IIIrd - Year - VIth SEM

Utilisation of Electrical Energy - [20EEE362C]

UNIT - 2

ILLUMINATION

* **Definition's** :—

1. **Illumination [E]** :— Illumination of a surface is defined as the luminous flux received by the surface per unit area.

It is represented by the symbol 'E'.

$$\boxed{\text{Illumination } E = \frac{\text{flux}}{\text{area}}} \text{ lux}$$

2. **Flux (or) Luminous flux (ϕ or F)** :—

It may be defined as "the rate of energy radiated in the form of light wave by a luminous body". It is represented by ϕ or F

$$\boxed{\text{Luminous flux, } F = \frac{\text{radiant Energy}}{\text{time}}} \text{ lumen}$$

3. **Plane Angle (θ)** :— A plane angle is subtended at a point in a plane by two straight converging lines.

It is usually represented by the 'θ'

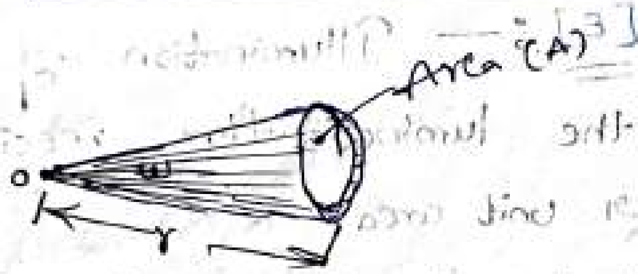
$$\boxed{\therefore \text{plane angle } \theta = \frac{\text{Arc}}{\text{Radius}}} \text{ radian}$$

4. Solid Angle (ω):—

A solid angle is subtended at a point in spa by an area and is the angle enclosed in the volume formed by an infinite number lin lying on the surface of the volume and m at the point.

It is represented by letter 'ω'

$$\therefore \boxed{\text{Solid angle } \omega = \frac{\text{Area}}{(\text{radius})^2}} \text{ steradian}$$



5. Candle Power (C.P):—

The Candle Power of a source is defined as the number of lumens emitted by that source in a unit solid angle in a given direction

$$\boxed{C.P = \frac{\text{lumens}}{\omega} = \frac{F}{\omega}} \text{ Candela}$$

6. Luminous Intensity [I]:—

It is the luminous flux per unit solid angle in a given direction.

It is represented by I

$$\boxed{\text{L. Intensity } I = \frac{F}{\omega}} \text{ Candela}$$

7. **Brightness or Luminance [B or L] :—**

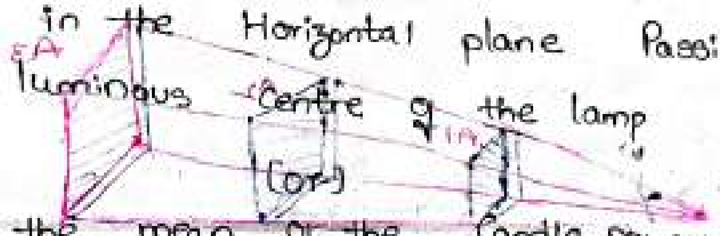
Brightness or luminance may be defined as the luminous intensity of the lamp per unit projected area of either light source or reflecting surface.

It is represented by B or L and is measured in Candela/m²

$$\boxed{B \text{ or } L = \frac{I}{A}} \; cd/m^2$$

8. **Mean Horizontal Candle Power [M.H.C.P] :—**

The M.H.C.P of a lamp is the average candle power in the horizontal plane passing through the luminous centre of the lamp



(or)

It is the mean of the candle powers in all directions in the horizontal plane containing the source of light.

9. **Mean Spherical Candle Power [M.S.C.P] :—**

M.S.C.P may be defined as the mean of the candle powers in all directions and in all planes from the source of light.

$$M.S.C.P = \frac{\text{Total flux}}{4\pi}$$

10. **Mean $\overset{emi}{\text{Horizontal}}$ Spherical Candle power [M.H.S.C.P] :—**

It is defined as the mean of the candle power in all directions below the horizontal

$$M.H.S.C.P = \frac{\text{flux emitted in hemi-sphere}}{2\pi}$$

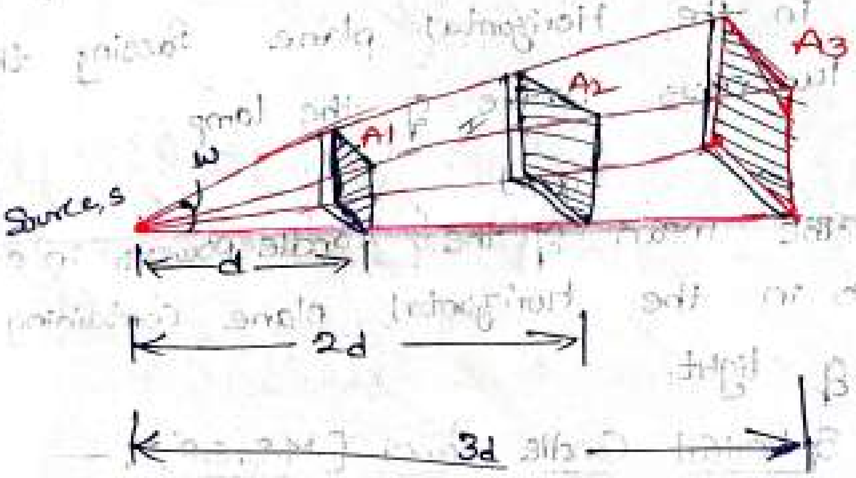
* Laws of Illumination :—

There are two laws of illumination

1. Inverse Square law
2. Lambert's Cosine law.

* Inverse Square law :—

It States that "the illumination of a surface is inversely Proportional to the Square of the distance between the surface and light source provided the light source is a point Source



Let

S = a point Source

A_1, A_2, A_3 = Three parallel Surface area's (m^2)

d, 2d, 3d = distance of A_1, A_2, A_3 from point Source (m)

ω = Solid angle (sr)

I = luminous intensity (lm/sr)

UNIT-II

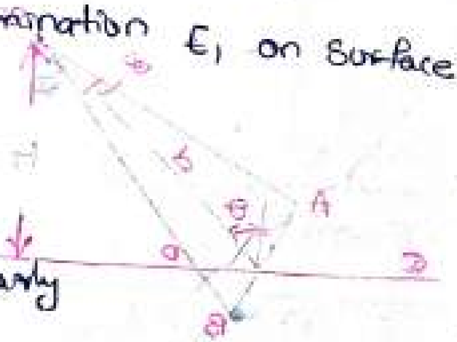
ectric Heating

For area A_1 solid angle $\omega = \frac{A_1}{d^2}$

flux ϕ_1 on area A_1 = luminous intensity × solid angle

$$= I \times \omega = I \times \frac{A_1}{d^2} = \frac{IA_1}{d^2}$$

Illumination E_1 on surface A_1 = $\frac{\text{flux } \phi}{\text{area } A_1} = \frac{IA_1}{d^2} \times \frac{1}{A_1}$



A_1 (on) $\boxed{E_1 = \frac{I}{d^2}}$ lux

Similarly

Illumination E_2 on $A_2 = \frac{I}{(2d)^2}$ lux

Illumination E_3 on $A_3 = \frac{I}{(3d)^2}$ lux and so on

$$\frac{E_1}{E_2} = \frac{(2d)^2}{(d)^2}$$

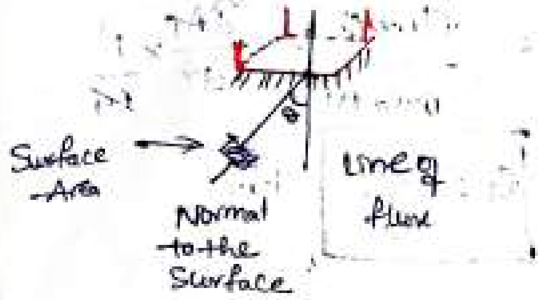
(or)

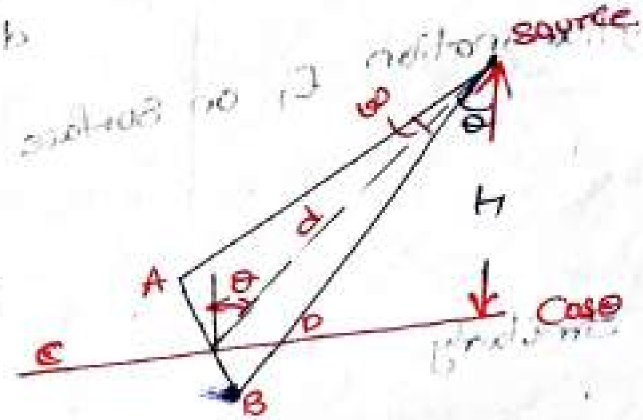
$$E_1 : E_2 : E_3 :: \frac{I}{d^2} : \frac{I}{(2d)^2} : \frac{I}{(3d)^2}.$$

——— ∝ ———

* Lambert's Cosine law :—

It State that "the illumination 'E' at any Poin of a Surface is directly Proportional to the Cosine of angle between the normal at that Point and line of flux".





Let AB = Surface area normal to the Source or inclined at θ to the vertical axis

$= CD \cos\theta$

CD = normal to the vertical axis and inclined at θ to the Source

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

d = distance between the Source and surface

H = height of the Source from Surface (m)

I = Luminous intensity (lm/sd)

ω = Solid Angle

lumen / Steradian or Candela

Illumination on Surface AB = $\frac{flux}{Area}$

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

Illumination on Surface CD = $\frac{flux}{area\ CD} = \frac{I}{d^2} \times \cos\theta$

$= \frac{flux}{(area\ AB/\cos\theta)}$ · I i.e., $$\boxed{E_{CD} = \frac{I}{d^2} \times \cos\theta}$$

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

(or) $$d = \frac{H}{\cos\theta}$$

Substituting 'd' value in above Equation

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

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

*** Cosine Cube ($\cos^3\theta$) law :—** It State that: "the illumination at any Point on a Surface is dependent on the Cube of Cosine of the angle between line of flux and normal at that point".

Important Definitions:—

*** Utilisation factor :—** It may be defined as "the ratio of total lumens received on the working plane to the total lumens Emitted by a light Source".

∴ Utilisation factor (or) Co-Efficient of utilisation $= \dfrac{\text{lumens received on the working plane}}{\text{lumens Emitted by a light source.}}$

factors affecting the utilisation factor:

⇒ Types of light fitting ie, direct, In-direct

⇒ Colour and surface of the walls and ceiling

⇒ Mounting height of the lamp.

⇒ U.F for direct fittings lies in b/w 0.4 and 0.6.
Indirect fittings lies in b/w 0.1 to 0.35

* Depreciation (or) Maintenance factor:

It may be defined as " the ratio of illumination under normal working condition to the illumination when every thing is clean or new.

$$\text{ie, Depreciation factor} = \frac{\text{Illumination under normal working condition}}{\text{Illumination when every thing is clean}}$$

⇒ Its value will be around 0.8.

⇒ this is due to the accumulation of dirt and dust on the lamp. frequent cleaning of lamp will improves the depreciation of maintenance factor.

D.factor some times also called afw (>1)

$$= \frac{\text{Illumination when Everything is clean}}{\text{Illumination under normal working condition}}$$

Reflection factor (or) Reflection ratio (or) Coefficient of reflection :—

It may be defined as " the ratio of luminous flux leaving the surface to the luminous flux incident on it."

ie, Reflection factor = $\frac{\text{Reflected light (lm)}}{\text{Incident light (lm)}}$

* Reduction factor (or) Spherical Reduction factor :—

It may be defined as " the ratio of mean Spherical Candle power of a source to the mean horizontal Candle power on

Reduction factor = $\frac{M.S.C.P.}{M.H.C.P}$

* Absorption factor :—

When the Atmosphere is full of fog (or) snow (or) Smoke, it absorbs some of the light Energy.

Hence absorption factor may be defined as "the ratio of net lumens available on the working plane after absorption to the total lumens Emitted by the lamp.

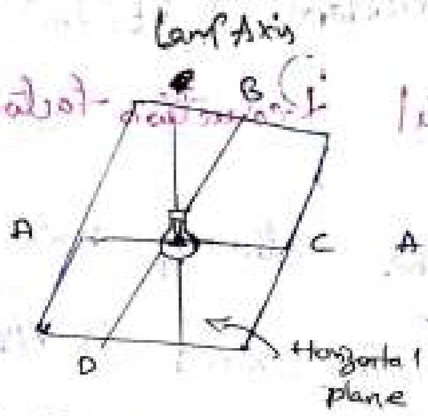
Absorption factor = $\frac{\text{Net lumens on working Surface after absorpt.}}{\text{Total lumens Emitted by the lamp}}$

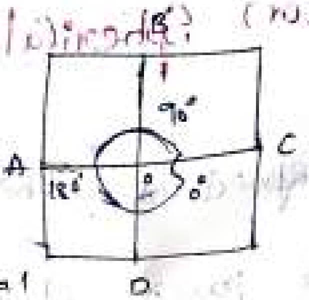
* **Polar Curves:** — [A Graph representing the light distrib... a lamp in a horizontal (or) vertical plane]

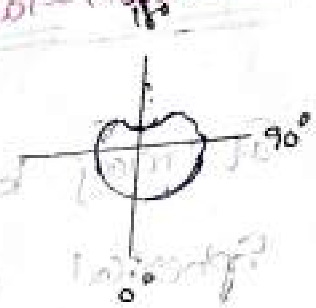
⇒ In most of the practical types of lamps or light, the luminous intensity or Candle power is not uniform in all directions.

⇒ This is due to its unsymmetrical shape and de...

⇒ It is essential to know Exactly how the light is distributed and is usually given in the form of Polar Curve.







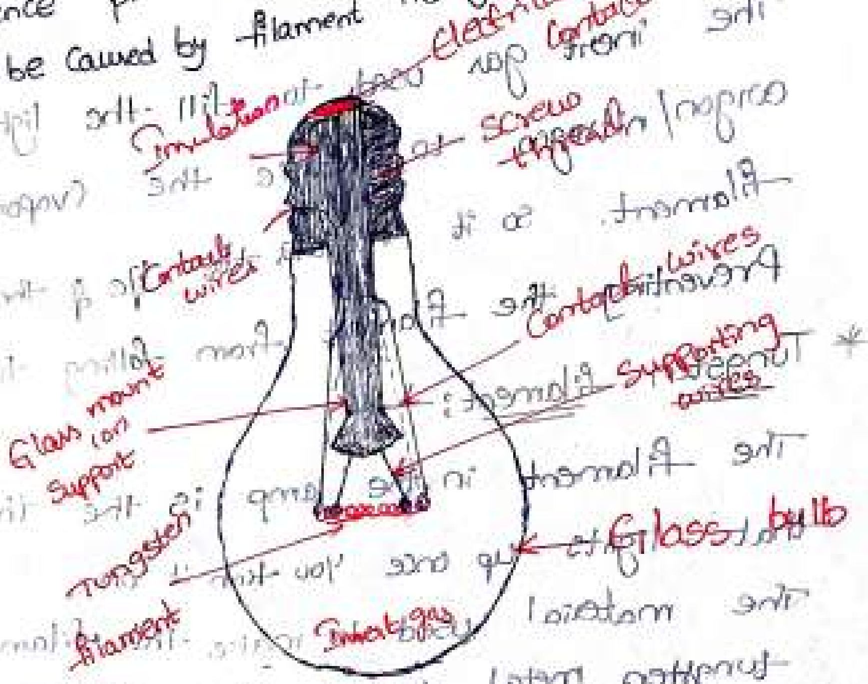
⇒ Shows an incandescent lamp. If the luminous intensity is measured in a horizontal plane about a vertical axis, a curve is plotted between luminous intensity and the angular Position.

⇒ The drop in luminous intensity along OC or at 0° of horizontal polar curve is due to the break in the filament ring where the current enters and leaves.

⇒ If the luminous intensity is measured in a Vertical plane at various angles a polar curve in the vertical plane is obtained as shown in fig.

⇒ The drop or depression in luminous intensity at 180° of vertical polar curve is due to the position of lamp holder.

Incandescent lamp :— The Incandescent lamp is an Electric light Source that works through the incande scence phenomenon that means the light Emission Can be Caused by filament heating.



* Construction :—

=> The Construction of an incandescent lamp Can be done by different parts like

- → Glass bulb
- → Inert gas
- → Tungsten filament
- → Contact wire to foot
- → Contact wire to base
- → Support wires
- → Glass mount (or) support
- → Base/Contact wire
- → Screw threads
- → Insulation
- → Electrical foot Contact

* Glass bulb :—

An incandescent lamp has a glass Enclosure including a tungten filament.

* Inert gas :—

The inert gas used to fill the light bulb is argon/nitrogen to reduce the evaporation of the filament. so it increase the life of the lamp by Preventing the filament from falling too quickly.

* Tungsten filament :—

The filament in the lamp is the thread or wire that lights up once you turn it on. The material used to make the filament is tungsten metal because the melting Point of this is very high and also heat resistant.

* Contact wire :—

The base of the bulb with two Connections is Called Contact wires which provide Electrical Connection towards the filament.

* Support wires :—

Support wires are Small wires which are Connected to the Stem to give support to the filament of the lamp.

* Glass Mount (or) Support :—

InCandescent light bulbs include a glass mount that is Connected to the base of the lamp which Permits the Electrical Contacts to run throughout the envelope without air (or) gas leaks.

thread :—

Most of the lamps Screw into a Socket. In household bulbs, a medium Screw base is Used which is Called an Edison Screw.

* Insulation :—

The base of the lamp is made of brass originally. Nowadays, aluminium is used at the outside of the lamp & glass is used to protect the inner base So that a Stonger base Can be formed.

* Electrical foot Contact :—

At the base of a lamp (or) light bulb is known as Electrical foot Contacts which are Coated with a material to protect the Electricity. These two Contacts will help in Connecting with an Electricity Source

* Working :—

=> An incadescent lamp mainly works on the incandescence Principle which means the light Can be generated through heat

=> In this type of lamp the Current is Supplied throughout a thin metal filament.

=> once the filament is heated then it glows to generate light

=> Generally these lamps use a tungsten filament due to their high melting Point.

=> A glass Enclosure avoids oxygen with in the air from reaching the filament otherwise the filament gets over head & oxidized with in Seconds

⇒ This incandercent lamp works quite well in gen
light.

⇒ So it suitable for a wide range of Applications

*Advantages:-

1. These lamps are not costly
2. ~~[illegible]~~ Light output is High
3. Manufacturing cost is less.
4. It turns on immediately
5. In the winter seasons, these lights are very helpful in increasing the room temperature.

* Disadvantage

1. It is not Energy Efficient
2. The lamp life time is low as compared to other bulbs
3. It is very delicate, so we need to handle it very carefully.
4. Not suitable for large areas.

*Application :-

⇒ These lamps are normally used in table lamps, desk lamps, accent lighting etc.

⇒ These lamps are widely used in Commercial & Household lighting purpose.

to the sodium Vapou

Electric discharge lamps :-

The production of light by these lamps is base on the phenomenon of Excitation and ionisation in a gas (or) vapour

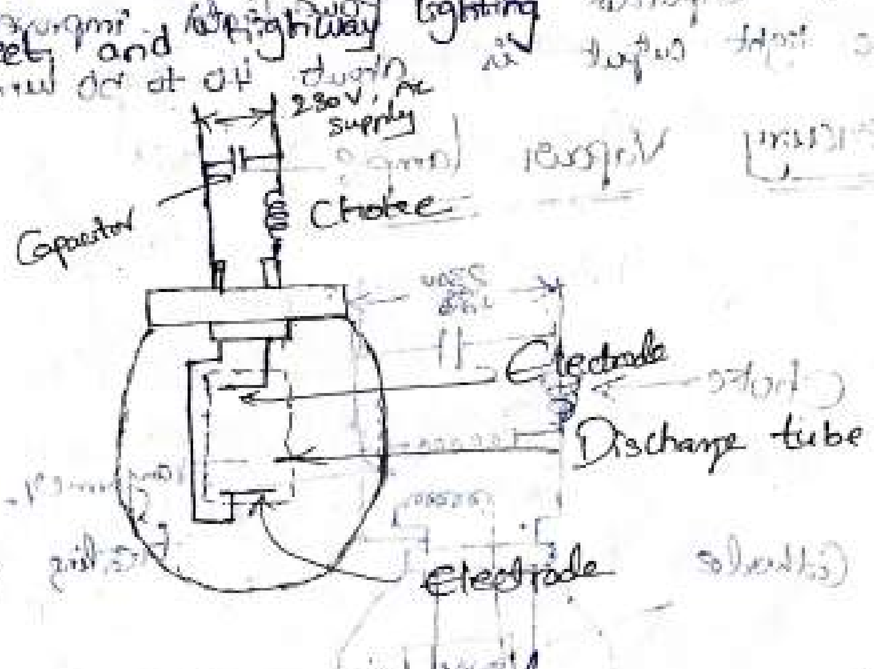
> If a Potential difference is applied to two Electrodes placed in a gas Having a large no. of free electrons these electrons will be attracted to the positive electrode an electron will strike other atoms

* Sodium Vapour lamp :-

Sodium Vapour Has the highest theoritical luminous efficiency & gives monochromatic orange - Yellow light.

⇒ The monocromatic light makes objects appears as grey

⇒ such lamps on account of this facts are used only for street and highway lighting



Sodium Vapour lamp

⇒ The lamp Consists of a discharge tube having Composition of glass to withstand the high-temp of the electric discharge.

⇒ The discharge tube is surrounded by an outer as shown above. for heating the Cathode is included.

⇒ Sodium below 60°C is in solid state, for the lamp the electric discharge is allowed to take place in neon gas.

⇒ The temperature inside the discharge tube rises and vaporises

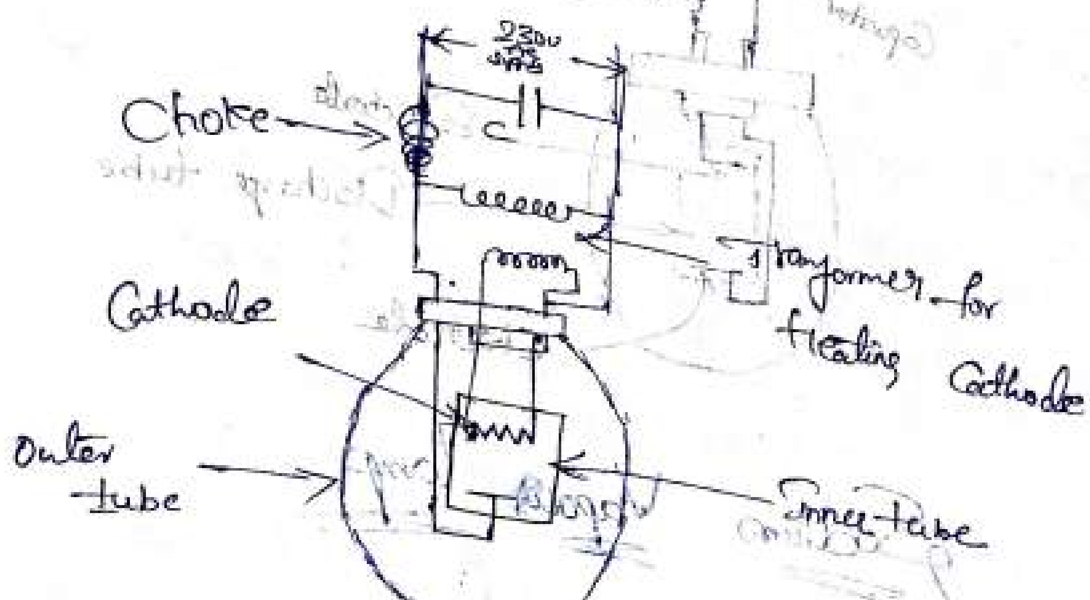
⇒ Sodium operating temperature is around 230°C
It takes about 10 minutes for the Sodium vapour to displace the red colour of neon by its vibration yellow colour.

⇒ The lamp takes about half an hour to reach full output

⇒ A Choke is provided for stabilising the electric discharge and a Capacitor for Power factor improvement.

⇒ The light output is about 40 to 50 lumens per watts

* Mercury Vapour lamp:



is Similar in Construction to the Sodium Vapour lamp.

The electrodes are tungsten Coils Containing an electron emitting material. which may be a Small piece of thorium or an oxide mixture.

⇒ Argon is introduced to help start the lamp.

⇒ The electric discharge first takes place through argon and this vaporises the mercury drops inside the discharge tube

⇒ The electron emitting material supplies electrons to maintain the arc.

⇒ The space between the two bulbs is filled with an inert gases

⇒ The pressure inside the discharge tube may range from one to 10 atmospheres in lamps used for lighting purposes as at these pressures the radiation is in the visible spectrum.

⇒ If the pressure inside the discharge tube is low, most of the light is in the ultraviolet region.

⇒ The efficiency is 30 to 40 lumens/watt.

* Lighting schemes :-

⇒ Lighting schemes refers to the arrangement and design of lighting in a space or setting.

⇒ such as a building, room, or stage.

⇒ A lighting scheme is typically Composed of multiple lighting fixtures, Each positioned and adjusted to Create a specific Effect, atmosphere.

* Requirements of Good lighting :-

=> Lighting is only good when it makes Seein easy and Comfortable.

=> Visual Comfort increases the efficiency of a

=> for instant, when the light is too dim, we observe the objects properly. on the other if the light is too bright. we don't like to open eye lids, if the eyes opened by force, the water drops comes out. It make seeing uneasy discomfort.

following requirements for good lighting

- -> Illumination level
- -> uniformity of illumination
- -> Absence of Glare
- -> Colour of the light
- -> Shadows
- -> Contrast

* Illumination level :-

The visibility of the object depends on the level of illumination, which inturn depends on the

- -> Size of the object
- -> State of the object
  - |-> Stationary objects require low light compared to the moving objects
- -> Period of observation
  - |-> Continuous observation require more light.

Colour of Object

|→ dark Colour object require more lighting.

* back ground Contrast

|→ A white object side by white wall requires more light.

* Uniformity of illumination :—

=> The human eye adjusts itself automatically to the brightness with in the field of Vision.

=> The visual Performance is best if the range of brightness is not greaterthan 3:1 which Can be achieved by general and local lighting.

* Absence of Glare :—

=> The glare may Come directly from the light Source or may be reflected from smooth / polished surface should be avoided.

=> light Sources should be mounted above the normal line of sight. use of diffusion absorbing fixture reduce glare.

* Colour of light :—

=> The colour appearance of an object differs under different Coloured lights.

=> The Composition of the light should be such that ~~[illegible]~~ the Colour appear in nature

~~[illegible]~~.

=> MV & SV lamps produces Colour distortion

* Shadows :-

⇒ long and hard shadows Should be elimated because they ~~are~~ Cause trouble on the eye.

⇒ Complete absence of Shadows is not an ideal lighting.

⇒ dull shadows are necessary to give the three dimensional view of any Solid object

* Contrast :-

The local light Should be Supported by the general lighting otherwise it Causes strain on the eyes.

* Types & design of lighting Schemes :-

1. Direct fitting
2. Semi - Direct fitting
3. General fitting
4. Semi - indirect fitting
5. Indirect fitting

* Direct fitting :-

⇒ In this method of scheme, about 90 to 100% of the light from the source is directed towards the working plane. or object or surface to be illuminated

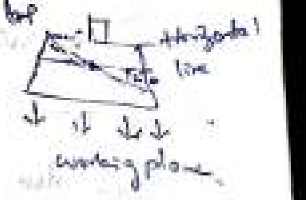
⇒ The Remaining about 10% of the total flux goes to the other direction (or) upper hemisphere may be directed on the working plane by the use of suitable reflectors.

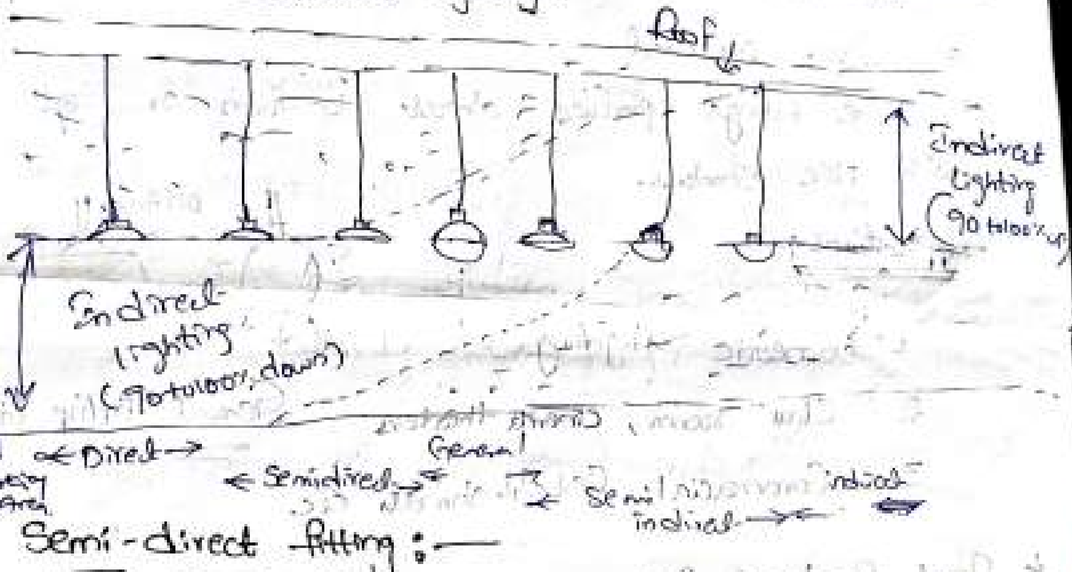
Direct light is cut off at an angle of 20° below the horizontal line.

=> The height of the lamp from the working plane should be two-thirds of the lamp spacing.

Application:—

1. Industrial lighting
2. Local lighting, houses, offices.
3. Decorative lighting





*** Semi-direct fitting:—**

=> In this method about 60 to 90% of the light from the source is directed towards the working plane.

=> The remaining 10 to 40% goes to other directions or upper hemi-sphere

=> for this purpose translucent reflectors are used as shown in fig

=> These fittings Produces soft shadow

uses:-
=> Show Case
=> Clubs etc

* General fitting :-

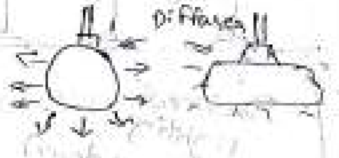
Shown general lighting fittings In this method about 40 to 60% of light flux from the source is directed on the working plane on lower hemisphere

=> The remaining light flux goes to other direction

=> It needs frequent cleaning

=> Here also translucent reflectors of different thickness or Colour are used

=> These fittings produce almost uniform or soft light with little shadows.



General fitting lamps

Applications :-

1. Domestic lighting
2. Class rooms, cinema theaters
3. Commercial Establishments etc

* Semi Indirect fittings :—

=> In this type of fittings about 10 to 40% of the light flux from the source is directed on the working surface or lower hemisphere

=> The remaining 90 to 60% of the light flux goes to upper hemisphere.

=> The light flux on the working surface is mostly due to the reflectivity of the Ceiling and walls frequent cleaning is necessary due to its shape

Semi-Indirect fitting

In-direct fitting

Applications:-

1. Decorative lighting Purpose in parks
2. Parking, gate posts
3. Shuttle courts etc

Indirect fittings:-

⇒ In this method 0 to 10% of the light flux from the source is directed on the working plane or lower hemi-sphere.

⇒ The remaining 90 to 100% of light goes to upper hemisphere

⇒ Actually the 0 to 10% of the light goes the working plane is also due to the reflectivity of the ceiling.

⇒ High wattage lamps will be used for this purp

Applications:-

1. Clubs
2. Restaurants Parts etc

=> Lighting schemes for diffrt situations :-

- => Direct fitting (90 to 100% downwords)
- -> Semi direct fitting (≈ 75% downwords)
- -> General fitting (50% downword)
- -> Semi indirect fitting (≈ 25% downwords)
- => Indirect fitting (≈ 10% downwords)

=> Advantages :-

Direct fitting :-

- -> Mounting of lamp is easy
- -> The objects are visible clearly
- -> It is cheap
- -> Extra fitting are not required

Semi - direct fitting :-

- -> well suited for commercial products advertisement.
- -> Customers can be attracted
- -> Soft shadows can be produced

General fitting :-

- -> Different colours can be produced by using colour reflectors
- -> Lamps attract the viewers

Semi - Indirect fitting :-

- -> lamp fittings of different shapes can be used
- -> lamps attracts the viewers

Indirect fitting :-

- -> It does not produce any glare (or) shadow
- -> Clubs and restaurants perfer this lighting.

UNIT-II

Electric Heating
&
Electric Welding

* Electric Heating is a process in which Electrical Energy is converted to heat Energy.

* Advantages:-

Cleanliness :- Electric Heating completely eliminates the dust and ash and it keeps the surroundings cleanly.

No pollution :- Due to the absence of flue gases there is no ~~risk~~ of the atmosphere

* Ease of Control:-

It is possible to control and regulate the temperature accurately either by manual or by fully automatically

* Uniform Heating :-

The Charge can be heated uniformly throughout whether the Charge is conducting can non-conducting material

* ~~High~~ Efficiency :-

The overall Efficiency of Electric heating is high since the heat can be produced directly in the Charge itself

Modes of Heat transfer :—

The different methods by which the heat is transferred from a hot body are

→ Conduction
→ Convection
→ Radiation

→ In solids heat is transferred from one molecule to the adjacent molecule and so on.
→ There is no actual motion of the molecules.
→ Conduction is more pre-dominant in solids.

* Conduction :—

The heat transfer by Conduction takes place in solids, liquids and gases.

The rate at which the heat is transferred depends on the temperature gradients i.e., on the difference between the temperatures of the two points / faces / surface of a body.

* Convection :—

In this method the heat is transferred from one point to another due to actual motion of the molecules

=> It is pre-dominant in liquids.

=> This is due to the difference in the fluid daity at different temperatures.

=> for vertical Surface in air, natural convection takes place according to the general law :—

where T_1 = temperature of the heating surface (°K)

T_2 = temperature of the air (°K)

* Radiation:—

=> In this method the heat transfer is confined to surfaces

=> The radiant energy is emitted and absorbed by different surfaces.

=> ~~According to St~~

Heat dissipation

$$H = 572\, ke\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right] \text{ watt/m}^2$$

where

K = radiant efficiency or a constant

= 1 for single element

= 0.5 to 0.8 for several elements placed side by side

e = emissivity

= 1 for black body

= 0.9 for resistance heating elements

T_1 = temperature of the source (°K)

T_2 = temperature of the absorbing surface (°K)

From the above expression the radiant heat is proportional to the difference of fourth powers of the temperature

=> It will have a very efficent heating at high tem

* Requirements of Good Heating material (Element):

* **High Specific resistance :—** High specific resistance will shorten the length of the wire for a given resistance.

* **Low temperature coefficent of resistance :—** Lower the temperature co-efficient of resistance of the material smaller the variation of resistance due to operating temperature.

* **High melting Point :—** It's melting Point should be sufficiently higher than its operating temperature otherwise a small increase in temperature will destroy the element

* **free from oxidation :—** The element material should not oxidise at high temperatures otherwise oxidised layers from the surface will flake off changing the resistance of the element and shortens its life.

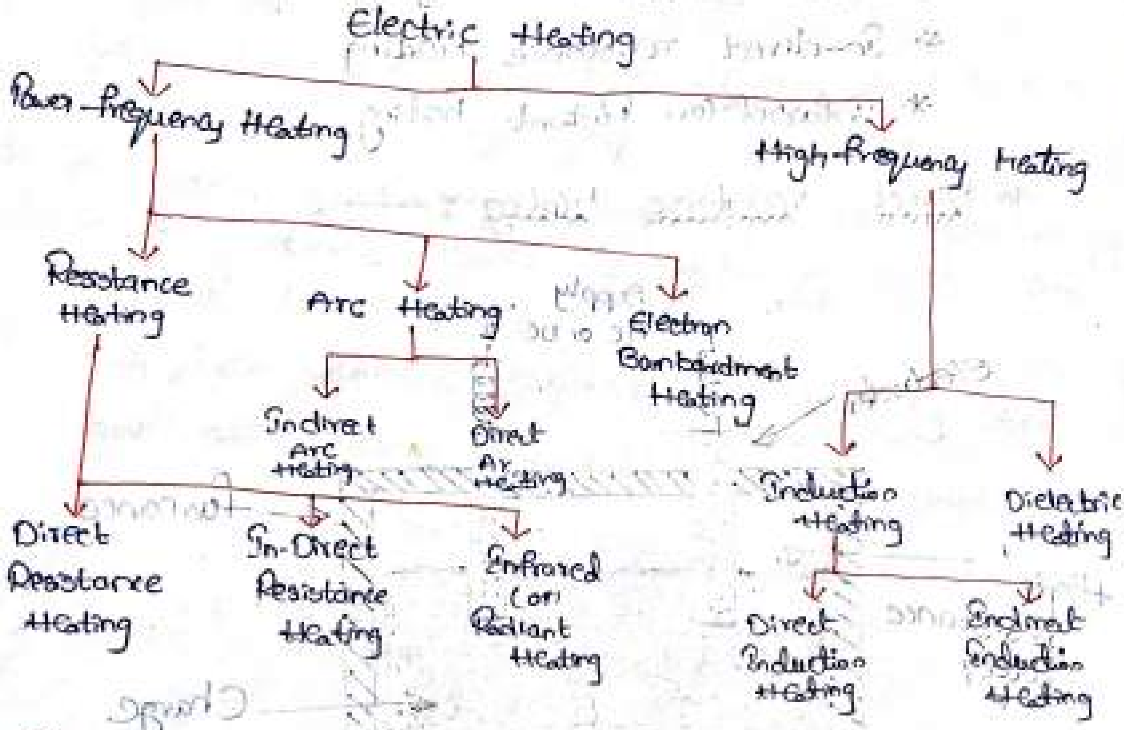
* **Non Corrosive :—** The element should not corrode when exposed to atmosphere or any other chemical fumes.

* **Ductile :—** It helps in obtaining different shapes and sizes of the element.

* **High Mechanical strength :—** The element should possess high mechanical strength and should withstand vibrations etc.

* **Economical :—** The cost of the material should not be high.

Electric Heating Methods :—



* Resistance Heating :—

When current passes through a resistance, power loss takes place there in which appears in the form of heat

$$\boxed{\text{Power loss} = I^2R \text{ watt}} = VI \text{ watt} = \frac{V^2}{R} \text{ watt}$$

where

R = Resistance of the Element

V = voltage

I = Current

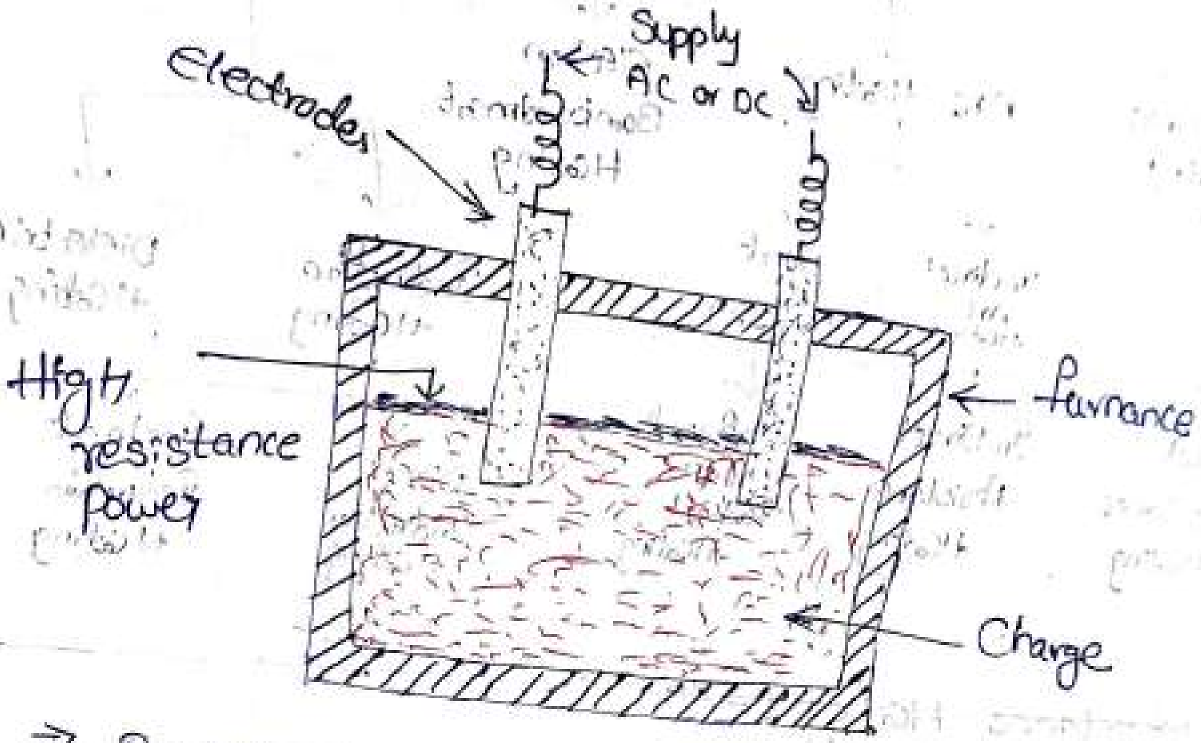
→ All the Electrical Energy given to a resistance heating Element will be converted into heat energy.

→ The loss of energy takes place only in transferring heat from Element to charge or load.

The resistance heating is futher Classified as :—

- Direct resistance heating
- In-direct resistance heating
- Infrared (or) Radiant heating

* Direct resistance heating :—



⇒ In this method of heating, current is passed through the material or charge to ~~the~~ be heated

=> The charge is considered in a furnance and two electrodes are immersed in the charge.

=> The supply ac or dc will be given to the electrodes as shown in fig.

=> The resistance offered by the charge to the flow of current causes power loss I^2R and it results in the heating of the charge.

=> The charge may be in the form of solid/metal pieces, Power or liquid.

=> when solid/metal peaces are to be heated a Powder material is sprinkled over the

Resistance Heating :-

surface of the charge to avoid direct short circuit.

=> Then the current passes through the charge and heat is produced.

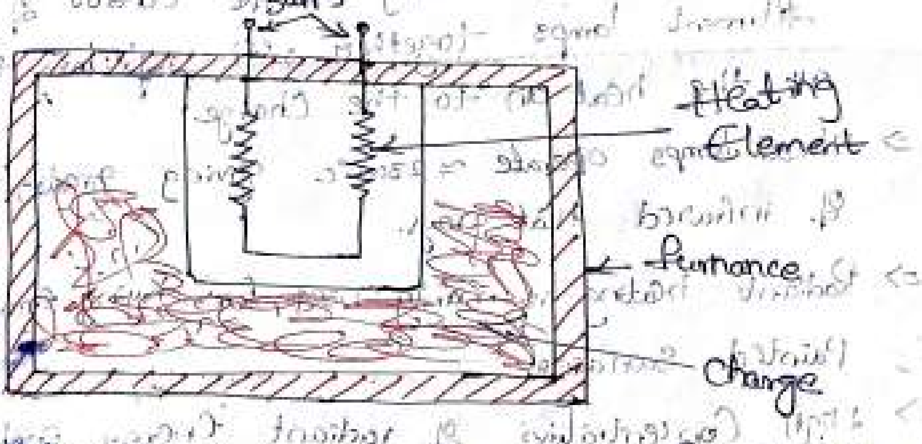
=> This method has quiet high efficiency since heat is produced in the charge itself.

=> This method of heating is employed in resistance welding in the Electrode boiler for ~~th~~ heating water and in salt bath furnance.

=> Salt bath furnance is used ~~to~~ for Hardening steel tools and prevents oxidation during hardening.

=> This arrangement Provides high and uniform temperatures.

* In-direct Resistance Heating :-



=> In this method the current is passed through a high resistance wire known as heating element as shown in fig.

=> The heating element can be placed above or below the furnance/charge.

=> Usually Charge will enclose the heating element for efficient heat transfer.

⇒ The heat produced in the element is transfe to the charge by radiation or convection me

⇒ This method of heating is used in room heat in bimetallic strip used in straters, immersion water heaters and in various types of resistance ovens used in domestic cooking and industrial salt bath furnances etc.

⇒ This arrangement provides uniform temperature

⇒ Automatic temperature control can be provided in this method.

* Infrared or Radiant Heating :—

⇒ Infrared heating, heating element consist of tungsten filament lamps together with reflectors to direct all the heat on to the charge.

⇒ These lamps operate ≈ 2300°c giving greater portion of infrared heat rays.

⇒ Radiant heating is mainly used for drying enamel or painted surfaces.

⇒ High concentration of radiant energy enables heat to penetrate the coating of paint or enamel to a depth sufficent to dry it out without wasting energy in the body of the working piece.

Applications of Resistance Heating

Direct Resistance Heating

- → Scrap heating
- → Resistance welding
- → Salt water bath furnance
- → Electrode boiler for water heating etc

In-direct Resistance Heating

- → Water heaters
- → Room heaters
- → Starters
- → Resistance ovens
- → Domestic cooking etc

* Electric ARC Heating [furnance]

⇒ When the electric supply given to two Electrodes is increased and are separated in air from each other; a stage arises that the voltage gradient in the air gap becomes a good conductor of electricity.

⇒ Arc Exists when current passes through air gap.

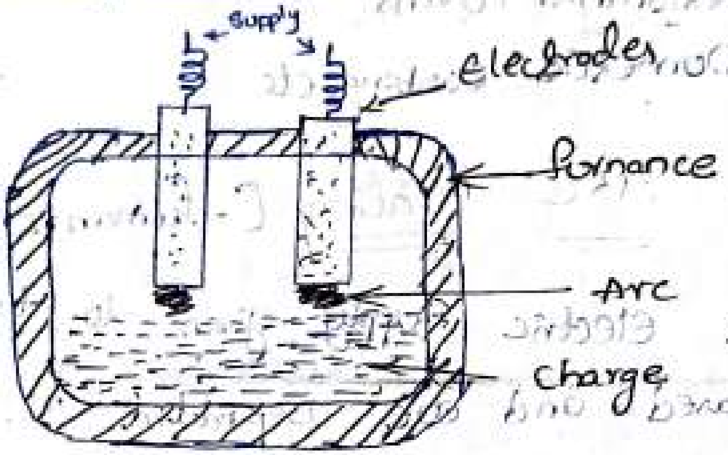
⇒ It should be noted that a very high voltage is required to establish an arc across the airgap but small voltage may be sufficient to maintain the arc.

⇒ without high voltage also arc can be established by short circuiting the two electrodes and on with drawing them back slowly.

=> The temperature of the arc developed will be aro
3500°c , the process can be carried out in
1500°c & 2500°c .

=> As mentioned Earlier there are two type
Electric arc furnances namely
→ Direct Arc furnance
→ In-direct Arc furnance

* Direct Arc furnance :—



⇒ There are two electrodes when supply is given to electrodes, two arcs are established and current Pass through the charges.

=> Heat is developed due to the electrical resistance(
of the charge

=> The most important feature of the direct arc furnance is that the current flows through the charge, the stirring action is inherent due to the electromagnetic force set up by the current.

=> This result in uniform heating of the charge

* Application:-

The main Application of this type of heating is Production of steel.

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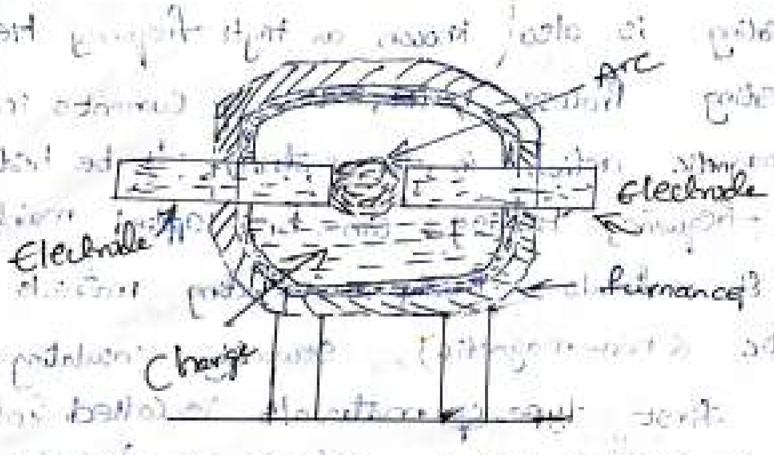
In-direct Arc furnance:—



⇒ In this type of furnance the arc exists between two electrodes and the heat developed in the charge is purely by the radiation from the arc as shown in fig

⇒ Since the charge is heated due to radiation only the temperature of the charge is lower than that in direct arc furnace.

⇒ As current does not flow through the charge there is no inherent stirring action provided and the furnace must be rocked mechanically.

⇒ Hence, these furnances are also referred to as rocking arc furnance.

⇒ That is why the indirect arc furnances are made of cylindrical or spherical in shape.

* Application:—

⇒ The main application of indirect-arc furnance is to melt Non-ferrous metals.

*Induction Heating :—

* Induction Heating is also known as high frequency Heating
* Induction heating Process makes use of Currents induced by electromagnetic action in the material to be heated.
* The high frequency heating can be applied mainly to two classes of materials :- firstly, conducting materials (ferromagnetic & non-magnetic), secondly insulating material :
* Heating of first type of materials is called Induction Heating and second type of materials as dielectric heating
* Induction furnances are further classified as :-
  → Core type Induction furnance
  ⇒ Coreless type Induction furnance

* Core type Induction furnance :—

* The core type of furnance is essentially a transformer in which the charge forms the secondary circuit and consists of one turn only formed by the metal to be heated.
* The charge is magnetically coupled to the Primary by an iron core as shown in fig.
* It can be seen from the diagram that the magnetic Coupling between primary and secondary is very poor resulting in high leakage current and a low Power factor.
* For this reason the furnance is operated at low frequencies of the order of 10 Hz or so

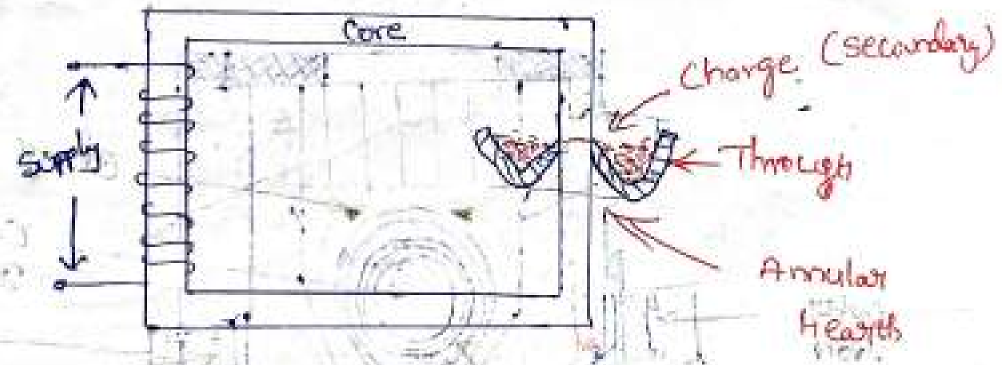
low frequency necessitates an additional motor generator set or frequency Convertor.

* To Start the furnance molten metal is poured in the annular Hearth or a sufficient quantity is left over from the previous Charge

* Other wise the Secondary winding is in Completely (open) and no current will induce and no heating will take place.

* This is inconvenient where the furnance is to be used for melting different types of Charges.

* The electro magnetic forces Causes turbulence the molten metal which although useful upto certain extent is liable too severe unless the frequency is low.



* Disadvantages :-

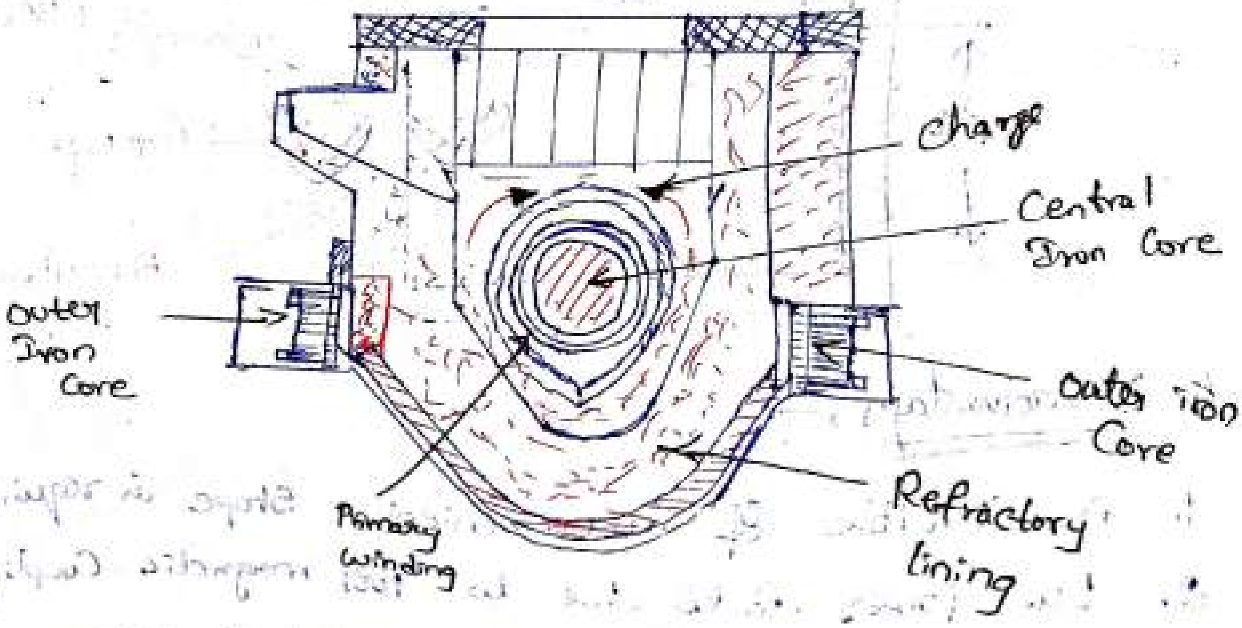
1. A Crucible of inconvenient Shape is required
2. Low power facto due to pool magnetic Coupling
3. At Start Some molten metal is necessary in the Crucible
4. It is bulky due to the presence of Core.

* Ajax Wyatt vertical Core furnance :

* It is an improvement over the Core type in furnance and over Comes some of the disadv mentioned above.

* It Employs a vertical Crucible instead of ho which avoids the pinch effect due to the weig of the charge in the main body of the Crucible

* The Circulation of the molten metal takes place around the vee portion by Convectio Current shown by dotted lines and by electromagneti force between the Currents in the two halves of the vee.



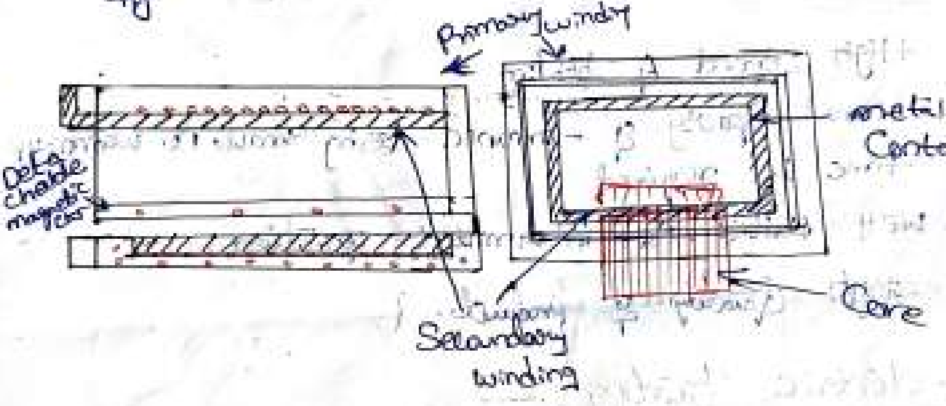
Indirect Core type induction furnance:-

This type of furnance is used for heat treatment of metals.

⇒ The wall of the container forms the secondary winding and the iron core links both the primary and secondary winding.

⇒ Heat produced in the secondary due to induced currents is transmitted to the charge by radiation.

⇒ A detachable magnetic circuit made of a special alloy is kept inside the chamber of the furnance as shown in fig.



* Core less Induction Heating :-

The eddy currents developed in any magnetic circuit are given by the Equation

$$\boxed{W_e \propto B_m^2 f^2}$$

W_e = Eddy current loss (watt)

B_m = maximum flux density

f = freqny (Hz)

⇒ This alloy will loose its magnetic properties at a particular temperature and the magnetic properties are regained when this alloy cools down to the same temperature

⇒ Thus on reaching the critical temperature the reluct
of the alloy increases and there by decreasing the induction effect.

↳ This virtually appears to be the power is cut-off.

⇒ Thus the temperature of the furnance can be effectively controlled ; it is a great advantage.

⇒ The furnance operates at a power-factor of around 0.8° and is having complicated construction.

* Advantages of Coreless induction furnance :—

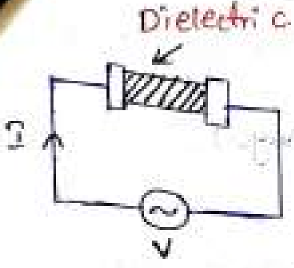
1. High speed of heating
2. Thermal capacity of furnance being small, no warm-up time is required
3. Well suited for intermittent operation
4. High Quality of product.

* Di-electric Heating :—

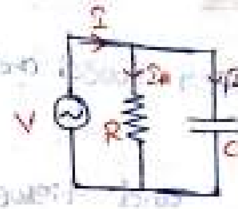
⇒ The process of heating in which a high frequency alternating electric field or radio waves or microwave electromagnetic radiation are used to heat the dielectric materials is known as dielectric heating.

⇒ Dielectric heating is also known as electronic heating, radio frequency (R.F) heating, high frequency heating and diathermy.

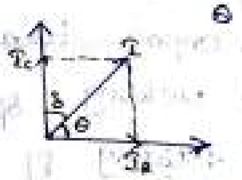
⇒ The dielectric heating method works on the same principle of the capacitor (ie, electrostatic)



Schematic diagram



Equivalent Circuit



phasor diagram

⇒ Dielectric heating can only be used for heating of non-conducting materials.

⇒ In this method of heating the dielectric material to be heating is placed between two conducting electrodes across which alternating voltage of high frequy is applied.

⇒ There are two electrodes which are separated by a dielectric medium (it is the material to be heated) and a potential difference of high frequy is applied across the electrodes.

⇒ The phasor diagram of the equivalent circuit is also shown in the above figure.

⇒ The capacitor formed in the arrangement for the dielectric heating may not be a pure capacitor, thus a resistor 'R' is also shown in parallel in circuit.

⇒ However, the value of resistance 'R' is very high so that the current flowing through it is very small.

⇒ for this reason, the capacitor current I_c can be considered equal to the total current I.

* Applications of dielectric Heating:—

1. Drying tobacco, Paper, wood and rayon
2. Welding of PVC
3. Heating of bones and tissues
4. Heat sealing of plastic sheets
5. Preparation of thermo plastic resins.

* Advantages of dielectric Heating:—

1. Heat is produced in the whole mass of the material
2. Heating non-Conducting materials is very speedy
3. Uniform heating
4. Materials Heated by this method are combustible which cannot be heated by flame.

* Problem:—

1. A piece of plywood is to be heated by dielectric heating the area of cross-sections of the piece is $0.5 m^2$ and the thickness is 2.5cm. If the frequency of 25 mega cycle per second is used and the power absorbed is 1000 watt. find the voltage employed necessary for heating. The relative permittivity of wood is 2.5 and power factor is 0.046?

Given data

$A = 0.5 m^2$

$d = 2.5 \times 10^{-2} m$

$f = 25 \times 10^6 Hz$

$P = 1000 W$

$\epsilon_r = 2.5$

$p.f = 0.046$

voltage, V = ?

We known

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d} = \frac{8.854\times10^{-12}\times2.5\times0.5}{2.5\times10^{-2}}$$

$$C = 4.427\times10^{-10} F$$

$$\therefore \phi = \cos^{-1}(0.046) = 87.363^\circ$$

$$\delta = (90-\phi) = (90-87.363) = 2.64^\circ$$

$$\tan\delta = \tan 2.64 = 0.0461 \text{ radian}$$

Power $P = 2\pi f V^2 C\delta$

$$1000 = 2\pi\times25\times10^{6}\times V^2\times4.427\times10^{-10}\times0.0461$$

$$= 3.2064\times10^{-3} V^2$$

$$V^2 = \frac{1000}{3.2064\times10^{-3}} = 311875.89$$

$$\therefore V = \sqrt{311875.89} = \underline{558.5} \text{ volt}$$

Electric Welding

⇒ Welding is the process in which metals are [redacted] Heated to melting point and adhere on solidification.

(or)

⇒ Welding is a process of making a permanent Joint by Establishing inter atomic bonds between two or more pieces of metals by using heat or heat and pressure.

* Advantages of Welding :—

1. A welded joint is as strong as the base metal
2. Welding Equipment is not costly and is portable
3. Welding products are lighter and strong
4. Welding joint are easier to inspect

* Dis-advantages :—

1. Welding Process requires skilled operators.
2. Welding Process gives harmful radiation and fumes
3. Welding requires edges preparation.

* Classification of Electric Welding :—

Electric Welding

- Resistance welding
  - Spot welding
  - Seam welding
  - Butt welding
    - Simple Butt welding
    - Flash Butt welding
- Arc welding
  - metal Arc welding
  - Carbon Arc welding
- Radiation Welding
  - Laser Beam welding
  - Arc image welding
  - Electric Beam welding

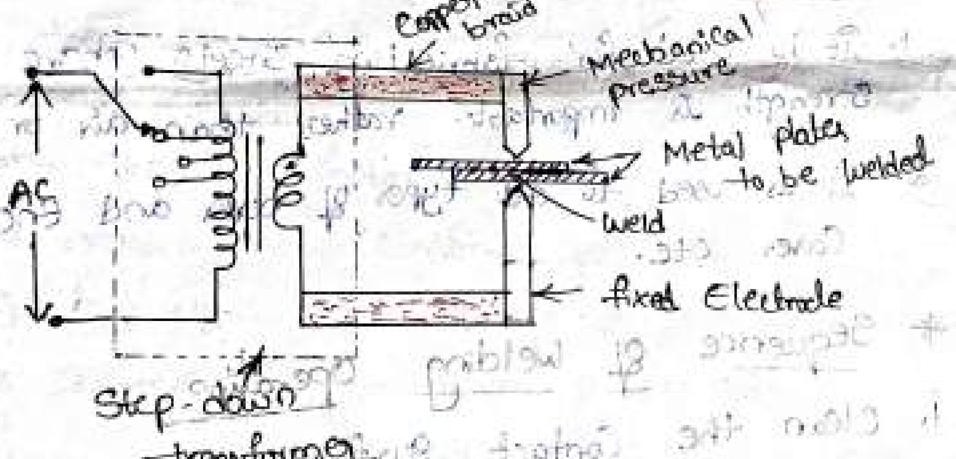
stance Welding :-

this method of welding, heat required for the Purpose of weld is produced by the resistance Offered to the flow of Current at the Junction of two metals and is given by I^2Rt loss.

* Spot welding :-

→ Spot Welding is used for joining two or more sheets of metal by means of an overlapping Joint.

⇒ The work pieces or plates to be welded are held between two Electrodes and pressed together by mechanical Pressure exerted through Electrode as shown in fig



Spot Welding

⇒ Now the current is Passed for a definite period of time, depending upon the size of the plates

⇒ The Passage of current will generate heat at the three Junction faces two between Electrodes and work pieces and one between two work pieces.

eat Produced between Electrodes and workp
Produces a Spot weld.

⇒ The unwanted heat generation between Electrodes and work piece is to be avoided either by water Cooled Electrodes, or by making the Electrodes with high Electrical and thermal Conductivity so that the heat developed is minimum.

⇒ The Passage of Current varies from a fraction of a Second to several Seconds.

⇒ The Current Strength time and pressure applied plays an important role in the quality of the Spot weld.

* Applications:-

1. It is used for fabricating sheets where mechanical strength is important rather than air or water tight
2. It is used to all types of boxes and Enclosing Cases etc.

* Sequence of welding operation

1. Clean the Contact Surfaces of the work pieces to be welded
2. Keep the work piece between the Electrodes
3. Switch on the Power Supply and apply mechanical Pressure
4. The weld obtained Can be Cooled by water.

Seam Welding:-

⇒ It is a series
Similar
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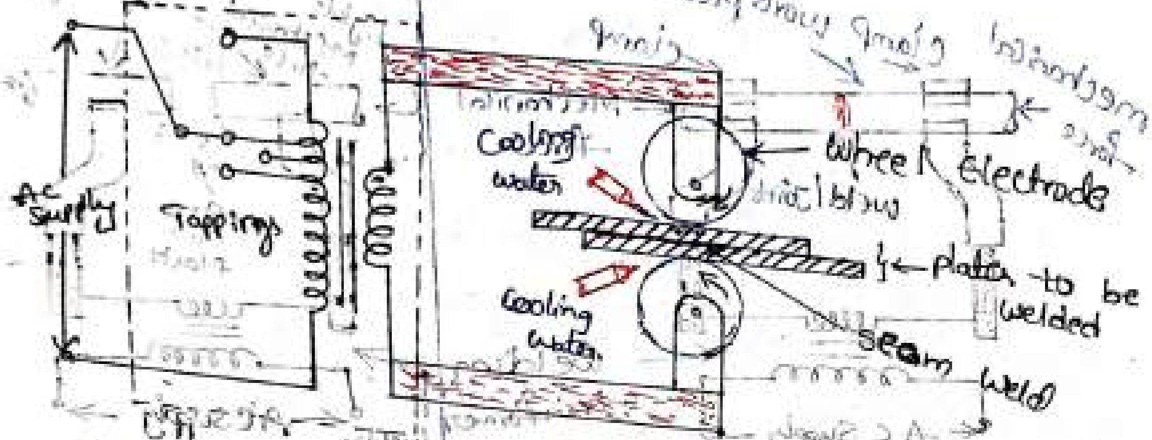
Seam Welding :-

⇒ It is a series of continuous spot welds and is similar to spot welding except the tipped electrod are replaced by roller electroda as shown in fig.



⇒ The two plates to be welded are passed ~~to~~ between roller electroda.

⇒ As these rollers travel over the metal pieces which are under pressure, the current passing between them heats the two metal pieces to the plastic state and results into continous spot welds.

⇒ Depending upon the number of welding current pulses per second, we get series of weld spots.

⇒ In practice, it is not satisfactory to make a continous weld, that is, to have the current flowing continuously, as there is then a tendency for the heat gradually to buildup as the weld progresses and cause burning and warping.

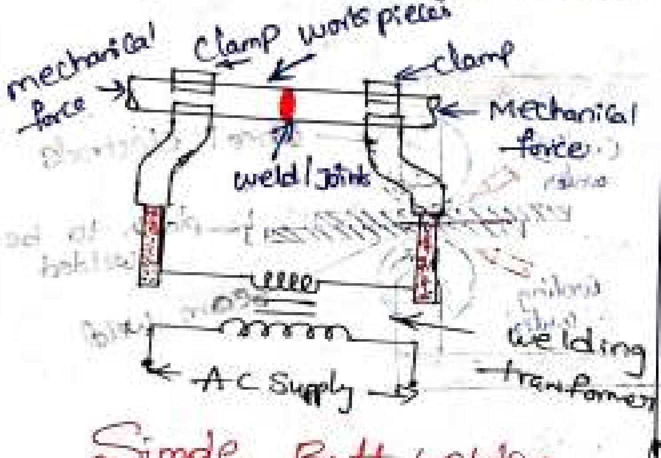
⇒ It is usual to employ therefore an intermittent current so that a seam weld is actually a series of overlappi spot welds.

*** Butt Welding :—** Butt welding is Similar to

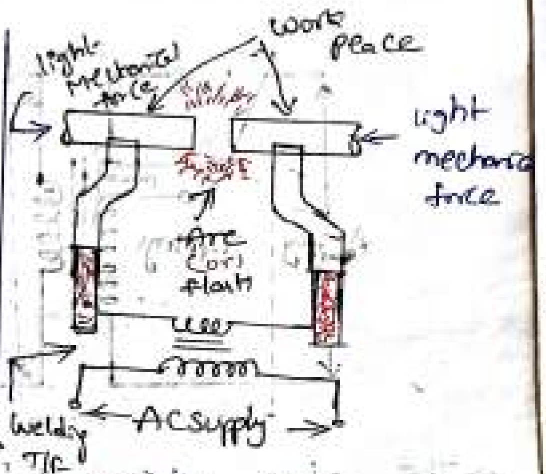
welding except for the fact that the parts to

butt welded now take the place of the Electrodes.

=> The two Ends are so prepared that they butt together with good Contact.



Simple Butt welding



Flash Buttwelding

* The simple Buttwelding Illustrates two work pieces to be welded together are fixed in clamps and butted against each other.

* When supply is Switched on, heavy current Passes through the Joint and heat is generated by the Contact resistance between two work pieces.

* When sufficient heat is developed, the work pieces are rammed by axial force by a Spring. Produces a bulged Joint. Thus Completes the weld.

*** Application :—**

→ It is most suitable for Joining metal parts end-to-end (or) edge-to-edge

→ It is used for rods, pipes, and wires.

utt welding :—

It is little different from simple butt welding. In this process, the ends of two pieces (work) to be welded ⑦ are put together under light axial mechanical pressure.

* A small gap will be remained in between the two work piece before supply is given.

* When supply is switched on Arcing will takes place as shown in fig

* This removes any unevenness at the Joint.

* Flashing is allowed till the two ends of the work pieces reach welding / melting temperature, the supply will be switched off and the pieces are rapidly brought together with light pressure.

* As the pieces are moved together the fused metal and slag comes out of the Joint making a good Solid Joint.

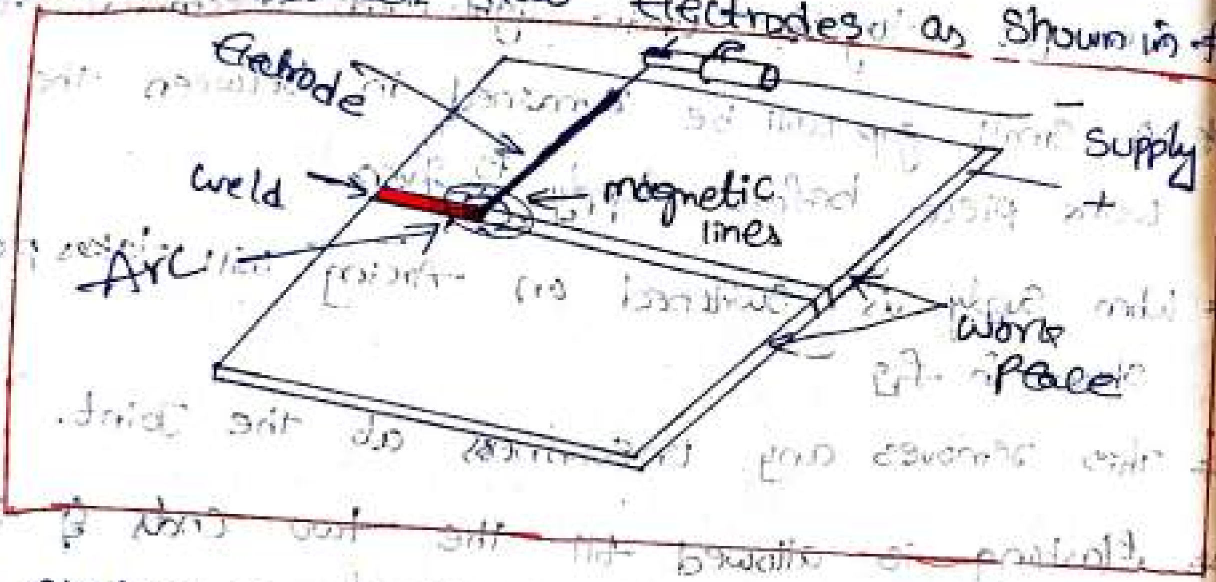
* A thin fin around the Joint so obtained can be easily removed to produce a sound weld

* Application

1. It is Extensively used in Production work.
2. It is Employed for welding Chains, rail ends, rolled Sections, Shaft axles etc.

* Electric Arc welding :—

In Electric Arc Welding, heat is obtained by an arc struck between an electrode and the metal to be welded or between two electrodes as Shown in f



An Electric Arc is struck by short circuiting the two electrodes, the path or arc resistance increases due decrease in Contact area of Electrodes.

This ionized air or gas acts as a conducting path for current.

In between the electrode and work piece a filler metals is required to fill in and Complete the Joint.

As the Arc welding is in process the ionization of arc path and its surrounding area increases.

The increased in ionization decrease the resistance of the path thus increasing the current with decrease in voltage. This phenomenon of decrease in Arc resistan is known as Negative Resistance Characteristic.

Metal Arc Welding :—

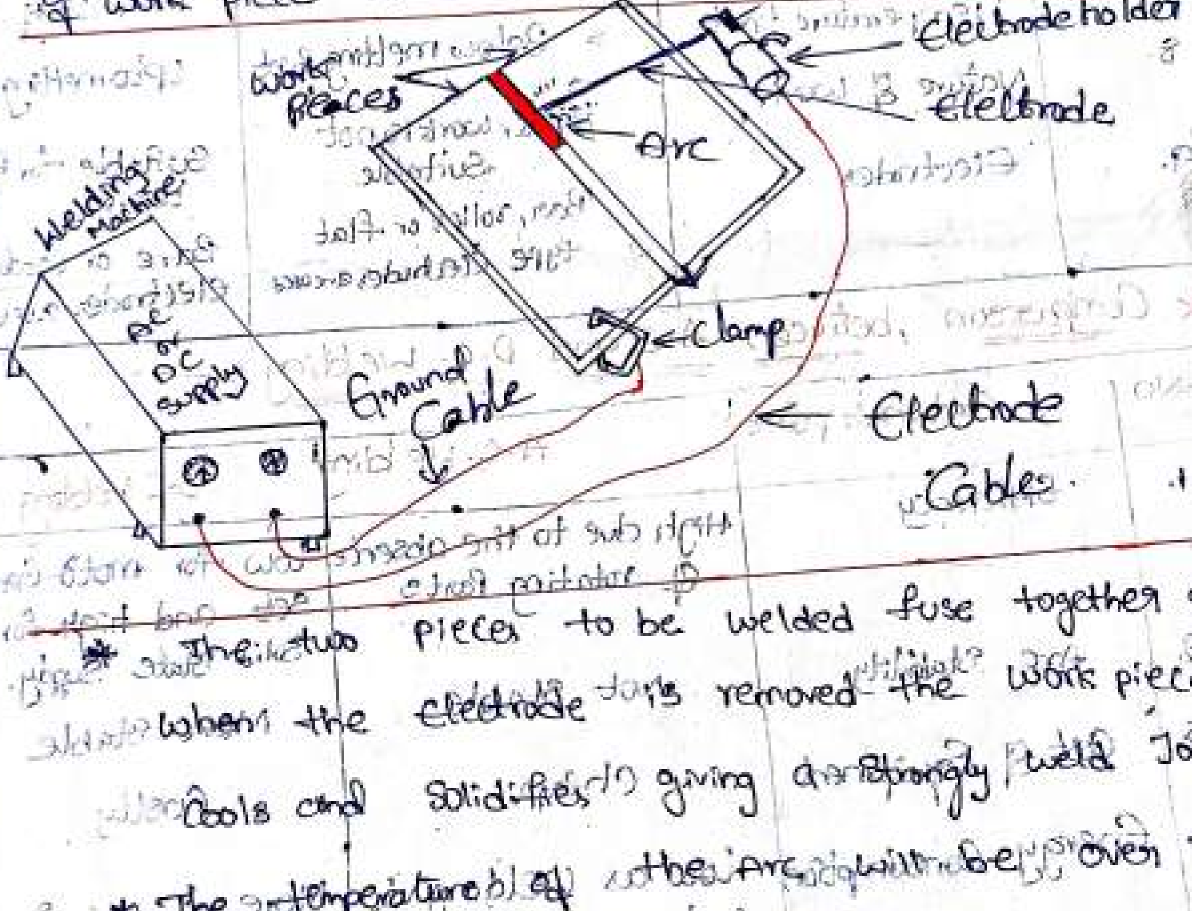
* In Metallic Arc Welding the electrode used must be of the same metal as that of work piece to be welded.

* The electrode itself forms the filler metal.

* for Metal arc welding both AC and DC can be used.

* An Arc is struck when electrode touches the work piece and withdrawn

* High temperatures of the Arc melts the little patch of work piece as well as the tip of the electrode.



* The two pieces to be welded fuse together and when the electrode is removed the work piece cools and solidifies giving a strongly weld joint.

* The temperature of the Arc will be over 3500°c

* It is the most common type of Arc welding and is normally manually operated process.

* therefore it is also refered to as Manual Metal Arc Welding

* Comparison between Resistance welding and Arc welding :-

S.No	Contrast point	Resistance Welding	Arc welding
1.	Cause of heat	flow of Current through Contact Resistance	Arc formed b/w Electrodes & work piece.
2.	Period of Current flows	Small	large
3.	Source of supply	A.C only	AC (1ϕ & 3ϕ) or DC
4	External pressure	Necessary	Not necessary
5.	Powerfactor	Low	very Low
6.	Power Consumption	low	HIGH
7.	Temperature limits	Below melting Point	upto melting Point
8.	Nature of work	Repair work is not Suitable	Suitable for Repair works
9.	Electrodes	Bar, rolles or flat type Electrodes are used	Bare or Coated Electrodes are used

* Comparison between A.C and D.C Welding :-

S.NO	Contrast point	A.C. Welding	D.C Welding
1.	Efficiency	High due to the absence of rotating Parts	Low for moto Generator set and high for Solid State Supply.
2.	Arc Stability	Not Stable	More Stable
3.	Cost of Equipment	Cheap.	Costly
4.	Energy Consumption	Low as welding is intermittent	More for Moto-Generator set & Low for Solid State
5.	Heating	Not uniform	uniform
6	Equipment	only transformer is required	motor - Generator set or transformer plus Rectifier is Required.

Electric Traction - I

UNIT - III

* Introduction :—

The System of traction involving the use of Electricity is Called Electric traction

Traction Systems Can be broadly Classified into two types:—

* Non- Electric traction and
* Electric traction

⇒ Non- Electric traction doesnot use Electricity at any Stage Such as Steam Engine drive and internal Combustion drive

⇒ The Electric traction involve the use of Electricity at Some stage or the other, Such as diesel Electric drive, battery Electric drive and Straight Electric drive

The Requirements of an ideal traction System are given below:-

1. Maximum tractive Effort Should be Exerted at Starting in order to have rapid acceleration.

2. Equipment Should be Capable of overloads for short periods.

3. The motors Speed Control Should be Easy

4. The Equipment used Should have high Efficiency, low initial Cost and maintenance Cost

5. The system Should have high reliability.

* Advantags of Electric traction:—

1. Electric traction system is very Clean and neat
2. The system does not requires water and Coal.
3. Electric motors occupy very less area Compared to steam, diesel traction.
4. Regenerative braking is Possible and the Power Can be pumped back.

* Dis-advantags:—

1. High initial cost on Electrification i.e., over head line
2. Additional Equipment is required for regeneration
3. Communication lines Experience interference if run Parallel with Power lines.

* System of Electric traction:—

The Electric traction ~~are~~ is classified as following:—

1. D.C. (Direct Current) system
2. Single phase A.C system
3. Three phase A.C system
4. Composite system
    - → Single phase to 3-φ system
    - → Single phase to D.C system.

Comparision between A.C & D.C System :—

A.C System	D.C System
1. It is preferred for main line . Railway service	1. It is Suitable for sub urban line railway service.
2. Due to higher voltage spacing of substations can be large of about 40-50 km	2. Spacing of substation is less than 5-6 km
3, Energy Consumption is more	3, Energy Consumption is less
4. The weight of A.C locomotive is more and has high maintenance cost	4. The weight of DC locomotive is less and require less maintenance cost
5. It Causes interference in the Communication lines	5. No interference in Communication lines.
6, In AC motors the regenerative braking is less Efficient	6, DC Series motor have more Efficient Regenerative Braking.
7, AC traction system gives less Acceleration	7, DC traction system gives High Acceleration

* Types of services:—

There are three type of Passenger train services Existing in Electric traction. They are:-

→ Urban (or) City services

→ Sub-urban services

→ main line services

* Urban (or) City Service :—

-> In urban (or) City Services, the distance between two stop is very small. ie., about [1 km].

-> High Acceleration & Retardations are required to achieve the schedule speed.

* Sub-urban service :—

The Sub-urban services the distance between two stops is longer ie. in between (3 to 5 km)

-> This service also needs almost same High Acceleration and Retardation to achieve the Schedule speed.

* Main line Service :—

The Main line service the distance between two stops is long ie, in between (30 to 50) km etc.

-> This services does not need high Acceleration & Retardation.

-> Because the total Running time is more as compared to small accelerating time.

* Special features of traction Motor :—

The General features of the Electric motors used for traction purpose are classified into two types.

-> Mechanical features

-> Electrical features.

Mechanical features :-

The Mechanical features of Electric motors used for traction applications

→ **Robustness :-** A traction motor must be Mechanically strong and robust so that it can be capable of withstand severe Mechanical vibrations.

→ **Small size :—** The overall dimensions of the traction motor must be minimum

→ **High Efficiency :—** The traction motor should have high mechanical and Electrical Efficiency. It has ~~so~~ Low losses [like windage & friction losses]

* Electrical features :—

The Electrical features of Electric motor used for traction purposes.

→ **High Starting torque :—** An Electric motor which is being used as the traction motor must have high starting torque.

→ **Easy Speed Control :—**

The speed control of the traction motor must be simple and Easy. This is required for the frequent starting and stopping of the motor in traction Application.

→ **Withstand High temperature :-**

The traction motor should have the Capability of withstanding High temperature without failure due to frequent starting & stopping the train.

* **Overload Capacity :—**

The Electric trains may have an overload Condition at any time, traction motor should have the Capability of handling Excessive overload.

* **Electric Braking Ability :—**

The traction motor should be able to Provide Easy and simple dynamic & Regenerative braking. So that the Energy efficency Can be improved.

* Methods of Electric Braking :—

The Electric braking of a DC motor is of three types

1. Rheostatic (or) dynamic braking
2. plugging (or) reverse Current braking
3. Regenerative braking.

* Rheostatic Braking :—

→ In DC Shunt motor Armature is disconnected from the Supply and a rheostat is Connected across it.

→ The field winding is left Connected across the Supply

→ Hence Machine starts acting as a Generator.

→ Thus the machine will now feed the Current to the Connected Rheostat and heat will dissipate at the I^2R.

→ Braking Effect is Controlled by varying the Resistance Connected across the armature.

plugging (or) Reverse current Braking :—

-> In this method, armature Connections are Reversed and hence motor tends to run in opposite direction.

-> Due to Reversal of the armature terminals, applied voltage V and Back Emf E_b starts acting in the Same direction and hence the total armature Current Exceeds.

-> To limit this armature Current a variable Resistor is Connected across the Armature.

-> plugging gives Greater Braking torque as Compared to Rheostatic Braking.

-> This method is Generally used in Controlling Elevators, Printing presses Etc.

* Regenerative Braking :—

-> Regenerative Braking is used where load on the motor has very high inertia (Eg in Electric trains).

-> When Applied voltage to the motor is Reduced to less than back Emf E_b.

-> Armature Current I_a will get reversed and hence Armature torque is Reversed. Thus Speed falls.

-> AS Generated Emf is Greater than applied voltage Power will be Returned to the line. this action is Called Regeneration

-> Speed keeps falling. Back Emf E_b also falls until it becomes lower than Applied voltage and direction of armature Current again becomes Opposite to E_b.

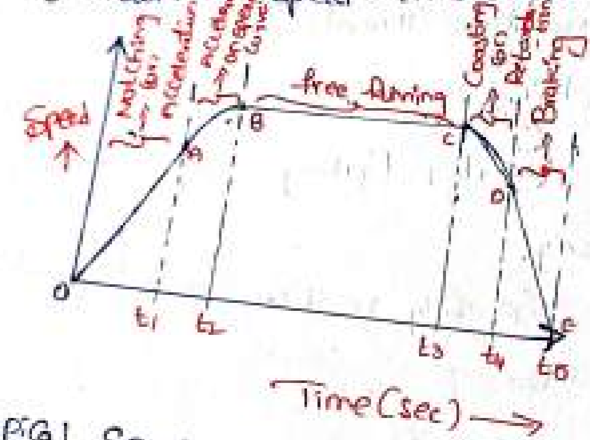
(5M)

Speed - time Curve for Different Services :-

A Speed - time curve is a graph showing the variation of speed with respect to time.

(or)

A curve drawn between the Speed of train in Kmph along ordinate and time in (sec) (or) (min) along abscissa is known as Speed - time curve.



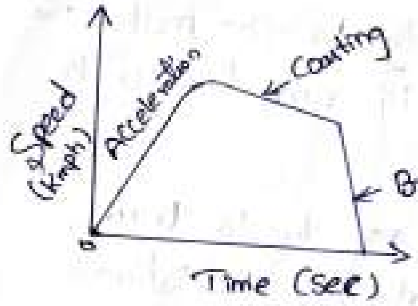
[Speed - time Curve for Main-line service]

A typical Speed - time Curve of a train having more than 10 km distance b/w two stops. (or) main line service is shown above fig.

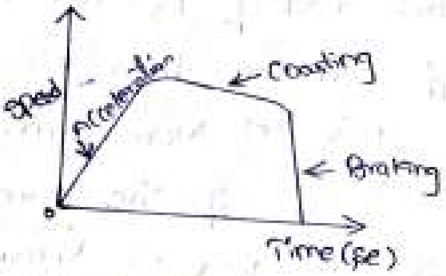
The Speed - time curve can be classified into the following

1. Nothing up (or) Acceleration
2. Acceleration on Speed - time Curve
3. Free Running
4. Coasting
5. Braking.

The speed time-curve for urban and Sub-urban Services



* Urban (or) City Service



* Sub-urban Service

* Notching up (or) Rheostatic Acceleration :— [0 to t_1]

→ During this period of Run. the current is maintained Constant by Cutting the Starting Resistance gradually which increases the voltage across the motor.

→ While cutting the starting Resistance the handle has to move from notch to another. Hence the time period is Given 0 to t_1.

* Acceleration on Speed curve :— (t_1 to t_2)

During this period, all the starting Resistance has been cut out, and the voltage acting across the motor remain Same. Effort exerted by the motor is morethan the train Resistance.

This Causes the increase in speed of the motor.

* Free Running :— (t_2 to t_3)

During this period, the train runs with Constant / maximum Speed which is attained at t_2.

The motor draws Constant Power.

* Coasting Period (t_3 to t_4) :—

→ At the End of t_3 the Power supply to the motor is cut-off and the train is allowed to run due to its own axis (or) Momentum.

→ The Speed of the train decreases due to train Resistance. This is known as Coasting Retardation.

* Braking Period (t_4 to t_5) :—

At the End of Coasting the Brakes are applied to Stop the train.

* Important Definitions :—

1. Maximum Speed (V_m) :— The highest Speed attained by the train during the run is known as maximum Speed.

2. Average Speed (V_a) :—

The ratio of Distance b/w two Stops to the time taken by the train to travel that distance

$$\boxed{V_a = \frac{D}{T}}$$ //

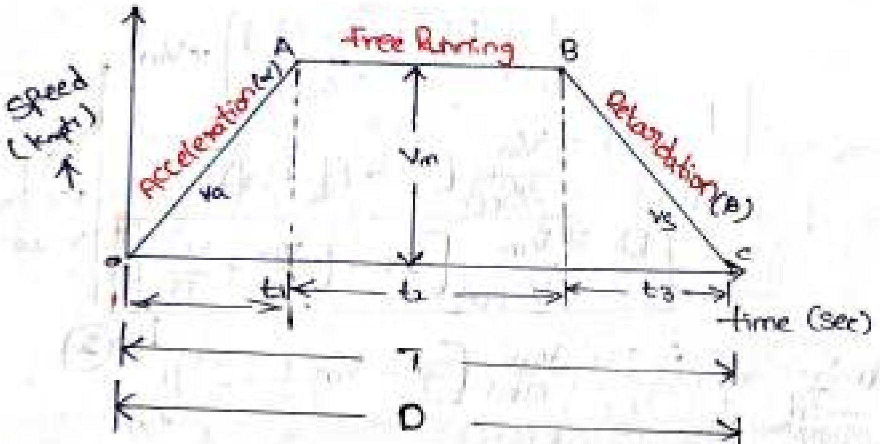
3. Schedule Speed (V_s) :— It is given by the ratio of distance moved b/w two Stops to the total time of run including time of Stop

$$\boxed{V_s = \frac{D}{T+t_s}}$$ //

Trapezoidal Speed-Time Curve:— [Imp] : [10M]

→ Trapezoidal Speed-time curve is a close approximation to main line service where the duration of free running is long.

→ Now we develop relationships between various quantities involved in the speed-time curve.



Let

D = Distance between two-stops in kmph

T = Total Running time between stops in second

α = Acceleration in kmphps

β = Retardation in kmphps

V_m = maximum speed in kmph

V_a = Average speed in kmph

V_s = Schedule speed in kmph

t_1 = time of acceleration in sec

t_2 = time of free Running in sec

t_3 = time of Retardation in sec

$\therefore K = \frac{1}{\alpha} + \frac{1}{\beta}$, $t_1 = \frac{V_m}{\alpha}$; $t_3 = \frac{V_m}{\beta}$ → ①

Total time between stops $T = t_1 + t_2 + t_3$

$$t_2 = [T - (t_1 + t_3)]$$

Distance between stops D = area of trapezium OABC

$$= \frac{1}{2}(OC + AB) \times V_m$$

∵ $T + t_2$ in sec

∵ $\frac{T+t_2}{3600}$ in hrs K

$$= \frac{1}{2}\frac{(T+t_2)}{3600} \times V_m$$

$$= \frac{1}{2}\left[\frac{T+(T-(t_1+t_3)}{3600}\right] \times V_m$$

$$= \frac{V_m}{7200}[2T - (t_1+t_3)]$$

$$\boxed{D = \frac{V_m}{7200}\left[2T - \left[\frac{V_m}{\alpha} + \frac{V_m}{\beta}\right]\right]} \to ②$$

∵ We known the value of t_1 & t_3

from Equation no '2'

$$\therefore D = \frac{V_m}{7200}\left[2T - V_m\left[\frac{1}{\alpha} + \frac{1}{\beta}\right]\right]$$

$$7200D = 2TV_m - V_m^2\left(\frac{1}{\alpha} + \frac{1}{\beta}\right) \to ③$$

$$\left(\frac{1}{\alpha} + \frac{1}{\beta}\right)V_m^2 - 2TV_m + 7200D = 0$$

∴ Put $\left[K = \frac{1}{\alpha} + \frac{1}{\beta}\right]$

$$\boxed{KV_m^2 - 2TV_m + 7200D = 0}$$

we known the Quadratic Equation

$$m = \frac{-b \pm \sqrt{b^2 - 4ac}}{2(a)}$$

Subsitute above Equation

$$V_m = \frac{2T \pm \sqrt{(2T)^2 - 4K \times 7200D}}{2K}$$

$$\therefore \boxed{V_m = \frac{T}{K} \pm \sqrt{\left(\frac{T}{K}\right)^2 - \frac{7200D}{K}}} \to ④$$

Again the Equation no '3'

$$7200D = 2TV_m - V_m^2\left(\frac{1}{\alpha}+\frac{1}{\beta}\right)$$

$$\frac{1}{\alpha}+\frac{1}{\beta} = \frac{2T\cancel{V_m}}{V_m^{\cancel{2}}} - \frac{7200D}{V_m^2}$$

$$\because V_a = \frac{D}{(T/3600)}$$

$$\therefore T = \frac{3600D}{V_a}$$

Subsituting 'T' in above Equation

$$\frac{1}{\alpha}+\frac{1}{\beta} = \frac{2\times3600D}{V_m\times V_a} - \frac{7200D}{V_m^2}$$

$$\boxed{\therefore \frac{1}{\alpha}+\frac{1}{\beta} = K = \frac{7200D}{V_m^2}\left[\frac{V_m}{V_a}-1\right]} \longrightarrow ⑤$$

* Quadrilateral Speed-time curve:— [Imp]

→ Quadrilateral Speed time Curve is a close approximation to the Urban and Suburban Services where Short distances are involved.

→ Now we develop the relationships between various quantities involved in Speed-time curve

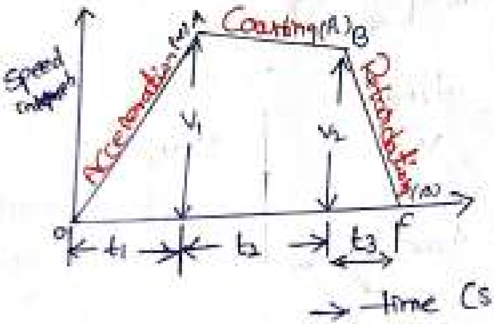
Let

V_1 = Speed at A in Kmph

V_2 : Speed at B in Kmph

β_c = Coasting retardation in kmphps

t_2 = Time of Coasting retardation in sec



$$\therefore t_1 = \frac{V_1}{\alpha}, \quad t_2 = \frac{V_1 \overset{+}{\bullet} V_2}{\beta c}, \quad t_3 = \frac{V_2}{\beta} \longrightarrow ①$$

Distance, D = Area of the quadrilateral OABC

$$= \frac{1}{2}\frac{t_1}{3600} \times V_1 + \frac{V_1 \mp V_2}{2} \times \frac{t_2}{3600} + \frac{1}{2}\frac{t_3}{3600} \times V_2$$

$$= \frac{V_1}{7200}(t_1 + t_2) + \frac{V_2}{7200}(t_2 + t_3) \qquad \left[\because T = t_1 + t_2 + t_3\right]$$

$$= \frac{V_1}{7200}(T - t_3) + \frac{V_2}{7200}(T - t_1)$$

$$= (V_1 + V_2)\frac{T}{7200} - \frac{1}{7200}(V_1 t_3 + V_2 t_1)$$

$$= (V_1 + V_2)\frac{T}{7200} - \frac{1}{7200}\left[V_1 \frac{V_2}{\beta} + V_2 \frac{V_1}{\alpha}\right]$$

$$= (V_1 + V_2)\frac{T}{7200} - \frac{V_1 V_2}{7200}\left(\frac{1}{\alpha} + \frac{1}{\beta}\right)$$

$$\boxed{\therefore D = \frac{1}{7200}\left[T(V_1 + V_2) - V_1 V_2\left(\frac{1}{\alpha} + \frac{1}{\beta}\right)\right]} \rightarrow ⑥$$

we known that $t_2 = \frac{V_1 - V_2}{\beta c}$

$$\therefore V_2 = V_1 - t_2 \beta c$$

$\because T = t_1 + t_2 + t_3$

$t_2 = T - (t_1 + t_3)$

$$\therefore V_2 = V_1 - \left[T - (t_1 + t_3)\right] \times \beta c$$

$$V_2 = V_1 - \left[T - \left(\frac{V_1}{\alpha} + \frac{V_2}{\beta}\right)\right] \times \beta c$$

$$= V_1 - \beta c T + \frac{V_1 \beta c}{\alpha} + \frac{V_2 \beta c}{\beta}$$

$$V_2 - \frac{V_2 \beta c}{\beta} = V_1\left(1 + \frac{\beta c}{\alpha}\right) - \beta c T$$

$$V_2\left(1 - \frac{\beta c}{\beta}\right) = V_1\left[1 + \frac{\beta c}{\alpha}\right] - \beta c T$$

$$V_2 = \frac{V_1\left(1 + \beta c/\alpha\right) - \beta c T}{\left[\frac{\beta - \beta c}{\beta}\right]}$$

$$\boxed{\therefore V_2 = \frac{\beta}{\beta - \beta c}\left[V_1\left(1 + \frac{\beta c}{\alpha}\right) - \beta c T\right]} \longrightarrow ⑦$$

Using Equation '6' and '7' we can Calculate D, V_1, V_2, α, β etc..

* **Problems on Speed-time Curve :—**

1. An electric train has an average speed of 45 kmph on level track between stops 1800 meters apart. It is accelerated at 2 kmphps and brakes at 3kmphps. Find its maximum speed assuming trapezoidal speed-time curve.

Sol Given data :—

$V_a = 45$ KmpH
$D = 1.8$ Km
$\alpha = 2$ Kmphps
$\beta = 3$ KmphPS
$V_m = ?$

$$V_a = \frac{D\times3600}{T}$$

$$45 = \frac{1.8\times3600}{T}$$

$$\therefore T = \frac{1.8\times3600}{45} = 144 \text{ sec}$$

$$K: \frac{1}{\alpha}+\frac{1}{\beta} = \frac{1}{2}+\frac{1}{3} = 0.8333$$

$$\therefore V_m = \frac{T}{K} - \sqrt{\left(\frac{T}{K}\right)^2 - \frac{7200}{K}}$$

$$= \frac{144}{0.8333} - \sqrt{\left(\frac{144}{0.833}\right)^2 - \frac{7200\times1.8}{0.8333}}$$

$$\therefore \boxed{V_m = 53.185 \text{ KmpH}}$$

//

A train has a Schedule Speed of 40 kmph between two Stops which are 4 Km apart. Determine the Crest Speed over the run if the duration of Stop is 60 Seconds and the acceleration and retardation are both Equal to 2 kmphps. Assume Trapezoidal Speed-time Curve.

*Sol: Given data:–

$V_s = 40 \text{ kmph}$

$D = 4 \text{ km}$

$t_s = 60 \text{ sec}$

$\alpha = \beta = 2 \text{ kmphps}$

$V_m = ?$

$$V_s = \frac{D \times 3600}{T + t_s}$$

$$40 = \frac{4 \times 3600}{T + t_s}$$

$$T + 60 = \frac{4 \times 3600}{40} = 360 \text{ Sec}$$

$$T = 360 - 60 = 300 \text{ sec}$$

$$\therefore K = \frac{1}{\alpha} + \frac{1}{\beta} = \frac{1}{2} + \frac{1}{2} = 1$$

$$\boxed{K = 1}$$

$$V_m = \frac{T}{K} \pm \sqrt{\left(\frac{T}{K}\right)^2 - \frac{7200 D}{K}}$$

$$= \frac{300}{1} \pm \sqrt{(300)^2 - 7200 \times 4}$$

$$= 300 - 247.38$$

$$\boxed{V_m = 52.61 \text{ kmph}}$$

3. The schedule speed and duration of stop of an Electric train are 30 kmph and 15 second i.e. The distance between stops in 900 mts. The Coasting and braking retardation are 0.15 kmphps and 2.5 kmphps i.e. of the Speed at the End of acceleration is 52 kmph. Determine the acceleration and duration of Coasting. [Assume Quadrilateral Speed-time Curve]

Sol Givendata:-

$V_s = 30$ kmph

$t_s = 15$ Sec

$D = 0.9$ km

$\beta_c = 0.15$ kmphps

$\beta = 2.5$ kmphps

$V_1 = 52$ kmph

$\alpha = ?$

$t_2 = ?$

$$(T + t_s) = \frac{D}{V_s} \times 3600$$

$$T = \frac{0.9 \times 3600}{30} - 15$$

$$T = 108 - 15 = 93 \text{ sec}$$

We known

$$V_2 = \frac{\beta}{\beta - \beta_c}\left[V_1\left(1 + \frac{\beta_c}{\alpha}\right) - \beta_c T\right]$$

$$= \frac{2.5}{2.5 - 0.15}\left[52\left(1 + \frac{0.15}{\alpha}\right) - 0.15 \times 93\right]$$

$$= 55.32 + \frac{8.2979}{\alpha} - 13.95 = 41.37 + \frac{8.2979}{\alpha}$$

We also know

$$D = \frac{1}{7200}\left[T(V_1+V_2) - V_1V_2\left(\frac{1}{\alpha}+\frac{1}{\beta}\right)\right]$$

Substituting V_2 & other value in above Equation

$$0.9 = \frac{1}{7200}\left[93\left(52+41.37+\frac{8.2979}{\alpha}\right) - 52\left(41.37+\frac{8.2979}{\alpha}\right)\left(\frac{1}{\alpha}+7.25\right)\right]$$

$$6480 = \left[8683.41 + \frac{771.7}{\alpha} - \frac{2151.24}{\alpha} - \frac{431.49}{\alpha^2} - 860.5 - \frac{172.6}{\alpha}\right]$$

$$-\frac{431.49}{\alpha^2} - \frac{1552.14}{\alpha} + 1342.91 = 0$$

$$1342.91\alpha^2 - 1552.14a - 431.49 = 0$$

$$\alpha^2 - 1.156\alpha - 0.32132 = 0$$

$$a = \frac{-b \pm \sqrt{b^2 - 4ac}}{2(a)}$$

$$\therefore a = \frac{1.156 \pm \sqrt{(1.156)^2 + 4(1)(0.32132)}}{2(1)}$$

$$a = \frac{1.156 \pm 1.619}{2}$$

$$\boxed{a = 1.388 \text{ Kmphps}}$$

Now $V_2 = 41.37 + \frac{8.2979}{1.388} = 47.348$ kmph

Coasting Period $t_2 = \frac{V_1 - V_2}{\beta c}$

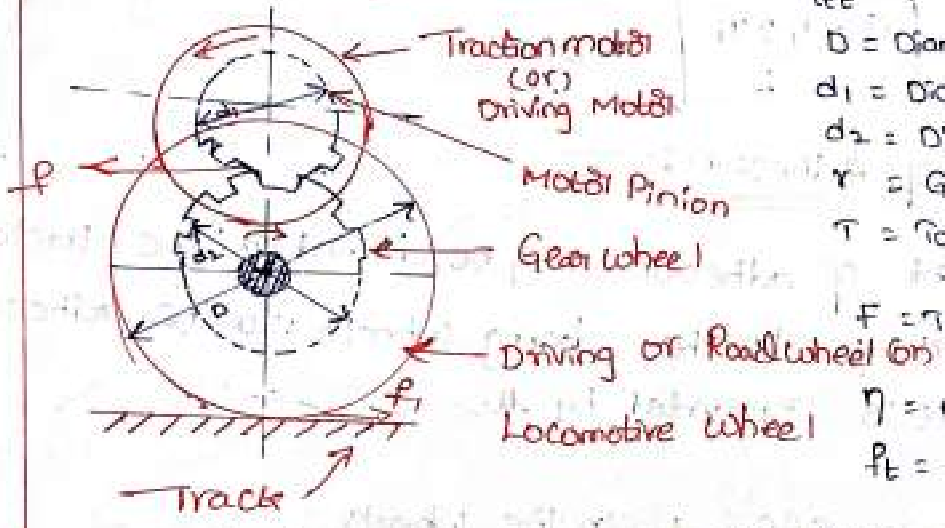
$$= \frac{52 - 47.348}{0.15}$$

$$\therefore \boxed{t_2 = 31 \text{ sec}}$$

UNIT-4

Electric Traction-2

* Mechanics of Train Movement :—



let

D = Diameter of driving wheel

d_1 = Diameter of Pinion

d_2 = Diameter of gear wheel

r = Gear ratio

T = Torque exerted by the traction motor

F = Tractive Effort at the pinion

η = Efficiency

F_t = Tractive Effort at the driving wheel/axle.

illustrates the transfer of Power from traction motor to the driving wheel.

-> The traction motor drives the pinion which meshes with gear wheel keyed to the driving axle.

-> The torque developed by the traction motor will be transmitted to the driving wheel through gear.

$$r = \frac{\text{speed of the motor pinion in rpm}}{\text{Speed of the driving axle in rpm}} = \frac{N_1}{N_2} = \frac{d_2}{d_1}$$

-> Torque at the edge of Pinion or motor $T = F \times \frac{d_1}{2}$ N-m

$$\therefore F = \left[T \frac{2}{d_1}\right] N$$

This tractive effort is transferred to gear wheel. So the tractive effort on driving wheel

$$F_t = \eta \times F \times \left[\frac{d_2}{D}\right] = \eta T \left[\frac{2}{d_1}\right] \times \frac{d_2}{D}$$

$$F_t = \eta \frac{T2[d_2/d_1]}{D}$$

$$\boxed{F_t = \eta \frac{2T_r}{D}}$$ newton

* Co-Efficient of Adhesion :—

The Coefficient of adhesion may be defined as "the tractive Effort needed to slip the driving wheels to the adhesive weight". It is represented by μ.

$$\mu = \frac{\text{Tractive Effort to slip the wheels}}{\text{Adhesive weight}} \quad (<1)$$

⇒ Adhesive weight :—

The weight of the train on the driving axles only is called adhesive weight.

* factors affecting the Coefficient of Adhesion :—

The value of Co-Efficient of adheson is affected by the following two factors.

→ Speed of the train

→ the Conditions of the rails.

The Higher the speed, smaller is the Co-Efficent of adhesion. If the rails are wet and greasy, the Co-Efficient of adheson is lower as Compared to when they are dry and sandy.

* Methods of Improving Coefficient of Adhesion :—

Methods of Improving Co-Efficient of adhesion :—

1. Torque developed by the driving motors should be Uniform
2. Driving wheels should be distributed over a much grater length.
3. Increasing the tractive Effort.

* Tractive Effort :—

⇒ force is required to move a vehicle from the rest position to moving condition. Depending on the load on the vehicle, track/road condition, fuel or electricity quality Etc.

"Tractive Effort is the force developed by the traction motors at the wheel rims to move the train."

* Expression for Tractive Effort :—

1. To over come the linear and angular acceleration of the train on level track
2. To over come the frictional Resistance and wind resistance to the motion.
3. To over come the gravitation force.

* Tractive Effort during Acceleration [f_a] :—

According to Newton's secound law of motion

Acceleration force = mass of the body × Acceleration

$$\boxed{f_a = (1000\,W) \times \frac{\alpha \times 1000}{3600} = 277.8\,W\alpha \text{ newton}}$$

this force is sufficient to give linear motion train with stationary Parts. for angular acceleration moment of inertia of the rotating Parts will be Consi

∴ The Effective, or acceleration mass of the train

$$W_e = W + W'$$

W' = Effect of rotational inertia

$$\boxed{F_a = 277.8 W_e \alpha} \text{ newton}$$

* Tractive Effort to overcome train Resistance [Fr] :—

Tractive effort is needed to balance the resistance to motion of the train. the train Resistance depends upon various factors and is difficult to analyse.

Train Resistance is due to
(a) friction at the track
(b) friction at various Parts of rolling stock
(c) air Resistance.

$$\boxed{F_r = W r} \text{ newton}$$

* Tractive Effort to overcome the Gravitational Pull [Fg]:-

When the train is moving on up-gradient.

θ = Inclination of gradient

W = train mass (tonne)

The train mass W can be Resolved into Wcosθ & W sinθ

The Wcosθ is perpendicular to direction of motion of the train and it has no effect on its motion.

The WSinθ opposes the motion of the train

dry and rainy

Tractive Effort During Acceleration [f_a] :—

Tractive Effort – (f_t)
[$\therefore f_t = f_a + f_r + f_g$]

According to Newton's Secound law of motion

Accelerating force = mass of the Body × Acceleration

$$f_a = (1000W) \times \frac{\alpha \times 1000}{3600}$$

$$\boxed{f_a = 277.8 W\alpha \text{ newton}}$$

W = mass of the train in ton

f_a = tractive force/Effort for accelerating the train

α = acceleration in kmphps.

* Tractive Effort to overcome train Resistance [f_r] :—

Tractive Effort is needed to balance the resistance to motion of the train.

Train Resistance is due to (a) friction at the track
(b) friction at various Parts of rolling stock

r = train Resistance in newton/tonne

$$\boxed{f_r = Wr} \text{ newton.}$$

* Tractive Effort to overcome the Gravitational Pull :- [f_g]

When the train is moving on an up-gradient

θ = inclination of gradient

W = train mass (tonne)

the train mass is Can be Resolved into Wcosθ and Wsinθ

The Wcosθ is the Perpendicular direction of motion of the train and it has no Effect on motion.

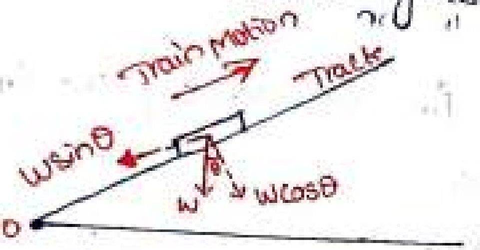
But Wsinθ opposes the motion of the train

In order to overcome this opposition, an additional tractive Effort required

$$f_g = 1000W \times 9.81 \sin\theta \text{ newton}$$

In railway department, gradient is expressed in terms of the distance to rise of 1metre or terms of rise per 100m of track.

let G = Percent gradient of the track.



Gravitational force

$$\sin\theta = \frac{\text{Elevation}}{\text{Distance along track}} = \frac{G}{100}$$

$$\boxed{\therefore G = 100 \sin\theta}$$

$$\boxed{f_g = 1000W \times 9.81 \times \frac{G}{100} = 98.1WG} \text{ newton}$$

⇒ Net tractive Effort (f_t)

$$f_t = f_a + f_r \pm f_g$$

(+) → Positive sign should be considered for up gradient motion

(−) → negative sign considered for down gradient motion

(10m)

$$\boxed{\therefore F_t = 277.8W_e\alpha + Wr \pm 98.1WG} \text{ newton}$$

* Methods of Improving Coefficient of Adhesion:—

1. Torque developed by the driving motors should be uniform
2. Driving wheels should be distributed over a much Greater length
3. Increasing the tractive Effort.

str

*** Tractive Effort:—** Tractive Effort is the force developed by the traction motors at the wheel rims to move the train.

NG ELECTRICAL E

Off Peak Loads- Use of Exhaust Steam,

Comparison of Private Plant and Public Supply

oblems on Tractive Effort :—

An Electric train weights 250 tonne is to be accelerated up gradient of 1 in 80 at an acceleration of 1.2 kmphps The Effect of rotational inertia and train Resistance are 10% of dead weight and 40 newton per tonne ie; find the tractive Effort.

Sol Given data :—

$W = 250$ tonne

$G = \frac{1}{80} \times 100 = 1.25$

$\alpha = 1.2$ kmphps

$W_e = 1.1W = 275T$

$r = 40$ N/tonne

$F_t = ?$

$$F_t = 277.8 W_e \alpha + W r + 98.1 WG$$

$$= 277.8 \times 275 \times 1.2 + 250 \times 40 + 98.1 \times 250 \times 1.25$$

$$\boxed{F_t = 132330.25}$$ newton

2. A train with an electric locomotive weight 300 tonne. The train attains a maximum speed of 50 kmph. in 25 second up a gradient of 1 in 150. The frictional resistance and rotational inertia are 50 newton / tonne and 10% of train weight respectively. find the tractive Effort required.

Sol Given data :—

$W = 300T$

$V_m = 50$ kmph

$t_1 = 25\,S$

$G = 1/_{150} \times 100 = \frac{2}{3}$

$r = 50$ N/tonne

$W_e = 1.1\,W$

$F_t = ?$

$$\alpha = \frac{V_m}{t_1} = \frac{50}{25} = 2 \text{ kmphps}$$

$$F_t = 277.8\,W_e\,\alpha + Wr \pm 98.1\,WG$$

$$= 277.8 \times 1.1 \times 300 \times 2 + 300 \times 50 + 98.1 \times 300 \times \left[\frac{2}{3}\right]$$

$$\boxed{F_t = 217968} \text{ Newton}$$

Problem on Coefficient of Adhesion & Power Transmission :—

1. A 500-tonne goods train is to be hauled by a locomotive up a gradient of 2% with an acceleration of 1.2 kmphps. Coefficient of adhesion is 25%, track resistance 40 N/tonne and Effect of rotating masses 10% of dead weight. Find the weight of locomotive and the number of axles if axle load is not to Exceed 21 tonnes.

Sol Given data :-

$W = (500 + W_L)$

$G = 2$

$\alpha = 1.2$ kmphps

$\mu = 0.25$

$r = 40$ N/T

$W_L = ?$

axles = ?

UNIT -5

ZING ELECTRICAL ENERGY

Use of Exhaust Steam, Waste

Plant and Public Supply.

$W_c = 1.1(500 + W_L)$

load/axle = 21 T

$F_t = 277.8 W_e \alpha + W r + 98.1 W G$

$= 277.8 \times 1.1(500 + W_L)1.2 + (500 + W_L) \times 40 + 98.1(500 + W_L) \times 2$

$= (500 + W_L)(277.8 \times 1.1 \times 1.2 + 40 + 98.1 \times 2$

$F_t = 602.9(500 + W_L)$ newton

$F_t = \frac{602.9(500 + W_L)}{9.81 \times 1000} = 0.0614576(500 + W_L)$ tonne

$\mu = \frac{F_t}{W_L}$

$0.25 = \frac{0.0614576(500 + W_L)}{W_L}$

$0.25 W_L = 30.7288 + 0.0614576 W_L$

$0.1885424 W_L = 30.7288$

$W_L = \frac{30.7288}{0.1885424}$

$\boxed{W_L = 162}$ tonne

Number of Axles $= \frac{W_L}{21} = \frac{163}{21} = 8$ //

* Specific Energy Consumption :—

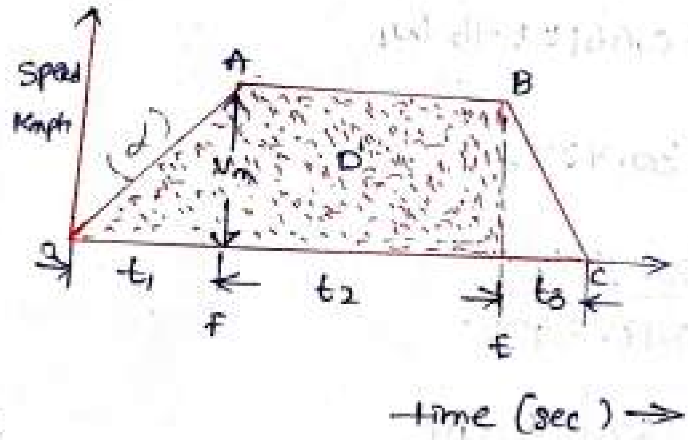
Specific Energy Consumption is defined as "the Energy Cons of train in (W-h) to the weight of the train in (tonne) and distance of run in (km)

∴ Specific Energy Consumption = $\frac{\text{Energy Consumption of Train in watt-hours}}{\text{weight of the train in tonne} \times \text{distance of run in km}}$

∴ Specific Energy output $\boxed{E_0 = \frac{E_t}{W\,D}}$ wh/tonne-km

* Determination of Specific Energy Consumption using a Simplified Speed time Curve :—

Consider a trapezoidal Speed-time curve as shown in fig



Let

E_a = Specific Energy output during acceleration

E_r = Specific Energy output to run against resistance

E_g = Specific Energy output to run against gravitation nergy output to accelerate the train from rest to a speed of V_m.

E_a = Power × time
= force × distance

$E_a = F_a \times$ area, OAF $\therefore [t_1 = \frac{V_m}{\alpha}]$

$$E_a = 277.8 W_e \alpha \left[\frac{1}{2} t_1 \times \frac{V_m}{3600} \times 10^3\right] \text{ N-m or wattsecond}$$

$$E_a = 277.8 W_e \cancel{\alpha} \left(\frac{1}{2} \times \frac{V_m}{\cancel{\alpha}} \cdot \frac{V_m}{3600} \times 10^3\right) \times \frac{1}{3600} \text{ watt-hour}$$

$$\Rightarrow \boxed{E_a = 0.01072 W_e V_m^2} \text{ watt hour.}$$

$E_r = F_r \times$ distance over which Power remains on i.e., area OABE (Shaded area D' km]

$$= F_r \times (D' \times 10^3) \text{ N-m (or) watt-secound}$$

$$= W_r \times \frac{D' \times 1000}{3600} \text{ watt-hour}$$

$$\boxed{E_r = 0.2778 W_r D'} \text{ watt-hour}$$

$$E_g = F_g \times (D' \times 10^3) \text{ N-m or watt-secound}$$

$$= 98.1 WG \times \left[\frac{D' \times 1000}{3600}\right] \text{ watt-hour}$$

$$\boxed{E_g = 27.25 WGD'} \text{ watt-hour}$$

Total Energy output $E_t = E_a + E_r + E_g$

$$\boxed{E_t = 0.01072 W_e V_m^2 + 0.2778 W_r D' \pm 27.25 WGD'} \text{ W-hr}$$

Specific Energy output $E_o = \frac{E_t}{WD}$ Wh/tonne-km

$$E_o = \frac{0.01072 W_e V_m^2}{WD} + \frac{0.2778 W r D'}{WD} \pm \frac{27.25 WGD'}{WD}$$

$$E_o = \frac{0.01072 V_m^2}{D}\cdot\frac{W_e}{W} + \frac{0.2778 rD'}{D}\cdot\frac{\cancel{W}}{\cancel{W}} \pm \frac{27.25 GD'}{D}\frac{\cancel{W}}{\cancel{W}}$$

$$E_o = \frac{0.01072 V_m^2}{D}\cdot\frac{W_e}{W} + 0.2778 r\cdot\frac{D'}{D} \pm 27.25 G.\frac{D'}{D} \text{ Wh/tonne-km}$$

If track is level [G = 0] then

$$E_o = \frac{0.01072 V_m^2}{D}\cdot\frac{W_e}{W} + 0.2778 r\frac{D'}{D} \pm \underbrace{27.25 \times 0 \times \frac{D'}{D}}_{0}$$

neglect hole-term

$$\boxed{\therefore E_o = \frac{0.01072 V_m^2}{D}\cdot\frac{W_e}{W} + 0.2778 r\frac{D'}{D}}$$ Wh/tonne-km

Specific Energy Consumption = $\frac{\text{Specific Energy output}}{\text{Overall Efficiency of traction motor \& gearing}}$

$$\boxed{\text{Speific Energy Consumption} = \frac{0.01072 V_m^2}{D\times\eta_t}\cdot\frac{W_e}{W} + \frac{0.2778 r}{\eta_t}\times\frac{D'}{D}}$$

Wh/tonne-km

blems on Specific Energy Consumption :—

The average Speed of a Electric train is 40kmph on a level track between two stops of 2.5 km. Determine the Specific Energy Consumption if the acceleration and retardations are 2 kmphps and 3.1 kmphps. Take the rotational inertia as 12%& track resistance as 60 newton per ton and overall Efficiency 88%. [redacted]

Sol Given data :—

$V_a = 40$ Kmph

$D = 2.5$ km

$\alpha = 2$ kmphps

$\beta = 3.1$ Kmphps

$W_e = 1.12 W$

$r = 60$ N/ton

$\eta_t = 88\%$

sp Energy = ?

$$T = \frac{D}{V_a} = \frac{2.5}{40} \times 3600 = 225 \text{ sec}$$

$$K = \frac{1}{\alpha} + \frac{1}{\beta} = \frac{1}{2} + \frac{1}{3.1} = 0.8223$$

$$V_m = \frac{T}{K} \pm \sqrt{\left(\frac{T}{K}\right)^2 - \frac{7200D}{K}}$$

$$= \frac{225}{0.8225} \pm \sqrt{\frac{(225)^2}{0.8223} - \frac{7200 \times 2.5}{0.8223}} = 273.53 \pm 230.07$$

$$\boxed{V_m = 43.45} \text{ Kmph}$$

$t_1 = \frac{V_m}{\alpha} = \frac{43.15}{2} = 21.725$ sec

$t_3 = \frac{V_m}{\beta} = \frac{43.45}{3.1} = 14.016$ sec

$\boxed{T = t_1 + t_2 + t_3}$

$\therefore t_2 = T - (t_1 + t_3)$

$= 225 - (21.75 + 14.016)$

$\boxed{t_2 = 189.26}$ sec

$= 2.5 - \frac{1}{2}\frac{t_3 V_m}{3600}$

$D' = 2.5 -$ area BCE

$= 2.5 - \frac{1}{2} \times \frac{14.016}{3600} \times 43.45$

$\boxed{D' = 2.415 \text{ Km}}$

Specific Energy Consumption on level track =

$$\frac{0.01072 V_m^2}{D \eta_t} \cdot \frac{W_e}{W} + \frac{0.2778 \gamma}{\eta_t} \times \frac{D'}{D} \text{ W-h/T-km}$$

$$= \frac{0.01072 (43.45)^2}{2.5 \times 0.88} \times \frac{1.12W}{W} + \frac{0.2778 \times 60}{0.88} \times \frac{2.415}{2.5}$$

$= \underline{\underline{28.6}}$ watt-hour/ton-km

tors Affecting the Specific Energy Consumption:—

For a given Schedule Speed, the factors which affects the Specific Energy Consumption are as follows:—

*** Distance between Stops:—**

The Greater the distance between stops the lesser will be the specific Energy Consumption.

*** Acceleration and Retardation:—**

Higher the acceleration and retardation lower the Specific Energy Consumption since, a longer Coasting Period Can be obtained for a Smaller Period of supply on.

There is a lower limit of acceleration for sub-urban Servi below which the Energy Consumption is High.

*** Train Resistance:—**

In General, higher the train Resistance higher will be the Specific Energy Consumption.

*** Gradient:—**

Higher the up-gradients, more the Specific Energy Consumption, Even through the Part of Energy is feed back during Regenerative Braking.

*** Type of train Equipment:—**

Efficient train Equipment will reduce the specific Energy Consumption

* Maximum Speed :— Specific Energy Consumption increases with increase in maximum speed beyond Critical value!

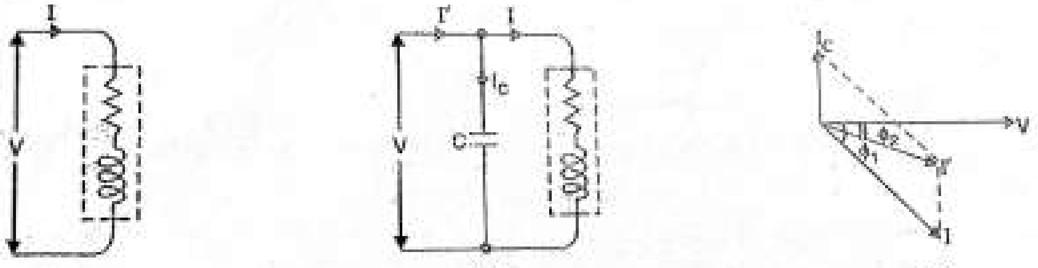
UNIT -5

ECONOMIC ASPECTS OF UTILIZING ELECTRICAL ENERGY

Power Factor Improvement, Load Factor improvement, Off Peak Loads- Use of Exhaust Steam, Waste Heat recovery, Pit Head Generation, Diesel Plant, General Comparison of Private Plant and Public Supply- Initial Cost and Efficiency, Capitalization of Losses, Choice of Voltage

❖ Power factor improvement :-

The low power factor is mainly due to the fact that most of the power loads are inductive and, therefore, take lagging currents. In order for Power Factor Improvement Methods, some device taking leading power should be connected in parallel with the load. One of such devices can be a capacitor. The capacitor draws a leading current and partly or completely neutralizes the lagging reactive component of load current. This raises the power factor of the load.



(i) (ii) (iii)

Fig. 6.3

The capacitor C is connected in parallel with the load. The capacitor draws current I_c which leads the supply voltage by 90˚. The resulting line current I' is the phasor sum of I and I_C and its angle of lag is Φ_2 as shown in the phasor diagram of Fig. 6.3. (iii). It is clear that Φ_2 is less than Φ_1, so that cos Φ_2 is greater than cos Φ_1. Hence, the power factor of the load is improved.

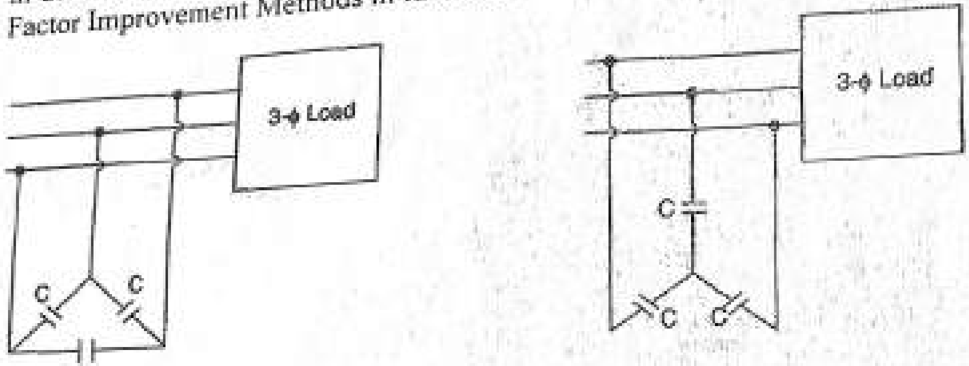
❖ Power Factor Improvement Methods (or) Equipment:

Normally, the power factor of the whole load on a large generating station is in the region of 0.8 to 0-9. However, sometimes it is lower and in such cases it is generally desirable to take special steps to to improve power factor.

This can be achieved by the following equipment :

1. **Static capacitors.**
2. **Synchronous condenser.**
3. **Phase advancers.**

1.Static capacitor: The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor (generally known as static capacitor) draws a leading current and partly or completely neutralises the lagging reactive component of load current. This raises the power factor of the load. For three-phase loads, the capacitors can be connected in delta or star as shown in Fig. 6.4. Static capacitors are invariably used for Power Factor Improvement Methods in factories



(*i*)

(*ii*)

Fig. 6.4

Advantages

- They have low losses.
- They require little maintenance as there are no rotating parts.
- They can work under ordinary atmospheric conditions.

Disadvantages

- They have short service life ranging from 8 to 10 years.
- They are easily damaged if the voltage exceeds the rated value.
- Once the capacitors are damaged, their repair is uneconomical.

2.Synchronous condenser: A synchronous motor takes a leading current when over-excited and, therefore, behaves as a capacitor. An over-excited synchronous motor running on no load is known as **synchronous condenser**.

When such a machine is connected in parallel with the supply, it takes a leading current which partly neutralizes the lagging reactive component of the load. These are the power factor improvement techniques.

① parallel
② capacitor

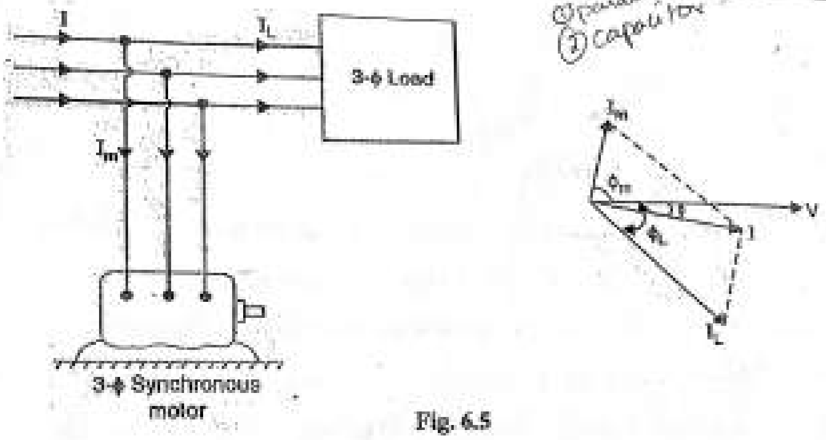


Fig. 6.5

shows the Power Factor Improvement Methods by synchronous condenser method. The 3Φ load takes current I_L at low lagging power factor cos I_L. The synchronous condenser takes a current I_m which leads the voltage by an angle Φ_m. The resultant current I is the phasor sum of I_m and I_L and lags behind the voltage by an angle Φ. It is clear that Φ is less than Φ_L, so that cos Φ is greater than cos Φ_L. Thus the power factor is increased from cos Φ_L to cos Φ. Synchronous condensers are generally used at major bulk supply substations for Power Factor Improvement Methods.

Advantages

- By varying the field excitation, the magnitude of current drawn by the motor can be changed by any amount. This helps in achieving stepless control of power factor.
- The motor windings have high thermal stability to short circuit currents.
- The faults can be removed easily.

Disadvantages

- There are considerable losses in the motor.
- The maintenance cost is high.
- It produces noise.
- Except in sizes above 500 kVA, the cost is greater than that of static capacitors of the same rating
- As a synchronous motor has no self-starting torque, therefore, an auxiliary equipment has to be provided for this purpose.

Note. The reactive power taken by a synchronous motor depends upon two factors, the d.c. field excitation and the mechanical load delivered by the motor.

Maximum leading power is taken by a synchronous motor with maximum excitation and zero load.

3.PHASEADVANCER

Phase advancer is a simple AC exciter which is connected on the main shaft of the motor andoperates with the motor's rotor circuit for power factor improvement. Phase advancer is used toimprove the power factor of induction motor in industries. As the stator windings of induction motortakes lagging current 90° out of phase with Voltage, therefore the power factor of induction motor islow.Iftheexcitingampere-turnsareexcitedbyexternalACsource,thentherewouldbenoeffectof excitingcurrentonstatorwindings.Thereforethepowerfactorofinductionmotorwillbeimproved.ThisprocessisdonebyPhaseadvancer.

Advantages:

- Lagging kVAR (Reactive component of Power or reactive power) drawn by the motor is sufficientlyreducedbecausethe excitingampereturns aresuppliedat slipfrequency(fs).
- Thephase advancercanbeeasilyusedwheretheuseofsynchronousmotors isUnacceptable

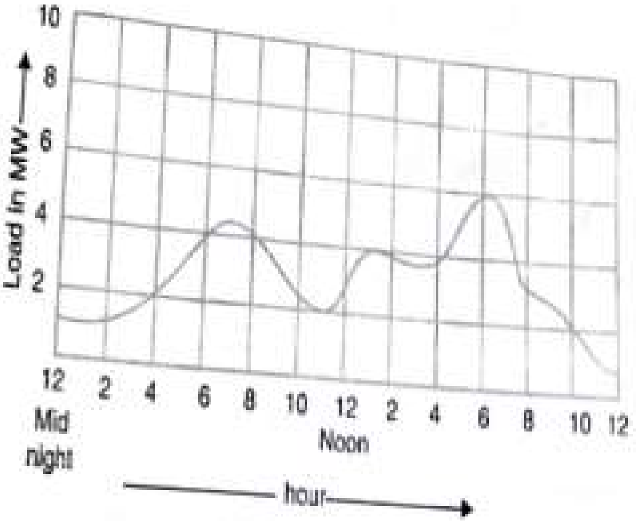
Disadvantage:

UsingPhaseadvancerisnoteconomicalformotorsbelow200H.P.(about150kW)

❖ IMPROVEMENTOFLOADFACTOR

Increasing your load factor will diminish the average unit cost (demand and energy) of thekWh. Depending on your situation, improving your load factor could mean substantial savings.

Theloadfactorcorrespondstotheratiosbetweenyouractualenergyconsumption(kWh)andthemaximumpower recorded(demand) forthat periodof time.



$$\text{Load Factor} = \frac{\text{Average Load}}{\text{Maximum Load}}$$

$$\text{Load Factor} = \frac{\text{Energy Generated in the Given Period}}{\text{Maximum Load X Hours of Operation}}$$

By analyzing your load profile and your needs, you may be able to improve your load factor by doing the following:

A–Demand reduction

Reduce demand by distributing your loads over different time periods.

B–Increase production

Keeping the demand stable and increasing your consumption is often a cost-effective way to increase production while maximizing the use of your power.

*In both cases, the load factor will improve and therefore reduce your average unit cost per kWh.The load factor percentage is derived by dividing the total kilo watt-hours(kWh) consumed in a designated period by the product of the maximum demand in kilowatts(kW) and the number of hours in the period. In the example below,the monthly kWh consumption is 36,000 and the peak demand is100kW. There were 30 days in the billing period.

❖ OFF-PEAKLOADS

Peak demand is considered to be the opposite to off-peak hours when power demand isusually low. There are off-peak time-of-use rates. Sometimes, there are 3 time-of-use zones: peak,shoulder and offpeak. Shoulder is often the time between peak and offpeak in weekdays. Weekendsare often just peak and off peak in terms of managing electricity loads for the network. The peakdemandofaninstallation orasystemissimplythehighestdemandthathasoccurredoveraspecified timeperiod . Peakdemand is typicallycharacterized as annual, daily or seasonal and hastheunitofpower.Peakdemand, peakload or on-peak aretermsusedin energydemandmanagement describing a period in which electrical power is expected to be provided for a sustainedperiodata significantly higher thanaveragesupplylevel.

Peakdemandfluctuations mayoccurondaily,monthly,seasonalandyearlycycles.Foran electric utility company, the actual point of peak demand is a single half-hour or hourly periodwhich represents the highest point of customer consumption of electricity. At this time there is acombination of office, domestic demand and at some times of the year, the fall of darkness. Someutilities will charge customers based on their individual peak demand. The highest demand duringeach month or even a single 15 to 30 minute period of highest use in the previous year may be usedtocalculatecharges.

❖ USE OF EXHAUST STEAM:

Steam condenser is a device in which the exhaust steam from steam turbine is condensed bymeans of cooling water. The main purpose of a **steam condenser in turbine** is to maintain a low back pressure on the exhaust side of the steam turbine. After releasing from nozzles, the steam has toexpand to a great extent for converting available energy into it to usable mechanical work. So, if thesteam after doing its, work, does not get condensed, it will not give required space to other steambehind it, to expand to its required volume. Condensation of steam in a closed system, creates anemptyplacebyreductionofvolumeofthelowpressuresteam.Itisfoundthat,1Kgofdrysteamat $1.033 kg/cm^2$absolutepressurehasavolumeof$1.673 m^3$whenitiscondensedintowater at100°Cin a steam condenser, its volume becomes $0.001044\ m^3$. The volume of

ElementsofSteamCondenser

Asteam condensingplantorsimplysteamcondenserconsistsof

1. Condenserchamber–where steamgetscondensed.
2. Coolingwatersupply– whichprovidescoldwaterto condensesteambyheatexchanging.
3. Wet Air pumps – They collect condensed steam, the air and un-condensed water vapour andgases fromcondenser.
4. Hot well in which the condensed steam is collected and from it steam boiler feed water may betakenifrequired.

Typesof Steam Condenser

In a steam condenser, steam is always condensed with help of cooling water, but the techniques aredifferent for different condensers. Depending upon condensation techniques, there are mainly twotypesofsteamcondensers.Theyaremainly

1. JetSteamCondenser.2.SurfaceSteamCondenser

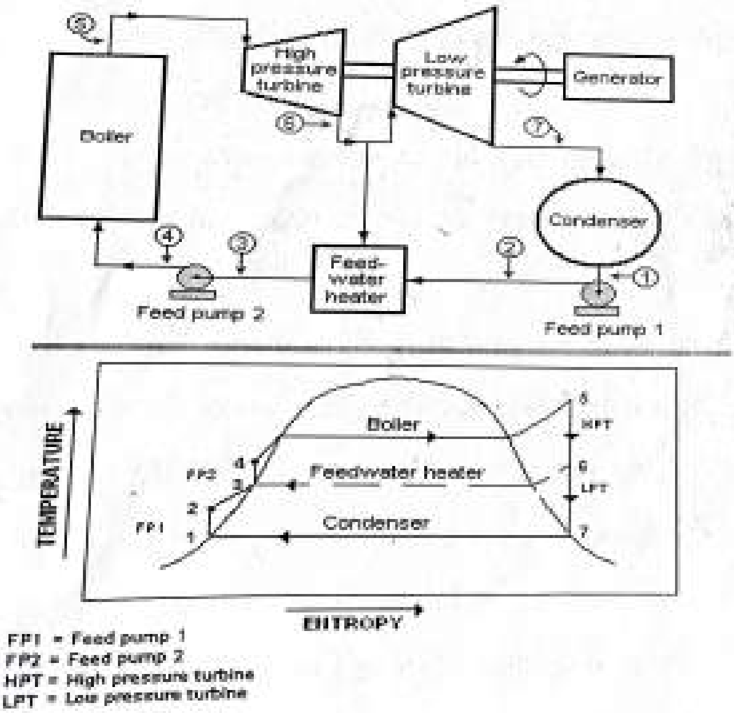


Fig.5.1.LayoutofSteamCondenser

❖ WASTEHEAT RECOVERYUNIT

A waste heat recovery unit (WHRU) is an energy recovery heat exchanger that recovers heat from hot streams with potential high energy content, such as hot flue gases from a diesel generator orsteam from cooling towers or even waste water from different cooling processes such as in steelcooling.

Heatrecoveryunits

Waste heat found in the exhaust gas of various processesor even from the exhaust stream of a conditioning unit can be used to pre heat the incoming gas. This is one of the basic methods for recovery of waste heat.Many steel making plants use this process as an economic method to increase the production of the plant with lower fuel demand. There are many different commercial recovery units for the transferring of energy from hot medium space to lower one:

1. Recuperators: This name is given to different types of heat exchanger that the exhaust gasesare passed through, consisting of metal tubes that carry the inlet gas and thus preheatingthe gas before entering the process. The heat wheel is an example which operates on thesameprinciple asasolarair conditioning unit.
2. Regenerators: This is an industrial unit that reuses the same stream after processing. In thistypeof heat recovery,theheat is regeneratedandreused inthe process.
3. Heat pipe exchanger: Heat pipes are one of the best thermal conductors. They have theability to transfer heat hundred times more than copper. Heat pipes are mainly known inrenewable energy technology as being used in evacuated tube collectors. The heat pipe ismainlyusedinspace,processorairheating,inwasteheatfromaprocessisbeingtransferredtothesurroundingdue toitstransfermechanism.
4. Thermal Wheel or rotary heat exchanger: consists of a circular honeycomb matrix of heatabsorbing material, which is slowly rotated within the supply and exhaust air streams of anairhandlingsystem.

5. Economizer: In case of process boilers, waste heat in the exhaust gas is passed along arecuperator that carries the inlet fluid for the boiler and thus decreases thermal energyintakeof theinletfluid.
6. Heat pumps: Using an organic fluid that boils at a low temperature means that energy couldbe regeneratedfromwastefluids.
7. Run around coil: comprises two or more multi-row finned tube coils connected to each other by a pumped pipe work circuit.

❖ DIESEL POWER PLANT :-Layout Of Diesel Power Plant

Diesel power plants produce power from a diesel engine. Diesel electric plants in the range of 2 to 50 MW capacities are used as central stations for small electric supply networks and used as astandby to hydroelectric or thermal plants where continuous power supply is needed. Diesel powerplant is not economical compared to other power plants.The diesel power plants are cheaply usedinthefieldsmentioned below.

1 .Mobileelectricplants

2.Standbyunits

3.Emergencypowerplants

4.Startingstationsofexistingplants

5.Centralpowerstationetc.

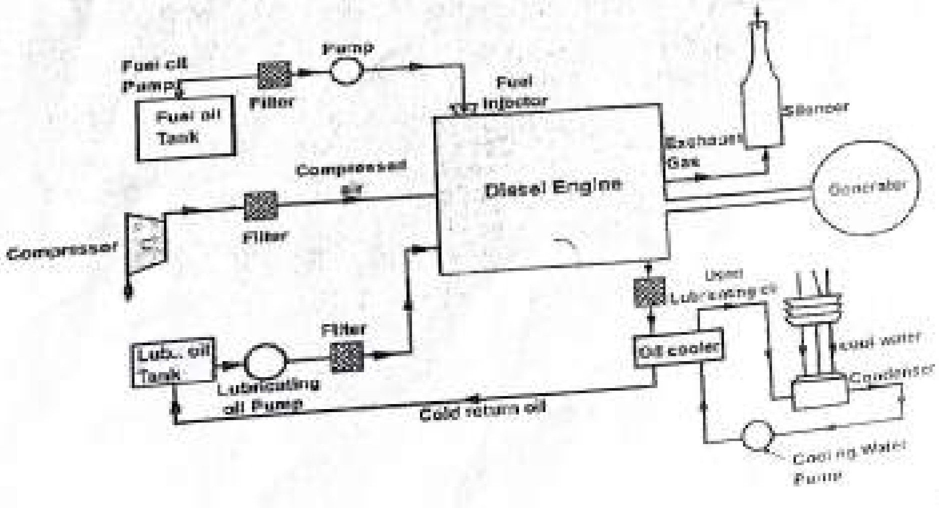


Figure shows the arrangements of the engine and its auxiliaries in a diesel power plant. The major Components of the diesel power plant are:

1)**Engine:-**

Engine is the heart of a diesel power plant. Engine is directly connected through a gear box to thegenerator.Generally two-stroke engines are used for power generation.Now a days ,advanced super & turbo charged high speed engines are available for power production.

2)**Airsupplysystem:-**

Air inlet is arranged outside the engine room. Air from the atmosphere is filtered by air filter and conveyed to the inlet manifold of engine. In large plants super charger/turbocharger is used for increasing the pressure of input air which increases the power output.

3)**ExhaustSystem:-**

This includes the silencers and connecting ducts. The heat content of the exhaust gas is utilized in a turbine ina turbocharger to compress the air input to the engine.

4)**FuelSystem:-**

Fuel is stored in a tank from where it flows to the fuel pump through a filter. Fuel is injected to theengine as pertheload requirement.

5)**Coolingsystem:-**

This system includes water circulating pumps, cooling towers, water filter etc.Cooling water is circulated through the engine block to keep the temperature of the engine in the safe range.

6)**Lubricatingsystem:-**

Lubrication system includes the air pumps, oil tanks, filters, coolers and pipe lines. Lubricant is given to reduce friction of moving parts and reduce thewear and tear of the engine parts.

7)StartingSystem:-

There are three commonly used starting systems,they are;

1) A petrol driven auxiliary engine
2) Use of electric motors.
3) Use of compressed air from an air compressor at a pressure of 20Kg/cm.

8) Governingsystem:-

The function of a governing system is to maintain the speed of the engine constant irrespective of load on the plant.This is done by varying fuel supply to the engine according to load.

Advantages

Diesel power plants can be quickly installed and

commissioned.Quick starting.

Disadvantages

Capacity of plant is low.

Fuel,repair and maintenance cost are high.

Life of plant is low compared to steam power plant.

THEEND