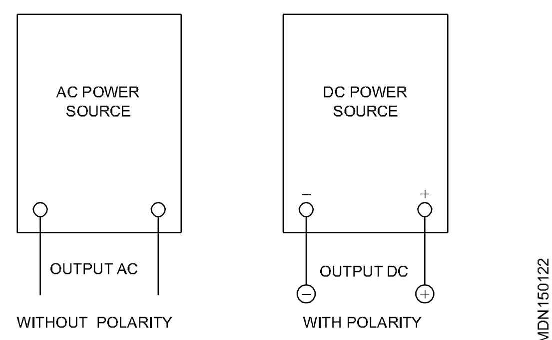
Power sources (Fig 2)

Basically the power sources are
- Alternating current (A.C.) welding machine
- Direct current (D.C.) welding machine.

These may be further classified as

D.C.Machines
- Motor generator set

Fig 2

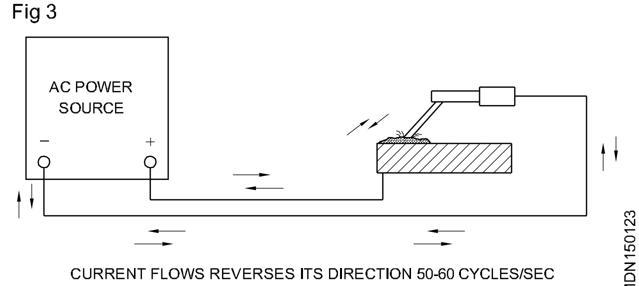


- Engine generator set
- Rectifier sets.

A.C.Machines
- Transformer sets

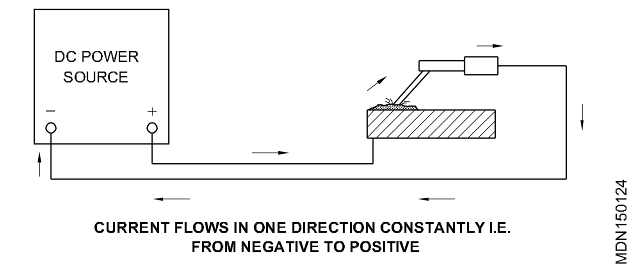
A.C. means Alternating Current. It changes or reverses its direction of flow 50-60 cycles per second. (Fig 3)

Fig 3



D.C. means Direct Current. It flows steadily and constantly in one direction. (Fig 4)

Fig 4



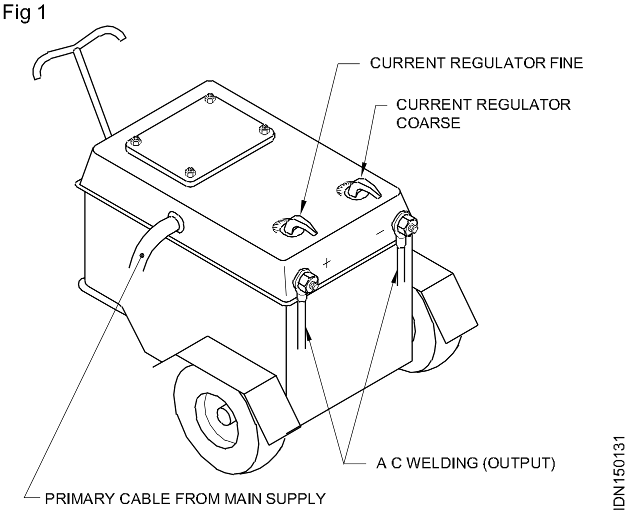
A.C. Arc welding machine

Objectives : At the end of this lesson you shall be able to
- **state the features of A.C. welding transformers**
- **state the advantages and disadvantages of A.C. welding machines.**

A.C. welding transformer

An A.C.welding transformer is a type of A.C. welding machine which converts the A.C. main supply into an A.C. welding supply. (Figs 1 and 2)

Fig 1



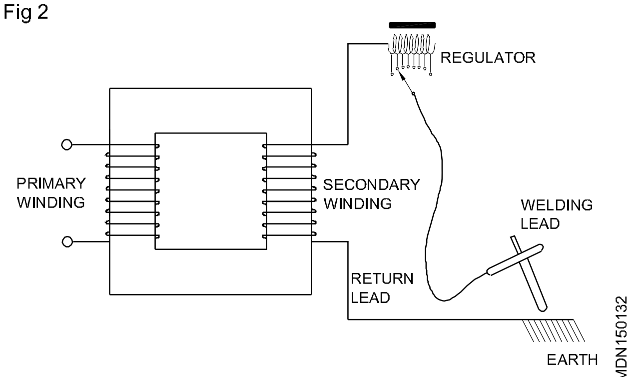
The A.C. main supply has high voltage - low ampere.

The A.C. welding supply has high ampere - low voltage.

It is a STEP-DOWN transformer which reduces the main supply voltage (220 or 440 volts) to the welding supply open circuit voltage (O.C.V.), between 40 and 100 volts.

It increases the main supply low current to the required output welding current in a hundred or thousand amperes.

Fig 2



The A.C. welding machine cannot be operated without the A.C. main supply.

Advantages

- Less initial cost
- Less maintenance cost
- Freedom from arc blow.

Magnetic effect which disturbs the arc is called the arc blow.

Disadvantages

- Not suitable for the welding of non-ferrous metals, light coated and special electrodes.
- The A.C. cannot be used without special safety precautions.

D.C. Arc-welding machines

Objectives : At the end of this lesson you shall be able to
- **state the features of a D.C. welding machine**
- **state its advantages and disadvantages.**

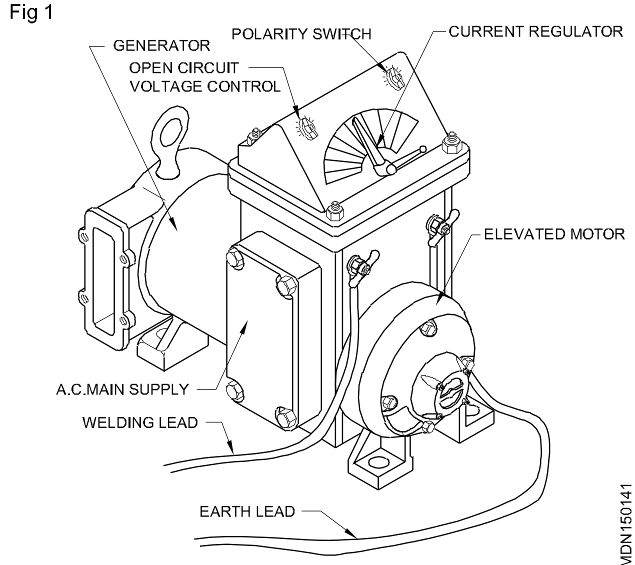
Motor generator set (Fig 1)

It is used to generate D.C. for arc-welding.

The generator is driven by an A.C. or D.C. motor.

Main supply is a must to run the machine.

Fig 1



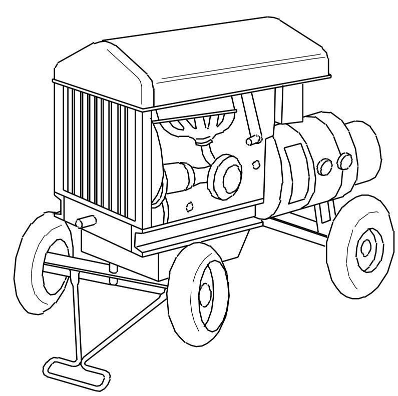
Engine generator set (Fig 2)

Equipment is similar to the motor generator set except that the generator is driven by a pertrol or diesel engine.

Its running and maintenance charges are higher.

It can be used anywhere in field work, away from electric lines.

Fig 2



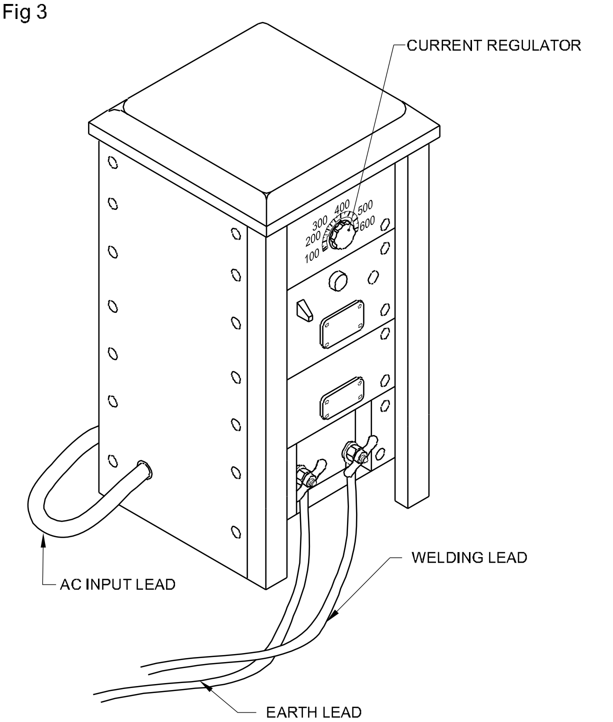
Rectifier set (Fig 3)

It is used to convert A.C. into D.C. welding supply.

Basically it is an A.C. welding transformer. The output of the transformer is connected with a rectifier to change the A.C. into D.C.

It may be designed to supply both A.C. and D.C. currents for welding (called A.C.-D.C. rectifier set).

Fig 3



Advantages

Suitable for welding all ferrous and non-ferrous metals using all types of electrodes

- Better heat distribution in the electrode and job due to polarity in the welding current supplies constant main load and accurate current setting.

It ensures safe working.

Disadvantages

- Initial cost is higher
- Maintenance cost is more
- Arc-blow trouble faced at certain times.

Edge preparation

Objectives: At the end of this lesson you shall be able to
- **state the necessity of edge preparation**
- **describe the edge preparation for butt and fillet welds.**

Necessity of edge preparation: Joints are prepared to weld metals. The preparation of edges are also necessary prior to welding in order to obtain the required strength to the joint. The following factors are to be taken into consideration for the edge preparation.

- The welding process like SMAW, oxy-acetylene welds, Co_2, electro-slag etc.
- The type of metal to be jointed, (i.e.) mild steel, stainless steel, aluminium, cast iron etc.
- The thickness of metal to be joined.
- The type of weld (groove and fillet weld)
- Economic factors

The square butt weld is the most economical to use, since this weld requires no chamferring, provided satisfactory strength is attained. The joints have to be bevelled when the parts to be welded are thick so that the root of the joints have to be made accessible for welding in order to obtain the required strength.

In the interest of economy, bevel butt welds should be selected with minimum root opening and groove angles such that the amount of weld metal to be deposited is the smallest. "J" and "U" butt joints may be used to further minimise weld metal when the savings are sufficient to justify the more difficult and costly chamferring operations. The "J" joint is usually used in fillet welds.

A root gap is recommended since the spacing allows the shrinking weld to draw the plates freely together in the butt joint. Thus, it is possible to reduce weld cracking and minimise distortion and increase penetration, by providing a root gap for some welded joints.

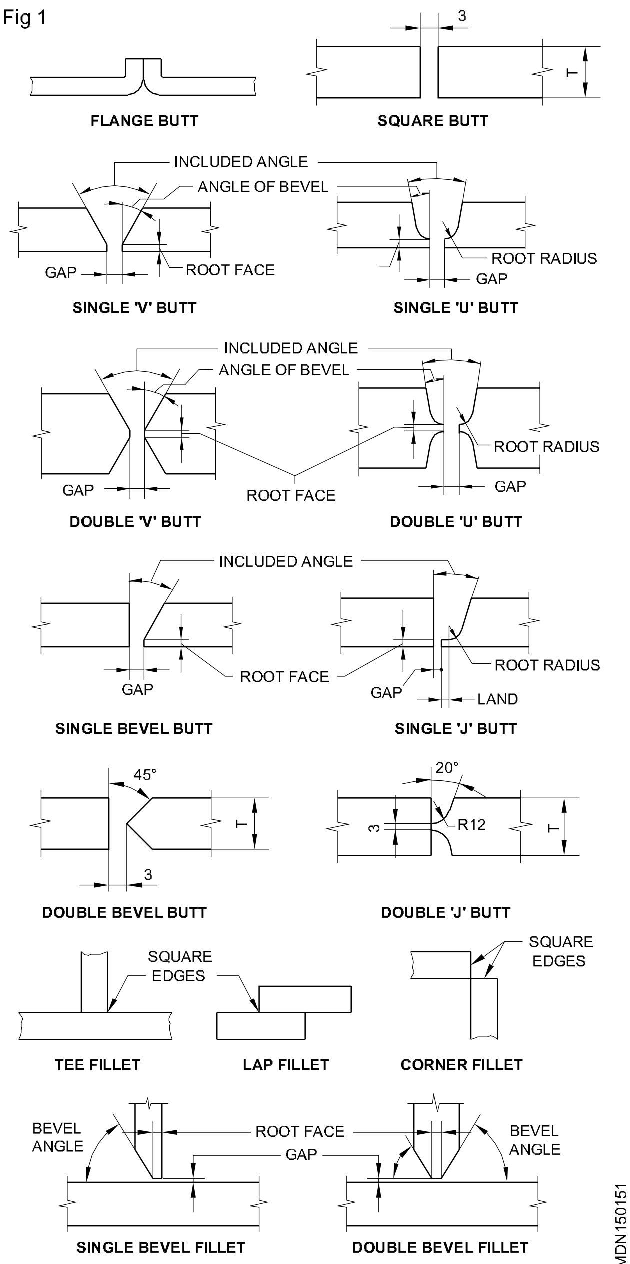
Method of edge preparation: The joining edges may be prepared for welding by any one of the methods mentioned below.

- Flame cutting
- Machine tool cutting
- Machine grinding or hand grinding
- Filing, chipping

TYPES OF EDGE PREPARATION AND SETUP

Different edge preparations generally used in arc welding are shown in (Fig 1).

Fig 1



Tools and equipment used in oxy-acetylene gas welding

Objectives : At the end of this exercise you shall be able to
- **compare the features of oxygen and acetylene regulators**
- **state the features of hose - pipes used in gas welding**
- **distinguish between the hose connections for oxygen and acetylene regulators and blowpipes**
- **state the features of a blowpipe and their functions**
- **state the features of a spark lighter**
- **state the use of a cylinder trolley.**

Gas welding principle

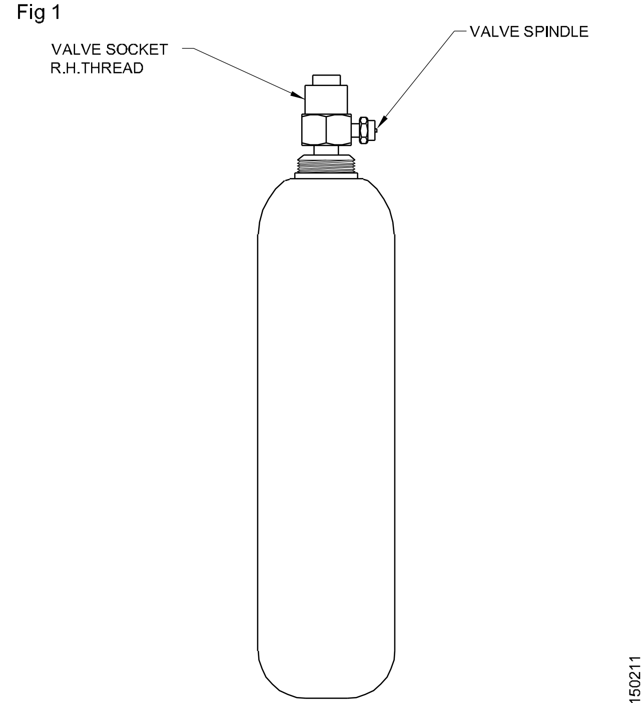
Gas welding is a most important type of welding process. it is done by burning of fuel gases with help of oxygen which form a concentrated flame of high temperature. This flame directly strikes the weld area and melt the weld surface and filler materials. The melted part of welding plates diffused one another and create a weld joint after cooling. This welding method can be used to join most of common metals used in daily life.

Oxy - acetylene gas welding

The essential requirement for a beginner dealing with oxy - acetylene gas welding is to identify the tools and equipment required and know their uses.

Oxygen gas cylinders (Fig. 1)

Fig 1



OXYGEN CYLINDER (COLOUR BLACK)

oxygen gas cylinder is black colour pointed steel bottle and it has a storing capacity of 7m^3 gas.

The valve socket has right hand threads.

The cylinder is used to store oxygen gas with a pressure of 120 to 150 kg/cm^2

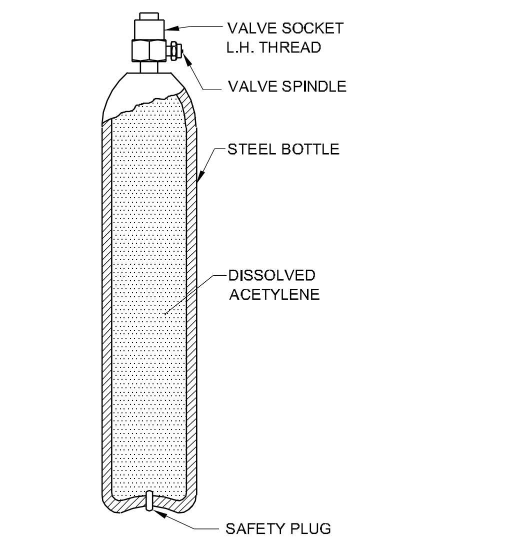
Dissolved acetylene cylinders (Fig. 2)

This is painted maroon and has a storing capacity of 6m^3. The valve socket has left hand threads. It is used to store acetylene gas in a dissolved state with a pressure of 15-16kg/cm^2.

Pressure regulators for oxygen

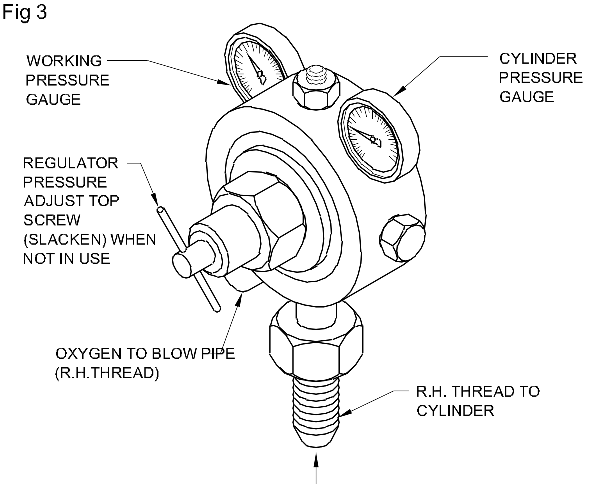
The regulator is used to reduce and control the oxygen cylinder gas pressure to a suitable working pressure and maintain constant rate of gas flow for the blowpipe. The regulator has right hand screws threads. (Fig. 3)

Fig 2



ACETYLENE CYLINDER (COLOUR MAROON)

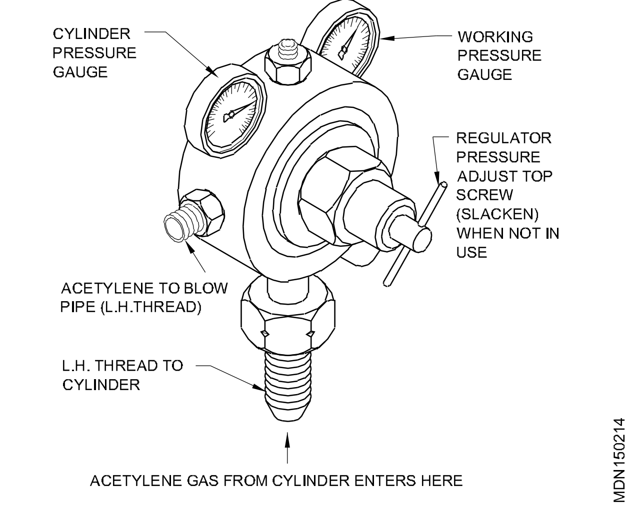
Fig 3



Pressure regulators for acetylene

This is to reduce and control the acetylene cylinder gas pressure to a suitable working pressure at a constant rate of flow for the blowpipe. This regulator has left hand screw threads. (Fig 4)

Fig 4

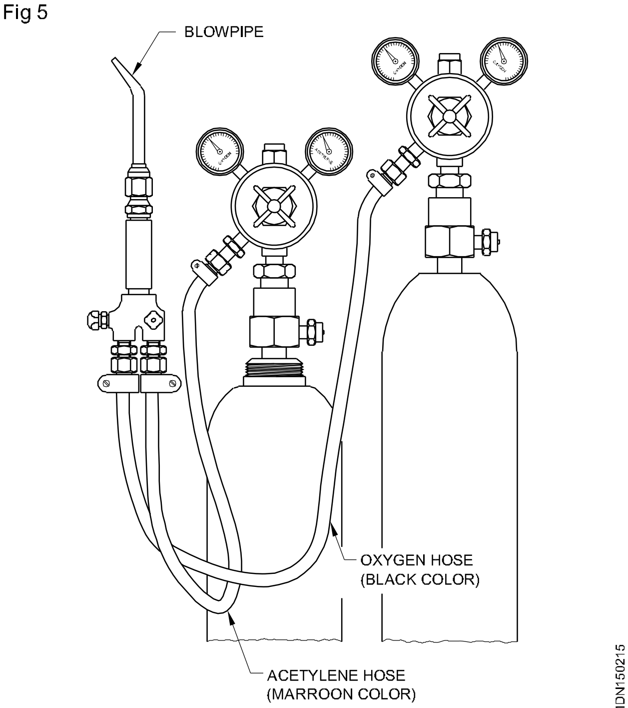


Both oxygen and acetylene regulators have a cylinder pressure gauge to indicate the cylinder gas pressure and a working pressure gauge to indicate the working pressure required for the blowpipe. (Figs 3 & 4)

Rubber hoses

The hose carries the gases from the gas regulators to the blowpipe. The hoses are made of strong canvas rubber and it having good flexibility. The hose pipe for the oxygen line is black in colour while that for the acetylene line is maroon colour. (Fig 5)

Fig 5

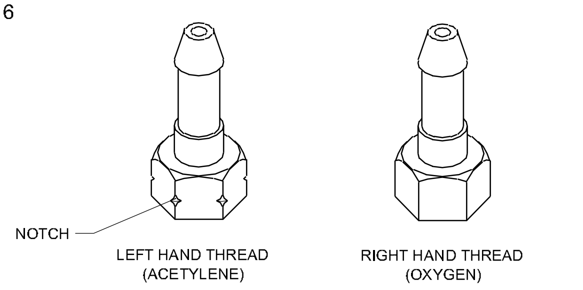


Hose pipe connections for regulators

This is a connecting union used to connect rubber hose pipes with the regulators.

Oxygen connection has right hand threads while the acetylene connection has left hand threads. (Fig 6). The nut used for the acetylene rubber hose connections will have a notch at its corners.

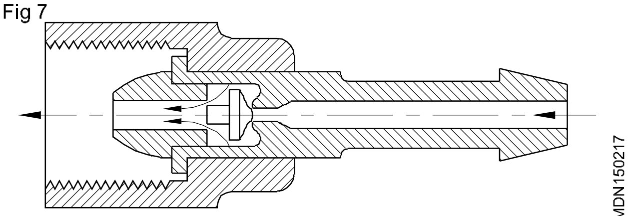
Fig 6



Hose pipe connections for blowpipes

This has the shape of a connecting union and is fitted with a non-return disc to prevent flash-back and backfire during welding. (Fig 7)

Fig 7



It is used to connect the rubber hose pipe with the blowpipe.

The oxygen connection has right hand threads while the acetylene one has left hand threads.

Blowpipe set with nozzle (Fig 8)

This is a device with a handle and inlet connection for acetylene (left hand threads) and oxygen (right hand threads). It has control valves for acetylene and oxygen gas flow, a gas mizing chamber, and a neck - pipe with a nozzle.

Fig 8

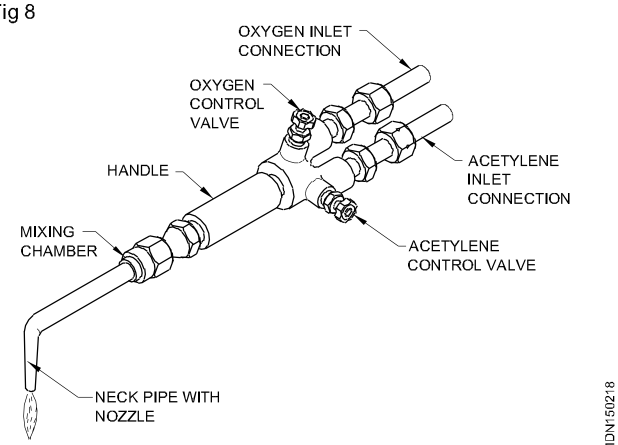
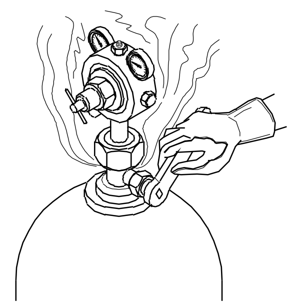
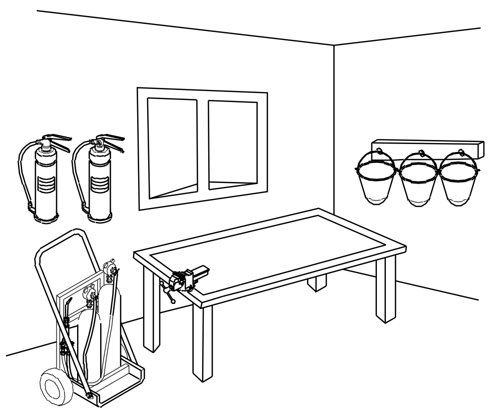


Fig 9



Always keep the working condition handy fire-fighting equipment to put off fires (Fig 10)

Fig 10



Keep the work area free from any form of fire.

Safety gas cylinders

Do not roll gas cylinders or use them as roller.

Use a trolley to the carry the cylinders.

Close the cylinder valves (Fig 9) when it is not in use or empty.

Keep full and empty cylinders separately.

Always open the cylinder valves slowly, not more than one and a half turn.

Use the correct cylinder keys to open the cylinders.

Do not remove the cylinder keys from the cylinders while welding. It will help to close the cylinders quickly in the case of a back-fire or flash-back.

Always use the cylinders in an upright position for easy handling and safety.

Always check the cylinder valves to clean the valve sockets before attaching regulators. (Fig 11)

Safety for rubber hose pipes (Fig 12)

Inspect the rubber hose pipes periodically and replace the damaged ones.

Do not use old bits of hose pipes / tubes.

Do not replace the hose pipes for acetylene with the ones used for oxygen.

Always use a black hose pipes for oxygen and maroon hosepipes for acetylene.

Fig 11

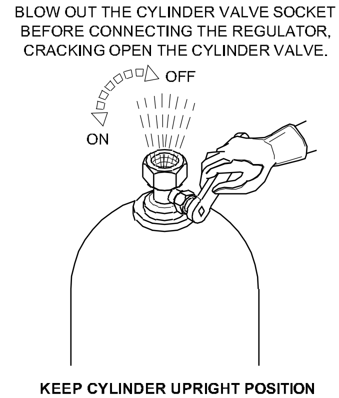
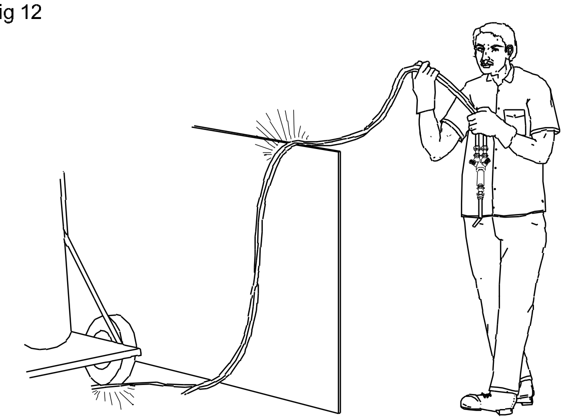


Fig 12



Safety for regulators (Fig 11)

Prevent hammer blows to the gas cylinders and ensure that water, dust and oil do not settle on the cylinders.

Right hand threaded connection for oxygen and left hand threaded connection for acetylene.

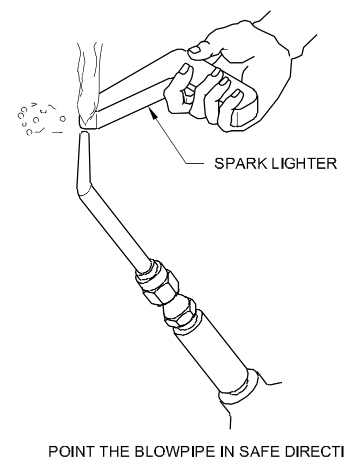
Safety for blowpipes

When a blowpipe is not in use put away from the flame and place the blowpipe in a safe place.

When flame snaps out and backfires, quickly shut off the both valves in blowpipe (oxygen first) then acetylene and their dip in water.

While igniting the flame, point the blowpipe nozzle in a safe direction. (Fig 13)

Fig 13



While extinguishing the flame, shut off the acetylene valve first and then the oxygen valve to avoid a backfire.

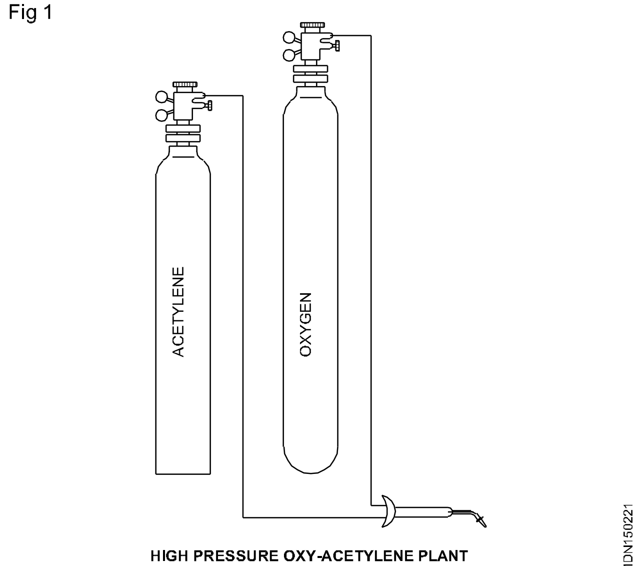
Systems of oxy-acetylene welding

Objectives : At the end of this lesson you shall be able to
- **distinguish between high pressure and low pressure acetylene plants**
- **distinguish the features of low pressure and high pressure blowpipes.**

Oxy-acetylene plants can be either high pressure or low pressure.

A high pressure plant utilizes acetylene under high pressure, upto 1 kg/cm^2. (Fig 1)

Fig 1



HIGH PRESSURE OXY-ACETYLENE PLANT

Dissolved acetylene (acetylene in cylinder) is a commonly used source.

A low pressure plant utilizes acetylene under low pressure (0.017 kg/cm^2) produced by an acetylene generator only. (Fig 2)

High pressure and low pressure plants utilize oxygen gas in compressed high pressure cylinders only.

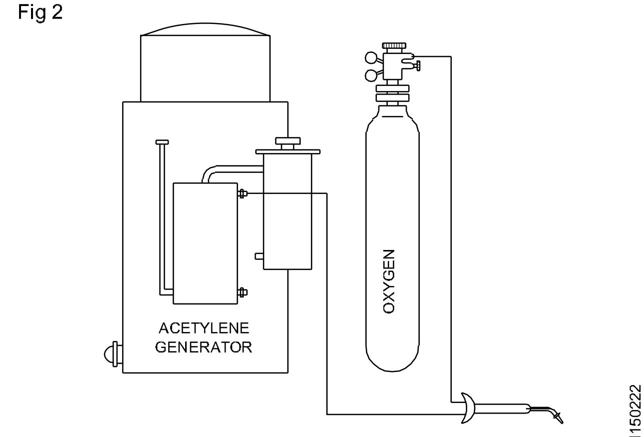
The high or low pressure systems used in oxy-acetylene welding refer only to the acetylene pressure.

Distinguishing features of blowpipes

For low pressure systems, a specially designed injector type blowpipe is required. This can be used for high pressure also. (Fig 3)

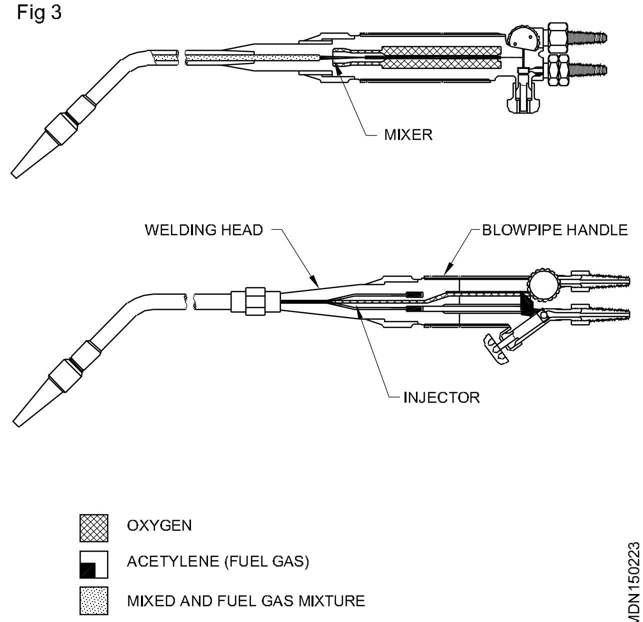
In a high pressure system, a mixer type high pressure blowpipe is used, this is not suitable for the low pressure system. (Fig 3)

Fig 2



LOW PRESSURE OXY-ACETYLENE PLANT

Fig 3

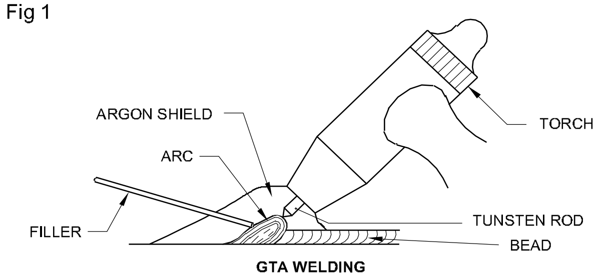


TIG Welding process and equipment

Objectives : At the end of this lesson you shall be able to
- **state the principle of TIG welding process**
- **state the application of TIG welding**
- **identify the TIG welding equipment**
- **name the parts of TIG welding equipment**
- **state the purpose of different parts.**

Introuction to TIG welding: The Gas Tungsten Arc Welding (GTAW) process fuses metals by heating them between a non consumable (does not melt) tungsten electrode and workpiece. The heat is necessary for fusion (mixing or combining of molten metals) and it is provided by an arcing electric current between the tungsten electrode and base metal.

Fig 1

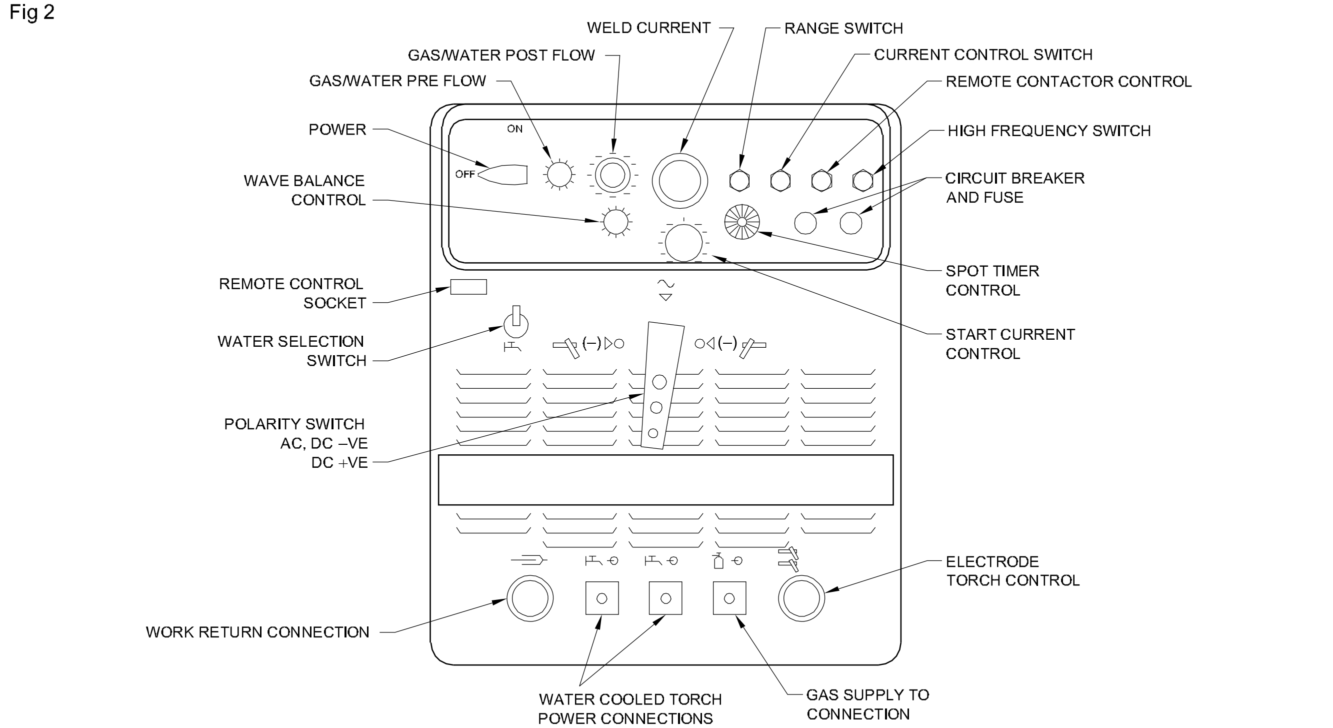


This type of welding is usually done with a single electrode. The tungsten electrode and the weld zone (area being welded) are shielded from the atmosphere (air around it) by an inert gas, such as argon or helium. Filler metal may or may not be used. This process is also called TIG (Tungsten Inert Gas) welding. Gas tungsten arc welding, is particularly used when welding stainless steel, aluminium, titanium and many other non-ferrous metals.

TIG welding equipment

- An AC or DC arc welding machine. (Fig 1 & 2)
- Shielded gas cylinders or facilities to handle liquid gases
- A shielding gas regulator
- A gas flowmeter
- Shielding gas hoses and fittings
- A welding torch (electrode holder)
- Tungsten electrodes
- Welding rods
- A water cooling system with hoses for heavy duty welding operations
- Foot rheostat (switch)
- Arc timers

Fig 2



Torch: There is a variety of torches available varying from light weight air cooled to heavy duty water cooled types. Fig.1 & 3. The main factors to be considered in choosing a torch are:

- Current carrying capacity for the work in hand
- Weight, balanced and accessibility of the torch head to the work in hand.

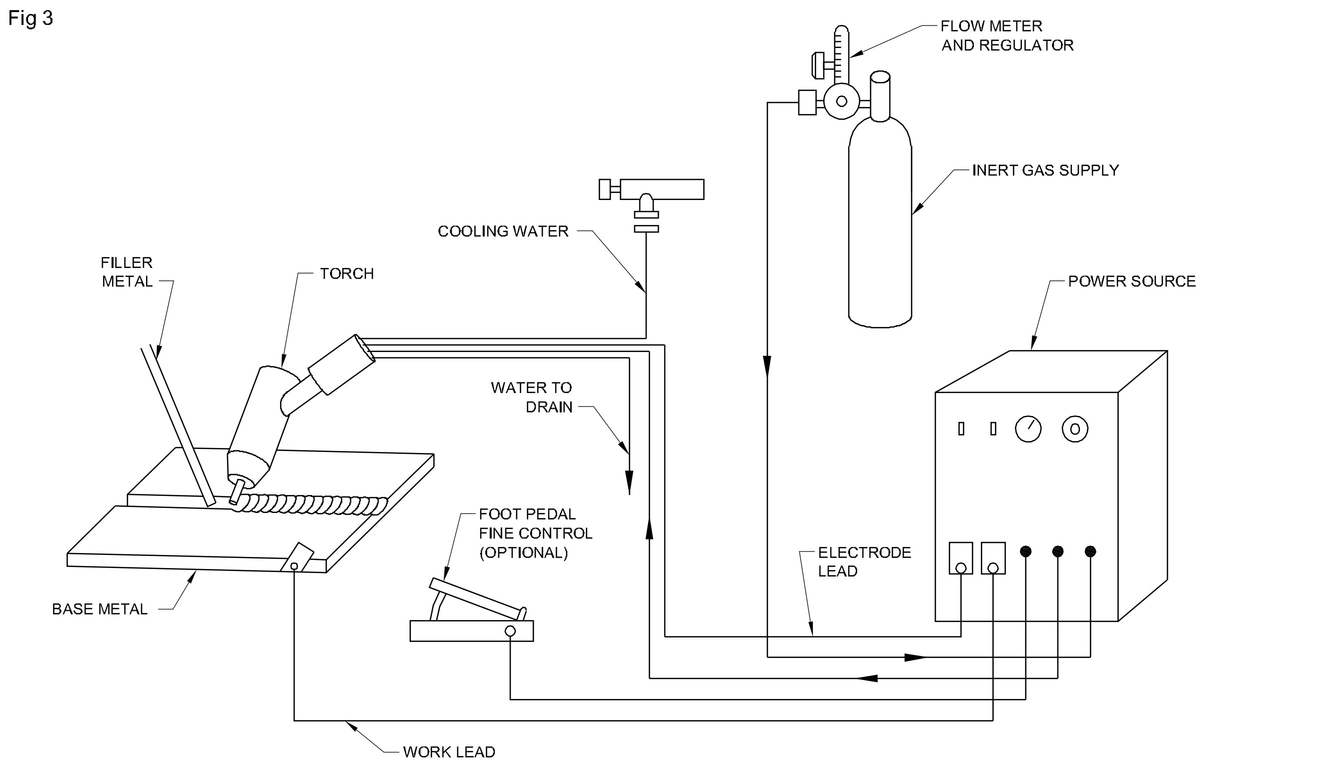
The torch body which a top loading compression-type collet assembly which accommodates electrodes of various diameters. They are securely gripped, yet the collet is easily slackened for removal or reposition of the electrode.

As the thickness of plate to be welded increases, size of torch and electrode diameter must increase to deal with the larger welding currents required.

Gas regulator, flowmeter (Fig 3 & 4): The gas regulator reduces the pressure in the argon cylinder from 175 or 200 bar down to 0-3.5 bar for supply to the torch.

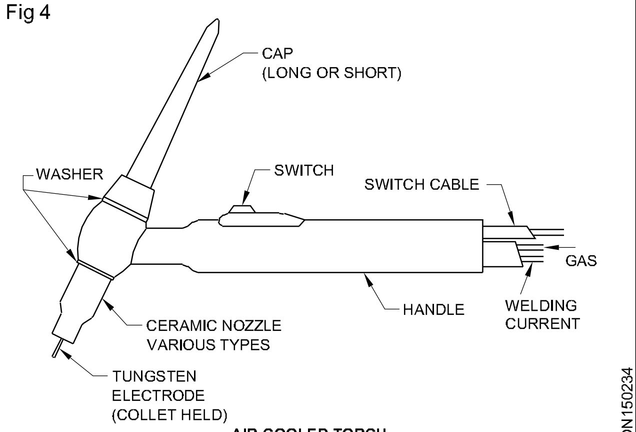
The flowmeter which has a manually operated needle valve, controls the argon flow from 0-600 litres/hour to 0-2100 litres/hour according to type.

Fig 3



A DIAGRAMMATIC DRAWING OF A COMPLETE GAS TUNGSTEN ARC WELDING

Fig 4

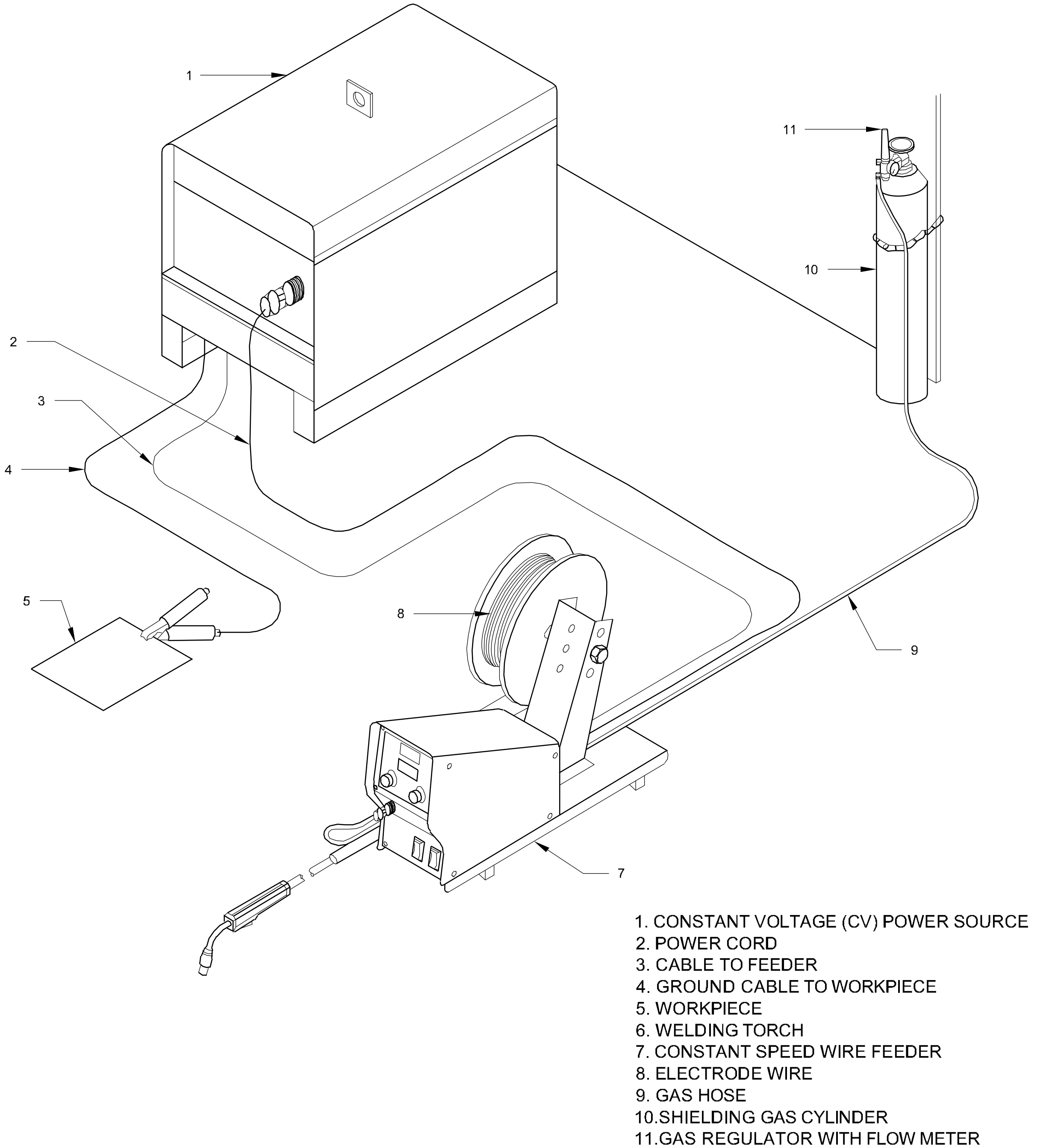


AIR-COOLED TORCH

Basic equipment for a typical gmaw semiautomatic setup (Fig 5).

- Welding Power Source - provides welding power.
- Wire Feeders - controls supply of wire to welding gun.
- Supply of Electrode Wire.
- Welding Gun - delivers electrode wire and shielding gas to the weld puddle.
- Shielding Gas Cylinder - provides a supply of shielding gas to the arc.

Fig 5



GMAW equipment and accessories

Objectives: At the end of this lesson you shall be able to
- **state the power sources for GMAW**

MIG welding power sources have come a long way from the basic transformer type power source to the highly electronic and sophisticated types we see around today.

Even though the technology of MIG welding has changed, the principles of the MIG power source have, in most cases, not. The MIG power sources use mains power and converts that mains power into CV (constant voltage), DC (direct current) power suitable for the MIG welding process.

MIG welding power sources control voltage – this is done by either voltage stepped switches, wind handles, or electronically. The amperage that the power source produces is controlled by the cross sectional area of the wire electrode and the wire speed, ie the higher the wire speed for each wire size, the higher the amperage the power source will produce.

Because the output of the MIG power source is DC (direct current) the terminals on the front will have + positive and negative on the output side. The principles of electric circuits states that 70% of the heat is always on the positive side.

> **This means that the lead that is connected to the positive side of the welder, will carry 70% of the total energy (heat) output.**

The characteristics volt, ampere curves (A & B) are shown in Fig.1.

Curve A (For SMAW): On the output slope or voltampere curve A, a change from 20 volts to 25 volts will result in a decrease in amperage from 135 amps to 126 amps. With a change of 25 percent in voltage, only a 6.7 percent change occurs in the welding current in curve A. Thus if the welder varies the length of the arc, causing a change in voltage, there will be very little change in the current and the weld quality will be maintained. The current in this machine, even though it varies slightly is considered constant.

This is called drooping characteristic power source. Also called constant current (CC)power source.

This type of power source is used in SMAW & GTAW process.

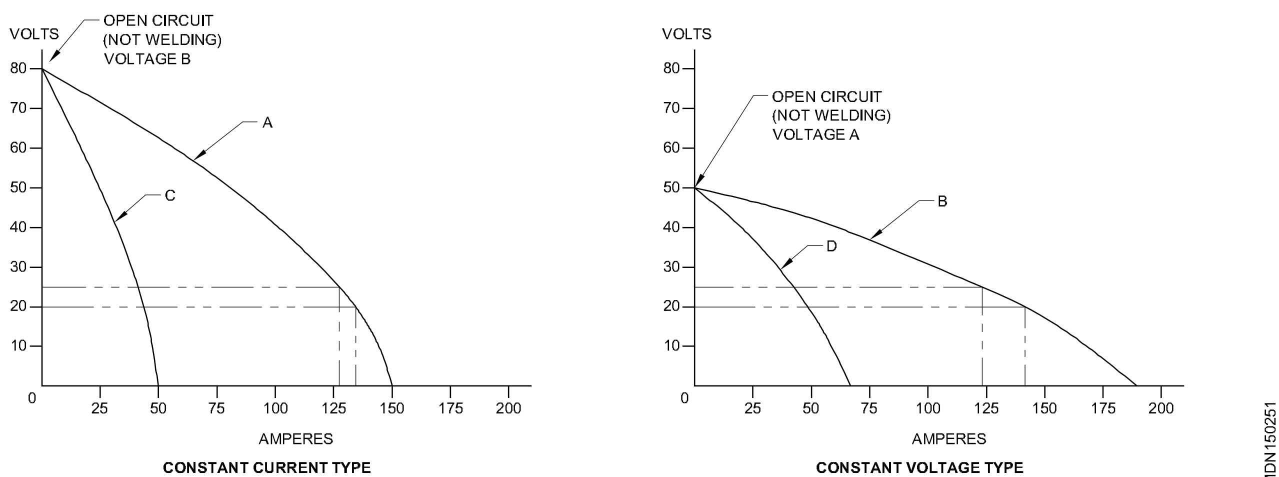
Curve B (For GMAW): The open circuit voltage curve for a setting of 50 volts on the machine is shown as curve B in the Fig.1. The same 20 volt to 25 volt (25 percent) change in the welding voltage will result in a drop in current from 142 amps to 124 amps or 13.3 percent. This slower sloping volt ampere curve output causes a large change in amperage with the same small change in voltage. A welder may wish to have this slower sloping (flatter) volt-ampere output curve.

This is called flat characteristic power source. Also called constant Voltage(CV)power source.

This type of power source is used in **GMAW & SAW** process.

With a flatter output slope the welder can control the molten pool and electrode melt rate by making small changes in the arc length. Control of the molten pool and electrode melt rate are most important when welding in the horizontal, vertical and overhead positions.

Fig 1



GMAW (MIG/MAG) torches

Objectives: At the end of this lesson you shall be able to
- **state the types and functions of torches.**

MIG/MAG Torch Connection

The torch connection is the system in which the MIG torch is connected to the wire feeder. There are various types of MIG torch connections. Different manufacturers can use any one of many systems to connect their torch to the wire feeder.

When ordering a new Torch tell the supplier

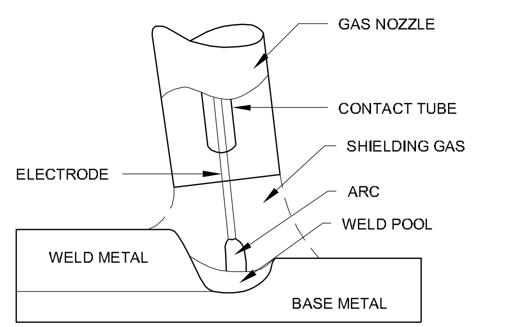
a) the type of torch you need, including amperage rating

b) the type of connection on the feeder so the Torch can be supplied to match the connection

The Torch connection is also the area where the wire electrode, welding current and welding gases are passed onto the welding torch. This means these components should be checked for damage or leaky seals etc, so the connection will do its job correctly.

MIG/MAG Torches

Fig 1



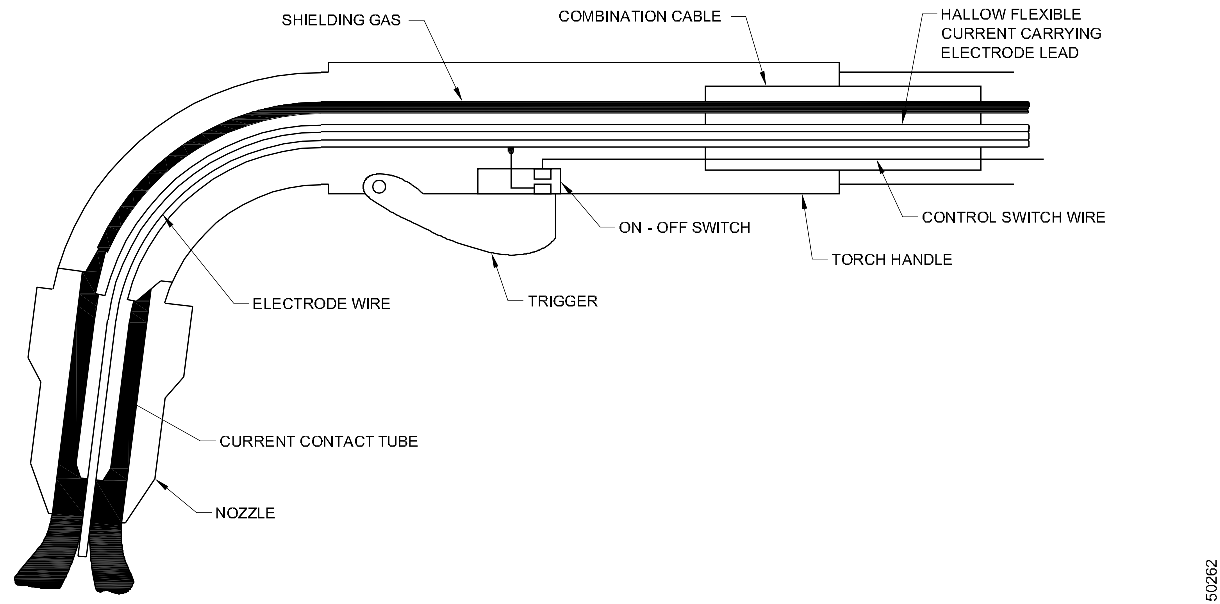
The MIG Torch is connected to the wire feeder, and its job is to deliver the wire electrode, shielding gas and the electrical welding current to the welding area. There are a lot of different shapes and styles of MIG Torch out in the marketplace but they all have things in common. (Fig. 1 & 3).

1 Aircooled (less than 200 Amps) or watercooled (above 200 Amps) (Fig 2)

2 Current rating. The operator must select the correct size Torch. Using a torch that is not sufficiently rated for the machine may result in the Torch overheating. This may result in a poor weld and damage to the Torch . A Torch with an excessive rating will be larger and heavier than the smaller Torch, which could result in discomfort for the operator.

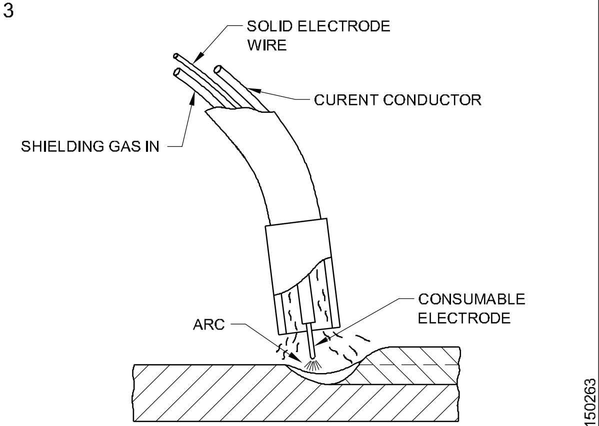
3 They all have parts that will wear out (consumables eg liners, tips, diffuser, nozzle, etc.)

Fig 2



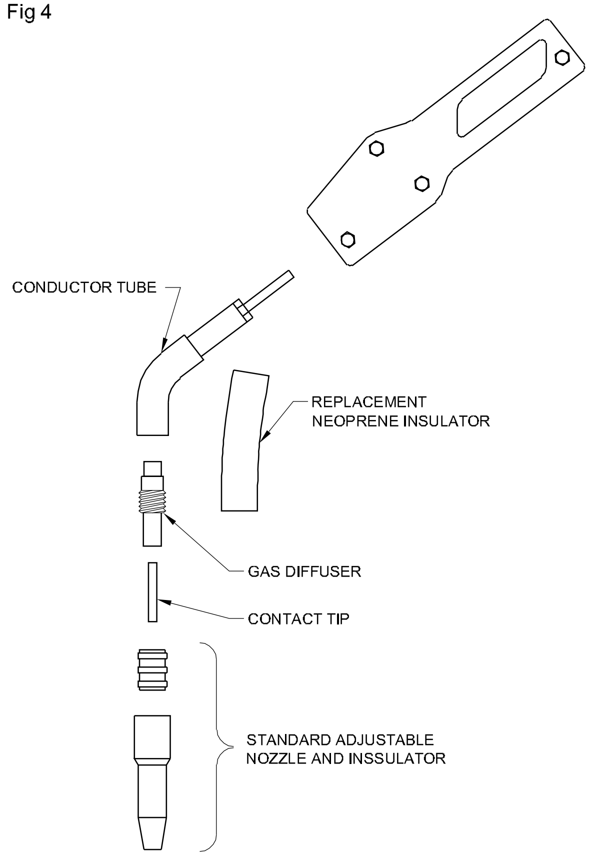
A SCHEMATIC CROSS SECTION OF AN AIR COOLED GAS METAL ARC WELDING TORCH

Fig 3



TORCH ASSEMBLY

Fig 4



WELDING TORCH

Let's take a look at each part (Fig 4)

Liner The liner causes the most problems. First, they have a life span that is approximately one to four rolls of MIG wire depending on the quality of the liner and wire. The life of the liner will also be increased if the operator removes and cleans it by soaking in non-corrosive and a non-toxic solvent. Each wire size needs to have the correct wire size liner. Be aware some liners may fit more than one size of wire.

There are also different materials for different types of wire electrode, eg steel or stainless liners for solid wires and Teflon liner for aluminium.

The liner length is most important. In the field it is very common to find even newly fitted liners that have been cut too short. This results in the wire being able to move around behind the welding tip and leading to bad wire feeding. The liner has to be fitted correctly and different MIG Torch will often have a different way of ending up with a liner that is the correct length.

Don't just take out the old liner and cut the new one to the same length. It could end up with an incorrect result. Please refer to MIG Torch manual.

All MIG Torch should be laid out straight ont he floor before trimming the liner, to prevent the new liner being cut too short. Do not cut the liner if the Torch lead is coiled up.

Gas Diffusers The gas diffuser's job is to make sure that the shielding gas is delivered to the shielding nozzle correctly. It is designed to make the gas come out as straight as possible and equally supplied around inside the gas shield nozzle. Diffusers can be made of different materials, eg copper, brass or fibre. Some diffusers will also be the tip holder.

Contact Tip Holder This is the item which holds the welding tip in place. Again, tip holders can be very different in design and are very often unique to that brand of MIG torch.

Contact Tips The Contact tip/tube is the key to good welding. First of all, it is the way that welding amperage is delivered to the welding wire electrode, often with a very high amperage.

Most contact tips are made of copper alloy, the better the alloy the better the tip will pass current to the wire electrode and the less wear the MIG tip will have; also the less the tip will oxidize.

The size is important. The right size contact tip must be selected contact . If the selected tip size is too large the wire electrode will not make a good contact, leading to poor welding performance.

If a contact tip selected is too small, the wire electrode will feed poorly and may even jam in the contact tip.

Nozzle: Guns are available with a straight or curved nozzle. The curved nozzle provides easy access to intricate joints and difficult-to-weld.

Torch angle

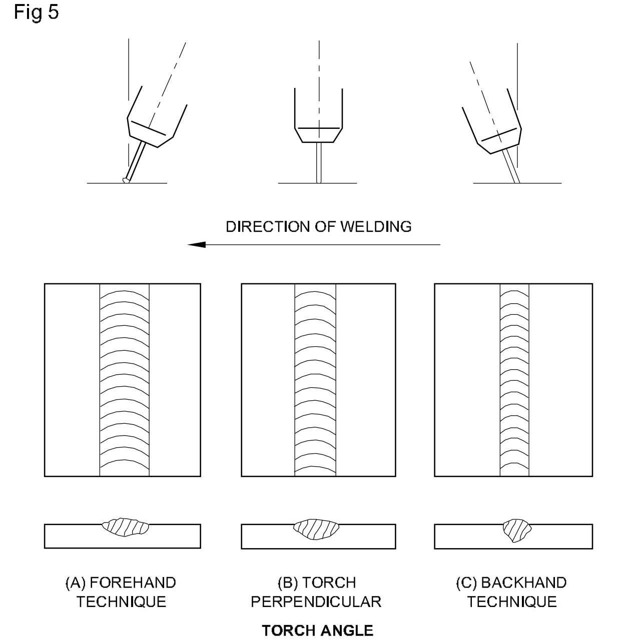
The position of gun and electrode with respect to the joint affects the weld bead shape and penetration rather than arc voltage or travel speed. The gun is usually maintained within 10 - 20º on either side of the vertical. Depending on which way the gun is incline, the technique is referred to as forehead and backhand. The various electrode positions and techniques and their effects are shown in (Fig 5). It is observed that as the electrode is changed from perpendicular to the forehand technique, the weld bead becomes shallower and wider and has less penetration.

Backhand technique gives a more stable arc, less spatter and a narrower, more convex weld bead with deep penetration. Perpendicular technique is used more in automatic welding and avoided in semi-automatic mode because the end of the gas nozzle restricts the operator's view of the weld pool.

Synergic Control

The complexity of setting welding parameters in conventional DC and pulsed GMAW promoted the development of equipment with 'Single-knob' controls known as Synergic control. These systems relied on selection of combinations of present welding (e.g. Wire feed speed/mean current and voltage) by means of a single control.

Fig 5



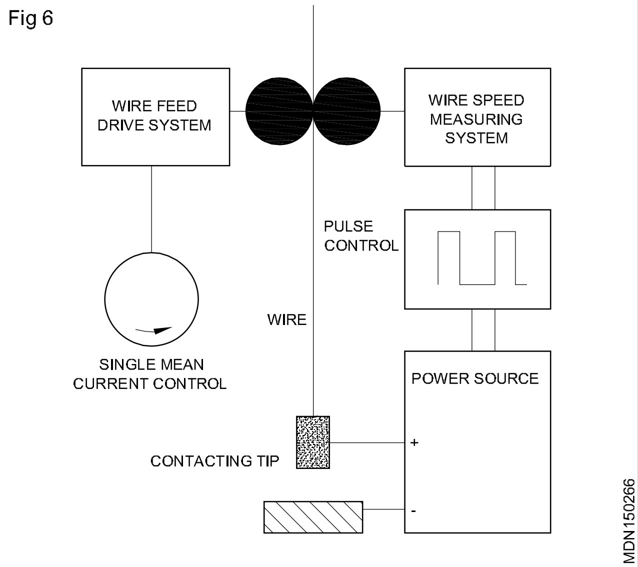
This is possible now because of development of electronic power regulation and micro processor control and programmable equipment which can supply a large number of predetermined welding conditions as well as allowing users to record and retrieve their own customerised parameters.

Although in the pulsed GMAW process the optimum welding parameters can be accurately predetermined, if a change in mean current is required the control settings must be recalculated and a number of the welding parameters reset. This could impose significant practical problems including the possibility of error and resultant deterioration in operating performance. Fortunately it is possible to store both the predetermined parameters and the control equations in the equipment and automatically adjust the output in response to a single input signal. This system is known as Synergic Control (Fig. 6).

Spot welding: This type of resistance welding machine is most commonly used for resistance welding. The material to be joined is placed between two electrodes as shown in (Fig 7a). Pressure is applied after a quick shot of electricity is sent from one electrode through the job to the other electrode.

1 **The frame:** It is the main body of the machine which differs in size and shape for the stationary and portable types.

Fig 6



2 **Force mechanism:** The compressed air cylinder and the pivoted rocker arm gives the necessary high pressure to the lever to which the upper electrode holder is attached.

3 **The electric circuit:** It consists of a step down trans former which provides for the necessary current to flow at the point of weld.

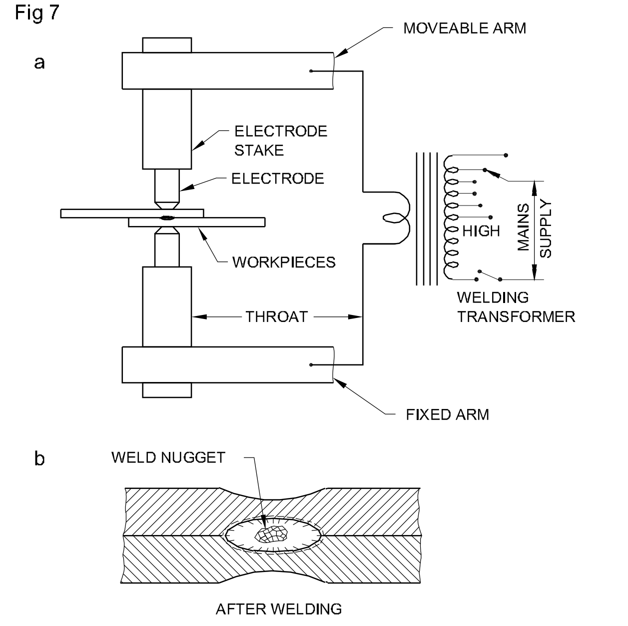
4 **The electrodes:** The electrodes include the mechanism for making and holding contact at the weld area.

5 **The timing controls:** The switches which regulate the value of current, current flow time and contact period time as the timing controls.

6 Water cooling system to circulate cooling water to the electrodes.

This is the additional part consisting of a water reservoir and flow system.

Fig 7



Spot welding is made in three steps.

The first step is when the parts to be joined are clamped between the electrodes. In the second step, a high current is allowed to pass through the clamped members and is raised to the welding temperature. The third step sees the current being cut off and high pressure being applied to the joint and the joint completed. A nugget is formed as shown in (Fig 7b).

A special copper alloy material has been developed for use as electrodes.

Cooling of the electrodes is accomplished by internally circulating water.

Cutting processes - plasma arc cutting

Objectives: At the end of this lesson you shall be able to
- **state the principle of plasma arc cutting**
- **explain the process of variable plasma cutting**
- **state the advantages of plasma cutting.**

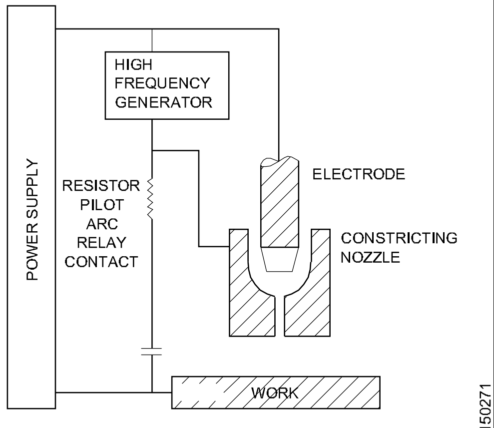
Cutting processes - plasma arc cutting

Plasma arc cutting process, was introduced in the industry in the mid 1950s. The process is used to cut all metals and non-metals. The common oxy-fuel cutting process (based on a chemical process) is suitable for cutting carbon steel and low alloy steel cutting only. Materials such as cpper, aluminium and stainless steels were earlier separated by sawing, drilling or sometimes by power flame cutting. These materials are now cut using a plasma torch, at faster rates and more economically. The Plasma cutting process is basically a thermal cutting process, free of any chemical reaction, that means, without oxidation. In plasma arc cutting an extremely high temperature and high velocity constricted arc is utilized.

Principle of operation

Plasma arc cutting is a process resulting from ionizing a column of gas (argon, nitrogen, helium, air, hydrogen or their mixtures) with extreme heat of an electric arc. The ionized gas along with the arc is forced through a very small nozzle orifice, resulting into a plasma stream of high velocity (speed up to 600 m/sec) and high temperature (up to 20000°K). When this high speed is reached, high temperature plasma stream and electric arc strike the workpiece, and ions in the plasma recombine into gas atoms and liberate a great amount of latent heat. This heat melts the workpiece, vaporizes part of the material and the balance is blasted away in the form of molten metal through the heat (Fig 1).

Fig 1



BASIC PLASMA ARC CUTTING CIRCUITRY

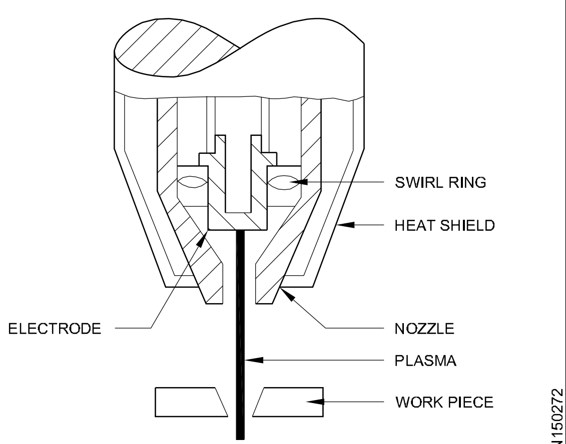
Plasma cutting system (Fig 2,3,4)

Plasma cutting requires a cutting torch, a control unit, a power supply, one or more cutting gases and a supply of clean cooling water (in case water-cooled torch is used).

Equipment is available for both manual and mechanical cutting. A basic plasma arc cutting circuit is shown in Fig 1. It employs direct current straight polarity (DCEN). The nozzle surrounding the electrode is connected to the workpiece (positive) through a current limiting reisitor and a pilot arc relay contact.

The pilot arc between the electrode and nozzle is initiated by a high frequency generator connected between the electrode and nozzle. The orifice gas ionized by the pilot arc is blown through the constricting nozzle orifice and forms a low resistance path to ignite the main transferred arc between the electrode and the workpiece when the ON/OFF switch is closed. The pilot arc relay may be opened automatically when the main arc ignites, to avoid unnecessary heating of the constricting nozzle. The constricting nozzle is of copper and normally water cooled to withstand the high plasma flame temperature (about 20000°K) and to have longer life.

Fig 2

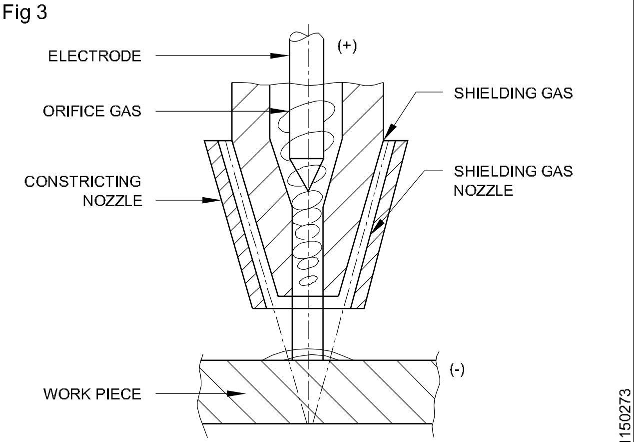


COMPONENTS OF AN AIR-PAC TORCH

In conventional gas plasma cutting, discussed above, the cutting gas can be argon, nitrogen, (argon + hydrogen), or compressed air. For all the cutting gases other than compressed air, the non-consumable electrode material is 2% thoriated tungsten. In air plasma cutting (Fig 2) where dry, clean compressed air is used as the cutting gas, the electrode of hafnium or zirconium. In used because tungsten is rapidly eroded in air. Wet and dirty compressed air reduces the useful life of consumable parts and produces poor quality.

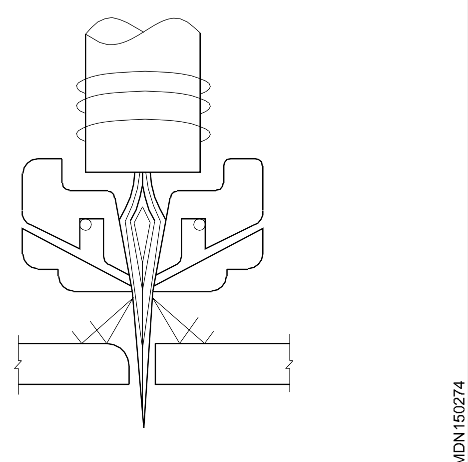
Several process variations are used to improve the cut quality for particular applications. Auxiliary shielding in the form of gas or water is used (Fig 3) to improve the cut quality and to improve the nozzle life. Water injection plasma cutting (Fig 4) uses a symmetrical impinging water jet near the constricting nozzle orifice to further constrict the plasma flame and to increase the nozzle life. Good quality cut with sharp and clear edges with little or no dross is possible in water injection plasma cutting.

Fig 3



DUAL FLOW PLASMA ARC CUTTING

Fig 4



Process variables (Fig 5 & 6)

1 Torch design - constricting nozzle shape and size.

2 Process variation - dual gas flow, water injection, air plasma.

3 Cutting gas type and its flow rate.

4 Distance between nozzle and job.

5 Cutting speed.

6 Plasma cutting current.

7 Power used during cutting.

8 Manual/machine cutting.

9 Material to be cut and its thickness.

10 Quality of cut required - rough or smooth.

11 The bevel angle and round off corner etc.

Advantages of plasma cutting

1 All metals and non-metals can be cut due to the high temperature and high velocity plasma flame.

2 Cuts are of very clear form with little or no dross.

3 High speed piercing is achieved.

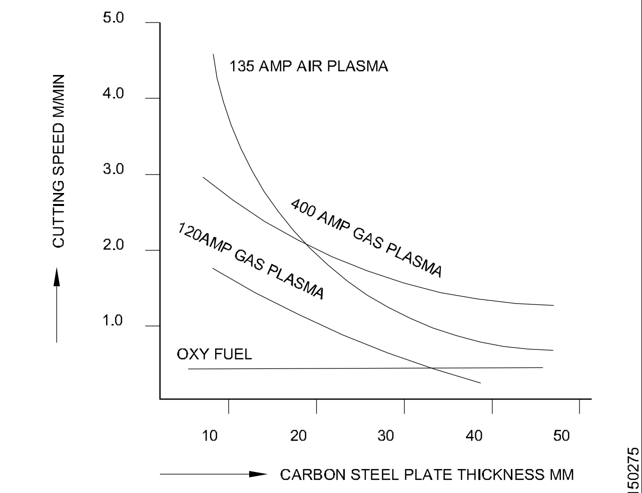
4 Cutting of piled plates is possible, even with different materials.

5 Cutting cost is quite low as compared to other processes, especially for stainless steels.

6 Cutting speed is high.

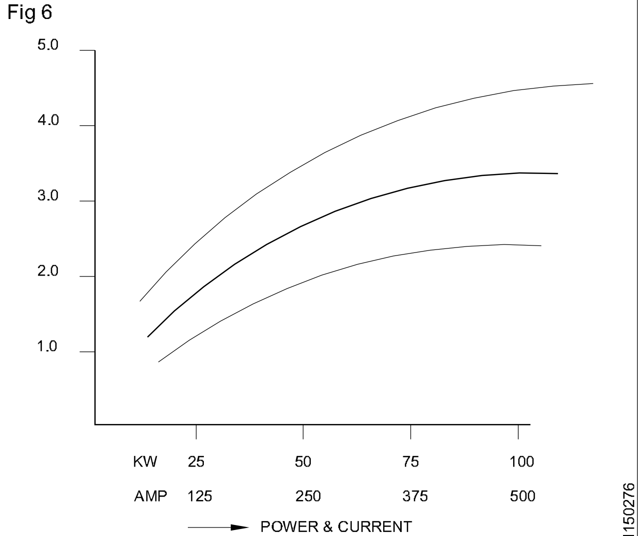
7 Cutting is possible in all positions and locations (underwater also).

Fig 5



COMPARISON OF OXY FUEL AND PLASMA CUTTING PROCESSES

Fig 6



RELATIONSHIP BETWEEN CUTTING SPEED & POWER

Application of plasma cutting

1 Straight and sharp cutting of all metals and non-metals.

2 Cutting of risers and gates for forging and casting.

3 Stack cutting of several sheets of 1.5 to 6 mm thickness.

4 For making holes in thick sheets (by piercing operation).

5 For gouging, rough machining etc.

6 For sizing the scarp.

Safety precautions in plasma cutting

The operator and persons in the vicinity of plasma cutting operation must be protected from:

1 arc radiation and spatter - protect body and eyes

2 metal fumes and gases - use breathing mask, proper ventilation

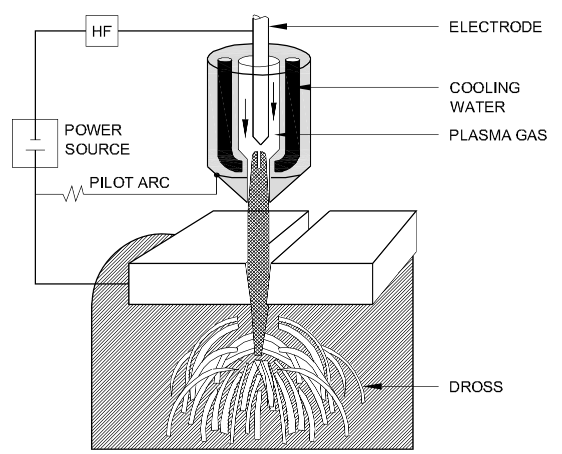
3 noise - up to 115 dB - use ear plugs

4 electrical shocks - high operating voltage (180-400V) and both anode and cathode in torch; input supply is to be switched off before attending to the torch etc.

Gases for Plasma cutting (Fig 7)

- no need to promote oxidation & no preheat
- works by melting and blowing and/or vaporisation
- “gases : air, Ar, N_2, O_2, mix of Ar + H_2, N_2 + H_2
- air plasma promotes oxidation and increased speed but special electrodes need
- shielding gas - optional
- applications : stainless steels, aluminium and thin sheet carbon steel.

Fig 7



GASES FOR PLASMA CUTTING

Heat Treatment

Objectives : At the end of this lesson you shall be able to

- **state the importance of heat treatment**
- **list the stages of heat treatment**
- **state the type of Heat treatment process**
- **explain the process of Annealing, Normalising, Hardening and Tempering**
- **state the importance of case hardening**
- **explain the process of carbursing, Nitriding, Induction hardening and flame hardening.**
- **state the types of heat treatment and surface hardening used for production of automotive components.**

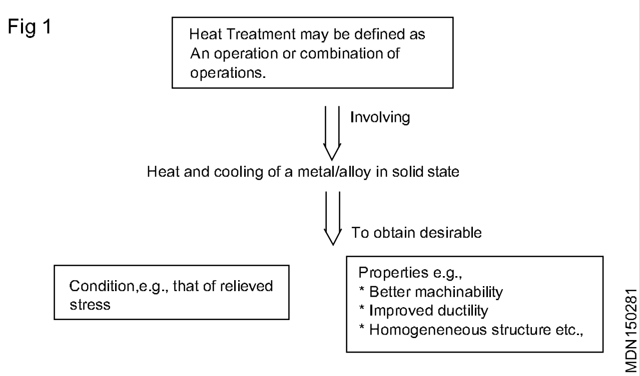
Introduction

The automobile is a typical industrial product that involves a variety of materials and technologies. Beginning with raw metal products leading all the way to final component assembly, various types of heat treatment and surface engineering processes are applied in the manufacture of automotive components.

Heat treatment impart the required strength or hardness properties as dictated by the given component application. Other processes involved in metal processing may include forming, machining as well as quench and tempering, carburizing and hardening and nitriding during production. Surface modification, when properly applied, yields optimum surface properties enhancing corrosion and wear resistance while improving frictional properties.

Definition of Heat Treatment (Fig 1)

Fig 1



Some of the common industrial heat treatment operations are as follows:

a) Annealing

b) Normalising

c) Hardening and Tempering

- Ferrous metals (metals with iron) are annealing, normalizing, hardening, and tempering.
- Nonferrous metals can be annealed, but never tempered, normalized, or case-hardened.

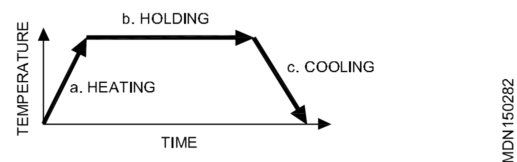
Stages of Heat Treatment (Fig 2)

Stage a : Heating the metal slowly to ensure a uniform temperature.

Stage b : Soaking (Holding) the metal at a given temperature for a given and cooling the metal to room temperature.

State c : Cooling the metal to room temperature.

Fig 2



Annealing

Annealing consists of heating a metal to a specific temperature-based on the carbon content, holding it at that temperature for a set length of time, and then cool it very slowly in the furnace

Full annealing is used to obtain the following properties:

- To relieve the internal stresses and strains developed by various fabrication methods like forgings, castings etc.
- To improving properties of elasticity and ductility
- To reduce hardness

Normalising

Normalising is a type of heat treatment applicable to ferrous metals only. It differs from annealing in that the metal is heated to a higher temperature and then remove from the furnace for air cooling.

Normalising may be employed to

- to remove the internal stresses induced by heat treating, welding, casting, forging, forming, or machining
- Refine the grain and provide homogeneous micro-structure, to improve response to hardening treatment.
- Improve machining characteristics

Hardening

Hardening is a heat treatment process in which steel is heated to an appropriate temperature based on the carbon content of the steel and held at this temperature for sufficient time to allow the steel to obtain a uniform temperature throughout the section. Then the steel is rapidly cooled through a cooling medium. Water, oil, molten salt or air may be used as a cooling medium depending upon the composition of the steel and the hardness required.

Carbon steels are usually quenched in brine or water, and alloy steels are generally quenched in oil.

Purpose of Hardening

- To increases the hardness and strength of the steel,but makes it less ductile

Tempering :

Tempering consists of heating the steel to a specific temperature generally below its hardening temperature, holding it at that temperature for the required length of time, and **then cooling it, usually instill air.**

Purpose Of Tempering

Steels in its hardened condition, it is often harder than necessary, generally too brittle and too severally strained in the quenching operation. The aim of tempering is:

- To relieve the steel from internal stresses and strains.
- To regulate the hardness and toughness
- To decrease the brittleness and to restore some ductility to induce shock resistance.

Tempering immediately after quenching prevents development of such destructive cracks

Case Hardening

Case hardening produces a hard, wear-resistant surface or case over a strong, tough core. The principal forms of casehardening are carburizing, cyaniding, and nit riding. Only ferrous metals are case-hardened.

Importance of Case Hardening

Case hardening is ideal for parts that require a wear-resistant surface and must be tough enough internally to withstand heavy loading. The steels best suited for case hardening are the low-carbon and low-alloy series.. In case hardening, change the surface of the metal chemically by introducing a high carbide or nitride content. The core remains chemically unaffected. When heat-treated, the high-carbon surface responds to hardening, and the core toughens.

While surface hardening by induction hardening and flame hardening does not change the chemical composition of the material techniques like carburizing. Nitriding and carbonitriding change the surface composition.

Carburising

Carburizing is a case-hardening process by which carbon is added to the surface of low-carbon steel. This results in a carburized steel that has a high-carbon surface and a low-carbon interior.

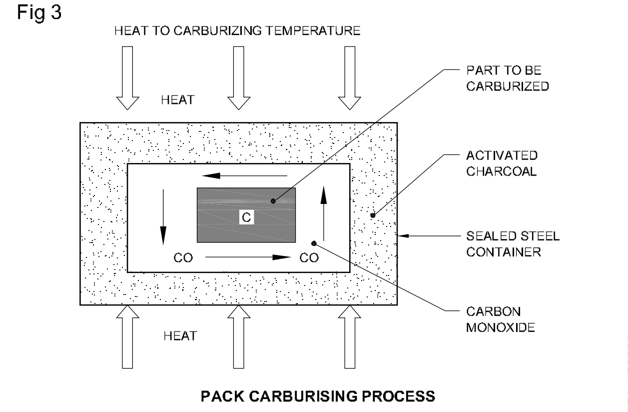
When the carburized steel is heat-treated, the case becomes hardened and the core remains soft and tough.

a) Pack Carburising

Components are placed in a container along with solid carburizing material like charcoal, wood charcoal energized by sodium, potassium and barium carbonate. A lid is fitted to the container made of heat resisting cast iron. The box with the contents is sealed with fire clay and is placed in muffle furnace at 900° - 920° C as shown in (Fig 3) and held for a period of time depending upon the case and held for a period of time depending upon the case depth required (Fig 4).

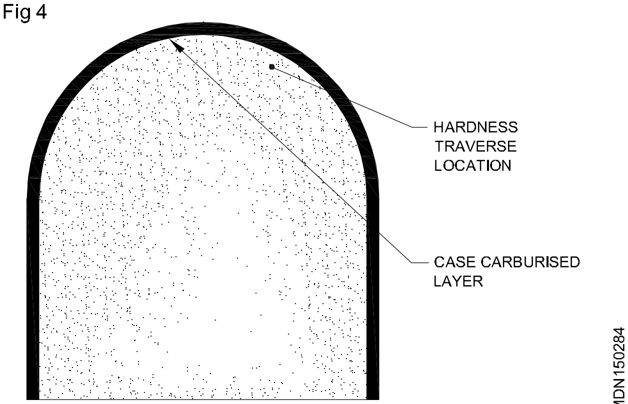
After carburizing the component is hardened by re-heating at 760 - 780° C followed by quenching in water or oil. Thus the case hardening improves surface hardness and the core toughness.

Fig 3



PACK CARBURISING PROCESS

Fig 4



Advantages : It requires no prepared atmosphere and is economical process.

b) Gas Carburising

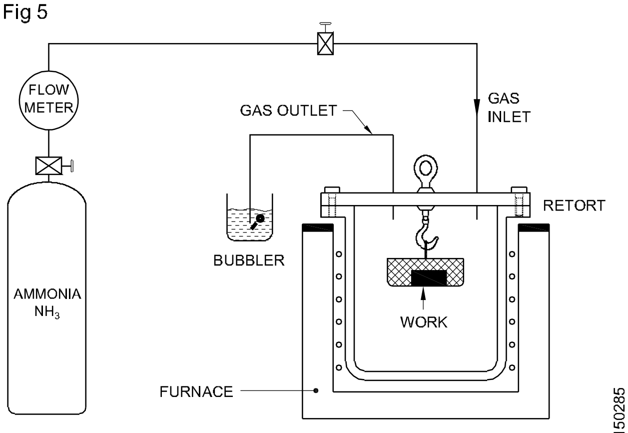
If a suitable carbonaceous furnace atmosphere namely hydro carbon atmosphere or carbon monoxide atmosphere can be provided, the components can be directly loaded in the furnace so as to achieve gas carburizing. The time and temperature can be compared to that of pack carburizing. Hydrocarbon atmosphere decomposes readily at the carburizing temperature at 95^{o}C.

Advantage : It is used to carburise large number of components simultaneously thus saving the heat energy, labour and carburizing compound. Thus it supercedes pack carburizing. It enables quicker handling by direct quenching.

Nitriding (Fig. 5)

Nitriding case-hardening method produces the hardest surface of any of the hardening processes it introduces nitrogen into the surface of steel. Medium carbon steels are generally nitride. It differs from the other methods in that the individual parts have been heat-treated furnace that has an ammonia gas atmosphere as shown in (Fig 5) No quenching is required so there is no worry about warping or other types of distortion. Time of nit riding is long and will be about 70 hours. The case depth is less than 0.5 mm.

Fig 5



NITRIDING PROCESS

This process is used to case harden items, such as gears, cylinder sleeves, camshafts and other engine parts, that need to be wear resistant and operate in high-heat area

Induction Hardening

When high frequency alternating current is passed through the heating coil an electromagnetic field is created around it. It gives rise to eddy currents in the surface of the metal bar centered in the coil.

Thus, the surface of the metal bar gets heated above the critical temperature and subsequently gets hardened during quenching.

This method is employed for very long parts and normally requires a cross sectional area that is uniform along the entire length of the hardened surface.

Flame Hardening

Flame hardening is another procedure that is used to harden the surface of metal parts. When you use an oxy-acetylene flame, a thin layer at the surface of the part is rapidly heated to its critical temperature and then immediately quenched by a combination of a water spray and the cold base metal. This process produces a thin, hardened surface, and at the same time, the internal parts retain their original properties.

Types of Heat Treatment And Surface Hardening Used For Production Of Automotive Components

Types of heat treatment	Typical components
Annealing	Forged blanks for gearing and misc. parts
Normalizing	Reduce hardness for machining
Quench and temper	Fasteners, Rods and Arms
Case hardening : Carburizing	For fatigue and wear resistance Gears and shafts
Induction hardening	Cam shafts, Drive shafts, steering knuckles
Nitriding :	Cam shafts, oil pump gears, valves, Brake pad liner plates, A/T gears