AUM SAI INSTITUTE OF TECHNICAL EDUCATION

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DEPARTMENT OF ELECTRICAL ENGINEERING

UTILIZATION OF ELECTRICAL ENERGY

&

TRACTION

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Lecture Note

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CONTENT

CHAPTER-1

Electrolytic Process

DEFINATION OF ELECTROLYTIC PROCESS

Electrolysis can be defined as a chemical process in which the bonded elements and compounds are dissociated by passing a direct electric current. This process is mainly used for separating the materials.

For example: The electrolysis of water.
In this process, water molecule is decomposed by passing an electric current to give hydrogen and oxygen gas. The reaction taken place in this chemical process is

$2H_2O$ + energy ----> $2H_2 + 2O_2$

ELECTRO DEPOSITION:

It is a process of coating a thin layer of one metal on top of a different metal to modify its surface properties, by donating electrons to the ions in a solution. This bottom-up fabrication technique is versatile and can be applied to a wide range of potentialapplications.

The process used in electroplating is called electrodeposition

Electroplating is a process that uses an electric current to reduce dissolved metal cations so that they form a thin coherent metal coating on an electrode.

Electroplating involves passing an electric current through a solution called an electrolyte. This is done by dipping two terminals called electrodes into the electrolyte and connecting them into a circuit with a battery or other power supply.

The electrodes and electrolyte are made from carefully choosen elements or compounds. When the electricity flows through the circuit they make, the electrolyte splits up and some of the metal atoms it contains are deposited in a thin layer on top of one of the electrodes—it becomes electroplated.

Faraday's Laws of Electrolysis

It states that the chemical deposition due to the flow of current through an electrolyte is directly proportional to the quantity of electricity (coulombs) passed through it.
i.e. mass of chemical deposition:

$$m \propto Quantity\ of\ electricity,\ Q \Rightarrow m = Z.Q$$

Where, Z is a constant of proportionality and is known as electro-chemical equival If we put Q = 1 coulombs in the above equation, we will get Z = m which implies that electrochemical equivalent of any substance is the amount of the substance deposited on the passing of 1 coulomb through its solution. This constant of the passing of electrochemical equivalent is generally expressed in terms of milligrams per coulomb or kilogram per coulomb. ent of the substance.

Faraday's second law of electrolysis:

It states that, when the same quantity of electricity is passed through several electrolytes, the mass of the substances deposited are proportional to their respective chemical equivalent or equivalent weight.

Chemical Equivalent or Equivalent Weight

- The chemical equivalent or equivalent weight of a substance can be determined by **Faraday's laws of electrolysis**, and it is defined as the weight of that subtenancy which will combine with or displace the unit weight of hydrogen.

- The chemical equivalent of hydrogen is, thus, unity. Since valency of a substance is equal to the number of hydrogen atoms, which it can replace or with which it can combine, the chemical equivalent of a substance, therefore may be defined as the ratio of its atomic weight to its valency.

$$Thus\ chemical\ equivalent = \frac{Atomic\ weight}{Valency}$$

Definations

Current efficiency:

Current efficiency is the ratio of the actual mass of a substance liberated from an electrolyte by the passage of current to the theoretical mass liberated according to Faraday's law. Current efficiency can be used in measuring electrodeposition thickness on materials in electrolysis

Energy Efficiency

On account of secondary reactions, the voltage actually required for the deposition or liberation of metal is higher than the theoretical value which increases the actual energy required.
Energy efficiency is defined as Theoretical Energy/ Actual Energy Required

Principle of Electro deposition:

FACTOR EFFECTING THE AMOUNT OF ELECTRO DEPOSITION:

1. Nature of Electrolyte:

The formation of smooth deposit largely depends upon the nature of electrolyte employed. The electrolyte from which complex ions can be obtained, such as cyanides, provides a smooth deposit.

2. Current Density

Electrodeposition depends upon the rate at which crystals grow and the rate at which fresh nuclei are formed, therefore, at low current densities the deposits are coarse and crystalline in nature.

The deposit of metal will be uniform and fine-grained if the current density is used at rate higher than that at which the nuclei are formed.

3. Temperature:

A low temperature of the solution favours formation of small crystals of metal; and a high temperature, large crystals. In some cases this is very marked, a difference of only 15°C resulting in a 50% decrease in strength of the metal deposited.

4. Conductivity:

The use of a solution of good conductivity is important from the standpoint of view of economy in power consumption and also because it reduces the tendency to form trees and rough deposits.

5. Electrolytic Concentration:

Higher current density, which is necessary to obtain uniform and fine-grain deposit, can be achieved by increasing the concentration of the electrolyte.

6. Additional Agents:

The addition of acids or other substances to the electrolyte reduces its resistance, as already mentioned. There is another class of additional agents which takes little or no direct part in the chemical reactions but influences the nature of deposit, sometimes even making an otherwise unworkable process into one of practical importance.

Such additional agents are glue, gums, dextrose, dextrin, gelatin, agar, alkaloids, albumen, phenol, glycerin, sugar, glucose, rubber etc. The crystal nuclei absorb the additional agent added in the electrolyte.

This prevents it to have large growth and thus deposition will be fine-grained.

7. Throwing Power:

This is the ability of electrolyte to produce uniform deposit on an article of irregular shape and is one of the most important characteristics of plating or deposition bath. The distance between the various portions of cathode and anode will be different due to irregular shape of the cathode.

Throwing power can be improved in two ways—firstly by increasing the distance between the anode and cathode and secondly by reducing the voltage drop at the cathode surface.

8. Polarization:

The rate of deposition of metal increases with the increase in electroplating current density up to a certain limit after which electrolyte surrounding the base metal becomes so much depleted of metal ions that the increase in current density does not cause increase in rate of deposition. Use of current density beyond this limit causes electrolysis of water and hydrogen liberation on the cathode. This hydrogen evolved on the cathode blankets the base metal which reduces the rate of metal deposition.

Application of Electrolysis:

extraction of metals:

This is done in two ways:

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

2. When the ore in molten state is available it is electolysed in a furnace.

Extraction of Zinc

The ore consisting of zinc is treated with concentrated sulphuric acid, roasted and passed through other processes to get rid of impurities by precipitation. The zinc-sulphate solution is then electrolysed. The cells consist of large lead-lined wooden boxes having aluminum cathodes and lead anodes. The current density is about 1000 amperes per square meter. Zinc is deposited on cathodes.

Extraction of Aluminium

Ores of aluminium are bauxite cryolite.Bauxite is treated chemically and reduced to aluminium oxide and then dissolved in fused cryolite and electrolysed.The furnce is lined with carbon.The temperature of the furnace is about C to keep the electrolyte in a fused state. Aluminium deposits at the cathode.

Refining of Metals

- **Electrolytic extraction gives about 98 to 99 percent pure metal. Further refining is done by electrolysis. The anodes are made of the impure metal extracted from its ores and the electrolyte is a solution of the salt of the metal. Pure metal is deposited on the cathode.**

Production of Chemicals:

- **Many chemicals such as caustic soda (NaOH) chlorine gas etc. are manufactured by electrolysis on large scale. Potassium permaganate** hydrogen and oxygen etc. are also produced by electrolysis on a large scale.

Electro-Typing:

This is a process by which type wood cuts etc. are reproduced in copper by a process of electro-plating. In this process a mould is first made of the type in wax, then it is coated with black lead to give it metallic surface and then it is subjected to the process of electro-deposition. Thus, a film of copper is formed on the prepared surface.

Electro-Forming:

- This is another application of electro-deposition. Reproduction of objects by electro-deposition on some sort of mould or form is known as electro-forming.

- In the reproduction of coins, molles, engraving etc. a mould is first made by impressing the object, say, in wax. The surface of the wax, which bears exact impressions of the object, is coated by powdered graphite in order to make it conducting. The mould is then dipped in an electro-forming cell as a cathode. After obtaining coating of desired thickness, the article and the wax core, is melted out of the metal shell.

Electro-Cleaning:

- The article to be cleaned of oil and grease is made the cathode and the iron tank or vat filled with an electrolyte solution of the electrolyte and heavy current is passed through the solution. Caustic soda and hydrogen are produced at cathode which removes the grease from the surface of the article. The process is called cathodic cleaning and is applicable to zinc and aluminium. For anodic cleaning, article is made anode.

CHAPTER-2
ELECTRICAL HEATING

Electric heating is a process in which electrical energy is converted to heat energy.

Electric heating is extensively used both for domestic and industrial applications.

Domestic applications include

(i) room heaters **(ii)** immersion heaters for water heating

(iii) hot plates for cooking **(v)** electric kettles **(v)** electric irons **(vi)** pop-corn plants **(vii)** electric ovens for bakeries and **(viii)** electric toasters etc.

Industrial applications of electric heating include

(i) melting of metal **(ii)** heat treatment of metals like annealing, tempering, soldering and brazing etc.

(iii) moulding of glass **(iv)**Baking of insulators **(v)** enamelling of copper wires etc.

Advantage of electrical heating:

As compared to other methods of heating using gas, coal and fire etc., electric heating is far superior for the following reasons:

(i)Cleanliness. Since neither dust nor ash is produced in electric heating, it is a clean system of heating requiring minimum cost of cleaning.

(ii)No Pollution. Since no flue gases are produced in electric heating, no provision has to be made for their exit.

(iii) Economical. Electric heating is economical because electric furnaces are cheaper in their initial cost as well as maintenance cost since they do not require big space for installation or for storage of coal and wood.

(iv)Ease of Control. It is easy to control and regulate the temperature of an electric furnace with the help of manual or automatic devices.

(v) Special Heating Requirement. Special heating requirements such as uniform heating of a material or heating one particular portion of the job without affecting its other parts or heating with no oxidation can be met only by electric heating.

(vi) Higher Efficiency. Heat produced electrically does not go away waste through the chimney and other by products. Consequently, most of the heat produced is utilised for heating the material itself. Hence, electric heating has higher efficiency as compared to other types of heating.

(vii) Better Working Conditions. Since electric heating produces no irritating noises and also the radiation losses are low, it results in low ambient temperature. Hence, working with electric furnaces is convenient and cool.

(viii) Heating of Bad Conductors. Bad conductors of heat and electricity like wood, plastic and bakery items can be uniformly and suitably heated with dielectric heating process.

(ix) Safety. Electric heating is quite safe because it responds quickly to the controlled signals.

(x) Lower Attention and Maintenance Cost. Electric heating equipment generally will not require much attention and supervision and their maintenance cost is almost negligible. Hence, labour charges are negligibly small as compared to other forms of heating.

Explain mode of heat transfer and Stephen's Law:

The different methods by which heat is transferred from a hot body to a cold body are as under:

I. Conduction

II. Convection

III. Radiation

I. Conduction

In this mode of heat transfer, one molecule of the body gets heated and transfers some of the heat to the adjacent molecule and so on. There is a temperature gradient between the two ends of the body being heated.

If T1 and T2 are the temperatures of the two sides of the slab in °K, then heat conducted between the two opposite faces in time t seconds is given by:

$$H= KA (T1)- (T2) / X$$

Where, K is thermal conductivity of the material.

II. Convection

In this process, heat is transferred by the flow of hot and cold air currents. This process is applied in the heating of water by immersion heater or heating of buildings.

The quantity of heat absorbed by the body by convection process depends mainly on the temperature of the heating element above the surroundings and upon the size of the surface of the heater.

It also depends, to some extent, on the position of the heater.

The amount of heat dissipated is given by H = a (T1 – T2),

where a is constant and T1 and T2 are the temperatures of the heating surface and the fluid in °K respectively. In electric furnaces, heat transferred by convection is negligible.

III. Radiation

It is the transfer of heat from a hot body to a cold body in a straight line without affecting the intervening medium.

Stephen's Law:

3. Stefan's law of radiation states that the rate of change of temperature from a body at absolute temperature T is

$$dT/dt = k(T^4 - T_0^4)$$

where T_0 is the absolute temperature of the surrounding medium.

(a) Solve this differential equation.

(b) Show that if $T - T_0$ is small compared to T_0, then Newton's law of cooling is a close approximation to Stefan's law.

RESISTANCE HEATING:

It is based on the I2R effect. When current is passed through a resistance element, I2R loss takes place which produces heat. There are two methods of resistance heating.

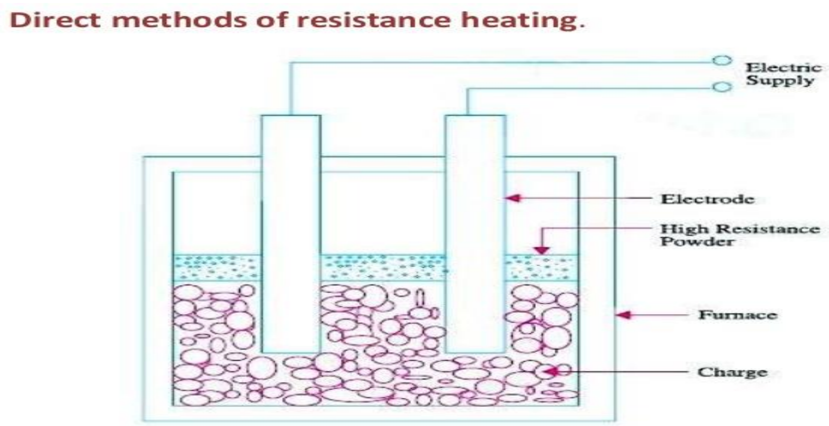
i)Direct Resistance heating

ii)Indirect resistance heating

1.Direct Resistance Heating:

- **In this method of heating, the material or charge to be heated is taken as resistance and current is passed through it. The charge may be in the form of powder, pieces or a liquid.**

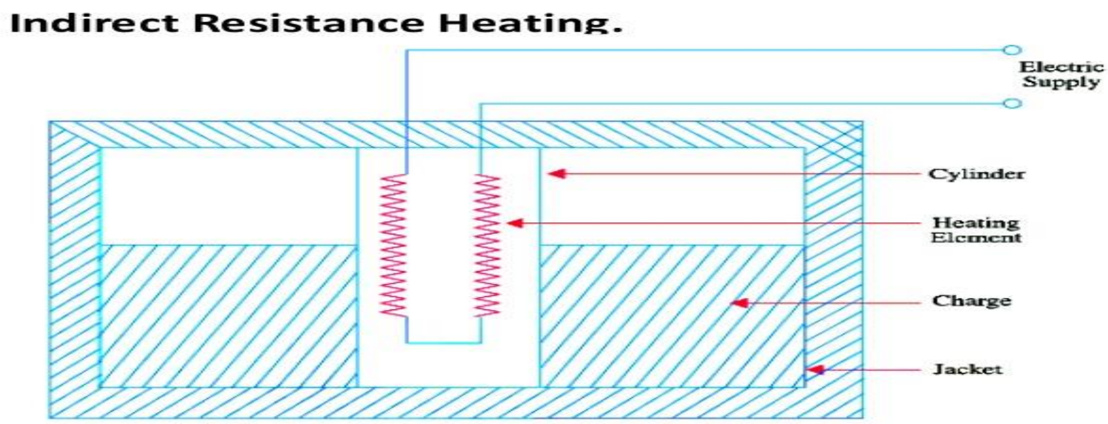
- Two electrodes are immersed in the charge and connected to the supply in case of availability of direct current or single phase ac supply and three electrodes are immersed in the charge and connected to supply in case of availability of 3-φ ac supply.



- When some pieces of metals are to be heated some highly resistive powder is sprinkled over the surface of pieces to avoid direct short circuit.

- The current flows through the charge and heat is produced. This method has high efficiency since heat is produced in the charge itself. As the current in this case is not easily variable, therefore, automatic temperature control is not possible. However, uniform and high temperature can be obtained. This method of heating is used in salt bath furnaces and in the electrode boiler for heating water.

- **2. Indirect Resistance Heating:**



- In this method of heating, the current is passed through a wire or other high resistance material forming a heating element.

- The heat proportional to I^2R loss produced in the heating element is delivered to the charge by one or more of the modes of transfer of heat viz. conduction, convection and radiation.

- If the heat transfer is by conduction the resistor must be in contact with the charge. An enclosure, known as heating chamber, is required for heat transfer by radiation and convection for the charge.

- For industrial purposes, where a large amount of charge is to be heated, the heating element is kept in a cylinder surrounded by jacket containing the charge.

- This arrangement provides a uniform temperature. Automatic temperature control can be provided in this case.

- This method of heating is used in room heaters, immersion water heaters and in various types of resistance ovens employed in domestic and commercial cooking, and salt bath furnaces.

Resistance Ovens and Furnaces:

- Resistance furnaces may be classified according to their operating temperature. Low temperature heating chamber with provision for ventilation is termed as oven.

- Resistance ovens are used for drying and baking potteries, drying varnish coatings, vulcanising and hardening of synthetic materials and commercial and domestic heating.

- They are also employed for tempering hardened steel pieces.

- Medium temperature furnaces having operating temperatures between 300°C and 1,050°C are employed for annealing, normalising of steel and non-ferrous metals, melting of non-ferrous metals and stove enamelling.

- High temperature furnaces having operating temperatures between 1,050°C and 1,350°C are employed for hardening applications.

- Typical furnace using heating elements and having provision of carrying out heating in particular atmosphere is depicted in Fig. 5.3.

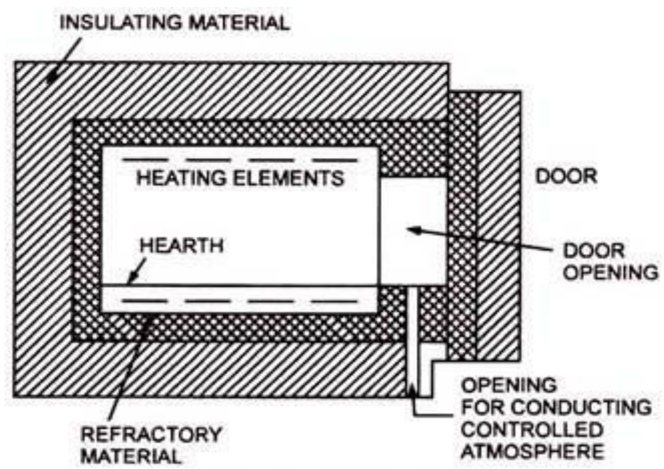


Fig. 5.3. ***Resistance Furnace***

- The resistance oven is constructed of firebricks or other heat insulating material supported on a metal framework. The heating elements are mounted on the top, sides or bottom of the oven, according to circumstances.

- The resistance furnace is an enclosure with a refractory lining: a surrounding layer of heat insulation and outer casing of steel plate, bricks or tiles.

- The inside proportions of a heating chamber are made to suit the character of the charge and type of furnace or oven.

- The nature of material required for the insulation is determined by the maximum temperature of the inner face of the layer of insulation of a heating chamber. The heating elements are mounted on top, sides or bottom of the oven as the circumstances permit.

WORKING PRINCIPLE OF DIRECT ARC FURNACE AND INDIRECT ARC FURNACE:

DIRECT ARC FURNACE:

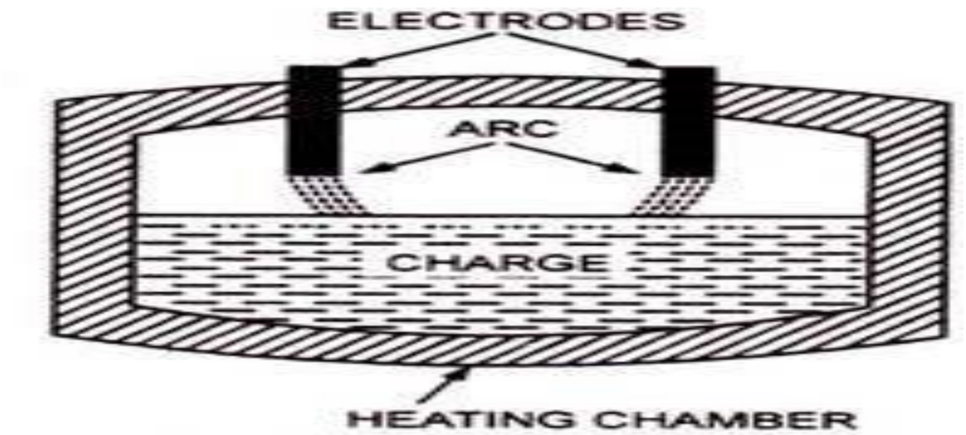


Fig. 5.4. Direct Arc Furnace

- In a direct arc furnace charge acts as one of the electrodes and the charge is heated by producing arc between the electrodes and the charge.
- Since in a direct arc furnace, the arc is in direct contact with the charge and heat is also produced by flow of current through the charge itself, the charge can be, therefore, heated to highest temperature.
- In case of a single phase arc furnace two electrodes are taken vertically downward through the roof of the furnace to the surface of the charge and in a 3- phase furnace three electrodes put at the corners of an equilateral triangle, project on the charge through the roof and three arcs are formed.
- The current passing through the charge develops electromagnetic field and necessary stirring action is automatically obtained by it. Thus uniform heating is obtained.
- It is commonly used for production of steel. The usually size of such a furnace is between 5 and 10 tonnes, though 50 and 100 tonne arc furnaces have also been developed.
- The main advantage of direct arc furnace over cupola method for production of steel is that purer production is obtained and the composition can be exactly controlled during refining process.

- Another advantage is that arc furnace can operate on 100% steel scrap which is cheaper than pig iron whereas the cupola requires a proportion of pig iron in cupola charge.

INDIRECT ARC FURNACE

Indirect Arc Furnace

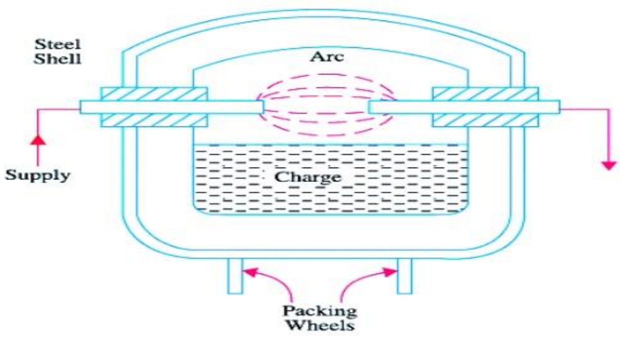


Fig. shows a single-phase indirect arc furnace which is cylindrical in shape. The arc is struck by short circuiting the electrodes manually or automatically for a moment and then , withdrawing them apart. The heat from the arc and the hot refractory lining is transferred to the top layer of the charge by radiation. The heat from the hot top layer of the charge is further transferred to other parts of the charge by conduction.

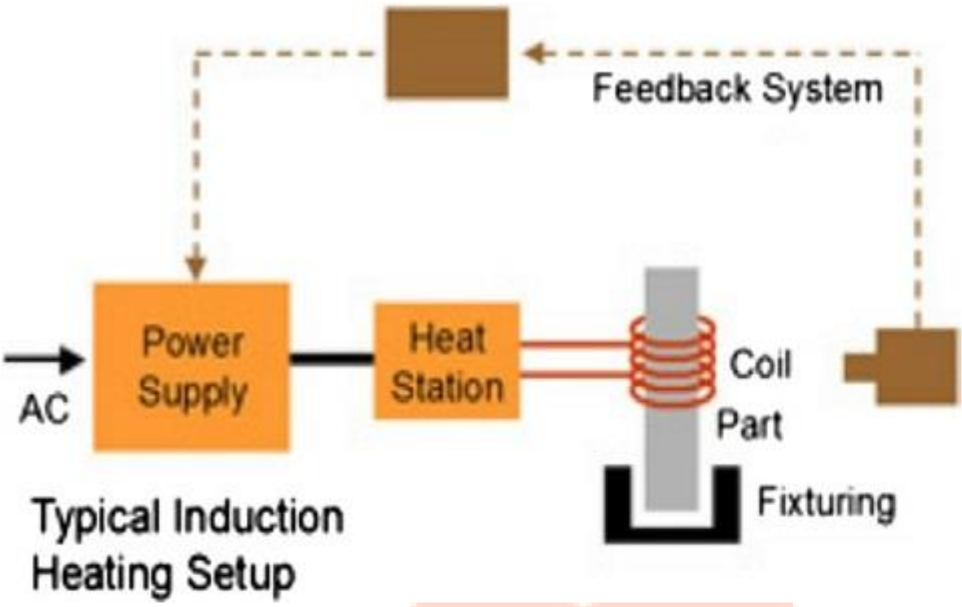
Since no current passes through the body of the charge, there is no inherent stirring action due to electro-magnetic forces set up by the current. Hence, such furnaces have to be rocked continuously in order to distribute heat uniformly by exposing different layers of the charge to the heat of the arc.

Application : Such furnaces are mainly used for melting nonferrous metals although they can be used in iron foundries where small quantities of iron are required frequently.

Induction Heating:

- **The working principle of the induction heating process is a combined recipe of Electromagnetic induction and Joule heating.**
- **Induction heating process is the non-contact process of heating an electrically conductive metal by generating eddy currents within the metal, using electromagnetic induction principle.**
- **As the generated eddy current flows against the resistivity of the metal, by the principle of Joule heating, heat is generated in the metal.**

- **The setup used for the induction heating process consists of an RF power supply to provide the alternating current to the circuit.**
- **A copper coil is used as inductor and current is applied to it. The material to be heated is placed inside the copper coil.**



- **By altering the strength of the applied current, we can control the heating temperature.**
- **As the eddy current produced inside the material flows opposite to the electrical resistivity of the material, precise and localized heating is observed in this process.**
- **Besides eddy current, heat is also generated due to hysteresis in magnetic parts.**
- **The electrical resistance offered by a magnetic material, towards the changing magnetic field within the inductor, cause internal friction. This internal friction creates heat.**
- **As the induction heating process is a non-contact heating process, the material to be heated can be present away from the power supply or submerged in a liquid or in any gaseous environments or in a vacuum.**
- **This type of heating process doesn't require any combustion gases.**

Advantages of Induction Heating

- **It is quick and clear.**
- **There is little wastage of heat in eddy current heating as heat is produced in the body to be heated up directly.**
- **Temperature control is easy i.e., by controlling the supply frequency.**

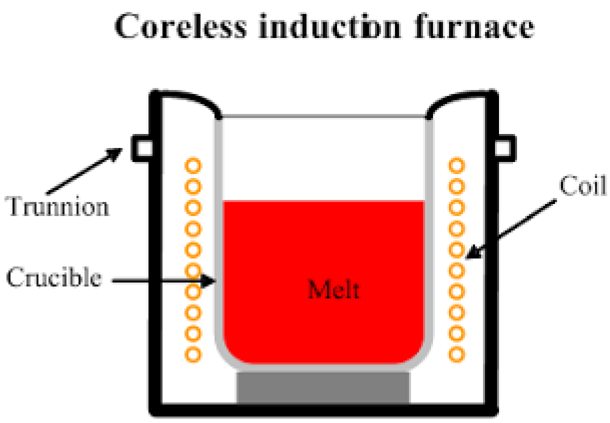
- The heat can be made to penetrate the metal surface to any desired depth.

Disadvantage of Induction Heating

- It is a costly method for the production of heat.
- The initial cost of eddy current heating apparatus is high.

Coreless Induction Furnace Working Principle:

core is provided in the coreless induction furnace. A crucible of more convenient shape can be employed.



- In this case, also the charge to be melted is made the secondary of the transformer.
- The primary is wound over the crucible itself. The eddy currents produced in the charge not only heat it up but also account for the stirring action. It is the basic **coreless induction furnace working principle**.

- Iron laminations are provided outside the primary winding to create a low reluctance path for flux and also contain the stray field, which may otherwise induce the heavy current in supporting steel structure.

- The frequency employed depends upon the size of the coreless induction furnace. For a low capacity furnace, a high frequency of the order of 3000 Hz is employed.

- Whereas for a high capacity furnace, frequencies are down to 600 Hz. Hollow copper tubes are used in which cold water is circulated to reduce the copper losses.

- The operating power factor of such furnaces is very low (between 0.1 and 0.3). Therefore, static capacitors are used to improve the power factor of the installation.

- Since the power factor does not remain constant during the operation of the furnace, the capacitance in the circuit during the heat cycle is varied to maintain power factor approximately unity.

- The coreless induction furnace is **chiefly used for the melting of steel and other ferrous metals**. The capacities available vary from 50 Kg to about 20 tones. The initial cost is more as compared to the arc furnace.

The advantages of coreless induction furnaces are as under:

- Low operating cost,
- an automatic stirring action produced by eddy currents,
- low erection lost,
- absence of dirt, smoke noise, etc.
- less melting time,
- simple charging and pouring, precise control of power,
- most suitable for the production of high-grade alloy steels.

skin effect

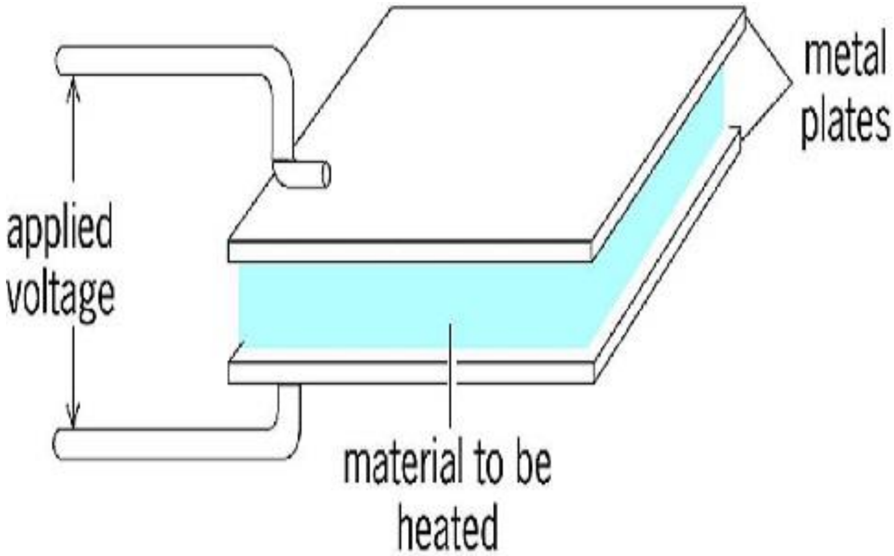
Skin effect is the tendency of an alternating electric current to become distributed within a conductor such that the current density is largest near the surface of the conductor, and decreases with greater depths in the conductor.

DIELECTRIC HEATING:

'the process of heating up material by causing dielectric motion in its molecules using alternating electric fields". All materials are made up of molecules that are composed of atoms.

- Polar molecules contain electric dipole moments. When such molecules are exposed to the electric field, they try to align themselves in the direction of the field. When the applied field oscillates, these molecules of the material undergo rotations in order to keep themselves aligned with the field.

- When the field changes direction, these molecules also reverse their direction. This process is called "Dielectric Rotation".



Dielectric Heating

- **The temperature of the molecules is related to the kinetic energy of the molecules. In the dielectric rotation of the molecules, as the kinetic energy of the molecules increases, the temperature of the molecules increases.**
- **When the molecules collide or come in contact with other molecules, this energy gets transferred to all parts of the material thus heating up the material.**
- **Thus dielectric rotation in the material is often referred to as Dielectric heating of the material.**
- **This heating is done using either electric fields of RF frequencies or electromagnetic fields.**
- **The applied field should be oscillating for dielectric rotation to take place. The frequency and wavelength of the applied field also affect the functioning of the system.**

Working:

- **As described below, the circuit diagram of the dielectric heating system consists of two metals plates to which the electric field is applied.**
- **The material to be heated is placed in between these two metals. There are two types of ways in which material are heating using the heating process.**

- Heating using low-frequency waves, as a near – field effect and heating with high-frequency waves using electromagnetic waves.
- The type of materials heated using these different types of waves is also different.

- Low-frequency waves have higher wavelengths. Thus they can penetrate through non-conductive materials more deeply than electromagnetic waves.
- The systems using low-frequency fields should have the distance between the radiator and absorber to be less than 1/2π of the wavelength. So, the process of heating using a low-frequency electric field is near – contact process.

- Higher frequency systems have lower wavelengths. Electromagnetic waves and microwaves are used for these systems.

- In these systems, the distance between metal plates is larger than the wavelength of the applied field. In these systems, conventional far-field electromagnetic waves are formed between the metal plate.

Advantages of Dielectric Heating :

1. Since heat is generated within the dielectric medium itself, it results in uniform heating.

2. Heating becomes faster with increasing frequency.

3. It is the only method for heating bad conductors of heat.

4. Heating is fastest in this method of heating.

5. Since no naked flame appears in the process, inflammable articles like plastics and wooden products etc. can be heated safely.

6. Heating can be stopped immediately as and when desired.

Application of Dielectric Heating:

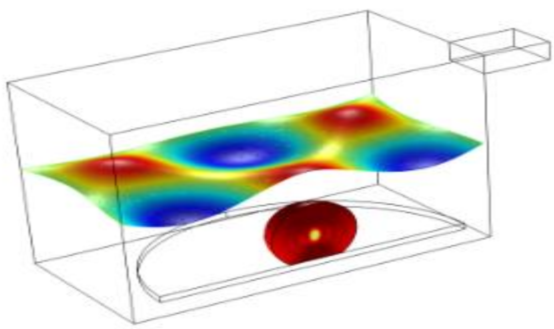
1. Preheating of Plastic Preforms:
2. Gluing of Wood
3. Baking of Foundary Cores:

4. Diathermy:
5. Sterlization:
6. Textile Industry
7. Electronic Sewing:
8. Food Processing

Principle of Microwave heating and its application:

The Microwave Heating Principle

- Microwave heating is a multiphysics phenomenon that involves electromagnetic waves and heat transfer; any material that is exposed to electromagnetic radiation will be heated up.
- The rapidly varying electric and magnetic fields lead to four sources of heating. Any electric field applied to a conductive material will cause current to flow.
- In addition, a time-varying electric field will cause dipolar molecules, such as water, to oscillate back and forth.
- A time-varying magnetic field applied to a conductive material will also induce current flow. There can also be hysteresis losses in certain types of magnetic materials.



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Application:

- microwave heating is in a microwave oven. When you place food in a microwave oven and press the "start" button, electromagnetic waves oscillate within the oven at a frequency of 2.45 GHz.
- These fields interact with the food, leading to heat generation and a rise in temperature.
- The efficiency of microwave heating depends upon the material properties. For example, if you place foods with varying water content in a microwave oven, they will heat up at different rates.
- A dinner plate may come out with some food on it that is very hot while the rest of it is still cold.
- Furthermore, the position of food relative to each other will also affect the electromagnetic field within the oven. That is why most microwave ovens have turntables to rotate the food and promote even heating.

CHAPTER-3

PRINCIPLES OF ARC WELDING

Explain principle of arc welding

Definition

It is the process of joining two pieces of metal or non-metal at faces rendered plastic or liquid by the application of heat or pressure or both. Filler material may be used to effect the union.

Working Principle:

- The working principle of arc winding is, in a welding process the heat can be generated with an electric arc strike among the workpiece as well as an electrode. This is glowing electrical discharge among two electrodes throughout ionized gas.

- The **arc welding equipment** mainly includes AC machine otherwise DC machine, Electrode, Holder for the electrode, Cables, Connectors for cable, Earthing clamps, Chipping hammer, Helmet, Wire brush, Hand gloves, Safety goggles, sleeves, Aprons, etc.

Welding Processes

All welding processes fall into two distinct categories:

1. Fusion Welding—it involves melting of the parent metal. Examples are:
(i) Carbon arc welding, metal arc welding, electron beam welding, electro-slag welding and electro-gas welding which utilize electric energy .

(ii) Gas welding and thermal welding which utilize chemical energy for the melting purpose.

2. Non-fusion Welding—It does not involve melting of the parent metal. Examples are:
(i) Forge welding and gas non-fusion welding which use chemical energy.

(ii) Explosive welding, friction welding and ultrasonic welding etc., which use mechanical energy.

(iii) Resistance welding which uses electrical energy.
Proper selection of the welding process depends on the (a) kind of metals to be joined (b) cost involved (c) nature of products to be fabricated and (d) production techniques adopted.

Use of Electricity in Welding

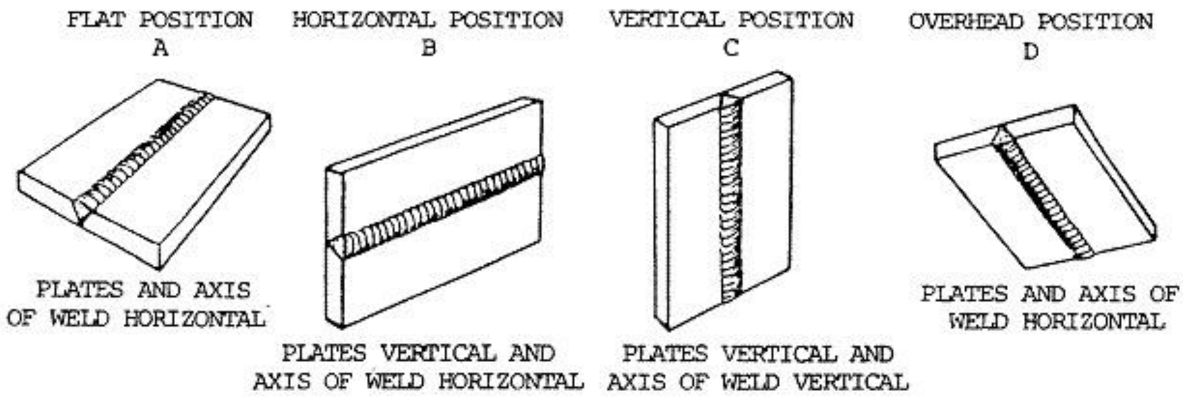
Electricity is used in welding for generating heat at the point of welding in order to melt the material which will subsequently fuse and form the actual weld joint. There are many ways of producing this localised heat but the two most common methods are as follows:

1. Resistance welding—here current is passed through the inherent resistance of the joint to be welded thereby generating the heat as per the equation I2Rt/J kilocalories.
2. Arc welding—here electricity is conducted in the form of an arc which is established between the two metallic surfaces

DIFFRENT POSITION OF ARC WELDING:

There are four basic positions in which manual arc welding is done.

1. Flat position. It is shown in Fig.20 (a). Of all the positions, flat position is the easiest, most economical and the most used for all shielded arc welding.
   It provides the strongest weld joints. Weld beads are exceedingly smooth and free of slag spots. This position is most adaptable for welding of both ferrous and non-ferrous metals particularly for cast iron.
2. Horizontal Position. It is the second most popular position and is shown in Fig.20(b). It also requires a short arc length because it helps in preventing the molten puddle of the metal from sagging.
   However, major errors that occur while welding in horizontal position are under-cutting and over-lapping of the weld zone .
3. Vertical Position. It is shown in Fig.20(c). In this case, the welder can deposit the bead either in the uphill or downhill direction.
   Downhill welding is preferred for thin metals because it is faster than the uphill welding. Uphill welding is suited for thick metals because it produces stronger welds.
4. Overhead Position. It is shown in Fig.20(d). Here, the welder has to be very cautious otherwise he may get burnt by drops of falling metal. This position is thought to be the most hazardous but not the most difficult one



Advantage and Disadvantage of Arc Welding:

Advantages :

- The main advantage of this process is that the temperature of the molten pool can be easily controlled by simply varying the arc length.
- It is easily adaptable to automation.
- It can be easily adapted to inert gas shielding of the weld and
- It can be used as an excellent heat source for brazing, braze welding and soldering etc.

disadvantages:

- A separate filler rod has to be used if any filler material is required.
- Since arc serves only as a heat source, it does not transfer any metal to help reinforce the weld joint.

Applications

- The joint designs that can be used with carbon arc welding are butt joints, bevel joints, flange joints, lap joints and fillet joints.
- This process is easily adaptable for automation particularly where amount of weld deposit is large and materials to be fabricated are of simple geometrical shapes such as water tanks.
- It is suitable for welding galvanised sheets using copper-silicon-manganese alloy filler metal.
- It is useful for welding thin high-nickel alloys.
- Monel metal can be easily welded with this process by using a suitable coated filler rod.
- Stainless steel of thinner gauges is often welded by the carbon-arc process with excellent results.

Types of Arc Welding:

The arc welding is classified into different types which include the following.

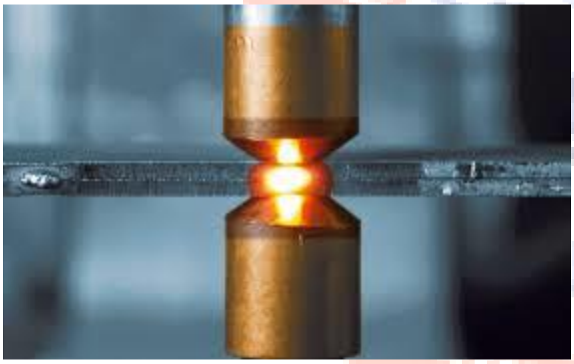
1. Plasma Arc Welding
2. Metal Arc Welding
3. Carbon Arc Welding
4. Gas Tungsten Arc Welding
5. Gas Metal Arc Welding
6. Submerged Arc Welding

Resistance Welding

Resistance welding can be defined as; it is a liquid state welding method where the metal-to-metal joint can be formed within a liquid state otherwise molten state.

This is a thermoelectric method where heat can be generated at the It is a thermo-electric process in which heat is generated at the edge planes of welding plates because of electric resistance and a weld joint can be created by applying low-pressure to these plates.

This type of welding uses electric resistance to generate heat. This process is very efficient with pollution free but the applications are limited because of the features like equipment cost is high, and material thickness is limited.



Working Principle:

The **working principle of resistance welding** is the generation of heat because of electric resistance.

The resistance welding such as seam, spot, protection works on the same principle. Whenever the current flows through electric resistance, then heat will be generated.

The same working principle can be used within the electric coil. The generated heat will depend on material's resistance, applied current, conditions of a surface, applied the current time period.

This heat generation takes place because of the energy conversion from electric to thermal. The **resistance welding formula** for heat generation is

$$H = I^2RT$$

Where

- 'H' is a generated Heat, and the unit of heat is a joule
- 'I' is an electric current, and the unit of this is ampere
- 'R' is an electric resistance, and the unit of this is Ohm
- 'T' is the time of current flow, and the unit of this is second

The generated heat can be used to soften the edge metal to shape a tough weld joint with fusion. This method generates weld with no application of any flux, filler material, and shielding gases.

Types of Resistance Welding

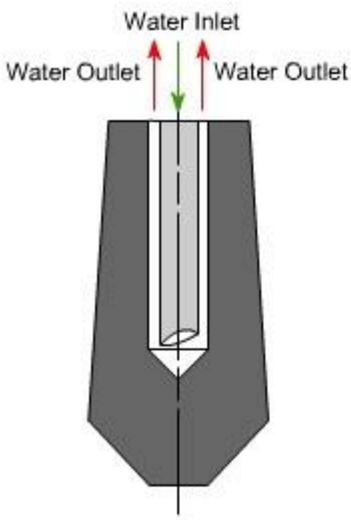
Different **types of resistance welding** are discussed below.

Spot Welding

Spot welding is the simplest type of welding where the work portions are held jointly below the force of anvil face. The copper (Cu) electrodes will make contact with the work portion & the flow of current through it.

The work portion material applies a few resistances within current flow which will cause limited heat production.

The resistance is high at the edge surfaces because of the air gap. The current begins to supply through it, then it will reduce the edge surface.

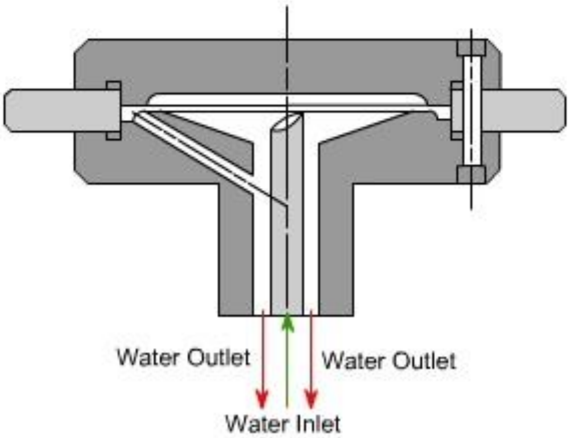


Spot Welding

The current supply & the time must be enough for the correct dissolving of edge faces. Now the flow of current will be stopped however the force applied with electrode continued for a second, whereas the weld quickly cooled. Later, the electrodes eliminate as well as get in touch with new spot to create a circular piece. The piece size mainly depends on electrode size (4-7 mm).

Seam Welding

- This type of welding is also known as continuous spot welding where a roller form electrode can be utilized to supply current throughout work parts. Initially, the roller electrodes are getting in touch with the work part. High current can be supplied through these electrode rollers to melt the edge surfaces & shape a weld joint.



- At present, the electrode rollers will begin rolling on work plates to make a permanent weld joint.

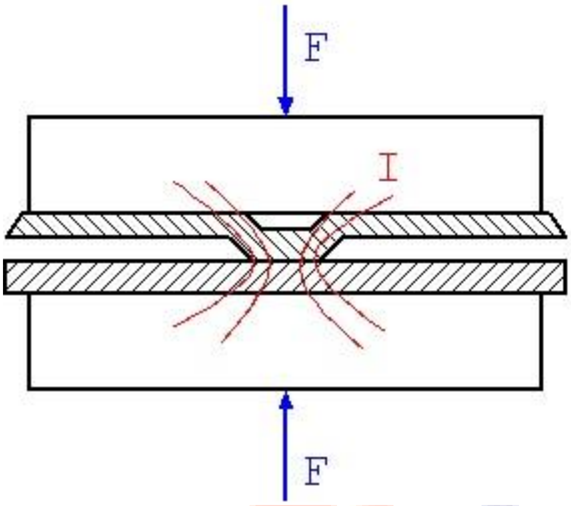
- The weld timing & electrode movement can be controlled to guarantee that the weld overlap & work part doesn't acquire too warm.

- The speed of the welding can be about 60 in per min within seam welding, which is used to make airtight joints.

Projection Welding

- Projection welding is similar to spot welding apart from a dimple can be generated on work parts at the place wherever weld is preferred. At present the work parts held among electrode as well as a huge quantity of current flow through it.

- A little quantity of pressure can be applied throughout the electrode on welding shields. The flow of current throughout dimple which dissolve it & the force reasons the dimple level & shape a weld.



Projection Welding

Flash butt Welding

- The flash butt welding is a form of resistance welding, used for welding tubes as well as rods within steel industries.

- In this method, two work parts are welded which will be held tightly during the electrode holders as well as a high pulsed flow of current within the 1,00,000 ampere range can be supplied toward the work part material.

- In the two electrode holders, one is permanent & other is changeable. At first, the flow of current can be supplied & changeable clamp will be forced against the permanent clamp because of the get in touch with the two work parts at high-current, the spark will be generated.

- Whenever the edge surface approaches into plastic shape, the flow of current will be stopped as well as axial force can be improved to create joint. In this method, the weld can be formed because of plastic deformation.

CHAPTER-4

ILLUMINATION

- Light is a form of radiant energy. Various form of incandescent bodies are the sources of light and light emitted by such bodies depend upon the temperature of bodies. Heat energy is radiated into the medium by a body which is hotter than the medium surrounding it.
- When the temperature increases the body changes red-hot to white-hot state, the wave-length of the energy radiated becomes smaller and enters into the range of the wave-length of light.

Terms used in Illuminations.

Luminous Intensity:-Luminous intensity in any given direction is the luminous flux emitted by the source per unit solid angle, measured in the direction in which the intensity is required.
It is denoted by symbol I and is measured in candela (cd) or lumens per steradian.

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

i.e., Lumens= candle power × solid angle = CP×ω
Or, total lumens given out by source of one candela is 4 lumens

Illumination:- When the falls upon any surface, the phenomenon is called the illumination.
It is defined as the number of number of lumens, falling on the surface, per unit area.
It is denoted by symbol E and is measured in lumens per square meter or lux or meter-candela.

If a flux of F lumens falls on a surface of area A , then the illumination of that surface is E =F / A

MHCP : (Mean Horizontal Candle Power) It is defined as the mean of candle powers in all directions in horizontal plane containing the source of light.

Mean Spherical Candle Power (MSCP):- It is defined as the mean of candle powers in all directions and in all planes from the source of light.

Mean Hemi-Spherical Candle Power (MHSCP):- It is defined as the mean of candle powers in all directions above or below the horizontal plane passing through the source of light.

BRIGHTNESS

- It is defined as luminious intensity per unit projected area of a given surface in a given direction.
- L=I/A Cd/m^2 where I = Luminous intensity, A= projected area

MAINTENCE FACTOR OF ILLUMINATION

- The ratio of **illumination** on a given area after a period of time to the initial **illumination** on the same area.
- used in **lighting** calculations to account for the **depreciation** of lamps or reflective surfaces

depreciation factor.

- Ans: It is the ratio of illumination when everything is perfectly clean to the illumination under normally working condition is known as depreciation factor.
- It is more than unity

Define solid angle.

- It is the angle generated by the line passing through the point in space and the periphery of the area.
- It is measured in steradians and denoted by **ω**
- **Ω** = Area / (Radius)$_2$

luminious efficiency

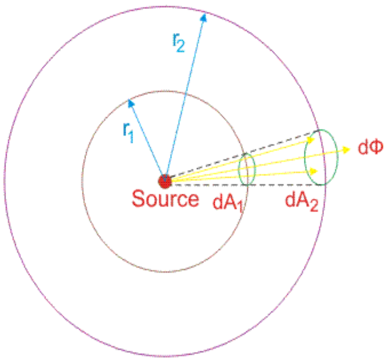
- It is defined as the output in lumens per watt of power consumed by the source of the light.
- It is measured in lumens per wattage

The Inverse Square Law of Illuminance

This law states that the Illuminance (E) at any point on a plane perpendicular to the line joining the point and source is inversely proportional to the square of the distance between the source and plane.

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

Where, I is the luminous intensity in a given direction.



Suppose a source is present with luminous intensity I in any direction. From this source two distances are taken as the radius making this source as centre.

As per the above figure, the two radiuses are r_1 and r_2. At distance r_1 dA_1 is the elementary surface area taken. In this direction of dA_1, dA_2 is considered at r_2 distance.
dA_1 and dA_2 are within same solid angle Ω with same distributed luminous flux Φ.
Area dA_1 at r_1 receives the same amount of luminous flux as area dA_2 at r_2 as the solid are the same.

$$Intensity\ I = \frac{d\phi}{d\Omega}\ is\ for\ dA_1\ and\ Intensity\ I = \frac{d\phi}{d\Omega}\ is\ for\ dA_2$$

Again solid angle for both elementary surfaces

$$d\Omega = \frac{dA_1}{r_1^2} = \frac{dA_2}{r_2^2} \ldots\ldots\ldots\ equation(i)$$

The Illuminance at distance

$$r_1 = E_1 = d\phi/dA_1 = Id\Omega/dA_1 \ldots\ldots\ldots\ equation(ii)$$

The Illuminance at distance

$$r_2 = E_2 = d\phi/dA_2 = Id\Omega/dA_2 \ldots\ldots\ldots\ equation(iii)$$

Now, from equation (i) we get,

$$dA_2 = \frac{r_2^2}{r_1^2} dA_1 \ldots\ldots \left[As\ d\Omega = \frac{dA_1}{r_1^2} \frac{dA_2}{r_2^2} \right]$$

Now in the equation (iii),

$$E_2 = Id\Omega / dA_2$$

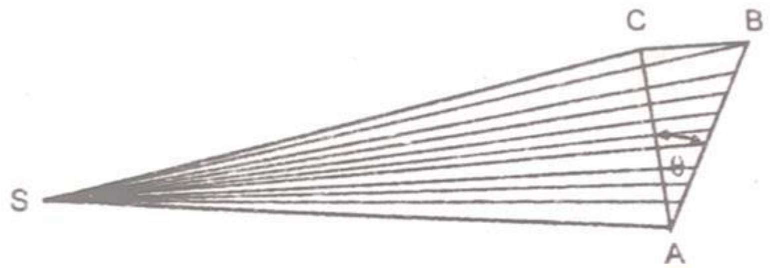
$$Putting\ dA_2 = \frac{r_2^2}{r_1^2} dA_1\ we\ get$$

$$E_2 = \frac{Id\Omega}{\frac{r_2^2}{r_1^2} dA_1} = \frac{r_1^2}{r_2^2} . \frac{Id\Omega}{dA_1} = \frac{r_1^2}{r_2^2} E_1$$

$$Or,\ \frac{E_1}{E_2} = \frac{r_1^2}{r_2^2}$$

This indicates the well known inverse square law relationship for point source.
It is seen that Illuminance varies inversely as the square of the illuminated point from the source.
If the light source is not a point source, then we can assume this large source as the summation of many point sources.
This relationship can be applied to all light sources

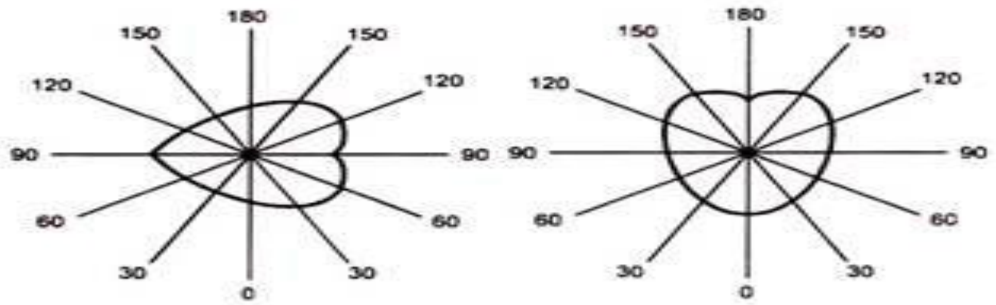
Lambert's Cosine Law



The above figure shows that the area over which the is spread is then increased in the ratio
AB/AC=1/cosθ
And the illumination decreases in the ratio cosθ/1
The expressions for the illumination then becomes
E=I cosθ / r2.

POLAR CURVE:

They are the plot drawn between the Candle Power and Angular Position



(a) Polar Curve For Horizontal Plane

(b) Polar Curve For Vertical Plane

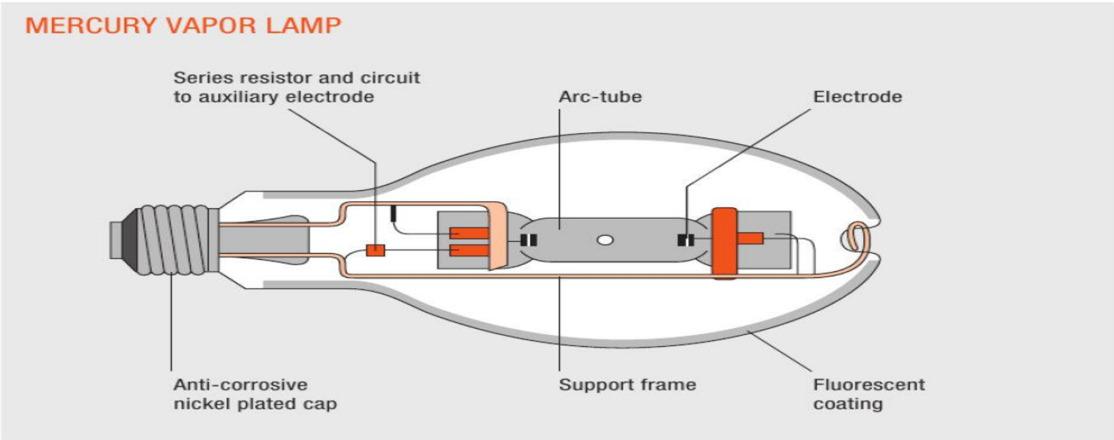
Fig. 7.19

- **The luminous flux emitted by a source can be determined using the intensity distribution curve.**
- **The luminous intensity or the distribution of the light can be represented with the help of the polar curves.**
- **The polar curves are drawn by taking luminous intensities in various directions at an equal angular displacement in the sphere.**
- **A radial ordinate pointing in any particular direction on a polar curve represents the luminous intensity of the source when it is viewed from that direction.**
- **Accordingly, there are two different types of polar curves and they are:**
    - **A curve is plotted between the candle power and the angular position, if the luminousintensity, i.e., candle power is measured in the horizontal plane about the vertical axis, called 'horizontal polar curve'.**
- **A curve is plotted between the candle power, if it is measured in the vertical plane and the angular position is known as 'vertical polar curve'.Figure shows the typical polar curves for an ordinary lamp.**

high pressure mercury vapour lamp.

- A mercury vapour lamp is a high-pressure, electric arc discharge lamp that provides intense illumination over a selected range of wavelengths.

- Mercury vapour lamps consist of two electrodes, that are closely spaced, placed in a high-pressure gas medium. The electrodes are made of tungsten alloys.

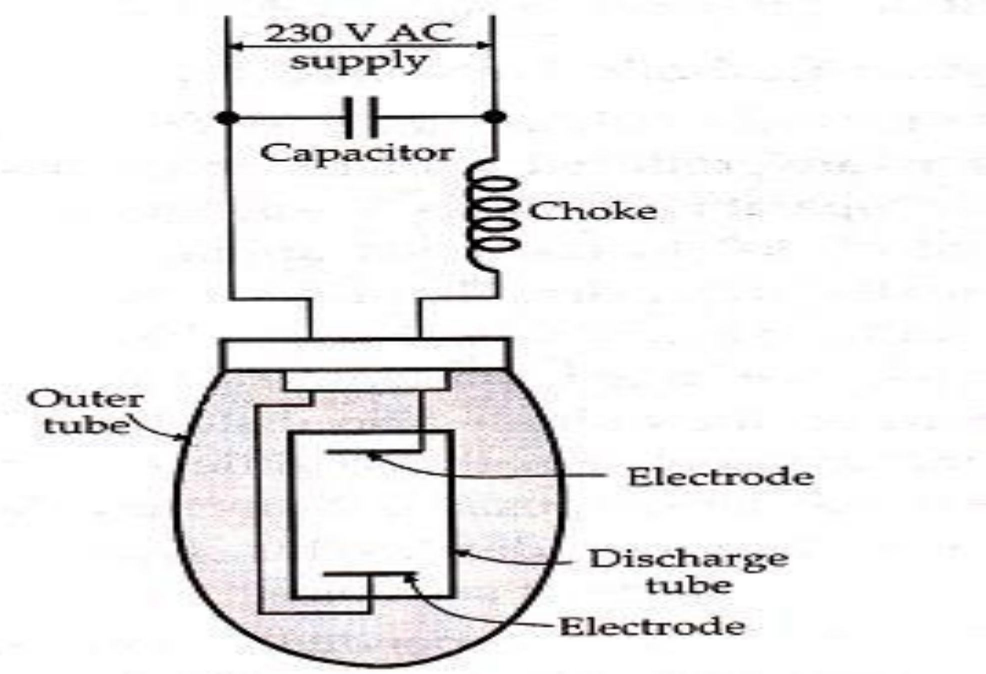


- Mercury vapour, at high pressure, is filled inside a glass tube with two electrodes.

- When current is passed through the tube, mercury vapour is ionized and emits a light in the ultraviolet region. In order to convert the radiation into visible radiation, the tube is coated with fluorescent material.

- The light emitted by the mercury vapour lamp has a bluish tinge. The output wavelength of mercury vapour lamps is distributed over the ultra violet, IR, and visible region.

Sodium Vapour lamp



- Sodium vapour has the highest theoretical luminous efficiency and gives monochromatic orange-yellow light.The monochromatic light makes objects appear grey. Such lamps on account of this factor are used only for street and highway lighting.
- The Lamp consists of a discharge tube having special composition of glass to withstand the high temperature of the electric discharge.
- The discharge tube is surrounded by an outer tube as shown below 60. For heating the cathode a transformer is included.Sodium below is in solid state.For starting the lamp the electric discharge is allowed to take place in neon gas.
- The temperature inside the discharge tube rises and vapourises sodium.Operating temperature is around 230 .
- It takes about 10 minutes for the sodium vapour to displace the red colour of neon by its brown yellow colour. The lamp takes about half an hour to reach full output. A choke is providing for stabilizing the electric discharge and a capacitor for power factor improvement. The light output is about 40 to 50 lumens per

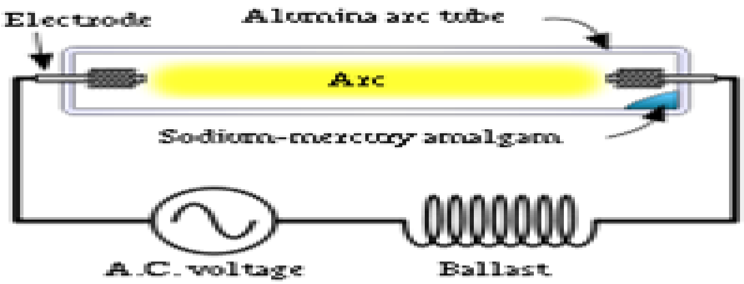
discharge lamp & basic idea about Gas discharge lamp

A *lamp* in which *light* is produced by an electric *discharge* in a gas-filled glass enclosure

- Gas Discharge Lamps
- Gas-discharge lamps are a family of artificial light sources that generate light by sending an electrical discharge through an ionized gas.
- Typically, such lamps use a noble gas (argon, neon, krypton and xenon) or a mixture of these gases.
- Most lamps are filled with additional materials, like mercury, sodium, and/or metal halides. In operation the gas is ionized, and free electrons, accelerated by the electrical field in the tube, collide with gas and metal atoms.
- Some electrons in the atomic orbitals of these atoms are excited by these collisions to a higher energy state.
- When the excited atom falls back to a lower energy state, it emits a photon of a characteristic energy, resulting in infrared, visible light, or ultraviolet radiation.
- Gas-discharge lamps offer long life and high efficiency, but are more complicated to manufacture, and they require electronics to provide the correct current flow through the gas.

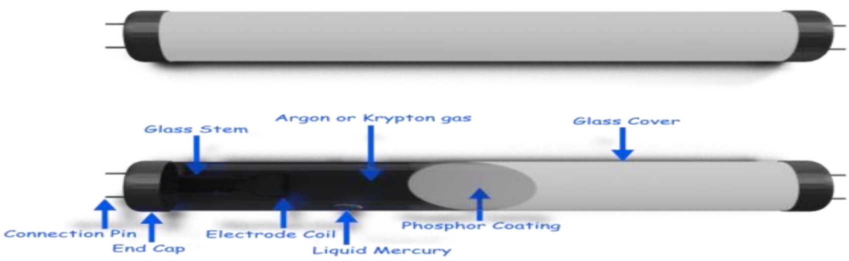
There are three groups of gas discharge lamp, namely:

- Low pressure discharge
- High pressure discharge
- High intensity discharge



Fluorescent Lamp:

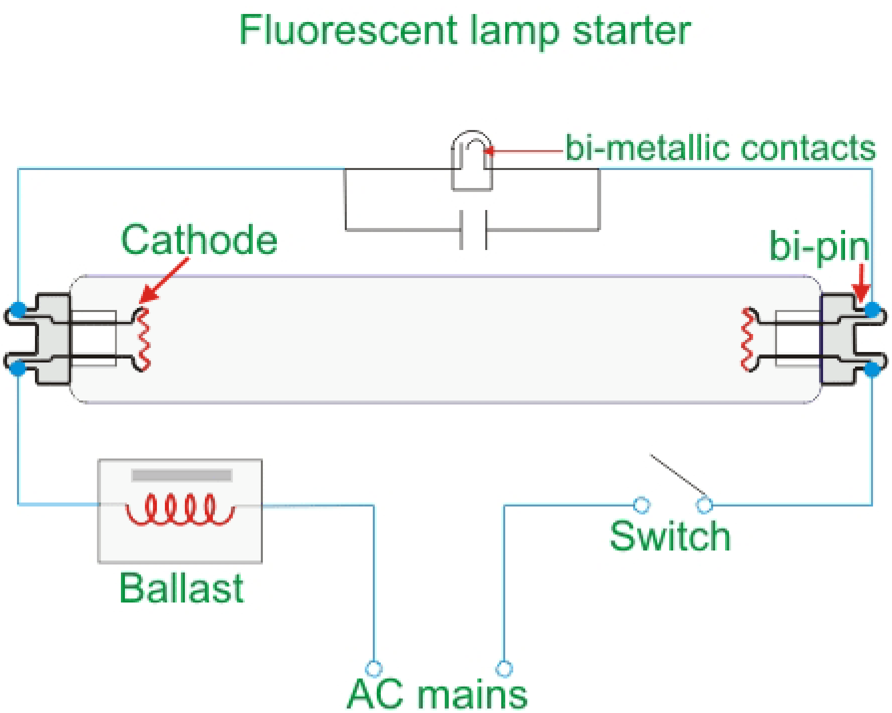
- A **fluorescent lamp** is a low weight mercury vapour lamp that uses fluorescence to deliver visible light.
- An electric current in the gas energizes mercury vapor which delivers ultraviolet radiation through discharge process and the ultraviolet radiation causes the phosphor coating of the lamp inner wall to radiate visible light.



- A fluorescent lamp has changed over electrical energy into useful light energy to a great deal more proficiently than incandescent lamps. The normal luminous viability of fluorescent lighting frameworks is 50 to100 lumens per watt, which is a few times the adequacy of incandescent lamps with equivalent light yield.

Fluorescent Lamp work

- Before going through the working principle of a fluorescent lamp, we will first show the circuit of a fluorescent lamp in other words circuit of tube light.



Here we connect one ballast, and one switch and the supply is series as shown. Then we connect the fluorescent tube and a starter across it.

- When we switch ON the supply, full voltage comes across the lamp and as well as across the starter through the ballast. But at that instant, no discharge happens, i.e., no lumen output from the lamp.
- At that full voltage first the glow discharge is established in the starter. This is because the electrodes gap in the neon bulb of starter is much lesser than that of the fluorescent lamp.
- Then gas inside the starter gets ionized due to this full voltage and heats the bimetallic strip. That causes to bend the bimetallic strip to connect to the fixed contact.
- Now, current starts flowing through the starter. Although the ionization potential of the neon is more than that of the argon but still due to small electrode gap, a high voltage gradient appears in the neon bulb and hence glow discharge gets started first in the starter.
- As soon as the current starts flowing through the touched contacts of the neon bulb of the starter, the voltage across the neon bulb gets reduced since the current, causes a voltage drop across the inductor(ballast).
- At reduced or no voltage across the neon bulb of the starter, there will be no more gas discharge taking place and hence the bimetallic strip gets cool and breaks away from the fixed contact.
- At the time of breaking of the contacts in the neon bulb of the starter, the current gets interrupted, and hence at that moment, a large voltage surge comes across the inductor(ballast).

$$V = L\frac{di}{dt}$$

$$Where,\ L\ is\ inductance\ of\ inductor$$

$$and\ \frac{di}{dt}\ is\ rate\ of\ change\ of\ current.$$

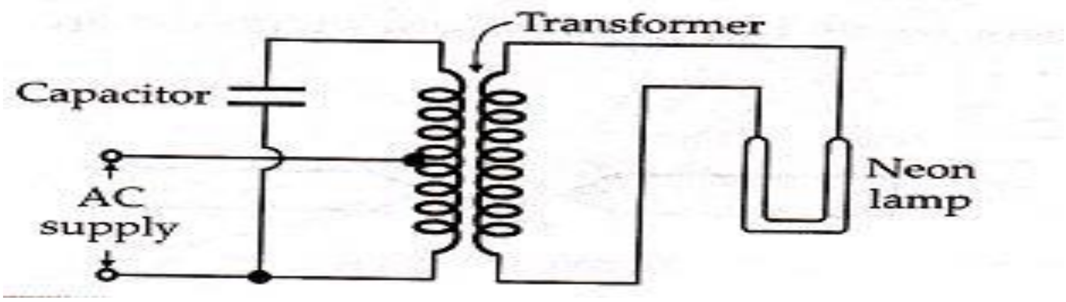
- This high valued surge voltage comes across the fluorescent lamp (tube light) electrodes and strikes penning mixture (mixture argon gas and mercury vapor).
- Gas discharge process gets started and continues and hence current again gets a path to flow through the fluorescent lamp tube (tube light)

itself. During discharging of penning gas mixture the resistance offered by the gas is lower than the resistance of starter.

- The discharge of mercury atoms produces ultraviolet radiation which in turn excites the phosphor powder coating to radiate visible light.
- Starter gets inactive during glowing of fluorescent lamp (tube light) because no current passes through the starter in that condition.

Neon Lamp :

- These belong to the cold-cathode category. The electrodes are in the form of iron shells and are coated on the inside.
- The colour of the light emitted is red and these lamps are mostly used for electrical advertising. High voltage is used for starting.
- If helium gas is used for in place of neon, pinkish white light is obtained. Helium and neon through coloured glass tubing produce a variety of effects. Figure below shows a circuit for a neon lamp.
- The transformer has a high leakage reactance, which stabilize the arc in the lamp. A capacitor is used for power factor improvement.



CHAPTER-5

INDUSTRIAL DRIVE

The **industrial drive** combines a suitable motor with a **drive** or inverter to control the speed, torque and position, as well as switches, sensors and communications links as part of the **Industrial** Internet of Things

Group Drive

Where a number of machines are driven through belts from a common shaft, it is known as *group drive*.

Alternatively, each machine may have its own driving motor, in which case it is called individual *drive*. In group drive case, one motor is used as a drive for two or more machines.

The motor is connected to a long shaft. The machines are connected to this shaft through belt and pulleys.
The use of this kind of drive is restricted due to the following reasons:
(i) If at certain instance all the machines are not in operation, then the motor will be working at low capacity.
(ii) In case of fault in the motor all the machines connected to this motor will cease to operate thereby paralyzing either complete or part of industry up till the time the fault is removed.
(iii) It is not possible to install any machine at a distant place.
(iv) The possibility of installation of additional machines in an existing industry is limited.

advantages of the group drive,
i. Initial cost of installing the industry is low.
ii. In certain industrial processes one process is connected to another process and will be advantageous if all these interconnected processes are stopped simultaneously.

Individual drive :

In this case there is a separate driving motor for each machines. Such a drive is very common in most of the industries. It has the following advantages :
i) If there is a fault in one motor, the effect on the production or output of the industry will not be appreciable.

ii) Machines can be located at convenient places.

iii) Continuity in the production of the industry is ensured to a higher degree.

disadvantage:
i) Initial cost will be high.

Choice of Electrical Drives:

- **Steady state operation requirements**: Nature of speed torque characteristics, speed regulation, speed range, efficiency, duty cycle, quadrants of operation, speed fluctuations if any, ratings.
- **Transient operation requirements**: Values of acceleration and deceleration, starting, braking and reversing performance.
- **Requirements related to the source**: Type of source, and its capacity, magnitude of voltage, voltage fluctuations, power factor, harmonics and their effect on other loads, ability to accept regenerated power.
- Capital and running cost, maintenance needs, life.
- Space and weight restrictions if any.
- Environment and location.
- Reliability.

running characterstic of dc motor

Running Characteristics
The running characteristics of a motor include the speed-torque or the speed-current characteristics, losses, efficiency and power factor at various loads. Power factor consideration crops up in the case of a.c. motors only.
D.C. Motor
In the case of DC shunt motors speed is fairly constant with load; there is only a slight fall in speed as the load comes up. The speed torque characteristic is a slightly drooping straight line.
For the DC series motor the speed is normally high at low loads and decreases as the motor is loaded .The speed –Torque characteristics is a supply drooping curve.

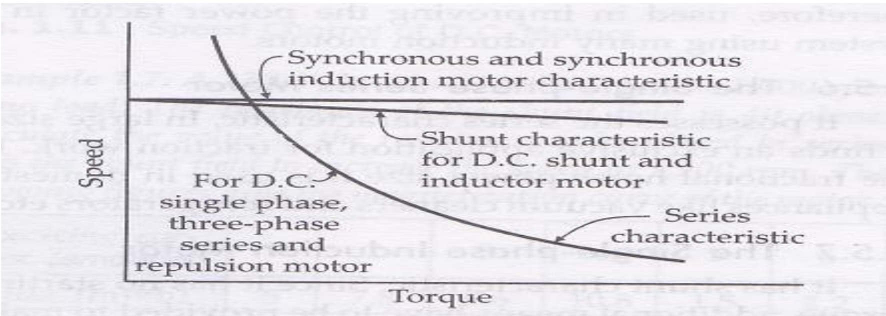


Fig..9 Torque speed relation of dc and ac motors

In the compound motor, the speed-torque characteristics may be made to lie anywhere between the pure shunt and the pure series by suitably adjusting the series and the windings

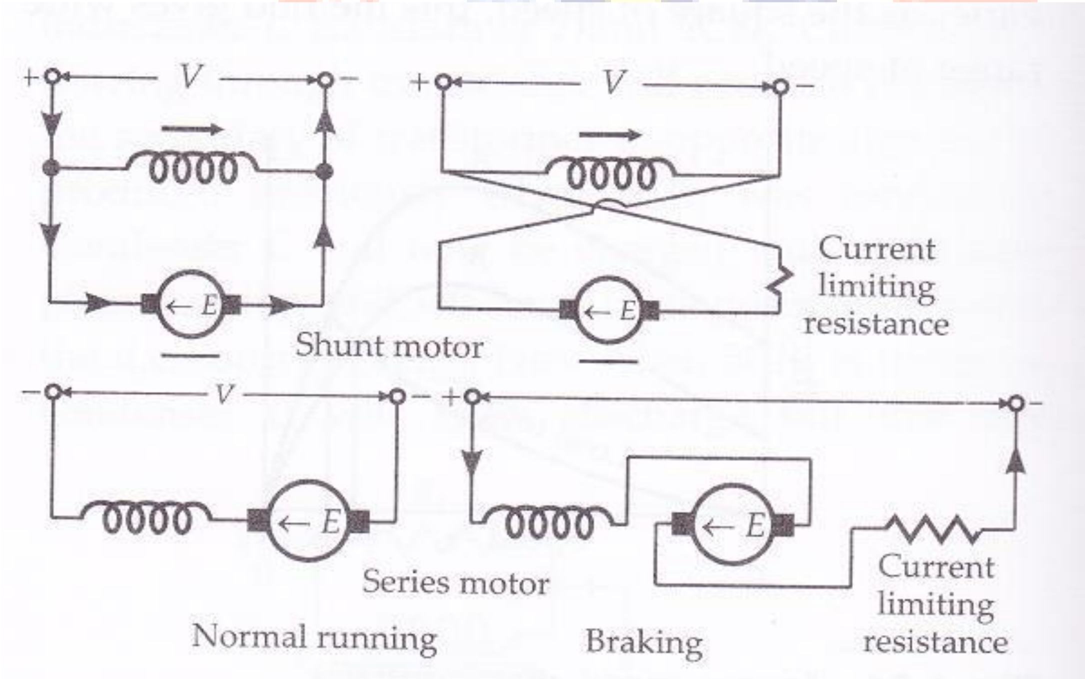
.

plugging with d.c motors

Plugging with D.C. motors

(a) The armature connections are reversed with respect to the field so that the current in the armature reverse .During normal running the back emf E is opposite to the direction of the armature current but during braking the back emf E and the armature current are in the same direction.

(b) At the instant of reversal of armature connections a voltage equal to V+E is impressed across the armature circuit, V being the supply voltage. Since E is very nearly equal to the V, the impressed voltage is approximately 2V.This will cause a great rush of current in the armature circuit. To prevent this, the starting resistance is reinserted in the armature circuit as shown below.



It should, however ,be noted that during braking, in addition to the kinetic energy of the motor being dissipated in the resistance, some energy is being drawn from the supply. There is, therefore, a waste of energy.

(c) If any two supply phases are interchanged with each other the direction of rotation of the magnetic field reverses and, therefore, the torque on the rotor also reverses providing a braking action. Supply, however, has to be cut off when the motor comes to rest, otherwise the rotor would start building up motion in reverse direction.

(d) The rotor and stator currents tend to be abnormally high and a resistance may have to be inserted in the rotor or stator circuit for the purpose of protection.

Applications of DC Motors

Series Motors

The series DC motors are used where high starting torque is required, and variations in speed are possible. For example – the series motors are used in Traction system, Cranes, air compressors.

Shunt Motors

The shunt motors are used where constant speed is required and starting conditions are not severe. The various applications of DC shunt motor are in Lathe Machines, Centrifugal Pumps, Fans, Blowers, Conveyors, Lifts, Weaving Machine, Spinning machines, etc.

Compound Motors

The compound motors are used where higher starting torque and fairly constant speed is required. The examples of usage of compound motors are in Presses, Shears, Conveyors, Elevators, Rolling Mills, Heavy Planners, etc.

Application of 1 phase Induction motor

- Pumps
- Compressors
- Small fans
- Mixers
- Toys
- High speed vacuum cleaners
- Electric shavers
- Drilling machines

Applications of Three Phase Induction Motor

- Lifts
- Cranes
- Hoists

- Large capacity exhaust fans
- Driving lathe machines
- Crushers
- Oil extracting mills
- Textile and etc.

Application of 3 phase synchronous motor

The synchronous motors are often used as a power factor correction device, phase advancers and phase modifiers for voltage regulation of the transmission lines. This is possible because the excitation of the synchronous motor can be adjusted as per the requirement.

Chapter-6.

ELECTRIC TRACTION

The system of traction involving the use of electricity is known as the electric traction .

There are various systems of traction are commonly used such as

1. Direct steam engine drive
2. Direct internal combustion engine drive
3. Steam electric drive
4. Petrol electric traction
5. Battery electric drive
6. Electric Drive
7. Internal combustion engine electric drive

System of Electric Traction

Two types of vehicles are in use for electric traction. In one type they receive power from a distribution network while in the other type they generate their own power. The former type vehicles may use both a.c. or d.c. ; the latter type will be the diesel-electric car or train, petrol-electric truck, lorry and battery driven vehicles.

DC TRACTION MOTOR

- Most suitable motors for dc system are the series and compound motors.

  DC Series Motor:
- The series motor used for traction purposes have following requirements
- The dc series motor develops high torque at start which is essential for traction services.
- The series motor is simple speed control method.
- Power drawn from supply mains varies as the square root of the load torque.
- Series motor is not suitable for regenerative braking as these are not electrically stable.
- In case of dc series motor commutation is excellent up to twice full load so replacement of brushes in not required frequently.
- 6 In cases of dc series motors the flux varies as the armature current, torque corresponding to a given armature current, therefore is independent of line voltage.
- 7 In case of dc series motor up to magnetic saturation, torque developed is proportional to the square of the armature current. Thus dc series motor requires comparatively less increased power input with the increase in load torque.
- The series motor when operated in parallel to drive a vehicle by means of different axles, share load almost equally even there is unequal wear of different driving wheels.
- The dc series motor is simple and robust in construction.

AC TRACTION MOTOR:

- AC Series Motor: Many single phase ac motors have been developed for traction purposes but only compensated series type commutator motor is best for traction.

- The construction of an ac series motor is similar to a dc series motor except that some modification such as whole magnetic circuit laminated, series field with as few turns as possible, large no of armature conductors, use of carbon brushes, numerous poles with lesser flux per pole.

- Compensating windings are provided to neutralize armature reaction and commutating or interpoles are provided for better performance in terms of higher efficiency and a greater output from a given size of armature core.

- The speed –Torque characteristics and the speed-current characteristics of compensated series type commutator motors are similar to those of D.C. series motor.
- The a.c. Series motor is not suitable to suburban services where stops are frequent. It is being extensively employed on main line work on the continent and in America and provides good service.

- If a d.c. series motor is worked on a.c. it would not operate in a satisfactory manner.
- Though the torque on the armature would be unidirectional, it would be at double the frequency since both the field current and the armature current reverse every half cycle.

- The alternating flux would cause heavy iron losses in the field and yoke.Heavy sparking would also take place at the brushes since the induced voltage and currents in the armature would be short-circuited at the time of commutation. The overall performance of the motor would be poor.

CONTROL OF MOTOR

Tapped Field Control :As the speed of the motor is inversely proportional to the flux (assuming line voltage constant), therefore, the speed can be varied by varying the flux. In case of series motors the flux can be varied either

(i) by connecting a variable resistance known as diverter in parallel with the series field winding

(ii) by cutting out some of the series field turns. Since in both the cases the flux can be only reduced, therefore, this method is known as field weakening method and speeds above normal can be obtained.

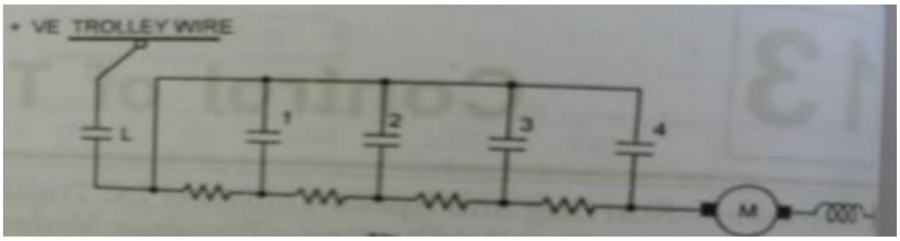
By this method speed can be raised to the extent of 15 to 30 percent of normal speed owing to design difficulties arising with traction motors.

The field weakening method is of no use for starting purpose. This method is used for increasing the speed of traction motors upto the extent of 10 to 15 percent when they have attained maximum possible sped by series-parallel control system. The advantage of this system is that it increases the flexibility of the train utility

RheostaticControl :

- A series motor can be started by connecting an external resistance (starter) in series with the main circuit of the motor.
- At the starting instant, since the back emf developed by the motor is zero, therefore, the resistance connected in series with the motor is maximum and is of such a value that the voltage drop across it with full load rated current is equal to the line voltage.
- As the motor speeds up, the back emf developed by the motor increases, therefore, the external resistance is gradually reduced in order to maintain the current constant throughout the starting or accelerating period.
- Basic traction motor circuit with rheostatic starting is shown in figure. In this method there is a considerable loss of energy in the external circuit.

- Fig.16 Rheostatic control method



Series Parallel Control:

- Here two identical motors are coupled together mechanically to a common load. Two speeds at constant torque are possible in this method one by connecting the motors armatures in series and the other by connecting them in parallel as shown in Fig. 7.60.
- When connected in series, the terminal voltage across each motor is V12 whereas when they are connected in parallel it is *V.* Thus armature control of speed is achieved.

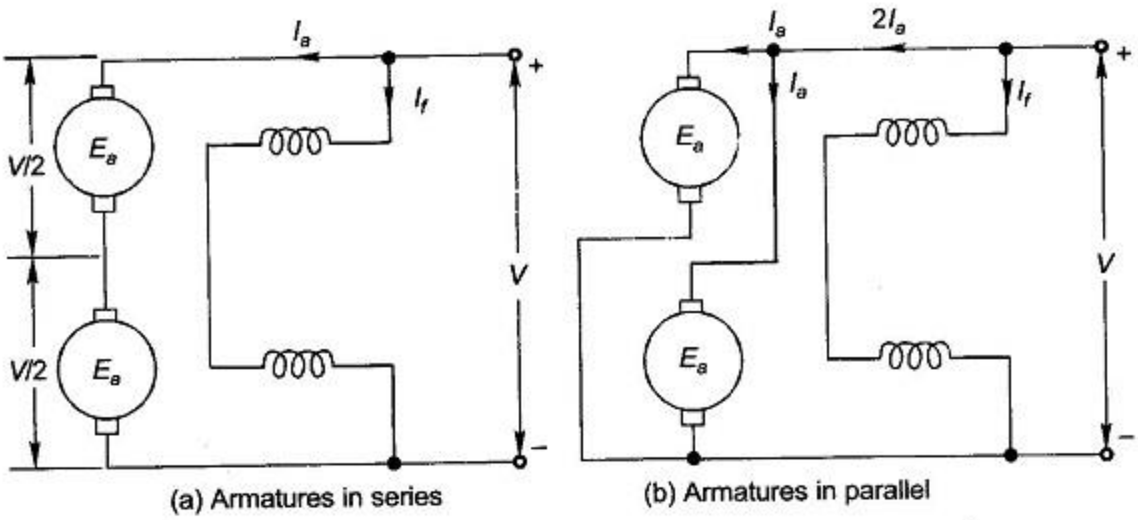


Fig. 7.60 *Series-parallel speed control (shunt-motors); case of constant load torque is illustrated*

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

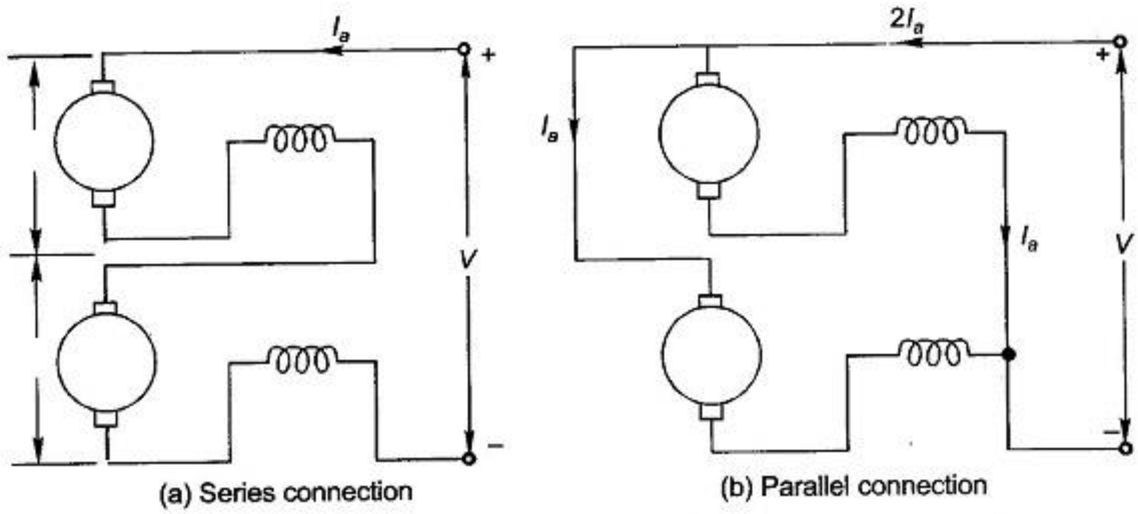


Fig. 7.61 *Series-parallel speed control of series motors; case of constant load torque is illustrated*

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

Metadyne Control of Traction Motor:

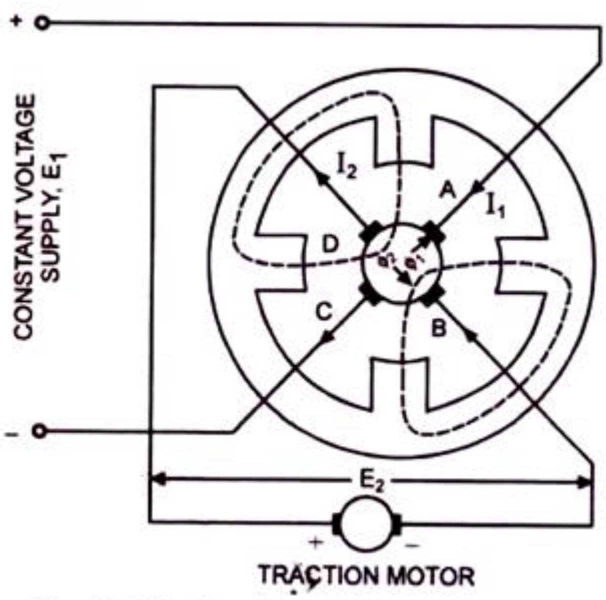
- The metadyne control system is based on constant current system of speed control.

- In metadyne control, current throughout the accelerating period remains constant, therefore, uniform tractive effort is developed and very smooth control, without causing any wastage of energy in the starting resistance, is achieved.

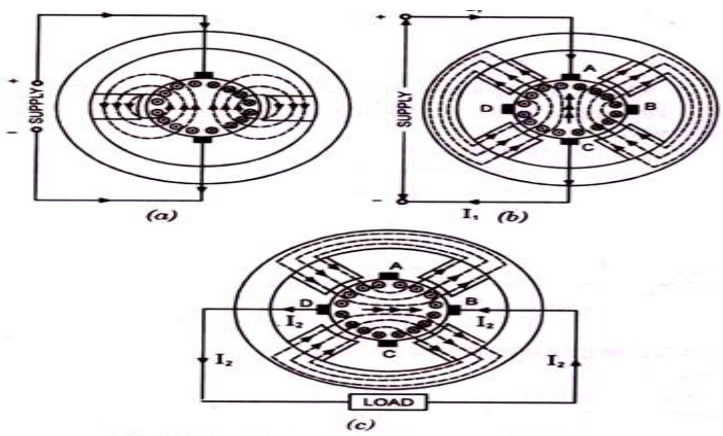
- The essential part of the metadyne control is metadyne converter. The metadyne converter is a cross-field machine which behaves like a transformer on direct current.

- The transformation ratio of a metadyne can be varied continuously. It takes power at constant voltage and variable current and delivers the same at constant current and varying voltage.

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



- Fig. 13.16. *Simple Metadyne Converter*
- For understanding the working of a metadyne converter consider first an ordinary dc machine with two poles and two brushes supplied with a current flowing in the direction shown in Fig. 13.17(a). It will cause armature current distribution, as illustrated in the figure with corresponding cross flux, mainly confined to the poles.



- Fig. 13.17. *Illustration of Metadyne Principle*
- Now consider that metadyne converter (a dc machine with two pairs of brushes and two pairs of poles) is running at constant speed and drawing a current I, from the dc supply main, which flows through the

armature conductors via the brushes A and C, as shown in Fig. 13.17 (b).

- **An armature reaction flux φ_1 , set up in usual way is provided with a fairly low reluctance path through the yoke by the four poles, as shown in the figure.**

- **Due to rotation of armature conductors in this primary flux, and emf $E_2 = KI_1$ is set up between the brushes B and D.**

- **When these brushes B and D are connected to a load, a current I_2 flows through the load. The load current I_2 sets up another flux φ_2 known as secondary flux, at the right angles to the first, the distribution is shown in Fig. 13.17 (c).**

- **This secondary flux φ_2 causes an emf, $E_1 = KI_0$ between brushes A and C opposing the applied voltage. As the applied voltage is constant, the resistance drop is negligible so the back emf E_1 opposing applied voltage and the current I_2 producing E_1 are also constant.**

- **Since input = $E_1I_1 = KI_2I_1 = KI_2 \times E_2/K = E_2I_2$ = output, therefore, power required to drive the metadyne is very small being equal to the running losses of the machine.**
- **The variator winding is supplied excitation from an exciter mounted on the same shaft, as shown in Fig. 13.18.**

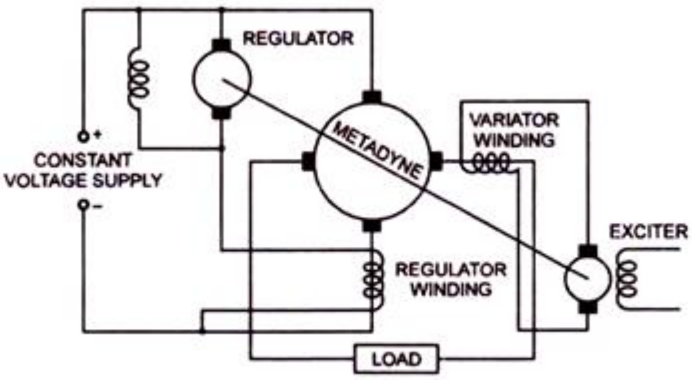


Fig. 13.18. *Metadyne Control System*

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

- The metadyne is employed whenever control of dc motors is required. The control provided by the metadyne is smooth and does not require any switching.

- Thus switchgear and arcing are avoided. In some cases it is cheaper than the Ward Leonard system in initial cost. In traction it provides smooth acceleration without skill on the part of driver and regenerative braking down to very slow speeds. The savings due to these items may easily counterbalance the additional cost of the more complicated equipment required and its additional maintenance cost. It is already being employed in the underground railway.

BRAKING :

Introduction

In traction work both electrical and mechanical braking are employed for bringing the vehicle to rest. Electrical braking cannot do away with the mechanical brakes since a vehicle cannot be held stationary by its use; it nevertheless forms a very important part of a traction system..

The main advantage of using electric braking is that it reduces the wear on the mechanical brakes and gives a higher value of braking retardation thus bringing a avehiclequickly to rest and cutting down considerably on the running time.

Where regenerative braking is employed , a part of the energy is returned to the supply thereby affecting a considerable saving in the running costs.

For D.C. motorsThere are three methods emp-loyed for electric braking:

(i) Plugging

(ii) Rheostatic braking

(iii)Regenerative braking

Plugging : Elaborate discussions have already been made on this in previous chapter and does need any more of it.

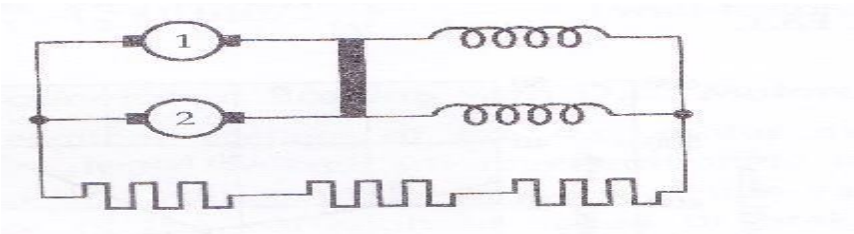
Rheostatic Braking

When two or three series motors are used for traction work,the motors are connected in parallel across a resistance.

The kinetic energy of the vehicle is utilised in driving the motors as generators which dissipate this energy in the form of heat in the rheostats to which they are connected.

The two machines in parallel amount to two series generators in parallel and in order that they may self-excite, an equalizer connection as shown has to be used. If the equalizer connection are not used,the machine that would build up first would send a current through the other in the opposite direction with the result that the second machine would excite withreversedvoltage.

The two machiones would be short-circuited on themselves and might even burn out on account of large currents. The equalizer prevents such a condition.



Rhestatic Braking-Equaliser connection.

BRAKING WITH SINGLE-PHASE SERIES MOTORS

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

Regenerative Braking

- For generative braking the regenerated power should be at the frequency of the main supply.
- This necessitates the energizing of the field winding from the main supply. Secondly, the regenerated current must be in phase opposition to the applied voltage and also the flux so that the power may be feedback into the supply system.
- The voltage applied to the field winding must be out of phase with respect to the supply voltage.An arrangement to obtain these conditions is shown below.

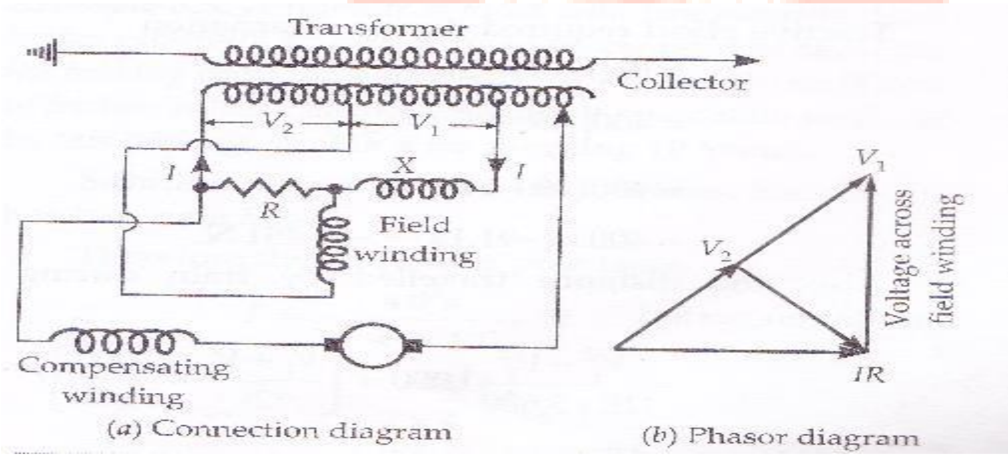


Fig.25 Regenerative braking with single phase series motor.

Magnetic Track Brake

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

- The exciting coil is enclosed in a water-tight case.

- The magnetic flux is perpendicular to the pole faces and the track. The force of attraction between the magnet and the track is given by
- $F = B^2a / 2\pi * 10^{-7}$ N,
- where B is the flux density in weber/
- and a is the area in the pole face in sq.m.
- The drag that it can produce on the car is given by micro farad, where t is the coefficient of friction.