GOVERNMENT POLYTECHNIC DHENKANAL

UTILIZATION OF ELECTRICAL ENERGY AND TRACTION

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ELECTROLYTIC PROCESS CHAPTER - 1

Electrolysis

* Definition and basic principle of Electrodeposition?

(2M) Electrodeposition is the process of coating a thin layer of one metal to the different metal.

Electrolyte- It is a substance which get dissolved in to ions when electric current flow through it.

Electrolytic Process:- The process of deposition of electrolyte by passes of electric current is called electrolytic process.

Electro deposition:-

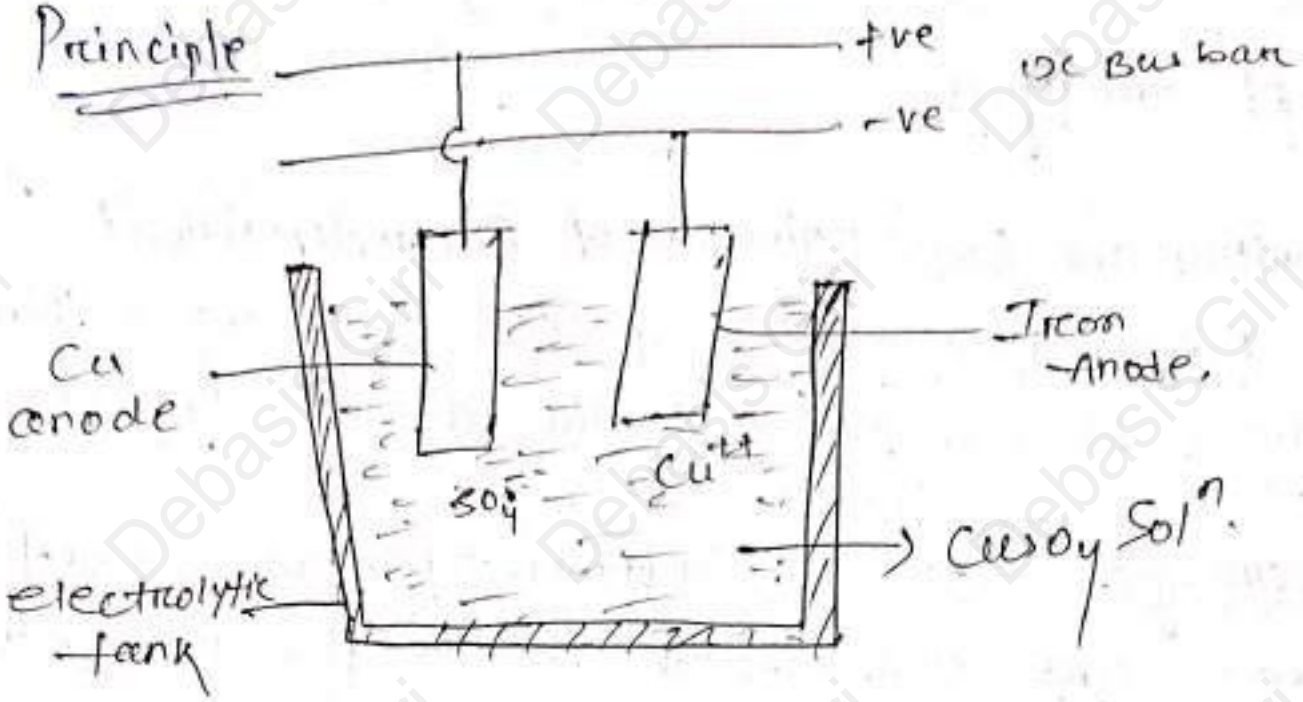
The process of deposition of metal over the surface of another metal by the process of electrolysis is called electro deposition or Electroplating.

Need of electroplating:-

-> To protect the metal against corrosion.
-> It is use to shining a metal.
-> To repair a damage casting.

2

Principle



→ Here two electrodes are taken and are deeped in an electrolyte and DC supply is applied to the electrodes. So the electrolyte will get dissolved into ions called anions and Cations.

→ Consider the case of iron ring to be plated with copper. In this case the electrolyte is taken as copper sulphate ($CuSO_4$). which will get dissolved into Cu^{++} and SO_4^{--}.

→ The iron ring which is to be plated is taken as cathode and the Cu metal is placed at the anode.

→ The dissolved SO_4^{--} ions will move towards the anode which have a surplus of two number of electrons. Each SO_4^{--} ion will donate the two no of extra electron to anode and become SO$_4$ radical.

→ The SO_4 radicals will attract the Cu anode to form $CuSO_4$ molecule. which again dissolves in water to maintain the electrolyte concentration.

→ The positive Cu^{++} ion will moves towards cathode and recieves two no of electrons from the supply to form 'Cu' atom. These 'Cu' atom get deposited at the cathode.

→ The Cu deposited at the cathode surface is practically having the same mass as loses by the anode. In maintaining the electrolysis strength.

→ These phenomenon of deposition of a metalic coating on the surface of other metal through the process of electrolysis is called electro deposition or electroplating.

TERMS REGARDING ELECTROLYSIS -

① **Electrolyte**-

The soln of salt when used in the process of electrolysis is called an electrolyte.

② **Electrodes** :-

The rods we must in an electrolyte and connected to DC supply is called electrodes.

3) ANODE :-

The +ve electrode are anode.

4) Cathode :-

-ve electrode are Cathode.

5) ~~Anaion~~ Anions / cations :-

When DC current is passed through an electrolyte it can dissolve into +ve ions and -ve ions.

The positively charged ions are called cations and negatively charged ions are called Anions.

⑥ Atomic Weight -

It is the ratio of an atom and of the element to the weight of an atom Hydrogen.

→ It is also defined as weight of all the isotopes present in that atom.

⑦ Valency :-

→ It is the no. of hydrogen atom with which the atom will react chemically.

(8) CHEMICAL EQUIVALENT WEIGHT (CEW):-

It is defined as the ratio of atomic weight to valency of the substance.

(9) CHEMICAL EQUIVALENT (ECE):-

It is the amount of substance deposited at the cathode on passing a steady electric current of 1A for 1 sec through it soln.

ELECTROLYTIC Process -

The process in which a chemical soln is decompose and deposited in cathode and anode terminals when current pass through it.

~~Terms relating to electrolysis~~

(1) ~~Electrolyte~~ -

~~The soln of salt when used in the~~

→ The terminal in which we connect anode ⊕ is +ve terminal and we connect the cathode in -ve terminal.

→ When we pass a current through the chemical soln, the soln decompose in to +ve & -ve

ions these ions are known as 'electrolytes'.

→ When the +ve ions are deposited in the cathode terminal these are known as 'Cation'.

→ When the -ve charge ions are deposited in anode terminal these are known as 'Anaion'.

FARADAY'S LAW OF ELECTROLYSIS

1st Law

It State that the weight of a substance liberated from an electrolyte in given time is proportional to the total quantity of electricity passed in that time.

* That is if 'W' is the weight of the substance liberated in grams, then.

$$W \propto Q$$

where 'Q' is the total quantity of charge passes through that electrolyte in that particular time.

We know that,

$$Q = It$$

$W \propto It$ ∴ where 'z' is a constant and 'z' is called as Electrochemical equivalent of the substance

$$\Rightarrow W = ZIt$$

And the value of 'z' depends upon the nature of the substance.

Electrochemical Equivalent (z)-

It is the amount of substance which is liberated in a unit time by the process of unit current.

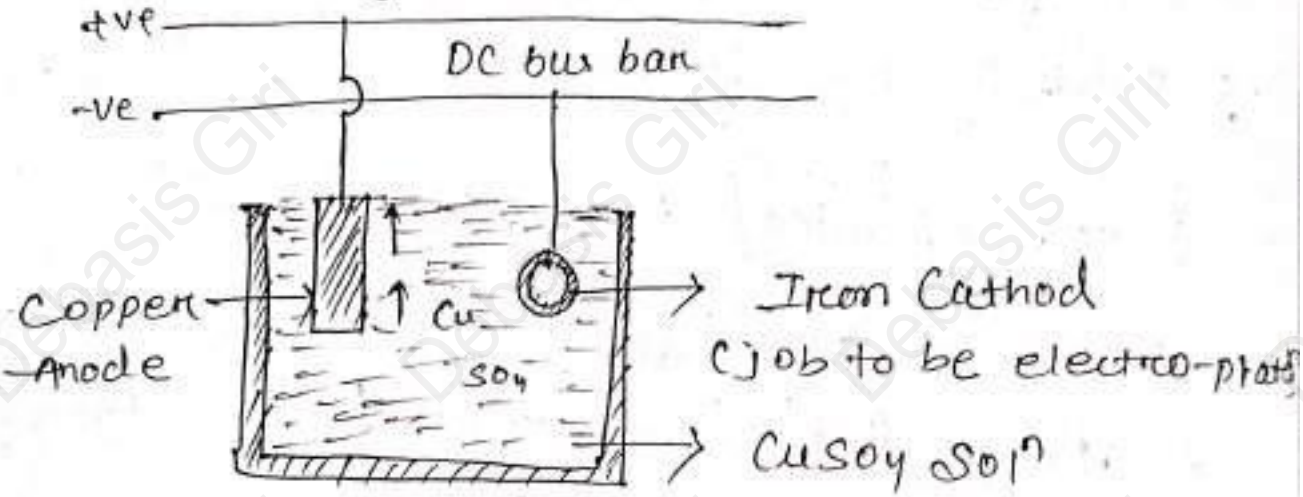
$$Z = W\ mg/c \quad (\text{Miligram/coulomb}).$$

2nd Law

It state that if in the same current flows for a given time through several electrolyte, then the weight of substance liberated and proportional to their chemical equivalent of those substances.

Electroplating -

→ Electroplating is the process of depositing a metal on the surface of same other metal by the process of electrolysis is called as electroplating.



Current efficiency

→ Due to impurity which cause secondary reaction the quantity of a substant liberated is less than that calculated from Faraday's Laws. Current efficiency is equal to actual quantity of substance liberated desired by the substance calculated from ~~End~~ Faraday's Law.

→ It's value lies between 90% to 98%.

Energy efficiency :-

An amount of secondary reaction the actual voltage required for the deposition or liberation of metal is higher than the theoritical value which increases the actual energy required.

→ What is energy efficiency.

$$= \frac{\text{theoritical energy}}{\text{actual energy required.}}$$

Electro deposition of Metal -

The proces of depositing metal over another metal or non-metal by electrolysis proces is known as electro deposition.

→ Electroplating is a very common example of such a proces.

Metal Deposition	Solution	Current Density (Amp/in)	Temp. of Soln
Nickel	Nickel sulphite	100 - 200	45° - 55° C
Chromium	Chromium acid	1800 - 2000	35°C
Silver	Double cyanide of silver Na	30 - 50	Cold.
Gold	Double cyanide of K & Au	100 - 300 Amp/ft²	25° - 30° C

Copper (from Sulphate soln)	Copper Sulphite	250 - 350	Warm or Cold
Copper (from cyanide soln)	Cuprous Cyanide and Nla Cyanide	30 - 40	$>0^{\circ}C$

Factors affecting the amount of electrodeposition

① Time :- Time is directly proportional to the quantity of electrodeposition therefore we can say that more masses will be deposited in more time less mass is deposited in less time if the other condition remains Constant.

② Efficiency :- Greater is the efficiency, greater is the quantity of metal deposited for a given time.

③ Current :- The value of current is directly proportional to the mass of metal deposited, greater is the current greater is the quantity of metal deposited while the other condition remains constant.

→ If we increase the current beyond a certain limit which is fixed for different metal separately, the metal deposited will be of different colour. Such as blackish this is known as 'burnt Metal'.

Strength of Solution :-

If the strength of sol is more than the mass of the metal deposited will be more.

Factors Governing Better Electrodeposition

→ The factors which affect the apperance of the deposited metal are discuss below.

current density -

→ At low value of current density the ions are realised in a slow rate therefore the deposit will be coarse and crystaline in nature.

→ At higher values of current density the quantity of deposit becomes more uniform and fine ground.

→ If the current density is show high that it ends limiting value then a spongy and porous deposit is obtained.

→ current density means Current / unit area

Its unit is A/ meter (I/A).

Electrolyting Concentration

Electrolyting Concentration depends upon the current density because by encreasing the Concentration of electrolyte higher current density is achieved.

→ Encrese of concentration of electrolyte tends to give better deposit and it is generally recomanded to use concentrate electrolyte.

Temperature -

→ The temperature of the electrolyte is different for different metal.

→ For example in chromium for electroplating temp. is maintained at 35°C.

→ But in 'Cu' it should be 50° centigrate and in Nickel plating temperature is maintained with in 50° to 60°.

Throughing Power -

The throughing power of an electrolyte may be regared less the quantity which produces a uniform deposited on a cathode which is having and irregular shape.

Extraction of Metal

There are two methods of extraction of metal from the ores depending upon the physical state of the ores.

Extraction of Metal

(i) The ore is treated with a strong acid to often a salt and the sol^n of the salt is electrolysed to reducate the metal.

(ii) When the ore is an molten state it is electrolised in the furnace.

Extraction of Zinc -

Zinc ore which as mainly zinc oxide is treated with concentrated H_2SO_4 acid roasted and passed through various chemical process to get rid of impurities like cardmium, Cu etc by precipitation.

(ii) The zinc sulphate sol^n obtained and then by electrolysis process it is carried out in wooded box with innerlings lead.

(iii) The anode are lining of lead and the cathode are of aluminium zinc is deposited on the cathode.

(iv) In this process of zinc extraction the current density at the cathode is about 1000 Amp/m^2 and the voltage drop in the cell 3.5 V.

Extraction of Aluminium -

The ores of aluminium are bauxite cryolite extricted chemically and reduced to aluminium - oxide and then desolved in fuse cryolite and electrolyist.

(ii) The furnace is lined with carbon aluminium metal gates deposited at cathode.

(iii) The temperature of the furnace is about 1000c and the area of furnace.

(iv) This is required of voltage about 8 volt and current of about 45000 Amp.

APPLICATION OF ELECTROLYSIS -

- Extraction of Metal from their ore.
- Extraction of Zinc.
- Extraction of Aluminium.
- Refining of Metal.
- Production of Chemical.
- Separating metal from their compound.
- Electrotyping.
- Electroforming.
- Electrodeposition.
- Electrocleaning.

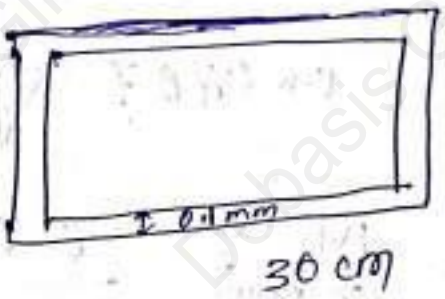
PROBLEMS

Q) A rectangular plate of 30 x 10 cm is to be coated with nickel, with a layer of 0.1 mm thick. Determine the quantity of electricity in amp-hr required for the process given that, current density is 200 A/m² current efficiency is 60%. specific gravity of Nickel 8.9.

Density

Sol

Given that



current density

$= 200 \text{ A/m}^2$

current efficiency $= 60\% = 0.6$

$$200 = \frac{I}{A} \Rightarrow 200 \times 0.03 = I$$

$$\Rightarrow I = 6A$$

$$30 \text{ cm} = \frac{30}{100} = 0.3 \text{ m}$$

$$10 \text{ cm} = \frac{10}{100} = 0.1 \text{ m}$$

Area $= 0.03 \text{ m}^2$

∴ electro chemical equivalent of Nickel.

$= 1.0954 \text{ kg / Amp-hr}$

16

Area = 30×10 cm^2 — volume = $300 \times 10^{-4} \times 0.1 \times 10^{-3}$

$= 300$ cm^2 —

$= 300 \times 10^{-4}$ $= 30 \times 10^{-7}$

$\Rightarrow$ Current density = 200 Amp / m^2

m = volume x density of Nickel.

$= 30 \times 10^{-7} \times 8.9$ g/cm^3

$= 0.0267$ kg.

$Q = \frac{m}{Z_{\text{Nickel}}} = \frac{0.0267}{1.0954/100 \text{ kg/Amp-hr} \times 0.6}$

$$\boxed{Q = 4.06 \text{ Ah}}$$

Q) If a current of 10 A deposits 13.42 gm of silver from a silver nitrate sol^n in 20 minute. Calculate the electrochemical equivalent of silver.

Ans) Current (I) = 10 A

Mass of the substance deposit (M) = 13.42 gm

t = 20 min. = $20 \times 60 = 1200$ sec.

$$Q = It$$

$$Q = 10 \times 1200$$

$$Q = 12000$$

$$Z = \frac{m}{Q}$$

$$Z = \frac{13.42}{12000}$$

$$\boxed{Z = 1.118 \times 10^{-3}}$$

Ch-2

ELECTRICAL HEATING

Electric heating is ~~prefault~~ Preferred over other type of heating method that is by wood, coal, oil & gas.

→ Practically all heating requirements can be fulfilled by some methods of electric energy.

→ Power dissipited in a circuit containing a resistance 'R Ω' and current 'I' flowing through it is 'I²R watt.

→ If the current flows for 't' seconds, energy consume is 'I²Rt' joules / watt-sec.

→ This energy is being converted in to heat energy and can be written as $H = \frac{I^2Rt}{4.2}$ cal.

$= 0.24\ I^2Rt$ Cal.

$$H = \frac{I^2Rt}{4.2} \text{ cal.}$$
$$= 0.24\ I^2Rt \text{ Cal.}$$

∴ Where 4.2 is a constant and called mechanical equivalent of heat.

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MODES OF TRANSMISSION OF HEAT

When electric current passes through a medium such as solid, liquid or gas heat is produce.

There are 3 typ modes of transmission of heat.

(i) Conduction (Solid)
(ii) Convection. (Liquid)
(iii) Radiation (gas).

(i) **CONDUCTION** -

The methods of heat transmision in solid is known as **CONDUCTION**.

(ii) **CONVECTION** :-

The method in which heat transmits through liquid medium is known as **CONVECTION**.

(iii) **IRADIATION** :-

The method in which heat transmits through Air medium by light is called as radiation.

Domestic Applications of Electric Heating.

(1) Electric Kettle
(2) Hair dryer
(3) Immersion heater.
(4) Geyser
(5) Electric Iron.

Industrial applications of electrical heating.

(i) Electric Welding.
(ii) Moulding of Metals.
(iii) Melting of Metals.
(iv) Making of plywood.

Advantages of electric heating over other methods of heating.

(i) Eco friendly.
(ii) Easy transportation.
(iii) Controlled temperatures.
(iv) Waste of energy is limited.
(v) Uniform heating.

Classification of Heating method -

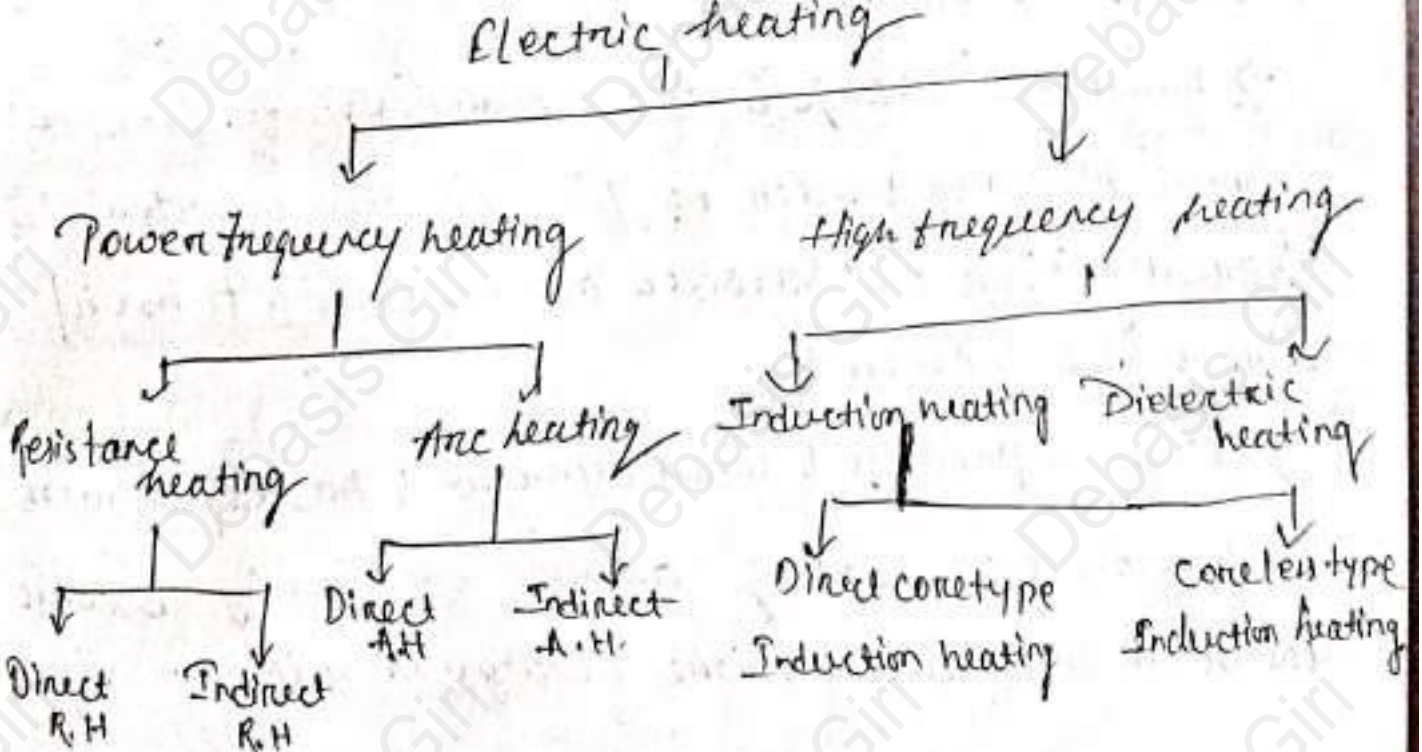
(i) Low temperature. (Up to 400°C).
(ii) Medium temperature. (400°C to 1150°C).
(iii) High temperature (above 1150°C),

Classification of electric energy -

Electric heating can be classified into 2 types
(1) Power frequency heating
(2) High frequency heating.

→ Basically heat will be produced due to circulation of current through a resistance.

→ Power frequency heating.



Power frequency Heating

⊗ Resistance heating

When current is passed through a resistance element, I^2R loss takes place which produce heat.

→ There are two methods of Resistance heating

① Direct Resistance heating

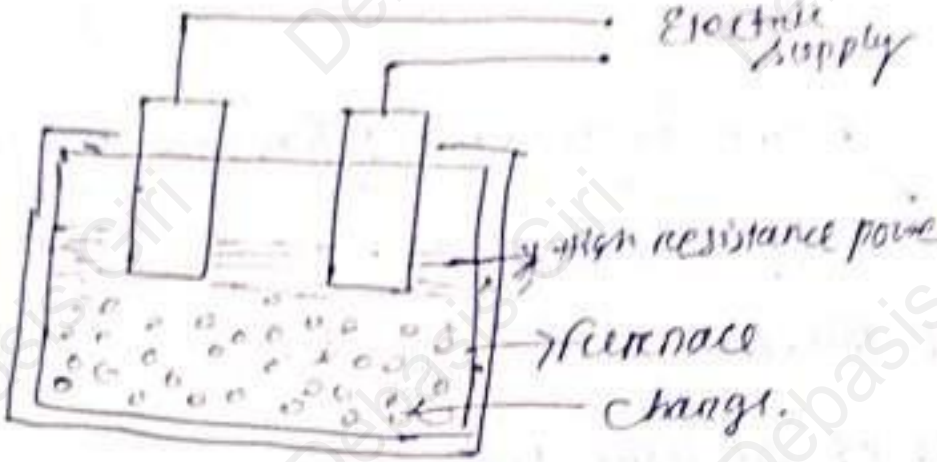
② Indirect resistance heating.

(i) Direct Resistance heating

→ In this method the material to be heated is treated as a resistance and current is passed through it. The charge may be in the form of powder, small solid pieces or liquid, the two electrodes to either ac or dc.

→ When the charge is in the ~~high resistivity~~ form of small pieces of powder of high resistivity materials sprinkly over the surface of the charge to avoid direct short circuit.

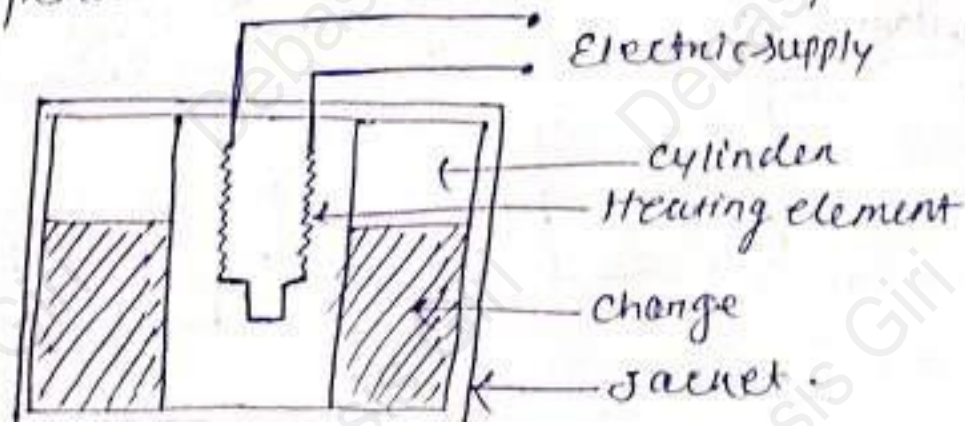
→ Heat is produced when current is passed through it. This method of heating as huge efficiency because, the heat is produced in the charge itself.



(ii) Indirect resistance heating -

→ In this method of heating, electric current is passed through a resistance element which is placed in a electric oven. Heat produced is proportional to I^2R losses in the heating element. The heat so produced is delevered to the charge either by radiation or convection or by the combination of the two.

→ Sometime resistance is placed in the cylinder which is surrounded by the charge placed in the jacket. This arrangement provides uniform temperature moreover automatic temperature control can also be provided.



(2) Arc Furnace -

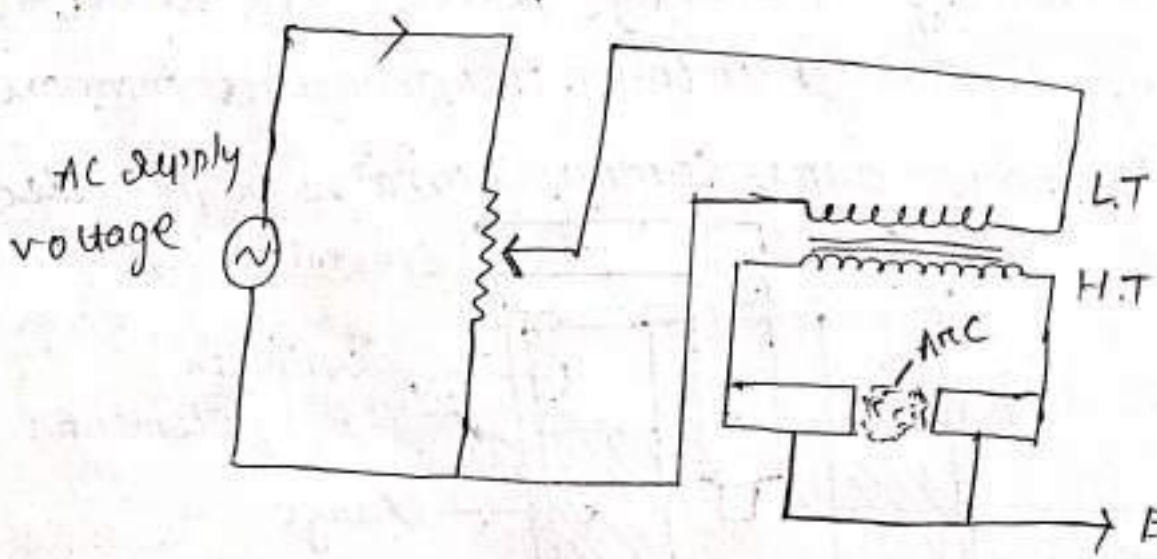
The furnaces used for melting on extraction of metals needs a high temperature ~~processing~~ operations. one of the method is High H.T Strike & L.T Strike.

Methods of Striking Arcs :-

There are two methods of striking the arc, in H.T Strike method, a constant gap is maintained across a pair of electrodes, the electrodes are connected across the H.T side of a transformer.

→ The primary of the transformer is feed with variable a.c voltage.

→ To strike for arc, the primary input voltage is gradually increased thus increasing the high tension voltage or HT voltage along the Secondary side.

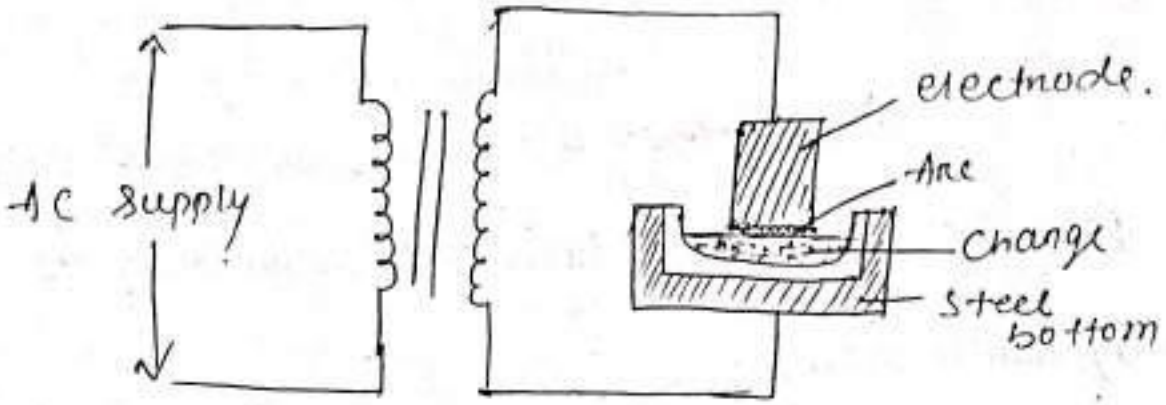


* Types of Arc Furnace

Depending upon the transmission of arc from one medium to another medium arc furnace can be divided into two types.

① Direct Arc furnace
② Indirect Arc furnace.

① Direct Arc furnace -



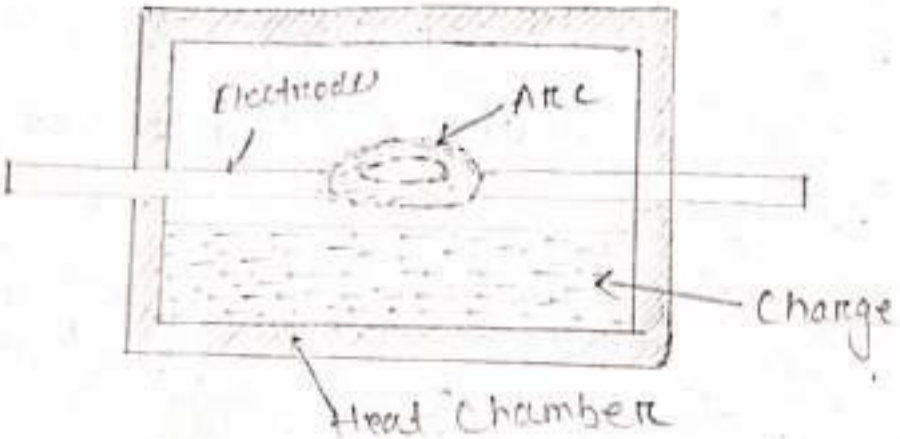
→ The arc is formed between electrode and charge in a direct arc furnace, the arc is in direct contact with the charge, the heat is also produced by flow of current through the charge itself.

→ A single phase arc furnace takes two electrodes vertically downward, through the roof of furnace to the surface of charge.

→ A three phase furnace takes three electrode At the corners of an equilateral triangle project on the

Charge through the roof of the furnace and three arc are formed.

(II) Indirect Arc furnace -



→ The arc that is formed between electrode above the charge and heat is transmitted to the charge by radiation.

→ In this case temperature of the charge is lower than that ~~of~~ indirect arc furnace.

→ Current doesnot flow through the charge directly and furnace is required to be knocked mechanically.

* Principle of Induction heating :-

→ The induction heating effects of current induced by electromagnetic action in the charge in employed.

→ The heat developed depends on the power drawn by the charge, the power consequently depends upon the voltage and the resistance of the charge.

→ In this case power drawn $\frac{V^2}{R}$ or I^2R.

→ To developed sufficient heat to melt the charge the resistance of the charge must be low which is possible only with metals, the voltage must be higher which is obtained by employing higher flux and high frequency.

→ Magnetic materials therefore can be easily treated than non magnetic materials because of their high-Permeability.

Types of Induction furnace -

Depending upon the cores use in the induction furnace it can be classified into 2 types.

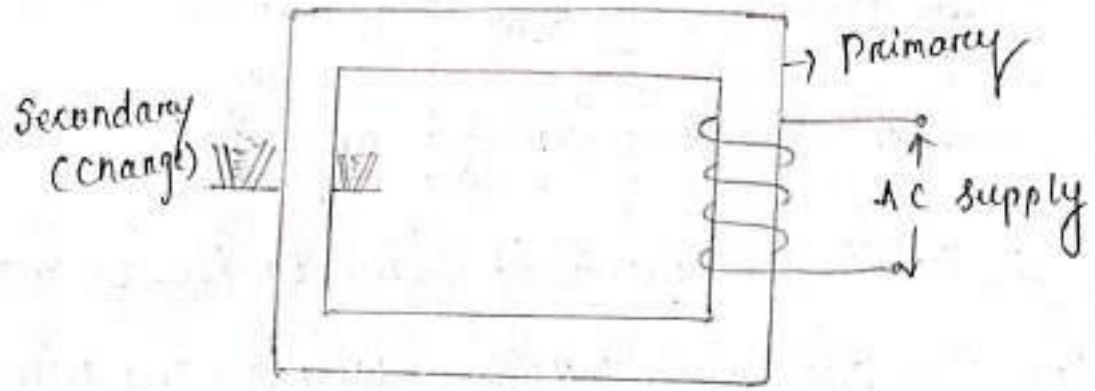
1. Core type Furnace
2. Core-less type furnace.

28) CORE TYPE FURNACE -

Again core type Induction furnace can be classified in to three types.

(i) Direct core type
(ii) Vertical core type
(iii) Indirect core type.

(i) Direct core type Induction furnace -



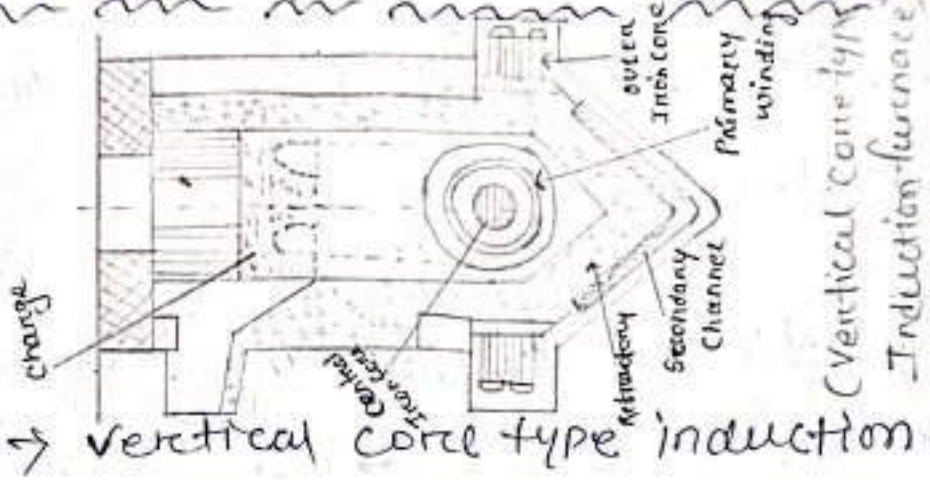
→ It consists of an iron core, crucible of some insulating material and primary winding connected to AC supply.

→ The charge is kept in the crucible which forms a single turn short circuited secondary winding. The current in the charge is very high in the Secondary of the order of several thousand amperes.

The direct core type Induction furnace has some drawbacks.

* The magnetic coupling keep the primary and secondary circuit is very poor, the leakage and reactance is high and power factor is low.

(ii) Vertical core type Induction furnace -



→ Vertical core type induction furnace is also known as Ajax Wyatt Vertical core type induction furnace.

→ This furnace employes a vertical channel instead of a horizontal one for the charge.

→ The convection current keep the circulation molten metal around the 'V' portion.

→ The 'V' channel is narrow so, even a small quantity of charge is sufficient to keep the secondary circuit close the chances of discontinuity of circuit is less.

→ The output of the furnace depends, upon the type and dimension of the channel used.

→ The Certain furnaces instead of 'V' shaped channel, 'U' shaped and rectangular are also employed.

→ The shell of the furnace is a terbistics, the top of the furnace is covered with an insulated which can removes by changing.

→ Necessary hydraulic arrangements are usually made for tilting the furnace to take out the inten metal.

Advantages -

→ Highly efficient, low operating cost and improved Production.

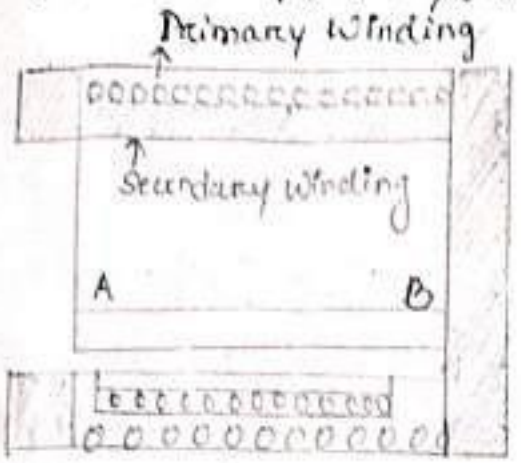
→ Absense of crucible.

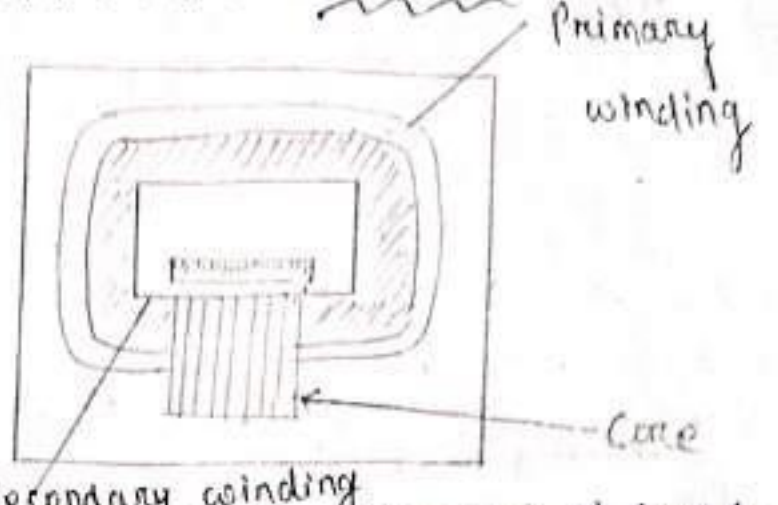
→ Accurate temp. control, uniform casting, resolved metal losses and reduction of rejects.

→ Simple control and ideal working condition with no dirt, noise or fuel.

→ Vertical Coretype Induction furnace are coidely used for melting and refining of brass and then heavy non-ferrous metal.

(iii) Indirect core type Induction furnace.





→ In this method a suitable element is heated by induction which its on the transfer the heat to the charge by radiation.

→ The secondary winding consist of metal container which forms the wall of the furnace.

→ The primary winding is magnetically coupled to the secondary winding by an Iron core.

→ When primary winding connected to AC supply Secondary current is used in the metal container by the Input action.

→ The metal container transfers the heat to the charge, this method is advantages, because its temperature can be automatically controlled without the use of external equipment.

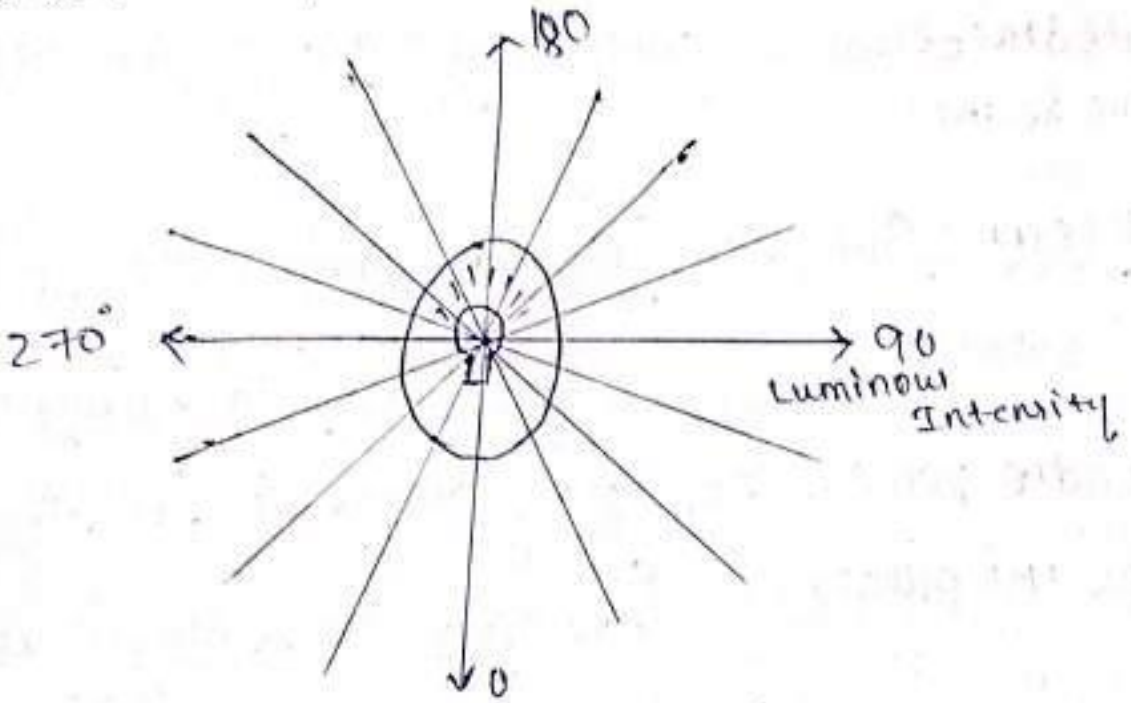
→ If the luminous intensity is measured in horizontal plane, a curve is plotted between luminous intensity on angular position that is horizontal polar curve.

→ The drop in the luminous intensity is at zero 0° of horizontal polar curve due to the holder position or due to the break in the filamenting.

→ Where the current enters & leave.

→ If the luminous intensity is taken along the vertical axis the polar curve can be as shown below.

(ii) Vertical Polar Curve -



This called the representation of vertical Polar curve to in which the luminous intensity is measured in vertical plane at various angle or angular positions of a light source.

→ The drop or depression in luminous intensity is at angle 0° due to the position of lamp holder.

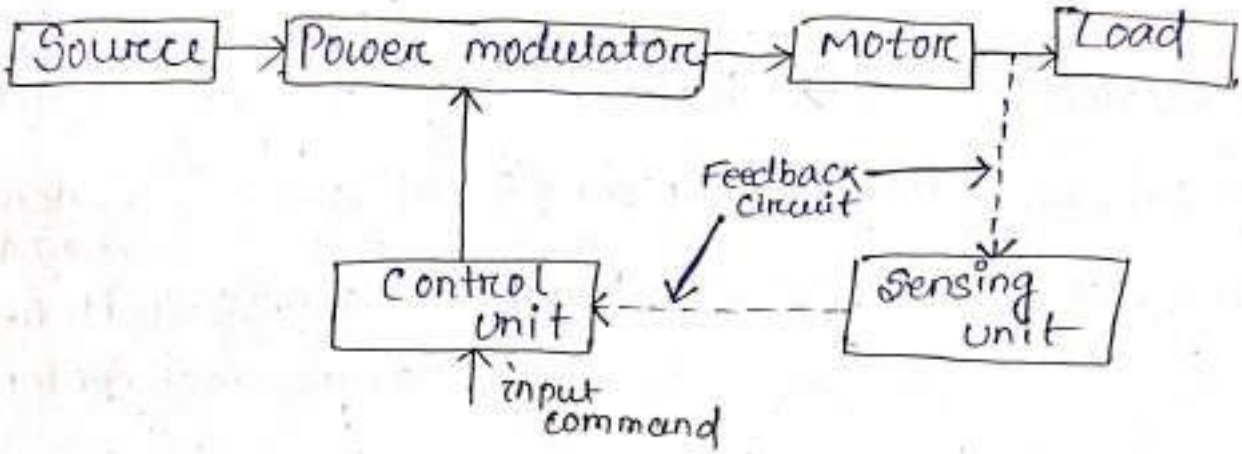
Design of

CH-5

INDUSTRIAL DRIVES

Electric drive.

An electric drive is defined as a form of machine equipment designed to convert electric energy into mechanical energy and provide electrical control of these processes.



(a) Source:- It is either type of electrical power d.c or a.c supply.

(b) Power Modulator :-

→ It converts electrical energy recieved from the source in the form suitable to the motor.

→ During transient operations, such as starting, braking and speed reversal it restricts source and motor currents within permissible limits.

→ It selects the mode of operation of motor i.e motoring or braking.

it while not position, the amount of light radiation being much more than heat energy.