Basic electricity as applied to welding

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

- **define simple electrical terms**
- **differentiate between electric current, pressure and resistance**
- **state AC and DC**
- **explain open circuit and arc voltage**
- **state OHM's law and its application**

Electricity is a kind of invisible energy which is capable of doing work such as:

- burning of lamps
- running of fans, motors, machines etc.
- producing heat.
- by creating an arc
- by electrical resistance of materials

It is dangerous to play with electricity.

Electric current: Electrons in motion is called current. The rate of flow of electrons is measured in amperes (A). The measuring instrument is called ampere meter, or ammeter.

Electric pressure/voltage: It is the pressure which makes the electric current to flow.

It is called voltage or electromotive force (emf). Its measuring unit is volt(V). The measuring instrument is called voltmeter.

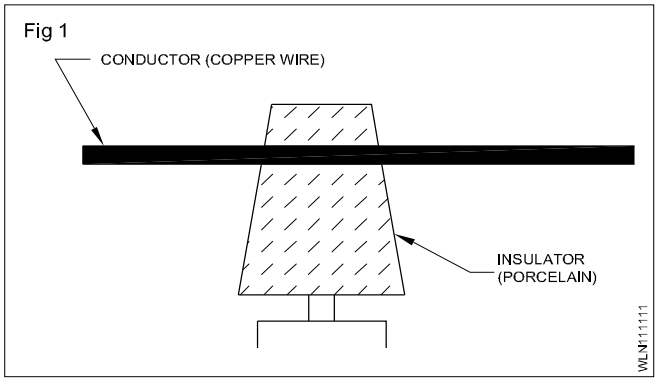
Electric resistance; It is the property of a substance to oppose the flow of electric current passing through it.

Its measuring unit is ohm and the measuring instrument is ohmmeter or megger.

- Resistance of a metal changes as given below:
- If the length is more the resistance will also be more.
- if the diameter is more the resistance will be less.
- the resistance will increase or decrease depending on the nature of the material.

Conductors: Those substances through which electricity passes are called conductors. (Fig 1)

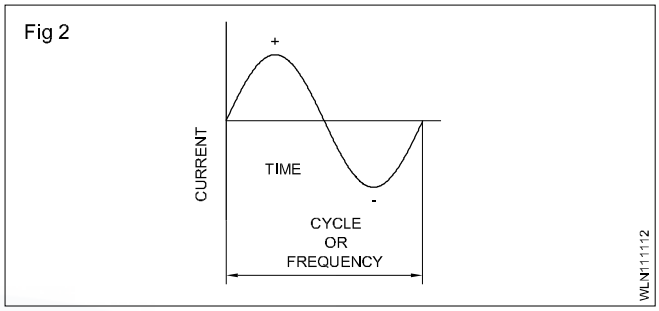
Fig 1



Copper, aluminium, steel, carbon, etc, are examples of conductors. The resistance of these materials is low.

Insulators: Those substances through which electricity does not pass are called insulators. (Fig 1)

Fig 2



Glass, mica, rubber. Bakelite, plastic dry wood, dry cotton, porcelain and varnish are examples of insulators. The resistance of these materials is high.

Electric circuits: It is the path taken by the electric current during its flow. Every electrical circuit comprises current, resistance and voltage.

The fundamental types of circuit are:

- series circuit
- parallel circuit.

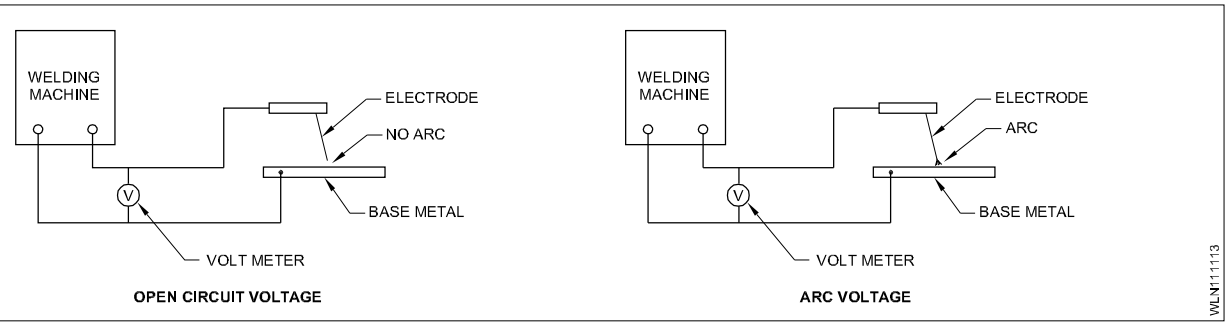
Series circuit: The resistances of a circuit are connected in a series end-to-end making only one path in which the current flows.

Parallel circuit: The resistances are connected side by side to each other with the ends connected to power source.

Alternating current (AC): Electric current which changes its direction of flow and magnitude at a certain number of times per second is called alternating current. E.g. 50 cycles means it changes its direction 50 times per second. Its rate of change is called frequency i.e. hertz (Hz). (Fig.2)

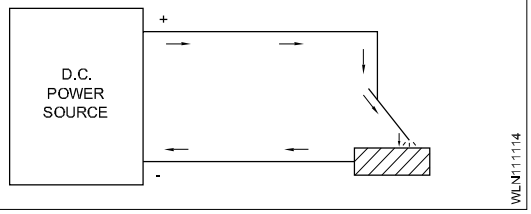
Direct current (DC) (Fig. 4): Electric current which always flows in a particular direction is known as direct current. (i.e) Negative to positive (electronic direction). Positive to negative (conventional direction).

Fig 3



Ohm's law: It is one of the most widely applied laws of electrical science.

Fig 4



It is the relationship of current, voltage and resistance, which was studied in 1827 by George. S.Ohm, a mathematician.

The law states:

In an electrical circuit, at constant temperature, the current varies directly as the voltage, and inversely as the resistance. i.e. current increases when voltage increases.

V=IR

Where V = Voltage

I = Current

R = Resistance

Current decreases when resistance increases.

Application of Ohm's law: The importance of this law lies in its practical use for finding any one value when the other two values are known.

The three forms in which ohm's law may be written are shown below.

$$I = \frac{V}{R} \text{ Where } I = \text{current in amps}$$

$$V = I \times R \text{ Where } V = \text{Voltage in volts}$$

$$R = \frac{V}{R} \text{ Where } R = \text{Resistance ohms}$$

Open circuit voltage and arc voltage: Fig 3 shows an electric circuit used in arc welding. After switching on the welding machine, when there is no arc created/struck between the electrode tip and the base metal then the voltage "V" shown by the voltmeter in the circuit is called "Open circuit voltage".

The value of this open circuit voltage will very from 60V to 110V depending on the type of machine.

After switching on the welding machine, if the arc is struck/ created between the tip of the electrode and the base metal then the voltage "V' shown by the voltmeter in the circuit is called "Arc voltage".

The value of this arc voltage will vary from 18V to 55V depending on the type of machine.

Use of electricity as applied to welding: For fusion welding, the pieces to be joined are to be melted by:

- creating a high temperature (4500°C) arc between the electrode and the work using electric voltage and high current. (All types of arc welding)
- heating the work to red hot condition by using the resistance property of the metal and passig a very high current for a fraction of a second and then applying a very heavy pressure. (All types of resistance welding)
- using highly concentrated electron beam on the joint of the workpiece (Electron beam welding)
- Using the resistance of the slag and the current to flow through the molten slag (Electro slag welding)

In all the above welding processes, the electrical energy is converted to heat energy which is used to either melt the metal fully or heat them to red hot condition and then melted by applying heavy pressure. So electricity is used to a very large extent in many welding processes.

Heat and temperature

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

- **differentiate between heat and temperature**
- **state the units of heat and temperature measurement**
- **differentiate between heat and temperature as applicable to welding**
- **convert centigrade to fahrenheit and vice versa, using tables.**

Heat and temperature: Heat is a form of energy, capable of flowing between two bodies which are at different temperatures. The addition of heat energy to a body increases the kinetic energy of motion of its molecules. Temperature is the degree of hotness or coldness of a body measured, usually in centigrade of Fahrenheit. Temperature is a measure of the intensity of heat.

Example: If we ask, 'how hot is a substance', the answer will be, 'it is so many degrees hot'. i.e. 40°C, 50°C, 150°F etc.

Temperature measurement: there are two basic scales for measuring temperature.

- Centigrade scale
- Fahrenheit scale

In both systems there are two fixed points which indicate:

- the temperature at which ice melts (Water freezes)
- the temperature at which pure water boils at standard pressure.

Temperature is measured by a unit called 'degree'.

Centigrade scale: This is a system for measuring changes in temperature in which the interval of temperature between the freezing and boiling points of pure water at standard pressure is divided into 100 equal parts. There freezing point is made zero of the scale (°0 C) and the boiling point is fixed at 100 degrees (100° C), each division part is called one centigrade degree (°C). Degree centigrade is also called as degree celsius.

Fahrenheit scale: A system for measuring changes in temperature in which the interval of temperature between the freezing and boiling points of pure water at standard pressure is divided into 180 equal parts. The freezing point is made 32 degree of the scale (32°F). The boiling point is fixed at 212 degree (212°F).

Each division part is called one Fahrenheit a degree (°F).

Conversion of temperature from °C to °F

The formula used for temperature conversion is

$$C = (F - 32) \times \frac{5}{9} \text{ and } F = \left[c \times \frac{9}{5} \right] \pm 32$$

To check this, a reading of 100°C may be changed to the Fahrenheit scale by substituting the value of (C) as given below.

$$F = (100\,c \times \frac{9}{5}) \pm 32 = 212^{\circ}$$

A reading of 122°F can be converted to centigrade scale by substituting the value of 122°F given below.

$$c = (122 - 32) \times \frac{5}{9}$$

Application of heat, temperature and their units (terms) in welding

Heat and temperature should not be confused with each other.

The temperature of oxy-acetylene flame is app. 3200°C.

Flames produced by small and large nozzles have the same temperatures but the large nozzle flame gives off more heat than the small nozzle flame. More volume of mixed gases comes out through larger size nozzles and so more heat is produced. Refer the chart given below.

Example

A thin piece of steel sheet 1.5 mm thick can be melted quickly with a small oxy-acetylene flame.

A thicker piece of steel plate (6 mm) will take a longer time to melt with the same oxy-acetylene flame.

Both pieces of steel have the same melting points of 1530°C.

To speed up the melting of the thicker plate, use bigger nozzles which will give a larger flame and more heat in less time.

Refer to the chart given below which gives different nozzle sizes and the corresponding volume of gasses flowing out of them per hour

When the nozzle size increases, the quantity of gas flow per hour (rate of gas flow) increases. So more heat is given out by larger nozzles and less heat by smaller size nozzles.

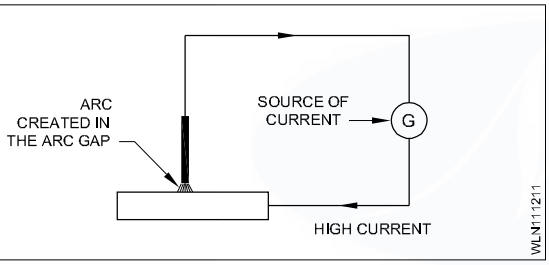
Given below is a chart showing welded plate thickness, nozzle size used and volume of gasses used.

Plate thickness (in mm)	Nozzle size	Approximate consumption of each gas litres per hour
0.8	1	28
1.2	2	56
1.6	3	85
2.0 to 2.5	5	142
3.0 to 3.5	7	200
4.0	10	280
5.0	13	370
6.0 to 6.5	18	510
8.0	25	710
10.0	35	990
12.0	45	1280

Principle of arc welding

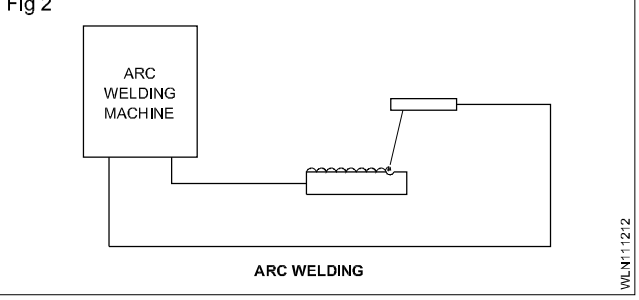
When high current passes through an air gap from one conductor to another, it produces very intense and concentrated heat in the form of a spark. The temperature of this spark (or arc) is app. 3600°C, which can melt and fuse the metal very quickly to produce a homogeneous weld. (Fig 1)

Fig 1



Shielded metal arc welding (Fig 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.

Fig 2

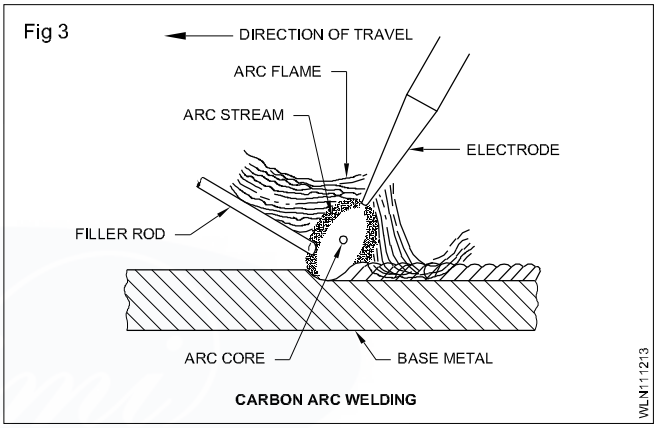


The metal electrode itself melts and acts as a filler metal.

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

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

Fig 3

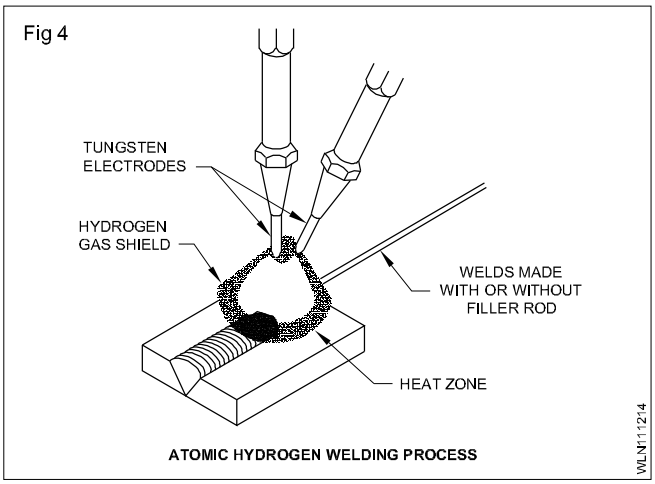


Atomic hydrogen arc welding (Fig 4): In this process the arc is formed between two tungsten electrodes in an atmosphere of hydrogen gas.

The welding job remains out of the welding circuit.

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

Fig 4

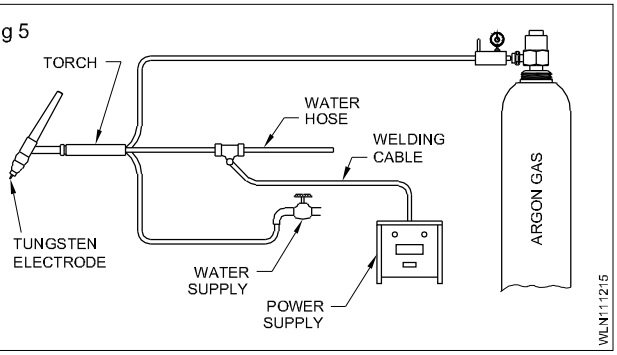


Tungsten inert gas arc welding (TIG) (Fig 5): In this case the arc is formed between the tungsten electrodes (non consumable) and the welding job in an atmosphere of an inert gas (argon or helium).

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

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

Fig 5



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.

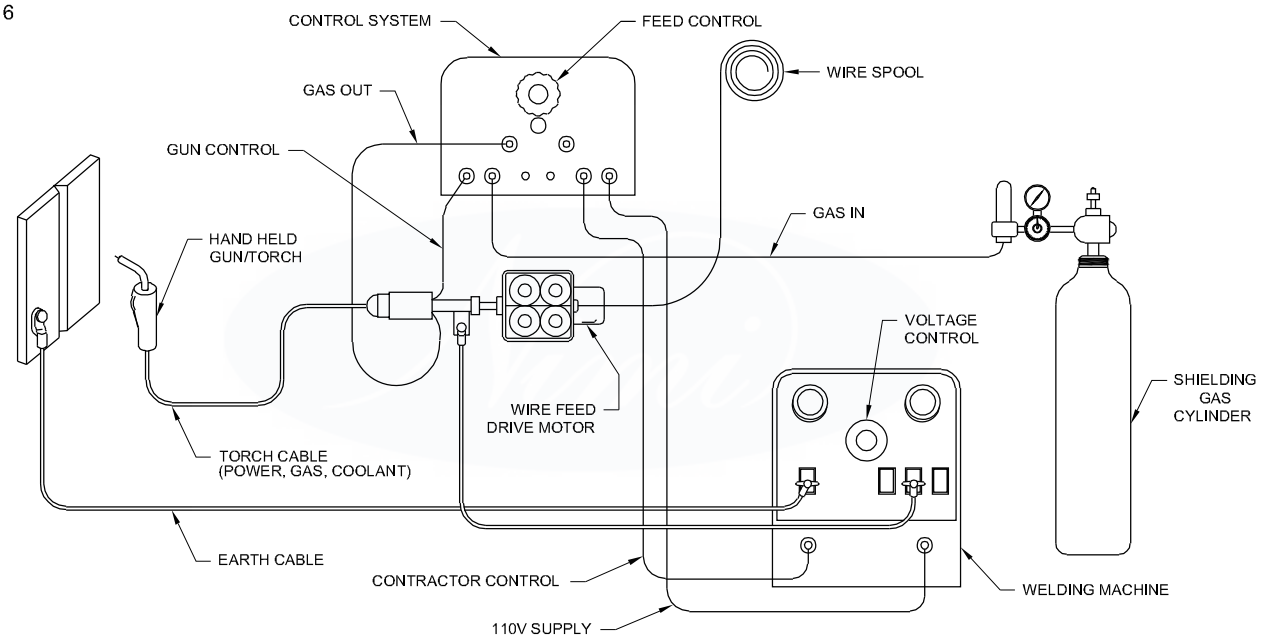
When the inert gas is replaced by carbon dioxide then it is called CO_2 arc welding or metal active gas (MAG) arc welding.

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

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.

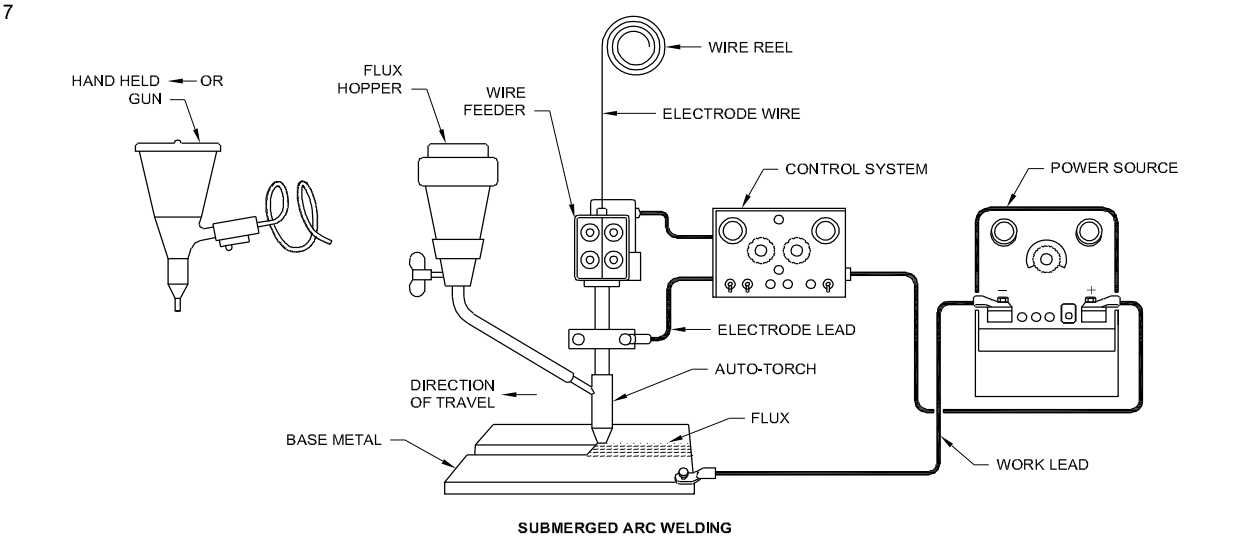
The arc is totally submerged in the flux (invisible).

Fig 6



BLOCK DIAGRAM (GMAW/MIG)

Fig 7

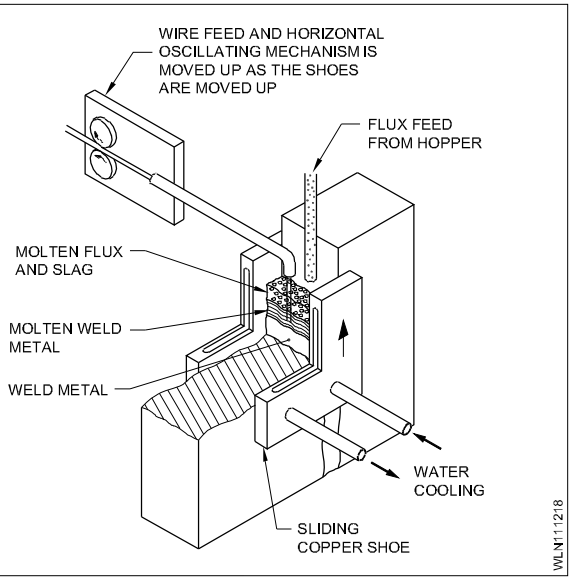


SUBMERGED ARC WELDING

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.

Fig 8



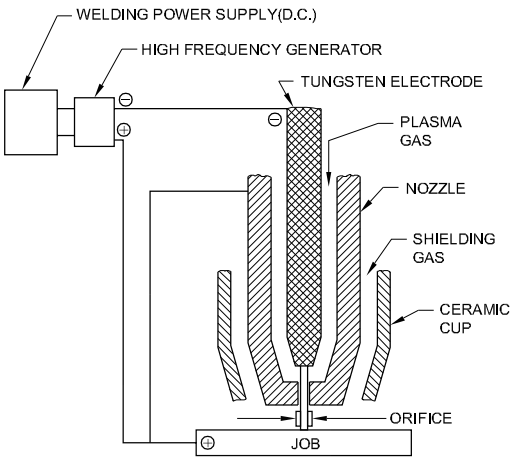
Plasma arc welding (Fig 9): In this process the arc is formed between a tungsten electrode and the welding job in an atmosphere of plasma-forming gas- nitrogen, hydrogen and argon.

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

The process is similar to TIG welding.

Plasma cutting is used to cut non-ferrous metals and alloys successfully and quickly.

Fig 9



PLASMA ARC WELDING SYSTEM