GOVERNMENT POLYTECHNIC, DHENKANAL

SEMISTER-5TH

LECTURE NOTES

ON

UTILIZATION OF ELECTRICAL ENERGY AND TRACTION

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ELECTROLYTIC PROCESS CHAPTER - 1

Electrolysis

* Definition and basic principle of electrodeposition?

ANS) Electrodeposition is the process of coating a thin layer of one metal to the different metal.

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

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

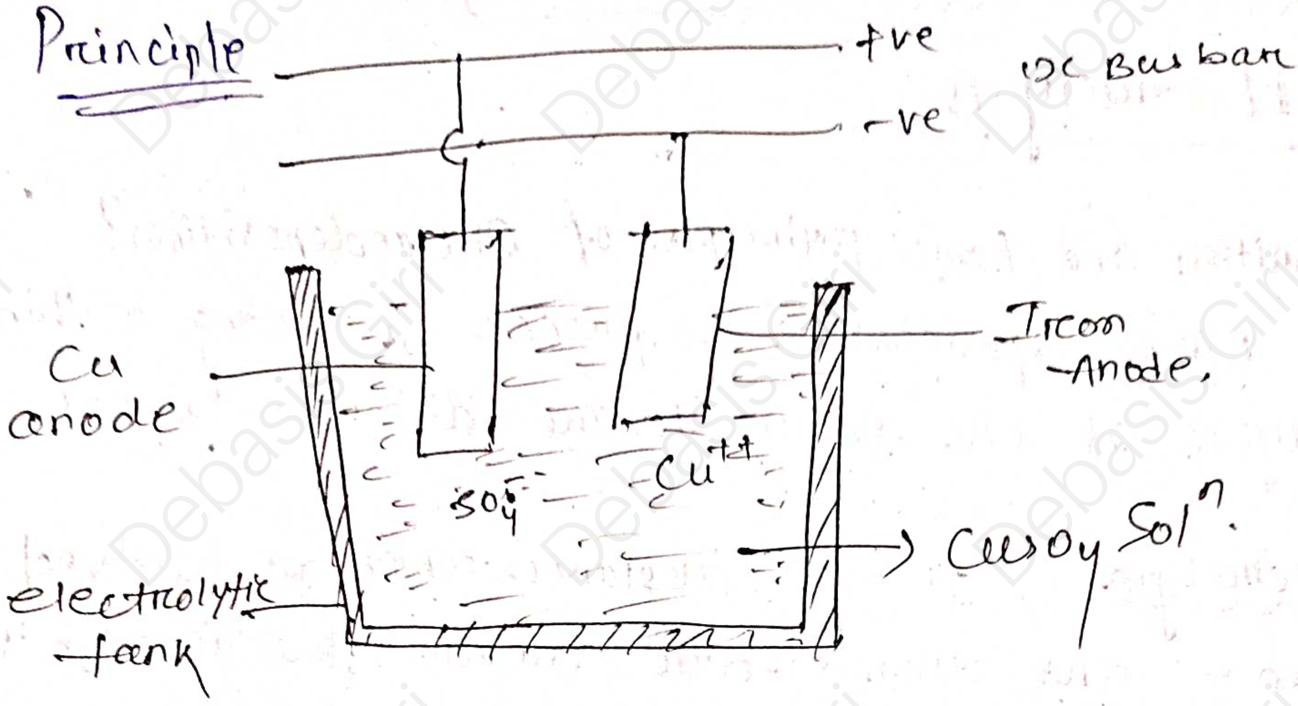
Electro deposition :-

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.

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 anaions 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 losses 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 sol^n of salt when used in the process of electrolysis is called an electrolyte.

(2) Electrodes :-

The rods we must in an electroctrolyte 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 sol^n.

ELECTROLYTIC Process -

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

~~Terms relating to electrolysis~~

① ~~Electrolyte~~ -

~~The sol^n 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 sol^n. The sol^n decompose into +ve & -ve ions thise ions are known as 'electrolytes'.

→ When the +ve ions are deposited in the cathod 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.

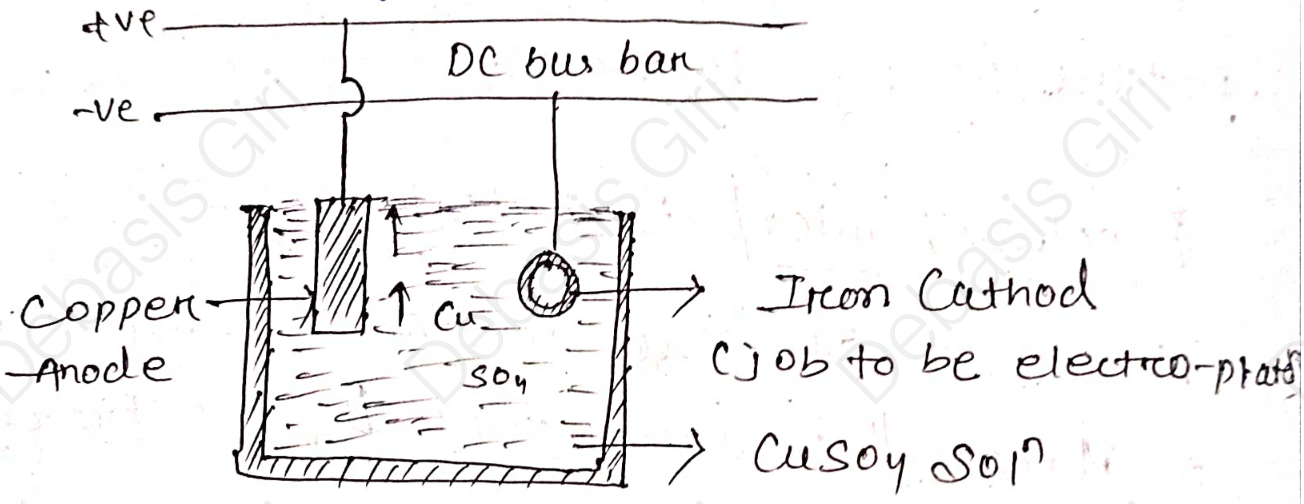
$Z = W$ mg/c (Miligram/coulomb).

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 othere 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 ~~Ead~~ 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 process of depositing metal over another metal or non-metal by electrolysis process is known as electro deposition.

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

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

Coppen (from Sulphate sol^n)	Copper Sulphite	250 - 350	Warm or Cold
Copper (from cyanide sol^n)	Cuprous Cyanide and Na Cyanide	30 - 40	50°C

Factors affecting the amount of electro deposition

① **Time** :- Time is directly proportional to the quantity of electro deposition 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** :- Greated is the efficiency, greater is the quantity of metal deposited for a given time.

③ **Current** :- The value of current is directly proportion to the mass of metal deposited, greater is the current, greater is the quantity of metal deposited while the other Condition remain 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 solⁿ 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 tend 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

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

(2) 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 rosted and passed through various chemical process to get rid of impurities like cadmium, Cu etc by Precipitation.

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

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Extraction of Aluminium -

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

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

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

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

APPLICATION OF ELECTROLYSIS -

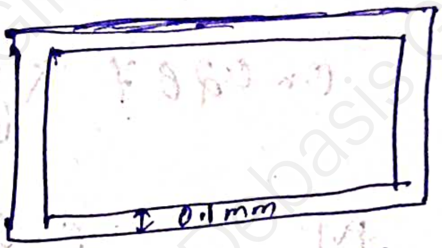
* Extraction of Metal from their ore.
* Extraction of zinc.
* Extraction of Aluminium.
* ~~E~~ Refining of Metal.
* Production of Chemical.
* Separating metal from their compound.
* Electro typing.
* Electro-forming.
* Electrodeposition.
* Electrocleaning.

PROBLEMS

Q) A rectangular plate of 30 × 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/m^2, current efficiency is 60%. Specific gravity of Nickel 8.9.

Ans

Density



Given that

Current density

$= 200\ A/m^2$

Current efficiency $= 60\% = 0.6$

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

$\Rightarrow I = 6\ A$

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

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

Area $= 0.03\ m^2$

∴ electro chemical equivalent of Nickel

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

Area $= 30 \times 10\ cm^2$ 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 $\times$ density of Nickel.

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

$= 0.0267\ kg.$

$Q = \frac{M}{Z \times \text{efficiency}} = \frac{0.0267}{1.0954/100\ kg/Amp\text{-}hr \times 0.6}$

$Q = 4.06\ Ah$

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

Ans) Current (I) = 10 A

Mass of the substance deposit (M) = 13.42 gm

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

$$Q = It$$

$$Q = 10 \times 1200$$

$$Q = 12000$$

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

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

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

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ELECTRICAL HEATING

Electric heating is ~~prefault~~ Prefered 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 'I^2R' watt.

→ If the current flows for 't' seconds, energy consume is 'I^2Rt' joules / watt-sec.

→ ✱ This energy is being converted into 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 transmission in solid is known as CONDUCTION,

(ii) CONVECTION :-

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

(iii) RADIATION :-

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 -

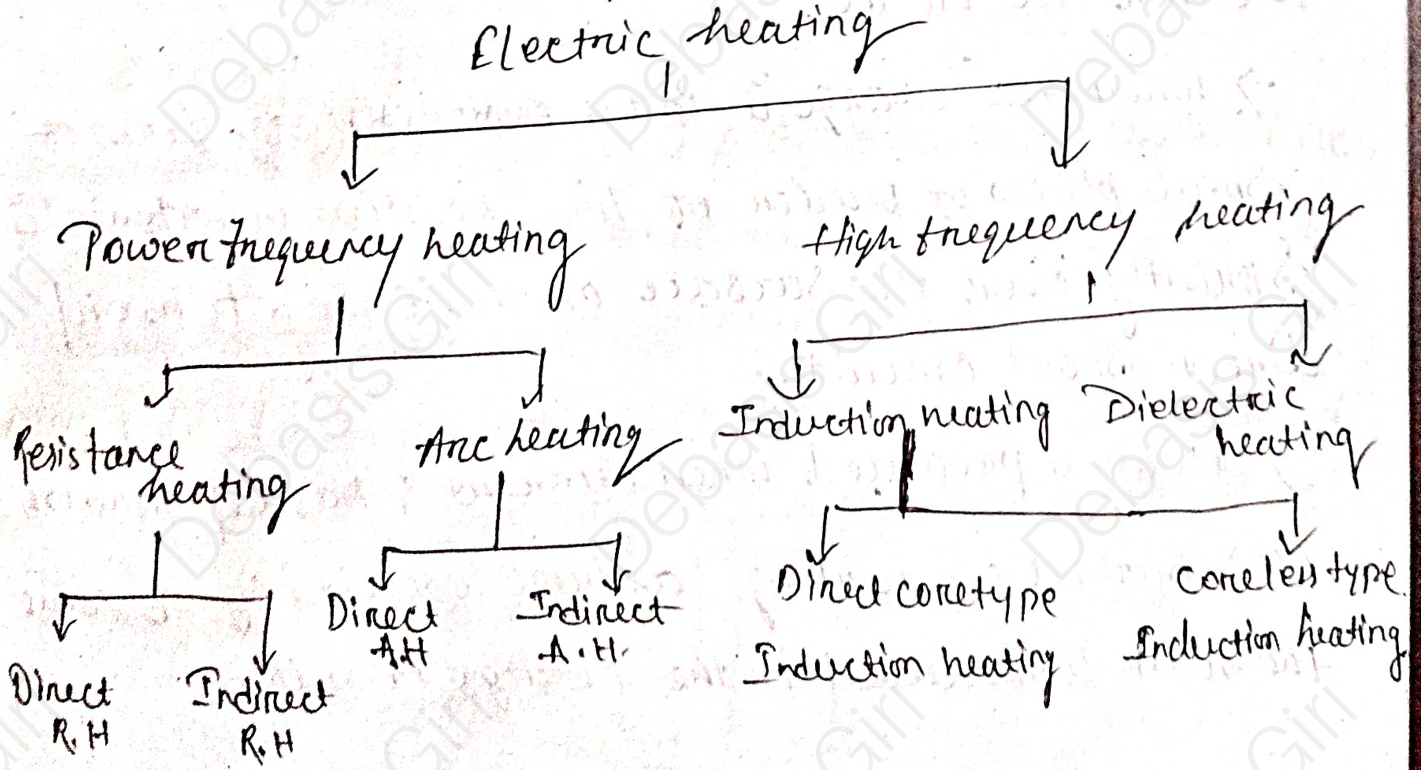
Electric heating can be classified into 2 types

(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.

→ Therefore two methods of resistance heating

① Direct Resistance heating

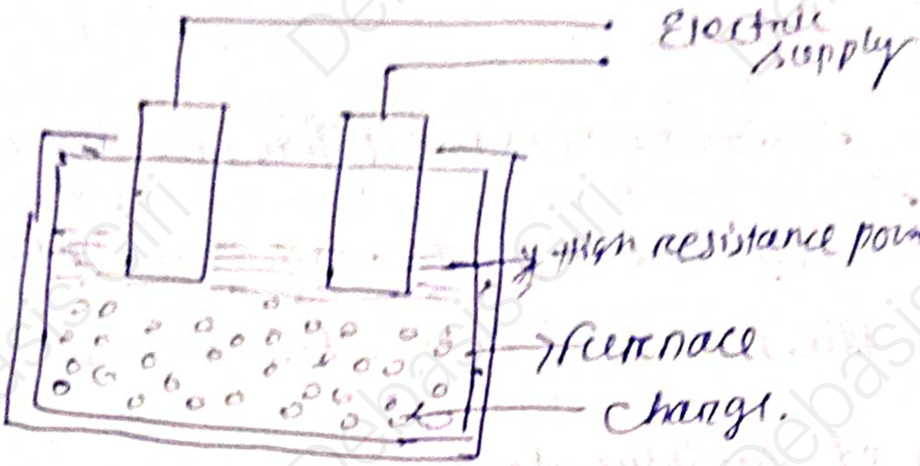
② Indirect resistance heating.

(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 material is sprinkly over the surface of the charge to avoid direct short circuit.

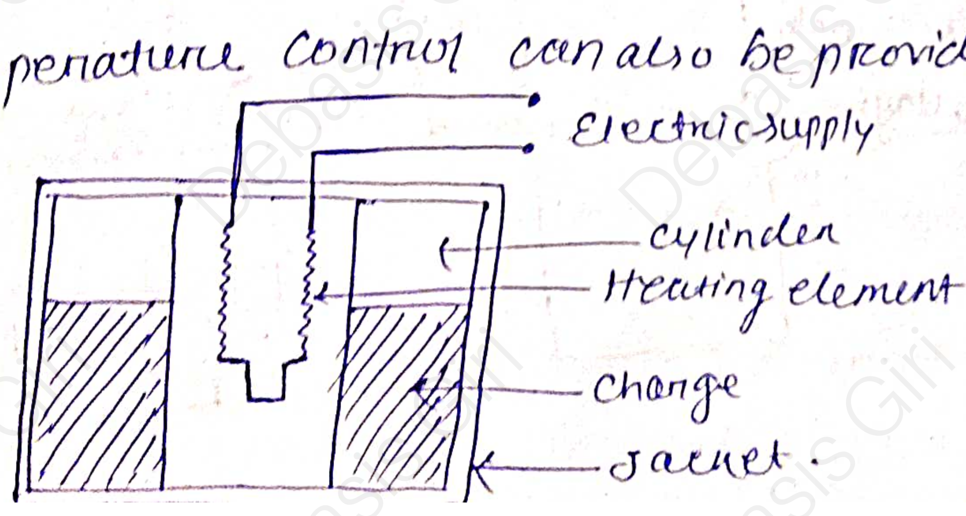
→ Heat is produced when current is passed through it. This method of heating as huge efficiency because, the heat is produced in the charge it self.



(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 -

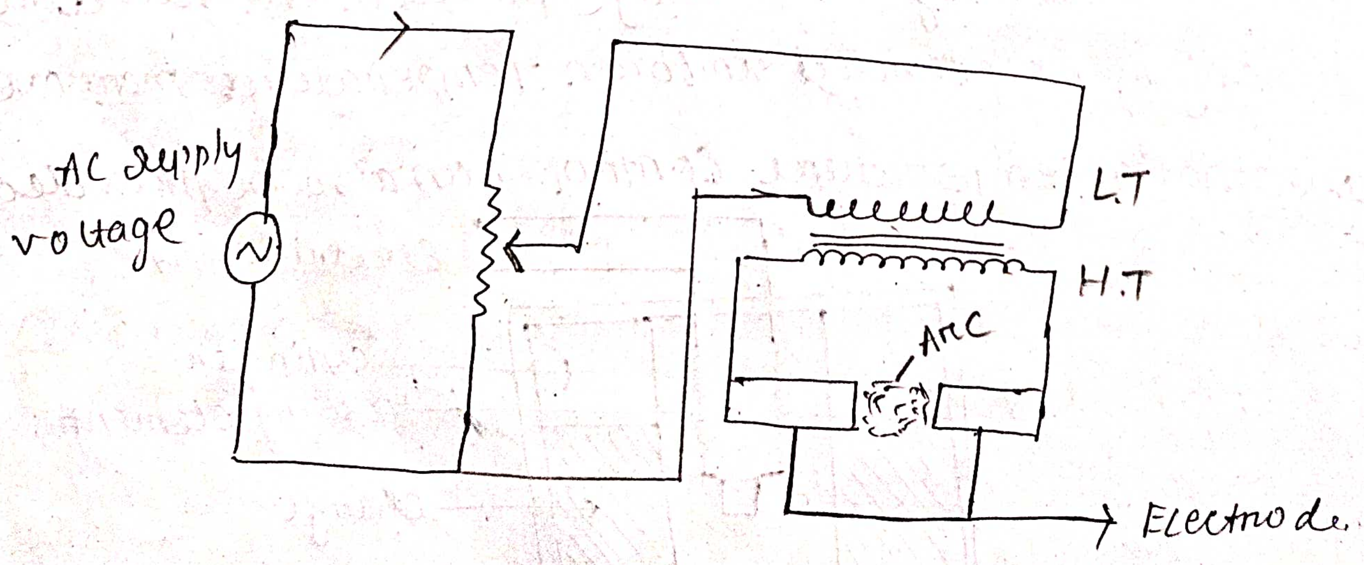
The furnaces used for melting or extraction of metals needs a high temperature ~~processing~~ operations, one of the method is high H.T Strike & L.T Strike.

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.

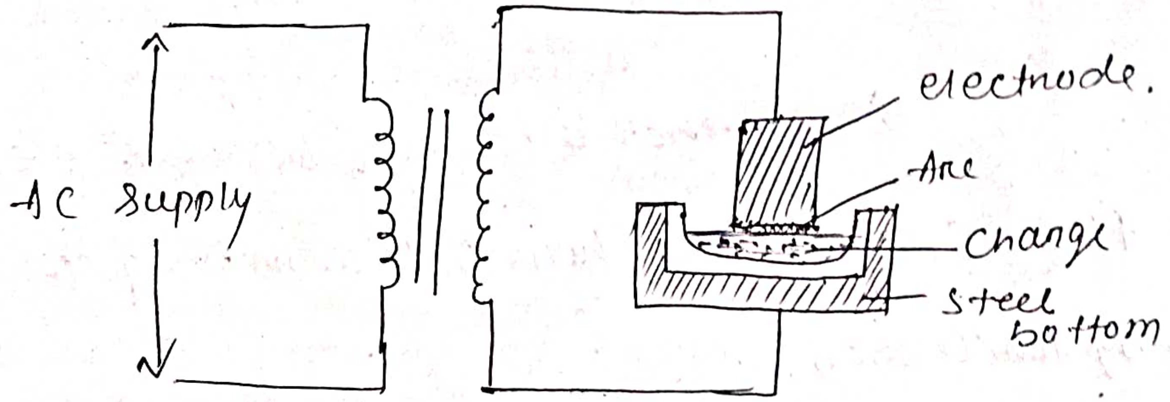


* Types of Arc Furnace

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 -



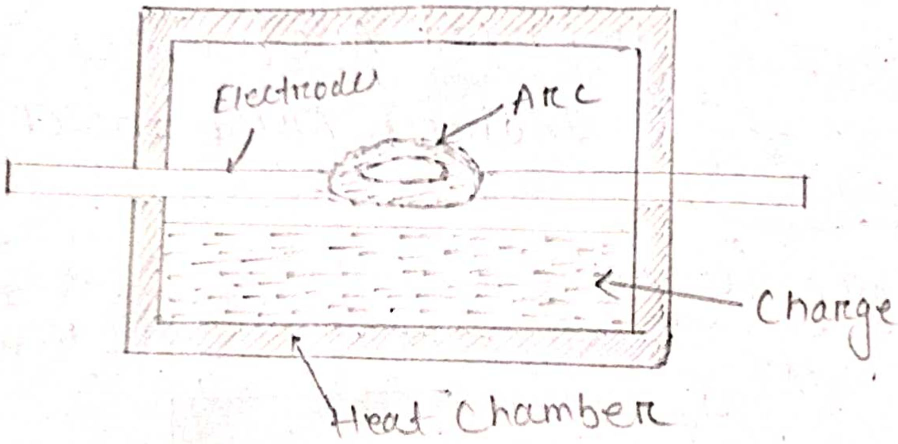
→ The arc is formed between electrode and charge in a direct arc furnace, the arc is in direct contact with the charge, the heat is also produced by flow of current through the charge itself.

→ 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 Causer than that 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 change in employed.

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

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

→ To developed sufficient heat to melt the change the resistence of the change 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

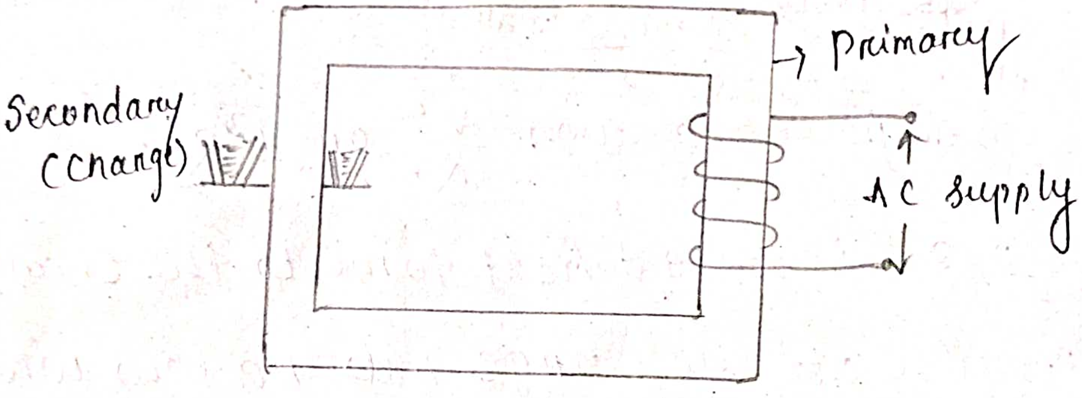
② core-less type furnace.

28 ① CORE TYPE FURNACE -

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

① Direct core type
② Vertical core type
③ Indirect core type.

(i) Direct core type Induction furnace -



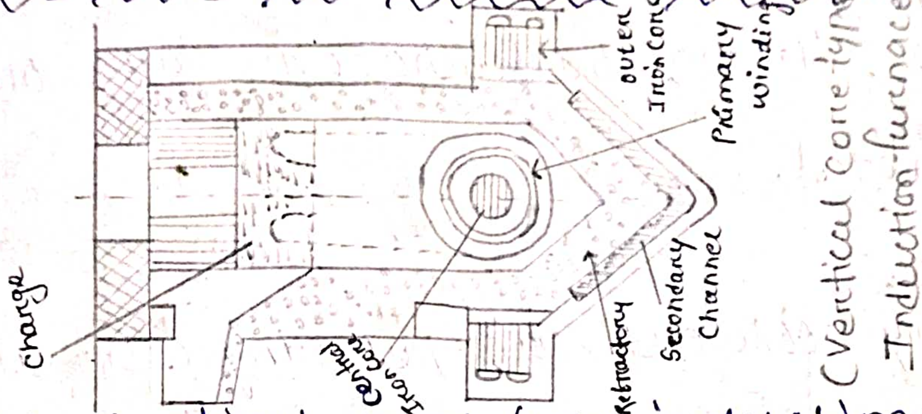
→ It consists of an iron core, crucible of some insulating material and primary winding connected to AC supply.

→ The charge is kept in the crucible which form 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 draw backs.

* The magnetic coupling help 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)

→ 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, 'V' shaped and rectangular are also employed.

→ The shell of the furnace is a terbistics, the top of the furnace is covered with an insculated which can ~~~~ removes by charging.

→ Necessary hydraulic arrangements are usually made for titting the furnace to take out the inter metal.

Advanteges -

→ Highly efficient, low operating cost and improved Production.

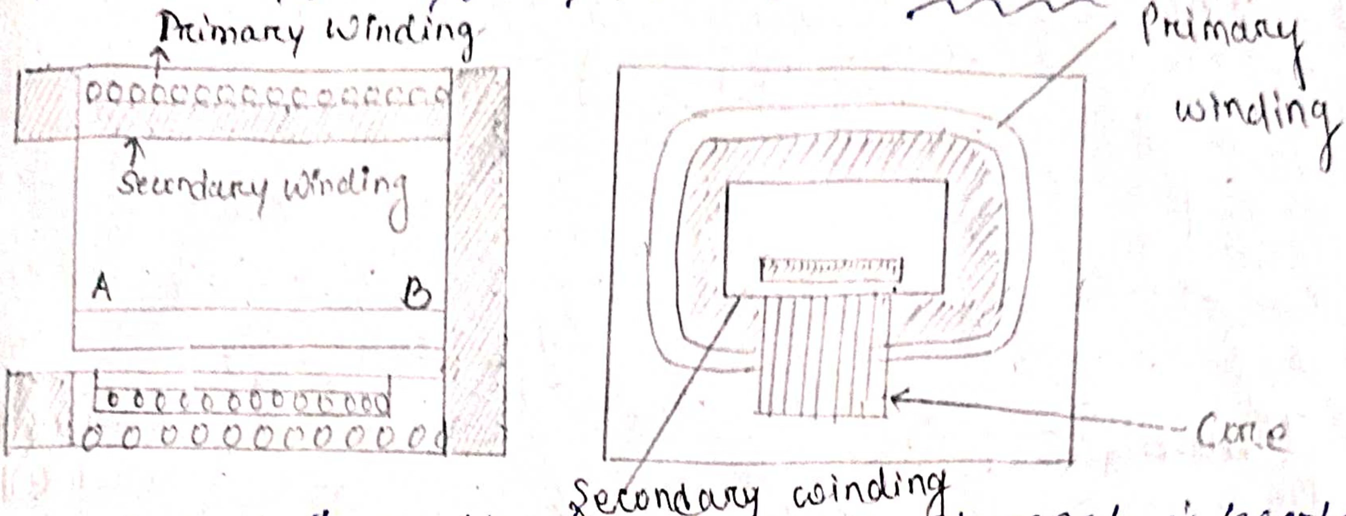
→ Absense of crucible.

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

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

→ Vertical Core type Induction furnace are widely used for melting and refircing 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.

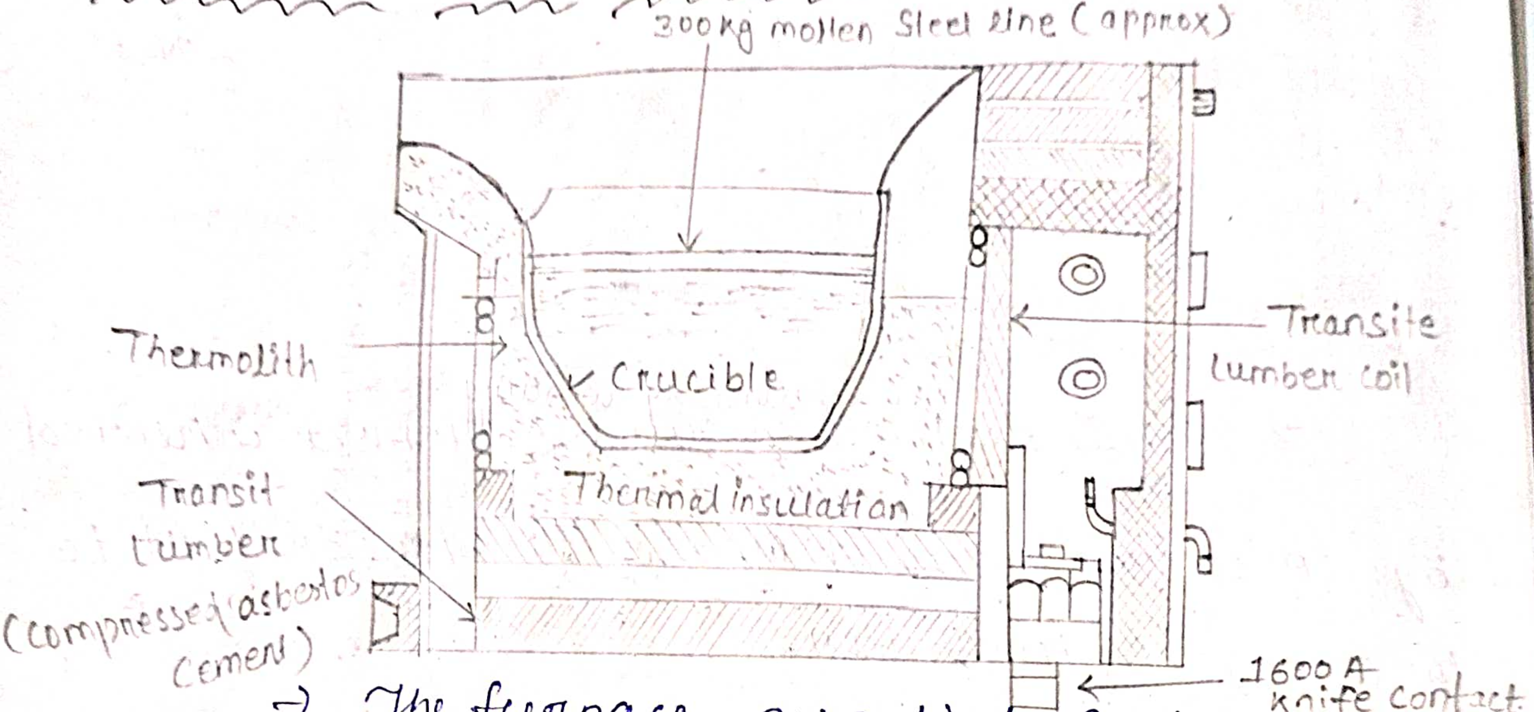
→ The secondary winding consist of metal container which forms the wall of the furnace.

→ 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.

(2) CORE-LESS TYPE INDUCTION FURNACE

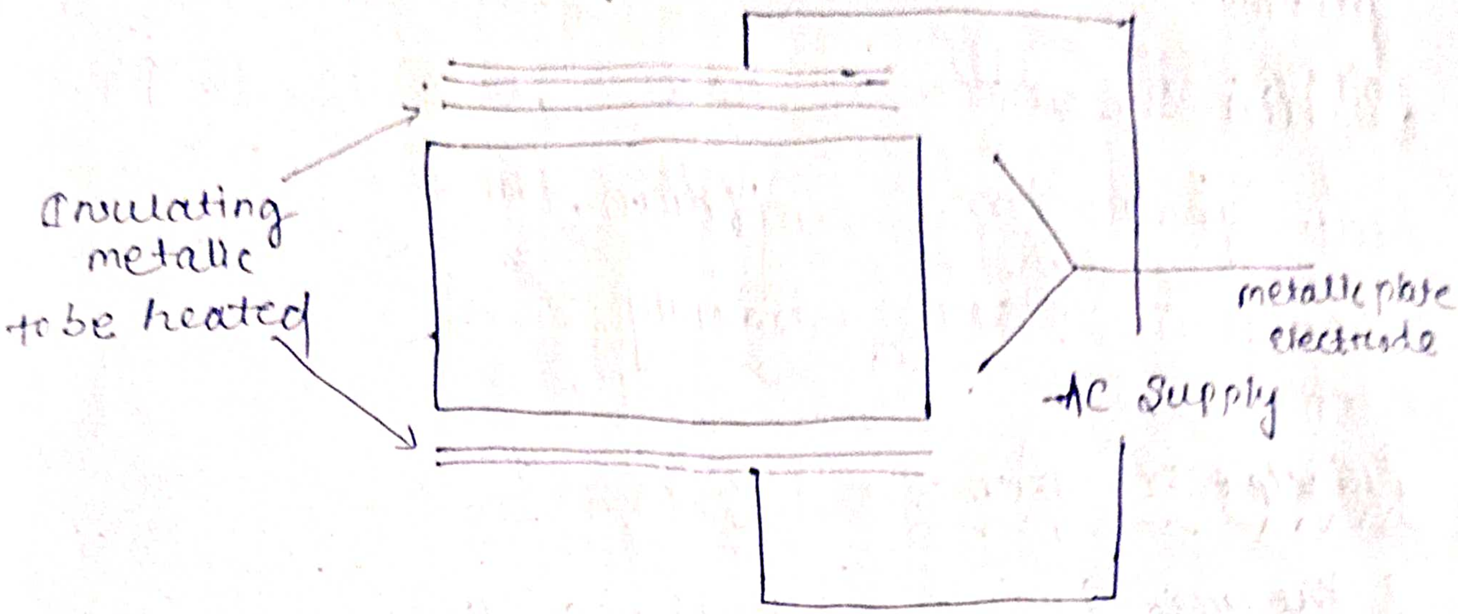


→ The furnace essential consists of 3 part

(1) Primary coil (2) The reflectory container
(3) The frame with induced and support

3)

Dielectric Heating



When non Metallic parts such as wood, Plastic, as subjected to alternating electrostatic field then di-electric loss occurs.

→ The material to be heated is placed as slap between metalic plates or electrodes an connected to high frequency A.C. supply.

→ The producing sufficient amount of heat frequency should be high that is between 10 to 30 MHZ.

→ The current drawn by the Capacitor when an A.C supply voltage applied across his two plate, it doesn't lead the supply voltage be 90° and there is always an in phase components of current.

→ In d. dielectric heating the heat is produced within the material heated, because of the heat generation is uniform, the directly material is ~~heating~~ heated uniformly.

Principle of operation

→ The principle of operation of dielectric heating is that when a capacitor is subjected to a sinosoidal voltage, the current drawn by it never leads the voltage.

→ The angle between voltage and current is known as loss angle.

$$\text{Loss angle } (\delta) = \frac{1}{2\pi}\left(\frac{\sqrt{\rho \times 10^7}}{\mu_r f}\ M\right)$$

where ρ = resistivity

μ_r = relative permeability.

f = frequency.

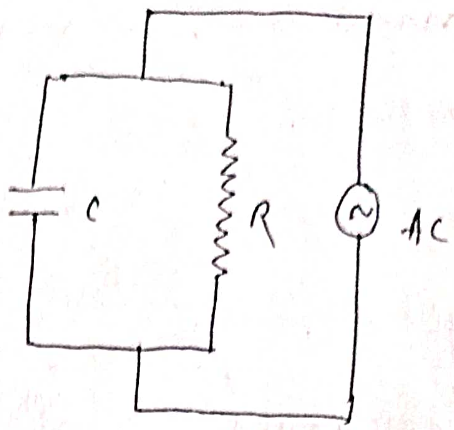
Advantages -

1. Heat is Uniform.
2. Simple and numerical cast less
3. Heat to generatey can be controlled
4. Time of operation is reduced.

Application

1. Food processing Bakery.
2. Plastic Winding

Equivalent Circuit.



{MICRO·WAVE HEATING}

Microwave heating is one of rapid energy efficient way heating materials.

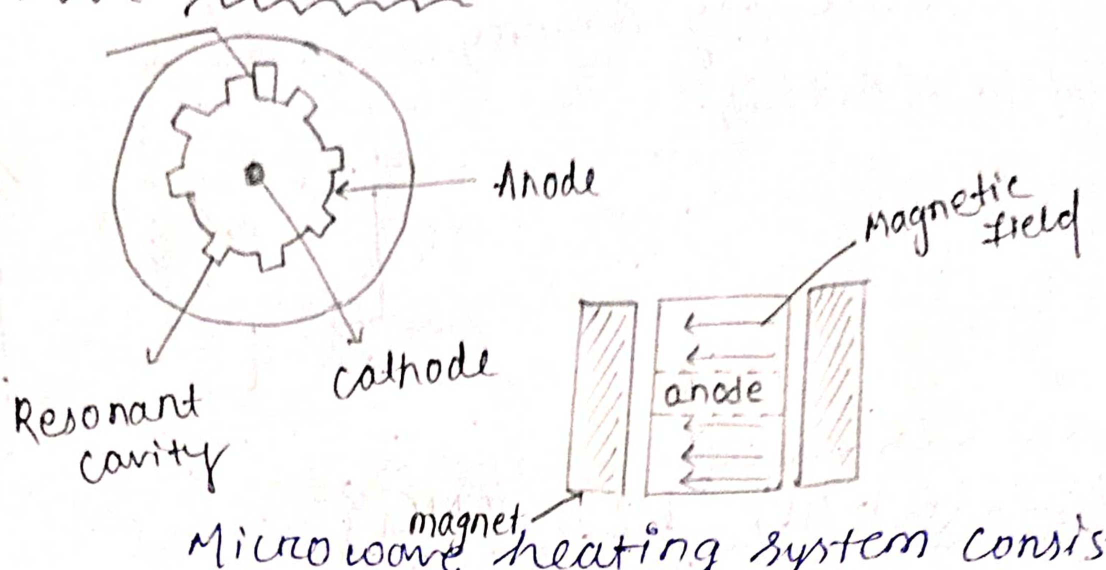
→ Microwave heating difference from convection heat transform and fundamental level.

→ Where ~~...~~ conventional heating operates through heat transfer from the surface of an object towards its centre.

→ Microwave deliver heat uniformly and simultaneously through out the bulk of the material.

→ This difference can provide unique advantages for microwave heating in many application.

Microwave Generation -



Microwave heating system consists of 3 primary components.

① Microwave Source.
② Wave guides
③ Applications

→ Power Supply is used here as microwave source that is connected to anode and Cathode.

→ The wave guides that transmits the microwaves from the source from to the point of application.

→ The application is chamber, that designed that the promote effective coupling of the microwave energy to the material heating.

Application -

→ Manufacturing of plastics.
→ Processing of Cement.
→ food processing.

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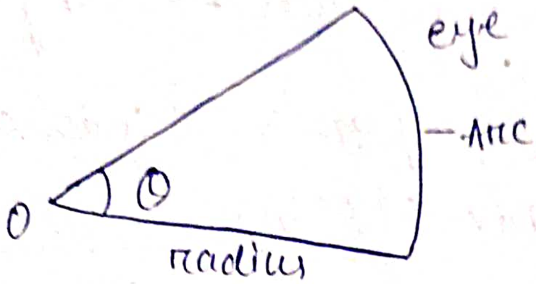
ILLUMINATION

→ Terms regarding Illumination -

① Plane angle -

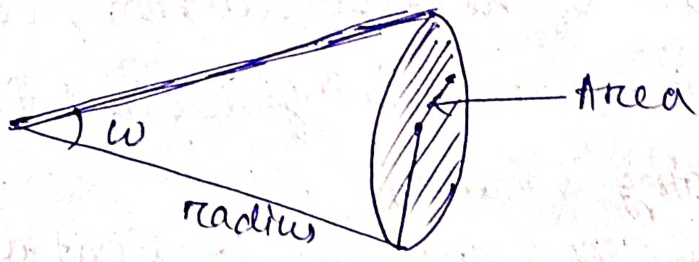


→ When two straight lines lying the same plane, meeting at a point the angle created between them is termed as the plane angle.

→ In this figure plane angle 'θ' can be represented a

$$\theta = \frac{\text{Arc}}{\text{radius}}$$

② Solid angle - (steradian) ω



→ This angle subtended at a point in a space by an area is termed as solid angle.

→ Solid angle is denoted as (ω) and can be expressed by

$$\omega = \frac{\text{Area}}{(\text{radius})^2}$$

→ If we consider a point light source which radiates energy in all directions which centre 'o' and any distance 'r' then the lines of flux from the light source with cross an area forming a cone.

→ So, we can write the largest 'ω' (solid angle) subtended at the centre of a space.

$$\omega = \frac{4\pi r^2}{r^2}$$

$$\boxed{\omega = 4\pi} \{\text{unit is = Steradian}\}$$

③ Luminous flux (lumen) :-

It is defined as the energy in the form of light radiated per sec from a luminous body.

→ The whole of the electrical power supply to the lamp is not changed into luminous flux. Some of the power is lost by heat conduction, convection and absorption. Of the remaining radiant flux only

~~→ Of the remaining radian~~

a fraction of it is converted into light wave which lies in between the visual range of wave length. i.e between 4000 A° to 7000 A° (wavelength) power as → Luminous flux

Radian flux → Power was an non luminous flux.

Total electrical power Input → Coduction, convection & Absorption (Powerloss)

④ Luminous intensity

Luminous intensity is any particular direction is the ~~som~~ luminous flux per unit solid angle.

⇒ luminous intensity can be denoted as (I)

$$I = \frac{df}{dw} = \frac{\text{luminous flux}}{\text{steradian}(w)} \text{ (candela)}$$

candela - Candela is the strength of light emission.

⑤ Lumen -

Lumen is a unit of luminous flux and is defined as the luminous flux and is defined as luminous flux per unit solid angle from a source of one candle power.

~~luminous intensity can be denoted~~

~~$\frac{df}{dw}$ = $\frac{\text{luminous flux}}{\text{steradian}}$ (cd)~~

Lumens = Candle Power x Solid angle

Lumens = candle power × solid power

$$\boxed{\text{Lumens} = C.P \times \omega}$$

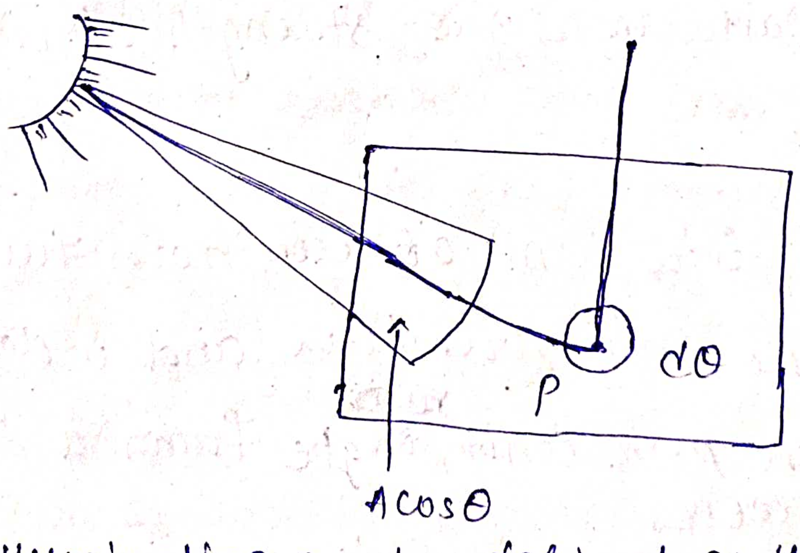
The total flux emitted by the source of one candle power = 4π lumen.

⑥ Candle Power -

Candle power is defined as the no of lumen per solid angle.

$$\boxed{C_p = \frac{\text{lumen}}{\omega}}$$

~~Laws of~~ {ILLUMINATION}.



$\frac{df}{\text{Area}}$

Illumination can be defined as the luminous flux recieves per unit area.

→ Its unit is 'Lux'.

→ These features of illumination is called as

$$\text{Illuminance} = \frac{df}{dA} = \frac{\text{luminous flux}}{\text{Area}}$$

In this given figure let the focus 'p' is obtain small area dA 'p'.

→ The cosine function of the area is the horizontal plane is A cos θ.

→ Illuminance (E) = $\frac{df}{dA}$ unit is lumen/Area

Lumen = candle power (C.P) × Solid angle (ω)

& $\omega = \frac{\text{Area}}{(\text{radius})^2}$

$$\text{Illuminance} = \frac{C.P \times \omega}{\text{Area}}$$

$$= \frac{C.P \times \frac{\text{Area}}{R^2}}{\text{Area}}$$

$$E = \frac{C.P}{R^2} \ (\text{LUX})$$

$\frac{\text{luminous flux}}{(\text{radius})^2}$

when 'R' is the distance ~~from~~ between the area and the point of solid angle formed.

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Glare -

Glare may be defined as the sencetion experiences by the human eye, when a very bright source of light enter the eye directly to cause discomfort annoyance or loss in visual performance or visibility.

→ It can be classified in to two types.

(i) Direct Glare

(ii) Indirect Glare.

(i) Direct Glare -

When a table lamp with low mount glows without reflector.

(ii) Indirect Glare -

Shining object reflecting light.

⇒ We can be abolide by fixing light source such a position that not direct light flux on the sining surface.

Direct light -

Direct layer can be avoided by increasing height of the lamp.

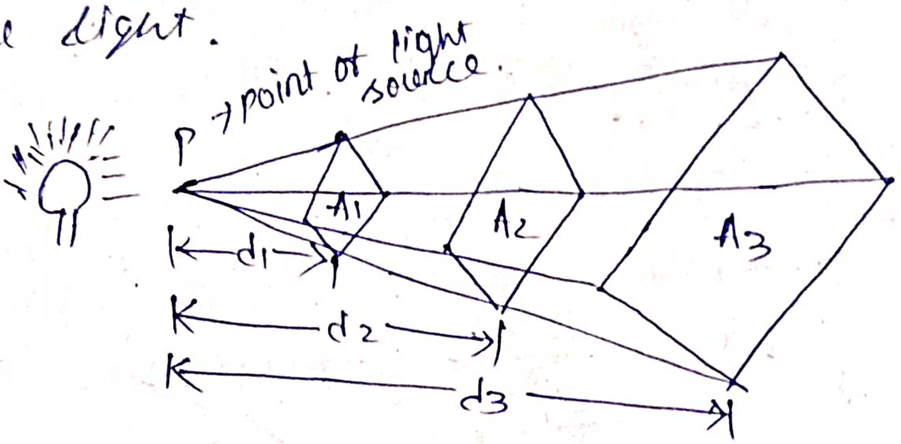
→ By using reflectors (20° horizontal).

LAWS OF ILLUMINATION

We have two Laws of Illumination.
(i) Inverse Square Law
(ii) Lambert's Cosine Law

① Inverse Square Law :-

This law states that the illumination on a surface is inversely proportional to the square of the distance from the surface and the source of the light.



Let there are three surface areas A_1, A_2 & A_3 and the distance from the point source is d_1, d_2, d_3 respectively.

→ Let 'I' is the luminous flux from the direction of source to surce.

Therefore $\omega = \frac{\text{Area}}{(\text{radius})^2 / (\text{distance})}$ $\left(\frac{A}{d_1^2}\right)$

The total flux on the surface 'A' will be

= luminous Intensity (I) x Solid angle

$\Rightarrow I = \frac{\text{luminous flux}}{\text{solidangle } (\omega)}$

Putting the value of 'ω' in this eq^n

$$I = \frac{flux \times d_1^2}{A_1}$$

$$flux = \frac{I A_1}{d_1^2}$$

Now Illumination E_1 on the surface A_1

$$\text{Illuminance } (E_1) = \frac{flux}{Area}$$

$$E_1 = \frac{I A_1 / d_1^2}{A_1}$$

$$E_1 = \frac{I}{d_1^2} \quad \text{——— (1)}$$

This illumination of the light source on the surface of area A_1.

Similarly ~~from~~ for Area A_2

$$Flux = \frac{I A_2}{d_2^2}$$

Illumination on the surface of Area A_2 will be

$$E_2 = \frac{I}{d_2^2} \quad \text{——— (2)}$$

~~By comparing eqn ① & ②~~

Illumination ~~of~~ on the surface of Area A_3 will be

$$\boxed{E_3 = \frac{I}{d_3^2}} \quad \text{——— (3)}$$

By comparing eqn ①, ② & ③

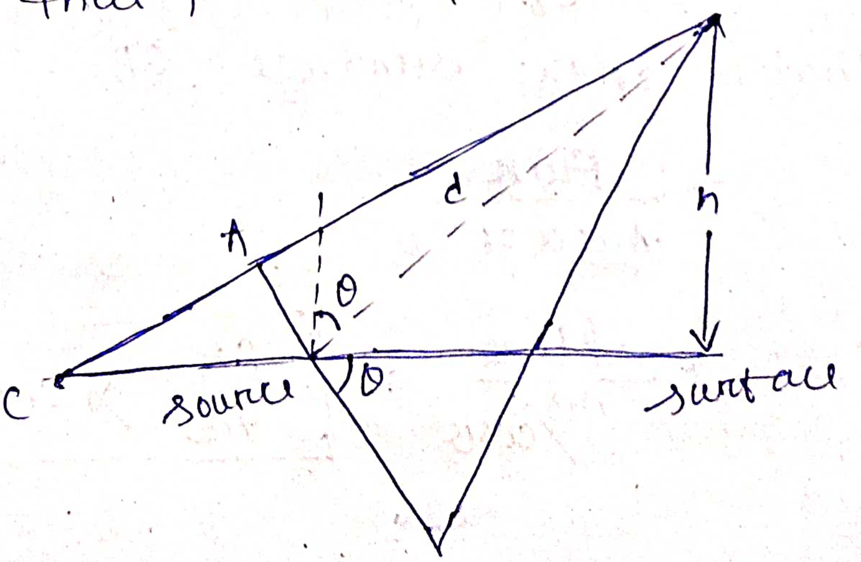
$$\boxed{E_1 : E_2 : E_3 = \frac{I}{d_1^2} : \frac{I}{d_2^2} : \frac{I}{d_3^2}}$$

$$E_1 : E_2 : E_3 = I\left(\frac{1}{d_1^2} : \frac{1}{d_2^2} : \frac{1}{d_3^2}\right)$$

from the above eqn we found the illumination and the surface of a body is inversely proportional the square of the distance betn the light source and the surface of the body.

(ii) LAMBERT'S COSINE LAW -

It states that the illumination E' at any point on a surface of body is directly proportional to the cosine of the angle betn the normal to that point and the line of flux.



Let AB ⇒ Surface area normal to that point and inclined at angle 'θ' to the horizontal axis 'CD'.

$AB = CD \cos\theta$

CD = normal to the vertical axis and inclined at an angle 'θ' to the source.

$$CD = \frac{AB}{\cos\theta}$$

d = Distance between source and the surface of the body.

h = Height of the source from the surface of the body

Let 'I' be the total luminous intensity $= \frac{\text{lumen}}{\text{solid angle}}$

Illumination on the surface AB

$$AB = \frac{I}{d^2}$$

Illumination on the surface CD

$$= \frac{\text{Flux}}{\text{Area of CD}}$$

$$CD = \frac{\text{flux}}{AB/\cos\theta} = \boxed{\frac{\text{flux}}{AB} \times \cos\theta}$$

Now, we can write illumination on the surface area 'CD'

$$E_{CD} = \frac{flux}{AB} \times \cos\theta$$

$$E_{CD} = E_{AB} \times \cos\theta$$

$$\boxed{E_{CD} = \frac{I}{d^2} \times \cos\theta} \quad \text{--- (1)}$$

$$\cos\theta = \frac{h}{d}$$

$$d = \frac{h}{\cos\theta}$$

~~By substituting value~~

By putting the value of 'd' the above eqn

$$E_{CD} = \frac{I}{(h/\cos\theta)^2} \times \cos\theta$$

$$\boxed{E_{CD} = \frac{I}{h^2} \times \cos^3\theta}$$

It is also known as cosine cube law and can be started as the illumination at any point on the surface of a body is dependent on the cosine of the angle between line of flux and normal at that point.

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POLAR CURVE

It is of two types

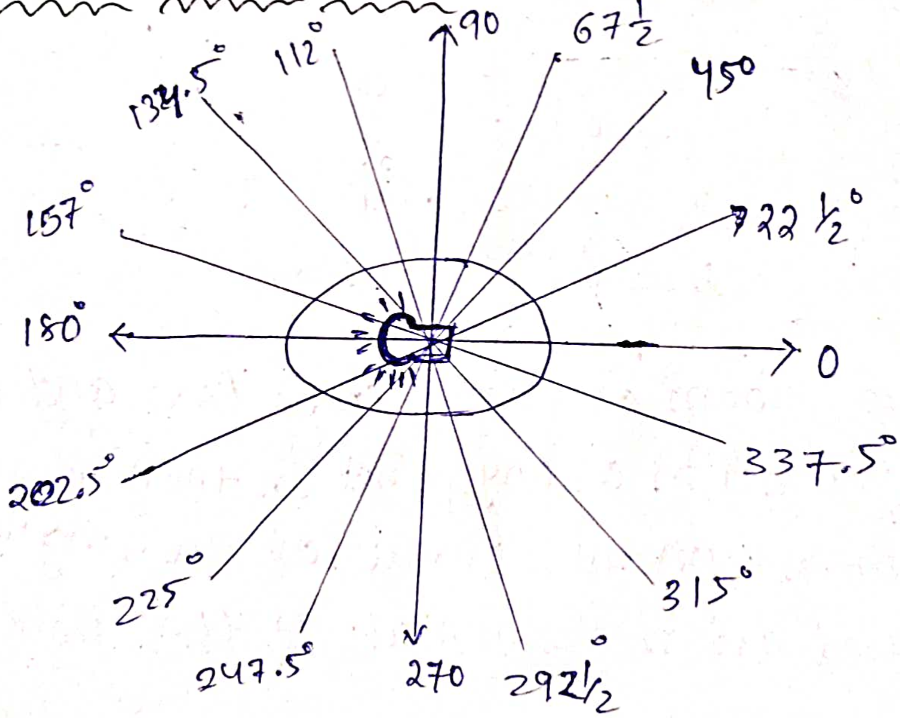
(i) Horizontal Polar Curve

(ii) Vertical Polar Curve.

→ Polarcurve is a curve or Graphical representation of illumination an angular position of light source.

* It can be divided in two types according to the luminous taken on a surface.

(i) Horizontal Polar Curve -



Horizontal polar curve incandenscent lamp -

This figure shows the illumination of surface in the incandescent lamp. area ~~horizontal polar curve.~~ ~~due to the holder Position~~ or ~~due to the breack in the filament ring~~.

→ Where the current enters and leave.

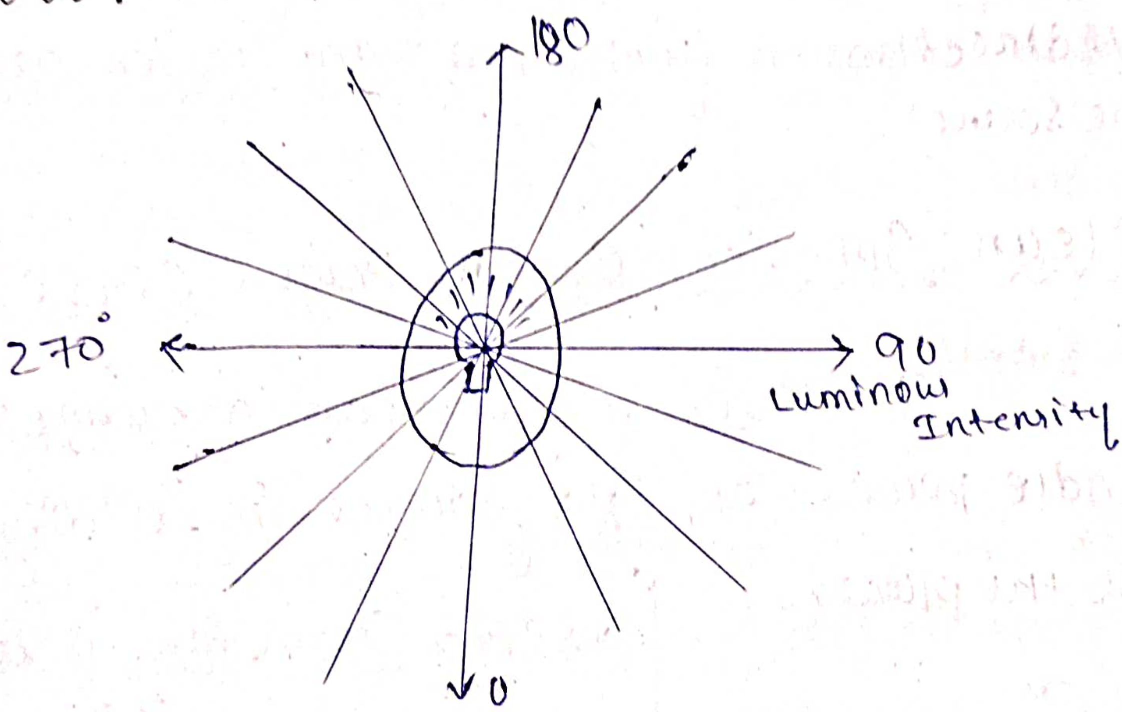
→ If the luminous intensity is measured in horizontal plane, a curve is placed between luminous intensity an angular position that is horizontal polar curve.

→ 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 filament ring.

→ where the current enters & leave.

→ If the luminous intensity is taken along the vertical axis the polar curve could 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.

Vertical Polar Curve -

Hence the polar curve make a defined as a graph representing the light distribution of a lamp in a horizontal or vertical plane.

TERMINOLOGIST RELATED TO ILLUMINATION

① **Mean Horizontal Candle Power (MHCP) :-**

The MHCP of a light source is the mean average of the candle power in all direction on horizontal plane which passes through the source.

② **Mean Spherical Candle Power (MSCP) :-**

The MSCP is the mean average of the candle power of light source in all direction in all the planes.

$$MSCP = \frac{\text{Total flux in lumens}}{4\pi}$$

③ **Mean Hemi Spherical Candle Power (MHSCP) :-**

The MHSCP is the mean average of the candle power in all direction within the hemispherical either above or below the horizontal plane.

Types of Lamp fitting :-

1. (i) Direct lighting
2. (ii) Semidirect lighting
3. (iii) Indirect lighting
4. (iv) Semi indirect lighting.
5. (v) General lighting.

(i) Direct lighting -

In the direct lighting scheme the light falls directly on the object to be illuminate.

→ The direct lighting scheme is usually employed in industries residential lighting commercial lighting etc.

→ While design such a scheme all the possibility which cause ~~glare~~ glare on eyes is to be illuminated

→ ~~Also~~ A current size of lamp with suitable fitting is to be selected.

→ The fittings are required to be clean regularly the 60% of the light is directed downwards as is seen the vertical ~~posture~~

Adventages of direct lighting -

→ Fittings ~~are~~ efficient.

→ Those are cheap.

→ Fittings give hard light.

(ii) Semidirect lighting-

The semidirect lighting system is efficien as well as the reducess the chances of glare on eyes with a considerable extends.

→ The shadows used are of such a type that about 60% of light is directed down ward and 40% is projected upwards.

→ The most important characteristics of such a System that, it provide almost uniform distribution of the light which increases the efficiency of system.

Advantages-

1. Uniform distribution light.
2. Highe efficiency.
3. Glare is avoided by employing debbusing gloves.
4. This fitting reduce the tremlling effect.

Uses of applicating-

→ Suitable for commercial application, i.e office or shop.

→ Suitable for room high silling.

(iii) Indirect Lighting :

→ The indirect system is widely employed for illuminating drawing offices workshop & other places where shadows to be illuminated.

→ The idirect type of lighting system is requiredwhere light ~~is mo~~ requirement is more than direct lighting.

→ The additional requirement of the light falls in the range of 50 to 100 %.

Advantages -

→ Free from glare.

→ have no shadows.

→ Illumination is softer and more defused.

Application -

→ Uses for declaration proposes in cinemas & hotels.

→ Used in workshops and other places, where shadows are the eliminated.

(iv) Semi-indirect Lighting :

Semi indirect lighting system is the light recieved by any object is due to defuse reflection that is directly throught.

→ This system doesnot posess the defect of indirect system.

→ The semiindirect lighting system through the 90% to 10% light from source directly 60% to 90% indirectly due to defuse deflection.

Advantages -

→ These fitting is give soft shadows.

→ Free from glare and plizing to eyes.

Application -

① Used for indoor light decoration.

② Suitable for high class utility applications like boared room, conference hall etc.

General lighting -

In general lighting system the shades employed will produced equal distribution upwards & downwards.

Advantages -

→ This fitting give soft light with soft shadows.

→ Uniform light distribution in all direction.

Applications -

→ Used for general lighting in shop.

→ Used for domestic lighting.

→ Used in offices.

→ Industrys along with local fitting.

Factors Used in design of Lighting Scheme :-

Utilization factor -

$$\text{Utilization factor (U.F)} = \frac{\text{lumens used in the working plane}}{\text{Total lumens from the light source}}$$

→ The value of this factor depends upon the following factor / conditions.

→ The area to be illuminated.

→ Height at which the lamps are mounted.

→ The colour of the surrounding that is walls, sellings etc.

→ The type of lighting that is indirect or direct.

⇒ The value of Utilization factor for direct lighting is 0.25 to 0.5.

⇒ The Utilization factor of indirect lighting vary betⁿ 0.1 to 0.3.

Depreciation factor -

Depreciation factor can be defined as the illumination on a working plane under normal working condition. And the illumination on that plane when every-thing is clean.

and can be written as,

$$\text{Depreciation factor (D.F)} = \frac{\text{Illumination under normal working cond}^n}{\text{Illumination when everything is clean.}}$$

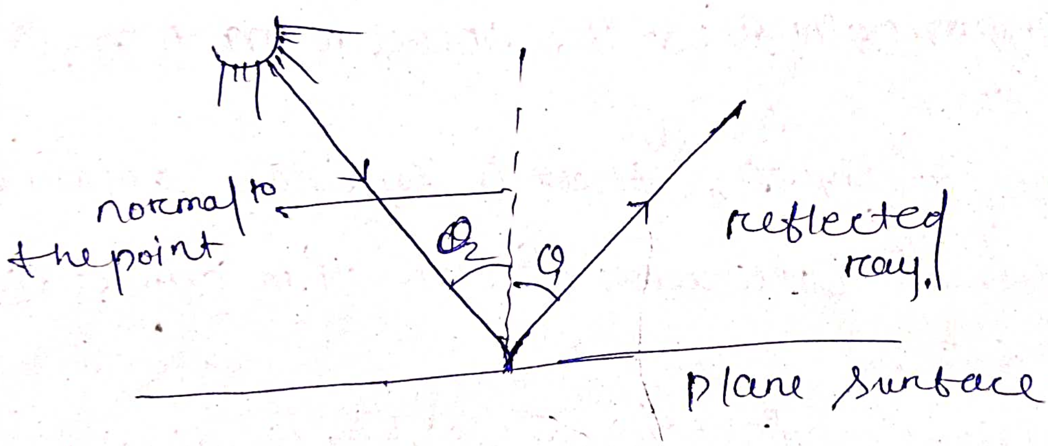
→ The average depreciation value is 0.8.

Waste Light factor -

A surface when illuminated by number of lamps there is a certain amount of wastage due to overlapping of light waves. That is waste light factor.

→ Waste light factor value for rectangular 1.2 and irregular are 1.5.

Reflection factor -



When a ray of light incident on a surface it is reflected from the surface in a certain portion of incident light is absorb by the surface. So, reflection factor can be = $\frac{\text{Total light Reflected}}{\text{Total light incident}}$.

Reduction factor -

$$\text{Reduction factor} = \frac{MSCP}{MHCP} = \frac{\text{Mean Spherical Candle power}}{\text{Mean Horizontal Candle power}}$$

Beam factor

$$\text{Beam factor} = \frac{\text{Lumens in the beam of the projector}}{\text{Lumens given out by lamp}}$$

→ It vary's between 0.3 to 0.6

Obesation factor

The places where atmosphere is full of smoke, fumes, there is a possibility of obsation of light. The obesation can be written as total lumens available

$$= \frac{\text{After obesation}}{\text{total lumen emitted by the source}}$$

It is unity for clean atmosphere and 0.5 foundries

Lumen's efficiency

It is defined as the ratio of luminous flux to the power input.

→ It's unit is $\frac{\text{lumens}}{\text{watt}}$.

Specific energy Consumption

It is defined as the ratio of power input to the average candle power.

→ It's unit is watt/candela. Space height ratio.

→ The horizontal distance are used those values varies between 1 & 2.

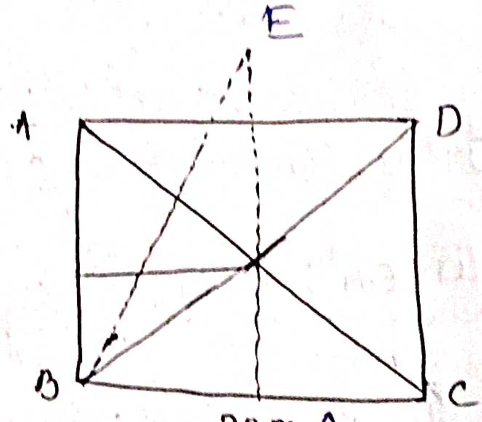
PROBLEM -

A lamp of 500 C.P is placed at the centre of room 20 m × 10 m × 5 m Calculate the illumination in each corner of the floor & a point in the middle of a 10 m wall at a height of 2m from the floor?

Solution.

Given,

Candle power $C_p = 500$



According to Lambert's cosine law

$$E = \frac{I}{h^2} \cos^3\theta$$

$$E = \frac{I}{d^2 \cos^2\theta} \times \cos^3\theta \quad (\because h = d\cos\theta)$$

$$\boxed{E = \frac{I}{d^2} \times \cos\theta}$$

In ΔBCD,

$$h^2 = p^2 + b^2$$

$$\Rightarrow h = \sqrt{100+400}$$

$$\Rightarrow \boxed{h = \sqrt{500} = 22.36\,m}$$

In Δ BOE,

$$BE = \sqrt{(11.18)^2 + 25}$$

$$= \sqrt{124.99 + 25}$$

$$= \sqrt{149.99}$$

$$\boxed{BE = 12.24\,m}$$

$BE = 12.24m = d$

$$\boxed{\cos\theta = \frac{b}{h} = \frac{5}{12.24} = 0.408}$$

$$E = \frac{Cp}{d^2} \times \cos\theta$$

$$= \frac{500}{(12.24)^2} \times 0.408$$

$$= \frac{500}{149.81} \times 0.408$$

$$\boxed{E = 1.361\ lux}$$

Requirement of good lighting in Design of lighting Schemes.

1. Illumination level
2. Uniformity of illumination.
3. Colour of light.
4. Shadows.
5. Glare.
6. Mounting height.
7. Spacing of luminaries.
8. Colour of surrounding walls.
9. Colour rendering.

ELECTRICAL SOURCE OF LIGHT

Incandescent lamp :-

These are also known as filament lamps.

Principle of incandensce -

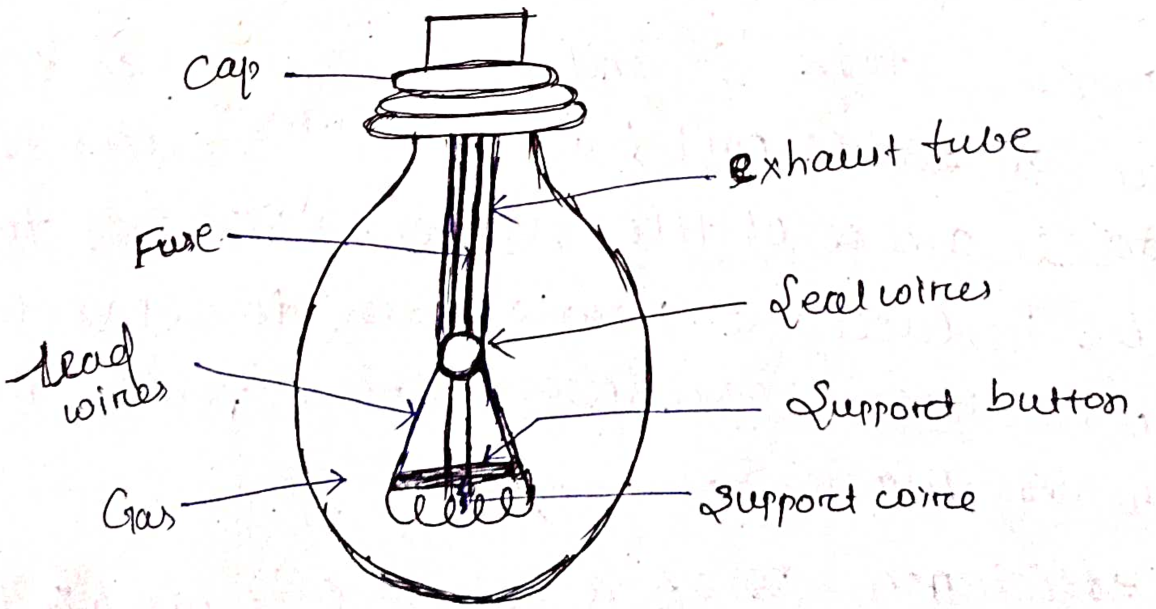
When current is passed through the wire both heat and light are produced. When wire is red hot it emits more heat as compare to light. At white hot position, the amount of light radiation being much more than heat energy.

The material used for filament of filament lamp must have following properties.

(i) Should have high melting point.
(ii) Should have high resistivity.
(iii) Should have low temperature coefficient.
(iv) Should have low vapour pressure.
(v) Should have mechanically strength to withstand vibration.

→ The material used for filament ~~in~~ ~~certain~~ are of carbon, osmium, tantalum & tungsten.

→ Tungsten is most commonly used metal filament, because it fulfil above all properties, Moreover lamps with tungsten filament has higher efficiency than, carbon, osmium & tungsten filament lamps.



Fig

→ This figure shows the construction of a gas filled incandescent lamp which is in common used these days.

→ It consists of a tungsten filament placed in a glass cover.

→ Tungsten has a high melting point of 3500°C, high specific resistance, low rate of evapouration, ductility and high mechanical strength.

→ The glass bulb is filled with a chemical inert gas as nitrogen or argon at about atmospheric pressure to reduce rate of evapoureration and to avoid the deterioration due to oxidation.

→ It causes increas in life of filament.

→ The filament is supported on wire hooks fixed in a glass stem 'S' and is normally in the holical or ~~coiled~~ coiled coil form. This reduces the surface area of the filament exposed to gas & thereby reduces the heat loss due to convection and it also reduces space requirement for the large length of filament.

→ The efficiency ~~of~~ of a coiled coil lamp is high as compared to single coil lamps and it requires less no of supports for the filament.

→ Lamps below 40 watt are not filled with gas. This is due to the fact that a lot of heat will be wasted in these small sized bulbs due to conventional flow of gas which will transfer heat from the filament to the walls of bulb which are quite close to the filament.
→ This will reduce the lumens emitted by the filament.

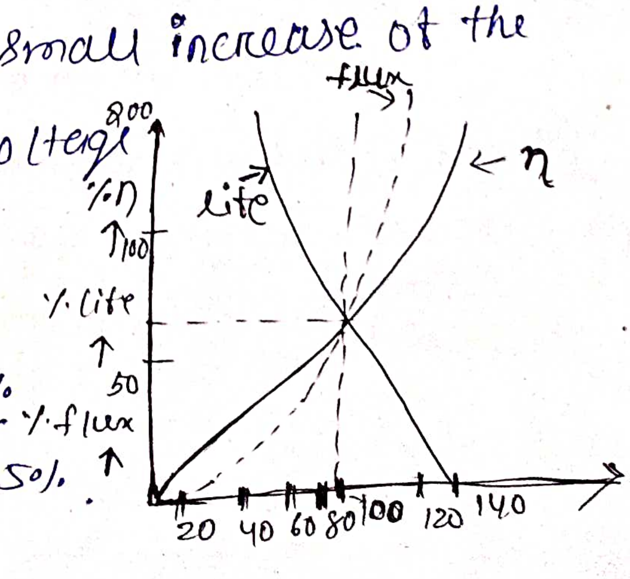
RATING

The rating of the bulb specified in volts and wattage i.e 60 watt, 230 V or 100 w, 250 v etc.

→ If the bulbs of a given voltage rating are not operated at the rated voltage, there is direct influence on the
(i) Lumens output
(ii) Life
(iii) Efficiency.

→ The above effect can be more appreciated by looking in the figure.

→ It can be noted that a small increase of the order of 5% in the operating voltage reduces the life by 50%.
Similarly 1% change in the applied voltage changes the wattage by 1.5%, efficiency by 2% and o/p by 3.5%.



→ We can conclude that, operation of lesser voltage than the operating value increases the life, at the same time output decreases.

EFFECT OF GLASS COVER -

→ The type and colour used for the glass cover produces a vital effect on the quality of light emitted from as incandescent bulb i.e milky glass cover gives a difused light output, which is almost like daylight. The bluish glass cover gives the moon light effect which is pleasant only on hot summer lights.

→ The gree, yellow & red glass covers are useful for signalling purposes.

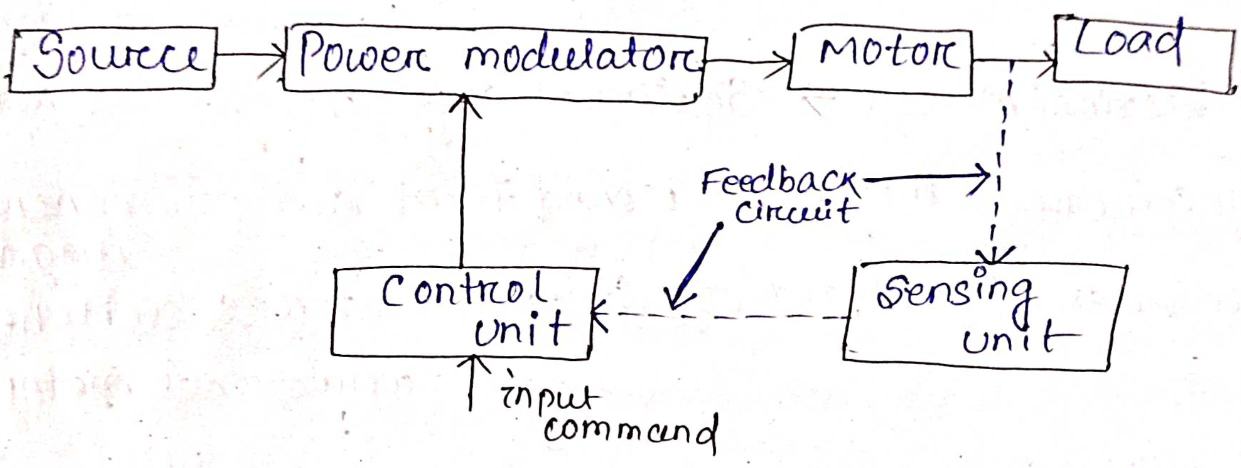
→ Other miscellaneous glass cover used for decorate purpose.

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) <u>Source:-</u> It is either type of electrical power d.c or ac supply.

(b) <u>Power Modulator :-</u>

→ 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.

(c) Load :-

It is usually a machinery designed to perform a given operation i.e fans, machine tools, domestic appliances, trains, pumps etc.

(d) Motor :-

Motors commonly used for electrical drives are D.C motor → Shunt, Series, Compound and permanent magnet.

Induction motor → Squirrel cage and wound rotor.

Synchronous motor → wound field and permanent magnet.

Brushless D.C motor → Stepper motor & switched reluctance motor.

(e) Sensing Unit :-

It is employed for sensing the drive parameters, such as speed, motor current etc. which may be required either for protection purpose or for closed loop operation. These signals are fed to control unit.

(f) Control Unit :-

It controls the power modulator besides generating commands for the protection of motor and power modulator. It usually operates at much lower voltage and power levels.

→ Input command signal, which adjusts the operation of drive forms an input to the control unit apart from signals from the sensing unit.

Types of Electric Drives

1) Group Drives
2) Indivisual Drives
3) Multi-Motor Drive

① Group Drives -

In this one motor is used as a Drive for two or more than two machines.

→ The motor is connected to a long shaft on which belt and pulleys are connected to run other machines.

→ It is also called line shaft drive.

→ This type of electric drive is economical, as a single motor of large capacity costs less than the costs of a number of small motors of the same total capacity.

Advantages :-

① Initial cost of group drive is less as compared to that of an indivisual drive.

② Group drive system is useful because all the operations are stopped simultaneously.

③ Less space is required in Group drives as Compared to indivisual drive.

④ It require little maintainance as compared to indivisual drives.

Disadvantages of Group Drives :-

① Group drive has low power factor.

② Group drive system when used, it all the machines are not running together the main motor shall work at very much reduced load.

③ In group drive, if the main motor fails then whole industry will come to stand-still.

④ Such arrangement is not possible for the places where flexibility is the factor.

⑤ Group drive doesnot provide constant speed.

⑥ Group drive is not suitable for driving heavy machines such as Cranes, lifts and hoists etc.

(2) Indivisual Drive.

→ In this type of electric drive a single electric motor is used to drive one indivisual machine.

→ Though it costs more than group drive but each operator has compleete control on his machine, which enables him to either increase the speed of the motor or to stop it while not in operation.

-> Machines can be located at convenient places.
-> If there is a fault in one motor, this will not affect the production of the industry appreciably.

Advantages of Individual Drives -

① Individual drive give desired operation as each machine is driven by its own individual motor.
② Individual motor works at good power factor.
③ Efficiency of the system is high.
④ Individual drives is more reliable.
⑤ Machine may be fitted wherever convenient.
⑥ More useful where constant speed is required.
⑦ Individual drive is more suitable for driving heavy machines such as lifts, hoists and cranes etc.

Disadvantages :-

1) In case of fault in motor, all the connected machines to this motor will case to operate.

2) If at certain instance all the machine are not in operation, then the motor will be working at low capacity.

3) It is not possible to install a new machine at a faraway distance.

4) Speed control of different machines using belts and pulley is difficult.

Choice of Electric Drives -

1) **Requirements related to the source :-**

Types of source, and its capacity, magnitude of voltage, voltage fluctuation, power factor, harmonics and their effect on other loads and ability to accept regenerated power.

2) **Steady State operation Requirements :-**

Nature of the speed torque characteristic, speed regulation, speed range, efficiency, duty cycle, quadrants of operation, speed fluctuations and ratings.

3) **Transient requirements :-**

Starting, breaking, values of acceleration and de-acceleration reversing performance.

4) Capital and running Cost.

5) Environment and Location.

6) Reliability.

7) Space and height restrictions.

Starting and Running Characteristics of DC and AC motors

DC Motors -

In all d.c motors, the torque is given by the equation

$$T = \frac{\phi Z P I_a}{2\pi A}$$

$\Rightarrow$ $T \propto \phi I_a$ ($\because 2\pi, Z, P, A$ are constant)

$\Rightarrow$ $T \propto I_a^2$ in case of series motor

$\because \phi \propto I_a$ upto saturation

Speed, $N = \frac{E}{\phi Z} \times \frac{60A}{P}$ rpm

$\Rightarrow$ $N = \frac{V - I_a R_a}{\phi Z} \times \frac{60A}{P}$ $(E = V - I_a R_a)$

Where, V = supply voltage.

I_a = Armature current.

R_a = Armature Resistance.

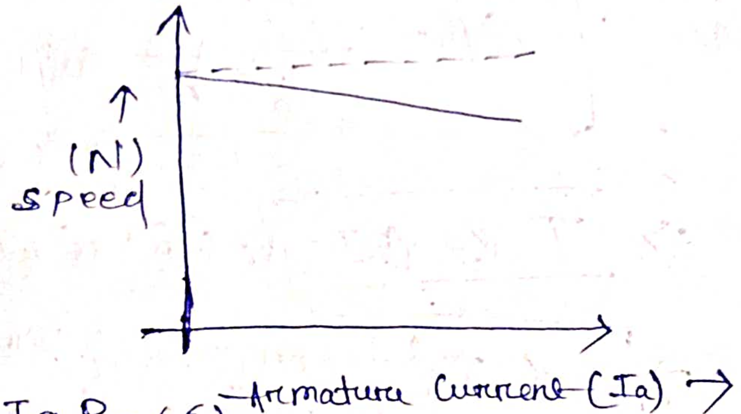
$$N \propto \frac{V - I_a R_a}{\phi}$$

(All other quantities being constant)

(i) D.C Shunt Motor -

In a Shunt motor the field winding is connected in parallel with armature winding.

(a) Speed - Current Characteristics :- (N ~ Ia)



$$N = \frac{V - I_a R_a (E_b)}{\phi}$$

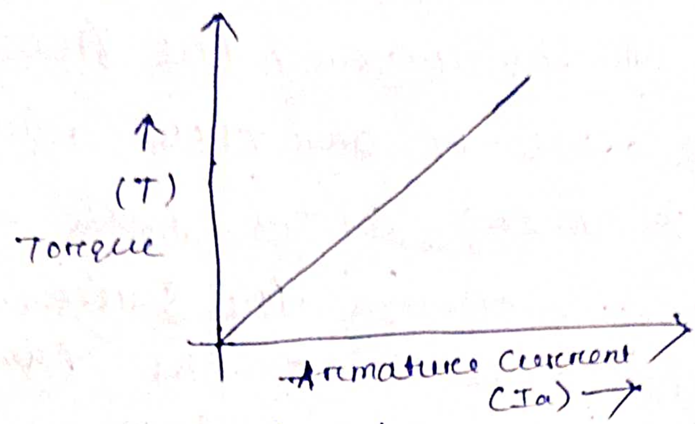
→ It is clear that the speed is directly proportional to the back emf E_b and inversely proportional to flux 'φ'.

→ But in this case if the applied voltage V is kept const. the flux 'φ' will be also constant.

→ When load on the motor is increased the current in armature increases thus increasing in the voltage drop in armature and hence decreasing the speed of motor.

→ As the drop in armature at full load is very small as compared to applied voltage V, therefore drop in speed from no load to full load is again very small and the motor can be used as compared to a constant speed motor.

(b) Torque - Current Characteristics :- ($T \sim I_a$)



From the expression for torque

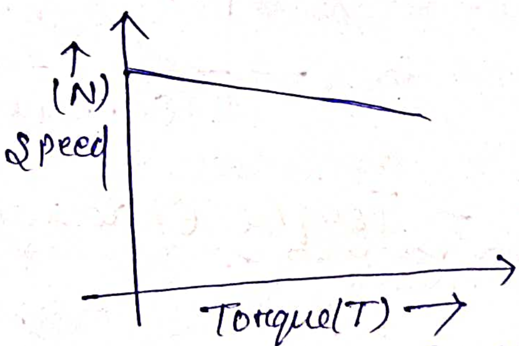
$$T \propto \phi I_a$$

In case of shunt motor ϕ is constant

i.e $T \propto I_a$

$$\Rightarrow \boxed{T = K I_a}$$

(c) Speed - Torque characteristics :- ($N \sim T$)



In a dc shunt motor, when the supply voltage 'V' is constant, the field flux ϕ is also constant and hence speed of the motor depends mainly on armature current.

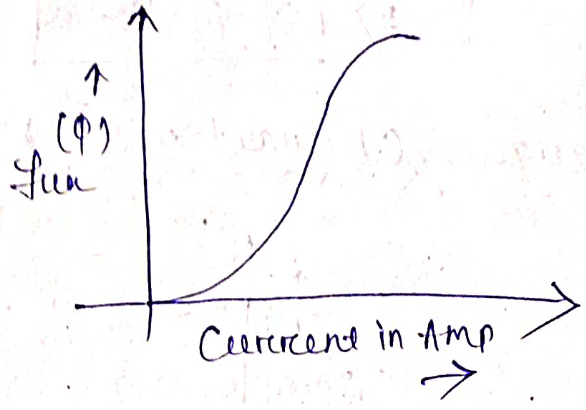
→ The speed decreases with the increase in armature current, But torque also increases with the increase in current. Hence the torque-speed characteristics for a d.c shunt motor will be a straight line with a slight drop.

(ii) D.C Series Motor -

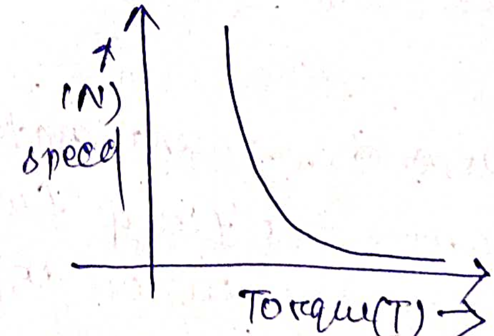
In this motor, the field winding is connec[ted] in series with the armature winding.

→ It means as the load on the motor increa[ses] the current through the series winding also increa[ses] or in other word the flux varies accordi[ng] to the load on the motor.

→ The flux φ first increases with the increase in load current and then become maximum at saturation point and finally becomes constant.

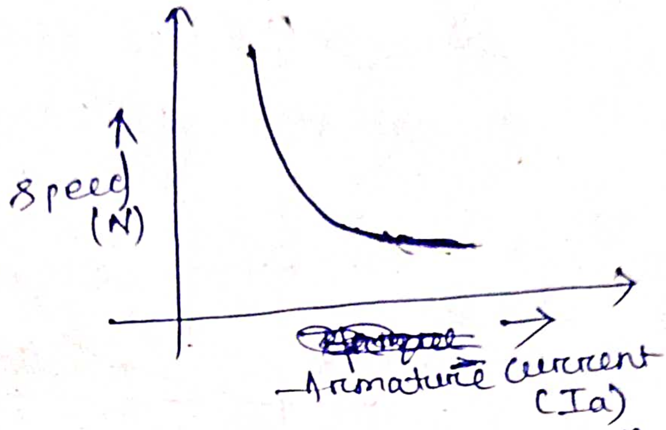


(a) Speed - Torque Characteristics :- (N ~ T)



Speed of the motor decreases with the increase in torque. Hence series motors are best suited for services where the motor is directly coupled to the load such as in electric trains.

(b) Speed - current characteristics :- ($N \sim I_a$)



→ Speed is a Series motor is inversely proportional to the applied voltage. flux/pole and directly proportional to the applied voltage is kept constant then

→ If the applied voltage speed at no-load $N \propto \frac{1}{\phi} \propto \frac{1}{I_a}$ because ($\phi \propto I_a$)

Hence at light loads the speed is dangerously high and comes down sharply with the increase in load.

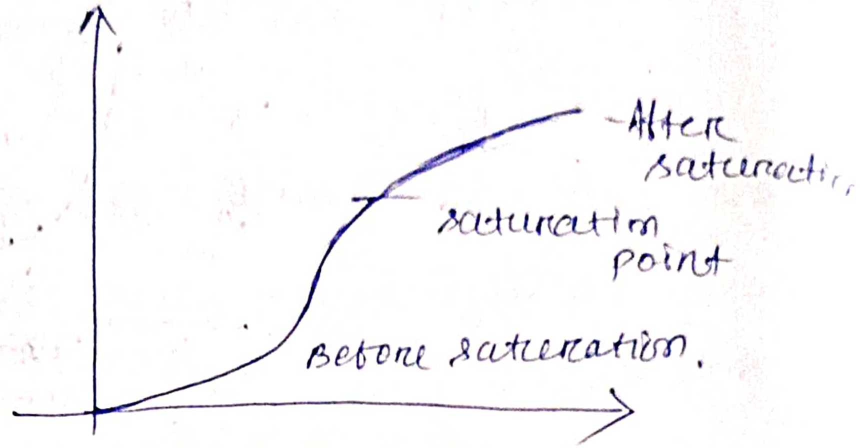
→ A series motor is a variable speed motor.

→ Dangerously high speed at no load may produce heavy centrifugal forces which in turn may result in damage to the machine.

Hence the series motor should never be used where there is a possibility of entire removal of load from the motor.

→ The automatic reduction in speed due to excessive current drawn by d.c series motor proves quite useful in electric traction as the motor relieves itself of excessive loads.

(c) Torque - Current Characteristics :- ($T \sim I_a$)



In Series motors torque $T \propto I_a^2$ upto Saturation Hence the curve drawn between armature current and Torque is parabola upto saturation point and after the saturation point flux φ becomes constant therefore torque $T \propto I_a$ and the curve becomes Straight line.

→ It is evident from the torque - current Characteristics; that at start torque is directly proportional to the square of the current. ~~of~~

→ Therefore the starting torque of the d.c series motor, is very ~~also~~ high so, it can be used where large starting torque is required such as in electric trains, cranes, ~~trolleys~~ trollys and other electric veichles.

(iii) Compound Motors -

(1) Cumulative Compound Motor.
(2) Differentially compound Motor.

(1) Cumulative Compound Motor:

In these motors series field winding is connected to assist the shunt field.

→ The characteristics of such motors are the combination of series and shunt motor.

* Cumulative Compound motors are used in driving machines which are subjected to sudden application of heavy loads i.e in rolling mills, shears and punches etc.

This type of motor is also used where a large starting torque is required

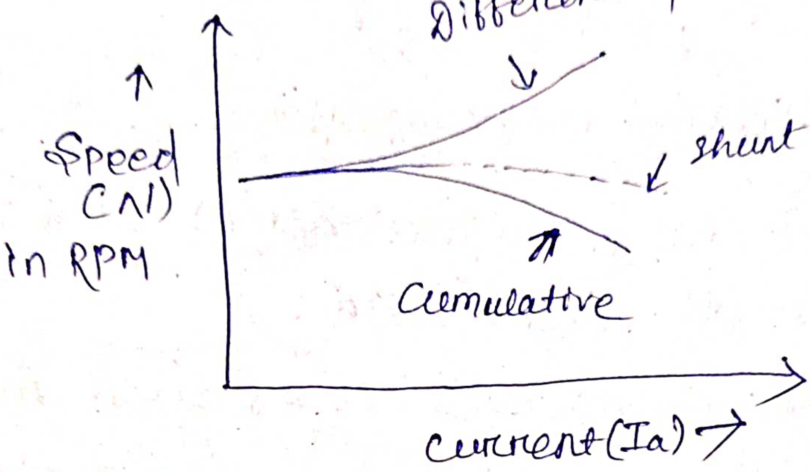
(2) Differentially compound Motor -

In this motor series field opposes the shunt field. Speed remains constant and sometimes increases with the increase in load.

→ This motor may rotate in opposite direction at high loads.

→ This type of motor is seldom used practically.

Speed ~ current characteristics of cumulatively Compounded motor and differentially compounded Motor



In case of compound motor, field has both shunt winding as well as series winding.

In case of cumulatively compounded motor

→ In case of cumulatively compounded motor series field helps the shunt field with the result that for the same value of armature current, the field of compound winding is more than that of shunt or series winding.

Speed 'N' of shunt motor drops down with increase in current,

$$N \propto \frac{E_b}{\phi}$$

Since flux of cumulatively compound motor is more than shunt motor, speed of this motor shall be lesser than that of shunt motor.

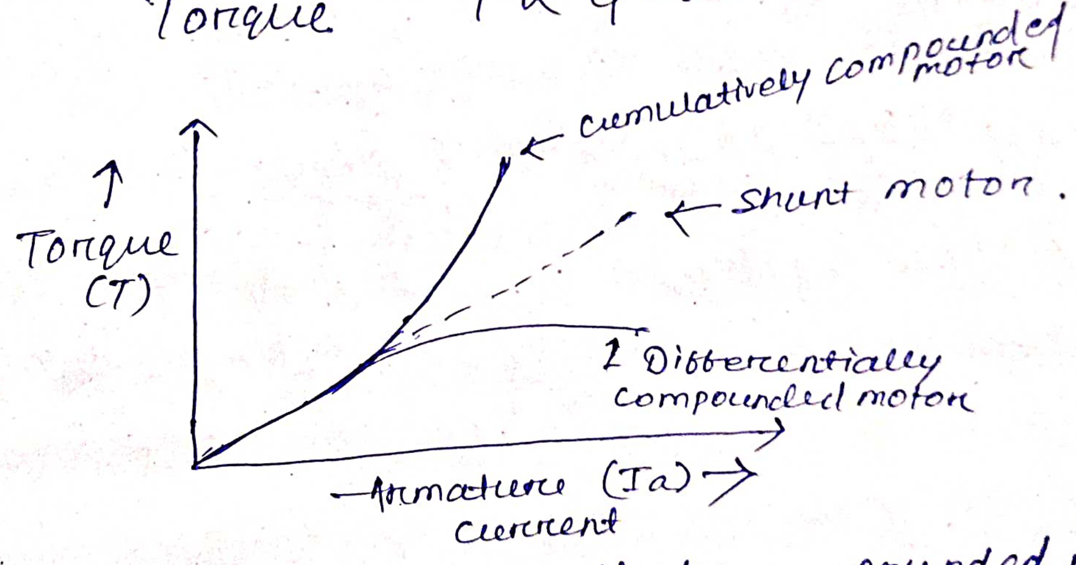
→ In case of differentially compounded motor, the series field opposes the shunt field as a result for the same value of armature current, the flux produced by differentially compounded motor is lesser than that of shunt motor.

$$N \propto \frac{E_b}{\phi}$$

Since, flux is lesser than of shunt motor, speed is more than that of shunt motor for the same value of armature current.

Torque ~ Current Characteristics of cumulatively compounded motor and differentially compounded motor

Torque $T \propto \phi I_a$



Flux in case of cumulatively compounded motor is more than the shunt motor so, torque developed in cumulatively compounded motor is more than that of shunt motor for same armature current.

→ In case of differentially compounded motor, flux is less than that of shunt motor so torque developed is lesser than that of shunt motor.

→ Thus cumulatively compounded motor are used in driving machines which are subjected to sudden application of heavy loads such as in Rolling mills, shear and punches.

→ This type of motor is also used when high starting torque is required and series motor cannot be used conveniently such as in cranes and elevators.