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DEPARTMENT OF ELECTRICAL AND ELECTRONICS

IVth YEAR / VIIIth SEMESTER

EE6801 – ELECTRICAL ENERGY GENERATION, UTILIZATION AND CONSERVATION

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UNIT – 3
HEAT AND WELDING

Electric Heating Introduction:

- Electric heating is any process in which electrical energy is converted to heat.
- Common applications include heating of buildings, cooking, and industrial processes.
- An electric heater is an electrical appliance that converts electrical energy into heat.
- The heating element inside every electric heater is simply an electrical resistor, and works on the principle of Joule heating: an electric current through a resistor converts electrical energy into heat energy.
- Alternatively, a heat pump uses an electric motor to drive a refrigeration cycle, drawing heat from a source such as the ground or outside air and directing it into the space to be warmed.

Definition

- Dielectric heating (also known as electronic heating, RF heating, high-frequency heating) is the process in which radiowave or microwave electromagnetic radiation heats a dielectric material.
- This heating is caused by dipole rotation.

Role electric heating for industrial applications:

- When current is passed through a conductor, the conductor becomes hot.
- When a magnetic material is brought in the vicinity of an alternating magnetic field, heat is produced in the magnetic material.
- Similarly it was found that when an electrically insulating material was subjected to electrical stresses, it too underwent a temperature rise (Dielectric heating).
- There are various method of heating a material but electric heating is considered to be far superior for the following reasons:

(i)Cleanliness:

Due to complete elimination of dust and ash, the charges to maintain cleanliness are minimum and the material to be heated does not get contaminated.

(ii)Ease of control:

With the help of manual or automatic devices, it is possible to control and regulate the temperature of a furnace with great ease.

(iii)Uniform heating:

Whereas in other forms of heating a temperature gradient is set up from the outer surface

(iv) Low attention and maintenance cost:

Electric heating equipments normally do not require much attention and maintenance is also negligible. Hence labour charges on these items are negligibly small as compared to alternative methods of heating.

Requirement of Heating Material:

i) Low Temperature Coefficients of Resistance: Resistance of conducting element varies with the temperature; this variation should be small in case of an element.

Otherwise when switched ON from room temperature to go upto say 1200˚C, the low resistance at initial stage will draw excessively high currents at the same operating voltage.

ii) Resistance coefficient Positive: If temperature is negative the element will draw more current when hot.

A higher current means more voltage, a higher temperature or a still lower resistance, which can instability of operation.

iii) High Melting Point: Its melting point should be sufficiently higher than its operating temperature. Otherwise a small rise in the operating voltage will destroy the element.

iv) High Specific Resistance: The resistivity of the material used for making element should be high. This will require small lengths and shall give convenient size.

v) High Oxidizing Temperature: Its oxidizing temperature should higher than its operating temperature. To have convenient shapes and sizes, the material used should have high ductility and flexibility. It should not be brittle and fragile.

vi) Should with stand Vibration: In most industrial process quite strong vibrations are produced. Some furnaces have to open or rock while hot. The element material should withstand the vibrations while hot and should not break open.

vii) Mechanical Strength: The material used should have sufficient mechanical strength of its own.

CLASSIFICATION OFMETHODS OF ELECTRIC HEATING

- Electrical Heating
  - Power frequency Heating
    - Resistance Heating
      - Direct Resistance Heating
      - Indirect Resistance Heating
    - Arc Heating
      - Direct Arc Heating
      - Indirect Arc Heating
  - High Frequency Heating
    - Dielectric Heating
    - Induction Heating
      - Direct core type Induction Heating
      - Coreless type Induction Heating

i) Power Frequency Method:

Direct resistance heating, indirect resistance heating, direct arc heating, and indirect arc heating.

ii) High Frequency Heating:

Induction heating and dielectric heating.

Resistance Heating:

- This method is based upon the I2R loss. Whenever current is passed through a resistive material
- heat is produced because of I2 R loss.
- There are two methods of resistance heating. They are

a. Direct Resistance Heating

b. Indirect Resistance Heating

Direct Resistance Heating:

- In this method of heating the material or change to be heated is taken as a resistance and current is passed through it.
- The charge may be in the form of powder pieces or liquid. The two electrodes are immersed in the charge and connected to the supply.
- In case of D.C or single phase A.C two electrodes are required but there will be three electrodes in case of three phase supply.
- When metal pieces are to be heated a powder of high resistivity material is sprinkled over the surface of the charge to avoid direct short circuit.
- But it gives uniform heat and high temperature. One of the major applications of the process is salt bath furnaces having an operating temperature between 500˚C to 1400˚C.

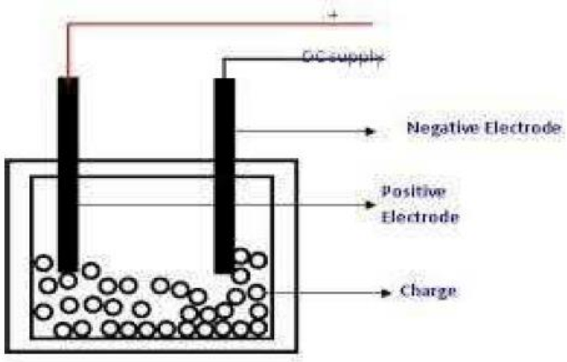
- An immersed electrode type medium temperature salt bath furnace is shown in figure The bath makes use of supply voltage across two electrodes varying between 5 to 20 volts.
- For this purpose a special double wound transformer is required which makes use of 3Φ primary and single phase secondary. This speaks of an unbalanced load.
- The variation in the secondary voltage is done with the help of an off load tapping switch of the primary side. This is necessary for starting and regulating the bath load.

Advantages:

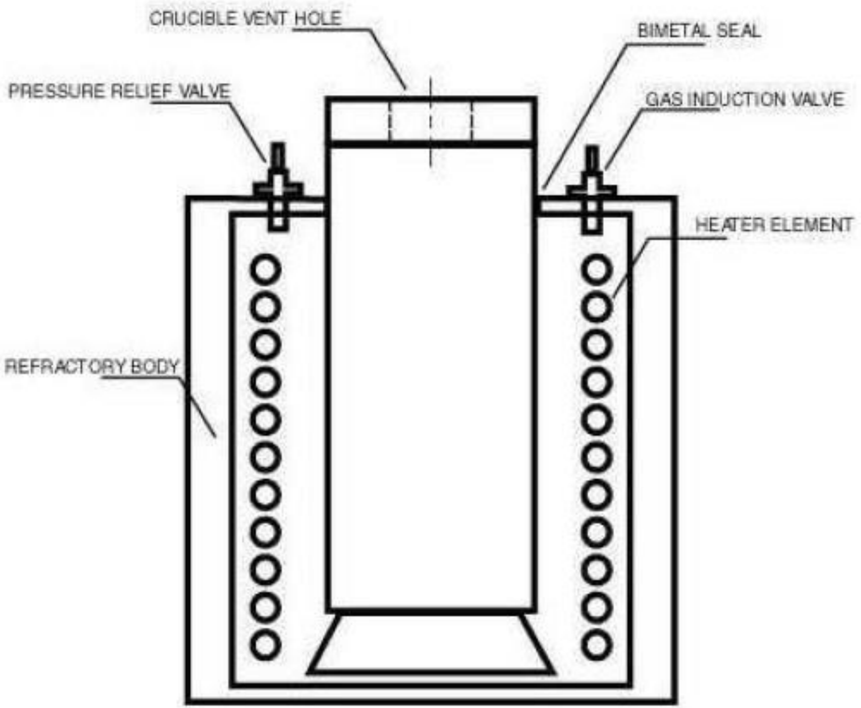
- High efficiency.
- It gives uniform heat and high temperature.

Application:

- It is mainly used in salt bath furnace and water heaters

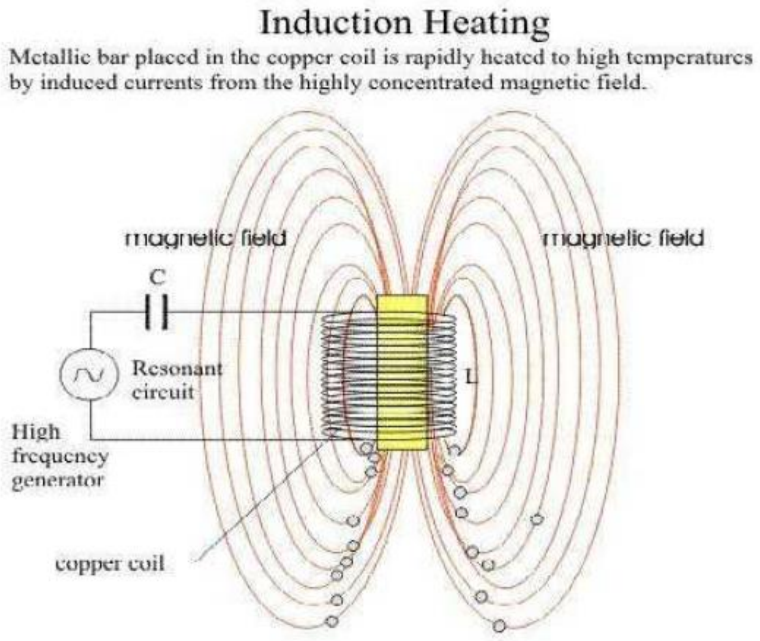


Indirect Resistance Heating:



- In this method the current is passed through a highly resistance element which is either placed
- above or below the over depending upon the nature of the job to be performed.
- The heat proportional to I2R losses produced in heating element delivered to the charge either by
- radiation or by convection.
- Sometimes in case of industrial heating the resistance is placed in a cylinder which is surrounded by the charge placed in the jackes.
- The arrangement provides as uniform temperature.
- Automatic temperature control can be provided in this case
- This method is used in room heater, in bimetallic strip used in starters, immersion water heaters and in various types of resistance ovens used in domestic and commercial cooking.

Induction heating:



- Induction heating processes make use of currents induced by electromagnetic action in the material to be heated.
- Induction heating is based on the principle of transformers.
- There is a primary winding through which an a.c current is passed.
- The coil is magnetically coupled with the metal to be heated which acts as secondary.
- An electric current is induced in this metal when the a.c current is passed through the primary coil.

The following are different types of induction furnaces

1. Core type furnaces

a. Direct core type induction furnace

b. Vertical core type induction furnace

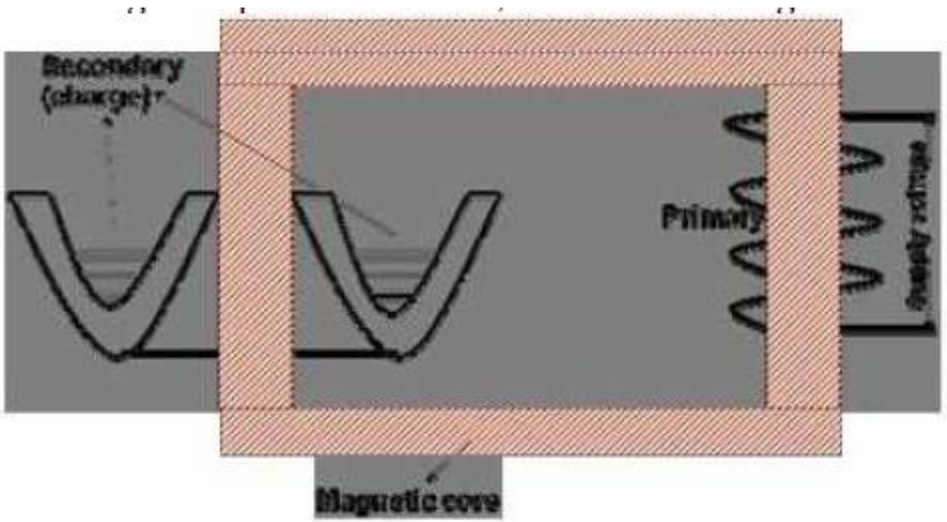
c. Indirect core type induction furnace

2. Core less type furnaces

Direct core type:

- The direct core type induction furnace is shown ion fig.
- It consist of an iron core, crucible and primary winding connected to an a.c supply.
- The charge is kept in the cruicible, which forms a single turn short circuited secondary circuit.

Direct core type:



- The current in the charge is very high in the order of several thousand amperes. The charge is magnetically coupled to the primary winding.
- The change is melted because of high current induced in it. When there is no molten metal, no current will flow in the secondary.
- To start the furnace molten metal is poured in the oven from the previous charge.

This type of furnace has the following drawbacks:

- The magnetic coupling between the primary and secondary is very weak, therefore the leakage reactance is very high. This causes low power factor.
- Low frequency supply is necessary because normal frequency causes turbulence of the charge. If current density exceeds about 5 amps/mm2 the electromagnetic force produced by this current density causes interruption of secondary current.
- Hence the heating of the metal is interrupted. It is called pinch effect. The crucible for the charge id of odd shape and inconvenient from the metallurgical point of view.
- The furnace cannot function if the secondary circuit is open.
- It must be closed. For starting the furnace either molten metal is poured into the crucible or sufficient molten metal is allowed to remain in the crucible from the previous operation.
- Such furnace is not suitable for intermittent services.

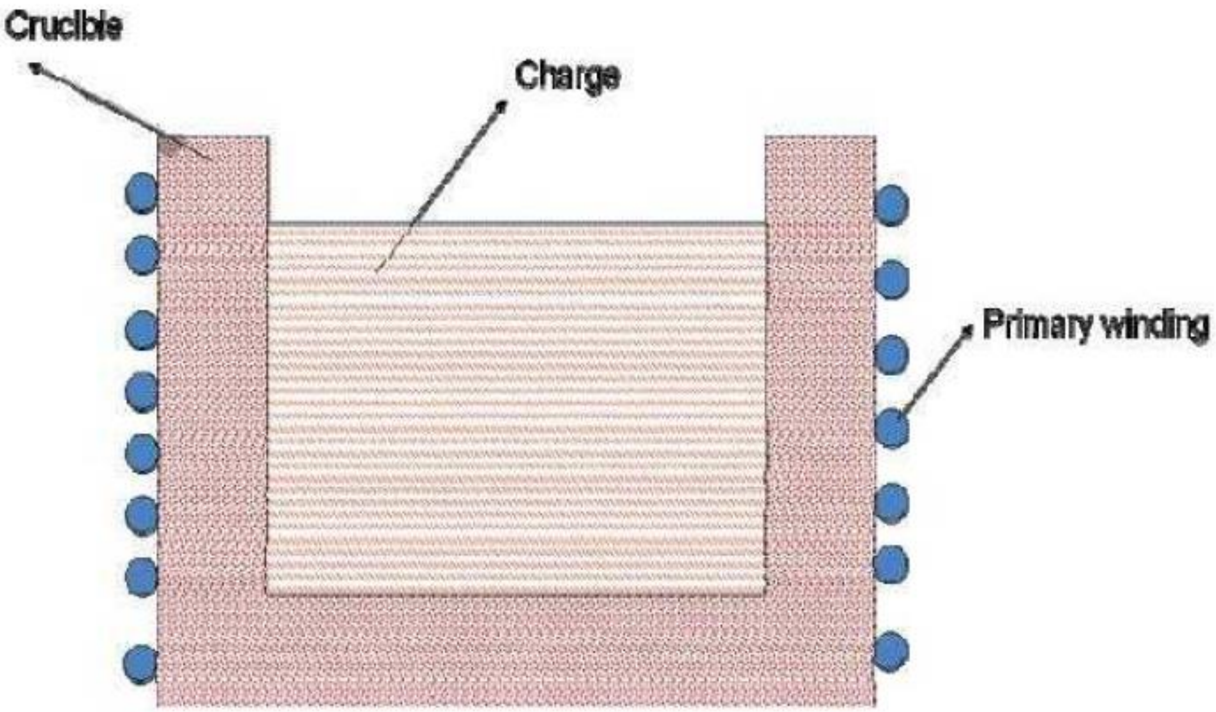
Indirect core type induction furnace:

- In this type of furnace induction principle has been used for heating metals.
- In such furnace an inductively heated element is made to transfer its heat to the change
- When the primary winding is connected to the supply, current is induced in the secondary of the metal container.
- So heat is produced due to induced current. This heat is transmitted to the charge by radiation.
- The portion AB of the magnetic circuit is made up of a special alloy and is kept inside the chamber of the furnace.
- The special alloy will loose its magnetic properties at a particular temperature and the magnetic properties are regained when the alloy will cooled.
- As soon as the furnace attains the critical temperature the reluctance of the magnetic circuit increases many times and the inductive effect correspondingly decreases thereby cutting off the heat supply.
- The bar AB is removable type and can be replaced by other, having different critical temperature.
- Thus the temperature of the furnace can be controlled very effectively.

Coreless induction furnace:

- Coreless induction furnace also operates on the principle of transformer. In this furnace there is no core and thus the flux density will be low.
- Hence for compensating the low flux density, the current supplied to the primary should have sufficiently high frequency.
- The flux set up by the primary winding produces eddy currents in the charge. The heating effect of the eddy currents melts the charge.
- Stirring of the metals takes place by the action of the electromagnetic forces. Coreless furnace may be having conducting or non conducting containers.
- Fig shows a coreless induction furnace in which container is made up of conducting material.
- The container acts as secondary winding and the charge can have either conducting or nonconducting properties.
- Thus the container forms a short circuited single turn secondary. Hence heavy current induced in it and produce heat.
- The flux produced by the primary winding produces eddy currents in the charge. The heating effects of the eddy currents melt the charge.
- Stirring action in the metals takes place by the action of the electromagnetic forces.

Block diagram



Advantages:

- Time taken to reach the melting temperature is less.
- Accurate power control is possible.
- Any shape of crucible can be used.
- The eddy currents in the charge results in automatic stirring.
- Absence of dirt, smoke, noise, etc.
- Erection cost is less.

Applications of Induction Heating

- Induction furnace
- Induction welding
- Induction cooking
- Induction brazing
- Induction sealing
- Heating to fit, Heat treatment

Advantages of Induction Heating

- Optimized Consistency
- Maximized Productivity
- Improved Product Quality
- Extended Fixture Life
- Environmentally Sound
- Reduced Energy Consumption

Dielectric heating:

- Dielectric heating is also sometimes called as high frequency capacitance heating.
- If non metallic materials ie, insulators such as wood, plastics, china clay, glass, ceramics etc are subjected to high voltage A.C current, their temperature will increase in temperature is due to the conversion of dielectric loss into heat.
- The dielectric loss is dependent upon the frequency and high voltage. Therefore for obtaining high heating effect high voltage at high frequency is usually employed.
- The metal to be heated is placed between two sheet type electrodes which forms a capacitor as shown in fig. The equivalent circuit and vector diagram is also shown in fig.
- When A.C supply is connected across the two electrodes, the current drawn by it is leading the voltage exactly 90˚.
- The angle between voltage and current is slightly less than 90˚
- But at high frequencies, the loss becomes large, which is sufficient to heat the dielectric.

Advantages:

- Uniform heating is obtained.
- Running cost is low.
- Non conducting materials are heated within a short period.
- Easy heat control.

Applications:

- For food processing.
- For wood processing.
- For drying purpose in textile industry.
- For electronic sewing.

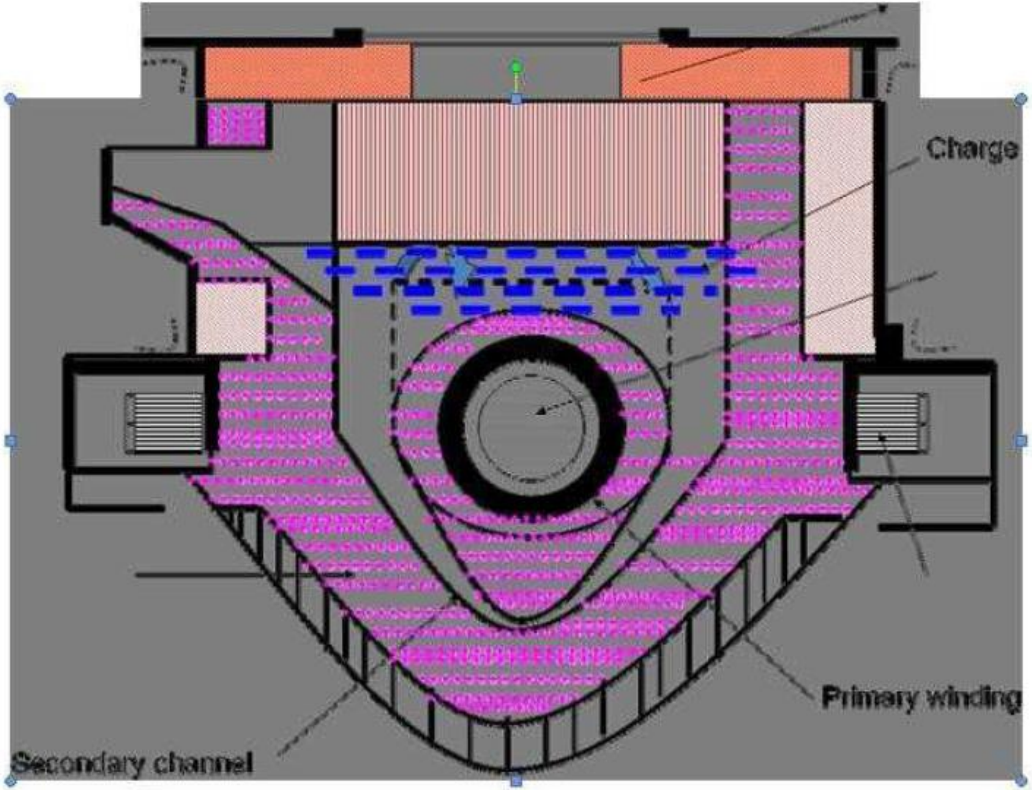
Electric arc furnaces:

AJAX WYATT Vertical core type furnace:

The principle of operation is that of a transformer in which the secondary turns are replaced by a closed loop of molten metal.

The primary winding is placed on the central limb of the core.

Hence leakage reactance is comparatively low and power factor is high. Inside of the furnace is lined with refractory depending upon the charge.



Electric Furnace

- The top of the furnace is covered with an insulated cover which can be removed for charging.
- Necessary arrangements are usually made for titling the furnace to take out the molten metal.
- The molten metal in the ‘V’ portion acts as a short circuited secondary. When primary is connected to the a.c supply, high current will be accumulated at the bottom and even a small amount of charge will keep the secondary completed.
- Hence a chance of discontinuity of the circuit is less.

Advantages:

- High efficiency and low operating cost.
- Since both primary and secondary are on the same central core, its power factor is better.
- The furnace is operated from the normal supply frequency.
- Chances of discontinuity of the secondary circuit is less, hence it is useful for intermittent operations.

Applications:

- This furnace is used for melting non ferrous metals like brass, zinc, tin, bronze, copper etc.

Introduction to electric welding:

- ❖ Welding is the process of joining two similar metals by heating.
- ❖ The metal parts are heated to melting point. In some cases the pieces of metal to be joined are heated to plastic stage and are fused together.
- ❖ The electric welding sets may be either dc or ac type.
- ❖ DC welding sets are of two types namely generator type welding set consisting of a differential compound wound dc generator, giving drooping volt-ampere characteristic, driven by any type of prime-mover (a squirrel cage induction motor or a petrol or diesel engine) and dry type rectifier (selenium rectifier) used in conjunction with a multiphase high leakage transformer.
- ❖ IN generator type welding sets the control may be obtained by
- ❖ tapping the series field or by providing a suitable shunt across the series field winding.
- ❖ In the rectifier type set dc voltage is controlled by regulating the transformer output. If supply from existing dc distribution system is to be used for welding then ballast (resistance) is put in series with the equipment and the control is affected by varying this external series resistance.
- ❖ In electric welding process, electric current is used to produce large heat, required for joining two metal pieces. There are two methods by which electric welding can be carried out. These are

a) Resistance welding and

b) Arc welding.

Types of electric welding:

1. Resistance welding

a) Seam welding

b) Projection welding

c) Flash welding

2. Arc welding

a) Carbon arc welding

b) Metal arc welding

c) Atomic hydrogen arc welding

d) Inert gas metal arc welding

e) Submerged arc welding.

Resistance welding:

- In resistance welding heavy current is passed through the metal pieces to be welded. Heat will be
- developed by the resistance of the work piece to the flow of current.
- The heat produced for welding is given by

H=I2Rt

Where,

H= Heat developed at the contact area.

I= Current in amperes.

R= Resistance in ohms.

t= time of flow of current.

Butt welding:

- In this process heat is generated by the contact resistance between two components.
- In this type of welding the metal parts to be joined end to end. Sufficient pressure is applied along the axial direction.
- A heavy current is passed from the welding transformer which creates the necessary heat at the
- joint due to high resistance of the contact area.
- Due to the pressure applied, the molten metal forced to produce a bulged joint.
- This method is suitable for welding pipes, wires and rods.

ii) Spot welding:

- Spot welding is usually employed for joining or fabricating sheet metal structure. This type of joint only provides mechanical strength and is not air or water tight.
- The plates to be welded are placed overlapping each other between two electrodes, sufficient mechanical pressure is applied through the electrodes.
- The welding current flows through electrodes tips producing a spot weld. The welding current and period of current flow depend on the thickness of the plates.

iii) Arc welding:

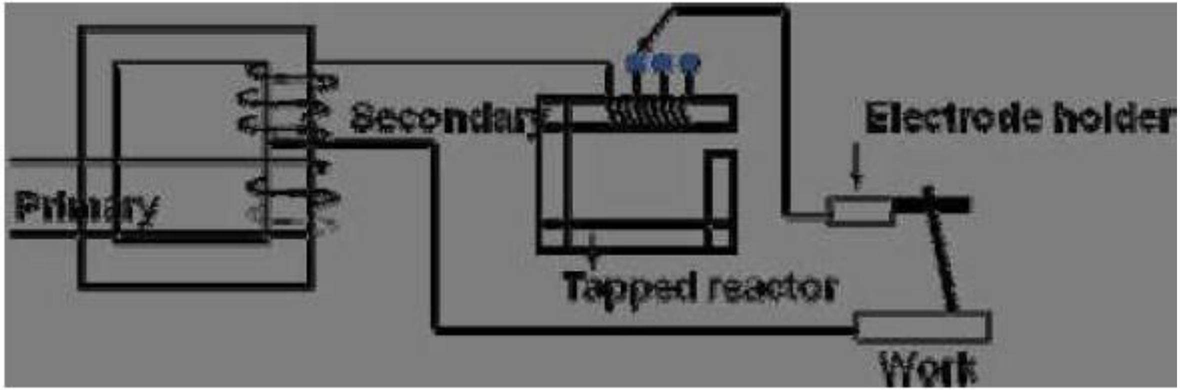
- An electric arc is the flow of electric current through gases.
- An electric arc is struck by short circuiting two electrodes and then with drawing them apart by small distance.
- The current continue to flow across the small gap and give intense heat.
- The heat developed by the arc is also used for cutting of metal.
- The electrode is made of carbon or graphite and is to be kept negative with respect of work. The work piece is connected to positive wir. Flux and filler are also used.
- Filler is made up of similar metal as that of metal to be welded.
- If the electrode is made positive then the carbon contents may flow into the weld and cause brittleness.
- The heat from the arc forms a molten pool and the extra metal required to make the weld is
- supplied by the filler rod. This type of welding is used for welding copper and its alloy.

iv)Metal arc welding:

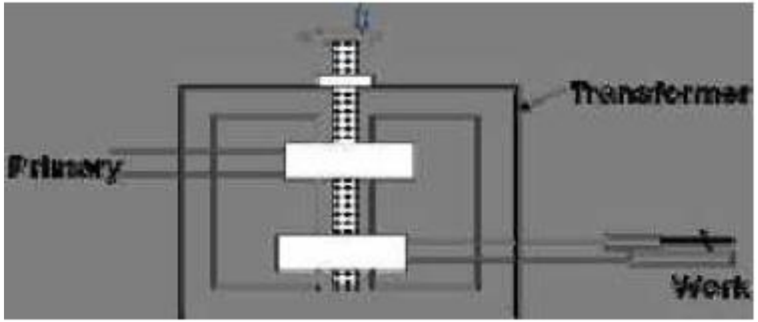
- In metal arc welding a metal rod of same material as being welded is used as an electrode.
- The electrode also serves the purpose of filler. For metal arc welding A.C or D.C can be used.
- Electric supply is connected between electrode and work piece.
- The work piece is then suddenly touched by the electrode and then separated from it a little.
- This results in an arc between the job and the electrode.
- A little portion of the work and the tip of the electrode melts due to the heat generated by the arc.
- When the electrode is removed the metal cools and solidifies giving a strong welded joint.

WELDING GENERATOR - A.C SUPPLY

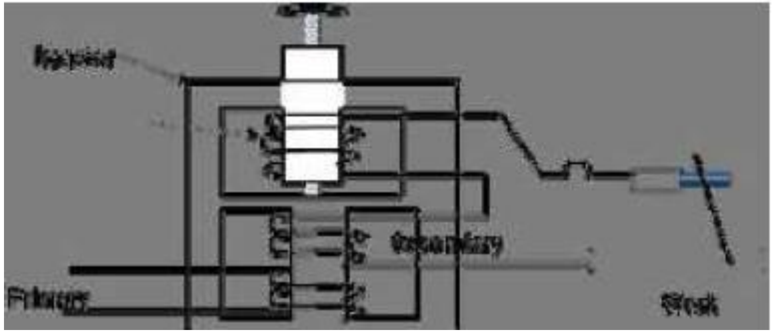
In tapped reactor method, output current is regulated by taps on the reactor. This has limited number of current settings.



In the moving coil method of current control, relative distance between primary and secondary windings is changed. When coils are more separated out current is less.



In magnetic shunt method, position of central magnetic shunt can be adjusted.
This changes the magnitude of shunt flux and therefore, output current.
When central core is more inside, load current will be less and vice versa.
In **continuously variable reactor method**, output current is controlled by varying the height of the reactor.
Greater the core insertion, greater the reactance and less the output current. Reverse is true for less height of core insertion

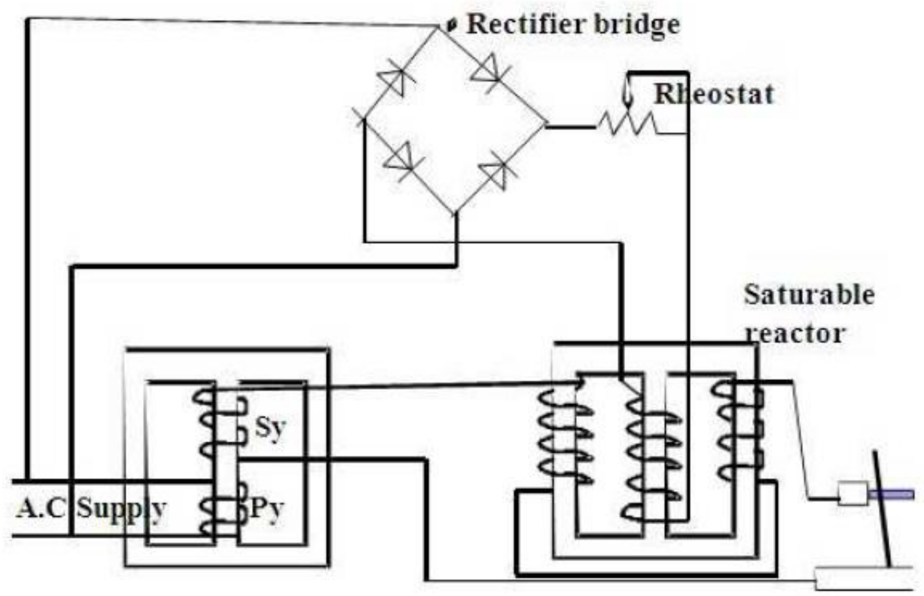


- **In saturable reactor method,** the reactance of the reactor is adjusted by changing the value of d.c excitation obtained from bridge rectifiers by means of rheostat.
- When d.c current in the central winding of reactor is more, reactor approaches magnetic saturation.
- This means the reactance of reactor becomes less. Vice versa happens on the
- A welding transformer is a step down transformer that reduces the voltage from the source voltage to a lower voltage that is suitable for welding, usually between 15 and 45 volts.
- The secondary current is quite high. 200 to 600 amps would be typical, but it could be much higher.
- The secondary may have several taps for adjusting the secondary voltage to control the welding current.
- The taps are typically connected to a several high-current plug receptacles or to a highcurrent switch.
- For welding with direct current (DC) a rectifier is connected to the secondary of the transformer.
- There may also be a filter choke (inductor) to smooth the DC current.
- The entire transformer and rectifier assembly may be called a transformer or welder, but "welding power supply" would be more appropriate term.

WELDING TRANSFORMER:

The impedance of a welding transformer may be higher that the impedance of a transformer designed for some other purpose.

The transformer impedance may play a role in the process of establishing an arc and controlling the current.



Special Features:

- ❖ Stepless current control within single range from front panel.
- ❖ For its high permitted load, its ideal for ferromatic welding
- ❖ Phase compensation facility optional. It’s a good investment as the primary current
- ❖ and rated output can be reduced, resulting in reduced fuse size and cable diameter
- ❖ Provided with wheels and handle for easy mobility
- ❖ Sturdy design for all working environments
- ❖ Horizontal shunt core travel ensures precise setting after prolonged use
- ❖ Class 'H' insulation provides longer coil life
- ❖ Multi voltage input supply

Problems

Problem 1

Calculate the value of extraterrestrial radiation for the day given below. (i) For December 21,1995 and (ii) For June 22, 1996.

Solution:

(i) For December 21, 1995

Day Number (n) = 355

$$I_{ext} = I_{SC}\left(1 + 0.033\cos\left(\frac{360n}{365}\right)\right)$$

$= 1411\ W/m^2$

(ii) For June 22,1996

Year 1996–Leap year

DayNumber (n) = 174

With similar calculation

$= 1322\ W/m^2$

Problem 2

Calculate the hour angle at sunrise and sunset on June 21 and December 21 for a surface inclined at an angle of 10o and facing due south. The surface is located in mumbai (19o 07 ' , 72o 51 ' E).

Given:

Case (i) For June 21, Number of days (n) = 173.

Case (ii) For Dec 21, Number of days (n) = 355.

For due south γ = 0°.

Latitude angle (φ) = 19.07°

Inclination Angle (β) = 10°

Solution:

$$Declination\ angle\ (\delta) = 23.45 \sin\left(\frac{360}{365}\ (284 + n)\right)$$

$$Declination\ angle\ (\delta) = 23.45 \sin\left(\frac{360}{365}\right)(284 + 173) = 23.45°$$

$$= 23.45 \sin\left(\frac{360}{365}\ (284 + n)\right)$$

Sunset or Sun rise time,

$$\omega_{st} = \text{Min}\left\{ \left|\cos^{-1}(-\tan\phi\tan\delta)\right|, \left|\cos^{-1}\{-\tan(\phi-\beta)\tan\delta\}\right| \right\}$$

$$= \text{Min}\left\{ \cos^{-1}(-\tan 19.07^o \tan 23.45),\ \cos^{-1}(-\tan[19.07^o - 10^o]\tan 23.45^o \right\}$$

$$= \text{Min}\ [98.6^o, 94.0^o]$$

$$= 94.0^o$$

$$\omega_{st} = \pm 94.0^o$$

Case (ii)

$$\text{Declination angle } (\delta) = 23.45 \sin\left[\frac{360}{365}(284+n)\right]$$

$$= 23.45 \sin\left(\frac{360}{365}(284 + 355)\right) = -23.45^\circ$$

With similar calculation, $\omega_{st} = \pm 81.4^\circ$

Problem 3

Determine the Local Apparent Time (LAT) corresponding to 1430h (IST) at Mumbai (19° 07' N, 72° 51' E) on July 1. In India standard time is based on 2.50° E.

Given:

Std. Time = 1430 *h*

Std. Time Longitude = 82.50°

Longitude of Location = 72.51° Day :

July 1

Solution:

For July 1, Number of days = 182

Equation of Time correction = 229.18 (0.000075+ 0.001868 cos B - 0.032077 sin B – 0.014615 cos 2B – 0.04089 sin 2 B)

$$\text{Where, } B = (n-1)\frac{360}{365} = 181 \times \frac{360}{365} = 178.5 \approx 179$$

Equation of Time correction = 229.18 [0.000075 + –8.90 × 10^{-4} – 0.02815 + 7.896 × 10^{-3}

= –2.9 minutes.

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Local Apparent Time = Std. Time $\pm$ 4 (Std. Time Longitude - Longitude of Location)

+ Equation of Time correction

$$= 1430h - 4(82.50 - 72.85) \text{ Minutes} + (-2.9) \text{ Minutes}$$

$$= 1430\ h - 38.6\text{minutes} - 2.9 \text{ minutes}$$

$$= 1348h$$