16/12/19

Now a days demand for utilization of electrical power in various field in form of power electrolysis and illumination, electrical heating, electrical welding, electrical traction and electrical drives. Hence this gives us knowledge how to utilize electrical energy in above application.

## Electrolytic process

The substance which decompose when an electric current is passed through them are called electrolytes.

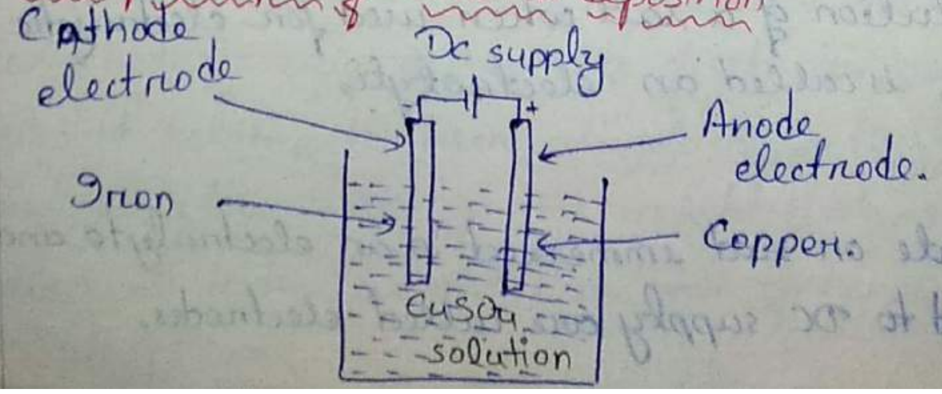
-> Which ion appear at anode is called anions (-ve charge) and which ion appear at cathode is called cation (+ve charge).

## * Electrolytic decomposition

Electrolytic decomposition may result when electric current is passed through an aqueous solution of a compound.

$$2H_2O \xrightarrow[\text{current}]{\text{Electric}} 2H_2 + O_2$$

## * Basic principle of electro deposition



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Electro deposition also known as electro plating is the process of depositing material on to a conducting surface from a solution of containing ionic spaces.

-> If two electrode are dipped in an electrolyte solution and a potential is applied across them, the electrode are named (+)ve on anode & (-)ve on cathode.

-> The molecules of the substance of the solution are broken of into two type of ions i.e. (+)ve and (-)ve ions.

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

-> Then (+)ve ion are deposited on to the cathode and electrode and (-)ve ion are deposited on to the anode electrode.

-> In this solution at anode $SO_4^{-}$ is deposited and at cathode $Cu^{++}$ is deposited.

-> The whole process described above is called ELECTROLYSIS.

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* Important terms regarding electrolysis

* Electrolyte

The solution of a salt when used for electrolytic process is called an electrolyte.

* Electrodes

The plate or rod immersed in an electrolyte and connected to DC supply are called electrodes.

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* **Anode**

The electrode connected to the (+)ve terminal of the supply is called anode.

* **Cathode**

The electrode connected to the (-)ve terminal of the supply is called cathode.

* **Ions**

When a direct current is passed through an electrolyte it gets chemically decomposed into two parts known as (+)ve & (-)ve ion.

* **Chemical equivalent weight**

Chemical equivalent weight of a substance may be defined as the ratio of its atomic weight to the valancy.

$$\text{Chemical equivalent} = \frac{\text{Atomic weight}}{\text{Valancy.}}$$

* **ECE (Electro Chemical Equivalent)**

ECE of a substance is the amount deposited on passing a steady electric current of 1 Amp for 1 sec. through its solution.

* **Atomic weight**

The ~~atmo~~ atomic weight of an element is a number which the average of the mass of its various isotops weight relative to their abundance on the atomic weight is the ratio of the weight of an atom of the element to the weight of an atom of hydrogen.

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* **Valancy**

The valancy of an atom or a group of atom is the number of hydrogen atom with which it will react chemically.

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* **Faraday's law of Electrolysis**

. Faraday was a scientist who reduced two law on the phenomenon of electrolysis which are called Faraday law of Electrolysis.

**First law**

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

Let $\omega$ is the weight of material/substance liberated in gram.

$\omega \propto Q$

$Q \rightarrow$ quantity of electricity passed.

$\omega \propto IT$

$I \rightarrow$ current

$T \rightarrow$ time. (in sec.)

$\omega = ZIT$

$Z \rightarrow$ proportionality constant is called electro chemical equivalent of that substance.

The ~~word~~ value of this depend upon the nature of the substance.

Z = ~~milli~~ gram/Culom (unit)

19/12/19

| Sl. No. | Element | Mgm/coulomb | kg/100 Ah |
|---|---|---|---|
| 1. | Copper (from sulphate solution) | 0.3290 | 1.1844 |
| 2. | Copper (from cyanide solution) | 0.6580 | 2.3688 |
| 3. | Nickel | 1.3043 | 1.0954 |
| 4. | Silver | 1.1180 | 4.0248 |
| 5. | Zinc | 0.3370 | 1.2132 |
| 6. | Tin | 0.6140 | 2.2104 |
| 7. | Oxygen | 0.0829 | 0.2984 |
| 8. | Hydrogen | 0.0104 | 0.0374 |

## Second law

This law state that if the same current flows for a given time through several electrolyte then the weight of the substance liberated are proportional to their chemical equivalent.

Q. ~~Find the~~ If a current of 1A. is passed for 100 min. through a electrolysis solution, then find the weight of copper deposited in that electrode.

copper density → 8.9

copper ECE → 0.0003295

SOLN

$I = 1A.$

$T = 100$ min. $= 6000$ sec.

$Z = \cdot 3295$ milligram/coulom.

$W = ZIT$

$= 1.977$ gram.

## * Current efficiency

20/12/19

Due to impurity which cause secondary reaction so that the quantity of a substance liberated is less than that calculated from Faraday law.

Mathematically

$$\text{current efficiency} = \frac{\text{actual quantity substance liberated}}{\text{theoretical quantity}}$$

20/12/19

* Energy efficiency

It is the ratio between theoritical eneorgy to the actual energy required.

* Factor effecting to the amount of electro-deposition

1) Time

Time is directly proportional to the quantity of electro-deposition, so we can say that more mass will be deposited in more time and less mass will be deposited in less time, if other condition remain same.

2) Efficiency

greater is the efficiency, greater the quantity of a metal deposited for a given time.

3) Current

The value of current is also directly proportional to the mass of metal deposited. If current is greater then quantity of metal deposited is high. But if we increase the current beyond a certain limit which is fixed for different metal separately. So that the metal deposited will be different colour such as blackish which is known as burned metal.

4) Strength of solution

If the strength of solution is more, then the mass of metal deposited will be more as compared to dilute solution of electrolyte if the other condition remain same.

* Factor Governing the electro-deposition- 23/12/19

In order that the deposite have a fine grained and smooth apperance, suitable condition have to be provided due to below factor.

⇒ Current density-

At low value of current denisty the ion are release at slow rate.

Therefore the deposite will be coarse and crystaline in nature.

→ At higher value of current density, the quality of deposite became more uniform and fine ground.

→ If the current density is so high i.e. it exceed the limiting value for the electrolyte then spongy and porous deposite is obtained.

→ The recommended current density per sq. meter

copper 33 to 44 I/A (Amp/m²).

Gold. 110 to 330 I/A.

Silver 33 to 66 I/A.

Nickel 110 to 220 I/A.

⇒ Electrolytic concentration

→ Those factor depend upon the current density because by increasing the concentration of electrolyte higher current density can be achieved.

→ Increase the concentration of electrolyte, tends to give better deposite and it generally recommended to use concentrated electrolyte.

23/12/19

⇒ Temperature

→ The temperature of electrolyte is different for different metals to have better deposite.

Ex-: in chromium plating the temprature is maintained at 35°C.

and in copper plating the temperature at

and in nickel plating the temperature between 50°C to 60°C.

⇒ Addition of agents

The quality of a deposite is improved by the presence of an addition agent which may be an organic compound such as gum, rubber and sugar etc.

→ The additional agent are suppose to be absorved by the crystal nuclear and prevent their growth into large crystals.

⇒ Nature of electrolyte

The smoothness of the deposite largely depend upon the nature of electrolyte.

Ex-: silver from silver nitrus solution form a rough deposite while that from cyaninde solution forms a smooth deposite.

⇒ Nature of metal upon which deposite is to be made

Those factor influence the growth of crystals since it is beleived that the operation of crystals in a continuous of those in the bare metal.

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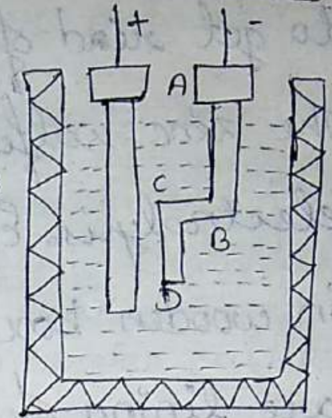
→ Throwing power




The throwing power of an electrolyte may be regardless as the quantity which produce a uniform deposite on an cathode having an irregular shape as shown in figure ABCD, so that the potential are varied in different point AB is far away from the electrode as reffered to CD.

∴ resistance to the current path from anode to AB is more than that in case of CD. Hence the thickness of deposite on the surface of AB will be smaller.

03/01/2020

* Application of electrolysis

→ Extraction of metal from their ores.

There are two methods of extraction of metals from ores depending upon their physical state of the ore.

1) The ore is treated with a strong acid to obtain a salt and the solution of the salt is electrolyied to liberate the metal.

2) When the ore is in moltan state it is electrolysed in the furnace.

→ Extraction of zinc

The zinc ore which has mainly zinc oxide is treated with concentrated sulfuric acid, roasted and passed through various chemical process

03/01/2020

to get read of impurities like cadmium, copper etc.

=> The zinc solfet solution thus obtained is then electrolysis. Electrolysis process is carried out in wooden box with inen lining of lead. The anode are lining of lead and cathode are of aluminium. Then the zinc is deposited on the cathode. The current density at the cathode is about 1000 Amp/m2 and voltage drop per cell is about 3.5 volt

-> Extraction of aluminium

The ore of aluminium are bauxite, cryolite bauxite is treated chemically and reduced to aluminium oxide and then disolved in fuse cryolite and electrolised.

=> The furnace is lined with carbon aluminium metal get deposited at the cathode and the temp. of furnace is about 1000°c and the furnace area 15 m² will require a voltage about 8 volt and a current of about 45000 Amp. Since electrolytic process require a large amount of power so such plants are located near to a big power station.

-> Refining of metal

The metal extracted from its ore is not that much pure which would be used for electrical

03/01/2020

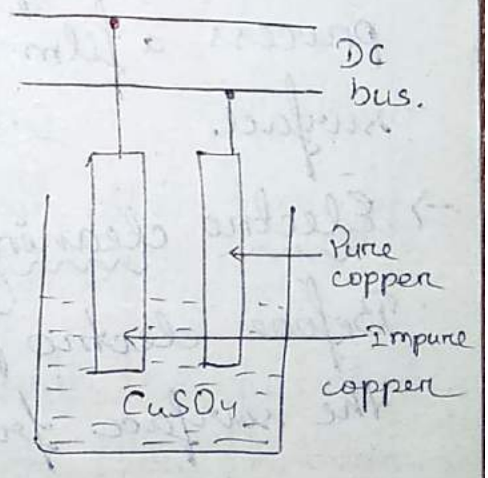
application the purity of copper obtained from its ore is about 98% but copper to be used in electrical application must have a purity of 99.95%.

=> This purity of copper is obtained by electrolysis.

=> The electrolyte solution used in copper sulfite The anode are made of impure copper extracted from its ore and pure copper is deposited on the cathode.

=> At regular the copper deposite is removed from the cathode and anode is also replaced whenever required.

=> energy consumption 150-300kVh. per turn of the refined copper.




-> Production of chemical

Many chemical such as caustic soda (KOH) chlorine gas, amonium sulphate, hydrogen, oxygen are produced by electrolysis on large scale.

06/01/2020

-> Separating metal from their compound.

Many metals are separated by electro-

06/01/2020

-lysis i.e. an ore of aluminium contains about 70%. Aluminium oxide, silical and iron oxide.

⇒ First pure aluminium oxide is obtained by suitable treatment and pure aluminium is obtained by electrolytic process.

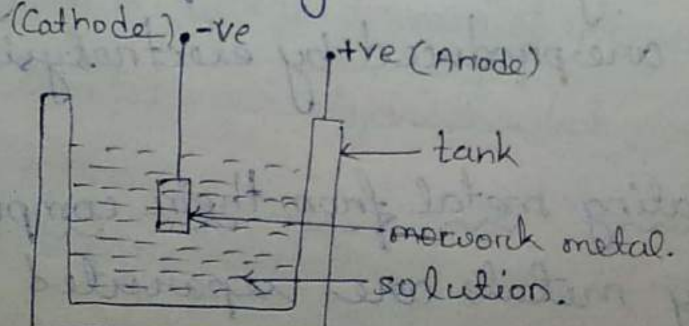
→ Electro typing

In this process wood cuts are reproduced in copper by the process of electro plating. in this case first the mould is made of the type in works wax, then it is coated with black lead to give a metalic surface and then it is subjected to the process a film of copper is formed on the prepared surface.

→ Electro cleaning

Before electro plating we should have clean the surface from grease, oil etc and they are cleaned by electro cleaning method.

⇒ Here a solution of sodium phosphate is used as an electrolyte in the plating tank.



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The tank is connected with (+)ve supply of the DC and work metal peice to be clean is made the cathode and connected to (-)ve supply is DC. Then it is suspended in the solution of sodium phosphate.

⇒ A heavy current is passed through the solution and caustic soda is produced on the cathode which has a cleaning action and also hydrogen gas is produced at the cathode which remove the greese etc. This process is called cathodic cleaning and is applicable to zinc and aluminium.

⇒ For anodic cleaning the work metal peice the anode is met and negative supply is given to plating tank.

## Electric heating

07/01/2020

Electric heating is preferred over other type of heating method i.e. by wood, coal oil and gas.

-> We are very much familier with the fact that whenever a current 'I' made to flow through any circuit having resistance of R Ω power dicipated in that circuit is $I^2R$ watt.

If the current flow for 't' second energy consumed is '$I^2Rt$' J. or Wsec.

-> There are 3 mode of transmission of heat.

1) conduction (medium is solid).
2) convection (medium is liquid).
3) radiation (medium is gas)

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# * Application of electric heating

## Domestic application

-> room heater for heating the building.
-> immersion heater for water heating.
-> hot plate for cooking.
-> gyseres
-> electric kettles
-> hot air driers.
-> Electric Iron.
-> Coffe maker.
-> pope corn plant
-> Electric ovens for baking products
-> Electric toaster.

## Industrial application

-> melting of metals.
-> heat treatment of metal like annealing, tempering, soldering, brazing and case of hardening
-> electric welding
-> molding of glass for making glass appearance
-> baking of insulator.
-> molding of plastic components
-> enameling of cu. conductors.
-> heat treatment for pointed surface.
-> making of plywood.
-> viterous enamelling of wire wound resistors. danger places and other metallic components.

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# * Advantages of Electric heating



1) Clean and neat atmosphere-

There is no coal, dust or smoke and operators hand do not go black while operating an electrical heating appliance.

2) No pollution-

Absence of flue gas does not result in polution of atmosphere and there are no heat loss involved as that through smoke or flue gas.

3) Controlled temperature-

Temperature can be controlled within $\pm 5°C$. which not possible in non-electric heating process.

4) Easy of control-

The heating can be started instantly or stopped at a required time keeping a time gap between switching OFF and cooling the heating circuit.

-> Automatic switch control are possible.

5) Localized application-

A work peice can be heated upto particular depth for heat treatment where as the piece as a whole receive heat in non electric heating process.

6) Low ambient temperature-

The temperature around an electrical furnace is much lower as compared to that around non-electrical furnace which is trouble some for worker.

09/01/2020

7) Uniform heating.

The heating can be generated from within the work peice resulting in uniform heating ~~two~~ through induction heating.

8) Heating of bad conductor of Heat and Electricity.

wood, plastic and bakery item can be uniformly and suitably heated with dielectric heating process.

9) Highest efficiency of utilisation.

Heat produce electrically does not go waste through chimny and other biproduct must of the heat produced is utilized by the material been heated electrically. So that the efficiency of electrical heating is high as compared to other type of non-electrical heating.

10) Cheap Furnaces.

The electrical furnace do not require big space for installation, no storage of coal and firewood is necessary. No chimny to be constructed. No extra heat insulation is necessary. Due to this the cost of electrical furnace is cheap then other type of non-electrical heating ~~pro~~ furnace.

11) Mobility of job

The peice under going heat treatment can be mounted on a converyer passing through the heating cabinate making use of electrical heater.

# Electrical heating method

10/01/2020

Basically heat will produce due to circulation of current through

The current may be circulating directly due to eddy current or potential difference.

## ⇒ Types of Electrical heating

- Electrical heating
  - High frequency heating
    - Dielectric heating
    - Induction heating
      - Coreless type induction heating.
      - Direct core type induction heating.
  - Power frequency heating
    - Arc heating
      - Indirect arc heating.
      - Direct arc heating
    - Resistance heating
      - Indirect resistance heating.
      - Direct resistance heating

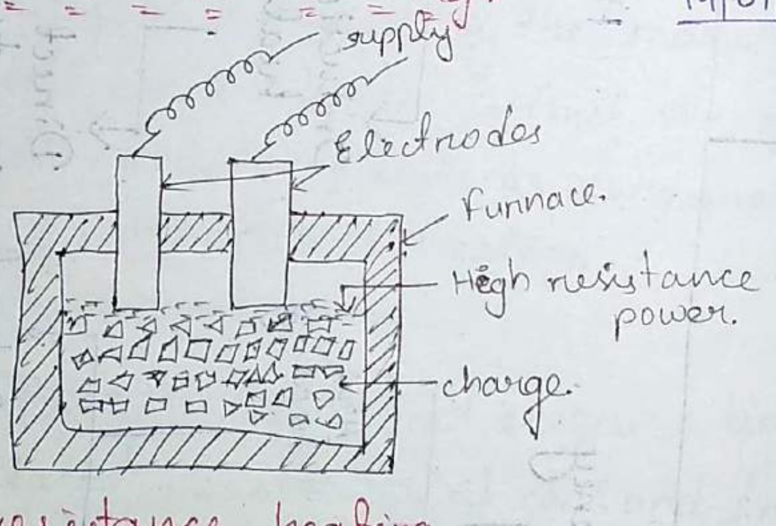
10/01/2020

Similarly in magnetic material hysteresis losses can cause heating. It is due to inter molecular friction produced by repeated change in allignment.

-> Production of an arc between an electrode and material to be heated can also be a method of heating.

-> Bombardment of by some high energy particle α, β, γ ray or X-ray or accelerating ions can produce heating of a surface.

* Direct resistance heating. 14/01/2020




* Direct resistance heating.

In this method of heating, the material or charge to be heated is taken as a resistance and current is passed through it.

-> The charge (material) may be in form of powder, peices or liquid.

-> Then two electrodes are immerged in the charge and connected to the supply. In case of dc or single phase

14/01/2020

ac two electrode are required but there will be three electrode in case of 3 phase supply.

-> When metal peice are to be heated a powder of high resistive material is sprinkled over the surface of the charge to avoid direct short circuit.

-> The current flows through the charge and heat is produced. This method has high efficiency since heat is produced in the charge itself.

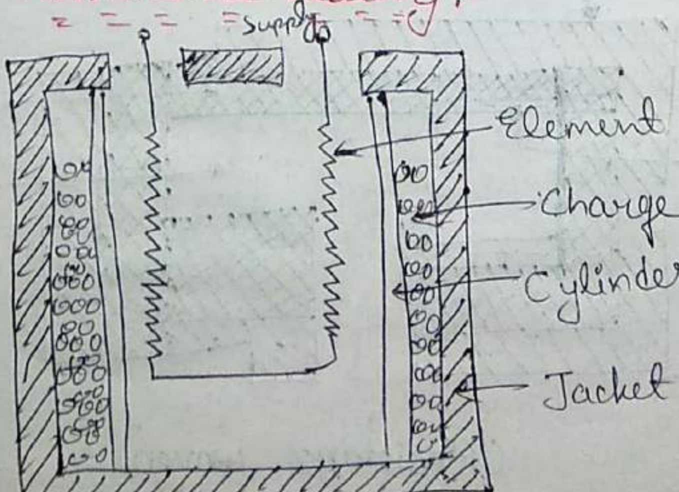
-> In this case temperature control is not possible. But it gives uniform heat and high temperature.

-> One of the measure application of the process is salt bath furnace having an operating temperature 500°C-1400°C.

-> Here the supply voltage across two electrode varying between (5-20) Volt.

-> For this purpose a special double wound T/F is required which makes use of 3ϕ primary and a 1ϕ secondary.

* Indirect resistance heating:-



20/01/2020

In this method the current is passed through a highly resistance element, which is either placed above or below the oven depending upon the nature of the job to be performed.

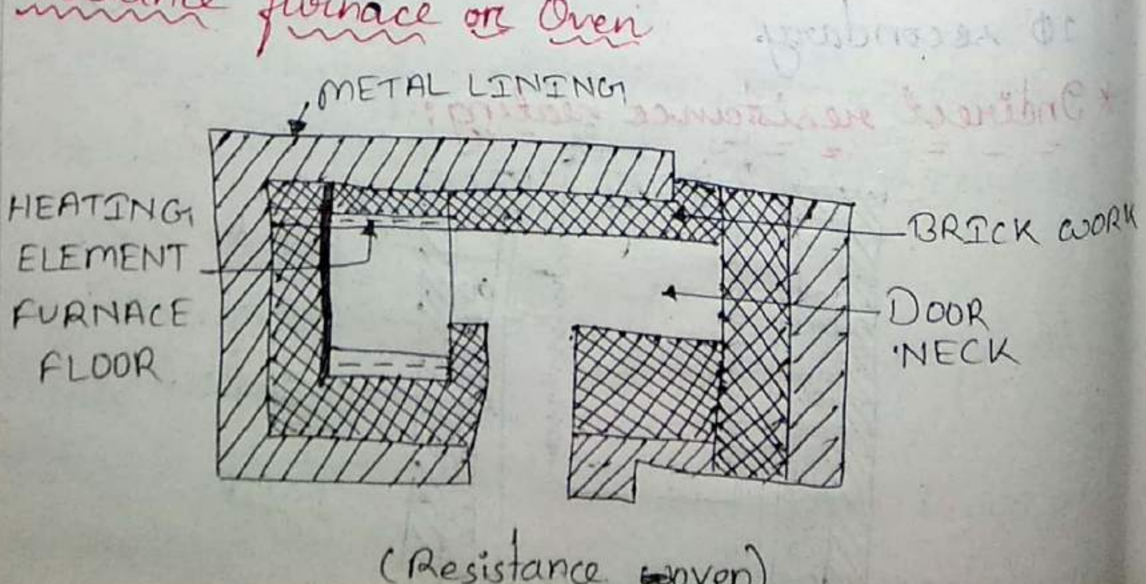
-> The heat is proportional to the $I^2R$ loss produced in heating element. delivered to the charge either by radiation or by convection.

-> Some time incase of industrial heating, the resistance is placed in cylinder which is surrounded by the charge placed in the jacket. This nmf provide an uniform temperature.

-> Here automatic temperature control can be provided in both ac & dc supply.

-> Both ac & dc supply can be used for this purpose at full main voltage depending upon the design of heating element, common ex. of this type heating is resistance oven.

* Resistance furnace or Oven




(Resistance oven).

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This is an enclosed chamber with a provision for ventilation used for drying and baking of pottery, commercial and domestic cooking, heat treatment of metal i.e. annaling, hardening etc.

. Helre temperature upto 1000°c can be attained by using high resistance elemetnt.

-> The heating element are generally nickel, cromium and alloy.

-> But to acchieve 3000°c and above we use the metal which are made of graphite.

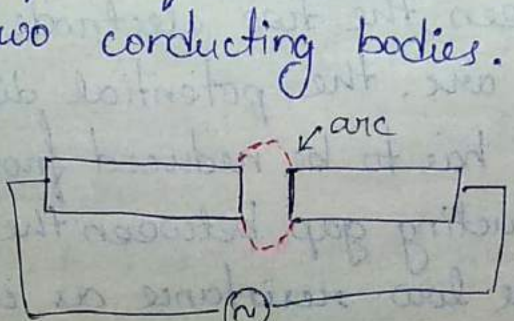
-> Heating element may be in the form of circular wire or rectangular ribons.

-> The oven is made of metal frame work having an internal lining of the fire bricks.

* Arc furnace 21/01/2020

The arc furnace used for melting or extraction of ferrous or non-ferrous material need a high temperature operation. Here one of method is through production of electric arc which gives an arc temperature between 3000°c to 3500°c on L.T. operation.

-> Arc is the flow of current through an air gap between two conducting bodies.



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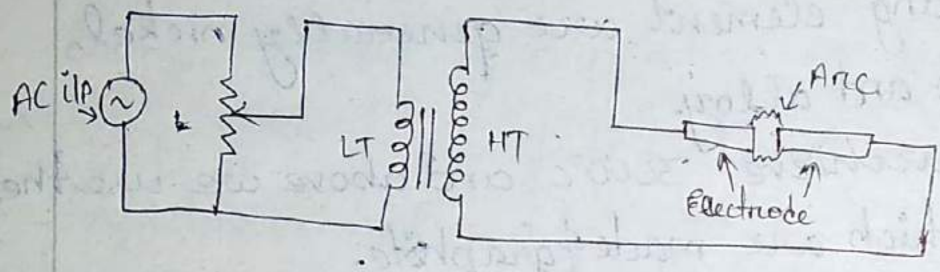
* **Method of striking Arc:**

There are 2 method of striking an arc between two electrodes.

-> One method is HT strike and the other is LT strike.

=> **HT strike**




In the HT strike method a constant gap is maintained across a pair of electrode made of carbon.

-> Electrodes are connected across the HT secondary of a step up transformer and the primary is fed with variable ac voltage as shown in fig.

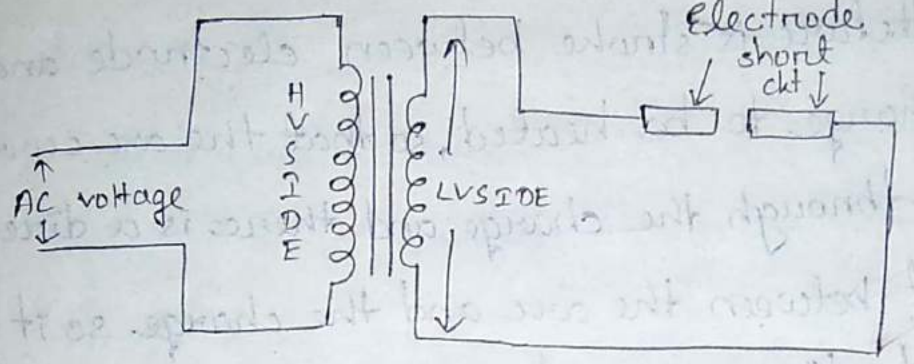
-> To strike an arc the primary input voltage is gradually increased, thus increasing the HT voltage across the secondary (electrode). A stage come when the medium between two electrode is ionized and became conducting. In that stage an arc stroke between the two electrode. Then after striking of the arc, the potential difference across the electrode has to be reduced from HT to LT. Since the conducting gap between the two electro has now negligible low resistance as compared to the

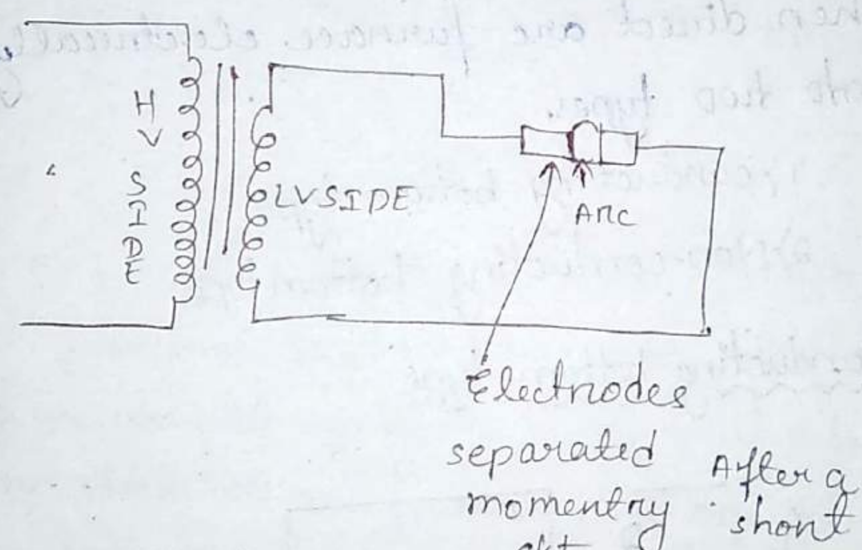
21/01/2020

gap resistance before striking of the arc.

-> It run upto a 1000 volt.

=> LT striking arc




In this case a low voltage main is enough to strike the arc. In this case electrode are connected to the lower voltage side of the transformer.

-> In this case the electrode are momentaryily short ckted and immediately separated, resulting in production of an arc.

-> In this method suitable and convinently used in different arc furnace.

The arc furnace can further sub devided into 2 parts.

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1) Direct arc furnace
2) Indirect arc furnace.

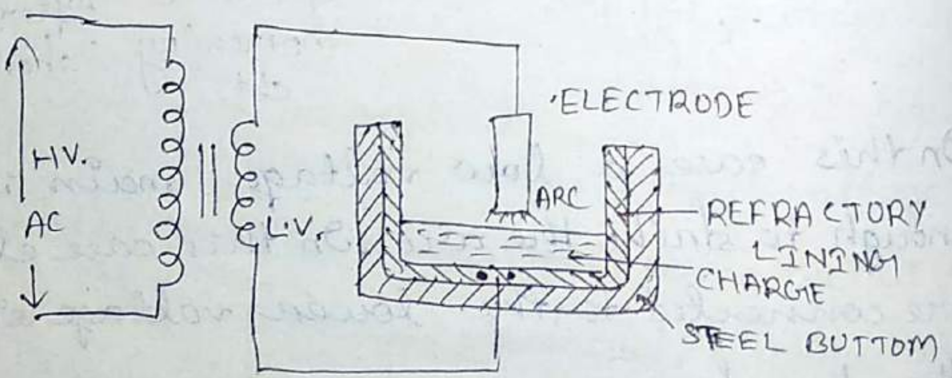
* Direct arc furnace 24/01/2020

when the arc is stroke between electrode and the charge to be heated, so that the arc current flows through the charge and there is a direct contact between the arc and the charge. so it is called direct arc furnace.

→ Then direct arc furnace electrically sub-devided into two types.

1) conducting bottom type
2) Non-conducting bottom type.

Conducting bottom type




(CONUCTING BOTTOM)

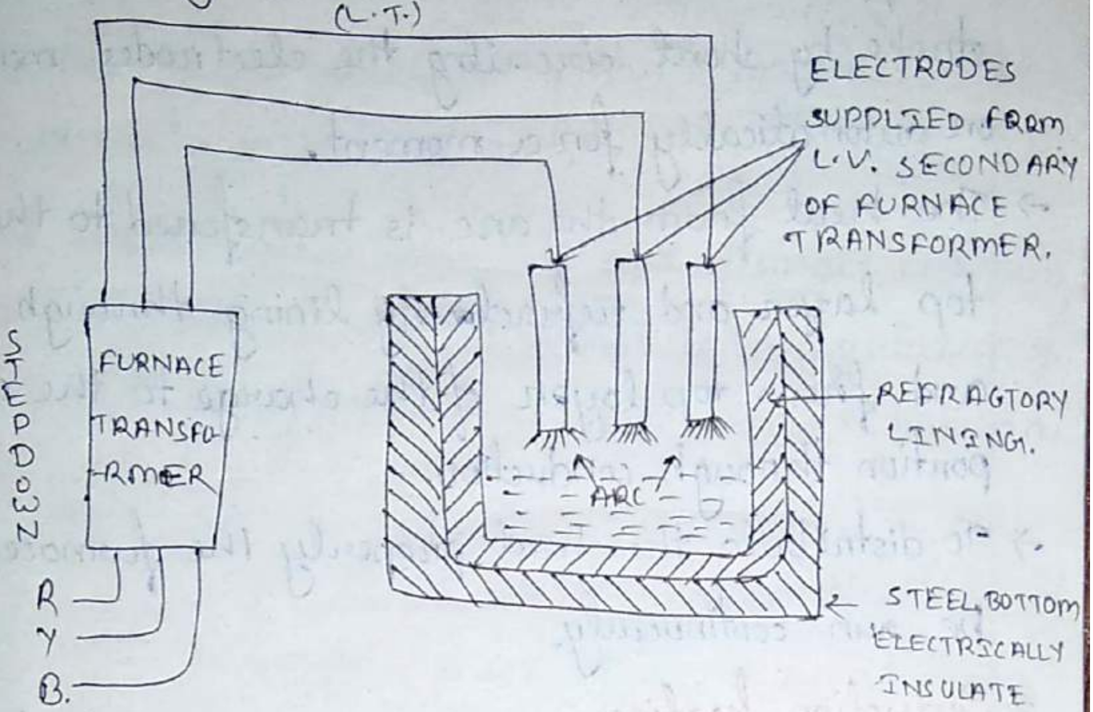
In this case the former has the bottom of the furnace as a part of the electrical circuit. whereas no current flows through the body of the furnace.

→ Here one supply terminal is connected to the bottom of the furnace and another terminal is connected to

24/01/2020

the electrode as shown in fig.

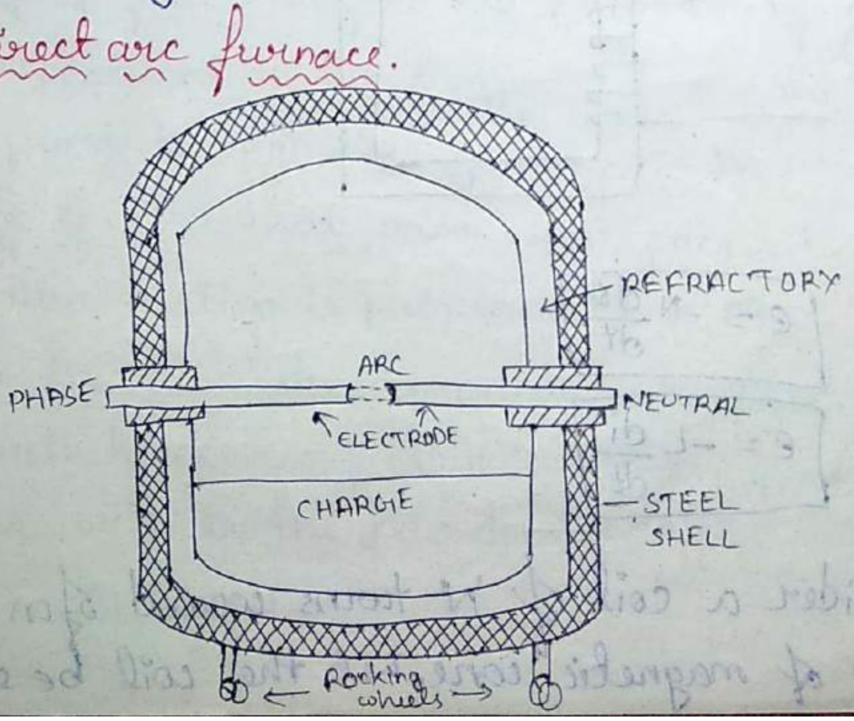
2) Non-conducting bottom




In this case supply is directly provided through electrode. If we use 1φ then the nu. of electrode is 2 & if we use 3φ supply, the nu. of electrode is 3.

-> Most of the electrical arc furnace used are non-conducting bottom type. due to insulation problem faced in case of conducting bottom.

* Indirect arc furnace.



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In this type of arc furnace low voltage $1\Phi$ ac is supplied across the electrodes. The arc is stroke by short circuiting the electrodes manually or automatically for a moment.

-> The heat from the arc is transfered to the charge top layer and refractory lining through radiation and from top layer of the charge to the other portion through conduction.

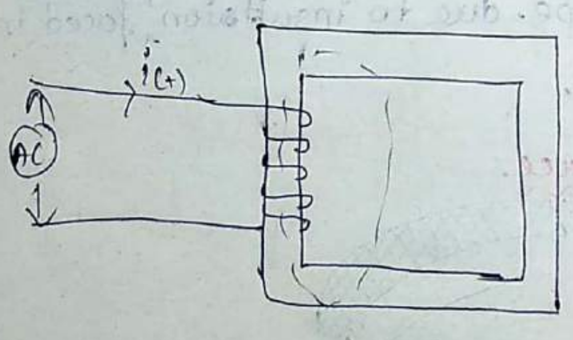
-> To distribute the heat properly the furnace has to be run continuously.

## * Induction heating

27/01/2020

1) Eddy current -

whenever a flux linking with any conduction body changes, the result is an induced emf which is a function of rate of change of flux or current.




$$e = -N\frac{d\phi}{dt}$$

or

$$e = -L\frac{di}{dt}$$

Consider a coil of 'N' turns wound of on a one limb of magnetic core but ...

27/01/2020

with alternating current from a source of ac supply and hence change in flux links with the coil as well as with the magnetic core resulting in an induced emf.

→ Since the core is a complete ckt of single coil turn. Then any induced emf will result in circulation of current through this core. This current is known as eddy current.

→ The magnitude of this current depend upon the induced emf and the resistance offered by the core material.

→ When the eddy current is flowing in the core there will be a $I^2R$ loss occur in the core. This power loss will utilize in heating.

Note

⇒ The below process are provided for the induction heating.

⇒ Since the induced emf is depend upon the rate of change of flux, therefore the magnitude of eddy current is propertional to the frequency of supply. If the frequency is high then greater will be rate of change of flux. Heat produced is propertional to $I^2R$ then heating is propertional to $F^2$.

⇒ Since the flux density produced is propertional to the reluctance so greater is relative permeability higher will be the flux density 'B'.

$B = \mu_0 \mu_r H$

$H = \frac{NI}{l}$

27/01/2020

N → num. of turn of coil.
l → effective length

⇒ greater is the number of turn on the coil, greater will be the magnitude of flux. Thus eddy current heating is a function of 'N'.

⇒ large is the current flowing through the coil greater will be the flux produced and higher will be the eddy current. So we can say that eddy current heating is proportional to the magnitude of the supply current.

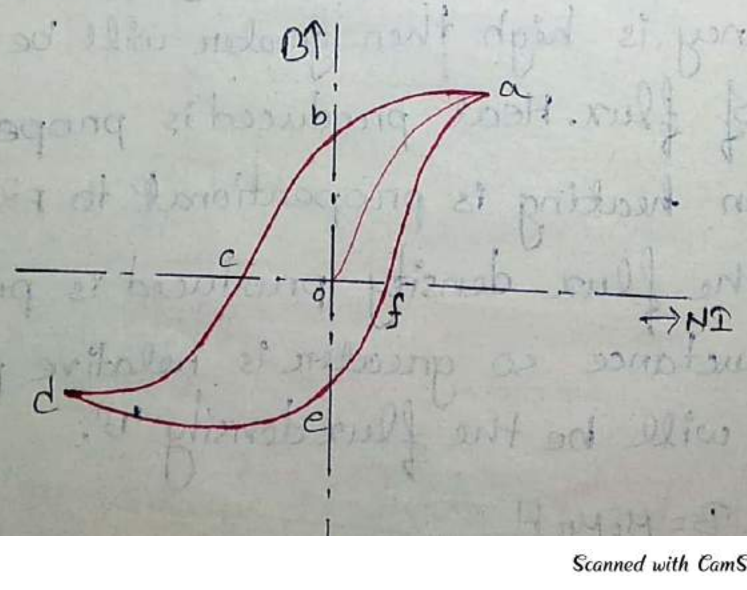
⇒ in the eddy current heating the resistive of the core material is less so that the eddy current is high.

$$W_e = K \cdot B_{max}^2 f^2$$

$W_e$ → pow dissipated through eddy current
$B_{max}$ → max. flux density
f → frequency
k → proportionality constant.

2) Hysteresis loss

31/01/2020



31/01/2020

A piece of magnetic material is magnetized, de-magnetized and remagnetized and again some energy is lossed in this process. This loss so occur any electromagnetic device, are named as hysteresis loss.

- The energy lost is converted into heat.
- During (+)ve $\frac{1}{2}$ cycle, the core is magnetized to the maximum at (+)ve peak. When the sinusoidal current became zero, the magnetic flux density is not reduced to zero, due to residual flux.
- During (-)ve $\frac{1}{2}$ cycle, some coercive force is necessary to reduce the residual flux to zero. The (-)ve $\frac{1}{2}$ cycle is continue, the flux density comes to maximum in reverse direction.

* Factors to hysteresis loss

frequency ↑ ⇒ hysteresis loss ↑

$$W_h = K \cdot B_{max}^{1.6} \times f$$

where, $W_h$ = power dissipated in a core due to hysteresis

$B_{max}$ = Maximum flux density

$f$ = frequency of induction

06/02/2020

## * Low frequency Induction heating

Induction heating is the process a current induced by electro magnetic action in the material to be heated.

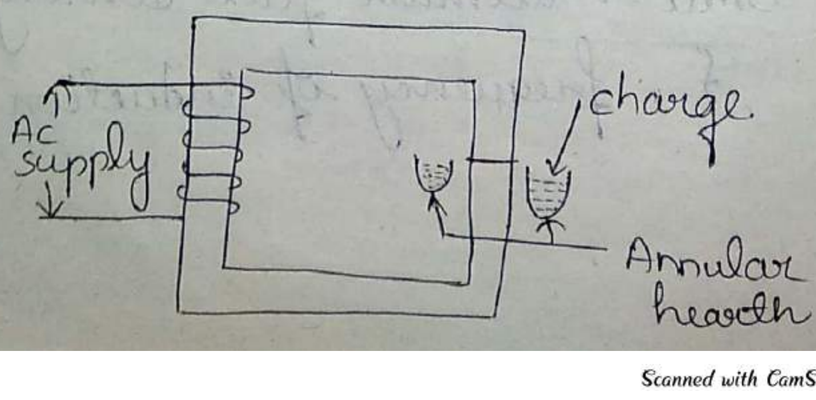
-> Induction heating is based on the principle of transformer.

-> There is a primary winding, through which an ac current is passed and the coil is magnetically coupled with metal to be heated.

## * Types of low frequency induction heating

- low frequency induction heating
  - core type
    - Vertical core type.
    - Direct core type.
    - Indirect core type.
  - Core less type.

## * Direct core type induction heating -



It is 06/02/2020

like a tranformer but one change is there, the secondary winding consist of one turn only formed by the metal to be melted.

-> Current in the charge is very high is about several thousand ampere. The charge is magnetically coupled to the primary winding.

-> Then electromagnetic force are set up by the high current in the molten metal.

-> When there is no molten metal, no current will flow in the secondary.

-> To start the furnace the molten metal is poured in the ~~an~~ annular hearth or a sufficient quantity is left over from the previous charge.

Draw back of Direct core type induction heating

-> leakage reactance is high ~~so that~~, P.F. is low due to poor magnetic coupling

-> low frequency supply is required and additional motor generator set or a frequency converter is required.

-> If current density is about 5Amp/cm² the pinch effect is there and that cause a complete interruption of secondary.

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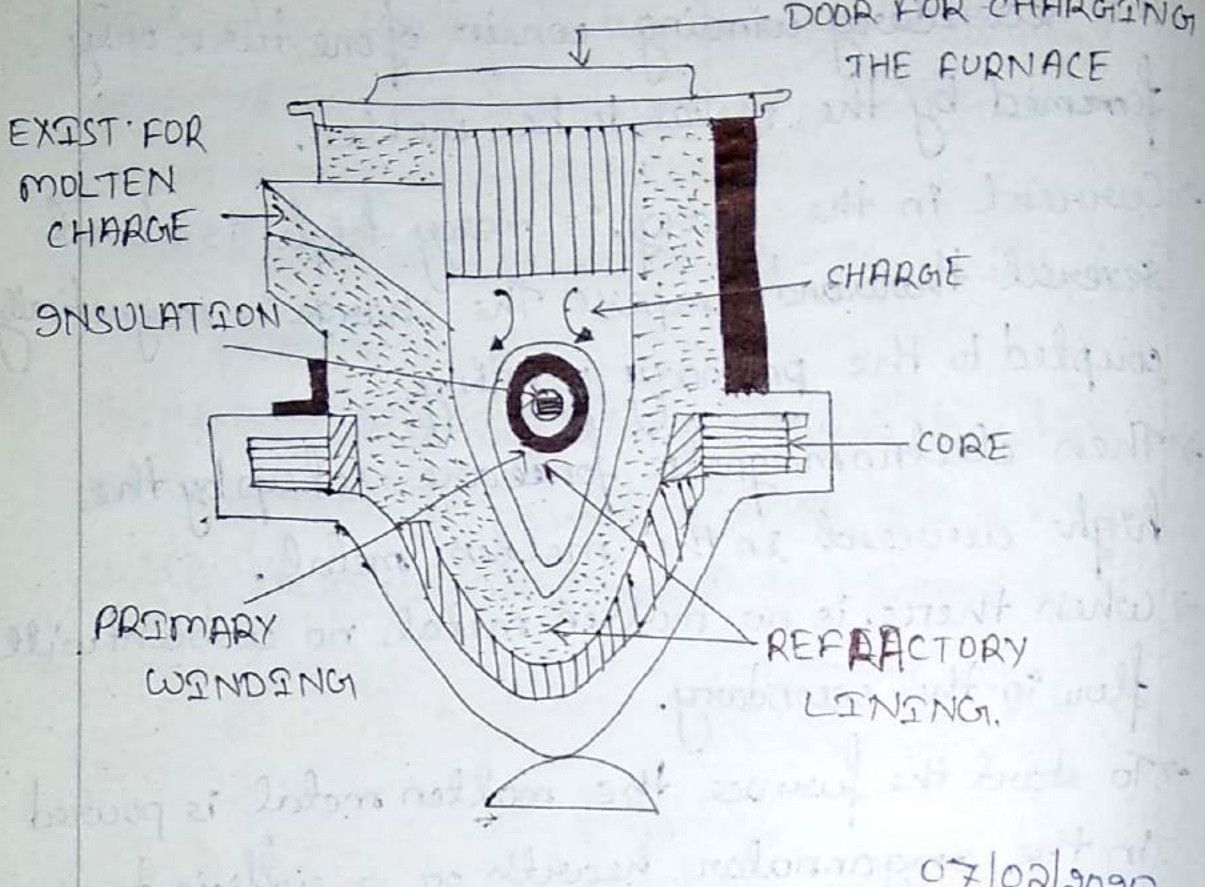
# * Vertical core type Induction heating




07/02/2020

This furnace is an improve over core type furnace.

-> It has vertical channel for the charge.

-> Magnetic coupling in this furnace is better than core type.

-> Hence the leakage reactance is comparatively low and power factor is high, so it can operate from normal supply.

-> Tendency of the ckt to repture due to the pinch effect is counter acted by weight of the charge in the main body of the crucible.

-> The circulation of molten metal is kept up round the 'V' porsion by the convenction current as the

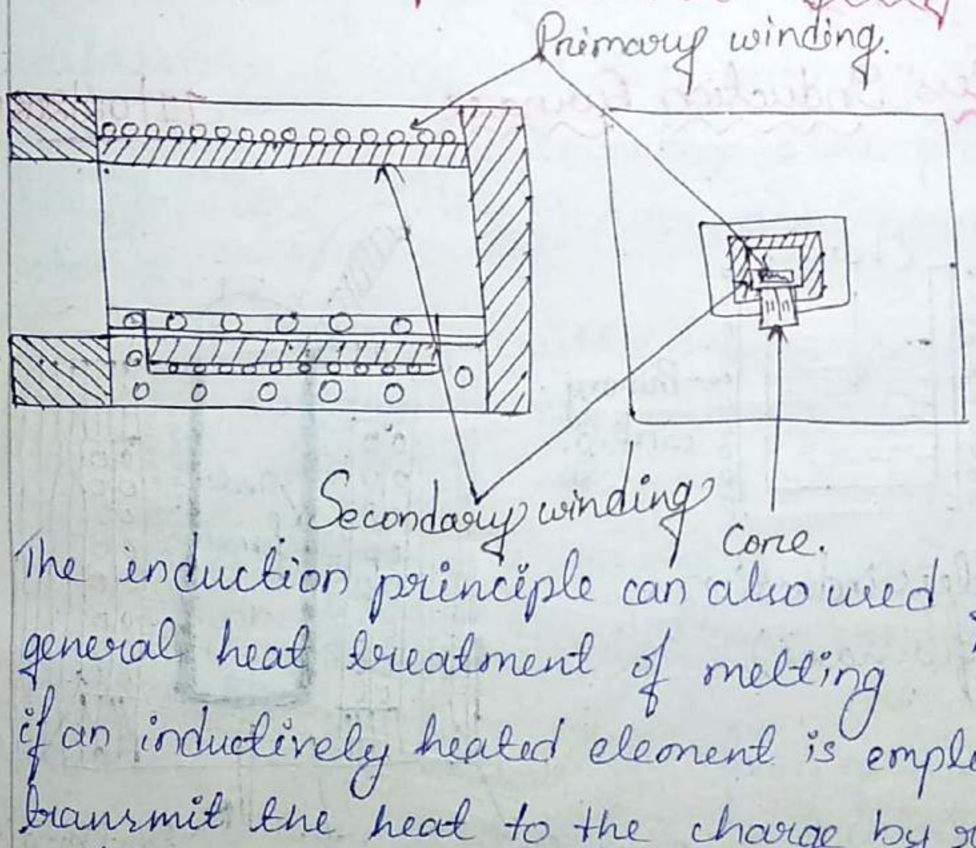
07/02/2020

indicated and by the electro magnetic force lower half of the Vee

-> It is necessary to keep the vee full of metal in order to maintain the continuity of the secondary circuit so this furnace is suitable for the continuous operation.

-> It is very widely used for foundaries for melting the refining brass and other non-ferrous metal.

* Indirect core type Induction heating




The induction principle can also used for general heat treatment of melting if an inductively heated element is employed to transmit the heat to the charge by radiation so far as the charge is concerned, condition similar to resistace heating.

-> In the indirect induction oven the secondary winding forms the wall of a metal container & the iron core links the primary as well as

07/02/2020

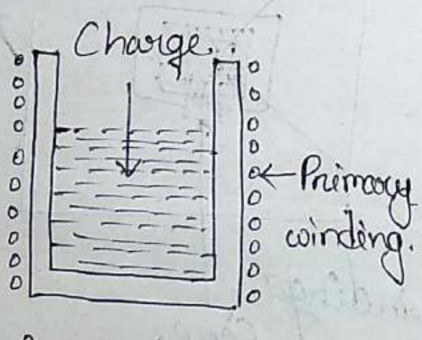
secondary.

-> Due to relatively poor power factor it must posses

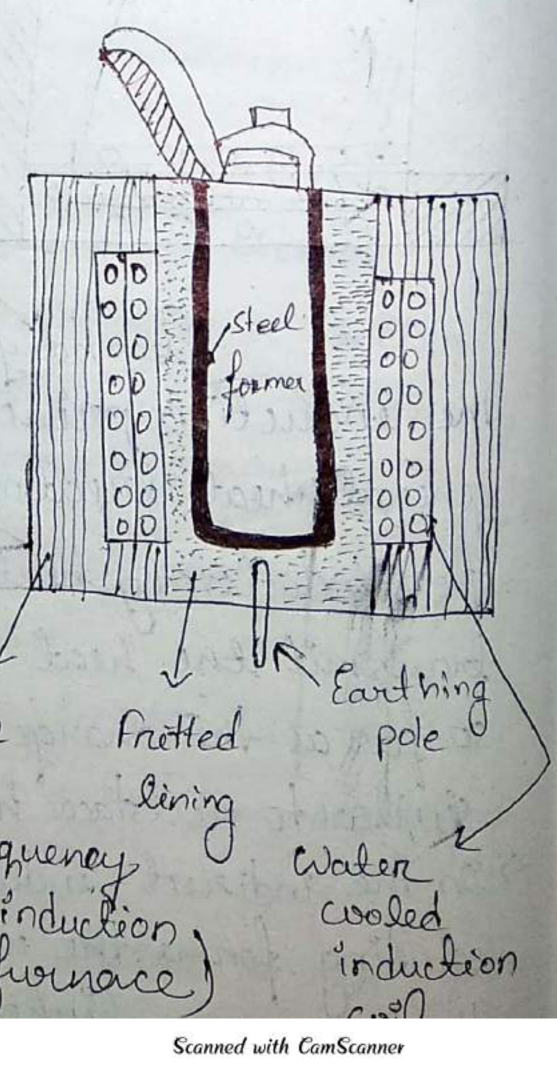
-> In this case the magnetic ckt is situated in oven chamber and made from a special alloy which looses its magnetic property to particularly time and regain when cooled approximately to the same temperature. The oven temperature is thus limited to the critical value w/o use of external control equipment.

## * Coreless Induction Furnace -

11/02/2020




(Coreless induction furnace)




(High frequency coreless induction furnace)

11/02/2020.

In this case the flux produced by the primary winding sets of eddy current in the charge.

-> The eddy current developed in any magnetic ckt is given by.

eddy current $\propto B^2 \propto f^2$.

where B is the flux density
f is the frequency.

-> The eddy current are sufficient to heat the metal to melting point and also sets of electro magnetic force which produce striking action.

-> Construction of this furnace is consist of a refractory lining and the primary coil wound around it. Then a alternating flux produced by the primary winding induce eddy current it the charge.

-> The direction of resultant eddy current will in opposite direction to the primary current coil.

-> Here the artificial cooling of primary coil is necessary because high amount of copper losses.

-> The temperature of the primary winding increases considerably.

-> The coil is constructed in the form of hollow tube. through which cold water is circulated.

-> The furnace is consist of a laminated yoke is built on the outside of the induction coil to provide a definite path for the flux. This minimize the stray field and also reduce the exciting current necessary to produce the flux.

13/02/2020

## * Skin effect

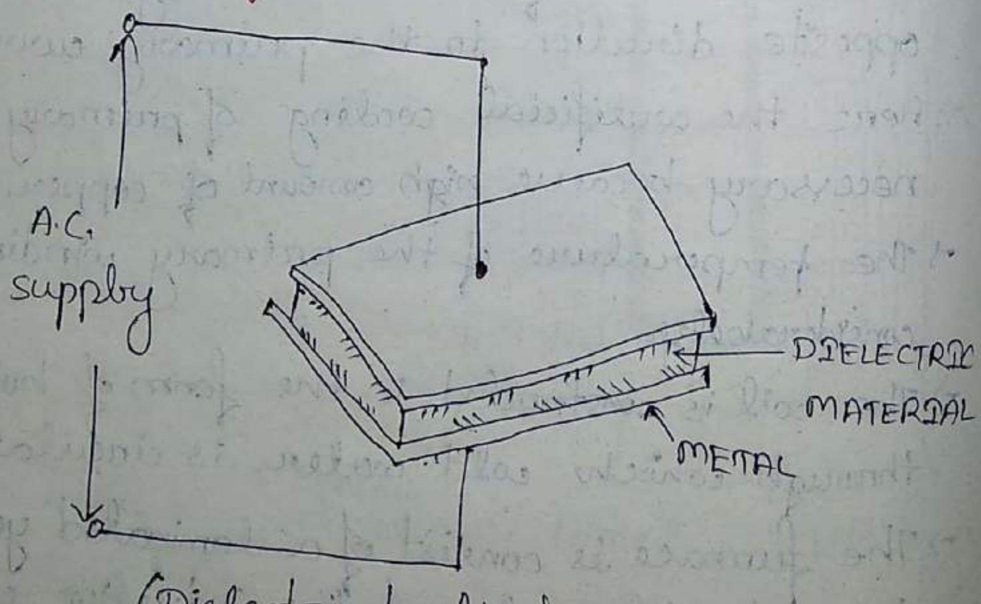
The steady direct current when flowing through a conductor distribute itself uniformly over the whole x-section of the conductor. But in case of altenanating current distribution is not uniform.

→ The alternating current tends to concentrate near the surface of the conductor and no current flows through the core of conductor. This phenomenon called SKIN EFFECT & this causes the increase of resistance of the conductor.

→ If the frequency is increased then the skin effect is also increased.

→ In standard conductor the skin effect is much smalled then with solid conductor.

## * Dielectic heating

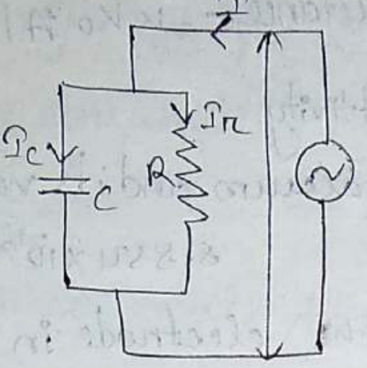



(Dielectric heating)

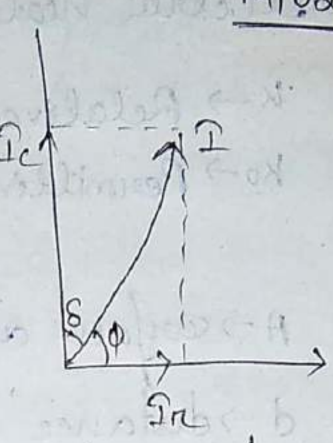
It is called high frequency capacitive heating and is employed for heating of insulating malorial like wood, plastic and ceramic etc. 13/02/2020

→ Here the supply frequency is 10 to 30 Mega cycle per second. and the applied voltage upto 20kV

14/02/2020




(equivalent ckt)




(phasor diagram)

The principle of dielectric heating is that when a capacitor is subjected to a sinusoidal voltage. The current drawn by it never leading to the voltage exactly by 90°. The angle between voltage and current is slightly less than 90°. say angle del (δ) where δ = loss angle

$$\left[\delta = \frac{1}{2\pi} \frac{\sqrt{\rho \times 10^7}}{\mu_r \cdot f} m\right]$$

Here $\rho$ → resistivity

$\mu_r$ → Relative permeability

$f$ → frequency.

It is clear that a small component of current which is in phase with the applied voltage and in turn produces a power loss in the dielectric. At normal supply frequency of 50c/s this loss may be small enough but at high

14/02/2020

frequencies of the order of 10-30 mega c/s the loss becomes so large that is sufficient to heat the dielectric.

→ Dielectric heater capacitance: $C = K K_0 A/d$ Farads

$K$ → Relative permittivity.

$K_0$ → Permittivity of vaccum and its value is $8.854 \times 10^{-12}$

$A$ → surface area of the electrode in $m^2$

$d$ → distance between two electrode in metres.

→ ~~The advantages of heating high frequency supply is obtained from a~~

→ The advantages of heating material of poor thermal conductivity by this method results from the fact that the heat is produced with in the material itself.

→ The dielectric heating is used in:

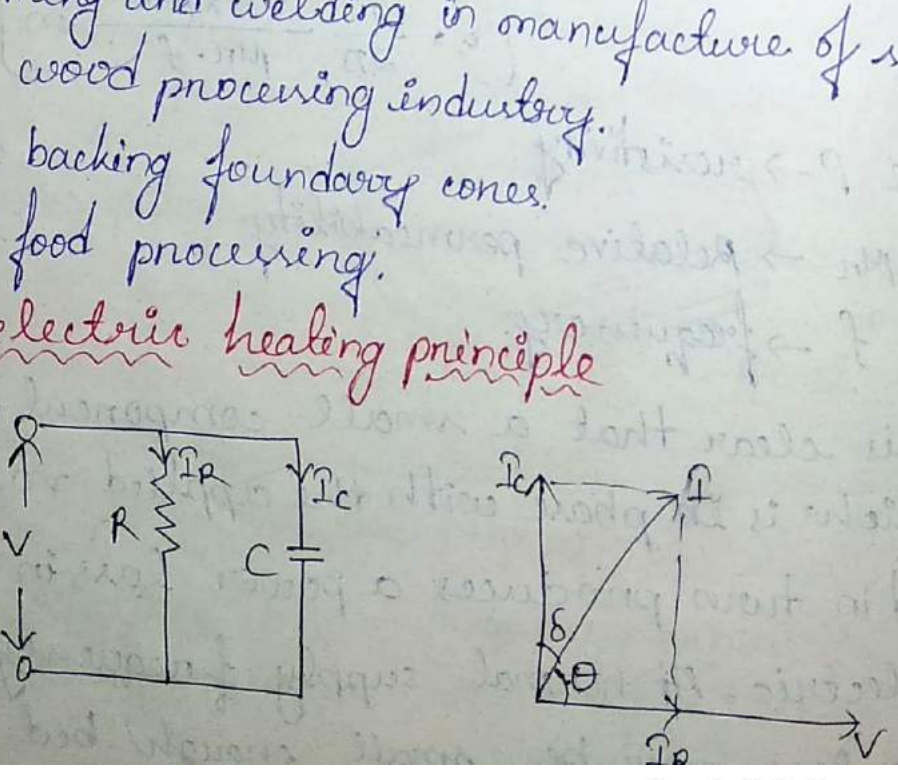
i) seaming and welding in manufacture of synthesis

ii) in wood processing industry.

iii) for backing foundary cones.

iv) for food processing.

## * Dielectric heating principle



14/02/2020

→ for heating non-conducting materials.

→ The materials to be heated is placed between two conducting electrodes across which alternating voltage of high frequency is applied.

Power consumed, $P = VI\cos\theta$

$$I = I_C - I_R$$

$I_R$ is so small that can be neglected.

$$\therefore I = I_C$$

$$\therefore P = VI_C\cos\theta$$

$$I_C = \frac{V}{X_C}$$

$$X_C = \frac{1}{2\pi f C}$$

$$\therefore I_C = V \cdot 2\pi f C$$

$$\therefore P = V(V \cdot 2\pi f C)\cos\theta = V^2 2\pi f C\cos\theta$$

$$\theta = (90° - \delta) \Rightarrow \cos\theta = \cos(90° - \delta) = \sin\delta = \tan\delta = \delta$$

$\delta \rightarrow$ small $\delta$ in radians.

$$P = 2\pi f V^2 C\delta \text{ watts.}$$

$$C = \frac{K_0 K_A}{t} \text{ farads.}$$

where $K_0 \rightarrow$ Absolute permittivity of air

$$= \frac{1}{36 \times \pi \times 10^9} = 10^{12} \times 8.854 \text{ F/m.}$$

14/02/2020

# * Applications of Dielectric heating.

1) Plywood industry
2) Sand cone baking
3) Plastic Industry
4) Tombaco Industry
5) Bakeries
6) Electronic Sewing.
7) Dehydration of Food.
8) Removal of moistures from oil emulsions.
9) Electro-medical applications
10) Book binding.

# * Microwave heating

17/02/2020

In this system electricity is converted to electromagnetic waves which generates energy and this energy is used to cook the food.

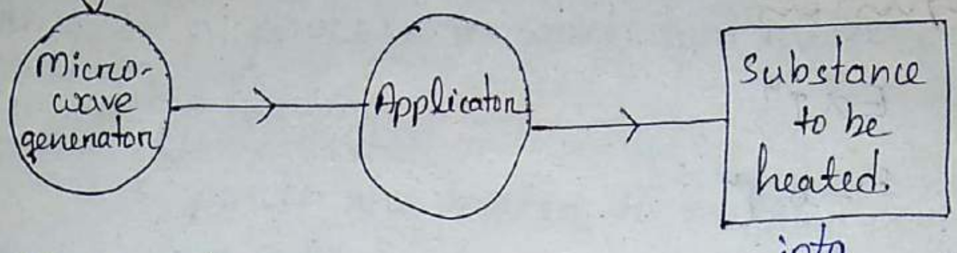
-> Generally those waves are high frequency radio wave and the wavelength of those wave are very small so it is called micro waves.

-> In the oven, microwaves are confined inside the oven cavity and reflected off to its walls and doors, once the door is opened all microwaves are automatically switched off.

-> Theremicrowaves vibrates millions time per second (2400-2500MHz).

17/02/2020

## Working principle




When a microwave energy comes into contact with some substance, it is reflected, transmitted or absorbed. Those wave are reflected by the metal, transmitted through paper, glass, plastic. and absorbed by water/moisture present in the food.

-> When this energy is absorbed heat is produced and cooking takes place.

-> The microwave are attracted to water, fat and sugar molecules. They cause those molecule to vibrate at 2400 MHz/sec. leading to friction within the food which generate heat which begin the cooking process.

## Application of Microwave heating

1) Baking - manufacture of Bread/Toast
2) Drying of paper and textiles.
3) Food processing/kitchen work.
4) Treatment of diseases like cancer
5) Manufacture of plastics
6) Processing of cement and timber.

* Stefon's law

$$E \propto T^4$$

$$E = \sigma T^4$$

This law state that the total radiant heat power emitted from a surface is directly propersonal to the 4th power of its absolute temp.

E = heat energy

T = Absolute temp.

$\sigma$ = constant

=X=

# PRINCIPLES OF ARC WELDING

18/02/2020

-> Welding is a process in which two metal parts are joined by heating.

-> The metal parts are heated to melting point which adhere on solidification.

-> In some cases the pieces of metal to be joint are heated to plastic stage and are fused together.

-> The process in which two metal parts are brought to a molten state and then allowed to solidify is known as FUSION WELDING.

It may be i> Gas welding ii> Thermit welding. iii> Arc welding

## * Electric welding

Electric welding is defined as the branch of welding in which electric current is used to produce the large heat required for joining together of two piece of metal.

-> Basically electric welding is of two type.

1> Resistance welding
- -> Butt welding.
- -> Flash welding.
- -> spot welding.
- -> projection welding.
- -> seam welding.

2> Arc welding.
- -> metal arc welding.
- -> carbon arc welding.
- -> Atomic hydrogen
- -> Helium or Argon welding.

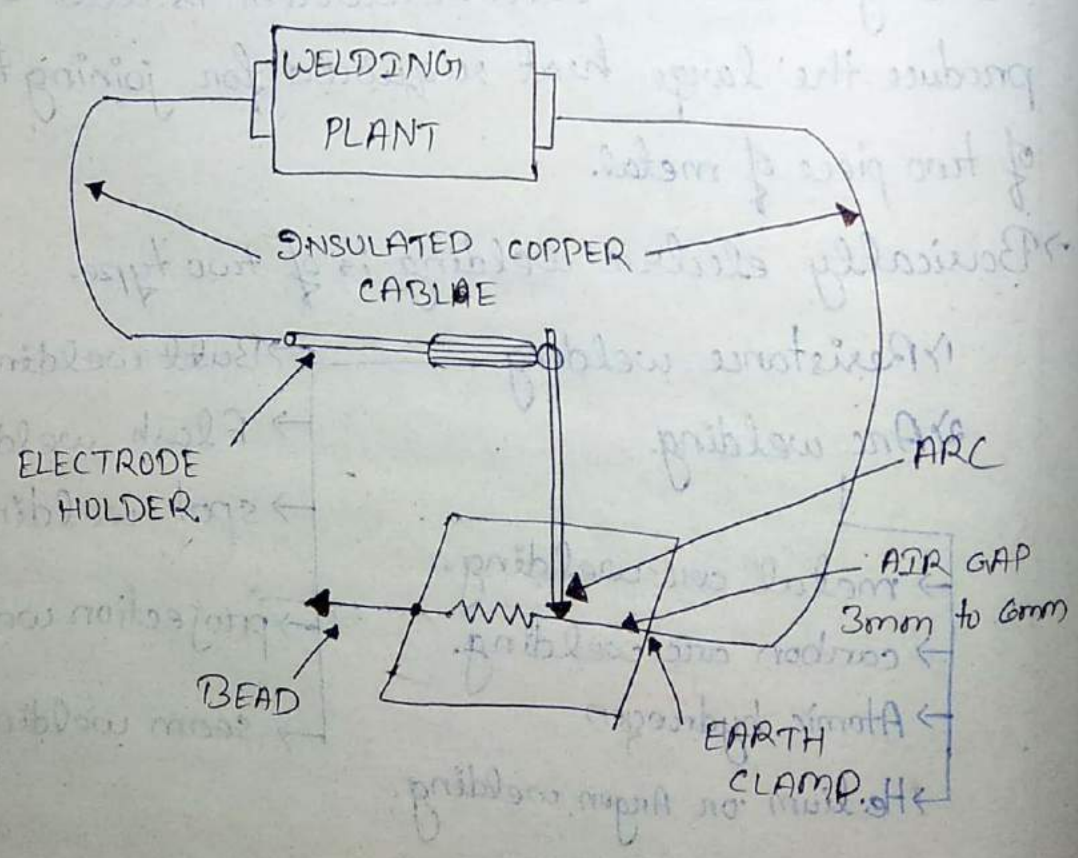
18/02/2020

## * Arc welding

An electric arc is produced by bringing two conductors connected to a suitable source of electric current, momentarily in contact and then separating by a small distance. then the current continuous flow across the small gap and gives intense heat.

-> Then the heat developed is utilized to melt the part of the work piece and the filler metal and thus make the joint.

-> For arc welding maximum voltage for safely operating is upto 100V. and current range from (30-500)Amp for manual operated welding & (75-600) Amp for automatic operated.



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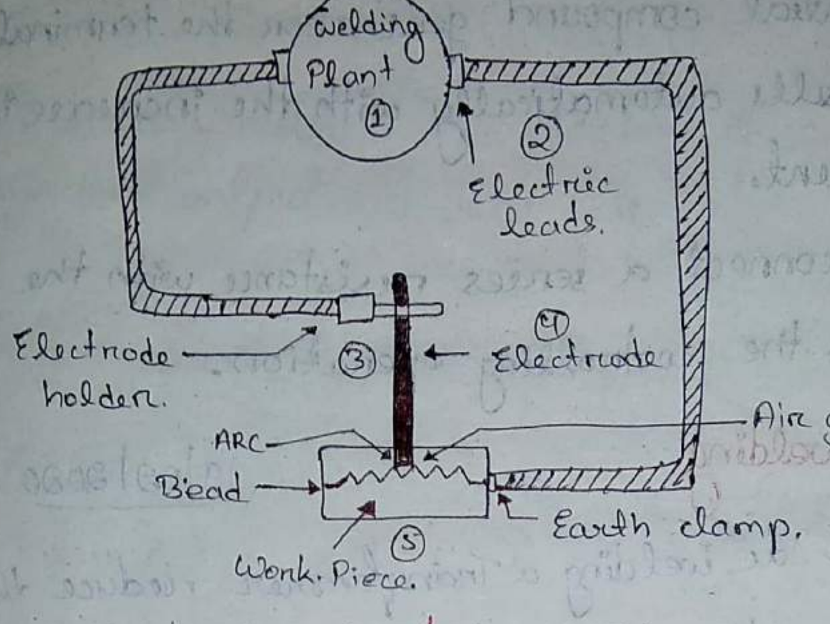


1. welding plant
2. Two electric leads
3. Electric holder
4. Electrode.
5. Workpiece.

## Working principle of arc welding

Current from a source either ac or dc is connected one terminal to the electrode & other to the workpiece & the circuit is completed through air.

-> The gap is provided between the tip of the electrode and the surface of the workpiece by keeping the electrode at a distance of about (3-6)mm from the surface of the workpiece.

-> Due to the interruption by the ~~arc~~ air gap or gas, heat is produced. & rise the temperature of the work piece from 3700°c to 4000°c.

=> In arc welding electrical energy is converted at the arc into heat energy.

=> **Dc arc welding**

It consist of a motor generator set.

-> Here the motor is a squirrel cage induction motor and generator is a differentially compound to give droping characteristics.

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18/02/2020

→ In differential compound generator the terminal voltage falls automatically with the increase in load current.

→ Here we connect a series resistance with the supply for the controlling operation.

## AC arc welding.

19/02/2020

In case of ac welding a Transformer reduce the voltage from the supply of 100V. Here we regulate the current and produce a dropping characteristics required a resistance and reactance may be used. When a resistance is used it must be designed to operate below the saturation point of its magnetic circuit to prevent the introduction of harmonics.

→ Here we use a reactance with a airgap in the magnetic circuit.

## * Advantages and Disadvantages of DC & AC welding.

### Advantages of DC arc welding.

It can select direct electrode positive and also known as direct current reverse polarity which produce deeper penetration weld than direct current electrode negative.

copper, nickles, aluminium.

→ In case of dc arc welding we used electrode having high metal deposition rate.

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Disadvantage of dc arc welding.

It is very costly then ac machine of same quality current output and duty cycle.

24/02/2020

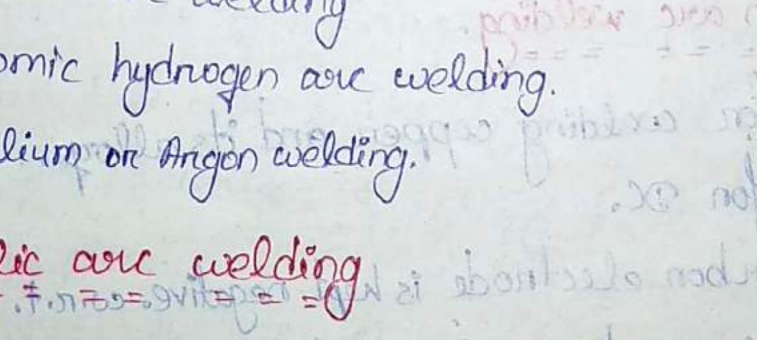
Advantages of AC Arc Welding Machines.

→ AC welds have usually moderate penetration.
→ The welding speed is fasted than dc welding.
→ For equal quality current output and duty rating ac arc welding machines are less expensive than dc arc welding.

* Types of arc welding

1) Metal arc welding
2) Carbon arc welding
3) Atomic hydrogen arc welding.
4) Helium or Argon welding.

1) Metallic arc welding




In the metallic arc system a metal rod is used as an electrode and the arc is struck between this electrode and work piece. Here we connect two terminal of the supply to the electrode and the

24/08/2020

work piece.

-> In this case we use both AC and DC supply.

-> Then the electrode touch to the work piece and then separated from it a little distance. Due to this heat is generated by the arc, a little portion of work melts as also the tip of the electrode. -

. Then two piece to be welded and fuse together.

-> After cooling the work piece, the joint and solid pipe giving a strongly welded joint.

-> Here the arc temperature over 3500°C at a particular point.

-> In this type of welding the supply voltage is (20-25)V. It can't exceed 30V.

2) Carbon arc welding.

-> used for welding copper and its alloys.

-> only for DC.

-> the carbon electrode is kept negative. w.r.t. its work

-> If the carbon electrode is made positive, the carbon particles have a tendency to go into the welded joint and cause brittleness. So that electrode should kept negative and the work piece is positive.

-> For this type of welding only dc can be used.

-> The heat from the arc forms a molten pool and the extra metal required to make the weld is supplied by a filler rod for same composition as that the

24/02/2020

molten metal.

-> It is of two methods.

i) no flux

2) flux.

flux is either in powder form or paste form.

-> In this type of welding basically we (joint) use NON FERROUS metal but now a days it is used in FERROUS METAL.

3) Atomic Hydrogen arc welding. 25/02/2020

-> In this case we gives supply between two tungsten electrode where arc is developed in between them. Due to arc heat is developed. In this case we can supply both AC and DC.

-> Then a molecule of hydrogen blown through the arc. Then the atom of the hydrogen is act as vehicle for transfer of energy from the arc to the work piece.

-> To maintain the arc the open circuit voltage of 300V is necessary. and the welding current range upto 50Amp. is required. Here we using taping transformer in primary which allow for various supply voltage and tapped reactor to permit adjustment of the current.

-> This method is used for welding stainless steel and non-ferous metals.

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25/02/2020

## 4) Helium or Argon Arc Welding

This method is used for welding aluminium alloy and managanizm alloy.

-> Here an arc is struck between electrode of tungsten and the work piece. and a helium or argon is used to give an inert atmosphere so that oxidation of the welded joint doesnot take place.

-> For supply we use both DC and AC.

-> Here the open circuit voltage is around 100v for AC and 70v for DC.

-> For welding aluminium and their alloy stainless and high alloy steels, nickle alloys and copper alloy up to $\frac{7}{8}$" or $\frac{1}{3}$ cm ac is suitable for welding.

-> DC may be used for other common metals and it is essential for the welding of copper and ~~stel~~ stainless steel and alloys over $\frac{1}{2}$" thick.

## * Resistance welding

27/02/2020

The principle of resistance welding is the generation of heat in the joint by passing a heavy current through the parts, this being followed by the application of mechanical pressure which weld the plastic metal and refine the grain structure.

-> The heat developed is equal to,

$$H = I^2 Rt$$

$I \rightarrow$ current passing through the material

R → electrical resistance of the joint where the weld takes place. 27/02/2020

t → time in second.

→ The temperature attained depend on this quantity and is affected by heat losses.

→ The amount of current necessary is (4000 - 5000)A. per sq. cm. of area to be welded.

→ The pressure varies from (280 - 565) kg/cm².

→ To generate high amount of heat the supply should be high current, low voltage.

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

Advantage

⇒ It is a quick method of joining two pieces.

⇒ There is very little wastage of metal

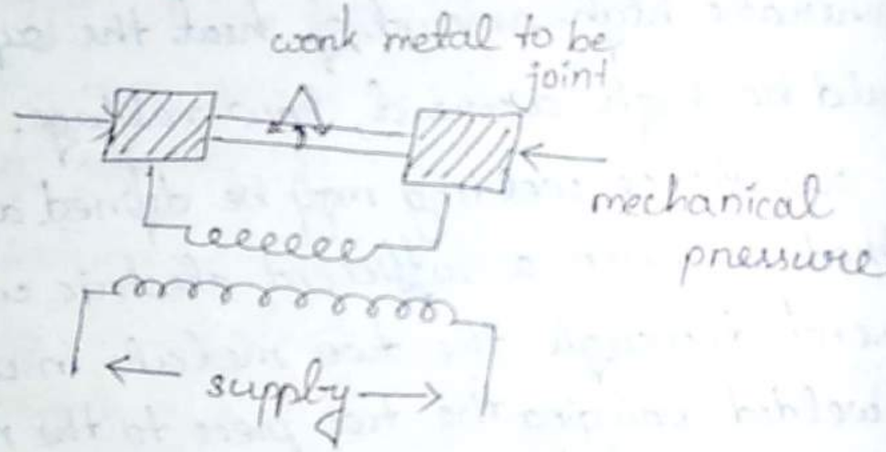
⇒ The process can be accurately controlled

⇒ The welds are consistently uniform

28/02/2020

* The following electric resistance welding processes are commonly used-
  a) Butt welding
  b) Flash boautt welding
  c) Spot welding
  d) Seam welding
  e) Projection welding

* Butt welding




-> In this process heat is generated by the contact resistance between two component. The face of the component should be edged prepared.

-> The two parts of component are brought together and the pressure is applied along axil direction by a spring.

-> Then a heavy current is passed from the welding transformer. (Basically welding transformer having less number of turn in secondary and more number of turn in primary winding)

28/02/2020

which create necessary heat at the joint due to the comparatively high resistance at the joint due contact area.

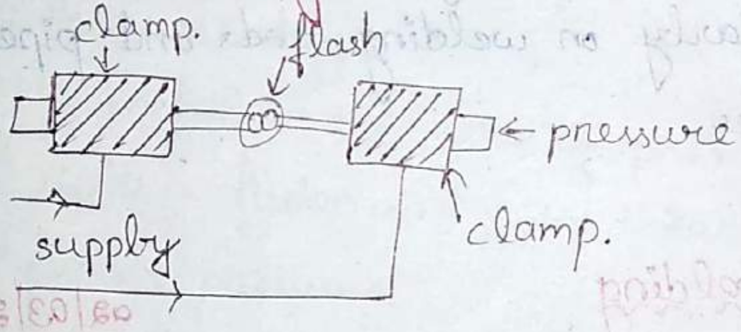
-> Then the metal at the joint melts and the two parts fuse together producing a bulged joint.

Application

-> where the parts are joined, end-end, edge-edge.

-> for welding of pipe, wires.

* Flash butt welding




-> It is similar to the butt welding except for the difference that in this case current is applied to the parts before they brought together.

So that when they need arcing or flashing takes place.

-> The two pieces to be welded are clamped strongly in a flash welding machine and the part are brought together and the resistance to the current flow heats the conducting surface.

-> Then as soon as the metal has been brought to a melting temperature the current is shut OFF and the piece are rapidly brought together by applying a mechanical pressure.

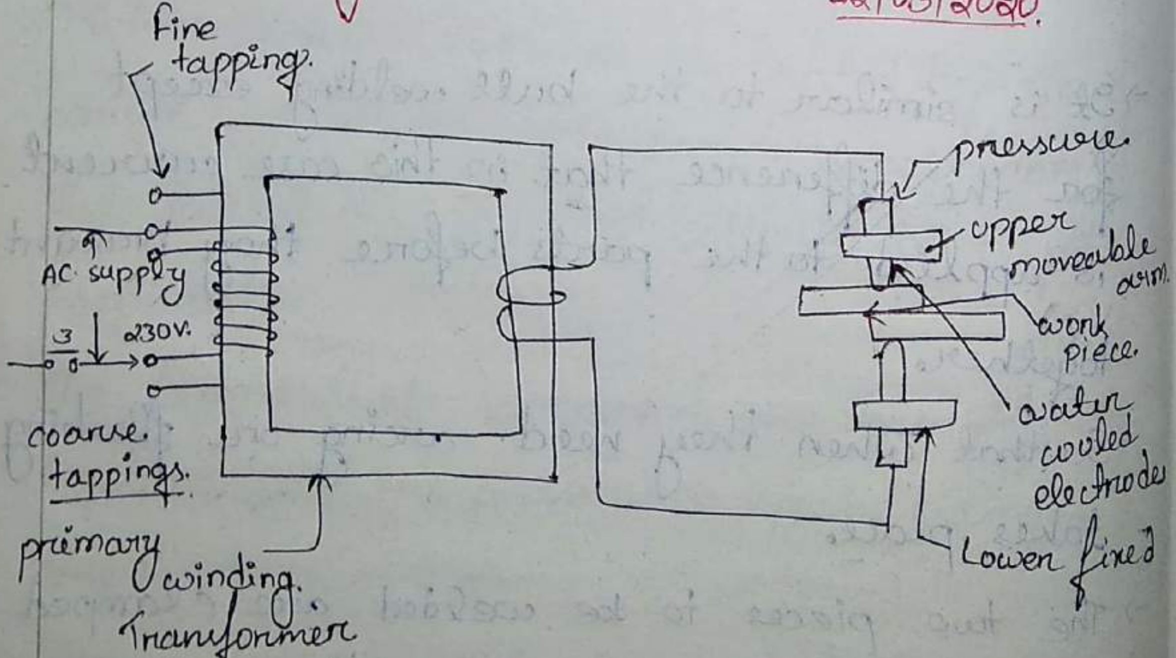
-> When this action takes place the squeezed molten metal gives off a spark of flash then the piece are fused together.

Application

This method of welding is used in production works particularly on welding rods and pipes together.

## * Spot welding

02/03/2020.




This is the simplest and most universally addopted method for making lap weld in thin sheet upto a maximum thickness of 12.7mm.

02/03/2020

-> In spot welding machine consist of transformer to produce high current at low voltage electrode are connected to the end of the secondary winding for leading the current to the work and apply the necessary mechanical pressure.

-> Here we use a tapping transformer in primary winding.

-> In the process of the metal to be welded are over lapped and placed between two water cooled electrode and impulse of current pass through the assembly.

-> Then the metal in the zone of pressure get heated upto a fusion and joint thus made gets cooled under pressure.

-> For the spot welding 5000Amp current is required and the voltage between the electrode usually less than 3V.

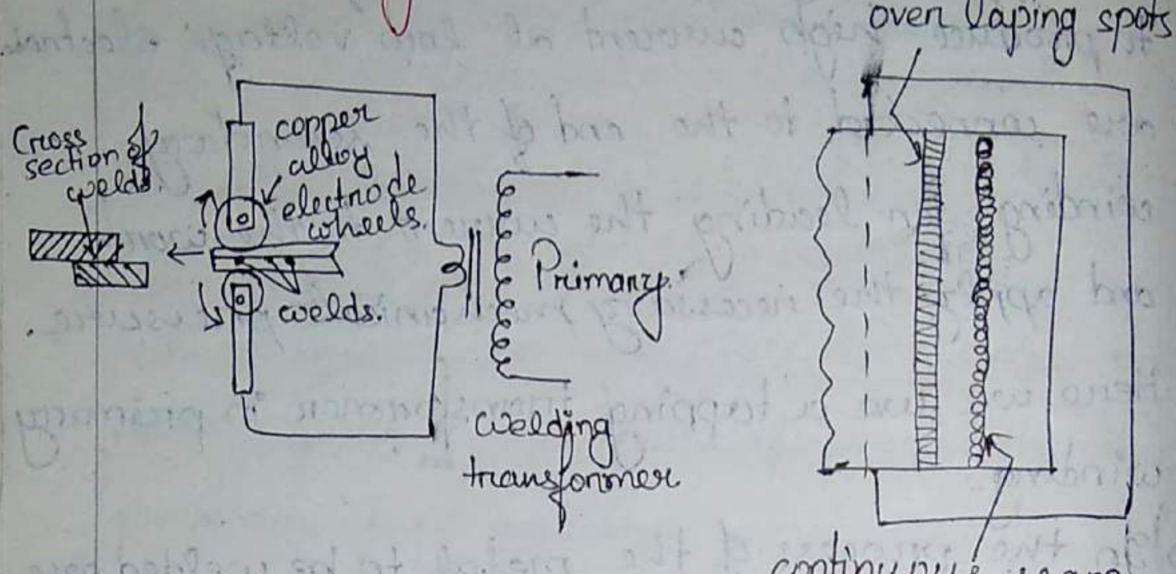
## Application.

-> It is applied to welding of sheet.

-> It is used for fabrication all type of sheet metal structure where the mechanical strength rather than the water or air tightness is required.

-> It may be applied boxes, cones and enclosing case.

* **Seam welding** 02/03/2020




It is similar to the spotwelding except that series of spot are produced by roler electrode instead of tipped electrode.

-> Most seam welding produce a continuous or intermediate seam weld near the edge of two over lapped metals, by using 2 roler electrode.

-> As those roler travel over the metal the pieces are under the pressure and current passing between them heats the two piece of metal to the fusion point.

-> The main object of the over lapped spot is to produce liquid leak proof lap joints.

-> For continious series spot welding the electrods are continuously ON and for the interrupted spot welding we ON OFF according to our desire.

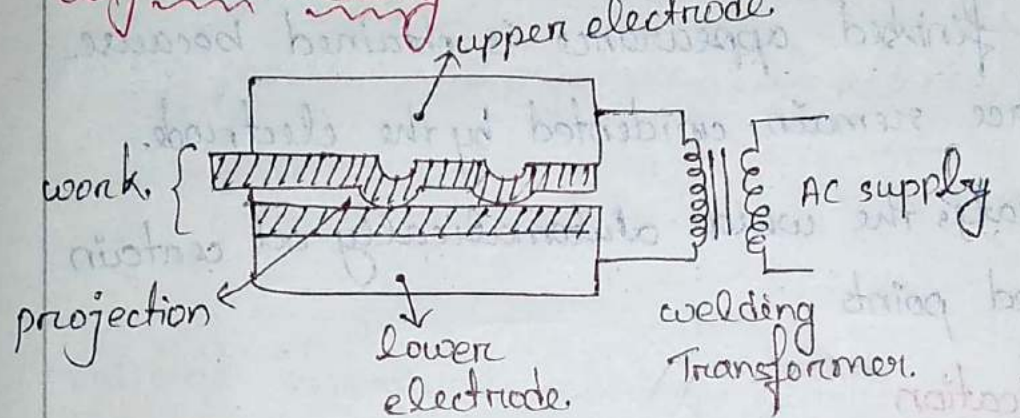
Application

-> It is used for making lap and butt welds.

-> It used for welding of sheet metal bcz it is quicker than spot welding. 02/03/2020

→ It is used on many type of pressure tight on leak tanks for various purposes. particullarly circular or rectangular container, car body, transformer, radieter unit.

## * Projection welding




It is the modified form of spot welding.

→ Projection welding consist of forming slight position on the sheet of the metal. The projection are accurately formed in precize location on the metal by a special set of dies.

→ After the projection are formed, the raised portion on one pieces are pressed into the contact with another piece while at the same time, a heavy current pass through the two pieces whose raised portion touch the second sheet as they are clamped by the electrode in a projection welder and the current is applied, then the current flows at the point and heats up and then fused together.

02/03/2020

## Advantage of projection welding over spot welding

-> more than one spot on weld are done at a time so that more output is obtained

-> Due to low current density and low pressure the electrode life is increased.

-> good finished appearance is obtained because surface remain unidented by the electrode.

-> It locates the welds automatically at certain desired points

## Application

-> in assembling parts made by punching or stamping and for welding studs, nuts to plate

= x =

# ILLUMINATION

06/03/2020

The illumination engineering should not only interest itself in the exact sciences and economics but also be thoroughly conversant with the physiology of eye, the peculiarities of our seeing process and psychological effects.

Radiant energy is always emitted or absorved in bondles. It is to be noted that valance electron are responsible for production of radiation in the visible region. And those electron in the outer most orbit are the important to the illuminating engineering.

→ Each photon may be consider to be associated with a wave which predicts how the photon will travel.

$v = \lambda f$

$v \rightarrow$ velocity

$\lambda \rightarrow$ wave length

$f \rightarrow$ frequency.

The wave length used by illuminating engineers are very short and the unit used micron or Angstrom Å ($10^{-10}$ meter).

1 micron = $10^{-6}$ meter.

06/03/2020

- 0.03 Å
- 0.1 Å
  ultra violet region
- 0.4 }
- 0.7 } visible region
- 300cm Infrared region
- $3 \times 10^8$ m.

| Frequency in c/s · in Hz. | Wave length in meters (m) | Nature of waves. |
|---|---|---|
| $3\times10^{22}$ | $10^{-14}$ | Cosmic rays. |
| $3\times10^{20}$ | $10^{-12}$ | γ-Rays |
| $3\times10^{18}$ | $10^{-10}$ | X-rays. |
| $3\times10^{16}$ | $10^{-8}$ | Ultraviolet Rays. |
| $3\times10^{14}$ | $10^{-6}$ | Visible light |
| $3\times10^{12}$ | $10^{-4}$ | Infrared Rays(Heat) |
| $3\times10^{10}$ | $10^{-2}$ | Short wave Radio waves. |
| $3\times10^{8}$ | 1 | |
| $3\times10^{6}$ | $10^{2}$ | Longwave Radiowaves. |
| $3\times10^{4}$ | $10^{4}$ | |
| $3\times10^{2}$ | $10^{6}$ | |

→ The visible range extend from about 0.4Å to 0.75Å.

→ The illumination engineers are interested in the conversion of electrical energy into radiation energy of such frequency has to visible to the human eye and also in the conversion of radient energy into electrical energy by photocell or thermocouple.

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| Wave length (A°) | Ultraviolet | Frequency in Hz |
|---|---|---|
| 4000 | violet | $7.5 \times 10^{14}$ |
| 5000 | Blue | $6.0 \times 10^{14}$ |
| | Green | |
| 6000 | Yellow | $5.0 \times 10^{14}$ |
| 7000 | Orange | $4.3 \times 10^{14}$ |
| | Red | |
| 8000 | Infrared | $3.75 \times 10^{14}$ |

(Colour of light and wave length)

Violet = 4100 A°
Orange = 6100 A
Green = 5300 A
Yellow = 5800 A
Blue = 4700 A
Red = 6000 A

1) 1 micron = $10^{-6}$ metre.
2) 1 metre = $10^{10}$ Angstrom.

* Terms using illumination 12/03/2020.

1) Light

Light is defined as the radiant energy from a hot body causing visual sensition upon the human eye.

2) Flux

It is known as luminous flux.

-> It is defined as the total quantity of light energy radiated on emitted per second from a luminous body in the form of the light wave.

12/03/2020

And it is measured in lumens. — and denoted by 'F' or 'Φ'.

-> And it also defined as rate of luminous energy.

3) Light energy

It is the energy obtained in visual radiation in a given time. and is expressed in lumen hour and is denoted by 'Q'.

4) Luminous efficiency or Radiant efficiency

It is defined as the output lumen per watt of the power consumed by the source of light.

-> measured in lumens per wattage.

If E = Energy radiated at wave length $\lambda$.

$\eta$ = The relative sensitivity of eye at wave length $\lambda$.

K = Maximum possible efficiency if whole of the electrical input were transformed into radiating energy at 5530 A.U.

= 620 lumens/watt

Efficiency at wave length, $\lambda = \eta K$

Total energy converted into visual effect $= K\int_{\lambda_1}^{\lambda_2} E\eta\, d\lambda$

Total energy radiated on all wave length

$= \int_0^{\infty} E\, d\lambda.$

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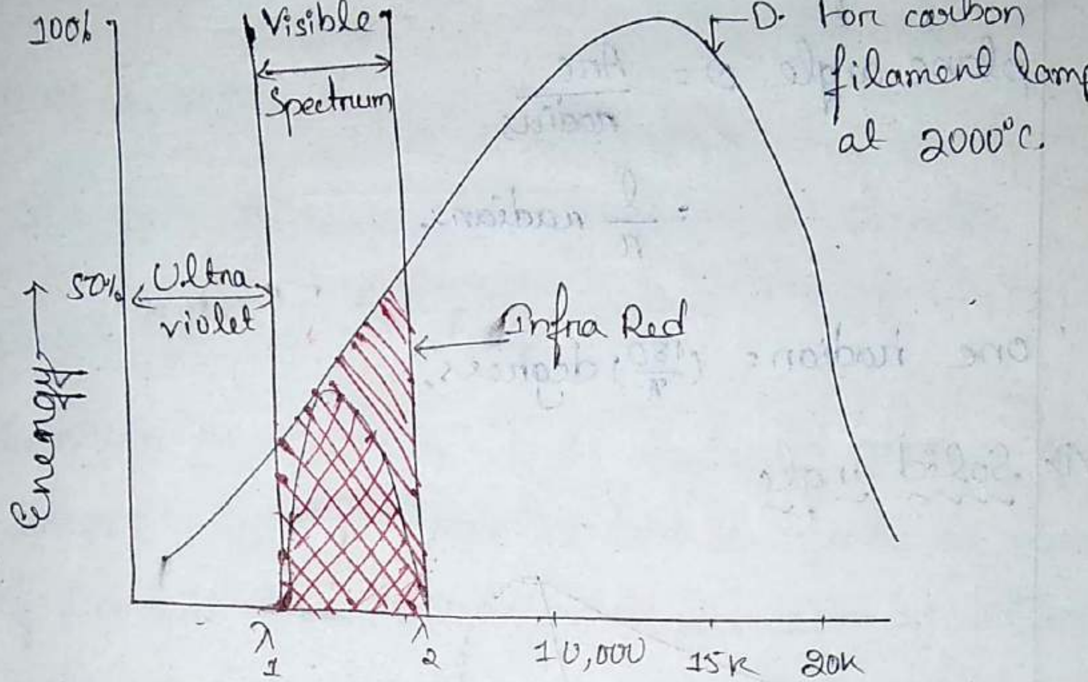
Luminous efficiency $= \dfrac{K\int_{\lambda_1}^{\lambda_2} E\,\eta\, d\lambda}{\int_0^{\alpha} E\, d\lambda}$

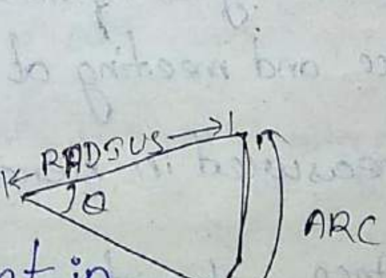



(Special Distribution Curve).

Q. If a bulb is rated at 500W. and 250V. has an efficiency of 13 lumen/watt, then total flux produced by the bulb = 500 × 13 = 6500 lumens.

5) Plane angle

Plane angle is ~~substained at~~ substended at a point in the same plane by two converging line.




→ This angle is measured in radians or degrees.

12/03/2020

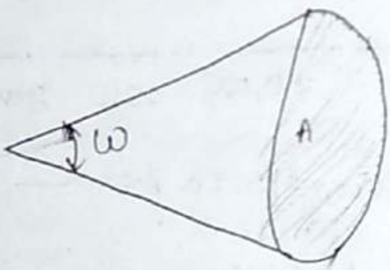
→ One ~~angle~~ radian is the angle substened at the centre of a circle by an arc whose light is equal to the radius of the circle.

plane angle $\theta = \frac{Arc}{radius}$

$= \frac{l}{r}$ radians.

one radian = $(\frac{180}{\pi})$ degrees.

vi) Solid angle




Solid angle is generated by the line passing through the point in a space and the periphery of area on a solid angle enclose a volume by an infinite number of line lying on a surface and meeting at a point.

→ It is measured in steradians and denoted by 'ω'.

$\omega = \frac{Area}{(Radius)^2}$ steradians.

$= \frac{4\pi r^2}{r^2} = 4\pi$ steradians.

7) Luminous Intensity 12/03/2020

In any particular direction is the luminonous flux emitted by per unit solid angle by a point source and is denoted by 'I'.

$I = \frac{F}{\omega} = \frac{\phi}{\omega}$ Lumens/steradians or Candla

8) Candle power (C.P.)

Candle power is the light rendering capacity of a source in a given direction and is defined as num. of lumens given out by the source in an unit solid angle in a given direction.

$C.P. = \frac{lumens}{\omega}$

a) Lumen

Lumen is defined as the amount of luminous flux given out in space reprerented by one unit solid angle by a source having an intensity of one candle power in all directions.

Lumens = Candle power x solid angle

$= C.P. \times \omega$

→ Total lumens given out by the source of one candle is $4\pi$ lumens.

12/03/2020

10) Mean spherical Candle Power (m s cp)

defined as the average of candle power in all directions and in all plans from the source of light.

$$m.s.c.p. = \frac{\text{Total flux in lumens}}{4\pi}$$

11) Mean hemi-spherical Candle Power (M.H.S.C.P.)

It is defined as the average of candle power in all direction above or below horizontal plane passing through the source of light.

12) Mean horizontal Candle power (M.H.C.P.)

It is average of all candle power in all direction in the horizontal plane containing the source of light.

13) Illumination

When the light falls on any surface, the phenomenon is called Illumination.

-> It is defined as the number of lumen falling on the surface per unit area.

-> It is denoted by 'E'.

-> measured in lumens per $m^2$ (or) lux (or) metre candle.

12/03/2020

# Illumination

When the light falls upon any surface, the phenomenon is called illumination. It is defined as the number of lumens, falling on the surface per unit area.

-> It is denoted by symbol E and is ~~marked~~ measured in lumens per square metre or lux or metre candle.

## Laws of Illumination

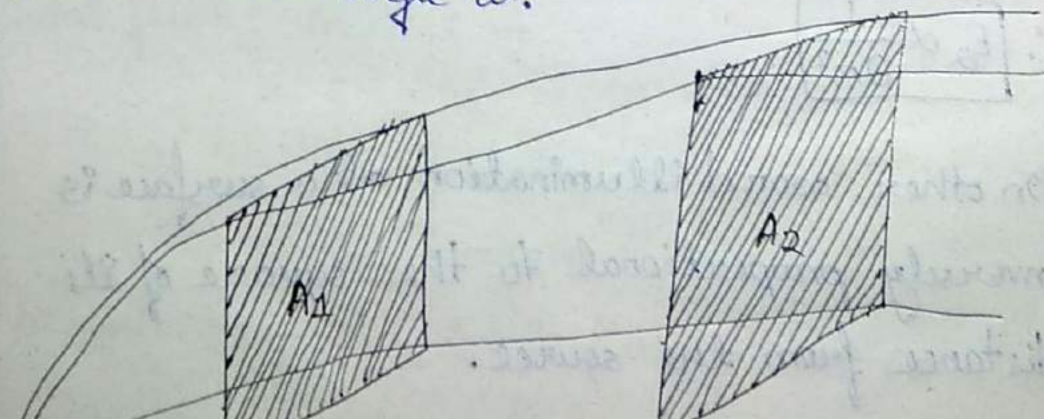
13/03/2020

1) Inverse square law
2) cosine law

### 1* Inverse square law

Consider a point source having an intensity 'I' lumen/steradian.

-> Let two surface having area $A_1$ and $A_2$ be placed at a distance r and 2r metres away respectively from the source. The two surface are enclosed in the same solid angle 'ω'.



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→ Since the source I lumen / steradian suface enclosed by solid angle 'ω' will receive total flux = I × ω lumens

Consider area $A_1$,

$$\omega = \frac{A_1}{r^2}$$

$$\text{Total flux} = \frac{I \times A_1}{r^2}$$

Consider area $A_2$,

$$A_2 = \frac{I \times A_2}{2r^2}$$

$$\boxed{E_1 = \frac{\phi}{A}}$$

$$E_1 = \frac{I \times A_1}{r^2 A_1} = \frac{I}{r^2}$$

$$E_2 = \frac{I \times A_2}{2r^2 A_2} = \frac{I}{2r^2}$$

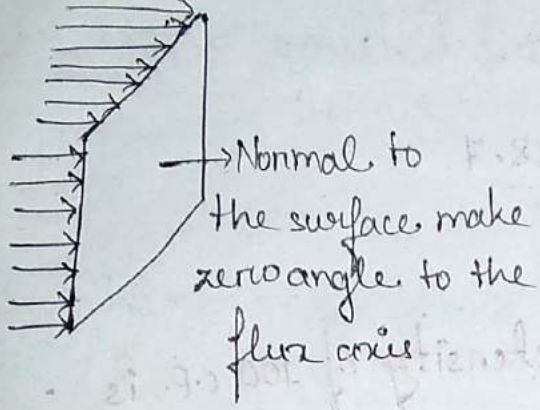
$$\therefore \boxed{E_1 \propto \frac{1}{r_2}}$$

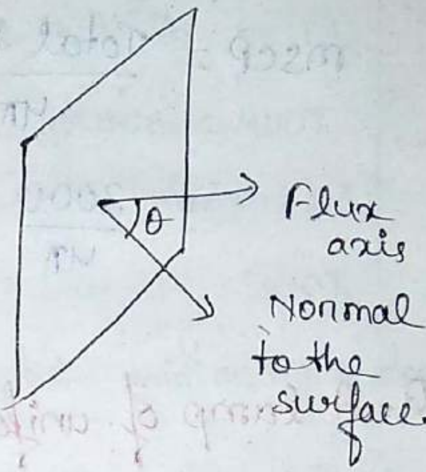
$$\therefore \boxed{E_2 \propto \frac{1}{2r^2}}$$

→ In other word illumination at a surface is inversely proportional to the square of its distance from the source.

2. Lambert's co-sine law 

According to this law illumination of a surface varies directly as the co-sine of the angle between the normal to the surface and direction incident light.




i.e. $E \propto \cos\theta$

i) In the normal surface case, $E = \frac{\phi}{\text{area}}$

ii) In the inclined surface case, $E = \frac{\phi}{\text{Area}} \times \cos\theta$

Q- Calculate the total flux from the lamp having mean spherical candle power of 35.

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

$\text{Total flux} = MSCP \times 4\pi$

$= 35 \times 4\pi$

$= 4 \times \frac{22}{7} \times 35$

$= 440$ lumens.

Q- A 250V lamp has total flux of 3000 lumen and takes a current 0.8 Amp.

Calculate i) Lumen / Watt

ii) MSCP / Watt

13/03/2020

Wattage of lamp = 250 × 0.8
= 200 Watt

Flux = 3000 lumen

Lumens / watt = $\frac{\Phi}{W} = \frac{3000}{200} = 15$

$MSCP = \frac{\text{Total Flux}}{4\pi}$

$= \frac{3000}{4\pi} = 238.7$

Q- A lamp of uniform intensity of 100 c.P. is enclosed inside a glass globe, 25% of light emitted by lamp is observed by the globe. Determine

i) Brightness of globe
ii) C.P. of globe, having
iii) Dia of globle is 20cm

Brightness = $\frac{\text{Light emitted by globe}}{\text{surface area of the globe}}$

Dia of globe = 20 cm

surface area of globe = $4\pi r^2$
$= 4\pi \times 10^2$
$= 400\pi$ lumens

C.P. of the lumen = 100

Total lumen emitted by the lamp

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$= 4\pi \times$ lumen

$= 4\pi \times 100$

$= 400\pi$ lumens

light absorved by the globe = 25%.

then light emitted from the globe = $400\pi (1-0.25)$

$= 400\pi \times 0.75 = 300\pi$

$$\text{Brightness of globe} = \frac{\text{light emitted by globe}}{\text{surface area of globe}}$$

$$= \frac{300\pi}{400\pi}$$

$$= \frac{3}{4} = 0.75$$

$$\text{C.P. of globe} = \frac{\text{lumens emitted from globe}}{4\pi}$$

$$= \frac{300\pi}{4\pi} = 75 \text{ C.P.}$$

Q- A surface of light has 500 CP in all directions below the lamp level. It is suspended at three metres above the ground. Calculate

i) Illumination at point A on ground directly below the lamp

ii) Illumination at point B, 5 metres away from point A assuming uniform distribution of light.

iii) Total flux of light within a circular of 1 m. dia around the point A assuming uniform illumination.

Ans CP of lamp = 500

$h = 3m.$

$d = \sqrt{5^2 + 3^2} = \sqrt{34}$ m

Illumination at A ; $E_A = \frac{I}{h^2} = \frac{500}{9}$

$= 55.55$ lux

at B, $E_B = \frac{I}{d^2} \cos\theta$

$= \frac{500}{34} \cos\theta$

$\cos\theta = \frac{3}{\sqrt{34}}$

$E_B = \frac{500}{34} \times \frac{3}{\sqrt{34}} = 7.56$ lux

Dia = 1m

surface area $= \frac{\pi}{4} D^2$

$= \frac{\pi}{4} (1)^2$

$= 0.7854 m^2$

Total flux $= 55.55 \times 0.7854$

$= 43.64$ lumens

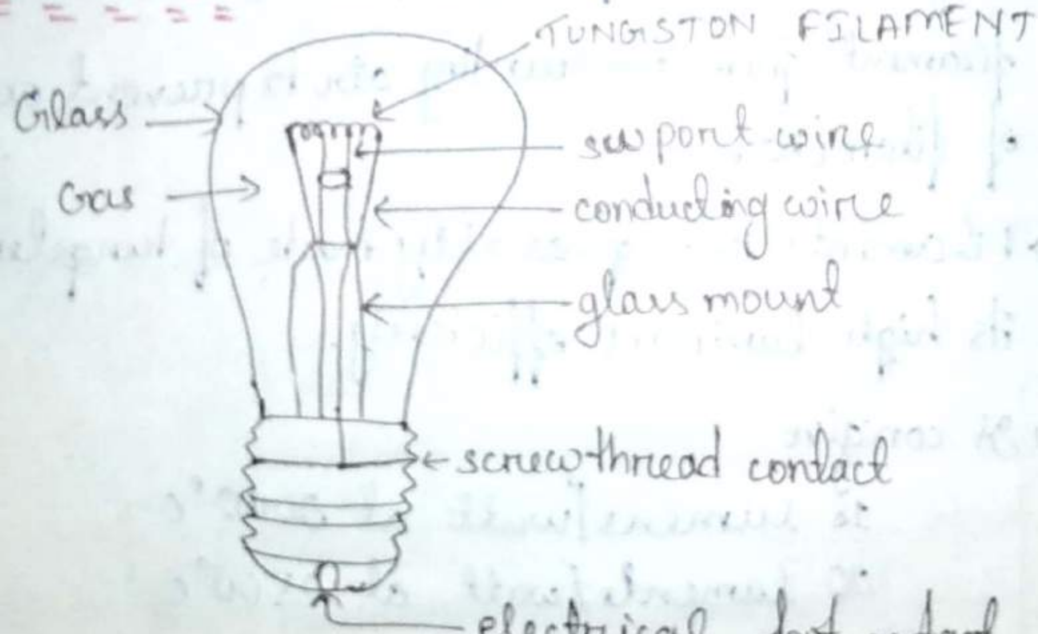
* Filament lamp (1879) 16/04/2020

→ a.k.a. Incandescent lamp.

→ An incandescent lamp works on the principle of incandesence, a general term meaning light produced by heat.

→ In an incandescent filament type of blub, an electric current passed through a thin metal filament, heating the filament until it glows and produces light.

Construction




→ The filament is attached across two lead wires one lead wire; ~~one lead wire~~ one lead wire is connected to the foot contact and other is terminated on the metalic base of the bulb. Both of the lead wire pass through glass support mounted at the lower middle of the bulb.

16/04/2020

-> Two support wires also attached to the glass support, are lised to support filament at its middle portion.

-> The foot contact is isolated from metalic, base by insulating material.

-> The entire system is encapsulated by a colored or phosphore coated or transparent glass bulb.

-> The glass bulb may be filled with inert gas (argon) or it is kept vacum, bcz it is isolate the filament from surrounding air to prevent oxidation of filament.

-> Filaments are generally made of tungsten bcz its high luminous efficiency.

-> It can give
18 lumens/watt at 2000°c
30 lumens/watt at 2500°c

-> It has high melting point

-> life span of incandescent lamp is 1000 hours

17/04/2020

## Fluorescent lamp :

A fluorescent lamp is a low weight mercury vapour lamp that uses fluorescence to deliver visible light.

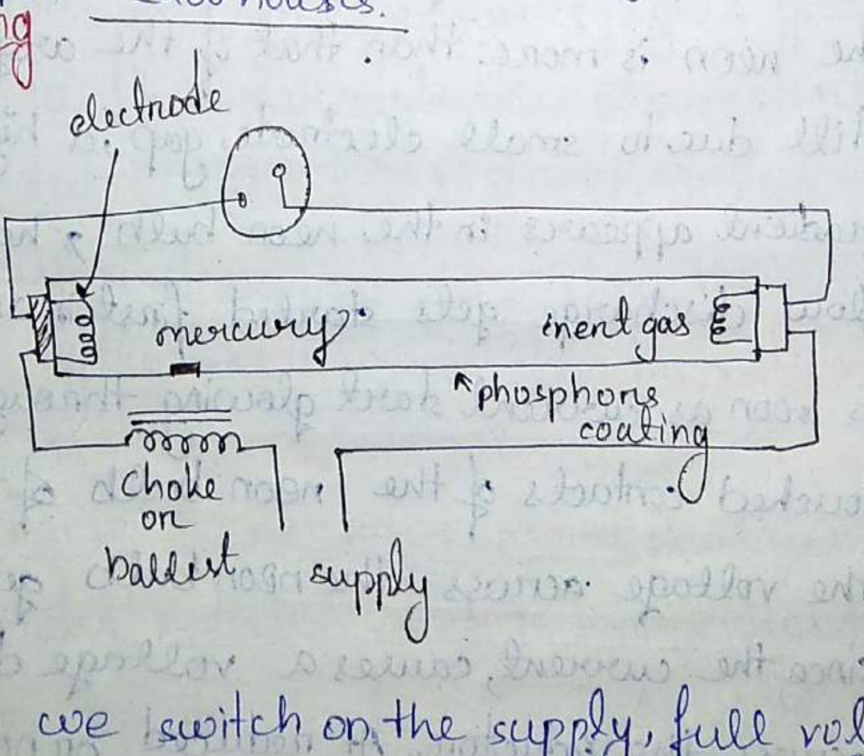
-> An electric current in the gas energizes mercury vapor which delivers ultraviolet radiation through discharge process and the ultraviolet radiation causes the phosphor coating of the lamp inner wall to radiate visible light.

-> luminous efficiency - 50 to 100 lumens per watt

-> a.k.a. low pressure mercury vapor lamp.

-> life span 2400 hours.

## Working




-> When we switch on the supply, full voltage comes across the lamp and as well as across the starter through the ballast. But at that instant, no discharge happens; i.e. no lumen output from the lamp.

-> at the full voltage first the glow discharge is established in the starter. This is because the electrodes gap in the neon bulb of starter is much lesser than that of the fluorescent lamp.

-> Then gas inside the starter gets ~~energized~~ ionized due to this full voltage and heats the bimetallic ~~lamp~~ strip. That causes to bend the bimetallic strip to connect to the fixed contact. Now, current starts flowing through the starter. Although the ionization potential of the neon is more than that of the argon but still due to small electrode gap, a high voltage gradient appears in the neon bulb, hence glow discharge gets started first in the starter.

-> As soon as current start glowing through the touched contacts of the neon bulb of the starter, the voltage across the neon bulb gets reduced since the current, causes a voltage drop across the inductor. At reduced or no voltage across the neon bulb of the starter, there will be no more gas discharge taking place

17/04/2020

and hence the bimetallic strip gets cool and breaks away from fixed contact. At the time of breaking of the contacts in the neon bulb of the starter, the current gets interrupted, and hence at that moment, a large voltage surge comes across the inductor (ballast).

-> The highest valued surge voltage comes across the fluorescent lamp (tube light) electrodes and strikes penning mixture (maximum argon gas and mercury vapor).

-> Gas discharge process gets started and continuous and hence current again gets a path to flow through the flourescent lamp tube (tube light) it self. During discharging of penning gas mixture the resistance offered by the gas is lower than the resistance of starter.

-> The distance of mercury atoms produces ultraviolet radiation which in turn excites the phosphor powder coating to radiate visible light.

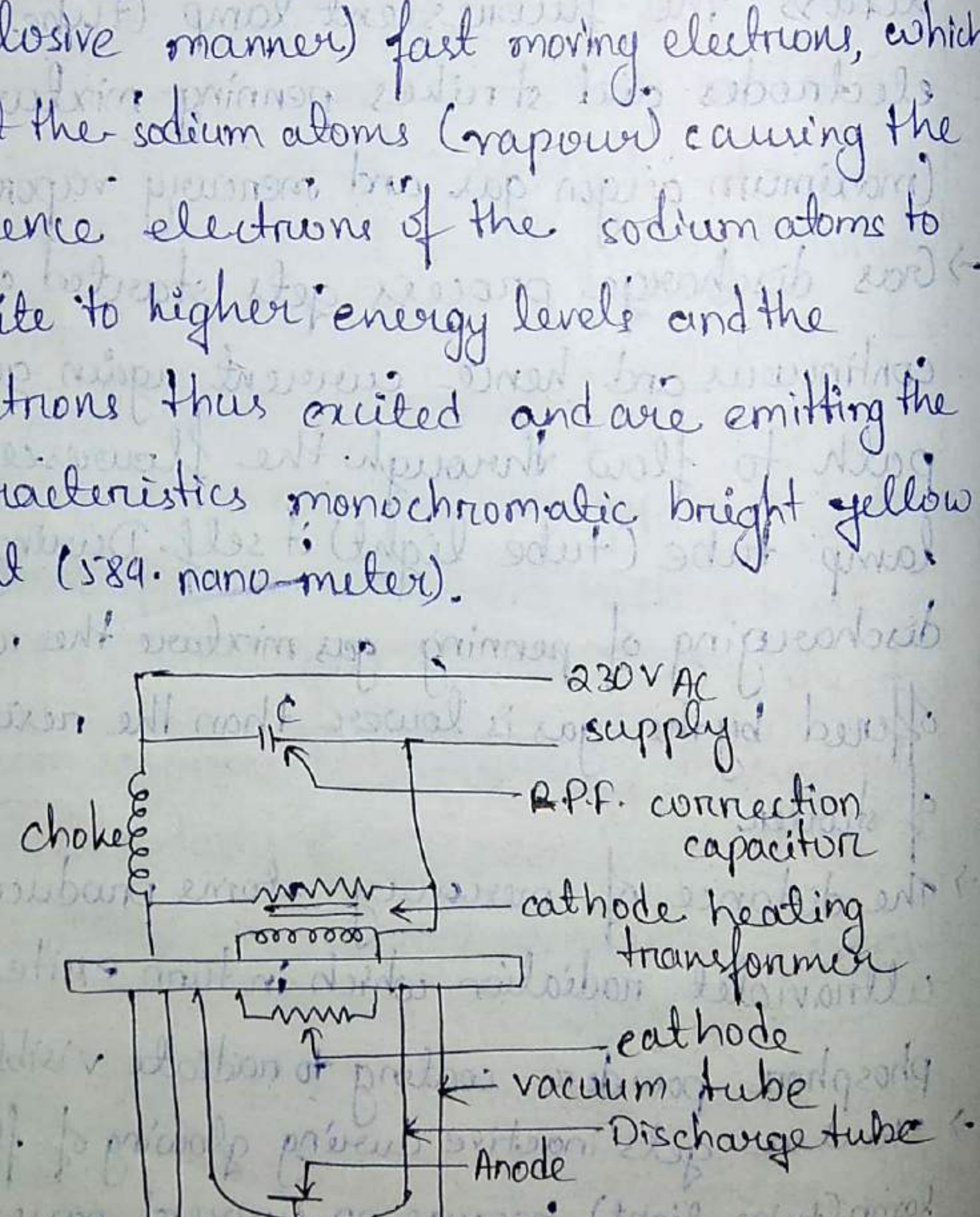
-> Starter gets inactive during glowing of florescent lamp (tube light) because no current passes through the starter in that condition.

# * Low pressure sodium vapour lamp

-> It is a gas-discharge lamp that uses sodium in an excited state to produce light.

## Working principle

It works by electric discharge (passage of electricity through sodium vapours at low and high pressure) filaments of the lamp. ~~supt~~ sputter (sputter means spit up in an explosive manner) fast moving electrons, which heat the sodium atoms (vapour) causing the valence electrons of the sodium atoms to excite to higher energy levels and the electrons thus excited and are emitting the characteristics monochromatic bright yellow light (589 nano-meter).



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## Construction

-> A low-pressure Sodium (LPS) vapour lamp contains an inner discharge tube made of borosilicate glass that is fitted with metal electrodes and filled with neon and argon gas and a little metallic sodium.

-> Neon gas serves to start the discharge and to develop enough heat to vaporize the sodium.

-> Argon has a lower glow voltage, argon helps the smaller lamps start a lower voltage.

-> The sodium vapour lamp is only suitable for alternating current, and ∴ requires choke control.

-> A voltage of the order of 380-450 volts (depending on the wattage) is necessary to start the discharge, which is obtained from a high reactance transformer on an auto-transformer.

-> Its operating PF is low (0.3), hence suitable capacitor must be used to improve the PF.

## Operation

18/04/2020

-> When the lamp is not in operation, the sodium is usually in the form of solid deposited on the side walls of the tube.

-> When it is connected across the supply mains current passes between the electrodes, it ionizeds the neon and argon, giving a red glow until the hot gas vaporizes the sodium.

-> The discharge tube is U-shaped. When the lamp is turned on it emits a dim red/pink light to warm the sodium metal and within a few minutes it turns into the common bright yellow as the sodium metal vaporizes.

-> LPS lamps have an outer glass vacuum envelope around the inner discharge tube for thermal insulation, which improves their efficiency.

-> At starting it creates a red glow due to the neon gas and the neon gas lights at a lower temperature.

-> As the temperature increaseds the sodium begins to vaporize and the lamp turns to a pure yellow, which makes objects appear as gray.

## Advantage

i) These lamps will restart immediately after interruption of power supply.

ii) Provides superior uniformity of light distribution over all HID lamps.

18/04/2020

iii) low power (energy) consumption.
iv) lumen output doesnot drop with age.

Disadvantage

i) expensive to install.
ii) have poor colour rendering characteristics.
iii) Run time to full output is the longest. (7-100 minutes)
iv) require special disposal considerations.

Application

1) Road lighting and railway marshalling yards
2) Security and orientation lighting.

-> luminous efficiency is 100-185 lumens per watt.
-> life span is 14,000-18000 hours.

* High pressure sodium vapour lamp
-> HPSV lamp is an improvement over the LPSV lamp in that it has more acceptable colour with the great efficiency of the sodium lamp.
-> The better colour rendering comes with a bit a sacrifice, it has less efficiency than the LPSV lamp.

Construction and Operation
1) HPSV lamps are smaller than LPS lamps.

18/04/2020

2) HPSV lamps with a polycrystalline translucent aluminium oxide discharge tube enclosed in a tubular outer glass envelope.

3) The discharge tube is internally coated with aluminium oxide powder.

4) The discharge tube contains an amalgam of mercury and sodium along with neon gas.

5) xneon is a colorless, dense, odorless and noble gas that occurs in the Earth's atmosphere in trace amounts.

6) The outer shell is evacuated and a better maintains this high degree of vacuum throughout the lamp life.

7) These lamps need a control gear comprising of ballast, ignitor and capacitor for optimum performance.

8) They produce a dark pink glow when first struck, and a pinkish orange light when warmed.

9) Some lamps also produce a pure to bluish which white light in between.

10) This is formed by the mercury glowing before the sodium is completely warmed.

-> life span = 24000 hours

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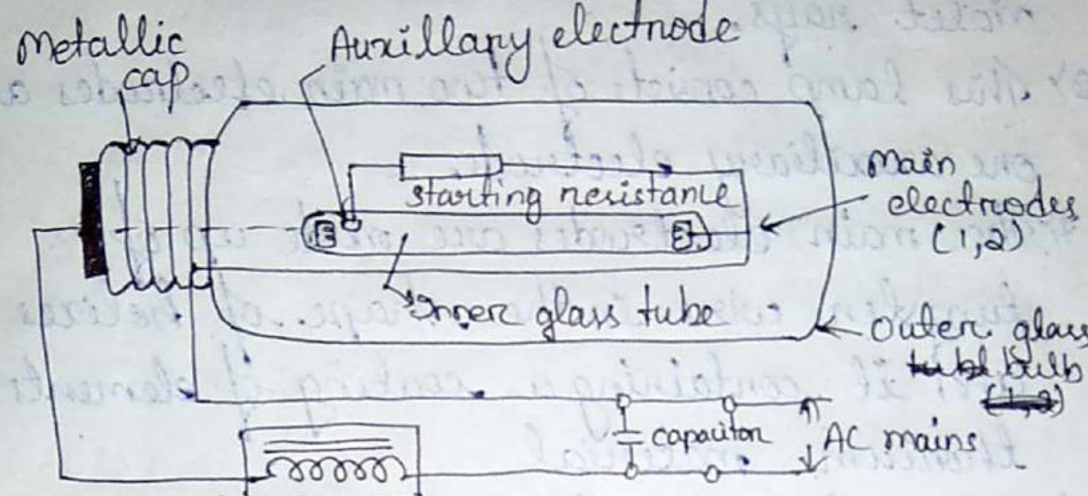
# * High pressure mercury vapour lamps




(HPMV lamp construction).

-> It is a High Intensity Discharge (HID) lamp and it is also called as hot cathode gas-discharge lamp.
-> may have lowpressure in the bulb.
-> efficiency more than sodium vapour lamp.

## Construction

1) It consist of a discharge envelope enclosed in an outer bulb of ordinary glass.
2) The discharge envelope may be of hard glass or quartz.
3) The space between the bulb is partically or completely evacuated to prevent heat loss by convection from the inner bulb.
4) The inner bulb consists of argon and a certain quantity of mercury and outer tube is coated with flouresent material.
(argon for initial charge of mercury)

19/04/2020

5) The outer bulb absorbs harmful ultra violet rays.

6) This lamp consists of two main electrodes and one auxiliary electrode.

7) The main electrodes are made up of tungsten wire in the shape of helixes and it containing a coating of elements of thorium material

8) An auxiliary on starting electrode is connected through a high resistance.

9) A choke coil having different tapping is connected in series with the lamp to give high starting voltage for discharge and for controlling the current and voltage across the lamp after discharge.

10) A capacitor is connected across the supply to improve the power factor.

Advantage.

-> colour rendering is more than that of HPSV lamp.

-> long life (16k to 24k hours)

Disadvantage:

-> 4-5 minutes cooling and restart time needed.

-> It takes 6A approximately when switched on and after six minutes it falls to 3A.

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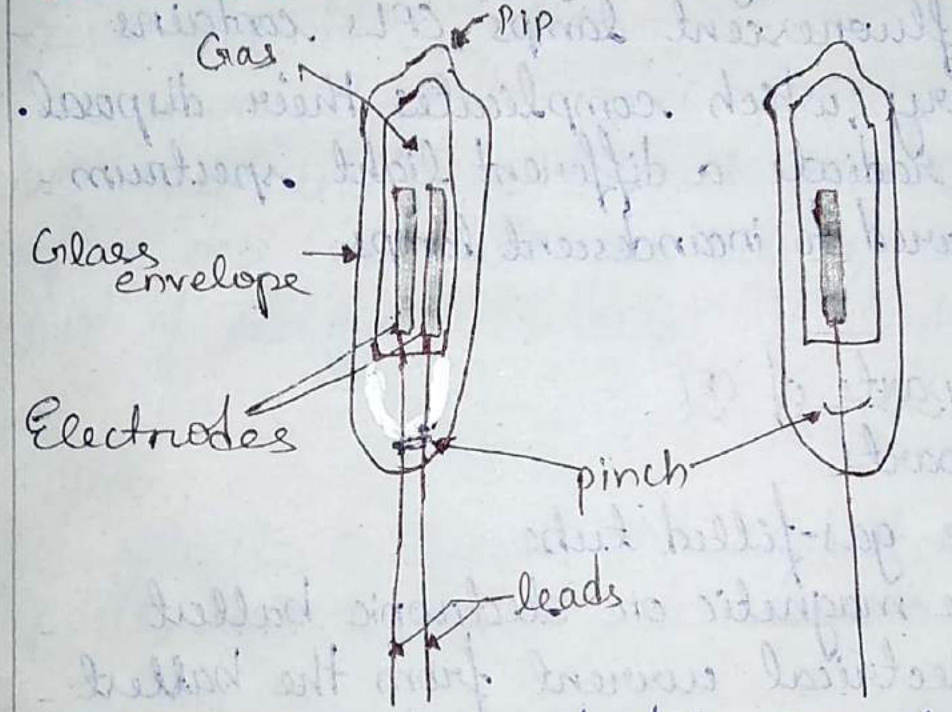
Application
-> used at parks, street lighting, high ceiling building and gyms.
-> industrial applications.

* Neon lamps 20/04/2020




.Neon lamps consist of a glass tube filled with neon gas and a small % of helium.
-> Two electrodes i.e. placed inside are of pure iron.
-> operated on 110 volt a.c. or 150 volt a.c.
-> give orange pink coloured light
-> luminous efficiency: 15-40 lumens per watt
-> power consumption 5 watt.
-> used as industrial lamps & night lamps.

20/04/2020

* High lumen output and low consumption fluorescent lamps
(CFL) Compact fluorescent lamp

-> A CFL produces the 1170 lumens uses only 20-21 watts.
-> a.k.a. energy saving light.
-> like fluorescent lamps, CFLs contains mercury, which complicates their disposal.
-> CFLs radiate a different light spectrum compared to incandescent lamps.

Main parts of CFL
2 parts
i) the gas-filled tube
ii) the magnetic or electronic ballet
1) An electrical current from the ballest flows through the gas (mercury vapour), causing it to emit ultraviolet light.
2) The ultra violet light then excites a phosphor coating on the inside of the tube.
3) This coating emits visible light.
4) electronic ballest are common.

Working
i) When a voltage is applied across the electrodes, the gas inside the tube gets ionized, conducts electricity and in the process generates ultra violet (UV) light.

20/04/2020

2) When the UV light hits the phosphor coating on the inside of the tube, the material glows to produce visible light.
3) When the lamp is switched on, the ballast produces a high voltage between the electrodes, which is necessary for initial ionization of gas in the tube.
4) The current and output voltage can be maintained usig a much lower voltage after once the lamp starts operating.
5) most of energy is converted into light.
6)

Types

spirals, a-shaped, globe, tubed, candle; posts, indoor reflectors, outdoor reflectors

Advantage
-> low energy consumption
-> less heat produces, higher life, pleasent light
->

20/04/2020

# Industrial drives

## * Drives

Systems employed for motion control are called drives.

-> A drive system is basically has a mechanical load, a transmission system and a prime mover.

Advantages of electric drives

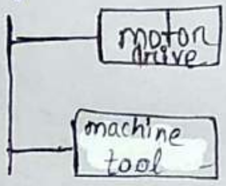
-> flexible control characteristics

-> starting and braking is easy and simple

## * Individual drive

Each machine tool has its own electric motor, which drives the machine through belt, chain, gearing or by direct coupling.

-> a.k.a. self contained drive.




## * Group Drive

The group drive system uses a high powered motor which drives an overhead shaft called the main shaft by means of chain or belt.

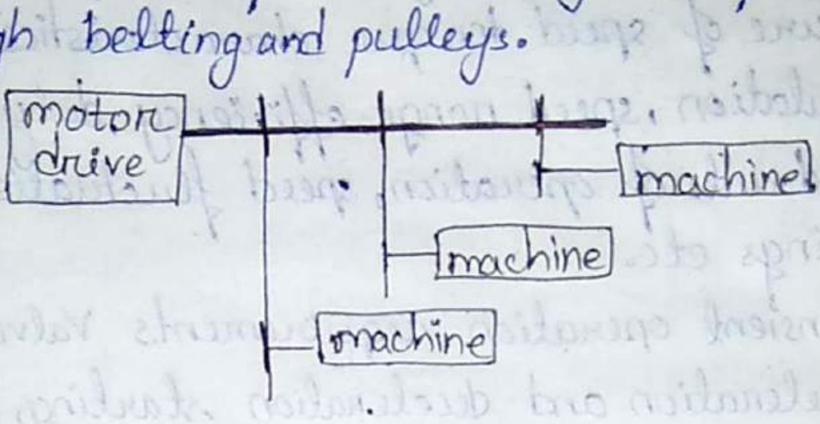
-> The main shaft runs across the workshop from one end to other ends.

-> The main shaft drives another shaft called

20/04/2020

counter shaft.

-> The counter shaft drives the group of machines through belting and pulleys.




| Individual drive | Group drive |
|---|---|
| -> It is suitable for small size workshop where machines may be moved frequently and machines are scattered over large area. | -> It is suitable for large and medium size workshop where machines are not scattered over large area. |
| -> Speed of a machine can be controlled separately. | -> Cone pulleys required to obtain a wide range of speed. |
| -> Machine shaft can be rotated in any direction. | -> Difficult to change the direction of main shaft. |
| -> Individual machine doesnot affect other machine when the fault of a motor occurs. | -> Failure of main shaft will stop the entire group of machines. |
| -> less power wasted if less machine working. | -> more power wasted if less machines working. |
| -> High initial capital investment. | -> less capital investment initially. |

21/04/2020

## * Choice of electrical drive

1. Steady state operating conditions requirements Nature of speed. torque characteristics, speed regulation, speed range, efficiency, duty cycle, quadrants of operation, speed fluctuations if any, ratings etc.
2. Transient operation requirements Valves of acceleration and deceleration starting, braking and reversing performance.
3. Requirements related to the type of source and its capacity, magnitude of voltage, voltage fluctuations, power factor, harmonics and their effect on other loads, ability to accept regenerative power.
4. Capital and running cost, maintenance needs life.
5. Space and weigh restriction if any.
6. Environment and location.
7. Reliability.

## * Characteristics of DC motors.

$T_a \propto I_a$ ; $N \propto \frac{E_b}{\phi}$

### i) Characteristics of DC series motor

a) Torque vs. armature current ($T_a$ - $I_a$)

$T_a \propto I_a$

In DC series motor field winding connected in series with armature.

i.e. $I_a = I_f$

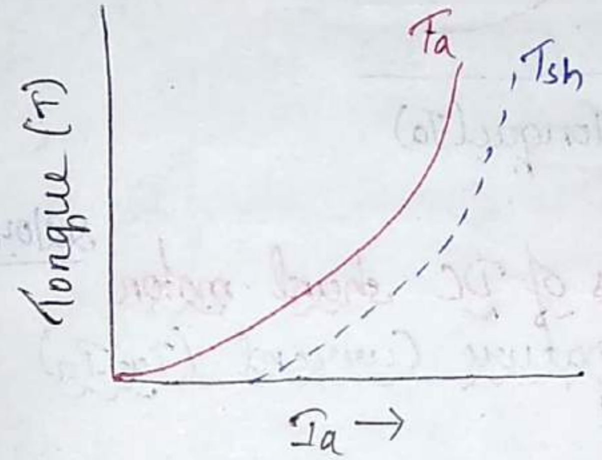
81/04/2020

∴ $\phi \propto I_a$ (before magnetic saturation)

$\Rightarrow T_a \propto I_a^2$

In DC series motor, torque increases as the square of armature current,

→ these motors are used where high starting torque is required.



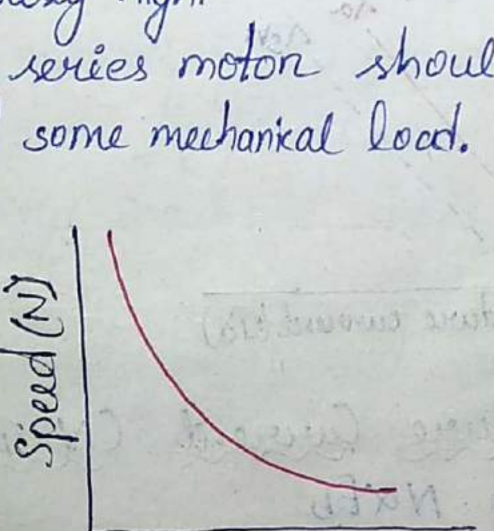

b) Speed vs. armature current (N-Ia)

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

∴

So when current is very small speed is dangerously high.

So a series motor should never start without some mechanical load.



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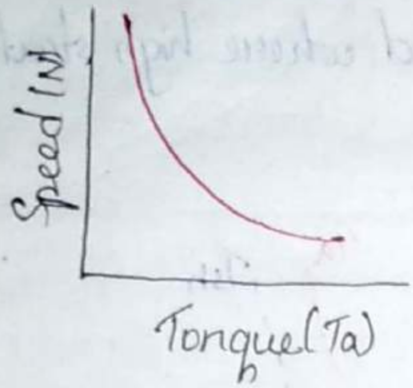
c) Speed vs. Torque ($N$-$T_a$)

a.k.a. mechanical characteristics.

when $N \uparrow$ ;

$\Rightarrow T \downarrow$




22/04/2020

2) Characteristics of DC shunt motor

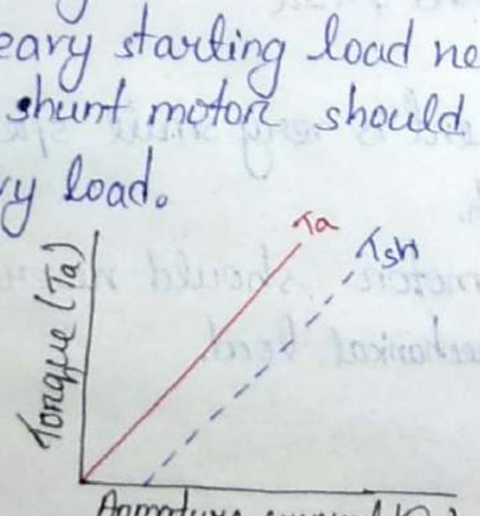
a) Torque vs. Armature Current ($T_a$-$I_a$)

$\phi$ constant

$T_a \propto I_a$

$T_a$-$I_a$ characteristics will be a straight line through origin.

- Since heavy starting load needs heavy starting current, shunt motor should never be started on a heavy load.




b) Speed vs. Armature Current ($N$-$I_a$)

$\phi$ constant so $N \propto E_b$

practically $\phi$ & $E_b$ decrease with increase in load. and the speed decreases slightly.

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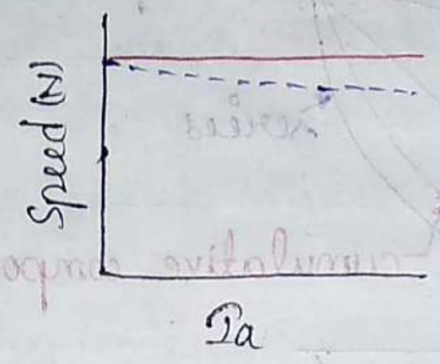
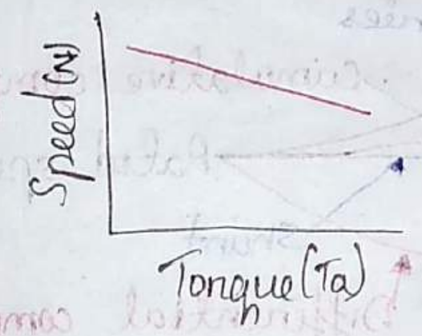
A shunt motor can be assumed as a constant speed motor.




c) Speed vs. Torque (N-Ta)




3) Characteristics of DC compound motor

1) Cumulative compound motor

If series and shunt windings are connected such that series flux is in direction as that of the shunt flux then the motor is said to be cumulatively compounded.

-> employed a flywheel where sudden and temporary loads are applied like in rolling mills.

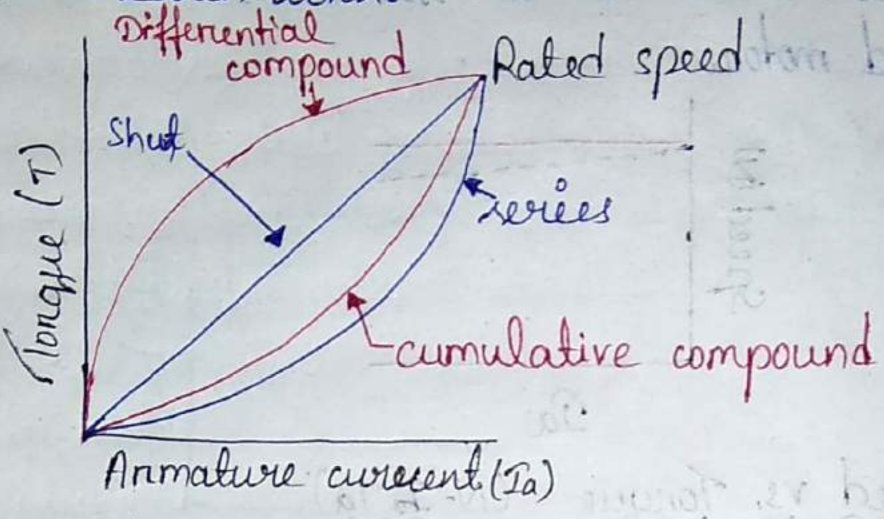
2) Differential compound motor

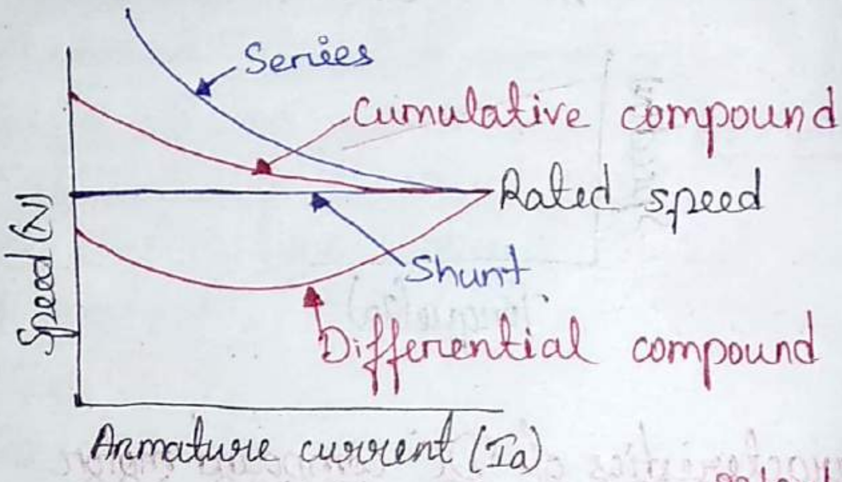
If series flux is in opposite direction to the shunt flux, the motor is said to be differentially compounded.

-> not commonly used, they have the applications

22/04/2020

in research work.

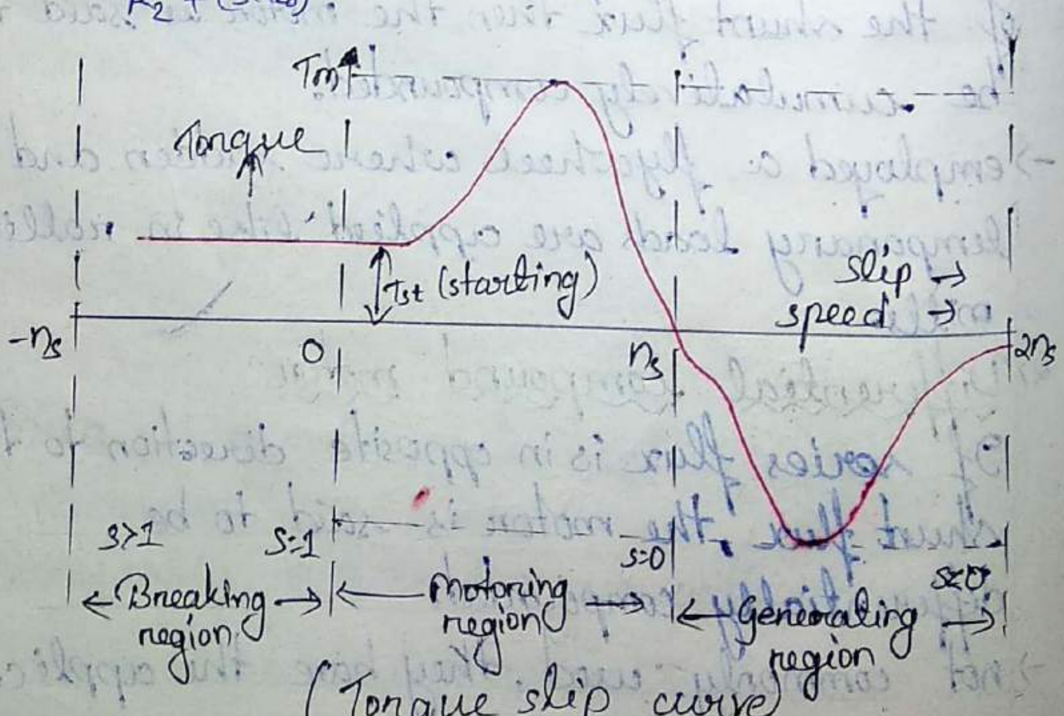



23/04/2020

## * Torque slip characteristics of 3ϕ IM.

$$T = \frac{K s R_2 E_{20}^2}{R_2^2 + (sX_{20})^2}$$




(Torque slip curve)

23/04/2020.

## Motoring mode

In this mode motor always runs below the synchronous speed.

- Torque ∝ slip ($T \propto S$)
- supply is given to stator side.

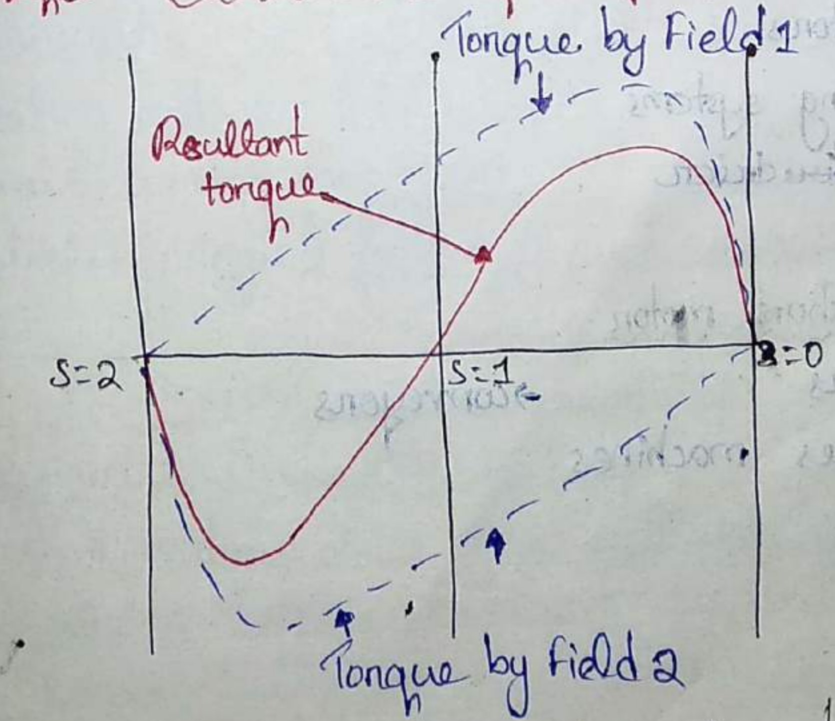
## Generating mode

- Here induction motor runs above synchronous speed.
- should be driven by a prime movert.

## Braking mode

polarity of voltage is changed so that motor rotates in reverse direction, and as a result the motor stop, i.e. called plugging.

## * Torque characteristics of single phase IM.




(Torque Slip characteristics)

23/04/2020

- at unity both forward and backward field devlops equal torque.
- forward speed increased, so forward slip decreases, forward torque increases, and the reverse torque will decrease, i.e. motor will start.

* Application of DC motor
as it has constant on low-speed torque, it is used for dynamic braking and reversing.

DC series motor
low, high, variable speed drives
- Electric traction
- cranes
- lifts
- Air compressor
- elevators.
- winching systems
- Hair drier

DC shunt motor
- wipers
- conveyors
- Lathes machines
- Drills
- lifts
- Fans
- shapers

23/04/2020

Separatedly excited DC motor
- washers
- Toys
- Automobiles as a starter motor
- Wheel chairs
- computer disc drives

Compound DC motor
- Presses
- Electric shovels
- Elevators
- Conveyors
- Rolling mills
- compressors

Brushless DC motor
- computer peripherals (disc drives, printers)
- Transport
- Heating and ventilation
- small cooling fans.
- vehicles ranging from aircraft to automobiles.

25/04/2020

* Application of Induction motor

Polyphase Induction motor
- wound rotor motors are suitable for loads requiring high starting torque and where a lower starting current is required.
- used for motors which require a gradual

23/04/2020

build up of torque.
-> used for loads that require speed control.
-> conveyers, cranes, pumps, elevators and compressors.

## Application of polyphase cage rotor IM

Class A motors
-> hv normal starting torque.
-> high starting current low operating slip
-> used for fans, blowers, centrifugal pumps.
-> efficiency is high at full load.
-> low resistance single cage rotor.

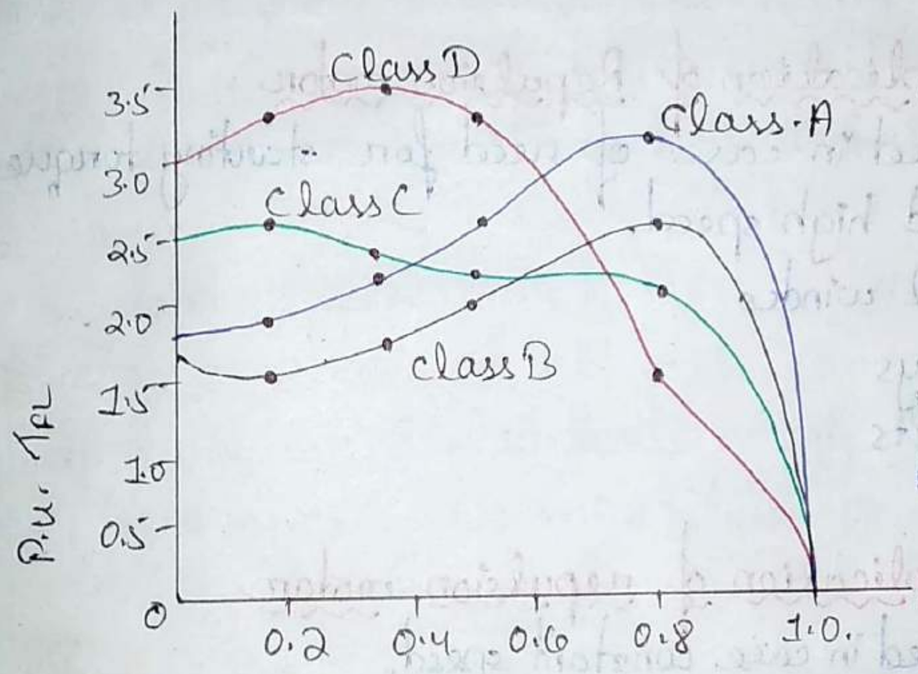
Class B motor
-> normal starting torque
-> low starting current, low operating slip
-> withstand high leakage reactance.
-> used in case full voltage starting.

Class C motor
-> high starting torque
-> low starting current
-> has higher motor resistance.
-> used for compressors, conveyers, reciprocating pumps, crushes.

Class D motors
-> highest starting torque as compared to others

23/04/2020

-> low starting current
-> high operating slip
-> uses => driving intermediate loads
punch presses
bulldozers
die stamping machine.




* Application of single phase Induction motor
-> fan, refrigerators, Air-conditioners, vaccum cleaners, washing machines, centrifugal pump, tool
-> used for low pressure but constant speed devices

* Application of Universal motor
-> purpose : speed control & high speed
-> portable drill machine
-> hail dryers, grinders, table fans.

-> blower, polishers and kitchen appliances

Application of single phase series motor
hair dryers, grinders, table-fans, blowers, polishers
-> speed control, and in case high speed.

Application of Repulsion motor
-> used in case of need for starting torque and high speed.
-> coil windes
-> toys
-> lifts

Application of repulsion motor
-> used in case constant speed.
-> applied in robot actuators.
-> ball mills, clocks
-> servomotors and timing machines

27/04/2020

# Electric Traction

-> By electric traction is meant locomotion in which the driving (or tractive) force is obtained from electric motors.

-> used in electric trains, tramcars, trolley buses and diesel-electric vehicles.

-> Traction system is of two types.

1) Non electric traction system
They do not involve the use of electrical energy.
ex: steam engine

2) Electric traction system
They involve use of electrical energy.
ex: battery-electric drive, diesel-electric drive.

## Ideal electric traction

i) Maximum tractive effort should be exerted at starting in order that a rapid acceleration may be attained.

ii) The equipment should be capable of overloads for short periods.

iii) The wear caused on the track should be minimum

iv) The locomotive or train unit should be self-contained and able to run on any route.

v) Braking should be possible without excessive wear on brake shoes and if possible the braking energy should be regenerated and returned to the supply.

27/04/2020

# * Advantages of Electric Traction

i) cheapness.

ii) Acceleration and Braking
these are smooth and rapid.

iii) Cleanliness
free from flue gases and smoke
so suitable for tubular railways and underground

iv) Maintenance cost
50% than that of steam traction system.

v) Starting time
It can be started without any loss of time whereas steam traction requires minimum 2 hours before a steam locomotive can be put into operation.

vi) High starting torque

vii) Braking
In electric traction, regenerative braking is used which feeds back about 40% of energy.

viii) Saving in high grade coal
Electric energy required for running electric locomotive is taken either from hydropower station or from a thermal power station which is run from low grade coal.

ix) Better co-efficient of adhesion

x) It has great passenger carrying capacity at higher speed as compared to steam locomotive.

xi) The fans and lights in train can be connected directly to the supply lines and there is no need for providing extra generators and batteries.

## Disadvantages of Electric traction.

i) Higher initial expenditure is involved in electric traction.
ii) Failure of supply is a problem to be faced in electric traction.
iii) The electrically operated vehicles have to move only on electrified track.
iv) For the achievement of electric braking and control, additional equipment is required.
v) When a.c. energy is utilized for traction then precautions are to be taken to prevent the distribution network to interfere with the adjacent telegraph and telephone lines.

## * Systems of Track Electrification

1) DC system - 600 V, 750 V, 1.5 kV, 3 kV
2) Single phase AC system - 15-25 kV, 25 and 50 Hz
3) 3ϕ AC system - (3k - 3.5k)V
4) composite system - involving conversion of 1ϕ AC into 3ϕ AC or DC.

1) DC system

dc traction only exist in bombay areas.
→ operating voltage about 600 volts for suburban railways and tram cars.

27/04/2020

-> For main line railways the operating voltage is from 1500 volts to 3000 volts.
-> The motor receive power from an over-head line with help of a pantograph and the railway steel track is the return conductor.
-> AC power received from substation is converted into dc power by using mercury arc rectifiers or rotary converters.
-> For suburban services the distance between the substations is 3 to 5 km; main line service it is about 40-50 km.

2) AC system

a) 1φ standard frequency system
-> a.k.a. composite system of traction.
-> employed in south-eastern and eastern railways.
-> single overhead wire supplied at 25kV 50c/s.
-> A voltage upto 132 kV is steped down to 25kV by the transformer mounted on the locomotive i.e. supplied to traction motors.
-> Driving force is obtained from DC series motor.

b) Single phase low frequency system
-> Single phase 15 kV, $16\frac{2}{3}$ c/s system is used in West Germany, Sweden, Australia for main line service.
-> A step down transformer is carried in the

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traction unit which steps down the voltage to 400V for the use of traction motors.

-> Series motor is employed for traction.

-> The voltage at the substation is stepped down and frequency is also converted by a motor-alternator set.

Disadvantage

A special low frequency power distribution network is required.

c) Three phase ac system

-> employs 3ϕ slip ring induction motors.

-> The voltage and frequency at which the motor made to operate are about 3600V and $16\frac{2}{3}$ c/s.

Advantage

regenerative breaking is obtained immediately as the speed exceeds synchronous speed.

Disadvantage

use of two overhead conductors and hence it is out of use.

d) Single phase to three phase system

Advantage

low cost distribution and the robust construction of induction motor.

-> Voltage used for distribution network is 16,000V at 50 c/s.

27/04/2020

-> 1ϕ high voltage ac system is employed for distribution network.

Methods of supply power to Railway trains-

1) Overhead system

-> adopted when distribution network is fed at high voltage.

-> current is collected from overhead network with help of collector.

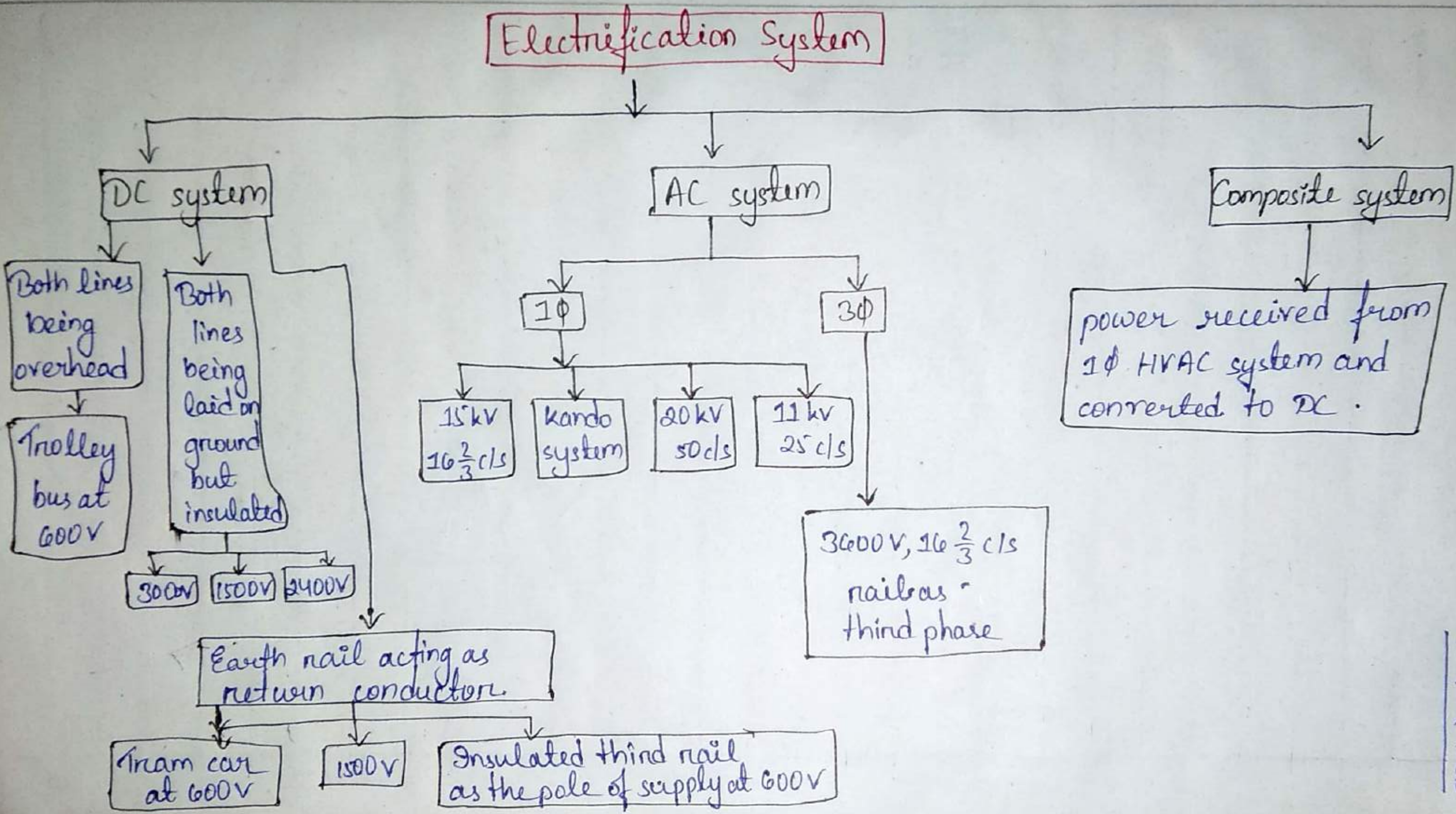
-> rail track is used as return path of conductor.

2) Conductor rail system

-> adopted for heavy electric traction.

-> current is collected with help of collector shoe.

-> The use of this system is restricted upto 0.8 kV only.


Electrification System
DC system
AC system
Composite system
Both lines being overhead
Trolley bus at 600V
Both lines being laid on ground but insulated
300V
1500V
2400V
Earth rail acting as return conductor.
Tram car at 600V
1500V
Insulated third rail as the pole of supply at 600V
1ϕ
3ϕ
15kV 16 2/3 c/s
Kando system
20kV 50c/s
11kV 25c/s
3600V, 16 2/3 c/s rail as third phase
power received from 1ϕ HVAC system and converted to DC.

27/04/2020

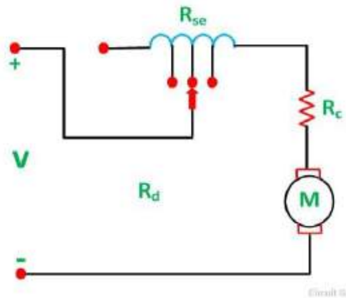
# SPEED CONTROL METHOD OF TRACTION MOTORS

## Tapped Field Control

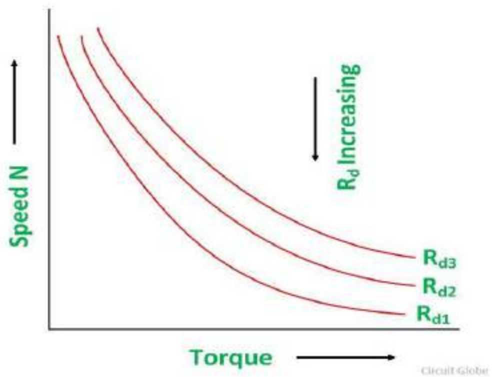
The second method used in a series motor for the variation in field current is by tapped field control.

$N = 60A\ E / PZØ$

The connection diagram is shown below.

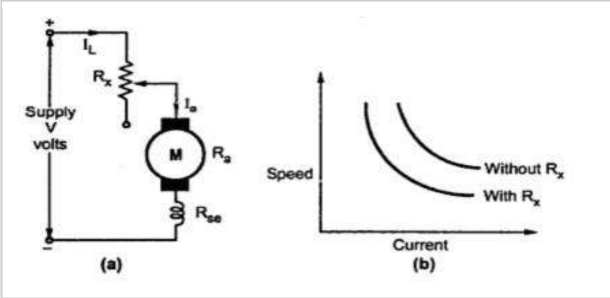



Here the ampere turns are varied by varying the number of field turns. This type of arrangement is used in an electric traction system. The speed of the motor is controlled by the variation of the field flux. The speed-torque characteristic of a series motor is shown below.




## Rheostatic Control

In this method, a variable resistance ($R_x$) is inserted in series with the motor circuit. As this resistance is inserted, the voltage drop across this resistance ($I_a R_x$) occurs. This reduces the voltage across the armature. As speed is directly proportional to the voltage across the armature, the speed reduces. The arrangement is shown in the Fig 1(a). As entire current passes through $R_x$, there is large power loss. The speed-armature current characteristics with changes in $R_x$ are shown in the Fig 1(b).




## Series Parallel Control:

Here two identical motors are coupled together mechanically to a common load. Two speeds at constant torque are possible in this method one by connecting the motors armatures in series and the other by connecting them in parallel as shown in Fig. 7.60. When connected in series, the terminal voltage across each motor is V/2 whereas when they are connected in parallel it is *V.* Thus armature control of speed is achieved.

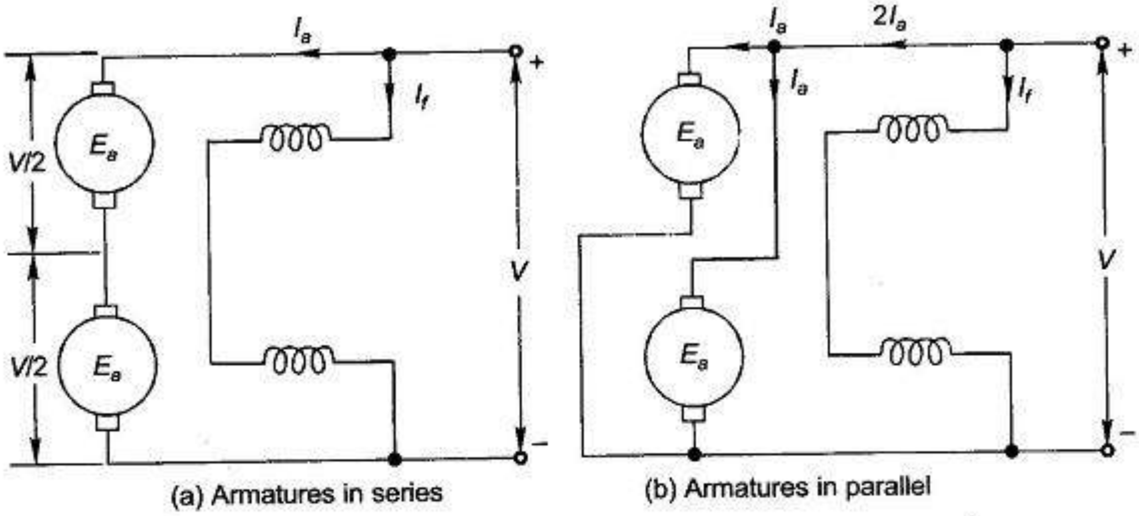



**Fig. 7.60** *Series-parallel speed control (shunt-motors); case of constant load torque is illustrated*

Figure 7.61 (a) and (b) gives the connections for series-parallel speed control of two identical series motors.

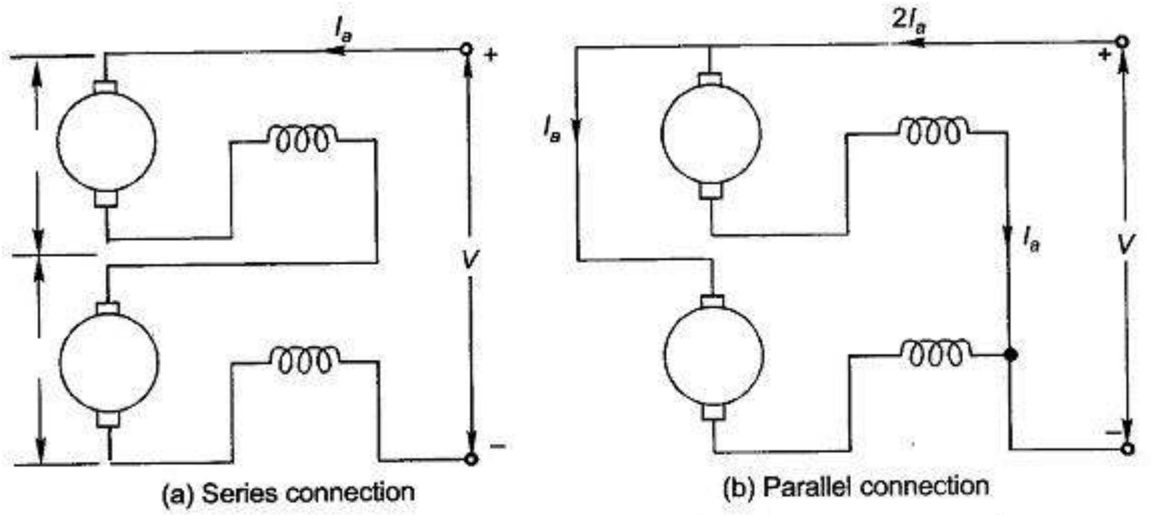



**Fig. 7.61** *Series-parallel speed control of series motors; case of constant load torque is illustrated*

This method is superior to the rheostatic control insofar as efficiency is concerned. It is, however, limited to two speed steps. The method is commonly employed for speed control of series traction motors.

**Metadyne Control of Traction Motor:**

The metadyne control system is based on constant current system of speed control. In resistance control or series- parallel control a great deal of energy is dissipated in the starting resistance and jerks are experienced when the controller of the starter moves from one position to another position. In metadyne control, current throughout the accelerating period remains constant, therefore, uniform tractive effort is developed and very smooth control, without causing any wastage of energy in the starting resistance, is achieved.

The essential part of the metadyne control is metadyne converter. The metadyne converter is a cross-field machine which behaves like a transformer on direct current. The transformation ratio of a metadyne can be varied continuously. It takes power at constant voltage and variable current and delivers the same at constant current and varying voltage.

The metadyne converter essentially consists, in its simplest form, of a 2 pole dc armature with two pairs of brushes and a four pole field magnet, as shown in Fig. 13.16. One pair of the brushes (say A and C) are connected across constant voltage dc supply while the other pair (B and D) are connected to the load (normally a dc series motor).

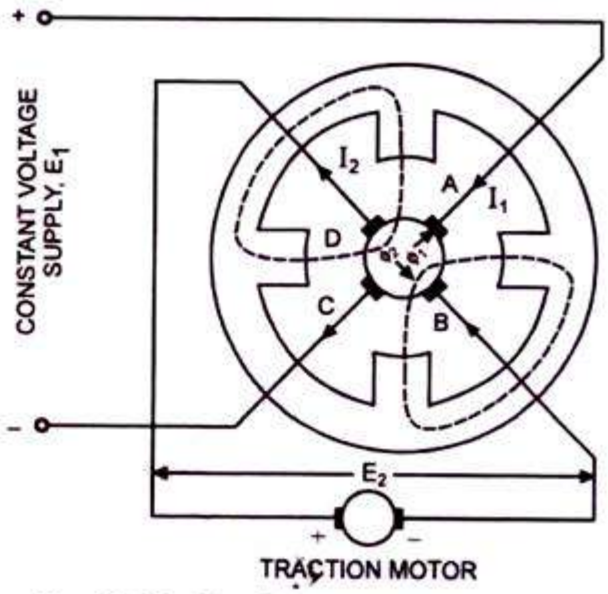



**Fig. 13.16.** ***Simple Metadyne Converter***

For understanding the working of a metadyne converter consider first an ordinary dc machine with two poles and two brushes supplied with a current flowing in the direction shown in Fig. 13.17(a). It will cause armature current distribution, as illustrated in the figure with corresponding cross flux, mainly confined to the poles.

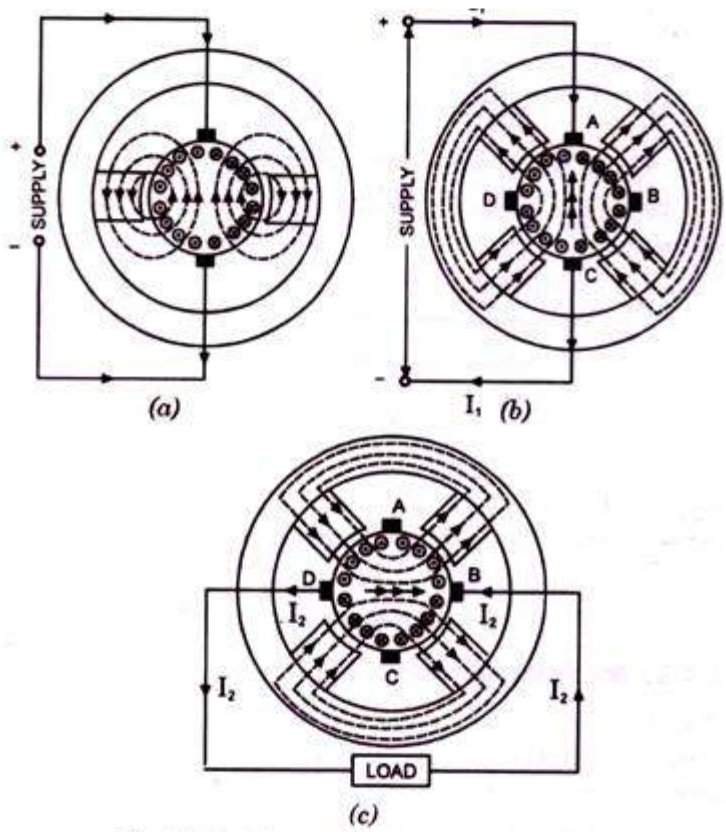



**Fig. 13.17.** ***Illustration of Metadyne Principle***

Now consider that metadyne converter (a dc machine with two pairs of brushes and two pairs of poles) is running at constant speed and drawing a current I, from the dc supply main, which flows through the armature conductors via the brushes A and C, as shown in Fig. 13.17 (b). An armature reaction flux $\varphi_1$ , set up in usual way is provided with a fairly low reluctance path through the yoke by the four poles, as shown in the figure. Due to rotation of armature conductors in this primary flux, and emf $E_2 = KI_1$ is set up between the brushes B and D. When these brushes B and D are connected to a load, a current $I_2$ flows through the load. The load current $I_2$ sets up another flux $\varphi_2$ known as secondary flux, at the right angles to the first, the distribution is shown in Fig. 13.17 (c). This secondary flux $\varphi_2$ causes an emf, $E_1 = KI_0$ between brushes A and C opposing the applied voltage. As the applied voltage is constant, the resistance drop is negligible so the back emf $E_1$ opposing applied voltage and the current $I_2$ producing $E_1$ are also constant.

Since input = $E_1I_1 = KI_2I_1 = KI_2 \times E_2/K = E_2I_2$ = output, therefore, power required to drive the metadyne is very small being equal to the running losses of the machine.

This simple metadyne converter transforms the constant voltage supply into a constant current variable voltage supply to feed the load. The arrangement, therefore, is quite suitable for starting dc traction motors. With this arrangement the load current $I_2$ and supply voltage V remain constant and as the load increases on account of building of back emf in dc traction motor $E_2$ and $I_1$ increases to meet with the increased load.

The metadyne described above has no winding on the poles and is capable of delivering only a single value of constant current but for supplying dc traction motors, after the motor has gained speed, the load current $I_2$ has to be reduced to the running value. For this purpose the field magnet poles are provided with variator and regulator windings, as shown in Fig. 13.18.

The variator winding sets up a flux in -the same direction as that set up by the load current $I_2$. Total flux $\varphi_2$ required in this axis being constant in order to produce a back emf $E_1$ equal to the constant supply voltage, therefore if some of this flux is set up by a separate winding, known as variator winding, the load current $I_2$ will decrease and can be of a smaller constant value. Similarly the load current can be increased by causing the current to flow in the variator winding in the opposite direction.

If the output current $I_2$ is, say, reduced in this way, the voltage remaining the constant, the total output will be reduced but input will remain the same and therefore, the set will speed up. In order to keep the speed of the metadyne converter constant, an additional winding known as regulator winding is provided. By adjusting the current in the regulator winding, the input current can be varied and therefore, input power can be adjusted equal to output power, the speed of the converter remaining the same.

The regulator winding is supplied from a small dc shunt generator mounted on the shaft of the metadyne. Any tendency towards a change in speed of the metadyne will cause corresponding change in the emf set up by the shunt machine and as it acts in the opposite direction of the supply voltage, so corresponding change in the regulator winding current will result in.

The variator winding is supplied excitation from an exciter mounted on the same shaft, as shown in Fig. 13.18.

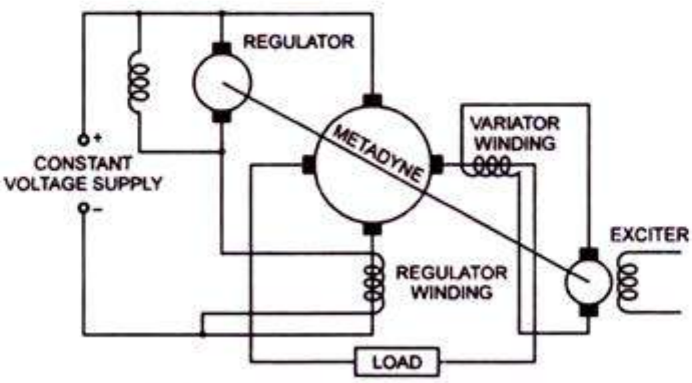


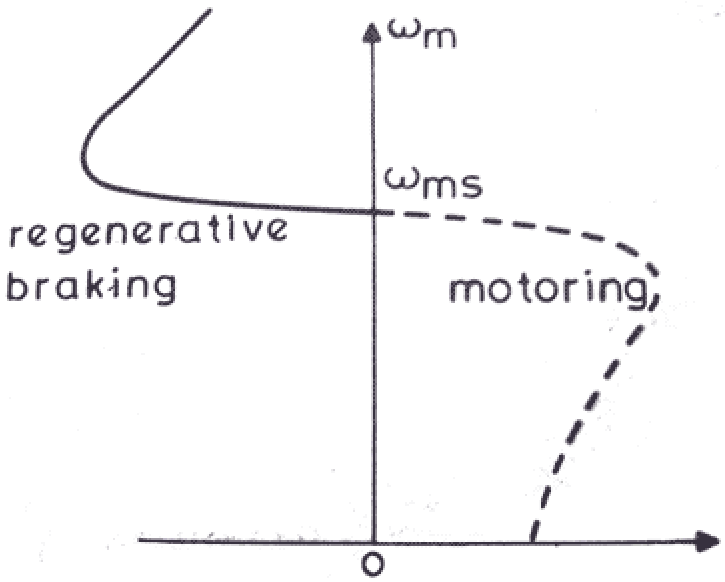

**Fig. 13.18.** ***Metadyne Control System***

With metadyne converter, regenerative braking can be accomplished very easily by reversing the field of the traction motor. This causes the reversal of direction of induced emf $E_2$ which in turn will change the direction of current $I_1$. Thus current $I_1$ can be supplied back to the supply source. By controlling the magnitude of reversed excitation of traction motors supplied by metadyne, the magnitude of regenerative braking can be regulated.

The metadyne is employed whenever control of dc motors is required. The control provided by the metadyne is smooth and does not require any switching. Thus switchgear and arcing are avoided. In some cases it is cheaper than the Ward Leonard system in initial cost. In traction it provides smooth acceleration without skill on the part of driver and regenerative braking down to very slow speeds. The savings due to these items may easily counterbalance the additional cost of the more complicated equipment required and its additional maintenance cost. It is already being employed in the underground railway.

# Regenerative Braking of Induction Motor

We know the power (input) of an induction motor is given as.
$P_{in} = 3VI_s\cos\varphi_s$




Regenerative braking

Here, $\varphi_s$ the phase angle between stator phase voltage V and the stator phase current $I_s$. Now, for motoring operation $\varphi_s < 90^o$ and for braking operation $\varphi_s > 90^o$. When the speed of the motor is more than the synchronous speed, relative speed between the motor conductors and air gap rotating field reverses, as a result the phase angle because greater than $90^o$ and the power flow reverse and thus regenerative braking takes place. The nature of the speed torque curves are shown in the figure beside. It the source frequency is fixed then the **regenerative braking of induction motor** can only take place if the speed of the motor is greater than synchronous speed, but with a variable frequency source regenerative braking of induction motor can occur for speeds lower than synchronous speed. The main advantage of this kind of braking can be said that the generated power is use fully employed and the main disadvantage of this type of braking is that for fixed frequency sources, braking cannot happen below synchronous speeds.

## Regenerative Braking with DC Series Motors:

The dc series motors cannot be used for regenerative braking in an ordinary way. Since the reversal of armature current necessary to produce regeneration would cause a reversal of field, therefore, series field connections must be reversed. But even if the field connections are reversed at the exact moment, this method would still be useless. Because at the instant of reversal, the emf induced in the motor will be small, so current will flow through the field in wrong direction, which will reverse the field and cause the motor emf to help the supply voltage. This will result in short circuit of supply. Due to these complications this method is not used for common industrial purposes. Regenerative braking is, however, used with series motors for traction either by modification of windings or by supplying the machines with separate excitation.

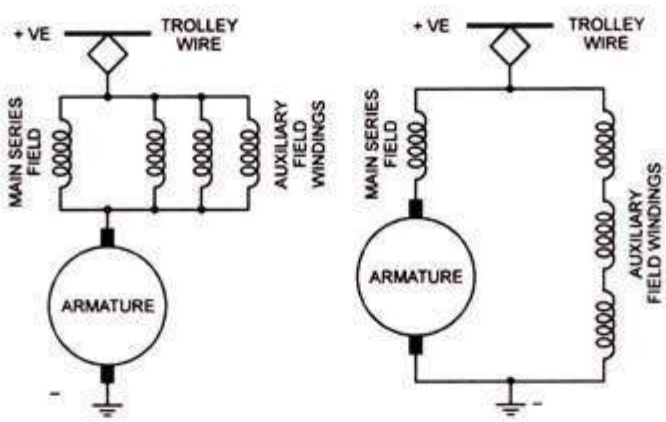



**Fig. 1.99.** ***French Method of Regenerative Braking***

One method of obtaining regenerative braking with series motors is the French method. If there is a single series motor as in case of a trolley buses, tramways, it is provided with a main series field winding and auxiliary field windings connected in parallel with the main series field winding as shown in Fig. 1.99 (a).

During regeneration (braking period) the auxiliary field windings are put in series with each other and are switched across the supply, as shown in Fig. 1.99 (b). The machine acts as a compound generator slightly differentially compounded. Such an arrangement is quite stable.

Any change in line voltage causes a change in excitation which produces a corresponding change in the induced emf of the machine so that inherent compensation is provided. For example, if the line voltage increases beyond the emf of the generator the increased voltage across the generator's field will send a large exciting current through it causing the emf of the generator to rise. The reversal of this will happen when the line voltage decreases.

If there are several motors, we do not require any auxiliary winding. During normal running the motors are connected in parallel with the field winding connected in series with their respective armatures, as shown in Fig. 1.100(a).

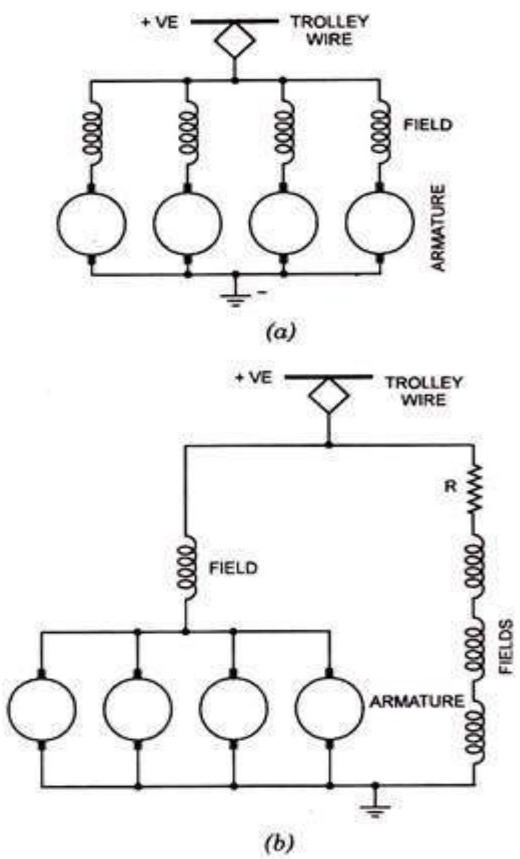



**Fig. 1.100**

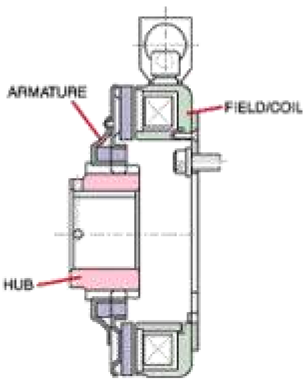
But during regeneration the motors are connected, as shown in Fig. 1.100 (b), i.e., all armatures are connected in parallel and series field windings of all motors but one are connected in series and placed across the supply. Suitable resistance is also connected in series with the series field windings, as illustrated in the Fig. 1.100 (b).

**MAGNETIC BREAKING**

**Electromagnetic brakes** (also called **electro-mechanical brakes** or **EM brakes**) slow or stop motion using electromagnetic force to apply mechanical resistance (friction).

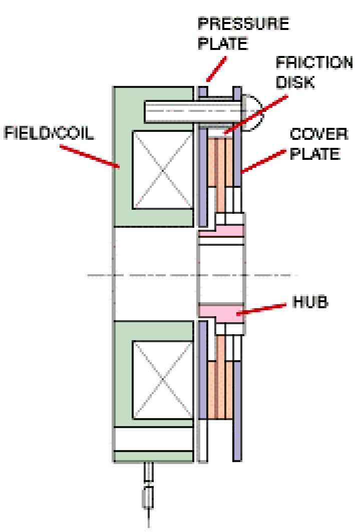
## Types of magnetic breaking

## Single face brake




A friction-plate brake uses a single plate friction surface to engage the input and output members of the clutch. Single face electromagnetic brakes make up approximately 80% of all of the power applied brake applications.

## Power off brake




Power off brakes stop or hold a load when electrical power is either accidentally lost or intentionally disconnected. In the past, some companies have referred to these as "fail safe" brakes. These brakes are typically used on or near an electric motor. There are 2 main types of holding brakes. The first is spring applied brakes. The second is permanent magnet brakes.

**Spring type -** When no electricity is applied to the brake, a spring pushes against a pressure plate, squeezing the friction disk between the inner pressure plate and the outer cover plate. This frictional clamping force is transferred to the hub, which is mounted to a shaft.

**Permanent magnet type** – A permanent magnet holding brake looks very similar to a standard power applied electromagnetic brake. Instead of squeezing a friction disk, via springs, it uses permanent magnets to attract a single face armature. When the brake is engaged, the permanent magnets create magnetic lines of flux, which can in turn attract the armature to the brake housing. To disengage the brake, power is applied to the coil which sets up an alternate magnetic field that cancels out the magnetic flux of the permanent magnets.

## Breaking with 1-ϕ Series Motor :-

In these motor, the breaking can be done by Rheostatic breaking, plugging and regenrative breaking.

→ In the rheostatic breaking the armature is disconnected from the ac supply and connected as an ac series generator. For this it is necessary that the to total resistance in the motor circuit should be less than the critical resistance, so that the generated generator may self-excite. Also in order that the flux may bulit up, the connection of the armature w.r.t. the field have to be reversed.

Normally the starting resistance provided for the breaking purposes. Since the torque proportional to the product of flux and current, we series motor electric breaking torque $= k\phi I$

$EBT = k\phi\left(\frac{E}{R}\right)$. where E is induced emf in the armature

EBT- Electrical breaking torque

R- Total Resistance in motor circuit.