Electrical Heating

Electrical heating is a process in which electrical energy Converted to heat energy.
E.g → Electric heater, Room heater, Immersion water heater.
For industries electrical heating is used for welding, melting, tempering, hardening & drying.

Advantages of Electrical heating :-

(1) No pollution / Cleanliness → dust & ash are completely eliminated in electric heating system.
(2) Free from flue gases → no flue gas is produced in this system.
(3) Economical → electric furnaces are cheaper in initial cost as well as Maintenance cost.
(4) Temperature can be done very easily → It can be controlled by hand operated or by fully automatic Switches.
(5) Automatic Protection → Automatic Protection against over Currents or over heating can be provided through suitable Switchgears in the electric heating system.
(6) Heating of non conducting Material → Use dielectric heating Process
(7) Uniform heating - The heating can be generated from within the workpiece resulting in uniform heating through induction heating.
(8) Noise free → It does not creat any noise.
(9) High efficiency → Most of the heat produced is utilised by the material being heated electrically. This results in the higher efficiency.
(10) Safety → Electric heating is quite safe & responds quickly

Mode of Heat Transfer :-

Heat will transfer in 3 modes

(1) Conduction
(2) Convection
(3) Radiation.

(1) Conduction is a process in which heat is transferred from the ~~holt~~ hotter part to the colder part in a body.
(bet? two substance)

E.g → when frying vegetables in a pan. Heat transfer takes place from flame to the pan & then to the vegetable.

$$\boxed{\text{Heat dissipation } (H) = \frac{KA}{x}(T_2 - T_2) \cdot \text{Time}} \quad w/m^2$$

K = Coefficient of thermal conductivity.
x = thickness
T_1 = Temp of the surface.
T_2 = Temp of the object absorving the heat.
A = Cross sectional Area.

(2) Convection → Heat is transferred in the liquid & gases from a region of higher temp. to a region of lower temperature.
E.g → Immersion of water, (water heater)

$$\boxed{H = a(T_1 - T_2)^b} \quad w/m^2$$

$a = 3.875$, $b = 1.25$

Radiation → Heat is transfer from hot body to cold body in a straight line without affecting the intervening medium.

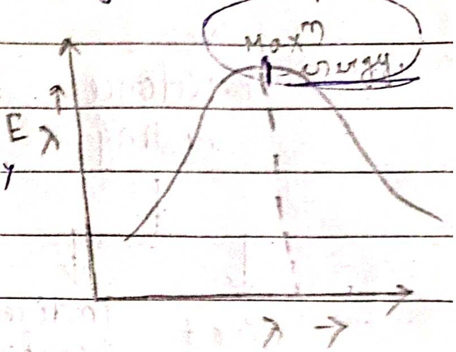
Rate of heat radiation is given by stephen's law :-

Energy radiated from a perfect black body is directly propotional to the fourth power of the absolute temperature.

consider:- Area under ($E_\lambda - \lambda$) curve represent the 'radiant emittance' of the body. Fig. show a curve bet^n wavelength (λ) & emissive power (E_λ) of black body.

Total Area below the curve = $\int_0^\infty E_\lambda d\lambda = E$

$\Rightarrow$ E = Radiant emittance of black body



(Radiant emittance

$\uparrow E_\lambda = \frac{1}{\lambda} \downarrow$

According to stephen's law.

$E \propto T^4$

$E = \sigma T^4$

σ = Stephen's constant

$\sigma = 5.735 \times 10^{-8}$ W/m^2K^4

$E' = e\sigma T^4$

e = emissivity of heating element.

Heat dissipated(H) = $5.72 \times 10^4 ke \left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right]$ W/m^2

where,

$\boxed{H = \sigma A t T^4}$

K = Radiant efficiency

K = 1 (for single element)

= (0.5-0.8) for several element

T_1 = Temp. of the surface

T_2 = Temp. of the object absorving the heat

Surface area from which heat is radiated (S) = πdl

If, H power radiated /m^2 of the heating surface then the total power radiated as heat (P) = $H\pi dl$

Electric heating

- Power freq. heating (50Hz)
  - Resistance heating
    - Direct R.H (Resistance welding, Electrode boiler)
    - Indirect Resistance heating (Room heater, water heater)
  - Arc heating
    - Direct
    - Indirect
- High freq. heating (used in freq. gen) (50-5000Hz)
  - Induction heating
    - Direct core type induction heating (low freq) for Refining & melting
      - Direct core type furnace.
      - Vertical core type furnace
      - Indirect core type furnace
    - Coreless type Induction heating (high freq) (soldering, hardening, eddy current heating)
  - Dielectric heating.

Resistance (oppose the flow of current through it)

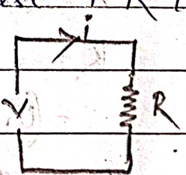
electrical power = $P = \frac{V^2}{R}$

$E = P.t$

$= I^2Rt$

* Resistance Heating :- Whenever current is passed through a resistive material heat is produced because I^2R loss.

→ Based upon I^2R loss.



I^2R loss

$H = I^2Rt$

↳ Heat produ

or :- When electric current passes through a resistance, a power loss takes place there in, which appears in the form of heat.

By taking the advantages of resistance w/ use it for heating method.

(1) Direct Resistance Heating.

(ii) In this method of heating, the material or charge to be heated is taken as resistance & current is passed through it.

→ (iii) High resistance material (charge) is contain in furnace. Two electrodes are immersed in the charge (liquid/powder/pieces)

* 3 ϕ supply we use 3 electrodes.

▶ (i) Electrodes remain directly connected with the charge that's why it is known as direct resistance heating.

(vi) → when metal pieces are heated, a power of high resistivity material is sprinkled over the surface of the charge to avoid short circuit.

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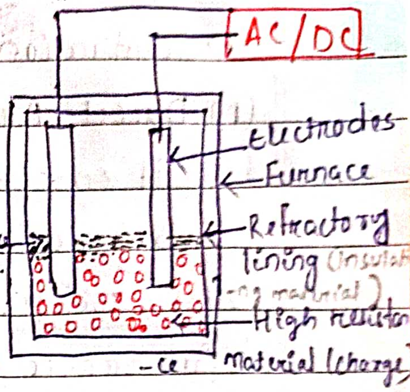
(iv) when electrodes connected with the supply, current flowing along the charge. (Due to I^2R effect charge heated)

According to Joule's law $H = I^2Rt$

High Resistance powder (Avoid S.C)

(v) → when electric current flow through the resistive conductor heat will be generate.

(vi) conduction process heat will be transferred.



Refractor → To save the furnace from heat.

Advantages → high efficiency, heat is produced in the charge itself, uniform heat & high temp.

Disadvantages → Automatic temp ~~cannot~~ control is not possible.

Application → salt bath furnace, resistance welding, melting, Electrode boiler for heating water. (Water heater)

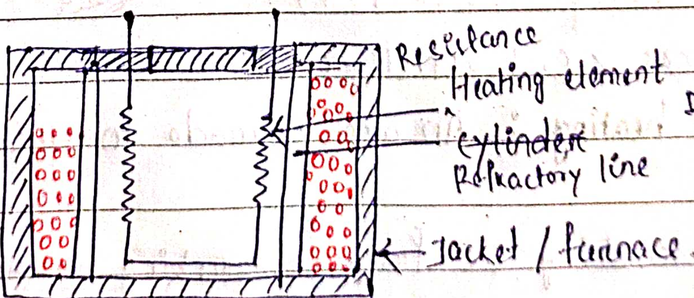
charge → The substance we want to heat.

Indirect Resistance Heating :- In this method, the current is passed through a highly resistance element which is placed above or below the oven.

→ The heat propotional to I^2R losses produced in heating element delivered to the charge either by radiation or convection.

Advantages → Uniform temp.
→ Automatic temp. Control.

Disadvantages → Efficiency low.



Application → Room heater, water heater, electric oven, hair drier ~~hot~~ toaster, Soldering Iron

Arc → The flow of current through an airgap between two conducting bodies.
Arc heating → The heating of material by the heat energy from an electric arc, which has a very high temperature & high concentration of heat energy.

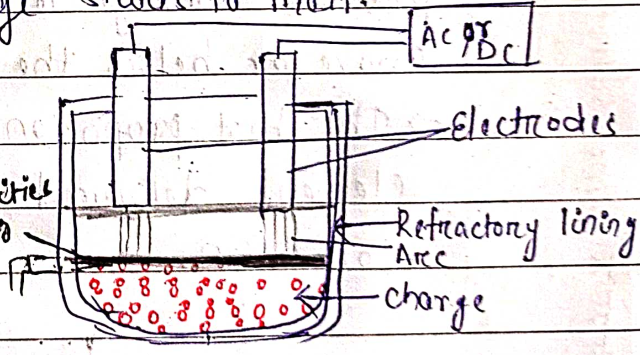
(1). Direct Arc heating :- (Direct Arc furnace) → Arc remain contact with the charge.

It concist of a circular furnace. Inner surface refractory (Heat Insulating materials) substance are coated. Refractories are used to save the furnace from heat. we poured charge inside this ~~surface~~ furnace.

An arc is made to strike between electrodes & charge itself. The heat energy of arc is absorbed by the charge & thus heating is done.

Material that have to heat is known as charge (Pieces). Medium between the electrode & charge is ionized & becomes a conducting medium. Current flows as a arc, due to arc heat will be generated. Due to high temp charge starts to melt.

(1000-3500°C)



Advantages → Pure product produce
Simply, easy to control.
Application → Production of Steel, Alloy Steel, Iron
Casting. (Producing Iron Product)
Disadvantages → cost effective.

Indirect Arc heating :- An arc is made to strike between two electrodes.
Fig. show a rocking arc furnace, working on the principle of indirect arc furnace. Supply is applied across the electrodes. The arc is struck by short circuiting the electrodes.
The heat from the arc is transferred to charge by radiation or through conduction.

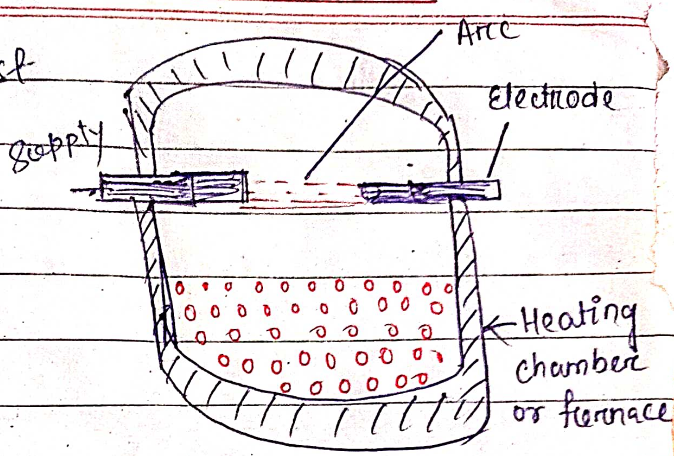
Advantages → lower the production cost

→ Metal losses are low.

→ Flexible in operation.

Application → Non ferrous metal.

→ Iron foundries.



Induction heating is a heating process in which eddy current is used to heat the metal work piece.

or

Induction heating processes make use of currents induced by electromagnetic action in the material to be heated.

→ It is based on the principle of transformer.

→ An electric current is induced in this metal when the ac current is passed through the primary coil.

Direct core type :-

It consist of an iron core, crucible & primary wdg. connected to an ac supply.

The charge is kept in the crucible, which forms a single turn short circuited secondary circuit.

The current in the charge is very high (several thousand amperes). The charge is magnetically coupled to the primary wdg.

→ The charge 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.

Disadvantages :- Because of air gap the leakage reactance is high. Power factor is low due to poor magnetic coupling.

→ Low freq supply is required.

$\uparrow X_L = 2\pi f \uparrow L$

so freq should be low.

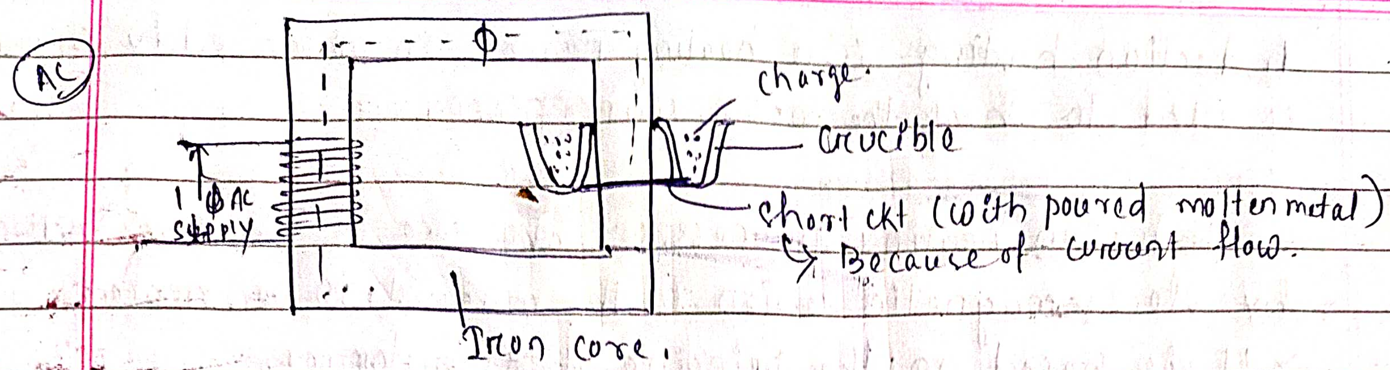
→ If current dencity is increase about $5A/mm^2$ the pinch effect (or) is there & that cause a complete interruption of secondary.

→ odd shape of crucibles are not convenient.

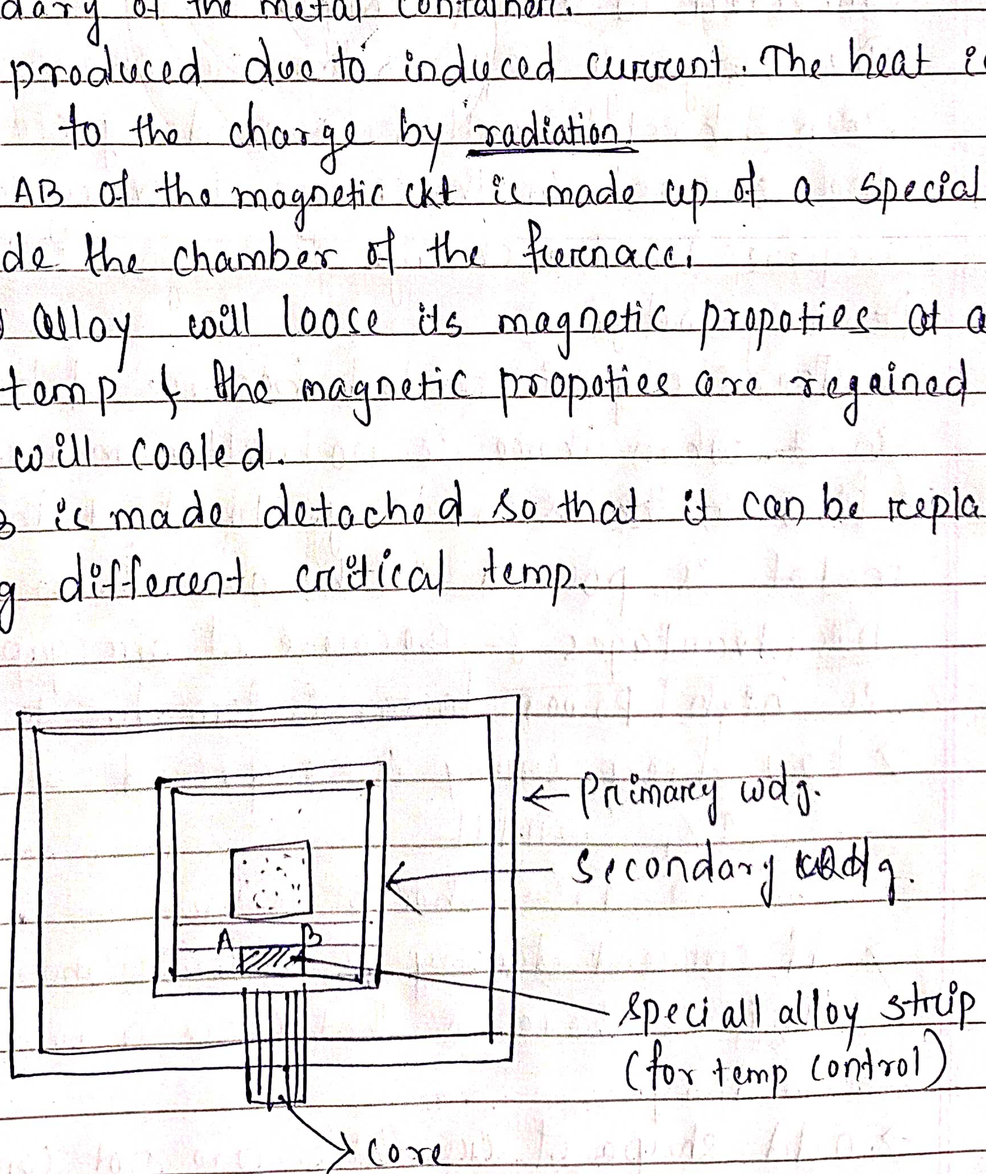
→ If secondary ckt is open furnace can not be function.

Pinch effect or f

Pinch effect → If the T/F sec current dencity exceeds $500A/cm^2$ then due to interaction of sec current with the alternating magnetic field, the molten metal is squeezed to the extent the secondary ckt is interrupted.



(2) Indirect core type - An inductively heated element is made to transfer its heat to the charge.
When the primary wdg is connected to the supply, current is induced in the secondary of the metal container.
→ So heat is produced due to induced current. The heat is transmitted to the charge by radiation.
→ The portion AB of the magnetic ckt is made up of a special alloy & kept inside the chamber of the furnace.
→ The special alloy will loose its magnetic propoties at a particular temp & the magnetic propoties are regained when alloy will cooled.
→ The bar AB is made detached so that it can be replaced by other having different critical temp.



Vertical core type (AJAX WYATT)

The principle of operation is that of a T/F in which the secondary turns are replaced by a closed loop of molten metal. The primary wdg is placed on the central limb of the core.

→ Hence leakage reactance is low & P.F is high. Inside of the furnace is lined with refractory depending upon the charge.

→ The top of the furnace is covered with an insulated cover which can be removed for charging.

→ To take out the molten metal outlet is constructed ~~in the secondary wdg.~~

→ The molten metal in the V portion act as a short ckt secondary when primary is connected to the ac supply, high current will be accumulated at the bottom & even a small amount of charge will ~~be~~ keep the secondary completed.

Advantages :-

→ High efficiency & low operating cost

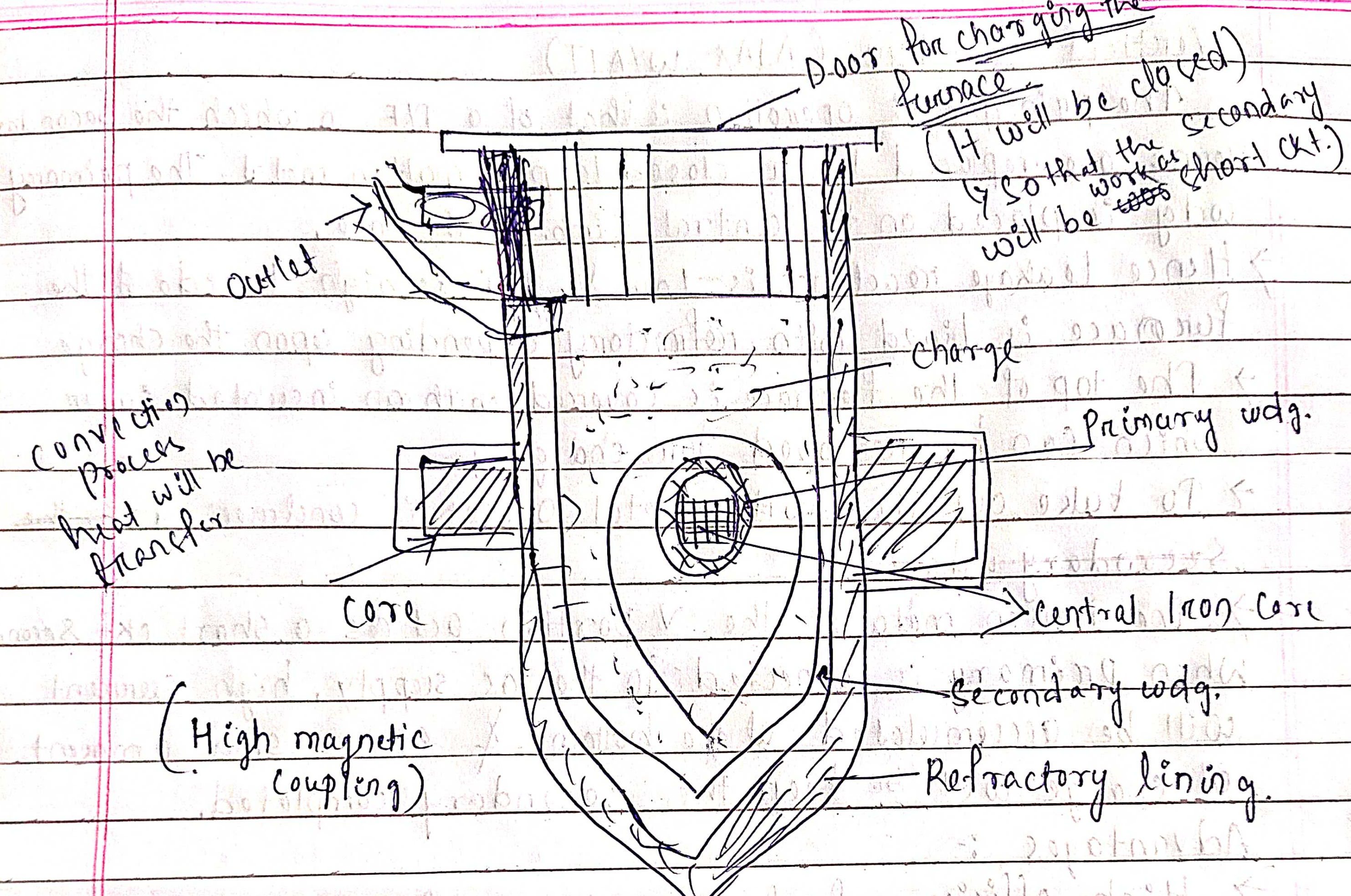
→ Since both primary & secondary are on the same central core, its P.F is better.

→ The furnace is operated from the normal supply freq.

→ chances of discontinuity of the secondary circuit is less hence it is useful for intermittent operation.

Application

Used in Foundries - for melting the refining brass & other non ferrous metal like (brass, zinc, tin, bronze, cu. etc)


Door for charging the furnace
(It will be closed)
(So that the secondary will be work as short ckt.)
Outlet
charge
convection process heat will be transfer
Primary wdg.
core
Central Iron Core
Secondary wdg.
(High magnetic coupling)
Refractory lining.

ॐ

Electrolyte → The substance which decompose when an electric current is passed through them are called electrolyte.
(Any chemical compound) → which conduct electricity.

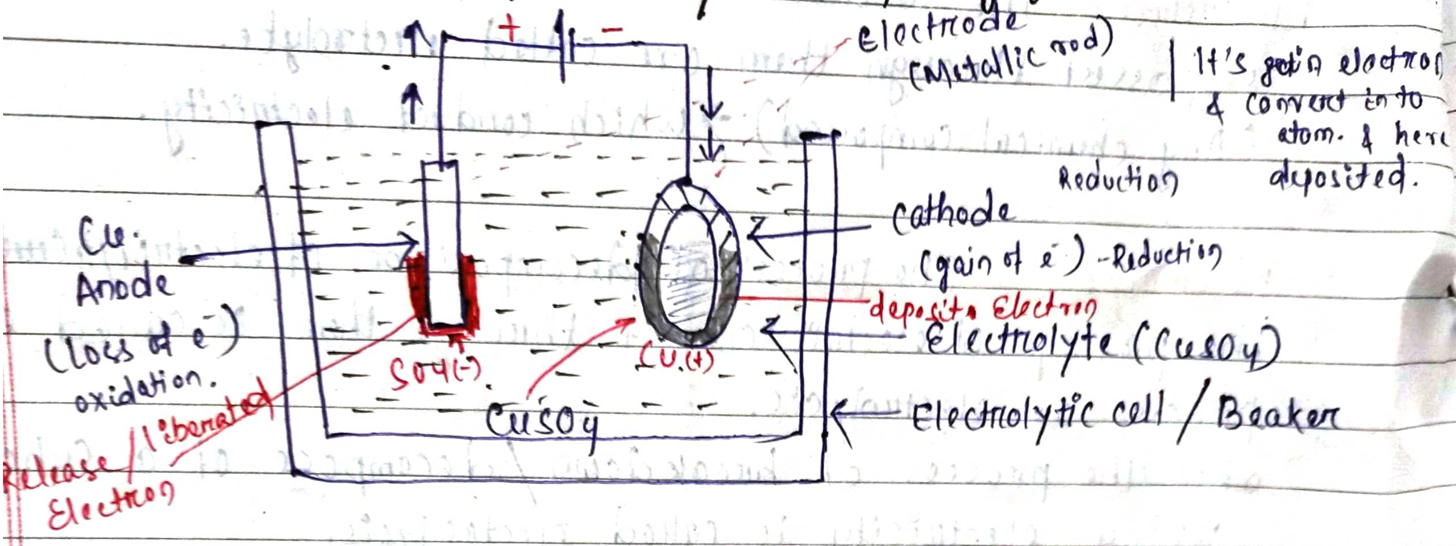
Electrolysis → The process of decomposition of electrolyte ~~current~~ by the passage of electric current through them is called electrolysis process or electrolysis. (2)
or// The process of breakdown / decompose of a substance using electricity is called electrolysis.
(non-spontaneous chemical reaction)
Electro (using electricity) + lysis (breakdown)

Electrolytic cell → Convert electrical energy into chemical energy. used in metallurgical processes, such as in extraction or decomposition, electro refining. Electro synthesis.

Electroplating or Electrodeposition :- (5/7)
The process of depositing a metal on the surface of some other metal by electrolysis is called electroplating.

Basic Principles of Electrodeposition :-
If two electrodes are dipped in an electrolyte & potential is applied across them, the electrodes are named as +ve (anode) & -ve (cathode). The molecules of the substance dissolved are dissociated. They are broken up into two types of ions i.e +ve & -ve ions. Since the ions are ~~dia~~ electrically charged, therefore the chemical & general propoties of an ion differ from those of same atom when free of charge.

Process of electro deposition / electroplating :-



Let us consider a ring of Iron to be given a copper coating.

$CuSO_4 \rightleftharpoons Cu^{++} + SO_4^{--}$

Copper sulphate ($CuSO_4$)

The sulphate SO_4 readily breaks into positive ions Cu^{++} (which are deficit in two electrons per ions) & SO_4^{--} -negative ions having two surplus electron per ion.

→ When two electrode get a dc supply through a battery, the -ve ions moves towards the anode (anion) made of copper. Each SO_4^{--} ion after transfer of two electrons to the anode becomes SO_4 radical. It attacks the copper anode to form $CuSO_4$ molecules; which dissolves one again in water to maintain electrolyte density at original level.

→ The positive copper ions reach the -ve electrode i.e the cathode & receive two electrons each from the supply ckt to become Cu. atoms. These get deposited on the cathode surface. Cathode as shown in fig is the job or article to be copper plated.

The Cu. deposited on the cathode surface is practically having the same mass as lost by anode, in maintaining the electrolyte strength.

charged
+ve. ions → Cations

At anode : SO_4^{--} (less two electrons) = SO_4 molecules in radical form.
(মৌলিক)

$$SO_4 + Cu \rightarrow CuSO_4$$

At cathode : Cu^{++} (plus two electron) = metallic Cu. atom to be deposited on the metallic cathode surface.

* The phenomenon of deposition of a metallic coating on the surface of some other metal, through the process of electrolysis is Electroplating / Electrodeposition.
(outside ckt electrons flow from cathode to anode) (-ve to +ve)

Important term
① Electrolyte - The soln of a salt when used for electrolytic process is called an electrolyte.
② Electrodes → The plates or rods immersed in an electrolyte & connected to dc supply are called electrodes.
leaves ③ → Anode → electrode connected to +ve terminal of the supply.
current enters ④ Cathode → " " -ve terminal "
⑤ Ions → when a DC is passed through an electrolyte, it get chemically decomposed into two parts knows as +ve ions & -ve ions.

ratio of its A.W & V.

$$\text{chemical equivant weight} = \frac{\text{Atmotic weight}}{\text{Valancy}}.$$

Electro chemical equivalent → Electro chemical eq. of a substance is the amount of deposited on passing a steady electric current of one ampere for one sec. through its soln.
Atomic weight → It is the weighted avg. of the atomic mass of all natural isotopes of an element.
Valency → It is a measure of its ability to combine with other atoms to form chemical compounds or molecules.

(2)
Imp **Current Efficiency :-** The percentage of the current which goes to the useful electroplating reaction.
→ It is the ratio betn the actual amount of metal deposit to that calculated theoretically from Faraday's law.

$$\text{Current Efficiency} = \frac{\text{Actual quantity}}{\text{Theoretical quantity}} \times 100.$$

$\boxed{90 - 98\%}$

Eg → Evolution of hydrogen occur during electrodeposition of Copper.

Energy Efficiency :- The actual voltage required for the deposition or liberation of metal. It is higher than the theoretical value which increase the actual energy required.

It is the ratio of

$$\text{Energy efficiency} = \frac{\text{Theoretical energy}}{\text{Actual Energy Required}}.$$

Imp **Faraday's Law's of Electrolysis :-** (5 or 7)
→ Faraday was deduced two laws on the phenomenon of electrolysis which are called Faradays law of electrolysis.
1st Law States :- The weight of substance liberated or deposited from an electrolyte in a given time is propotional to the total quantity of electricity passed in that time.
If W is the weight of substance liberated in grams.
then,
$$W \propto Q$$
$$W \propto I \cdot T$$
$$W = Z\,IT$$

Q = quantity of electricity passed.
= Strength of current (I) in ampe X Time in second during which the current in flow (T)

$Q = I T$

High amount of electr...
high amount of liberated/depo...

Z = constant
= electro chemical equivalent of the substance.
(It's value depends upon the nature of the substance)
If $I = 1A, T = 1\,sec$ $\boxed{W = Z}$

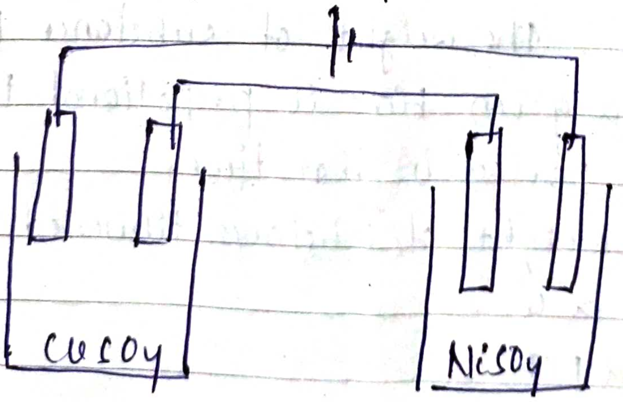
Electrochemical equivalent of a substance is the amount of that substance by weight liberated in a unit time by the passage of unit current.

Second law states :- If the same current flow for a given time through several ~~electricity~~ electrolytes, the weights of substance liberated are propotional to their chemical equivalent.

$$\text{Chemical Equivalent} = \frac{\text{Atomic weight of substance}}{\text{Valency}}$$

According to this law, if we take two electrodytes of copper sulphate ($CuSO_4$) & nickel sulphate ($NiSO_4$) in which the same current flow for the same time, then

weight of cu. deposited depends on chemical equivalent weight of cu.
weight of nickel deposited depends on chemical eq. weight of nickel.



M_1 & M_2 mass of element deposited.
E_1 & E_2 chemical equivalent

$M_1 \propto E_1$
$M_2 \propto E_2$

$$\frac{Z_1 I_1 T_1}{Z_2 I_2 T_2} = \frac{E_1}{E_2} \quad (I_1 T_1 = I_2 T_2)$$

$$\Rightarrow \frac{Z_1}{Z_2} = \frac{E_1}{E_2} \quad \Rightarrow \boxed{Z \propto E}$$

Electrodeposition :- The process of coating a thin layer of one metal on top of different metal to modify its surface propoties.

→ It is done to achieve the desire electrical & corrosion resistance, reduce water & friction, improve the tolerance & for decoration.

* Electroplating is a method of using an electric current to deposit a thin layer of metal over another. (From a solⁿ of containing a dissolved salt of the selected metal)
Chromium plating used in vechiles.
↳ Decorative, provide corrosion resistance, ease cleaning procedure.
Watch, mug, Automobiles, spoon.

Imp Factors Affecting the amount of Electrodeposition :- (5 or 7)

1. Time :- Time is directly propotional to the quantity of electrodeposition so we can say that more mass will be deposited in more time Less mass will be deposited in less time.
2. Efficiency :- Greater is the efficiency, greater is the quantity of metal deposited for a given time.
3. Current :- The value of current is also directly propotional to the mass of metal deposited.
→ Greater is the current, greater is the quantity of metal deposited.
4. strength of solⁿ :- If the strength of solⁿ is more, then the mass of Metal deposited will be more as compared to the dilute solⁿ of electrolyte if the other condition remain the same.

Imp Factors governing the better Electrodeposition :- (5 or 7)

(1) Current density :- A low value of current density, the ions are released at slow rate, therefore the deposit will be coarse & crystalline in nature.

At higher value of current density the quality of deposit ~~ions are released~~ become more uniform & fine ground. If the current density is so high that exceeds the limiting value for the electrolyte then a spongy & porous deposit is obtained.

$$\text{Current density} = \frac{\text{Current}(I)}{\text{Area}(A)} \ \text{Amp}/m^2$$

(2) Electrolytic concentration :- It depends upon the current density because by increasing the electrolyte higher current density can be achieved.

→ It gives better deposit & it's use concentrated electrolyte.

(3) Temperature :- The temp of electrolyte is different for different metals to have better deposit.

Chromium – 35°C, Co. → 50°, Ni – 50 to 60°C

(4) Addition of Agents :- The quality of a deposit is improved by the ~~pressure~~ presence of an addition agent which may be an organic compound such as gums, rubber, alkalies, & sugar etc.

→ Agents are absorbed by crystal nuclei & prevent their growth into large crystals.

(5) Nature of the Electrolyte :- The smoothness of the deposit largly depends upon the nature of the electrolyte.

(6) Nature of the metal upon which deposit is to be made :-
These factors influence the growth of crystals since it is believed that the operation of crystals is in continuation of these in the base Metals.

(1) Throwing power → Throwing power of an electrolyte may be regardless as the quantity which produces a uniform deposit on a cathode having an irregular shape.
It can be improved by 2 ways -
(i) By increasing the distance betⁿ the object & the anode so that the relative variation in resistance betⁿ the anode & the different parts on the the object is reduced.
(ii) By using some colloidal matter which results in the increase of current density. For this reason solⁿ of the ~~cy~~ cyanides of metals usually give a greater throwing power than solⁿ of the sulphate.

✓Application of Electrolysis :- (2)
1. Extraction of metal from their ores.
2. Extraction of Zinc.
3. Extraction of Al.
4. Refining of metals.
5. Production of chemicals.
6. Separating metal from their compounds.
7. Electrotyping
8. Electro forming
9. Electro deposition.
10. Electro cleaning.

Q. The worn out circular shaft 14 cm in diameter & 30 cm long it to be repaired by coating it with a layer of 1.5 mm of nickel. Determine the theoretical value of current required & the time taken if the current density used is 200 amps/m². Electro-chemical equivalent of nickel is 0.000304 gm/coulomb electricity & density of nickel is 8.9 gms/cu-cm.

Sol- Given data,

Diameter of shaft(d) = 14 cm , Thickness = 1.5 mm = $\frac{1.5}{10}$ cm

Length of shaft(L) = 30 cm , Current density = 200 amp/m²

density of nickel = 8.9 gm/cu-cm

E.C.E = 0.000304 gm/coulomb

Surface area of shaft = $\pi d L$

$= \pi \times 14 \times 30$

$= 1320\ cm^2$

Mass of Nickel to be deposited.

= Surface area × Thickness of Coating × Density of metal

$= 1320 \times \frac{1.5}{10} \times 8.9$

$= 1762.2$ gms

Theoretical value of quantity of electricity required.

$Q = \frac{m}{Z}$ (m = Q.Z)

$Q = \frac{1762.2 \text{ gms}}{0.000304 \text{ gm/clu-cm}} = 5796.710$ Amp/sec

(sec convert to hrs) 1hr.-3600sec

$Q = \frac{5796.710}{3600} = 16102$ Amp.hrs

Current density = $\frac{\text{Current}}{\text{Area}}$

→ Current = Current density × Area

Now current density used is 200 amp/m²

Current = Current density × Surface area in m²

$= 200 \times 1320 \times 10^{-4}$

$= 26.4$ Amp

Q = I.T

T = $\frac{Q}{I}$

Time required $= \frac{Q}{I} = \frac{1610.2}{26.4}$

$\boxed{T = 61 \text{ hrs}}$ (Ans)

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

$= \frac{1759.53}{0.000304}$

$= 5787927.631$ sec

hr

$= \frac{5787927.631}{3600}$

$= 1607.75$ hr.

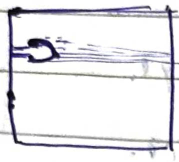
$I = 26.4$ Amp.

$T = 60$ hr.

Illumination

When the light falls on a surface then the surface become illuminated. This phenonomenon is called illumination.

$E = \phi / A$



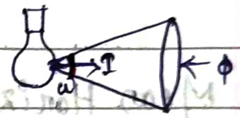
Light → cause

Illumination → Result.

Illumination makes the surface look more/less bright with a certain colour & it is this brightons & colour which the eye sees.

(ii) **Luminous Intensity** :- In any particular direction is the luminous flux emitted by the Source per unit solid angle in that direction.

$I = \frac{\phi}{\omega} = \frac{Flux}{Solid\ Angle}$ Candla



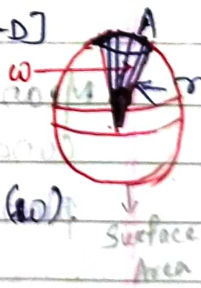
$cd = lm/sr$ = lumens / steradian

Plane Angle :- The angle subtended at a point by two converging lines lying in the same plane is called plane angle. [2-D]

θ = arc / radius (Radian)

(viii) **Solid Angle** :- The angle subtended by the partial surface area of a sphere at its centre is called as solid Angle. [3-D]

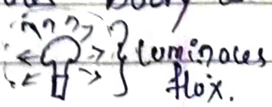
$\Omega = \omega = \frac{Area\ of\ Surface}{Square\ of\ Radius} = \frac{A}{r^2}$ Steradians.



No of angle creates in the ~~sphere~~ particular surface called (ω).

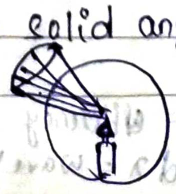
* Steredian :- when area = Radius $\omega = 1$ $\omega = r^2/r^2$

Luminous Flux :- The total quantity of radiant energy/second responsible for visual sencation from a luminous body is called luminous flux. (F or ϕ) → lumens



(i) **Lumen** :- Luminous flux emitted per unit solid angle from a point source of one candle power.

→ Unit of luminous flux.



02

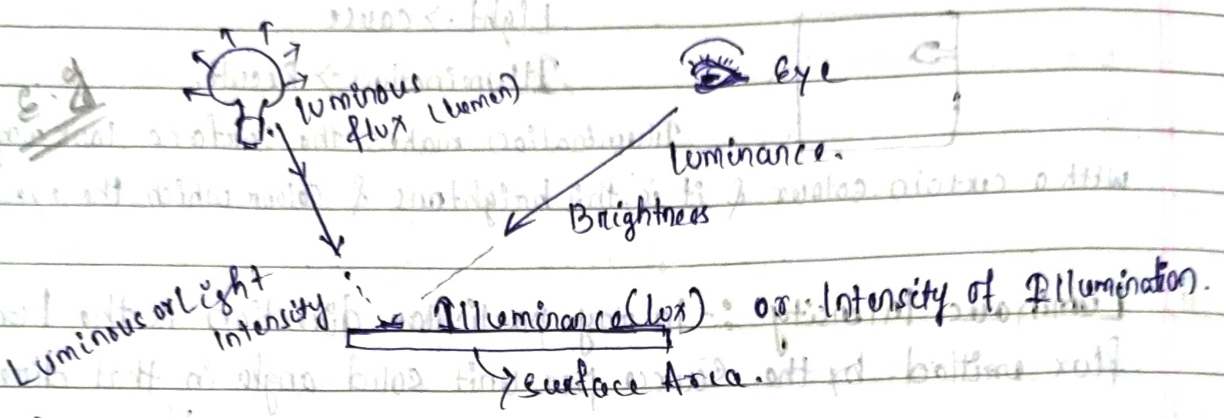
(viii) Brightness → It is defined as luminous intensity per unit projected or apparent area of either a surface source of light or illuminated surface.

I/A

→ depends upon Angle

Candle power – The light radiating capacity of a source is called its candle power.

C.P = Flux emitted / solid angle.



(iv) Mean Horizontal candle power (MHCP) :- It is average power of all the candle powers in all directions in the horizontal plane containing the source of light.

(v) Mean Spherical candle power (MSCP) :- The average of candle power in all directions (360°) & in all plane from the source of light.

MSCP = Total flux in lumens / 4π

(vi) Mean hemispherical candle power (MHSCP) :- The average of candle power in all directions above or below the horizontal plane passing through the source of light.

MHSCP = Total flux / 2π

(ix) Luminous efficiency / Radiant efficiency :-

It is defined as the o/p in lumens / watt of the power consumed by the source of light.

$$\frac{K\int_{\lambda_1}^{\lambda_2} E\,\eta\,d\lambda}{\int_0^{\alpha} E\,d\lambda} = \frac{\text{Total Energy converted into visual Effect}}{\text{Radiated on all wave lengths.}}$$

λ = efficiency at wave length.

$d\lambda$ = wavelength sampling increment.

λ_1 = Integrate over visible spectrum

λ_2 =

Intensity of Illumination → It is also called as illuminance. The intensity of light falling at a given place on a lighted surface i.e the luminous flux incident per unit area is called intensity of illumination. It is expressed in lumen per unit of area.

Inverce square law :- According to this law, the lumination of a surface is inversely propotional to the square of distance between the source & surface provided that the distance bet^n the source & surface is sufficiently large so that the source can be regarded as a point of source.

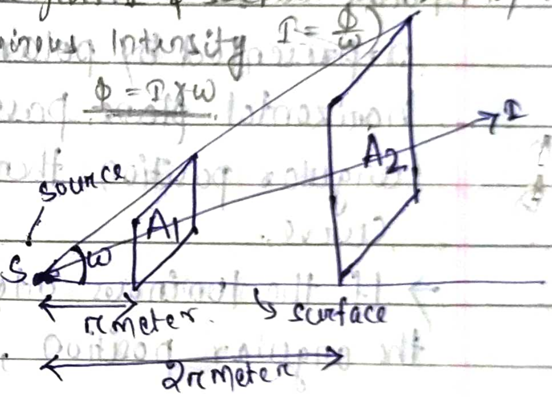
→ Consider a point source (S) having an intencity (I). Let two surface having areas A_1 & A_2 be placed at distance r & 2r m. from the source. The two surface area are enclosed in the same solid angle (ω). Source gives I & surface enclosed by ω

Total flux = I × ω (from luminous intensity $I = \frac{\phi}{\omega}$)

$\phi = I \times \omega$

Solid Angle (ω) = A_1/r^2, $\phi = I \times \omega$

$$\phi_1 = \frac{I \cdot A_1}{r^2}$$



Illumination, E_1 on Surface A_1

$$E_1 = \phi / A_1 = \frac{I \cdot \cancel{A_1}}{r^2} \times \frac{1}{\cancel{A_1}} = \frac{I}{r^2}$$

Similary $\phi_2 = \frac{I \cdot A_2}{(2r)^2}$ $\quad E_1 = \frac{I}{r^2}$

$$E_2 = \frac{I \cdot \cancel{A_2}}{2r^2} \times \frac{1}{\cancel{A_2}} = \frac{I}{4r^2}$$

$$\boxed{E_1 : E_2 :: \frac{I}{r^2} : \frac{I}{(2r)^2}}$$

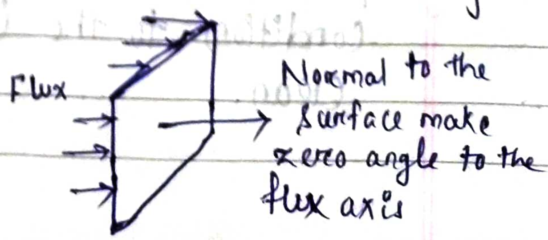
▶ Illumination at a surface is inversely propotional to the square of the its distance from the source.

Lambert's Cosine law :- According to this law illumination of a surface varies directly as the cosine of the angle bet^n the normal to the surface & direction of incident light.

$$\boxed{E \propto \cos\theta}$$

In normal surface

$$E = \frac{\phi}{Area.}$$

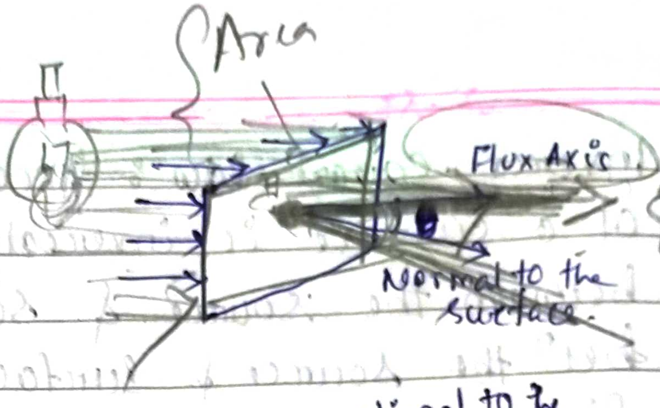


04

cos

$Sin = \frac{p}{h}$

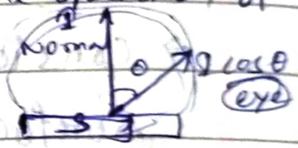
$Cos = \frac{b}{h}$



Inclined surface Area.

$$E = \frac{\phi}{Area} \times \cos\theta$$

Illumination on any surface (α) directly propotional to the cosine angle bet^n the direction of incident flux & $\perp$ (Perpendicular) to the area.

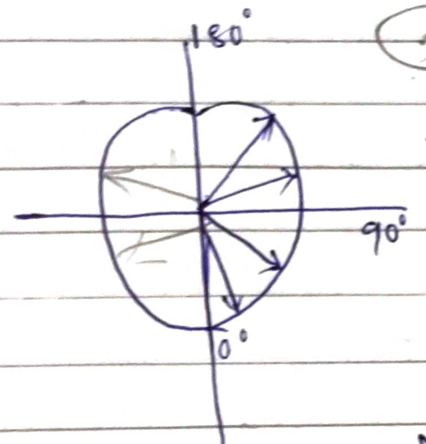


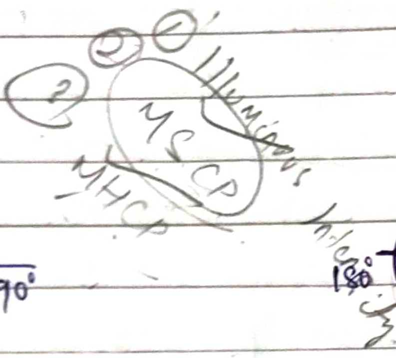
— x —

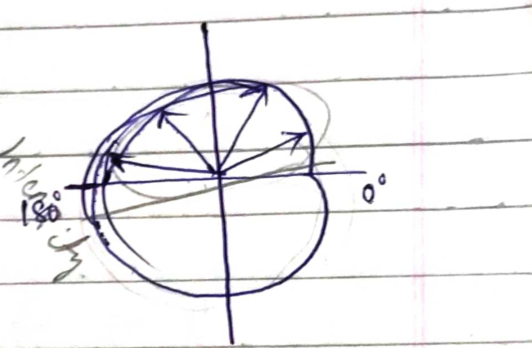
Polar Curve :- The luminous intensity in all directions can be represented by polar curve. The luminous intensity of any practical lamp is not uniform in all direction due to its unsymmetrical shape. The distribution of light is given by polar curves.

→ If the luminous intensity in a horizontal plane passing through the lamp is plotted against angular position then the curve is known as horizontal plane.

→ If the luminous intensity in a vertical plane is plotted against the angular position, then curve is known as vertical polar curve.







(vertical polar curve)
↳ Due to lamp holder

(Horizontal Polar Curve)
↳ Due to coil filament

* Angular position of horizontal / vertical plane & luminous intensity or candle power.

→ Polar curve are used to find the mean horizontal candle power (MHCP) & mean spherical candle power (MSCP).

→ It is also used to find the actual illumination of surface by employing the candle power in that specific direction. as read from the vertical polar curve in illumination ~~equation~~. Calculation.

→ From the horizontal polar curve by taking the mean value of the candle power in a horizontal direction.

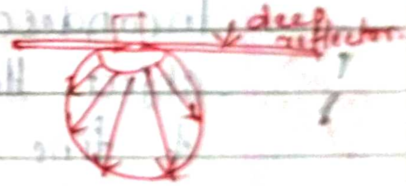
Maintenance factor :- The ratio of under normal working condition to the illumination when the things are perfectly clean.

Depriciation factor :- It is defiend as the ratio of initial meter candles to the ultimate maintained meter candles on the working plane. It is also the inverse of the maintenance factor.
[> 1]

Lighting scheme :-
It gives visual comfort. Visual comfort enhances the efficiency of a workman. Min^m glare & brightness ~~contra~~ contrast.

→ Lighting scheme are classified accroding to the location, requirement, & purpose etc.

(1) **Direct lighting** :- Almost 90 - 95% light falls directly on the object on the surface. The light is made to fall upon the surface with the help of deep reflectors.



Application → Industries & commercial lighting.
Disadvantages → glare & shadows.

(2) **Indirect lighting** :- The light does not fall directly on the surface but more than 90% of light is directed upwards by using diffusing reflectors.
→ The ceiling acts as a source of light & this light is uniformly distributed over the surface & glare is reduced to minimum.
→ It provide shadowless illumination.
Uses → Drawing offices, composing rooms, cinemahalls, hotels etc.

(3) **Semi direct lighting** :- This is also an efficient system of lighting & chances of glare are reduced. Here transparent type shades are used through which about 60% light is directed downward & 40% upword.
→ It provides a uniform distribution of light & for room with high ceilings.

07

Semi Indirect lighting :- (60 - 90%)

Total light is thrown upward to the ceiling for diffused reflection & the rest reaches the working plane directly.

→ A very small amount of light is absorbed by the bowl.

→ Used for Interior decoration.

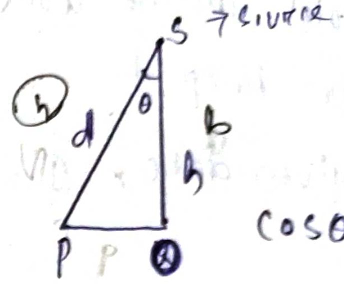
General lighting :- This system employs such type of luminaries, shades & reflectors which gives equal illumination in all directions.

→ The bulb is enclosed in a diffused glass envelope so as to produce uniform illumination in all directions.

08

Illumination at a point

let p be the point on a plane surface at a distance of d metre from a source of light s, the source is at a height h metres the source. source has a I candle power (C.P).



Now by 1st law of Illumination,

Illumination at point p

$$\boxed{E_p \propto \frac{1}{d^2}} \quad -(1)$$

According to 2nd law

$$\boxed{E_p \propto \cos\theta} \quad -(2)$$

$\cos\theta = -$

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

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

Combining (1) & (2), we get

$$E_p \propto \frac{1}{d^2}\cos\theta$$

$$E_p = \frac{I}{d^2}\cos\theta$$

$$= \frac{I}{\left(\frac{h}{\cos\theta}\right)^2}\cos\theta$$

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

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

Similarly illumination at point O can be calculated

At point O, $\cos\theta = 1$ (as $\theta = 0°$)

$d = h$

So illumination at point $O = \frac{1}{d^2} = \frac{1}{h^2}$

The illumination at a point on a working plane directly below the lamp is to be 100 lumens/m^2. The lamp gives 256 cp uniformly below the horizontal plane. Determine the height at which the lamp is suspended & the height at which the lamp is suspended & find illumination at a point on the working table 1.2 metres away from the vertical axis of the lamp.

$h = r.$

Given data, $I = 256\,CP$

$E = 100$ lumens/m^2

Let height of lamp from $A = h$ metre.

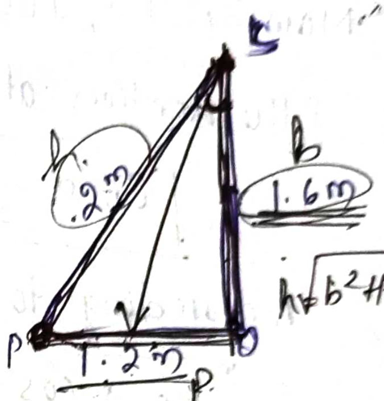
Illumination at E $\qquad I = \frac{\Phi}{\omega}$

$$E_A = \frac{I}{h^2}$$

$$\Rightarrow 100 = \frac{256}{h^2}$$

$$\Rightarrow h = \sqrt{\frac{256}{100}}$$

$$\Rightarrow h = 1.6\,m$$



$h = \sqrt{b^2 + p^2}$

$$\cos\theta = \frac{OS}{PS} = \frac{1.6}{2} = 0.8$$

$$\sqrt{(1.2)^2 + (1.6)^2} = 2$$

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

$h = \sqrt{p^2 + b^2}$

$h = 2$

Illumination at point P

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

$$E_P = \frac{256}{(1.6)^2}(0.8)^3$$

$E = \underline{51.2}$ lux (Ans)

Angle opposite side always perpendicular
Angle side Base.

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

Incandescent lamp / Filament lamp :-

Incandescent means producing visible light by heating an object. An incandescent lamp works in the same principle. In other words, the lamp working due to glowing of the filament caused by electric current through it is called filament lamp.

(i) Construction :- The filament is attached across two lead wires. Both of the lead wires pass through glass support mounted at the lower middle of the bulb. Two support wires also attached to glass support, are used to support filament at its middle portion. The entire system is covered by a glass bulb.

→ The glass bulb filled with inert gasses (argon & Nitrogen) argon & nitrogen are used to minimize the evaporation of the lamps. Gas is filled into the bulb with the rating more than 40 W.

→ To adjust the large filament in small space we used coiled coil filament. Tungsten is used in filament. Because tungsten has high melting point as well as it has high resistive material, high luminous efficiency.

(ii) Working :- When an object is made hot, the atoms inside the object become thermally excited. In this case lamp connected to the supply. Current flow across filament.

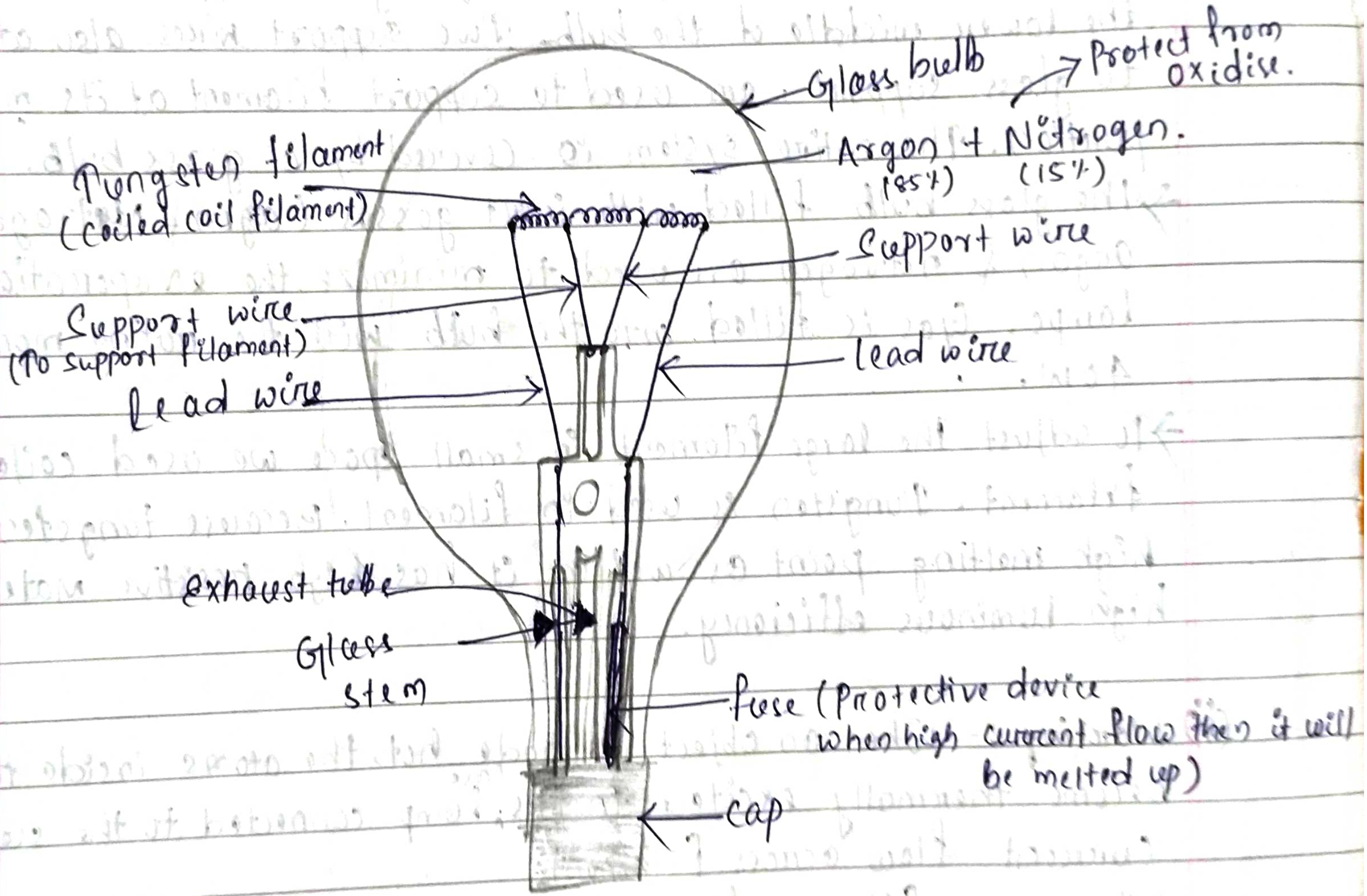
→ Tungsten filament has high resistance that's why temperature increases along the filament.

→ The outer orbit electrons of the atoms jump to higher energy & its again fall back to lower energy levels, the electron release their extra energy in a form of photons. These photons are then emitted in the form of electromagnetic radiation.

→ The electromagnetic wave with the wavelengths within visible range is light energy.

Based on the availability of wattage the bulbs are common in the market with 25 W, 40W, 60W, 75W, 100W, 150 W. & 200W etc.
Tungsten has high resistivity (5.6 Ω).
high Melting point (3400°C)

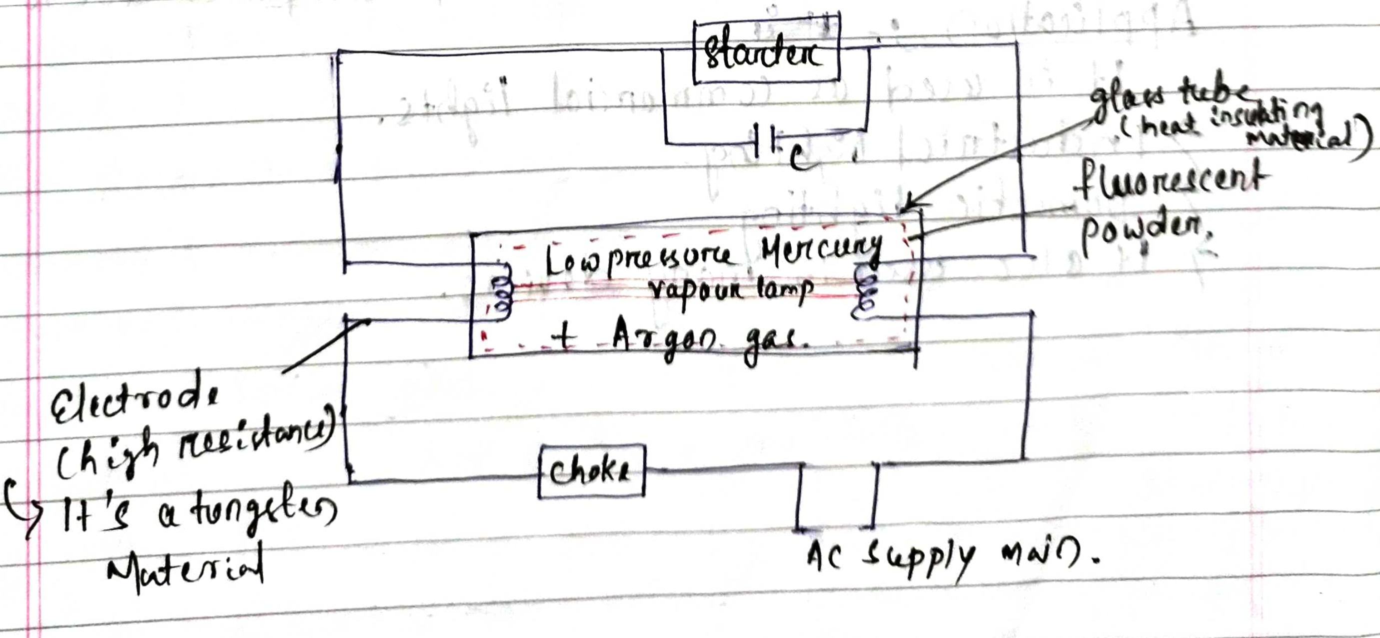
Application :-
(1) Desk lamp
(2) table lamp
(3) Outdoor bulb.



Luminous efficiency = 40 lumens/watt
Life span = 1000 working hours

Fluorescent lamp :- Fluorescent lamp is a type of low pressure Mercury vapour lamp which produce the visible light using fluorescent.

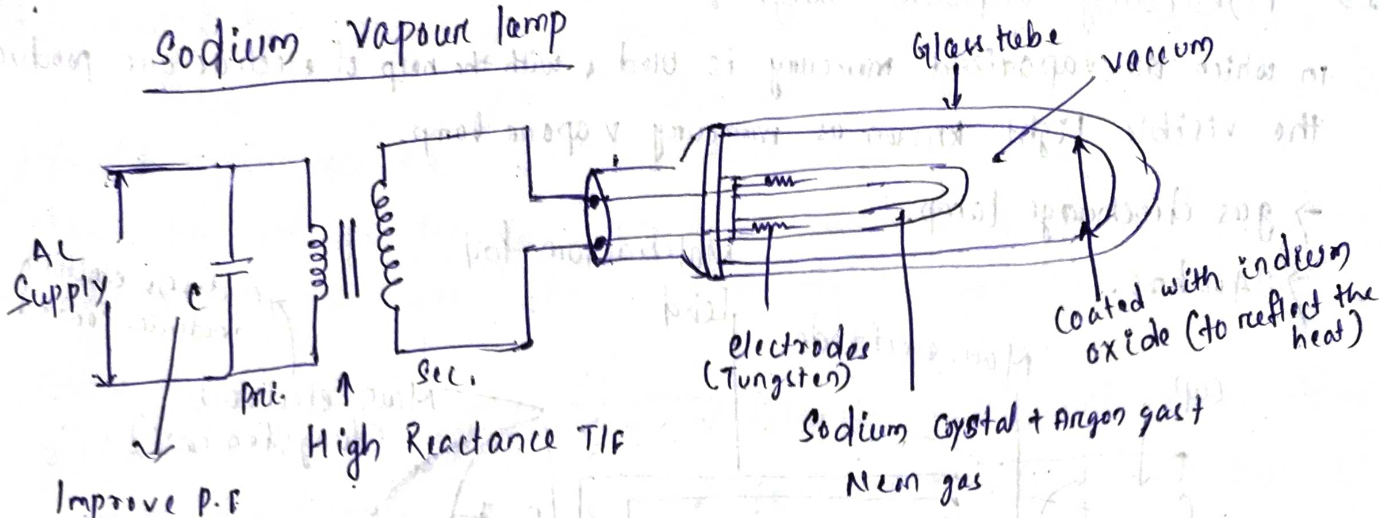
Construction :- Electrodes placed inside the tube. Tip of electrodes made up a spiral form, spiral coil is made up of tungsten material. Coil is coated with ~~electrod~~ electron emitting material.
Tube is made up of lime glass, which is a heat insulating Material. Inner Surface of tube coated with fluorescent powder.
Low pressure Mercury vapour & argon gas contain inside the tube. In this ckt starter & choke are connected.
Choke help in keeping the current through the ionised medium within safe limits.
Starter is allows in required amount current flow across two electrodes. capacitor is improve power factor & avoid the noise signal.



Working :- When we get supply to the ckt then the current will pass through the choke. it will reach at starter.
Starter provide some current to the electrodes. So electrodes started to heat when current flow.
Then it's temp will increase due to heat temperature increase.
→ Inside the tube mercury vapour & argon gas ionized due to heat. When medium is ionized bet^n two high voltage electrodes arc is formed.
Arc among electrons releases energy in the form of electro-magnetic radiation.
In the tube it will be coated with fluorescent powder which increase the wave length of radiation. And produce the visible light. Thus fluorescent lamp works.

Advantages :- efficiency fluorescent lamp is higher as compared to incandescent lamp.
→ It designed different shape & length.
→ It produced desired colour.
Disadvantages → It is available at expensive price due to starter & choke.
Application :- ~~It is~~
It is used as commercial lights.
→ Industrial lighting.
→ Domestic lighting
→ It also used in many devices.

Sodium Vapour lamp



→ Sodium vapour lamp is an electric discharge lamp which produce yellow/orange colour using sodium particles & neon & argon gas.

→ Metal electrodes are placed inside the glass tube. To increase the length of the arc tube is designed U shape.

→ Tube don't damage in high temp.

→ Horizontally placed.

→ Outer envelope of lamp is made up of glass. Inner surface of the outer glass is coated with indium oxide to reflect the heat.

Working :- To operate 40w lamp, 380 v is required. 100 w lamp 450v is required. That's why high reactance T/F is used to reaches the required voltage.

→ When reaches the required voltage arc is formed b/w both electrodes.

→ Since neon & argon gas are present in the inner tube. So during a starting lamp produce reddish pink light. & temp ↑ inside the tube.

→ Due to heat sodium particles start to convert in vapour, after 10 to 15 min when sodium completely vaporized. Lamp start to produce light of orange color

η = 40 to 70 lumens/ watt

Manufactured = 45 w, 60 w, 85 w, 140w.

→ 3000 hr. (Working time)

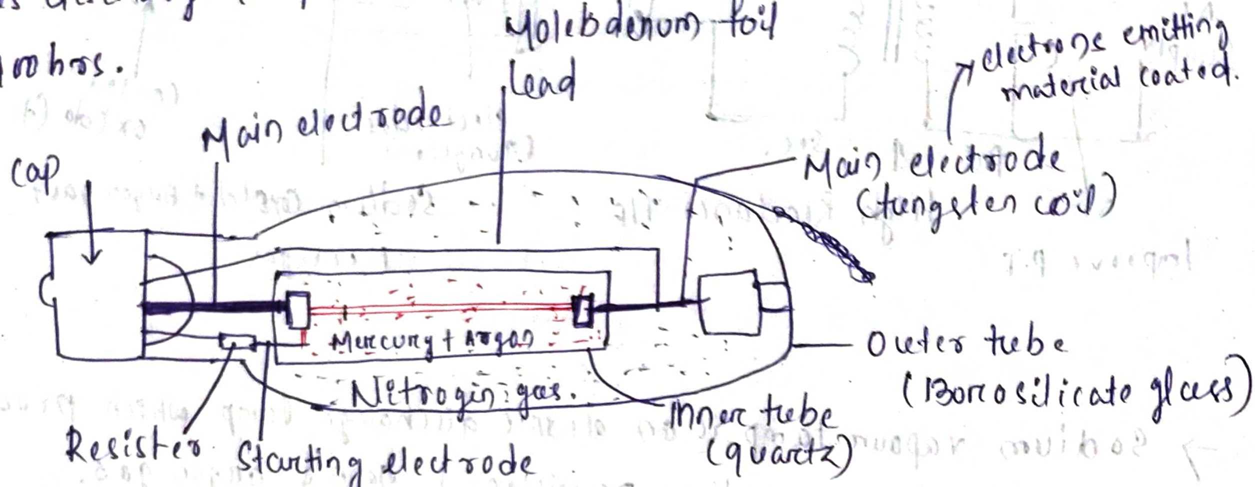
Advantages	Disadvantages
→ Yellow light, More light o/p for same energy than other source.	→ Starting time is required.
→ low operating temp.	→ Additional T/F required.
→ Effective in rainy & foggy season.	→ poor P.F
	→ cost is more.
	→ size is bulky.
	→ Not suitable for indo

15 Mercury Vapour Lamp :-

In which the vaporized mercury is used & with the help of electric arc produces the visible light known as mercury vapour lamp.

→ gas discharge lamp.

→ 2400 hrs.



Inner tube of Mercury lamp is made by quartz Material, (1300 k) outer (700k) envelope is made up of borosilicate glass. both are heat insulating material.

Funⁿ :- don't damage due to heat.

Nitrogen gas is filled betⁿ inner tube & outer glass.
↓
It provide thermal insulation. And protect the metal parts from oxidation.

Mercury & argon gas are present inside the inner tube.

Two electrodes present inside the inner tube
↗ Main ↖ Starting. → Tungsten coil is connected at the both tip of electrodes.

electrodes emitting material is coated on the electrode, due to coating → arc (E.g → Thorium, Calcium & Barium carbonate) will be easily develop. electrodes remain contact with molybdenum foil lead.

→ Resister is connected with starting electrodes.
 ↳ To limit the current
 → Vertically placed.

Working :- when Lamp is connected with supply, current flow through both electrode. Less gap betⁿ bottom main electrode & starting electrode due to small gap voltage gradient remain high. A small arc create betⁿ both electrode.

→ Current of electrode is limit by resister

95

due to arc heat generated inside the tube, mercury gas vaporized due to heat. Also heat generate at main electrodes due to voltage. that heat ionize the vaporized mercury.

Thus main arc develop betn both main electrodes small arc stop after forming the main arc (After increasing the resistance of resistor)

~~Small ar~~

→ After 5-7 min Mercury gas completely vaporized. Free electrons across the arc produce visible light in the form of electro magnetic radiation

→ It produce light green & yellow color of light.

→ 3000 working hours,

η = 40 lumens/watt.

Application

→ Industrial lighting

→ Street "

→ Parking lots,

Neon Lamp :- Neon lamp are gas discharge lamps that contain neon gas & argon gas at a low pressure, enveloped in a glass bulb. Neon lamps emit light when electric light is passed through the gas.

→ It is also known as cold cathode lamp. (Means cathode is not electrically heated by a filament. If it emits more electrons that can be supplied by thermionic emission alone)

→ The tube has electrodes sealed at both ends. 2 to 3mm gap is provided in bet^n two electrodes which are made by high resistive material.

→ Voltage require for starting & operation is 10000 V or 10 KV. This high voltage is obtained from transformer.

Working :- Whenever voltage is provided to the supply terminals the arc will produced in bet^n the two electrodes. Due to high resistive material there is more I^2R loss.

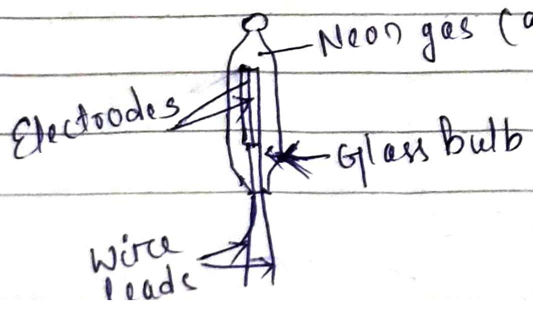
→ Due to this thermal energy is produced. Hence arc will produced in bet^n the electrodes & light will be emitted through the neon lamp.

→ By adding the chemical powders, the colour of light can be changed (e.g → Hg + Neon = Red light, Ar + Neon = green light)

Advantages
- It gives instant glow
- Small size
- Wide operating Range
- Low power consumption

Disadvantages
- Low light o/p for given i/p power
- Small range of colour spectrum

Application → It is used as indicator, used for advertising.

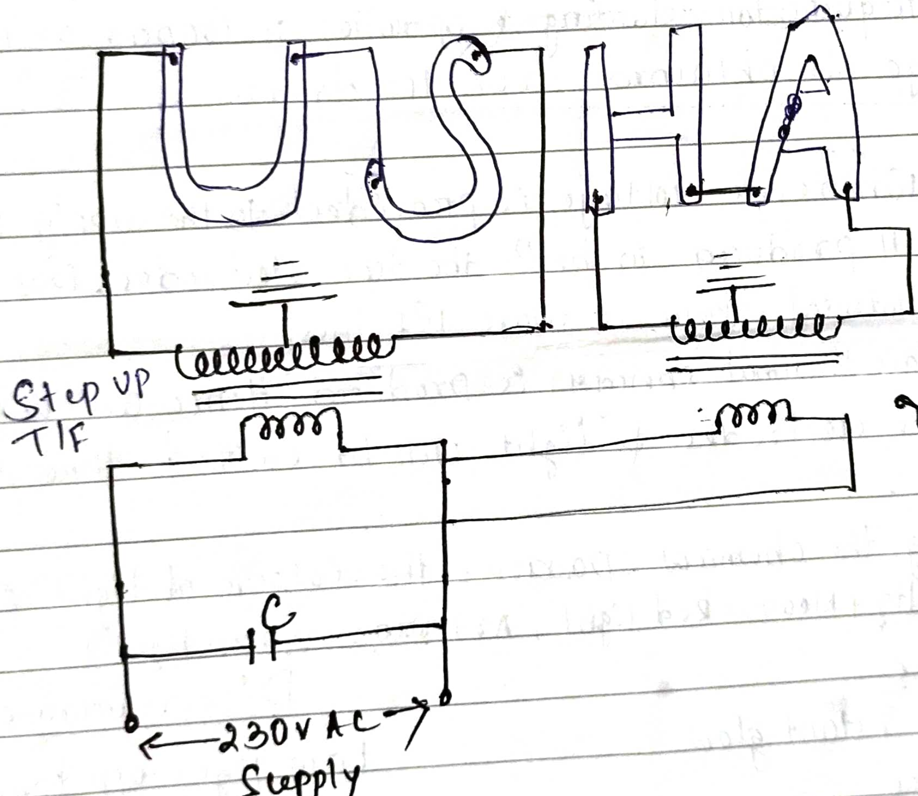


Basically neon tube is used for advertisement or decoration purpose. The max^m length of tube is 8m & diameter of neon tubes are (5 mm to 30 mm)

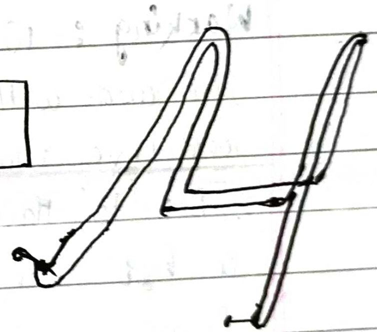
→ When the supply is switched on at primary, high voltage is induced in secondary wdg of HT transformer. This voltage applied across electrodes.

→ At this high voltage, a discharge occurs in neon gas. In the neon tube we can achieve various color changing the constituents of the gasses & mercury filled in the tube.

→ Choke is used for ballast & P.F improvement capacitor is also used.



Neon sign



Tube arrangement for H

HT → High Tension → It provides high volt. line Applicable for 11 kv. bulk power system.

Carbon Arc Welding :-

Carbon Arc welding is a welding process in which heat is generated by an electric arc struck between a non consumable carbon electrode (graphite) & the work piece to be welded.

→ It consists of an electrode holder to which a carbon electrode is attached. The arc is maintained between the metal piece & the carbon electrode held in the holder.

→ The arc is struck by touching the electrode with the metal piece, at a little distance about 3mm to 6mm.

→ The arc is allowed to touch on the surface to be welded till a molten pool forms & then the holder is steadily moved along the joint.

→ In carbon arc welding, the electrode is usually connected to the −ve terminal & the work piece connected to +ve. If the carbon electrodes is made +ve the carbon particles have a tendency to go into the welded joint & cause break.

→ For this type of welding only DC can be used. A voltage of about 40 volts is used & temperature which is about 3200°C is used in this welding. Due to longer life & low resistance, graphite electrode is preferred over carbon electrode.

Two methods of carbon arc welding are used.

(1) No flux used, (For non ferrous metals)

(2) Flux either in form of powder or paste is used to prevent the weld from oxidation. (Applied for ferrous metals)

* Advantages of carbon ARC welding :-

(1) Low cost

(2) The process is easily automated

(3) Low distortion of work piece.

(4) CO_2 gas is inexpensive & capable for producing high quality welding.

Disadvantages :-

(1) The quality of weld is poor, as the carbon particles contaminates the weld & results in porous & brittle weld.

(2) It consumes large amount of current.

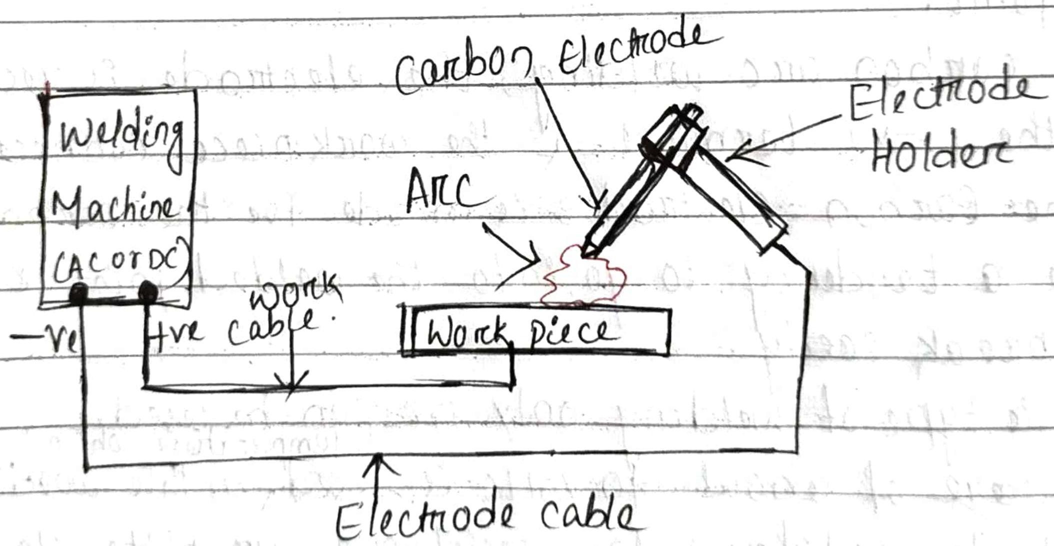
(3) There are chances of carbon being transferred from electrode to weld thus causing a harded weld deposit.

Application :-

(1) welding steel, aluminium, nickel, copper, molten metal

(2) Employed for brazing

(3) Both ferrous & non ferrous metals can be welded.



Atomic Hydrogen Arc welding :-

It is an arc welding process that uses an electric arc between two tungsten electrodes in the presence of hydrogen. In this welding the electric arc breaks the molecules of the hydrogen very efficiently. Later these hydrogen molecules recombine & release high amount of heat. During the release of the heat, temperature in the range of 3400° to 4000°C are reached.

* Equipment used in Atomic Hydrogen welding :-

(i) 2-Tungsten Electrode - The two tungsten electrodes are used in this technique. The arc is produced betⁿ the two electrodes which help in welding.

(ii) Hydrogen Gas Cylinder :- Hydrogen gas is an essential factor in the welding process.

(iii) Filler Rod → The filler rod is optional in the atomic hydrogen welding process.

(iv) Electrode Holder - These electrode holders hold ~~are~~ the tungsten electrode & ~~ho~~ also prevent them from coming in direct contact with the hands of a welder.

(v) Nozzles :- Two nozzles are connected to the electrode holders. They supply an ample amount of hydrogen to surround the tungsten electrodes.

(vi) AC power Supply - The AC power supply device is to maintain the voltage of 300v. This power supply produces an arc between two tungsten electrode.

* AC is preferred instead of DC because it needs due to equal power is required in both the tungsten electrodes to make an arc between them.

How AHW works ?

When the electric arc ~~current~~ passes through the hydrogen gas it dissociates into the atomic hydrogen.
Due to the absorption of a large amount of heat produced in the process.

→ As the atomic hydrogen touches the cold work pieces. This process liberates a large amount of heat.

* Advantages :-

(I) Less distortion.

(II) Faster welding process

(III) No requirement of the flux

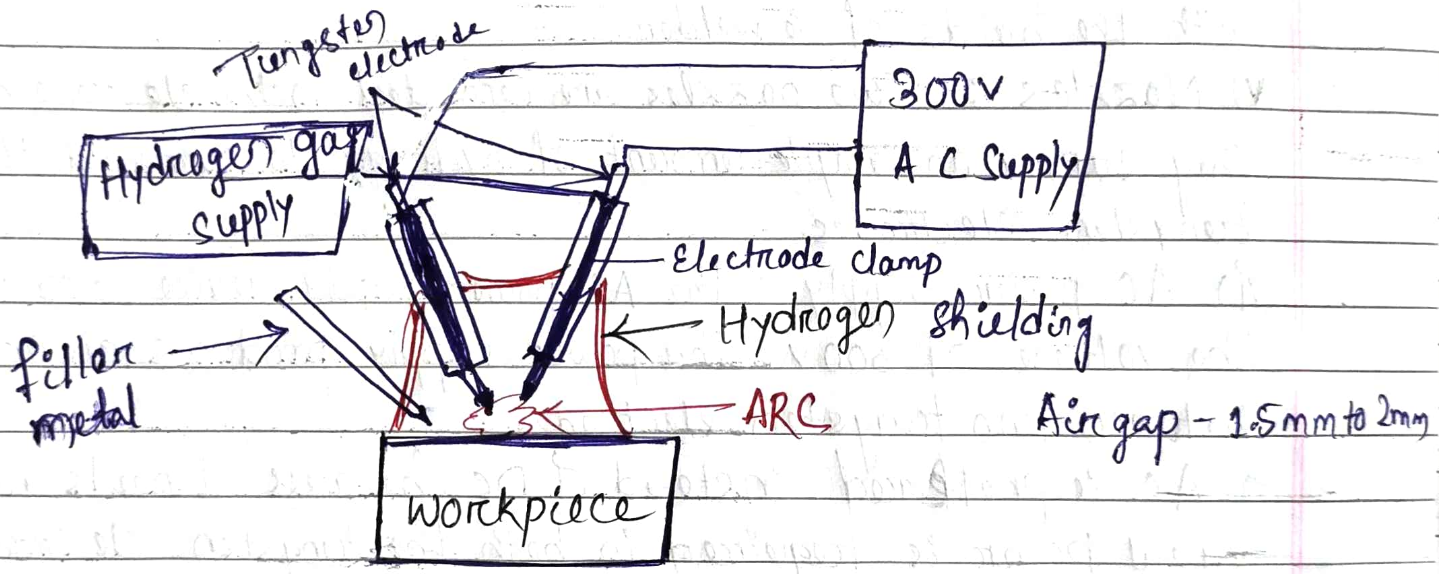
Disadvantages

(I) It might be dangerous because the hydrogen gasses.

(II) Required a highly skilled person.

Application → welding for stainless steel.

Used for ferrous & non ferrous metals.



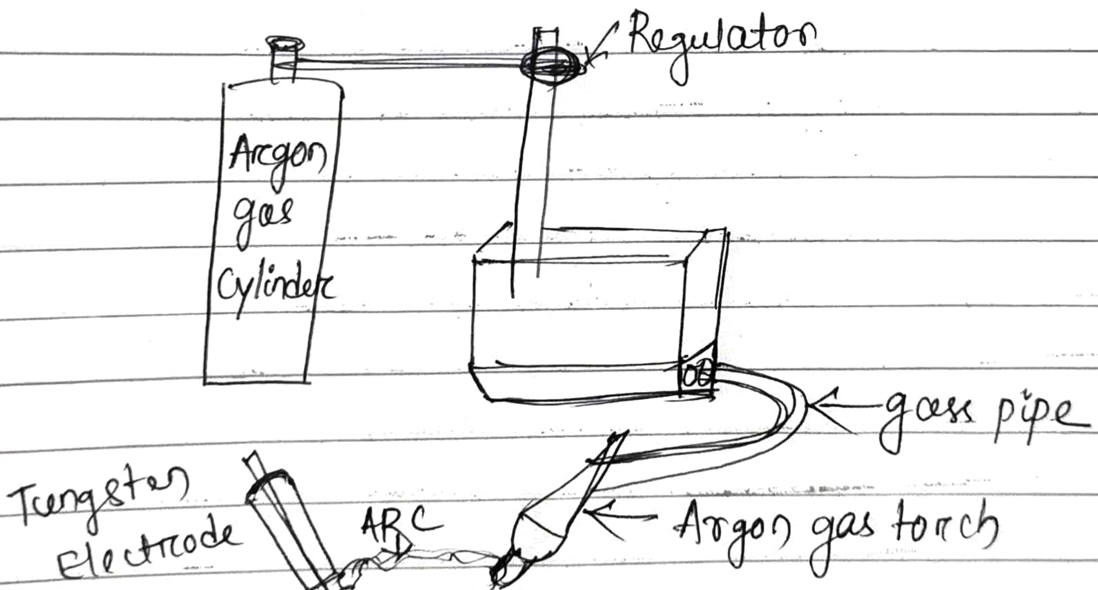
Helium or Argon Arc Welding :-

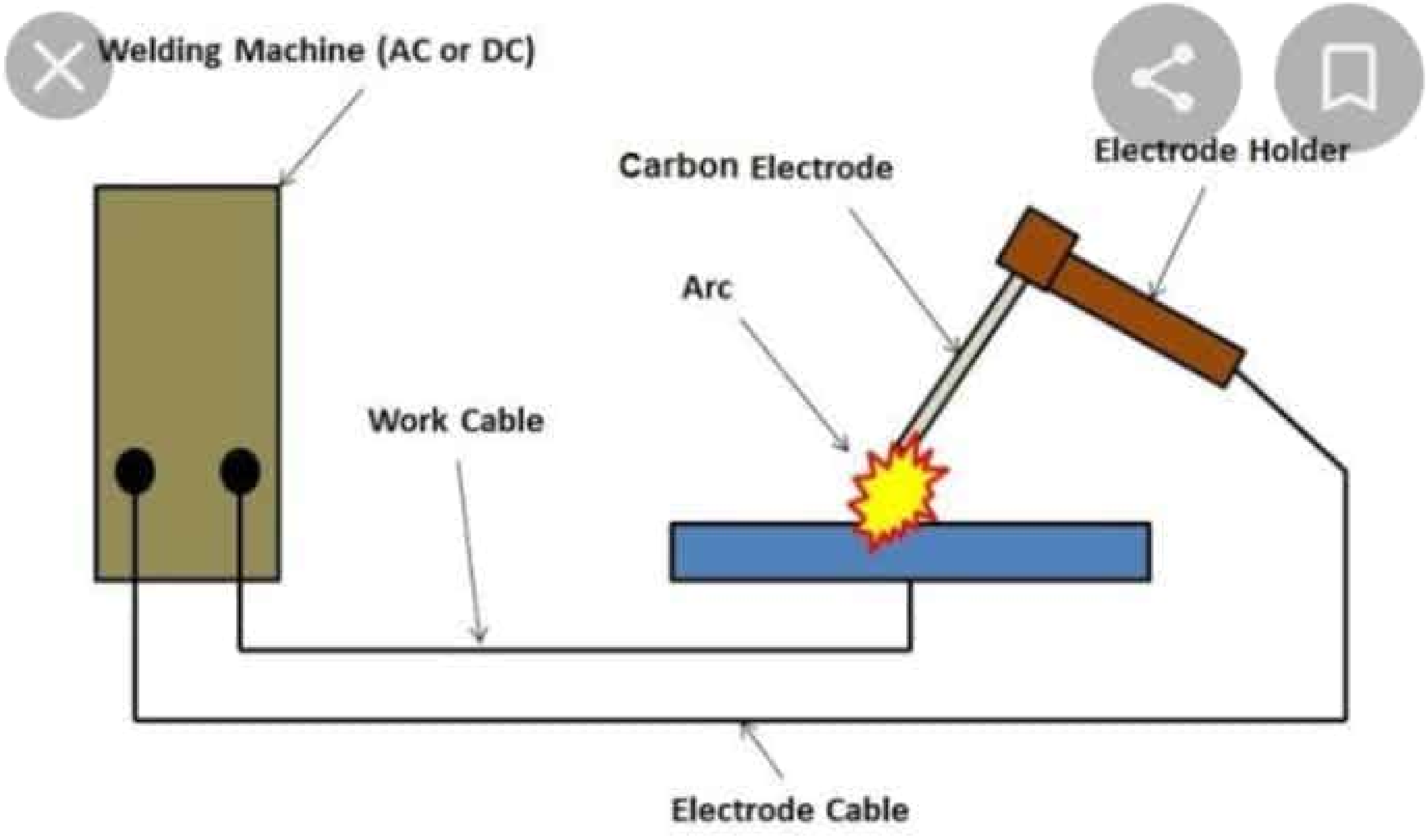
In this method the arc struck between a tungsten electrode (consumable) and the work piece within a shield of the inert gas argon, which excludes the atmosphere & prevents contamination of electrode & molten metal.

Argon or helium eliminates the necessity of adding flux. The mixture of 70% Argon & 30% helium gives fast welding speed.

Standard DC or AC welding equipment may be used provided the open circuit voltage is around 100V for AC & 70V for DC.

→ This method is used for aluminium alloys, magnesium alloy. AC is suitable & DC used for all other common metals.



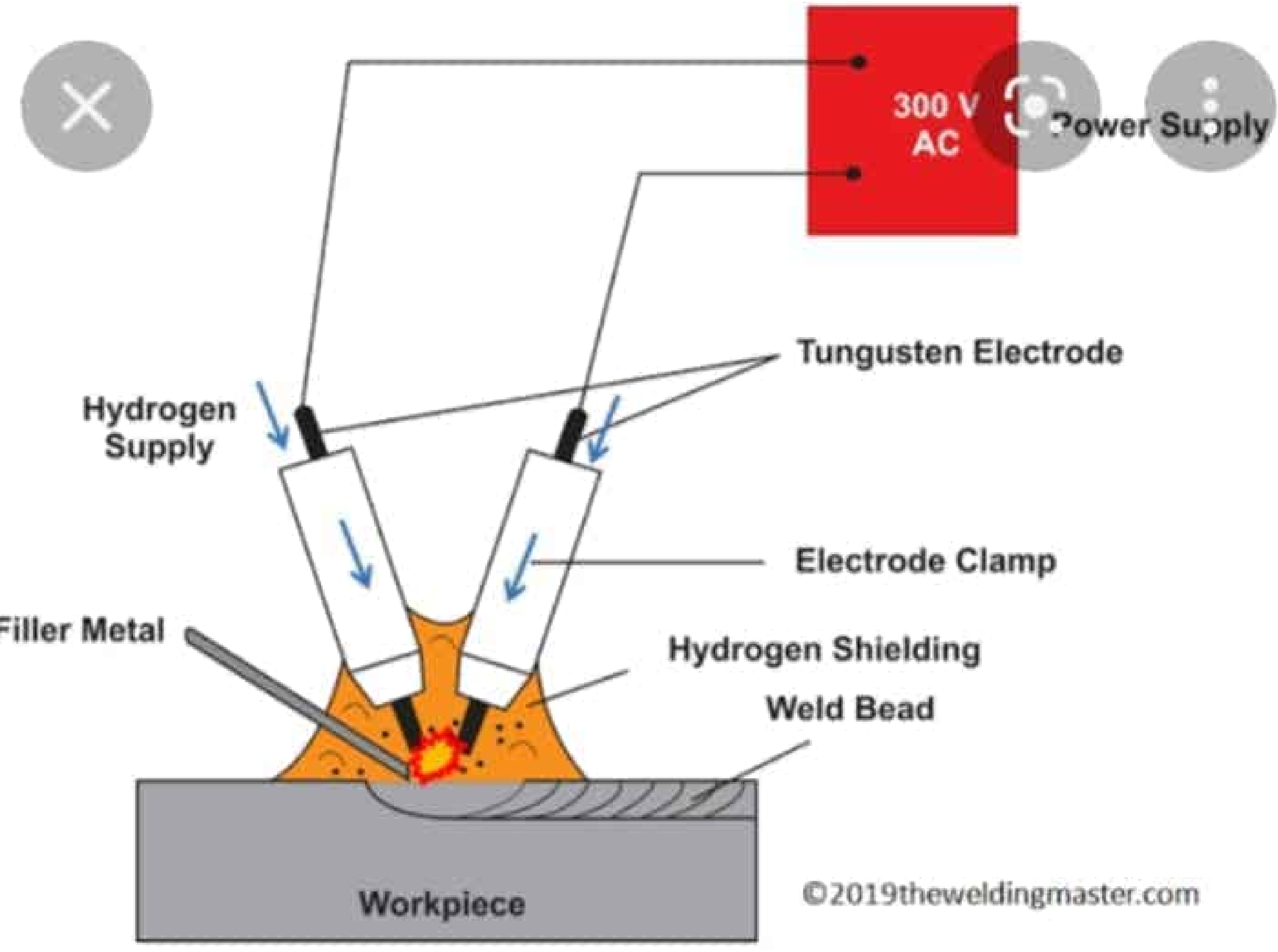


The Welding Master

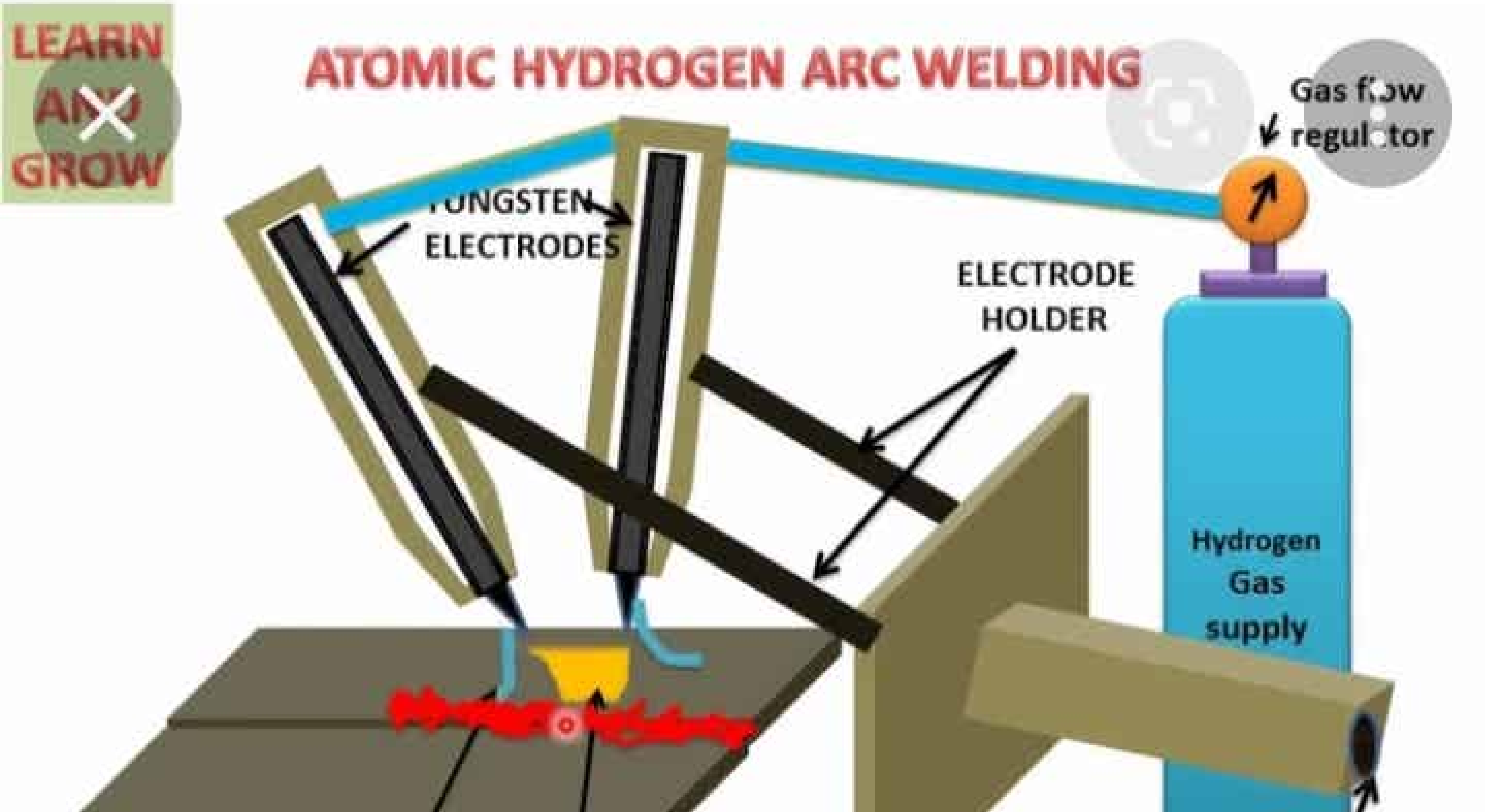
Visit

What is Carbon Arc Welding and How it

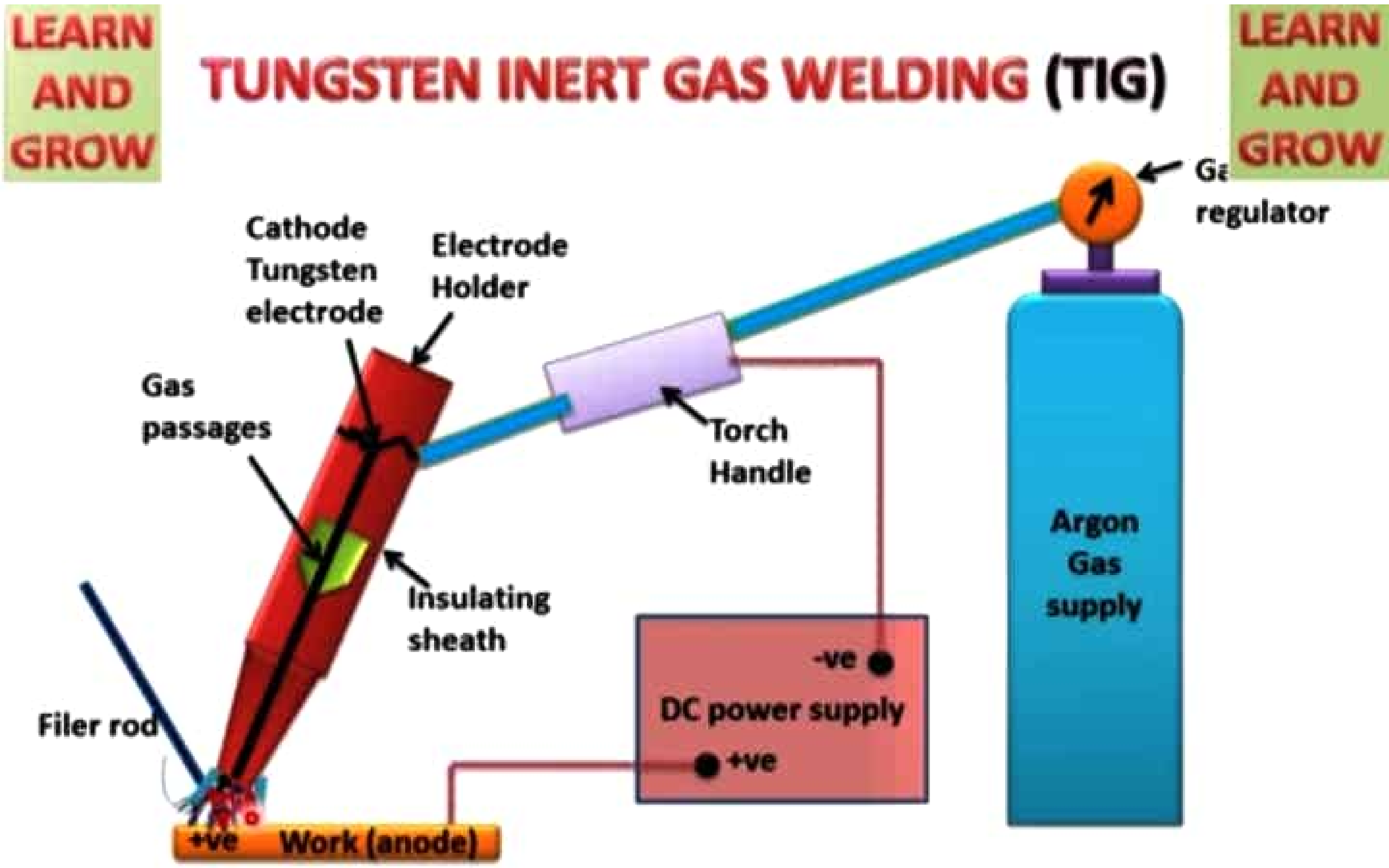

TWI



Atomic Hydrogen Welding



LEARN AND GROW
ATOMIC HYDROGEN ARC WELDING
Gas flow regulator
TUNGSTEN ELECTRODES
ELECTRODE HOLDER
Hydrogen Gas supply
Shielding gas
ARC
SHIELD
TO POWER SUPPLY



LEARN AND GROW
TUNGSTEN INERT GAS WELDING (TIG)
LEARN AND GROW
Ga
regulator
Cathode Tungsten electrode
Electrode Holder
Gas passages
Torch Handle
Argon Gas supply
Insulating sheath
-ve
DC power supply
+ve
Filer rod
+ve
Work (anode)

The resistance welding may be defined as the method in which a sufficiently strong electric current is sent through the two metals in contact to be welded bringing the two pieces to the molten state and thus applying mechanical pressure at this time to complete the joint.

4.20. Advantages of Resistance Welding

Resistance welding has a number of advantages as noted below:

(*i*) It is a quick method of joining two pieces,

(*ii*) There is very little wastage of the metal,

(*iii*) The process can be accurately controlled, and

(*iv*) The welds are consistently uniform.

This type of welding is particularly well suited to all forms of automatic production. The following electric resistance welding processes are commonly used :

(*a*) Butt welding,

(*b*) Flash welding,

(*c*) Spot welding,

(*d*) Seam welding,

(*e*) Projection welding.

(*a*) **Butt Welding.** In this process, heat is generated by the contact resistance between two components. The faces of the components should be machined or edge prepared as shown in Fig. 4.13. The two

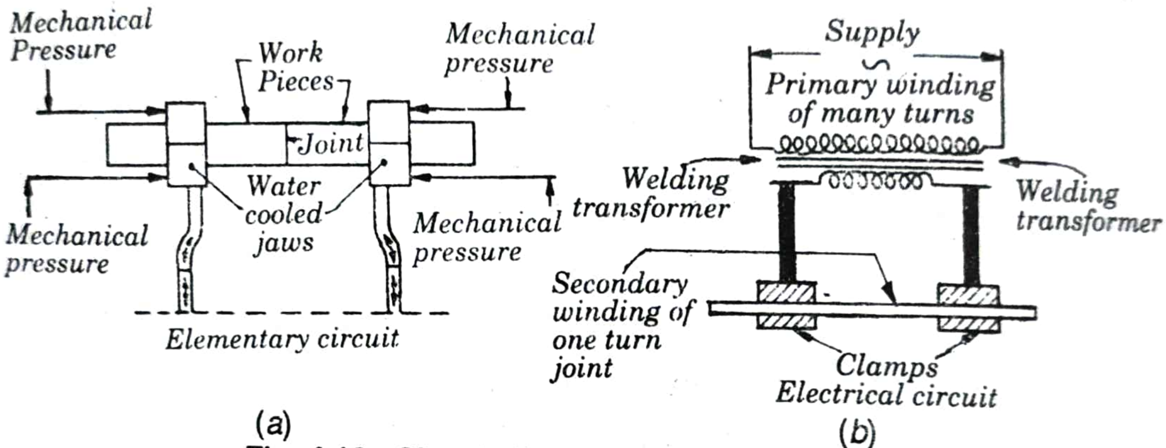


Fig. 4.13. Circuit diagram for butt welding.

parts or components are brought together and the pressure is applied along the axial direction by a spring. A heavy current is passed from the welding transformer (which is having comparatively larger number of turns on the primary and lesser number of turns on the secondary) which creates the necessary heat at the joint due to the comparatively high resistance of the contact area. The metal at the joint melts and the two parts fuse together producing a bulged joint.

Applications. The main applications of butt welding are :

(*i*) Where the parts are joined end to end or edge to edge.

(*ii*) For welding pipes, wires and rods.

(*b*) **Flash Welding.** This is similar to butt welding except for the difference that in this case current is applied to the parts before they are brought together so that when they meat arcing or flashing takes place. The two pieces to be welded are clamped strongly in a flash welding machine. The parts are brought together and the resistance to the current flow heats the contacting surfaces. As soon as the metal has been brought to its melting temperature, the current is shut off and the pieces are rapidly brought together under considerable pressure. When this action takes place the squeezed molten metal gives off sparks or flash, hence the name. As the metal is heated to its plastic state, the pieces are forced together under high pressure which forces fused metal and slag out of the joint making a good solid weld. Fig. 4.14 shows two pieces of metal before and after being flash welded together.

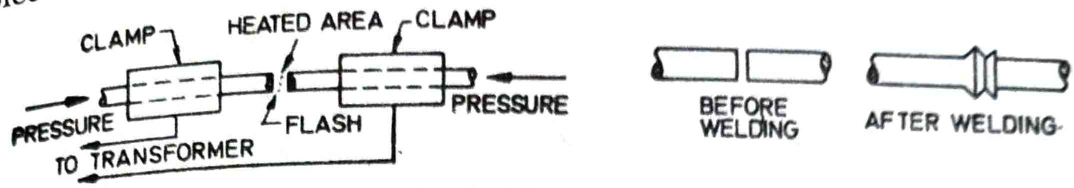


Fig. 4.14. Flash welding.

Applications. This method of welding is used extensively in production work, particularly in welding rods and pipes together. The flash method has almost entirely superseded the butt weld method.

(*c*) **Spot Welding.** This is the simplest and most universally adopted method of making lap welds in thin sheets up to a maximum thickness of 12.7 mm. In its simplest form the spot welding machine consists of a transformer to produce high current at low voltage : electrodes are connected to the ends of the secondary winding for leading the current to the work and to apply the necessary mechanical pressure. In addition, there must be a mechanical arrangement to bring the electrodes in to contact with the work.

A diagrammatic representation is shown in Fig. 4.15. On this are shown :

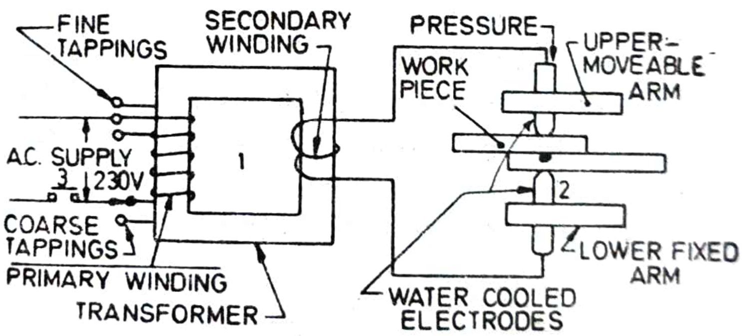


Fig. 4.15. Spot welding.

1. The transformer.
2. The electrodes.
3. The electrical control switch.

It is used to provide tappings on the primary winding of the transformer to regulate the secondary voltage, and thus the welding current. A common arrangement employs tapping at both ends of this winding, one end giving coarse adjustment and the other fine adjustment.

In the process the materials to be welded are overlapped and pressed between two water cooled electrodes and a impulse of current is passed through the assembly. The metals in the zone of pressure gets heated up to fusion and joint thus made gets cooled under pressure. For spot welding 5,000 Amp of current is required and the voltage between

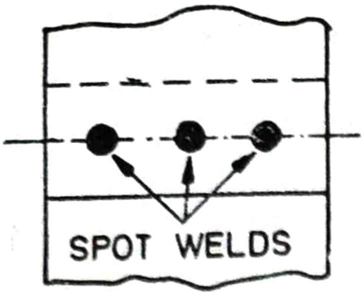


Fig. 4.16. Spot welding.

the electrodes is usually less than 3 volts. The open circuit voltage is less than 12 volts. The value of the welding current, the time for which the current flows and the pressure between the electrode tips (made of copper or copper alloy) are the main factors affecting the quality of the spot weld. The time period of flow of current varies depending upon the thickness of sheets and kinds of metal etc. for thin sheets this period is about 1/50 sec. for each 0.26 mm of total thickness of the two sheets to be joined.

Applications. (*i*) It is applied to welding of sheets.

(*ii*) It is used for fabricating all types of sheets metal structures where mechanical strength rather than water or air tightness is required.

(*iii*) It may be applied to all types of boxes, cores and enclosing cases etc.

Seam Welding

The seam welder differs from ordinary spot welder only in respect of its electrodes which are of disc or roller shape as shown in Fig.28(a). These copper wheels are power driven and rotate whilst gripping the work. The current is so applied through the wheels that the weld spots either overlap as in Fig.28 (b) or are made at regular intervals as in Fig.28 (c). The continuous or overlapped seam weld is also called **stitch weld** whereas the other is called roll weld.

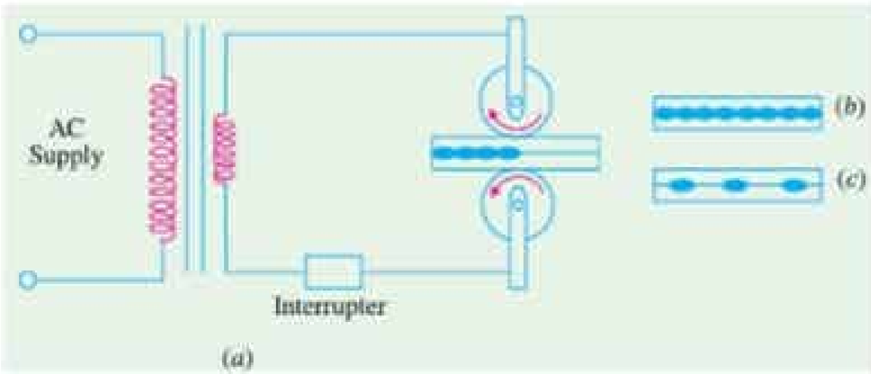
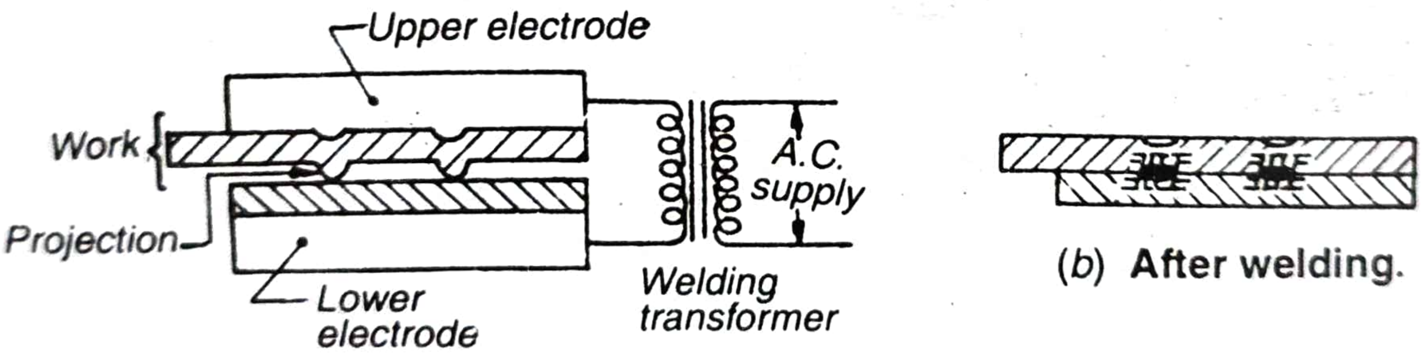


Fig-9

Seam welding is confined to welding of thin materials ranging in thickness from 2 mm to 5 mm. It is also restricted to metals having low harden ability rating such as hot-rolled grades of low alloy steels. Stitch welding is commonly used for long water-tight and gas-tight joints. Roll welding is used for simple joints which are not water-tight or gas-tight. Seam welds are usually tested by pillow test.

(*e*) **Projection welding.** It is modified form of spot welding. Projection welding consists of forming slight projections on the sheet of metal. The projections are accurately formed in precise locations on the metal by a special set of dies. After the projections are formed, the raised portions on one piece are pressed into contact with another piece, while at the same time a heavy current is passed through the two pieces. When these raised portions touch the second sheet of steel, as they are clamped by the electrodes in a projection welder and the current is applied, current flows at the points, heats and fuses the two pieces together. Projection welding has following advantages over spot welding :

(*i*) More than one spot or weld are done at a time. Therefore, more output is obtained.



(*b*) **After welding.**

(*a*) **Before welding.**

Fig. 4.20. Schematic diagram of metal before and after it is projection welded. When the projection is stamped some of the depression formed remains on the top surface of the finished weld.

(*ii*) Due to low current density and low pressure the electrode life is increased.

(*iii*) Good finished appearance is obtained because surface remains unindented by the electrodes.

(*iv*) It locates the welds automatically at certain desired points by the position of projections.

Applications. It is advantageous in assembling parts made by punching or stamping and for welding studs, nuts to plates.

ELECTRIC TRACTION

Traction :- The action of pulling something over a surface (especially a road or a track) is known as traction.

Electric Traction - The traction system which uses electric power for its operation is known as electric traction.
→ It is used in electric train, tramcars, trolley buses & hybrid vehicles etc.

Advantages of Electric Traction :-
Cleanliness, Less starting time, Less maintenance cost & time, High starting torque, High traffic handling capacity, Lesser terminal space, Regenerating is possible.

* Disadvantages :-
(i) high capital cost (ii) because of power failure causes distortion in traffic (iii) It can be used only electrified.

Explain System of Traction :-
On the basis of Electrical Power drive :-
(1) Non Electrical Traction
(2) Electrical Traction

(1) Non Electrical Traction → Traction system which does not uses the electrical power to drive, are called non electrical traction system.
(a) Steam Engine
(b) Diesel Engine or Direct Internal combustion Engine.
(c) Battery Electric Drive
(2) Electrical Traction → Traction system which uses electrical power to drive, are called Electrical Traction.
(a) AC Traction System (b) DC Traction System

The track electrification refers to the type of source supply system that is used while powering the electric locomotive system.

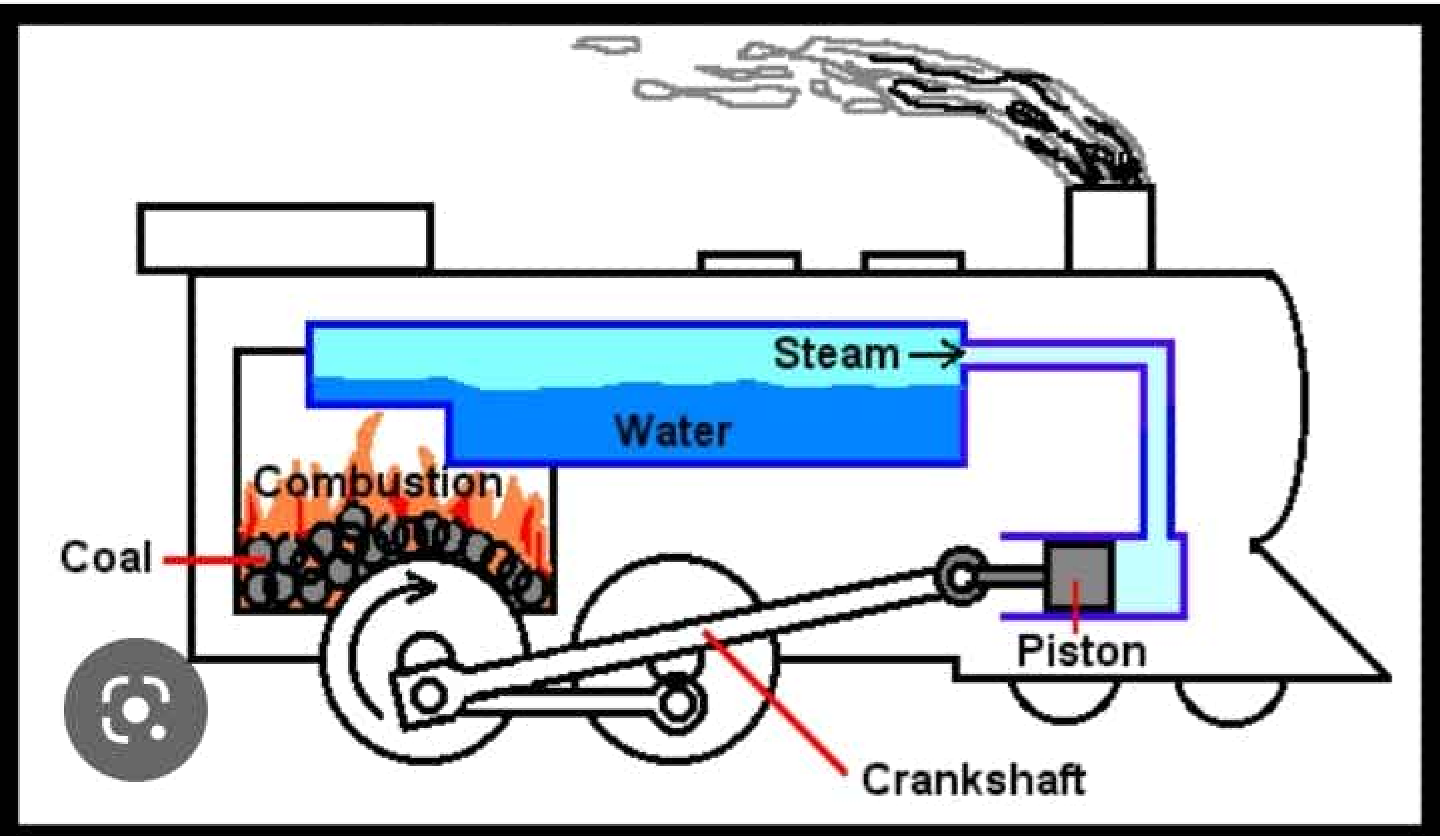
(1) Direct steam Engine :-
Direct steam engine is employed for rail road operation the simplicity of connection between cylinder & the driving wheel & easy speed control.

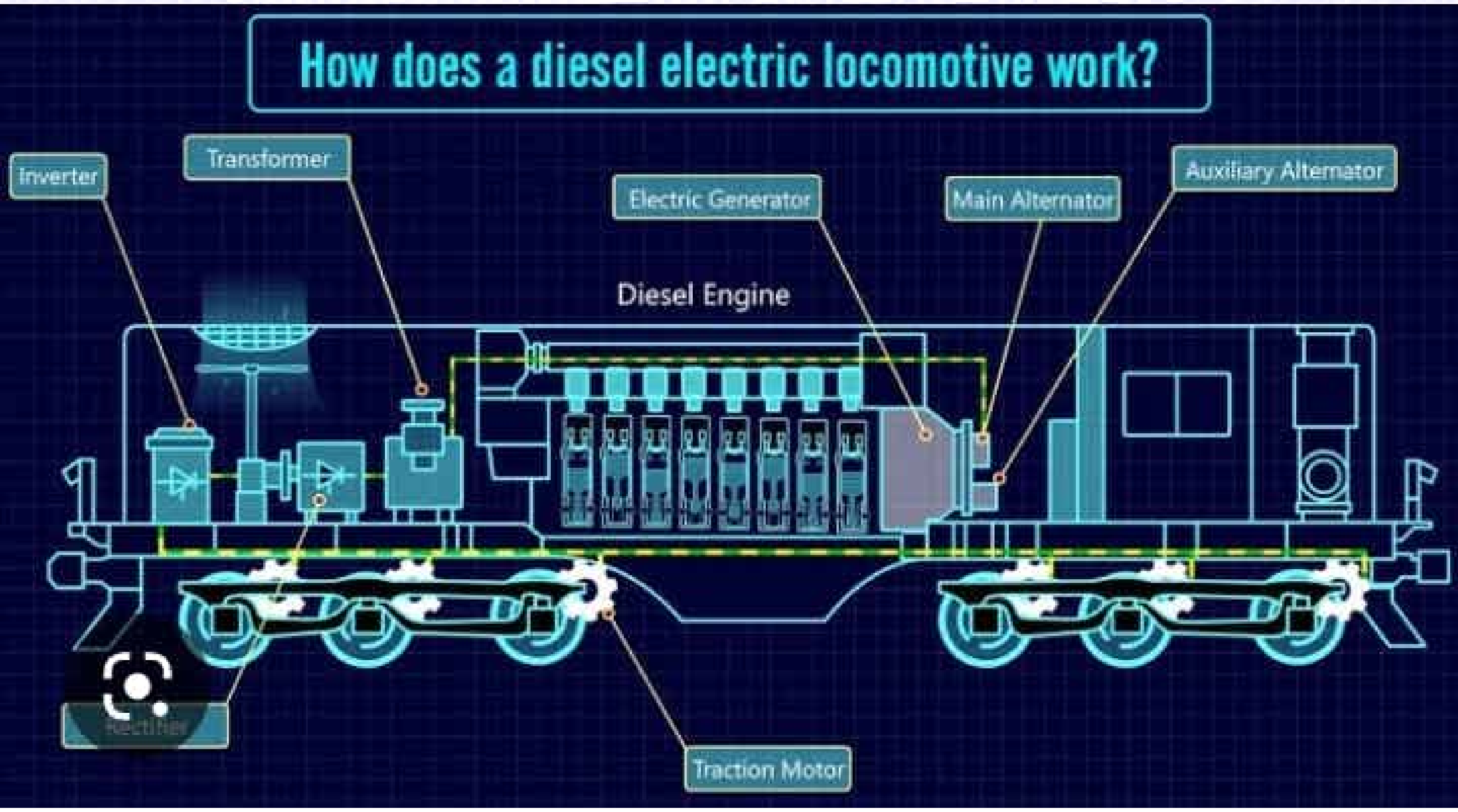
(b). Direct Internal combustion Engine :-
(1) Petrol Engine - The characteristic of an internal combustion engine is that it produced constant torque at all speed.
→ To increase the starting torque & also for speed control a gear box has to be provided.

Diesel Engine - In this system gear box are eliminated as a diesel engine drive & dc generator coupled to it at a constant speed which supply power to electric motor fitted with wheel.

Battery Electric Drive → In this system the locomotive carries the secondary batteries which supply power to DC series motor employed for driving the vehicles.

Electric Drive - In this system the locomotive is driven by the electric motors which are fed from the overhead distribution system.
→ Now a days the electric drives are widely used in traction work.


Steam
Water
Combustion
Coal
Piston
Crankshaft


How does a diesel electric locomotive work?
Inverter
Transformer
Electric Generator
Main Alternator
Auxiliary Alternator
Diesel Engine
Traction Motor


GE Transportation's
Battery-Electric Locomotive
Massive power generation capabilities up to
2400 kWhrs
Huge fuel savings of at least
10-15 %
Trip Optimizer™
smart automated cruise control
AC Traction System Inverters
Energy Storage
replacing engine & cooling system
Powered Axels

Electrification → The conversion of a m/c or system to the use of electrical power.

System of Track electrification :-

System of Track electrification comprises

(1) DC system

(2) single phase AC system

(3) Three phase AC system

(4) Composite system

(2) and (3): AC system

Types of Electric Traction System

- DC system
- AC system
  - 1 ϕ AC system
    - 1 ϕ low freq
    - 1 ϕ high freq
  - 3 ϕ AC system
    - 3 ϕ low freq
- Composite system
  - 1 ϕ to 3 ϕ system or (Kando System)
  - 1 ϕ AC to DC System

(1) DC system :-

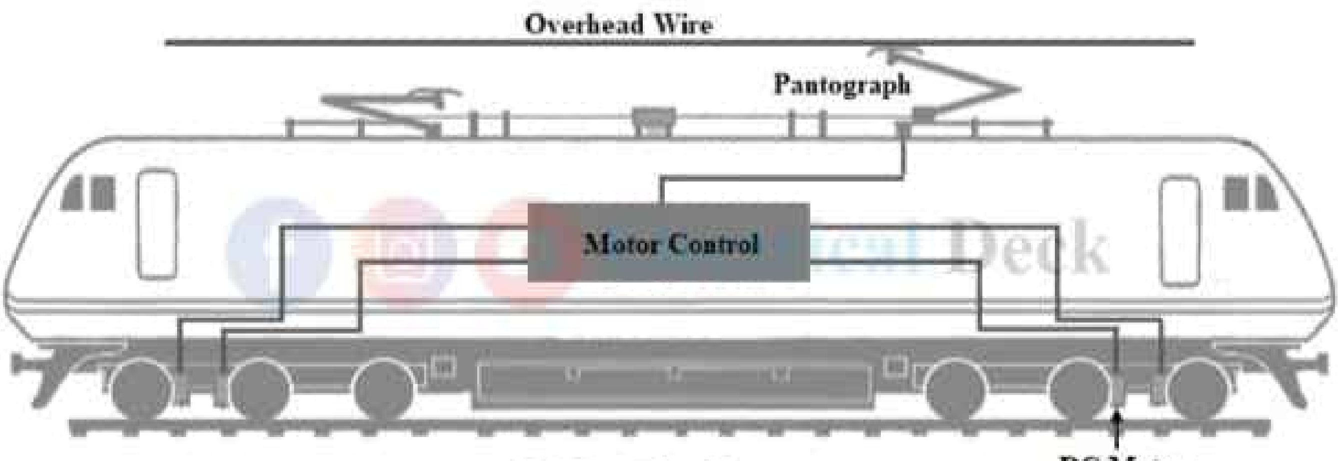
In this system the electric motors used are dc series motors. The operating voltage is from 600 V to 750 V for tramways & for many sub-urban railways & from 1500 V to 3000 V for main line railways.

The driving motors receive power from distribution system. Then this ac power is converted into dc power by using mercury arc rectifier.

For sub urban services the distance between the substation is 3 to 5 km where as for main line services it is about 40 to 50 km.

→ ~~These substation are costly~~

→ These arrangement reduce the maintenance cost & losses, better speed control. The cost of substation is also more due to heavy cost



DC Traction System

of converting machinary.

Application → It is preferred for suburban services & road transport where stop are frequent & distance are small.

→ It is exists in Bombay & Madras.

(2) AC system :-

The modern development in electric traction is to use 1ϕ ac supply. The ac system in India is being employed from Howrah to Tundla & from Madras to Tambram.

It is 4 types

(a) Single phase AC system :-

In this system the electric motors used are AC series motor.

AC system units draw alternating current from an overhead line.

Fewer substation are required & the lighter overhead current supply wire can be used, Reduce capital cost.

(i) Single phas low frequency system :-

In this system AC series motor are used for getting the necessary motive motor.

→ The voltage employed for distributing network is 15kV to 25kV at 16.7Hz or 25Hz. which is step down on the locomotive to a low voltage (300 to 400V) transformer carried on the locomotive.

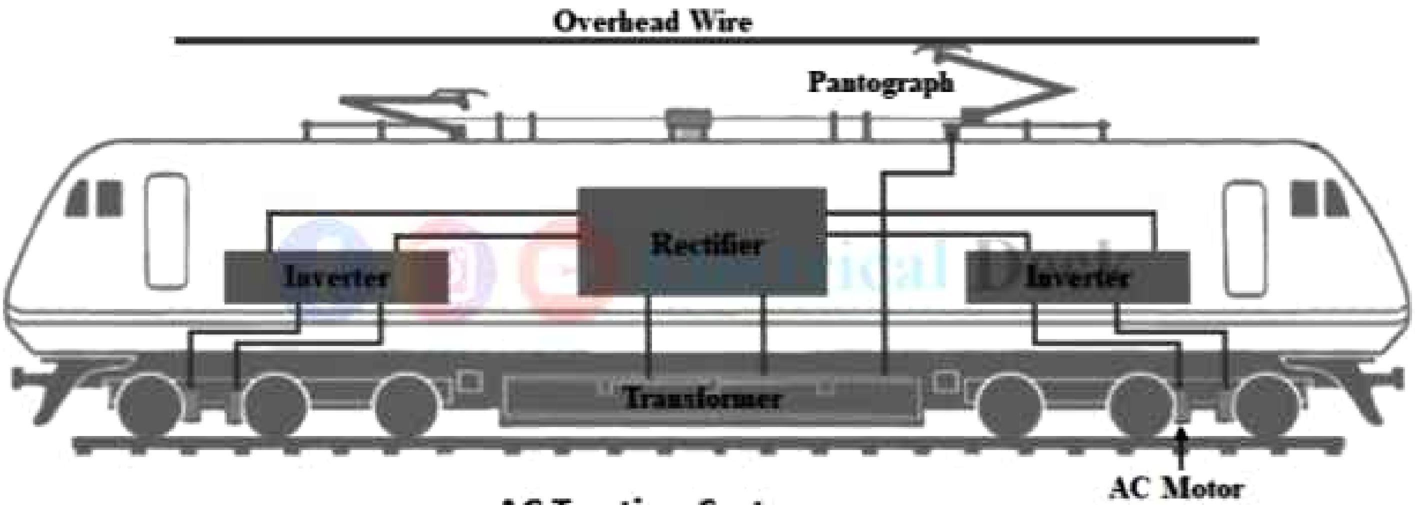
→ The spacing of substation is 50 to 80km.

→ The change of frequency becomes necessary because of better performance of ac series motor at low frequency.

→ Low frequency operation of AC motor improve its commutation properties improve power factor (because of less impedance $\uparrow \cos\phi = \frac{R}{Z\downarrow}$) & high efficiency (because of low frequency the skin effect will be less $f \propto$ Skin effect) so that efficiency is high because of losses will be less.

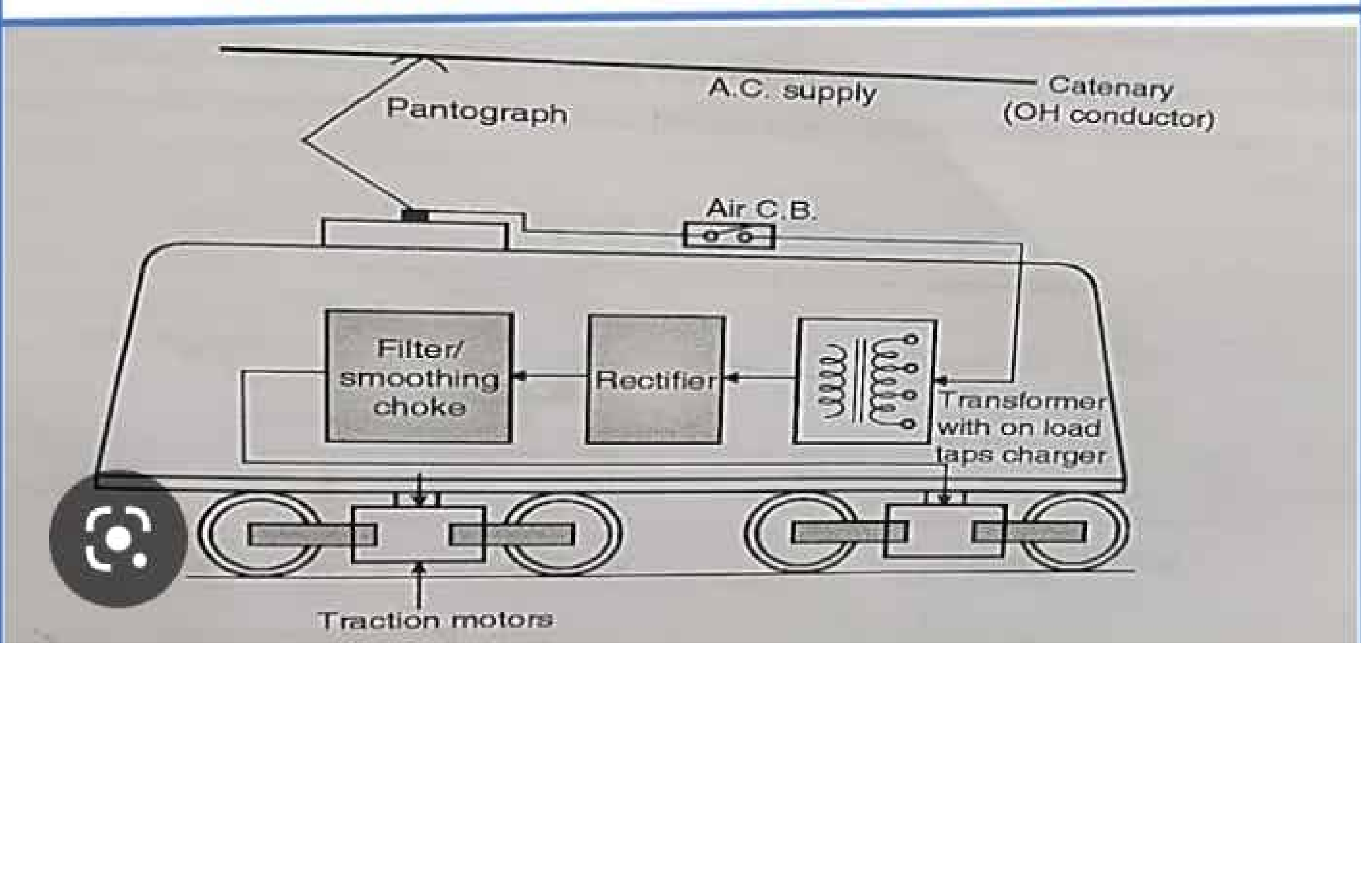
→ Low frequency operation of overhead transmission line reduce the line reactance & hence the voltage drop will be less.

$$\downarrow X_L = 2\pi f \downarrow L$$



AC Traction System

Electric A.C. Locomotive



→ AC system is generally adopted for main line service where the cost of overhead structure is more importance & rapid acceleration. &

→ It is used in west germany, Sweden & Australia for main line service.

(ii) 1 ϕ Standard frequency system :-

The system has a single overhead wire supplied at 25KV; 50Hz which is standard industrial frequency.

→ This system also known as single phase high frequency system. A transformer is mounted on the locomotive & it steps down the voltage which is rectified & supplied to the traction motor. The driving Force is obtained from DC series motor.

(b) 3 ϕ low frequency AC system :-

In this system 3 ϕ slip ring induction motors operating at 3000 to 3600v & normal frequency of 16.7Hz are ~~fre~~ employed for getting the required motive power.

→ The 3 ϕ induction motors are simple & robust in construction & have a high operating efficiency & propoties of automatic regenerative breaking without requiring & additional equipment.

* Drawback → Low starting torque, high starting current & absence of speed control.

→ This system are employed in hilly areas, where the o/p power required is high & regeneration on large scale is possible.

Composite Traction System :-

Composite system or multi system trains are used to provide continous journey along routes that are electrified using more than one system.

→ This system combine the advantages of dc & ac or 1 ϕ & 3 ϕ system.

→ composite system involving conversion of 1ϕ to 3ϕ or AC to DC.

→ 1ϕ AC system has less distribution cost where as DC system has excellent driving capacity by DC motor & 3ϕ system have automatic regenerative breaking capacity.

→ The overall performance of traction system gives better result than individual system. so we adopt composite system.

* It is a type
(i) 1ϕ to 3ϕ System (Kando system)
(ii) AC to DC system

(I) Single phase to three phase system (kando system)

In this system single phase 16kV, 50Hz supply which is fed from the substation & is being carried through a single overhead conductor. The single phase supply is then converted into 3ϕ supply of the same frequency using phase converter equipment in the locomotive itself.

→ It is also possible to ~~design~~ develop high starting torque of induction motors by reducing the supply frequency.

→ This system is also known as Kando system. As the 3ϕ AC traction system has some disadvantages such as tapping of power supply through two overhead conductors which is eliminated in the kando system.

→ The system has the advantages low cost distribution & robust construction of Induction motor.

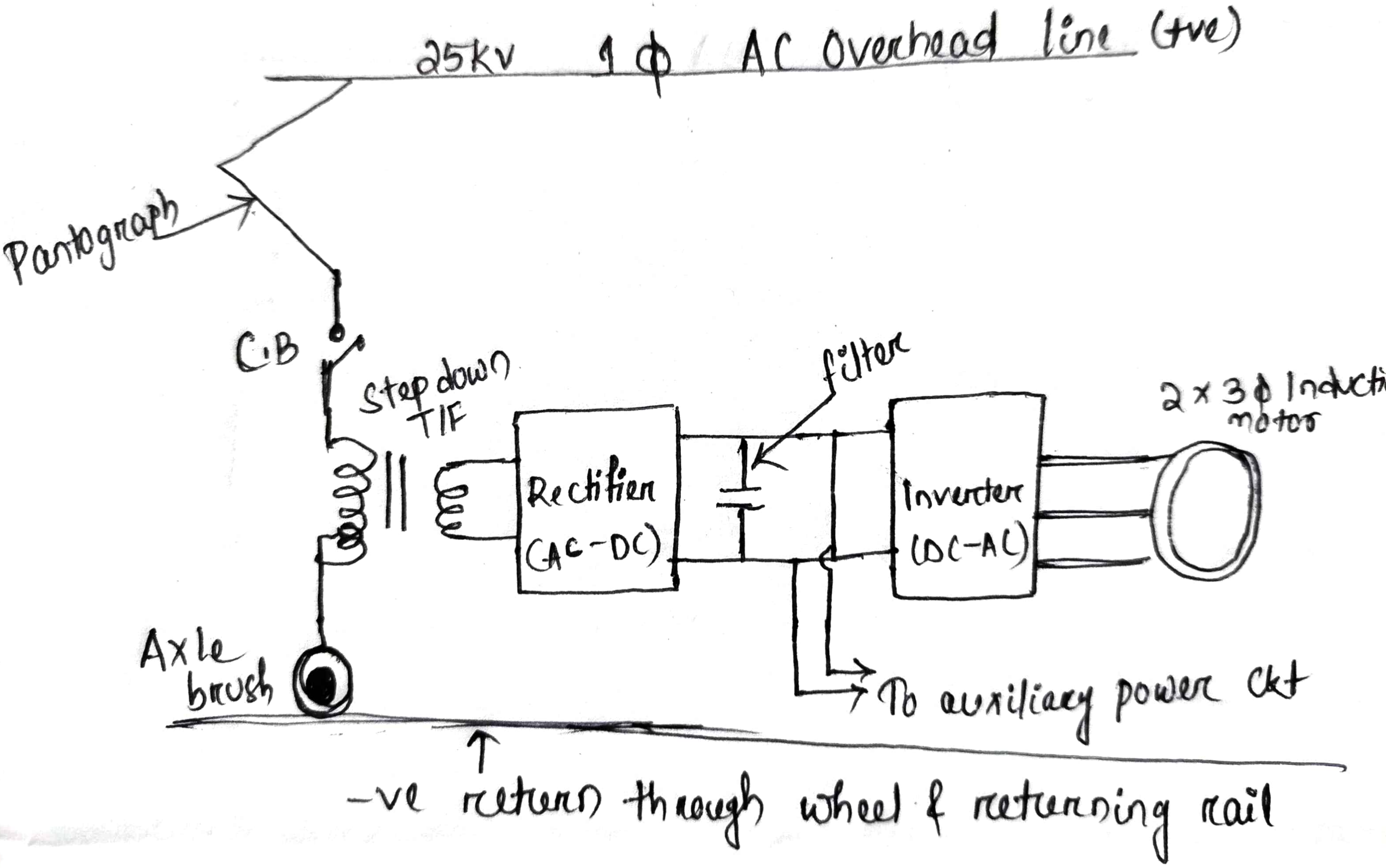
(II) AC to DC system :-

This system combines the single phase high voltage AC distribution at industrial frequency with DC series motor traction.

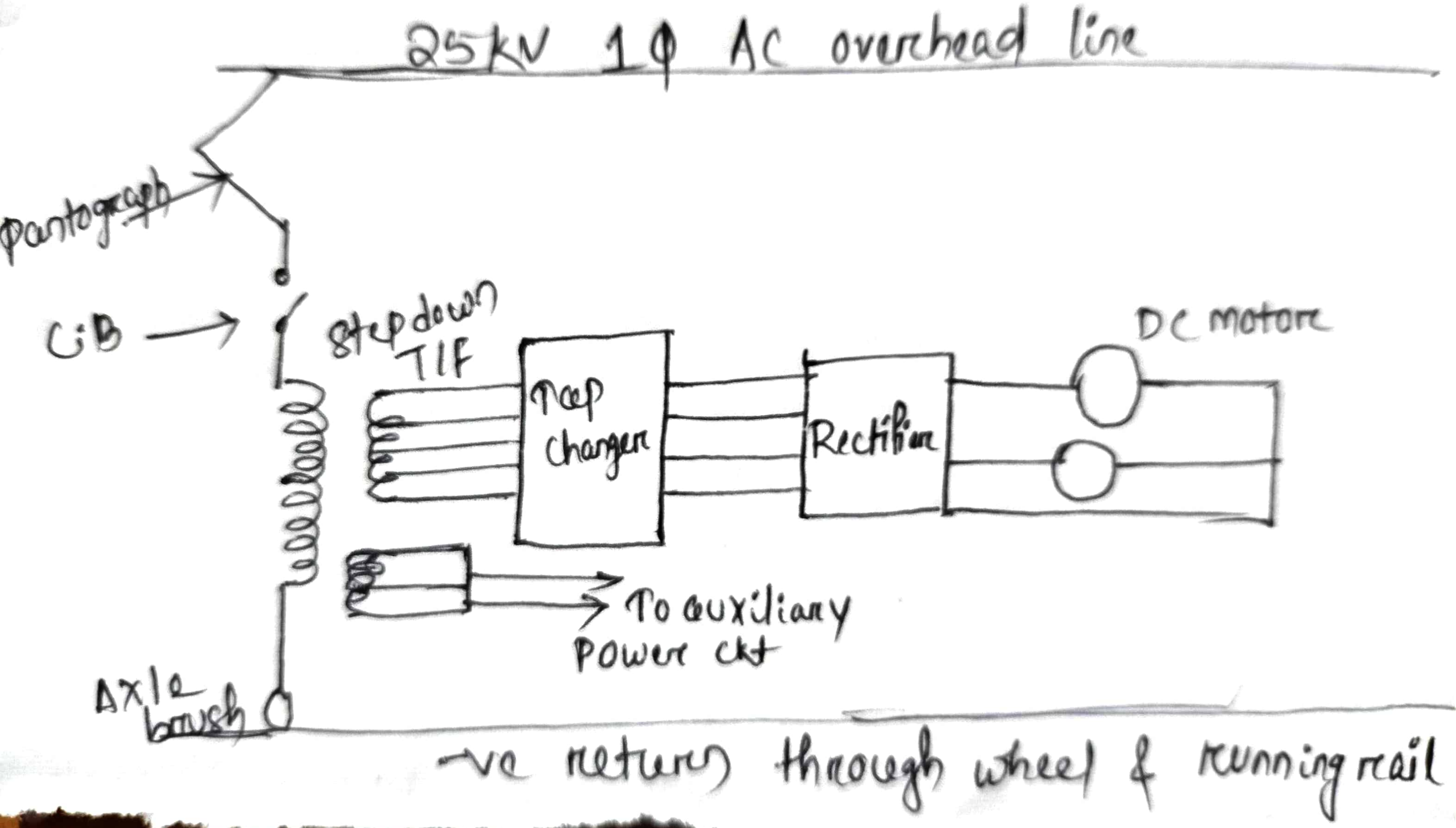
→ In this, the overhead line carries single phase 25kV, 50Hz supply which is then stepped down to a desired range using step down transformer located in the locomotive unit itself.

→ This single phase supply is then converted into DC using rectifier & then applied to DC series motor.

1 ϕ to 3 ϕ system :-



1 φ AC to DC system :-



Page No

Electrical Drive

The system employed for motion control is called drive.
Example - Motor.
Electrical Drive → It is defined as a form of machine equipment designed to convert electrical energy in to mechanical energy & provide electrical control of these processes.
For obtaining electrical drive both AC & DC motors are used.
Electrical Drive used in Industry divided into 2 types
(I) Group Drive
(II) Individual Drive

(*a*) **Group Drive.** 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.

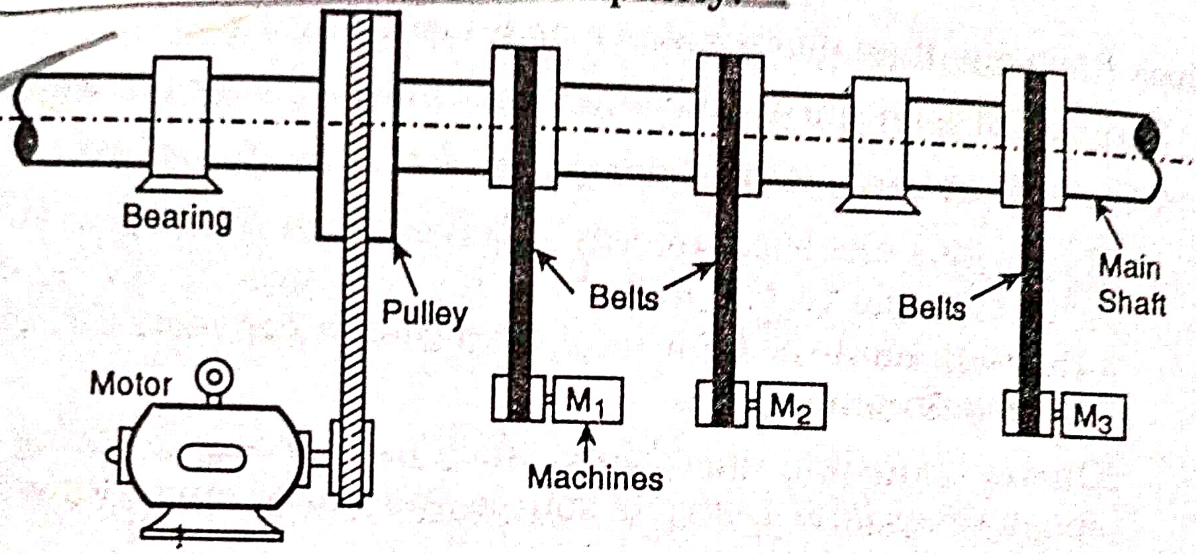


Fig. 1.1 (*b*) Group Drive.

The use of this kind of drive is restricted due to the below mentioned reasons :

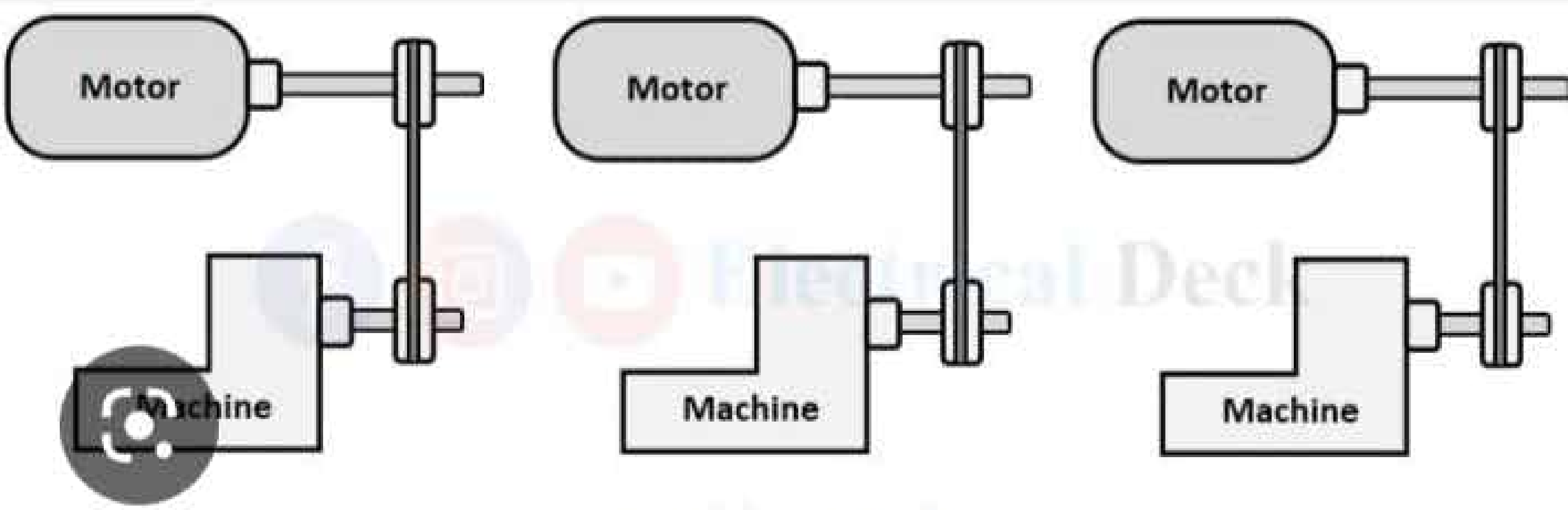
(*i*) In case of fault in the motor, all the connected machines to this motor will cease to operate.

(*ii*) If at certain instance all the machines are not in operation, then the motor will be working at low capacity.

(*iii*) It is not possible to install a new machine at a far away distance.

(*iv*) Speed control of different machines using belts and pulley is cumbersome.

(*b*) **Individual Drive.** In this type of electric drive a single electric motor is used to drive one individual machine. Though it costs more than Group drive but each operator has complete control on his machine, which enables him to either increase the speed of 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 effect the production of the industry appreciably.



Individual Drive

1.9 Comparison Between two drives.

Points	Individual Drive	Group Drive
1. Initial cost	More	Less
2. Power factor	Works at good p.f.	Low p.f.
3. Efficiency	High.	Low, when motor works at light load.
4. Reliability	More reliable.	If main motor fail whole industry will come to stand still.
5. Flexibility	Machines may be fitted wherever convenient.	Such arrangement is not possible in group drive.
6. Speed	More useful where constant speed is required.	Does not give constant speed.
7. Sequence of operation	Useless, where sequence of operation is required.	Useful, because all the operations are stopped simultaneously

8. Types of machines	This is must for driving heavy machines *e.g.* Cranes, lifts etc.	This system not employed in such cases.
9. Space utility	Space can be fully & conveniently utilized	More space is required in group drive.

1.9 (*a*) Choice of Electrical Drives

(i) **Requirement related to electric supply** –

AC or DC supply and magnitude of voltage, voltage fluctuations, power factor, harmonics level.

(ii) **Nature of the drive** – Individual machine or a group of machines multimotor.

(iii) **Cost and Maintenance requirement**-

capital cost, maintenance cost should be considerable values.

(iv) **Nature of load**- T & N

Whether the load requires light or heavy starting torque T_{st}

Whether load torque increases with speed remain constant $T_L = T_f + T_w$.

Whether the load has heavy inertia which may require longer time .

(v) **Electrical characteristics of motor**- $T \times N$

Starting characteristics, running characteristics, speed control and Braking characteristics.

(vi) **Size, rating and duty cycle of motors** -Whether the motor is going to the operator for a short time or whether it has to run continuously Intermittently or on a variable load cycle

(vii) **Mechanical considerations** - Type of enclosures, type of bearings, transmission of drive and Noise level.

Motor → Load

(viii) **Space and weight restrictions**-It is based on application and needs. In aerospace & vehicle space needed is more.

(ix) **Steady state operation-Speed** –torque characteristics, speed regulation and its range, efficiency, duty cycle, duty ratio, Quadrants of operation.

(x) **Transient operation**-Acceleration, deceleration, starting, braking and reverse performance

Starting & Running characteristic of DC Motor :-

The performance of a DC motor can be judged from its characteristic Curve known as motor characteristics.

- There are 3 principal types of dc motor
  - (1) Shunt motor. (Constant speed motor)
  - (2) Series motor (High starting torque & low speed motor)
  - (3) Compound motors

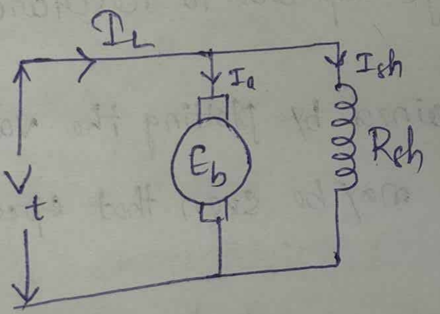
3 important characteristic of dc motor.

(i) Torque & Armature current characteristic (T/I_a)

(ii) Speed & armature current characteristic (N/I_a)

(iii) Speed & Torque characteristic (N/T_a)

(1) characteristic of shunt Motors :-



* The field current I_{sh} is Constant the field wdg is connected to the supply voltage V which is assumed to be constant. Hence the flux in a shunt Motor is approximately Constant.

(i) T/I_a characteristics :-

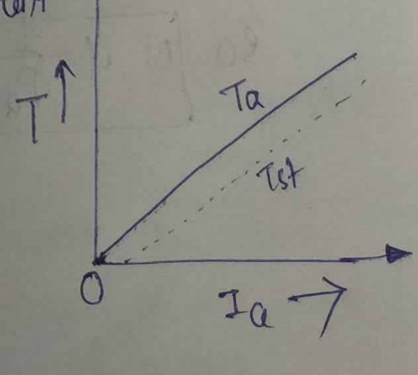
we know that in a dc motor.

$T \propto \phi I_a$

Because of constant supply voltage ϕ is Constant

$\boxed{T_a \propto I_a}$

So starting torque (T_{st}) is not high



(ii) N/ I_a characteristics :-

The speed N of a dc motor is given by

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

$$\phi \propto I$$

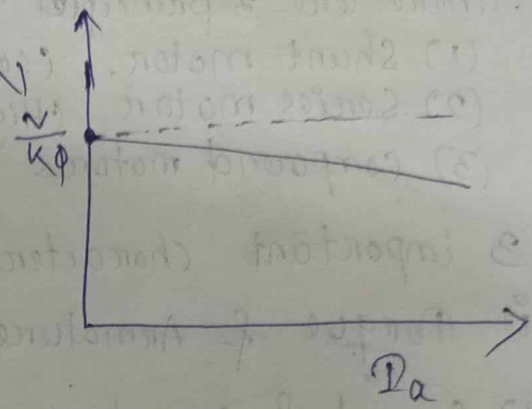
$$E_b = V - I_a R_a$$

$$N = \frac{E_b}{K\phi}$$

$$N = \frac{V_t - I_a R_a}{K\phi}$$

$$N = \frac{V_t}{K\phi} - \cancel{\frac{I_a R_a}{K\phi}} \rightarrow 0 \text{ (Ideal condition)}$$

$$N = \frac{V_t}{K\phi}$$



$$\boxed{N \propto \frac{1}{I_a}}$$

But ideally it is not possible

So there will be little bit voltage drop due to resistance.

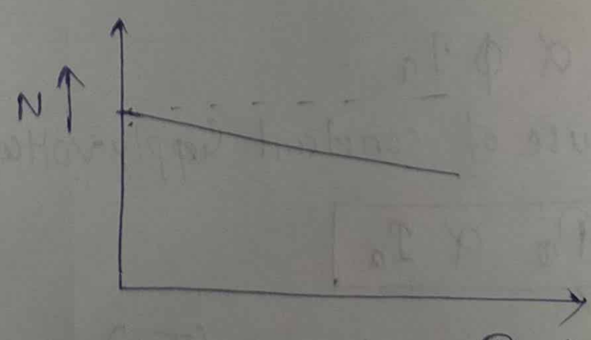
(iii) N / T_a :- The curve is obtained by plotting the values of N & T_a for armature current. It may be seen that speed falls as the torque increases.

→ There is a slight change in the speed of a shunt motor from no load to full load. Hence it is a constant speed motor.

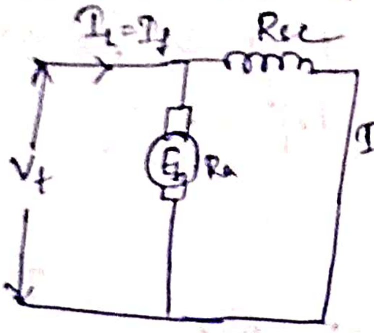
$$N \propto \frac{1}{I_a}$$

$$T \propto I_a$$

So $\boxed{N \propto \frac{1}{T_a}}$



Characteristic of Series Motor :-



The current passing through the field winding is the same as that in the armature.

If the load on the motor increase then the I_a is also increase.

(i) T/I_a characteristics :-

we know that

$T_a \propto \phi I_a$

Upto magnetic Saturation $(\phi = I)$

$\phi \propto I_a$ So that $T_a \propto I_a^2$ (Parabola)

(If $T_a = y$ & $I_a = x$ then $y = x^2$)

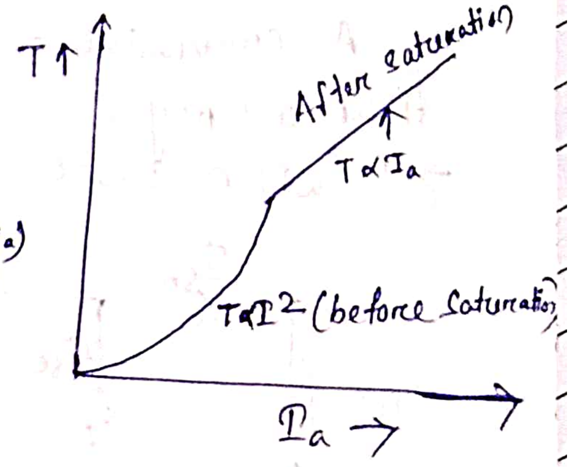
After magnetic Saturation $(\phi \neq I)$

ϕ is constant

So that $T_a \propto I_a$

$T = kI_a$

$y = x$ (linear)



(ii) N/I_a characteristics

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

$E_b = V_t - I_a(R_a + R_{se})$

$N = \frac{E_b}{k\phi}$

$N = \frac{V_t - I_a(R_a + R_{se})}{k\phi}$

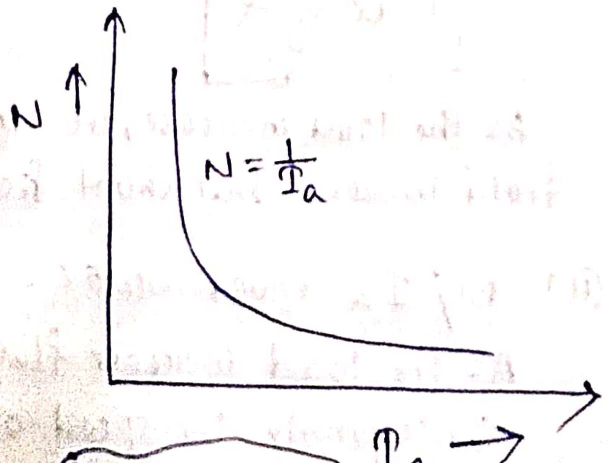
$N = \frac{V_t}{k\phi} - \frac{I_a(R_a + R_{se})}{k\phi}$

At no load (I is zero)

$\phi = I_f = I_a = 0$

$N = \frac{1}{I_a} = \infty$ $\quad y = \frac{1}{x}$ (hyperbola)

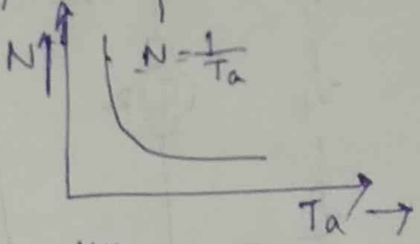
Here $y = N$ & $x = I_a$ So condition is hyperbola



So series dc motor is never switched on at no load. Because at no load cond^n speed is infinite. High speed can cause damage to the motor.

(iii) N / T_a Characteristic :-

DC Series motor develops high torque at low speed & low torque at high speed.



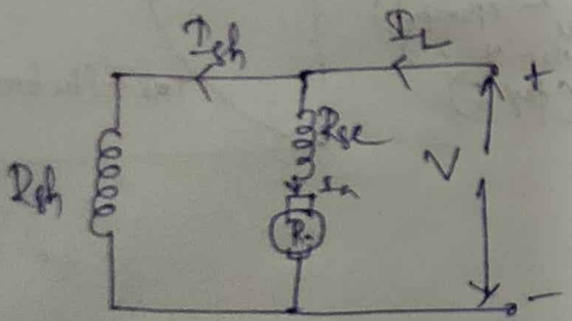
$$N \propto \frac{1}{T_a}$$

if $N = y$ & $T_a = x$ then $y = \frac{1}{x}$ its hyperbola condition

C/s of compound motors :-

A cumulative compound motor each pole carries a series & shunt field winding.

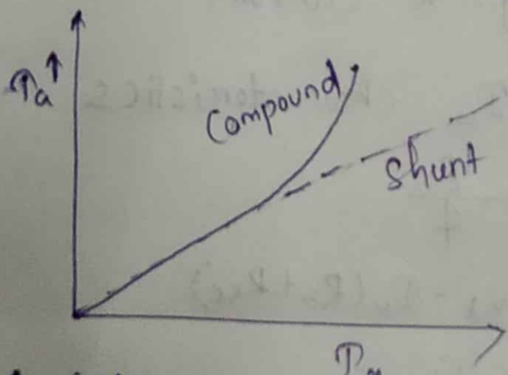
→ In which series field aids the shunt field.



(i) T_a / I_a characteristics

$N \propto \frac{1}{\phi}$ $T_a \propto I_a$

$\boxed{N \propto \frac{1}{I_a}}$

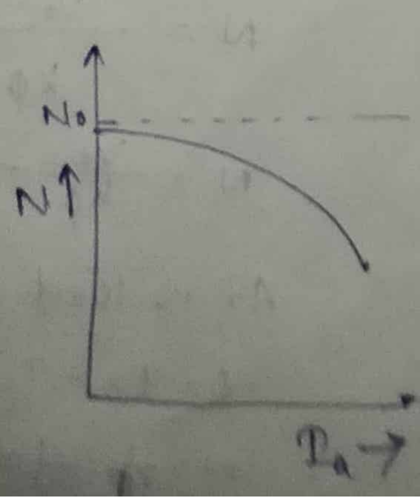


As the load increase, the series field increase but shunt field constant.

(ii) N / I_a characteristic.

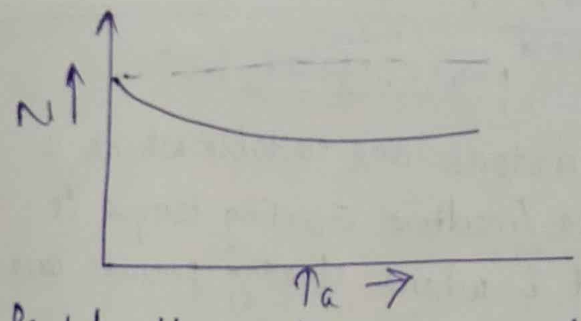
As the load increase flux per pole also increase. Consequently the speed of motor falls.

$$\boxed{N \propto \frac{1}{I_a}}$$



(iii) N / T_a characteristic :-

$$\boxed{N \propto \frac{1}{T_a}}$$



Note: Due to the presence of shunt field, the motor is prevented from running away at no load.

Due to the presence of series field the starting torque is increased.

Starting & Running characteristic of AC Motor :-

Torque slip characteristic of 3 ϕ Induction Motor :-

$$\boxed{\begin{aligned} T_f &\propto \frac{s R_2}{R_2^2 + (s X_2)^2} \\ T_s &\propto \frac{R_2}{R_2^2 + X_2^2} \\ T_m &\propto \frac{1}{2 X_2} \end{aligned}}$$

→ for Running condⁿ ...See Ar

→ for starting condⁿ ...See Ar

→ for max^m condⁿ ...See Ar

reactance ... in the rotor circuit to give ...
phase is necessary in the rotor circuit to give ...

9.18 TORQUE-SLIP CHARACTERISTICS

As shown in Art. 9.16, the motor torque under running conditions is given by ;

$$T = \frac{K_2\, s\, R_2}{R_2^2 + s^2 X_2^2}$$

If a curve is drawn between the torque and slip for a particular value of rotor resistance R_2, the graph thus obtained is called torque-slip characteristic. Fig. 9.22 shows a family of torque-slip characteristics for a slip-range from $s = 0$ to $s = 1$ for various values of rotor resistance.

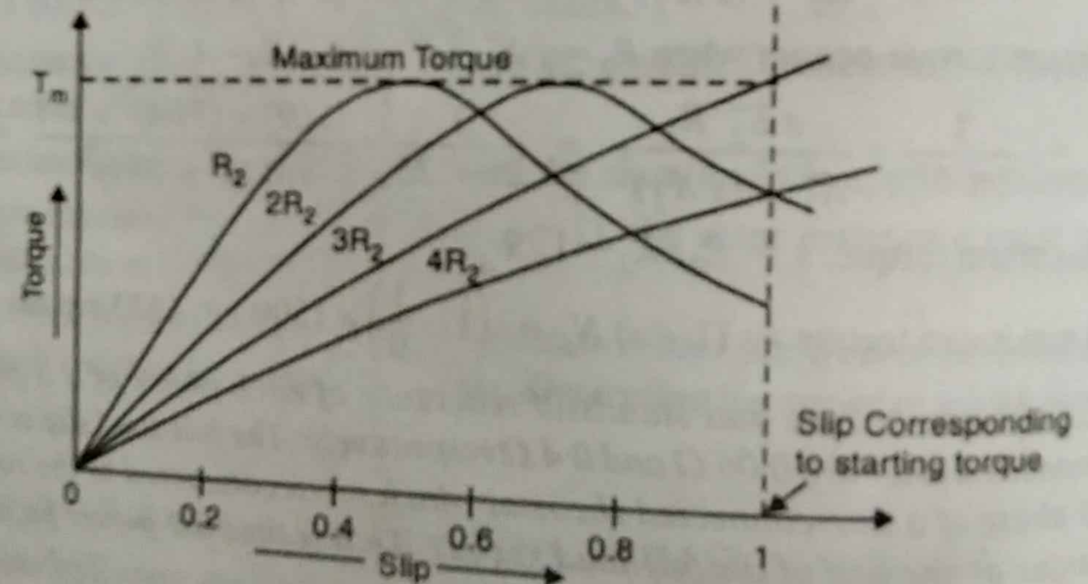


Fig. 9.22

The following points may be noted carefully :

(i) At $s = 0$, $T = 0$ so that torque-slip curve starts from the origin.

(ii) At normal speed, slip is small so that $s\, X_2$ is negligible as compared to R_2.

$$T \propto s/R_2$$

$$T \propto s$$

as R_2 is constant.

Hence torque-slip curve is a straight line from zero slip to a slip that corresponds to full-load.

As slip increases beyond full-load slip, the torque increases and becomes maximum at $s = R_2/X_2$. This maximum torque in an induction motor is called *pull-out torque* or *breakdown torque*. Its value is atleast twice the full-load value when the motor is operated at rated voltage and frequency.

When slip increases beyond that corresponding to maximum torque, the term $s^2X_2^2$ increases very rapidly so that R_2^2 may be neglected as compared to $s^2X_2^2$.

$$T \propto s/s^2X_2^2$$

$$\boxed{\propto 1/s} \qquad \text{...as } X_2 \text{ is constant}$$

Thus the torque is now inversely proportional to slip. Hence torque-slip curve is a rectangular hyperbola.

(iv) The maximum torque remains the same and is independent of the value of rotor resistance. *Therefore, the addition of resistance to the rotor circuit does not change the value of maximum torque but it only changes the value of slip at which maximum torque occurs.*

[(i) 33 A (ii) 0.9 lag (iii) 88% (iv) 68 h.p.]

10.9 SPEED CONTROL OF INDUCTION MOTORS

10

The slip of an induction motor is very small (< 3%) so that it is essentially a *constant-speed motor. Therefore, it is suitable for use in essentially constant-speed drive systems. However, many industrial applications require several speeds or a continuously adjustable range of speeds. Traditionally, d.c. motors have been used in such adjustable-speed applications. However, d.c. motors are expensive and require frequent maintenance of commutators and brushes. On the other hand, the induction motors (particularly the squirrel cage motors) are cheap, rugged, have no commutators and are suitable for high-speed applications. The engineers have devised several methods to change the speed of induction motors. This has made it possible to use induction motors in variable-speed applications.

The relation between motor speed (N), synchronous speed (N_s) and slip (s) is given by :

$$\boxed{N = (1-s)N_s}$$

or $$\boxed{N = (1-s)\frac{120\,f}{P}} \quad \ldots(i) \quad \left[\because N_s = \frac{120\,f}{P}\right]$$

Eq. (i) reveals that the speed of an induction motor can be changed by the following methods

1. By changing the number of stator poles (P).
2. By changing the line frequency (f).
3. By changing the slip (s) for a given load. The slip can be changed ;
   - (i) By changing the applied voltage.
   - (ii) By changing resistance in the rotor circuit.
   - (iii) By inserting foreign voltage of appropriate frequency in the rotor circuit.

... the motor.

10.12 SPEED CONTROL BY CHANGING APPLIED VOLTAGE

We know that torque developed (T) by an induction motor is directly proportional to the square of applied voltage (V) *i.e.* $T \propto V^2$. Therefore, by changing the applied voltage, the torque and hence speed (or slip) of the motor can be changed. Fig. 10.21 shows the arrangement to control the speed of induction motor (squirrel cage or wound rotor motor) by changing the applied voltage.

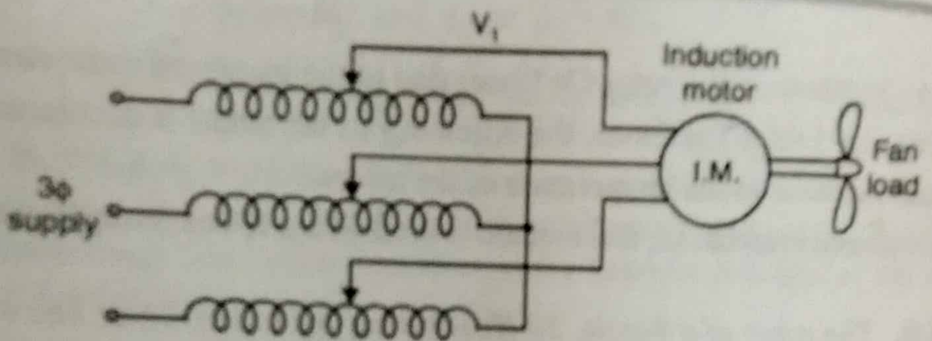


Fig. 10.21

The motor is supplied from 3-phase supply through a 3-phase auto-transformer. The motor drives fan load. The voltage applied to the motor can be changed by the autotransformer and hence desired motor speed can be obtained.

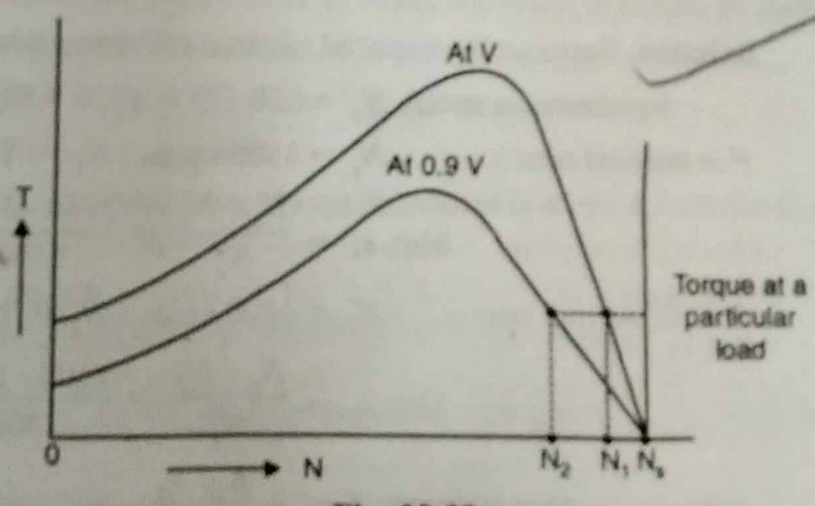


Fig. 10.22

In fact, when we change the applied voltage, the slip (s) of the motor is changed *i.e.* motor speed changes. Let us illustrate this point. Suppose the applied voltage is V (say V = 400 volts) and the motor is running at a speed N_1. If the applied voltage is reduced to 0.9 V, the torque will be reduced from T to 0.81 T ($\because$ Torque $\propto V^2$). Fig. 10.22 shows torque-speed curves for applied voltages V and 0.9 V. Since the torque is reduced, the rotor cannot continue to run at speed N_1. The rotor speed will decrease (*i.e.* slip will increase) until the increased rotor current produces the required load torque at a lower speed N_2

Methods of starting 3-phase induction motors

It is desirable to start a.c. motors at full voltage to attain simplicity and economy in the starting gear. Induction motors can be designed and built to enable them to be started on full voltage. But in case of cage motors the starting current may be large enough to produce considerable voltage drop in the distribution system which may adversely affect other apparatus and also cause light flicker.

Induction Motors are therefore, started on reduced voltage .The various methods of starting are discussed as follows:

1. **Resistor starting method**

A series resistor is used in each line and may be arranged in a manner that the resistance is reduced to zero in steps so that the motor current may increase to the full value gradually and transients are avoided.

The torque efficiency which is

$$\frac{\text{Torque developed by the Motor/ Full load torque}}{\text{Current of Motor / Full load current}}$$

A motor having a starting torque equal to twice the full-load torque and a starting current six times the full load current ha s a torque efficiency = 2/6=0.33.

If the same motor is started at 60 percent voltage by using resistors, the line current will be(0.6 x 6 x full-load current) and the starting torque will be [0.6 x 0.6 x 2 x full-load torque].The Torque efficiency will be (0.6 x 0.6 x2)/0.6 x 6 = 0.2 .

2. **Reactor starting**

It is not a frequently employed as resistors or auto transformer starting, though the method is similar to resistor starting. The acceleration is very smooth in this case though the acceleration time is comparatively longer.

3. **Autotransformer starting**

Taps are provided on the auto transformer so that the motor can be started at reduced voltage. Taps are for 50, 65 and 80 percent of line voltage; the 50 percent tap being provided only in the case of sizes above 50 H.P. In the second method of operation the large transient current is reduced since the motor is always connected through the auto-transformer winding to the line.

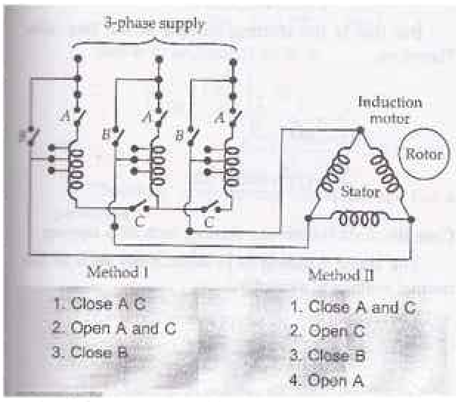


Fig. 3. Starting of SQIM by Autotransformer starter

We can determine the reduction in the starting current when using auto-transformer starter. Consider an auto-transformer with a transformation ratio $K = \frac{\text{Primary Voltage}}{\text{Secondary voltage}}$. Consider also that the motor has a starting torque equal to twice full-load torque and starting current equal to six times the full load current. If the motor is started at full voltage, phase voltage $E_{ph} = E/\sqrt{3}$ and starting current = 6I.when the motor is started through an auto-transformer, the phase voltage is E_{ph}/k and the starting current = 6I/k.

Also we have $\frac{E_{ph}}{V_{ph}} = k = \frac{N_1}{N_2} = \frac{I_2}{I_1}$

1.4. Single-Phase Induction Motors

A single-phase induction motor does not have a rotating magnetic field. it has only a pulsating field and therefore does not possess any starting torque. The following three methods are employed to make the motor self-starting.

(a) **Pole-shading**: The motor is of squirrel-cage type and the stator pole is shaded by a heavy copper wire or strip. The current induced in the shading coil causes the magnetic field through the shaded portion of the pole face to lag behind the main flux thereby producing a rotating Magnetic field. Such motors have a low starting torque but are quite economical in small sizes.

(b) **Phase-splitting**: A two-phase supply is obtained from a single-phase line by using a capacitor. The motor has a cage-rotor and a stator containing two separate windings located in the same manner as for a two-phase stator. One of the windings is connected directly to supply and the other through the capacitor. A rotating magnetic field is obtained in the air-gap. There are two types of capacitor motors: the capacitor start motor, in which case the capacitor is in circuit only during the starting period and is disconnected at a predetermined speed by a centrifugal switch; the other type is the capacitor start and run motor where the capacitor is connected permanently and improves the power factor of the motor.

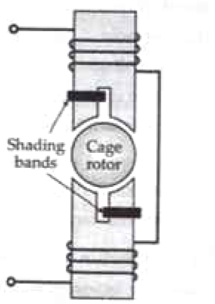


Fig..7 Shaded pole motor

(c) **Repulsion motor starting:** the rotor has a repulsion motor winding and therefore starts as a repulsion motor giving high starting torque. As it runs to speed a centrifugal device short-circuits the commutator bars and lifts the brushes, converting the motor into a plane squirrel cage one.

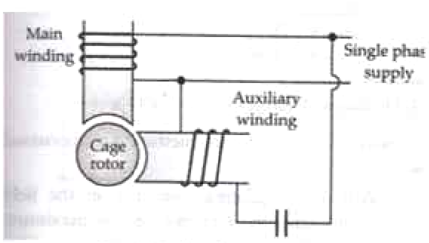


Fig..8 Split phase starting

(d) **Synchronous motors:** There is no starting torque in a synchronous motor. It has to be run up to synchronous speed by another motor and synchronized to the supply. To make it self-starting a cage winding is provided on the poles. It starts as a plain squirrel cage motor and when it has attained nearly synchronous speed at no-load, the d.c excitation is switched on and the rotor pulls into synchronism. Starting torque between 50 to 100 percent full load torque can be obtained with twice full load current. The synchronous Induction motor has a cylindrical rotor with a slip-ring induction motor winding. It starts as a slip-ring induction motor with good starting torque and when it has almost reached the synchronous speed, d.c. is passed through the rotor winding making rotor pull into synchronism.

The Theree-phase Induction Motors

It possesses shunt characteristics. The power factor is very poor at low loads but improves as the load increases. The power factor, however, always remains less than unity.

The Synchronous and synchronous-Induction motor

The synchronous motor is a constant speed motor: The speed is fixed by the frequency of the supply. It is not, however, self starting. It is started by an auxiliary motor and synchronized to the supply .This disadvantage is eliminated in a synchronous-Induction Motor where the machine starts as plane Induction motor and when the speed is very near the synchronous speed the DC excitation to the rotor is switched on and the motor pull into synchronism.

By varying the field excitation of these types of motors the power factor may be made unity or even be made leading. An over-excited synchronous motor works as a leading power factor while an under-excited motor works as lagging power factor. It is, therefore used in improving the power factor in a system using many induction motors.

Single-phase series motor

It possesses the series characteristics. In large sizes it finds an exclusive application of Traction work .In fractional horse power size it is used in domestic appliances like vacuum cleaners and refrigerators etc.

Single-phase Induction motor

It has shunt characteristics. Since it has no starting torque, additional means have to be provided to make it starting. Repulsion start and the capacitor start motor are the common modifications of the single phase induction motor.

Repulsion motor

It has series characteri9stics and closely resembles the series motor in construction.The armature is short circuited in itself.

SPEED CONTROL

5.27 APPLICATIONS OF D.C. MOTORS

1. Shunt motors. The characteristics of a shunt motor reveal that it is an approximately constant speed motor. It is, therefore, used

(*i*) where the speed is required to remain almost constant from no-load to full-load

(*ii*) where the load has to be driven at a number of speeds and any one of which is required to remain nearly constant

Industrial use : Lathes, drills, boring mills, shapers, spinning and weaving machines etc.

2. **Series motors.** It is a variable speed motor *i.e.*, speed is low at high torque and *vice-versa*. However, at light or no-load, the motor tends to attain dangerously high speed. The motor has a high starting torque. It is, therefore, used

(*i*) where large starting torque is required *e.g.*, in elevators and electric traction

(*ii*) where the load is subjected to heavy fluctuations and the speed is automatically required to reduce at high torques and *vice-versa*

Industrial use : Electric traction, cranes, elevators, air compressors, vacuum cleaners, hair drier, sewing machines etc.

3. **Compound motors.** Differential-compound motors are rarely used because of their poor torque characteristics. However, cumulative-compound motors are used where a fairly constant speed is required with irregular loads or suddenly applied heavy loads.

Industrial use : Presses, shears, reciprocating machines etc.

5.28 TROUBLES IN D.C. MOTORS

Applications of Squirrel Cage Motors

Q. 4.57 What are the applications of squirrel cage induction motor ?

Ans. :

- The squirrel cage motors have small or moderate starting torques and it is not possible to ... external rotor resistances for increasing the starting torque.
- These are constant speed motor.
- So these motors are preferred for the following applications :

1. Fans and blowers.
2. Grinders
3. Drilling machines
4. Blowers and Water pumps
5. Lathe machines
6. Printing machines.

Applications of Slipring Induction Motors

Q. 4.58 What are the applications of slipring induction motor ?

Ans. : They are used for the following applications :

1. Hoist 2. Lifts 3. Elevators 4. Cranes 5. Compressors.

All these are actually high starting torque applications.

Application of 1ϕ Induction Motor :-

(i) Application of split phase Induction Motor :-

These motors are suitable where a moderate/medium starting torque is required & where starting periods are rare.

To drive fan, washing machine, oil burners, small machine tools etc.

(ii) Application of capacitor start motor.

· Where the high starting torque is required & the high starting period may be long e.g to drive - compressors, large fans, pumps, high intertia loads.

(iii) Application of capacitor start, Capacitor Run Motor :-

Where the constant torque is required. The motor is vibration free & can be used in hospital, studios, & other places where silence is important.

(iv) Shaded pole motor :-

Gives high starting torque.

Used → small fans, toys, hair driers, desk fans etc.

overload, the power factor is lower.

UNIVERSAL MOTOR

Applications. The fractional horsepower a.c. series motors have high-speed (and corresponding small size) and large starting torque. They can, therefore, be used to drive :

(*a*) high-speed vacuum cleaners (*b*) sewing machines

(*c*) electric shavers (*d*) drills (*e*) machine tools *etc.*

Example 11.17. *A universal series motor has resistance of 30 Ω and an inductance of 0.5 H.*

The main application of repulsion motor is **electric trains**. It starts as a repulsion motor and runs as an induction motor, where the starting torque should be high for a repulsion motor and very good running characteristics for an induction motor. 02-Mar-2021

Page No.

Explain Control of Motor :-

Control of speed for an industrial drive depends upon the nature of being carried out. A certain operation may require a continuously varying speed another one may only require fixed speed. For most industrial drives, however a control speed within ±20 % may be suitable.

→ For electric motors in service are a c motors, the dc motor is considerable for industrial importance.

→ Advantages of dc motor is that its speed control can be possible but in ac a fine speed generally ~~can~~ not be possible

* Speed control of ~~speed~~ motor :-

EMF equation of a DC motor

$$E_b = \frac{P\phi Z N}{60A}$$

It can also be given as

$$E_b = V - I_a R_a$$

From above equation

$$N \propto \frac{E_b}{\phi} \qquad (N \propto E_b ,\ N \propto \frac{1}{\phi})$$

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

It is clear that speed can be controlled by varying flux per pole, resistance & the applied voltage.

(1) Tapped field Control :-

These method is used for changing the flux per pole in dc series motor.

Or by varying the flux ϕ, the motor speed can be changed. In this method the flux is reduce ~~by~~ hence speed is increased by decreasing the number of turns of the series field winding.

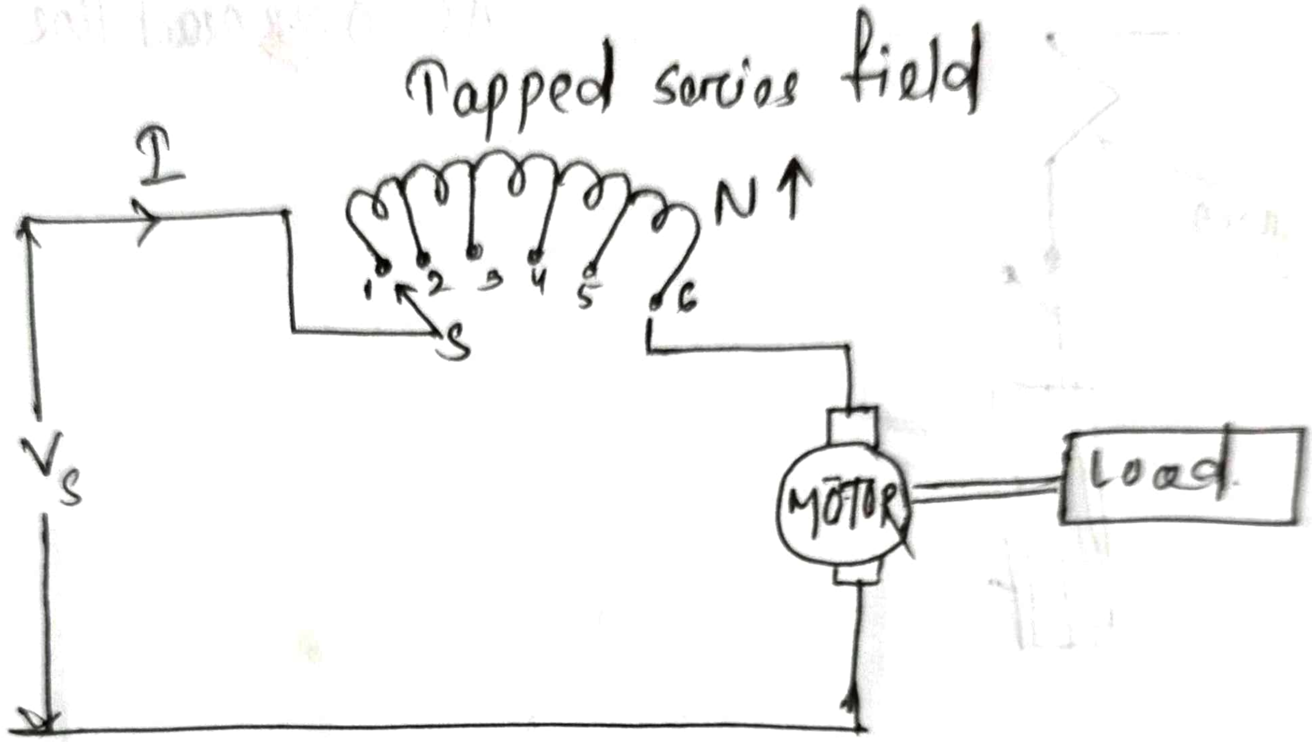
Tapping are provided on the field winding & current may be passed through different number of turns there by changing the field ampere turns.

The switch (S) can be short ckt any part of the field winding thus decreasing the flux & raising the speed.

With full turns of the field winding the motor runs at normal speed & as the field turns are cut out. Speed higher than normal speed are achieved.

→ This method is used for series motor in traction work.

speed control of dc



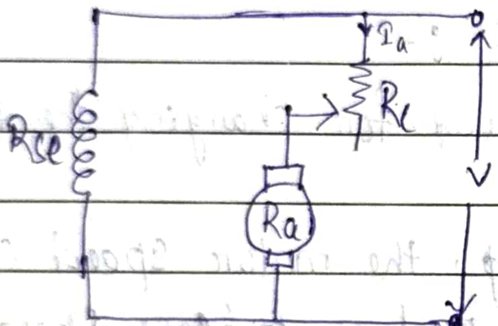
$$\uparrow N \propto \frac{1}{\phi \downarrow}$$

(2) Rheostatic Control :-

Variation of resistance in the armature circuit is called armature resistance control or Rheostatic Control.

(a) Armature control method in dc shunt Motor.

→ In this method ~~by~~ varying the voltage available across the armature, the back emf & hence the speed of the motor can be changed. This is done by ~~chang~~ inserting a variable resistance (R_c) (known as controller resistance in series with the armature resistance



$N \propto V - I_a(R_a + R_c)$

$\downarrow I_{sh} = \dfrac{V \downarrow}{(R_{sh} + R_{ext}) \uparrow}$

$\downarrow I_{sh} \propto \phi_{sh} \downarrow$

$\downarrow \phi_{sh} \propto \dfrac{1}{N \uparrow}$

$\uparrow N \propto \dfrac{1}{\phi \downarrow}$

$\boxed{N > N_{rated}}$

$\boxed{\text{speed rise}}$

$V \downarrow \propto N \downarrow$

Due to voltage drop in controller resistance, the back emf is decreased. So the speed of the motor is reduced.

$\downarrow N \propto E_b \downarrow$

The ~~highest~~ speed obtainable at $R_c = 0$ i.e normal speed.

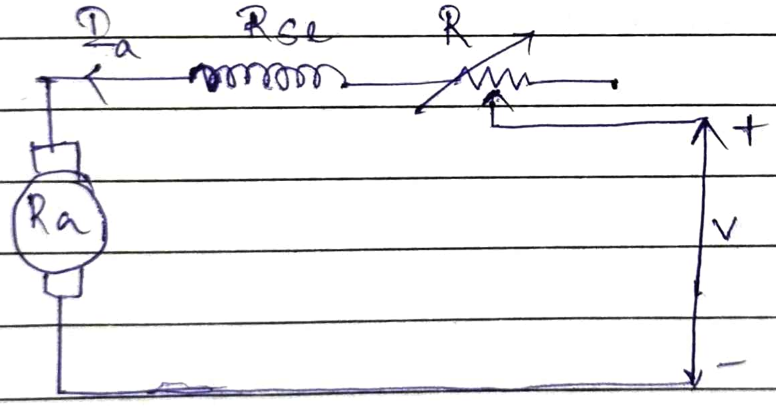
→ Hence this method is applicable for normal speed.

(b) Armature Resistance Control in dc Series motor.

In this method a variable resistance is directly connected in series with the armature.

→ This reduce the voltage available across the armature & hence the speed falls.

→ By changing the value of variable resistance any speed can below the normal speed can be obtained.



$N \propto V - I_a(R_a + R_{se})$

Magnetic Braking

- It is used in tramcars. The electromagnet is bipolar. The body is made of cast steel and the pole faces are made of soft steel and can be renewed.

- The exciting coil is enclosed in a water-tight case. The magnetic flux is perpendicular to the pole faces and the track. The force of attraction between the magnet and the track is given by

$$F = \frac{B^2 a}{2\pi \times 10^{-7}} N$$

- Where B is the flux density in Weber/m_2 and a is the area in the pole face in square meter. The drag that it can produce on the car is given by micro farad, where t is the coefficient of friction.

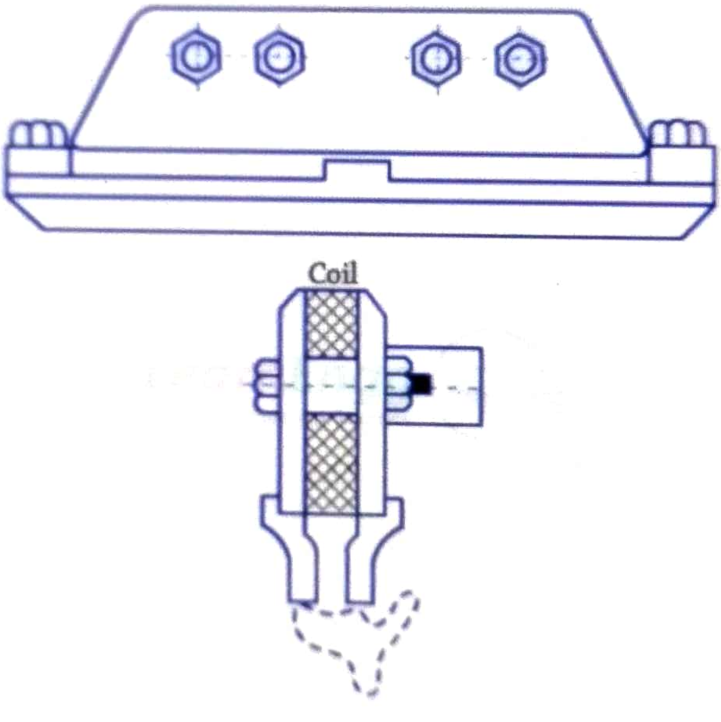


Fig 11

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Braking with 1-phase series motor

- In this case both Rheostatic and regenerative braking are possible.

Rheostatic Braking

- The motors are worked as separately excited generators supplying energy to resistance load.
- The fields are energized at low voltage from suitable tapings on the train transformer.
- The kinetic energy of the rotor is dissipated as electrical energy in the load resistance. Also, the fields of the motors may be excited from one of the motors acting as a series generator.
- In this case D.C. will be generated in the rotors of the motors and the kinetic energy of rotors will be dissipated as D.C. power in the loading resistors.

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Rheostatic braking of D.C. shunt motor

- Rheostatic braking can be obtained by disconnecting the armature from supply and connecting an external resistance across the armature terminals.
- The figure shows schematic arrangement for dynamic braking of D.C. shunt motor.

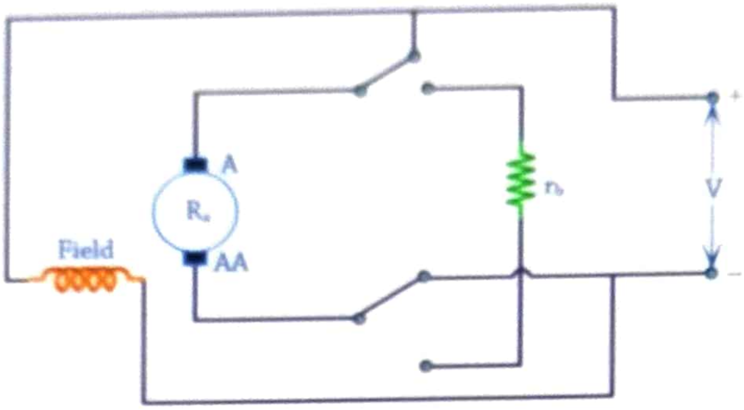

Fig 1: Dynamic braking of D.C. shunt motor

- The field winding is left connected across the supply and it is undisturbed.
- The braking effect is controlled by varying the braking resistance r_b.
- The figure shows that the speed-torque characteristics of a D.C. shunt motor under dynamic braking conditions.

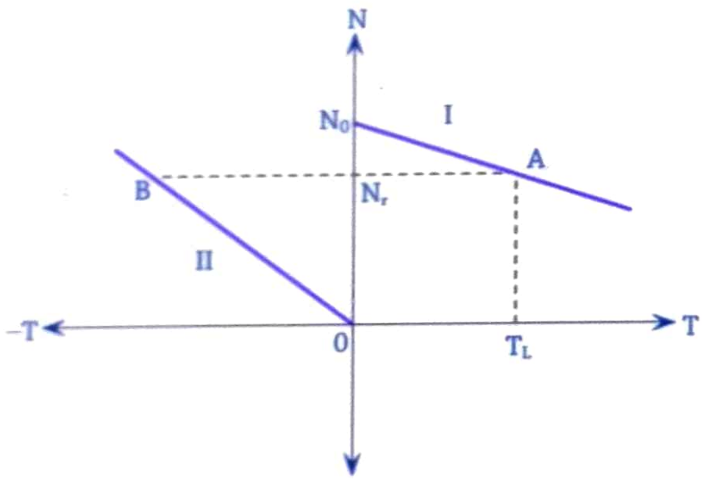

Fig 2: Speed-torque characteristics of a D.C. shunt motor under dynamic braking

- The motor is operating steadily for a given load torque T_L at the point A on its natural characteristics i.e., characteristics-I when dynamic braking is executed.
- Due to braking the operating point shifts to B on the characteristics-II from point A.
- The D.C. motor then decelerates along BO to standstill.
- The slope of the braking characteristics can be controlled by varying the braking resistor r_b.

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Rheostatic braking of D.C. series motor

- The D.C. series motors dynamic braking may be achieved in two ways.
  - With self excitation
  - With separate excitation
- The figure shows the motoring and dynamic braking with self excitation.

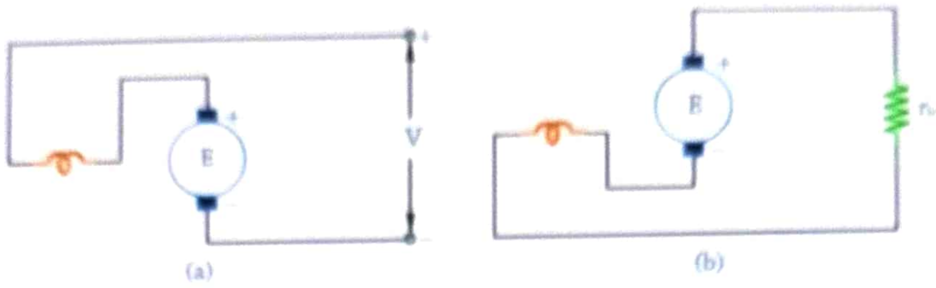

Fig 3: Motoring and dynamic braking with self excitation

- The both armature and the field winding are disconnected from the supply and shunted across a braking resistor r_b and when dynamic braking executed.
- The figure shows connection diagram for dynamic braking of D.C. series motor with separate excitation.

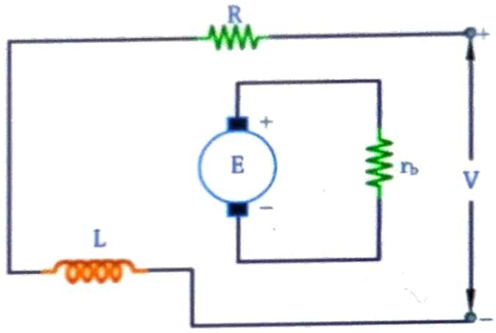

Fig 4: Dynamic braking of D.C. series motor with separate excitation

- The speed-torque characteristics of D.C. series motor under dynamic braking is shown in figure.

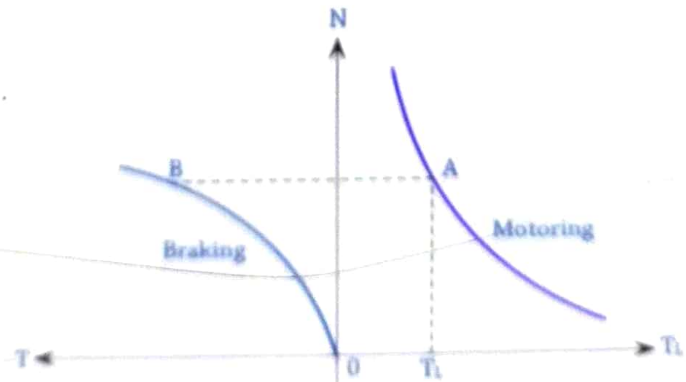

Fig 5: Speed-torque characteristics of D.C. series motor

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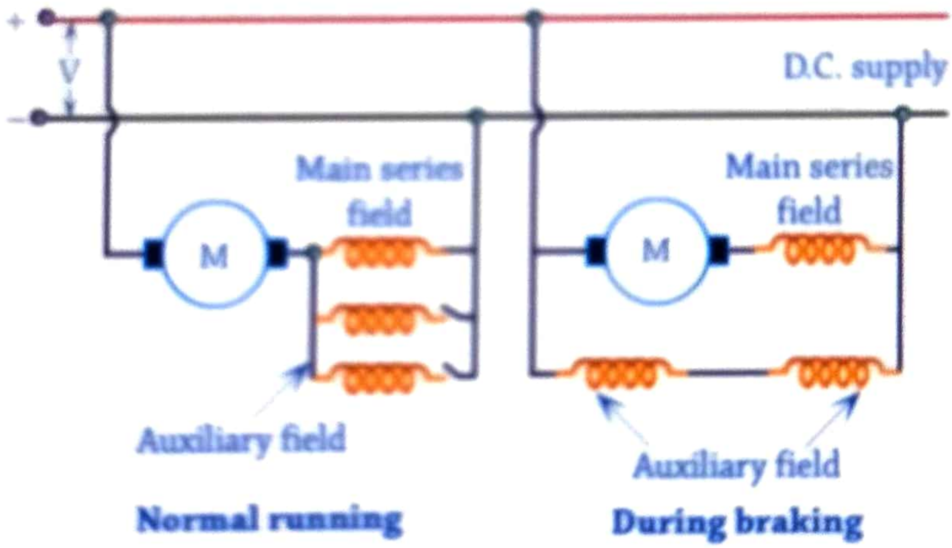

Fig 9: Regenerative braking of D.C. series motor

- For D.C. series motor regenerative braking is not possible because with the reversal of direction of armature current, the direction of field excitation also reverses.
- The regenerative braking method of D.C. series motor is used in traction drives with special arrangements.

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