Module 1: THERMAL ENERGY CONVERSION SYSTEM

Content:

Objectives

After studying this module, the student should be able to

- Understand the importance of energy resources for the production of electicity.
- Know about the types, preparation and handling of fuel in steam power plant.
- Know about Layout and components of steam power plant.

1.1 **Introduction**

Cheap and abundant supply of electrical power is essential in the development of country. Next to the food, the fuel and power are the most important items on which economy of countrydepends.Apart from its use in industrial organisations and domestic purposes, electricity is needed in agricultureforpumping water for irrigation and in defence for improving production methodsandothervarious operations. Our modem life is much dependent on electric power and it's per capita consumption is regarded as an index of national standard of living in the present day civilization. Therefore electrical energy is considered as a basic input for any country for keeping the wheels of its economy moving to provide prosperity and standard of living to the people of a nation. Energy exists in various form,e.g. Mechanical, thermal, electrical etc., but has one thing in common. Energy is possessed of the ability to produce a dynamic, vital effect. With the use of suitable arrangements energy can be converted from one form to another. Among other forms of energy, electrical energy has the advantages such as easy transfer with minimum loss, economical in use, and easy conversion to other forms etc., hence electrical energy is preferred over other forms of energy. Power can be defined as the rate at which energy is produced and consumed. Any physical unitof energy when divided by a unit of time becomes unit of power. However, the term 'Power' is generally used in connection with mechanical and electrical forms of energy. It is the rate of flow of energy and a power plant is a unit built for the production and delivery of a flow of mechanical and electricalenergy.

1.2 **Energy Resources**

TheVarioussources of energy are

1. Fuels

a) Solid fuels; coal, coke, anthracite etc.,

b) Liquid fuels; petroleum and its derivatives

c) Gases; Natural gas, blast furnace gas etc

2. Energy stored in water or hydraulic energy
3. Nuclearenergy
4. Wind Power
5. Solar energy
6. Tidal energy
7. Geothermal energy

1.3 Fuels used for steam generation

.The various fuels which are commonly usedfor stean Generations in powerplants are; coal, oil and gas. A Coal is heoldest fuel and still used in large scale throughout the world for power generation. Coal is a heterogeneous compound and it's constituents are always carbon, hydrogen,oxygen, sulphur, nitrogen and certain mineral non combustibles.The phenomenonby whichtheburievegetation consisting of wood, grass, shrubs etc., transformed in to coal is known metamorphism.The nature of coal will dependupon the type of vegetation buried, andnature And duration of metamorphism. The classification of coal is based on the physical andchemical composition of the coal and therefore it is required to study the chemical composition of thecoal.The proximate and ultimate analysis are the common tests which are used to find the commercial value of the coal. The proximate analysis gives characteristics of the coal such as percentages of moisture, ash and Volatile matter.
Ultimate analysis of coal is used to find out the chemical analysis of coal like carbon, hydrogen,oxygen,nitrozen, sulphur and ash.It also gives an indication about fusion temperature and the heating valueof the coal. Each constituent in the coal plays a very important role in adopting type of coal for power plant.

Carbon: Higher percentage of carbon in the coal is an indication of higher heating value and this reduces the size of combustion chamber required.

Hydrogen : In coal, hydrogen exists in combined fonn with oxygen known as inherent moisturewhichcames heat with flue gases without playing any role in the combustion. Higher percentage of free hydrogen is always desirable, as it increases the heating value of the coal.

Oxyzen: Coal contains oxyzen in combined form with Hydrogen. Always lower percentage of Oxygen is desirable as it reduces percentage of hydrogen available for heating.

Nitrogen: It has no heating value and does not play any role in combustion process.
Sulphur: It exists in coal as pyrites, sulphates, iron sulphides and organic sulphur compounds. It is responsible for clinkering, slagging, corrosion and air pollution. It adds a little heating value.

Ash: It is a residue from combustion. Melting of ash results in the formation of clinkers. Ash contains sillica, alumina, ferric oxide, calcium oxide, magnesium oxide and alkalies. It also contains 1-2% of sulphur.

Classification of coals

In the increasing order of heating value, coals are classified in to following types.

1. ***Peat:*** It is a low grade coal and first stage in the progress of transformation of buried vegetationin to coal. It contains huge amount of moisture (90%) and small percentage of volatilematterand carbon. Due to its moisture content, it is not suitable for use in power plants. It is suitable for domestic and other purposes. It is to be dried for about 1 to 2 months in sunlight toremovegreater part of moisture before it is put to use.

2. ***Lignite and brown coals:*** It is the intermediate stage in the development of coal. It also possesses high content of moisture (30 to 45%) and ash and can be dried just by exposing to air.
In comparision with peat, it has high heating value and carbon. It should be stored properly to avoid spontaneous combustion. It can be used as fuel in pulverised form. Lignites are brown in colour and burns with a smoky flame. These are suitable for local use only due to difficulty of easy breaking during the transportation.

3. ***Bituminuous coal:*** It is most popular fonn and has low moisture content and non disintegrating properties. It may posses low or high ash contents which varies from 6 to 12%. It has high percentage of volatile matter and the average calorific value is about 31350 kJ / Kg. It may be available in two forms, caking and non caking. When the coal is heated, the volatile matter isdriven off, leaving behind pure carbon known as coke. The process is known as caking.

Metallurgical industries uses low volatile matter and high caking coals and high volatile matter and lowcaking coals are suitable for gas making purposes
Sub Bituminuous coal is similar to lignite and contains lessmoisture than lignite. It is used in bliquettes or pulverised.

Semi Bituminuous coal is intermediate between Anthracite and Bituminuous coals and is the highest grade of Bituminuous coals. It releases less smoke, and has high carbon content and heating value. It posses less moisture content, ash, sulphur and volatile matter. It has a tendency of breaking to small sizes during storage or transportation.

4. *Anthracite Coals:* It is the last stage in the formation of coal and contains highest carboncontent and has the volatile matter of 8%. It has less heating value and ignites slowly unless furnace temperature is high. It has high calorific value in the range of 35500KJ/Kg. It has low ash content, zero caking power and it is difficult to pulverise the Anthracite coal.

Desirable Properties of god fuel

Agood coal should posses

1. High calorific value and low ash content.
2. Less sulphur content (less then 1%)
3. Good burning characteristics to ensure complete combustion.
4. High grindability index (Inballmillgrinding)
5. Highweatherability.

Grading of coal can be done on thebasis of i) Size ii)Ash content iii) Sulphercontenti V) Heating value.

Liquid Fuels:The liquid fuels of powerplant are alwaysby productof petroleum.Crude petroleum oil contains mainly carbonandhydrozenwith small amounts of oxygen, nitrozen and sulphur.The chemical composition of petroleum and its derivatives is; carbon 83-87%, hydrozen-10-14% and various percentages of sulphur, nitrogen, oxygen etc., The hydrozen is present inthe form of hydrocarbon mixtures.The hydrogen andcarbon are combined as hydrocarbons into specialised products like gasoline, fuel oil etc., The liquid fuels havehigher percentage of hydrogen as compared to coal, resulting in increased moisture loss in the flue gases.

Gaseous fuels

The gaseous fuel may either be natural gas or a manufactured gas. The manufactured gas is costly,therefore only natural gas is used in steam generation.

Naturalgas is found under neath the earth's surface and mainly contains methane (CH, and Ethane The calorific value is nearly equal to 21000 KJ/m3and is colour less and odourless.The manufactured gases are coal gas, coke-oven gas, blast furnace gas, producer gas andwateror illuminating gas. First two are produced by carbonizing high volatile bituminous coal.Thesegases are used in boilers and some times used for commercial purposes. The blast furnace

Gasis used in steel industry and is the by product of blast furnace. The heating value of this gas isverylow.Producer gas is manufactured from the partial oxidation of coal, coke or peat whentheyare burnt with insufficient quantity of air.

Advantages

1. Better control of combustion
2. Excess air required is less for complete combustion.
3. It is clean, no problem of storage and transportation, as it can be transported through pipe lines
4. It has no ash content in it.
5. These are adaptable to automatic controls.

1.4 Layout of steam power plant

The general layout of a thermal (steam) Power Plant mainly consists of four circuits.

1. Coal andash circuit

2. Airandgascircuit

3. Feed water and steamcircuit

4. Coolingwatercircuit

1. **Coaland ash circuit**: Coal stored at the storage yard is fed to the boiler through suitable Coal handling equipment for the generation of steam.The combustion of coal produces ash which is collected and removed to ash storage yard through ash handling equipment.

2. **Air and gas circuit**: ED fan or I.D fan or both are used to supply the air to combustion chamber of the boiler through the air preheater.The airs preheater is placed in the path of flue gases between combustion chamber and chimney and thus recover the heat of flue gases to preheat the air..

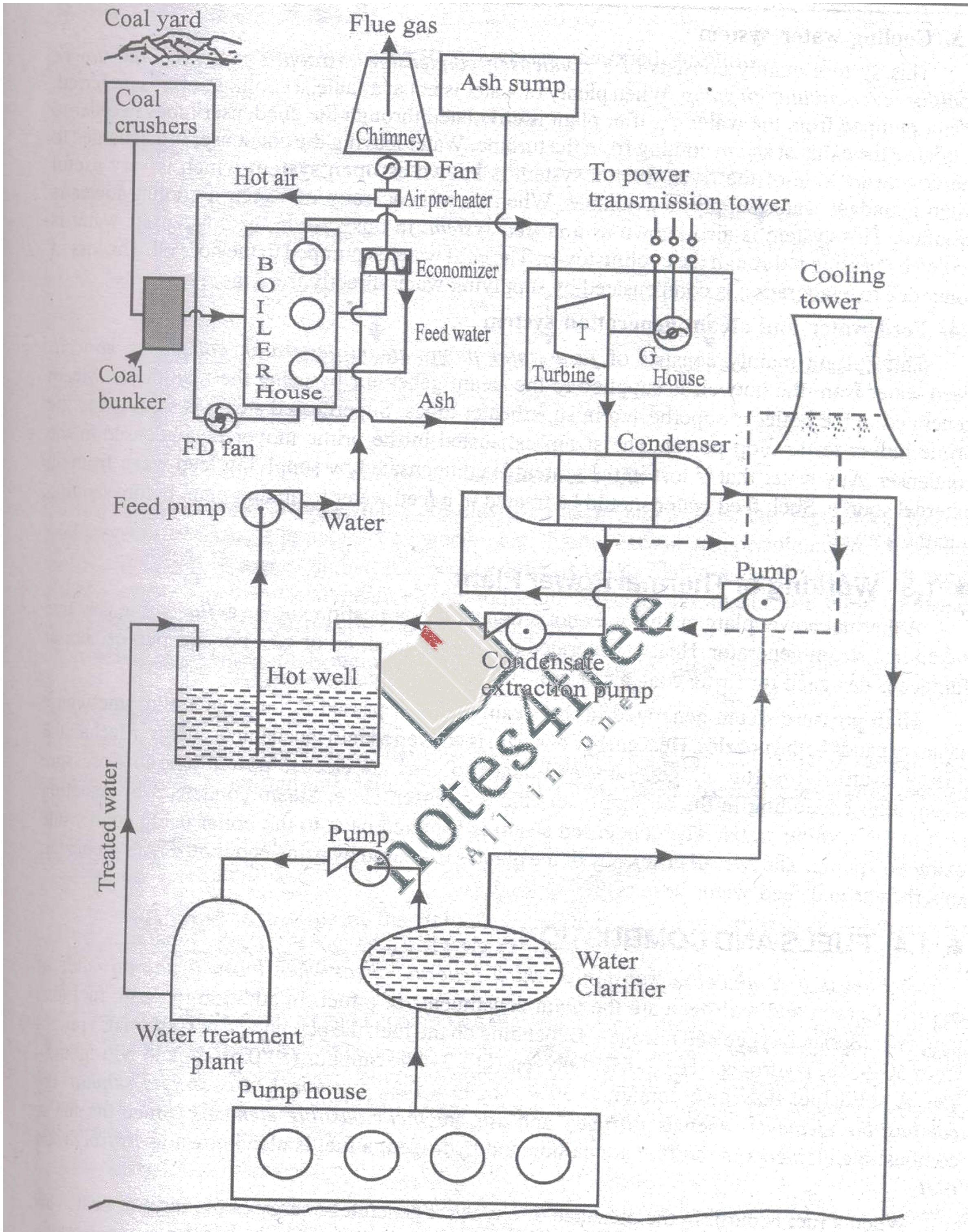


Fig 1.1 : General layout of a steam power plant

3. *Feed water and steam circuit:* The prime mover develops power by utilizing steamGenerated in the boiler.Then a condenser is used to condense the steam coming out of prime mover and a pump is used to feed the condensate to the boiler. In the boiler shell and tubes, water circulation is setup due to density difference of waterbetween low and high temperature sections. A super heater is used to super heat the wetsteam from boiler drum and is then supplied to the prime movers.

4. *Cooling water circuit:* In the condenser, quantity of cooling water required to condense of the steam is large and is taken either from lake, river or sea. The cooling water is taken from upper side of the river and then passed through the condenser to condense the steam. The hot water is then discharged to the lower side of the river. This system is known as open system.When water is not available in abundant, then water from the condenser is cooled either river or coolingpond or in cooling tower and the systemisknown as closed system. .

1.5 Equipment for burning coal in lump form

Early boilerswere set very close to the grates and the combustion space was limited and hence resulted in smoke and poor efficiency.Later, furnaces were made largerand the boilerswere set at higher level above the grates.Ahand fired furnace with large combustion spaceisused tobum a wide varietyof coal.

The following aspects areconsidered while selectingcombustion equipments.

1. Initialcostoftheequipment

2 Combustionspaceavailableandit's abilityto withstandhightemperature

3. Grate area

4. Operatingcost.

The two most commenly used methods for burning of coal in lump form are stoker firing and pulverised fuel fIling.

- Stokers
- Solid Fuel Firing
- Chain gratestokers
- Travellingsystem

The selection of firing method depends upon the following factors.

1. Characteristics of the available coal.

2. Capacity of the powerplant.

3. Power plant load factor

4. Loadfluctuations.

5. Reliabilityand efficiency of the various types of combustion equipments used in powerplant.The classification of combustion equipments used for coal burning is as shown below.

1.5.1 Stoker firing

Mechanicalstokers are used to fire almostall kinds of coal.AStokerconsists of a power Feeding mechanism and grate. Stokers are mainly classified in to spreaderstokers,underfeed stokers, Vibrating grate stokers and travelling grate stokers.Among these types,spreaderstokersare receiving the greatest interest and sales effort of any stoker type.

Advantagesof stoker firing

1. Allvarietyof coalscan be fired
2. System is reliable and requires less maintenance.
3. It produces less smoke.
4. A greater flexibilityof operations assured
5. Generally, it requires less bulding space.

Disadvantages

1. Construction is complicated
2. In caseof larger units, the initial cost may be higher than that of pulverised fuel.
3. The system cannot meet any suddenchangesin the steamdemand

1.5.2 Classification of stoker firing

Automatic stokers are classified as

1. Over feed stokers 2. Under feed stokers.

Overfeed stokers:

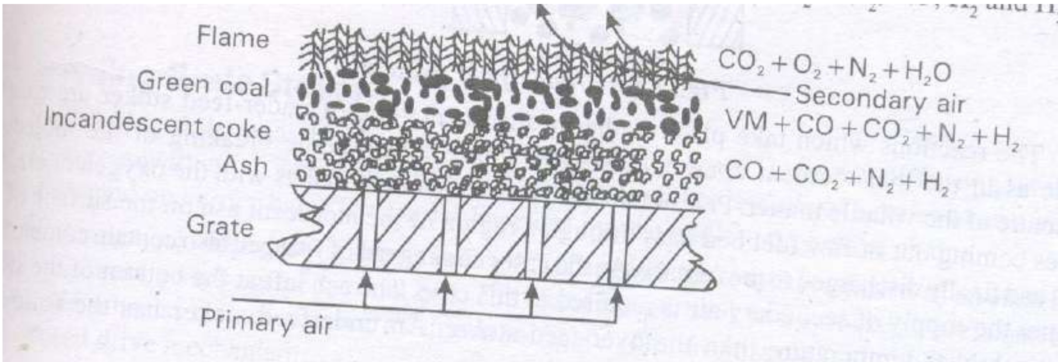


Fig 1.4 : Over feed stoker principle

In case of overfedstokers, the coal is fed in to the grate above the point of air admission.Theseareusedforlargecapacityboilerswhere pulverized coalisbeingused. Themechanismof combustionin overfeed stokeris describedbelow.

1. The air from ED fan with its water vapourcontent from atmosphere enters the bottom of the cograte underpressure.As air passes throughthe grate, it absorbs heat from ash and grate it self; anthuscoolsboth of them.Then the hot airpassesthrougha bed of incandescentcoke, where' 02'reacts with 'C' to form CO2'

(a) Primary air + water vapour (b) Primary air + water vapour

Entirely depends on the rate of air supply. Generally, all the °2 present in the air disappears in theincandescentregion for a fuel bed of 8cm deep. Hence no free oxygen will bepresent in the gases leaving the incandescent zone. Water vapour entering with air also reacts with carbon to form CO, CO_2 and free H_2.While travelling through incandescent region, some of the CO_2 reacts with coke.

Underfeed stokers

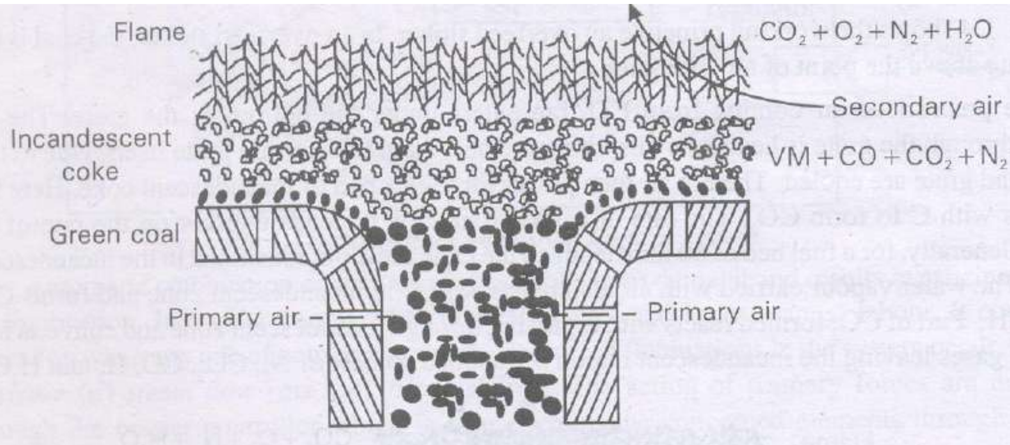


Fig. 1.5 : Under feed principle

In this type, the coal is admitted in to the furnace below the point of air admission. ie., bothcoaland air moves in the same direction. This type is suitable for burning the semi-bituminous and bituminouscoals.

The combustion mechanism in underfeed stoker can be explained as follows.

Air enters through the holes in the grate and meets the green coal. It diffuses through the bedofthe green coal and meets volatile matter produced by green coal. The heat for distillation is obtained by conduction from the incandescent coke which exists above the green coal. The air and formed volatile matter mix with each other and enters in to the incandescent zone by passing through the ignition zone.

Principle of underfeed stoker

In incandescent zone, the reactions are similar to over feed system except some breaking ofthe molecular structure of the volatile matter and a portion of this reacts with oxygen present in the air. The gases leaving the green coal bed pass-through a region of incandescent ash and thedischarged in to the furnace. It contains the constituents similar to overfeed stokers. Thia secondary air is supplied at a very high speed to create turbulence in order to facilitate completecombustion. At the bottom of the stoker, the ash is at higher temperature than the overfeedsystem.

1.5.3 Types of over feed strikers

The over feedstokersareof mainly classified in to two types.

1. Travelling grate stoker/ Chain grate stoker
2. Spreader stoker

1. Travellinggrate stoker:

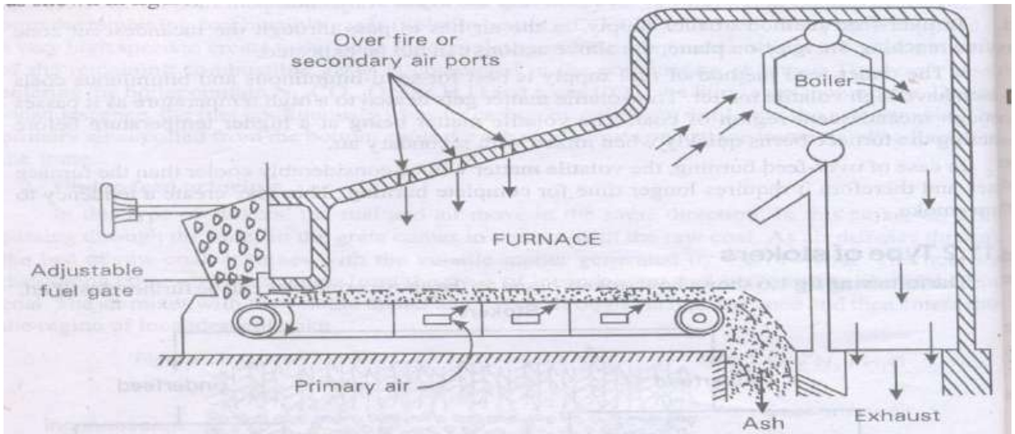


Fig. 1.7 : Chain Grate Stoker

The travelling grate stoker may be of chain grate type or bargrate type. These two, differ only in the constructionof grate.Thechaingrate stoker employs an endless chain which is constructed to form a support for the fuel bed. The travelling grate stokerconsists of grate bars carried by steel chains. In both the cases, the chain travels over twosprockets,one at the front end and other at the rear end of the furnace. The front sprocket isconnectedto a variable speed driving mechanism. Depending up on the type of the coal burned,thegratehas air openings in the range of 20 to 40 percent of the total area.ExhaustA travelling type chain grate stoker is as shown in figure.It consists of an end less chainwhich fOlms support for the fuel bed. The two sprockets, one at the front end of the furnace andconnected to variable speed driving mechanism and other at the rear end, carries an end lesschain as explained earlier. The speed of the stoker is 15cm to 50 cm per minute. Coal is fed bygravity from a hopper located at the front of the stoker. The fuel depth on the grate is regulatedby a handadjusted gate. The fuel bed thickness can be regulated either by adjusting the openingof the fuel grate or by control1ing the speed of the stoker driving motor i.e., the grate speedchanges the rate of coa1feeding in to the furnace. The combustion control automatica1ly regulatesthe grate speed to maintain steam pressure. The ash with combustible matter is carried over therear end of the stoker and then disposed in to the ash pit.The air required for combustion is admitted from the under side of the grate and the secondaryair is supplied above the grate as shown in figure. Air dampers are used to control the supply ofair to vaious zones. The grate should be saved from being over heated. For this, the coal shouldhave sufficient ash content which will form a layer 6n the grate. Practica1lythere is no agitation ofthe fuel bed, non caking coals are best suited for this type of stoker. These can bum about 150kg of coal per m2per hour with natura1 draught and from 200 to 300 kg of coa1 per m2per hourwith forced draught.

2 *Spreader stoker (Sprinkler stoker)*

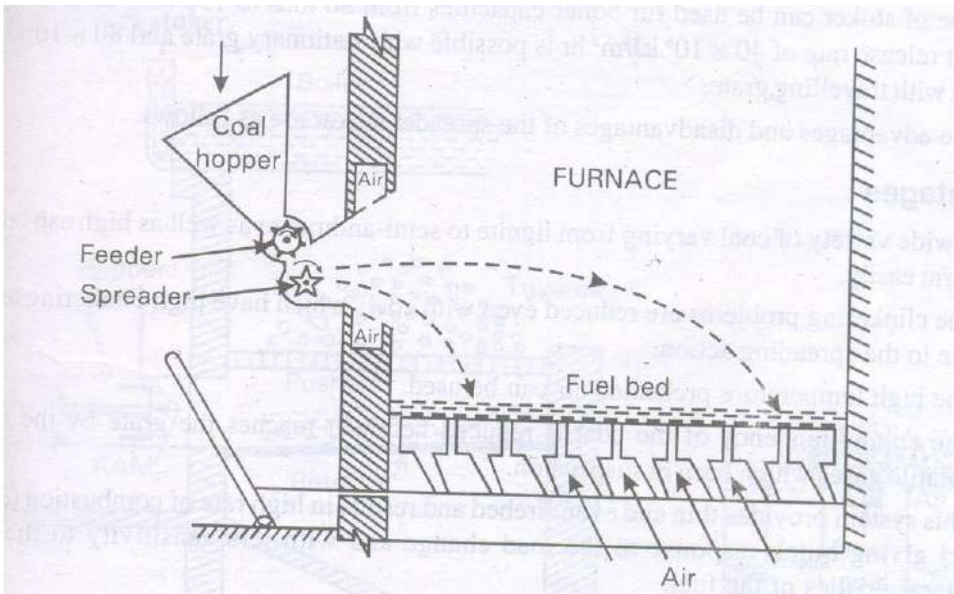


Fig. 1.8 : Spreader stoker

Thistype of stoker can bum any type of coal from lignite to semi anthracite. In this type ofstoker,the grate is used only to support a ash bed and move it out of the furnace. The coal bumspartlyinsuspension and partly on the grate.

It consists of a variable feeding mechanism which throws the coal uniformly on the grate.Theairrequiredfor combustion is supplied through the holes in the grate. The spreader distributescoalinthe furnace and fine particles of coal bums in suspension and remaining falls on the grate.

Furnace

The FD. fan is used to supply primary air to bum coal on the grate, volatile matter and finesuspended particles of coal. The secondary air or over fire air to create turbulence for propercombustionof fu iedthroughnozzleswhicharelocateddirectlyabovetheignitionarch.The unburnt coal and ash are deposited on the grate and are removed peliodically to rempve theash from the grate.

The feeder used in the feeding mechanism may be a reciprocating mm or end less belt whichsupplies coal to the spreaders in a continuous stream. The feeder speed may be varied to controlthe combustion as per load on the plant.

Spreader is a rapidly rotating shaft carrying blades on it. The function of the spreader is todistribute the coal uniformly over the grate.

This stoker can be used for boiler capacities from 70000kg to 140000 kg of steam perhour.The coal size used should rangesbetween 6 cms to 36 cms.

1.6 Pulverised fuel firing

The Pulverization of coal is a means of exposing a large surface area of the coal to the actionof oxyzen and consequently accelerating combustion. The conventional or stoker firing methodswere unable to meet the variable loads on the plant and were unsuitable for large capacity plants.Nowadays pulverised fuel firing method is universally used for large capacity plants. It gives higher thermal efficiency, better control as per load on the plant and uses low.

Advantages

1. Since coal is in the powdered form, coal of any grade can be used.

2. Widevariety and lowgrade coal can be burnt easily.

3. Practically,it is free from slagging and clinkering problems

4. Therate of coal feed can be regulated properly resulting in fuel economy

5. Thecombustion rate is faster due to greater surface area of coal per unit mass of coal. Itmeans more coal surface is exposed to heat and oxyzen. This decreases, excess airrequired for complete combustion and also decreases fan power.

6. Theexternal heating surfaces are free from corrosion and fouling

7. The use of highly preheated secondary air (3500C), results in rapid flame propagation.

8. There are no stand by losses due to banked fires.

9. In thefurnace,moving -parts are not subjected to high temperature. increases systemlife. .

10. Thereis an increased rate of evaporation and higher boiler efficiency due to completecombustionof fuel

11. The system is free from ash handling problems.

12. Greater capacity to meet peak loads

13. The system work successfully in combination with gas and oil.

14. Theflame length is less due to turbulence created by the burners in the furnace. Thus the Volumeof furnace required is considerably less.

Disadvantages

1. Thesystemrequiresmanyaddtional equipmentsand also coal preparation plant, thusincreasingthecapitalandoperatingcost.

2. This system requires skilled operators

3. As coal burns like a gas, there will always be dangerof explosions

4. A special equipment is requiredto start the system.

5. It requireslargebuildingspace,especiallyincase of centralsystem.

6. Highworkingtemperaturecauses rapid deterioration of the refractory surface of thefurnace.

7. Aspecialcare is to be taken while storingcoal in powderedform to protect it from irehazards.

The pulverised coal system may be classified in to two types.
1. Unit system or direct firing system
2. Central system or Bin system (storage system)

Unit system or Directfiring system

Most of the power plants with pulverised coal as the fuel are being installed with unpulveriser. In this system each burner or a group of burners and the pul veriser constitute a unitThe over headbunker suppliesraw coal by gravity in to a feederwhere it is dried with thehellof hot air. Then the coal passes on to the pulverising mill where it is crushed to the requiredsizt(fine powder). The feeder supplies coal to the pulverising mill at a variable rate governed by theCombustion requirementsof the furnace and steam generating rate required in the boiler. The PrimaryairfromtheIDfancarries pulverized coalfromthemillto theburnerthrough.delivery pipe. In the seperator,the big coal particles are seperated from the fine dust and thesplagainfall downin to the mill. Beforethefuelentersin to combustionchamber,the secondaryairistobesupplied to theburnerasshownin figure.

Advantages

1. It hasgreater simplicity and permits easy operation.

2. Itrequires less space, less capital and operating costs.

3. Itis cheaper than central system

4. Itpermitsdirect control of combustion from the pulveriser.

5. Incaseof replacement of stokers, the old conveyor and bunker equipment may be used.

6. Betterfuel feed in to the furnace is possible

Disadvantages

1. The power consumption is high per torof the load at part load. The mill operates atvariableload,a conditionnot conduciveto best results.

2. Whencompared to central system, it has less flexibility.

3. Withloadfactors common in practice, total mill capacity must be higher than for centralsystem.

4. Thefanhandlesair andcoal particles and results in exessive wear and tear of the fanblades. .

5. Incaseof failure of auxiliaries of one of the burners, the burners has to put off as there isnoreserve capacity.

Centralsystem (Bin system):This system employs a limited number of large capacitypulverisersatacentralpointtopreparecoalfor all theburners.Thebin systemwaswidelyusedbeforepulverising equipment became reliable enough for continous steady operation.As it consistsofmany stagesof drying, storing, transporting etc, the bin system is subject to fire hazards.Nevertheless,itis stillinuseinmanydiderplants.Thearrangementofthe systemis asshownin.Thecrushed coal from the raw coal bunker is passed to the drier by the action of gravity.Thecoalisdriedeitherbyusinghotgases,preheatedair or bled steam.Then the feedersuppliescoaltothepulveriser.The airsuppliedfromJ.D.fan carries pulverized coalfrom the pulverisermilland the pulverised coal is seperated in the cyclone seperator. A fabric bag filter is used to separate andexhaustthe moisturedair to the atmosphere and dischargethe pulverised coal tostoragebins(central bunker), through conveyor. This system uses all the equipments as used inunitsystemwithhighercapacityof each part. In addition to otherequipments,the system alsousesstorage bins.The pulverised coal is fed to the various burners through seperate feeders. Thebinmaycontainfrom 12 to 24 hours of supply of pulverised.

Advantages

1. Thesystemismorereliable,asthefailureofthecoalpreparationunitdoesnot immediate affect theplantoperation.

2. Thequantities of fuel and air can be regulated accurately and seperatly.This leadgreaterdegreeof flexibility.

3. Thesystemoffersgoodcontrol of coalfineness.

4. Dueto the presenceof storagebin betweenmillandburner,thepulverisermayworkconstantload.

5. It requireslesslabour.

6. It consumesless power per tonneof coal handled.

7. Thefan handlesonly air,hencethereisn9problemof excessive wearandtearof thefan blades.

8. Burnerscan be operated independentof the-9perationof coal preparation plant.

Disadvantages

1. The initialcost is highand it occupiesa large space

2. Theauxiliaries used in the system consumelargepower.

3. Thereis possibilityof fire hazardof storedpulverisedcoal.

4. Thesystemuses driers.

5. For the samecapacity,operationandmaintenancecosts are higherthan unit system.

6. Thecoaltransportationismuchmorecomplex.

1.6.1 Pulverised Coal burners

The function of coal burner is to fire the pulverised coal from the mill, along with the primary airin tothe furnace. The coal is pulverised in a mill and is carried by the primary air to the furnaceJ and the primary air is only about 20% of the total air required for combustion. Before the coal, entersin to the furnace, additional air known as secondary air is to be supplied for proper and completecombustionof coal. The secondary air is supplied seperatly around the burner or elsewherein the furnace. The proper utilization of pulverised coal depends upon the ability of burners toproduceuniformmixing of coal and air and turbulence within the furnace. Ignition take place: by means of radiation and flame propagation from the fuel, already burninig in the furnace. The burner shouldmaintainstable ignition of the mixture and control the shape of flame and its travelinthefurnace.The mixture must move away from the burner at the rate of flame front travel.

Thepulverized coalburners should satisfy the following requirements.

I. Thereshouldbe thorough mixing of coal and primary air and the mixture is to be fired inthefurnaceproperly with secondary air.

2. Itshouldcreateproper turbulence and maintain stable ignition of the mixture in the furnace.

3. It shouldcontrol the flam~ shape and its travel in the furnace.

4. Thecoal and air mixture should move away from the burner at the rate equal to flametravelin order to prevent flash back in the burner.

5. Theburnermusthave adequate protection againstover heating, internal fires and excessiveabrasive wear.Theperformance of the pulverised coal burner is depends up on the

characteristics ofthecoalused,finenessof pulverized coal,geometryofblimer,volatilematter,proportionsofprimaryandsecondaryair,furnace design etc.,

Pulverisedcoal burners may be classified as follows;

I. Longflame burners

2. Turbulentburners

3. Tangentialburners

Longflame burners: These are also known as U flame or stream lined burners. Theseburnersare suitable for furnaces with low volatile coal, and produces a long flame path forslowerburningparticles.The arrangement of primary air and coal flow and the supply of secondaryairisasshownin figure. The supply oftertiary air near the burner fonns an envelope around theprimaryairand fuel and helps in better mixing. The mixture is discharged vertically in one stream fromtheburnerwithout turbulence and fonns a long flame. The supply of secondary air at rightanglestothe flame helps in better and rapid combustion of the mixture.

Turbulent burners

It is alsoknownas shortflameburner.Theseburnersare set in to the furnace wallsandahorizontallyoratsomeinclinationsasshown in thefigw-e.Thefuelairmixtureandsecondaryhot air arrangedto pass through the burner in such a waythat there is good mixing andmixture is projected in highly turbulent form in the furnace. Due to this, there is an intense buruning of the mixture and combustion is completed in a short distance. In comparision with other burntuses bituminous coal and a long penetratingflame or short intensely hot flame may be obtained. This burnersuitable for high volatile coals and is used in all modem power plants.

Tangential burners

In this case, four burners are arranged atfour comers of the furnace and they dischargethefuel airmixture streamstangent toan imaginarycircle in the centre of the furnace. The swirlingaction produces intense turbulence and thoroughmixing of fuel and air so that combusion iscompleted in a short period. This avoids the need

of producing high turbulence at the burner itself.This method of firing gives high heat release rates.Some times the burner tip may be angled'through a small vertical arc (:1:30°). Thisarrangementhelps to raise or lower position ofmolten ashtheturbulent combustionregion in the furnace. The gastemperature at the furnace aperture canbecontrolled with this method, so that a constant super heat temperature of steam cans bemaintained.The furnace iscompletelyfilled withflamebytiltingtheburnersdownward.Thisdecreasefsurnaceexit gastemperatureandheatgiven to the superheater.When bumersaretilted upwardit,increasethseheatgiventosuperheaters, of thatdependingontheload,aconstantsteamsuperheattemperaturecanbemaintained.

1.7 Pulverisers: (Pulverising mills)

The function of pulveriser is to grind the raw coal to increase its surface exposure and henceto accelerate the combustion without using large quantities of excess air. It is the most importantpart of the pulverised coal system. The satisfactory performance ofthe pulverised fuel system depends up on the performance of the pulverisers. The pulveriser should deliver the rated tonnage of coal, and shouldconsume nominalrateof Power.It should be quiet in operation and shouldPulverize thefuelto satisfactoryfinenessovera widerangeof capacities.Coalswithlowvolatilecontentshouldbe pulverisedto a higherdegree of finenessthan thosewith higher volatile.It iswastefulof energyto pulverize coalfinerthanrequiredto obtainsatisfactorycombustion.Thethreestagesof pulverizing processof coalarei) feedingii) dryingandiii)grinding.Thefeedingsystemregulatesthe fuelfeed rateasper loadon theplantandrequiredair rate (primaryair)fordryingandthen projectsthe pulverized fuel andprimary air streamin to the combustionchamber through burner. Dryers are the integral part of pulverising unit to remove moisture contentof the coal.The air preheater forces hot air at temperatureof 350°C in to the pulveriser.Then it mixed with coal as it isbeingcirculatedandground.Pulverisersaretheheartof the equipment forpreparing pulverizedcoal.Thegrindingispetfonnedbyimpact, attrition, crushingorcombinationofthese.Basedonthe methodof achievinggrinding, the pulverisersareclassifiedin to

1. Attritionmills

i.'Bowlmills, ii.Ballmills

2. Impactmills

i. Ballmills, ii.Hammermills,

1.7.1 Bowl mills

The bowl mill i&-widelyused for grinding coal.The pulveriser shown in figure 1.21hasgrindingelementsconsisting*of* stationaryrollersandapowerdrivenbowlin whichpulverizationandintermediatesizes*of* coal arepickedupfrom the top by a stream*of* heatedprimary airand is carried in to theclassifierabovefor classification.The vanes *of* theclassifierreturns the coarse particles*of* coal

Throughthe centrecone*of* the bowl for furthergrinding.Thecoal whichhas been pulverized tothe desired fineness passes out *of* the mill, through the fan and is carried to the burner. Theautomaticcontrolchangesthe coal supplyto thebowl*of* the millby adjustingfeederspeedandthe flow *of* primary air by regulating a damper in the line from the pulveriser to the fan. Theheaviercoal particlesare thrownover the side in to thespacebelow the bowl due to centrifugalforce and are dischargedto a seperate place.

Thisisalsoknownascontactmill and it crushes coal betweentwo moving smfaces, balls andraces,byattrition.It consists of stationary and power driven elements, which are arranged to obtainarollingactionwithrespecttoeach ()ther.The coal passes between the rotatingelementsgainandagain,untilithasbeen pulverized todesiredfineness.Thegrindingpressureismaintained byadjustablesprings.The coal is crushed between two moving surfaces namely balls and races.heballsrollin a race running over a surface. The upper race is a stationary one and a worm and

;eardrivesthelowerrotating race. The coal is to be fed in to the inner side of the races. The coalscrushed to the powderedformbetween the movingballsandraces.The hot airsuppliedpicksthecoal dust as it flows between the balls and races, and then enters the classifier. Theclassifierseperatesthe over sized particles and returns them for further grinding and the coalrequired size are discharged from the top of the classifier.

The grinding elements of these mills are protected from excessive wear and possible breaklby heavy foreign objects in the coal. These heavy particles resist the up ward thrust of the stmof primary airand collect in acompartmentin the base and are to be removed periodically.

The coal supplyto the burner is automaticallyregulatedby the combustioncontroladditionalcoal is required, the flowof primaryair is increasedand itshighervelocityin thencarriesadditionalcoal to the burner.

Advantages

1. Lower capital cost
2. Lowerpower consumption
3. Lesser space required
4. Lowerweight.

Disadvantages

1. These mills have greater wear comparedto other types.

1.7.2 Ball mills

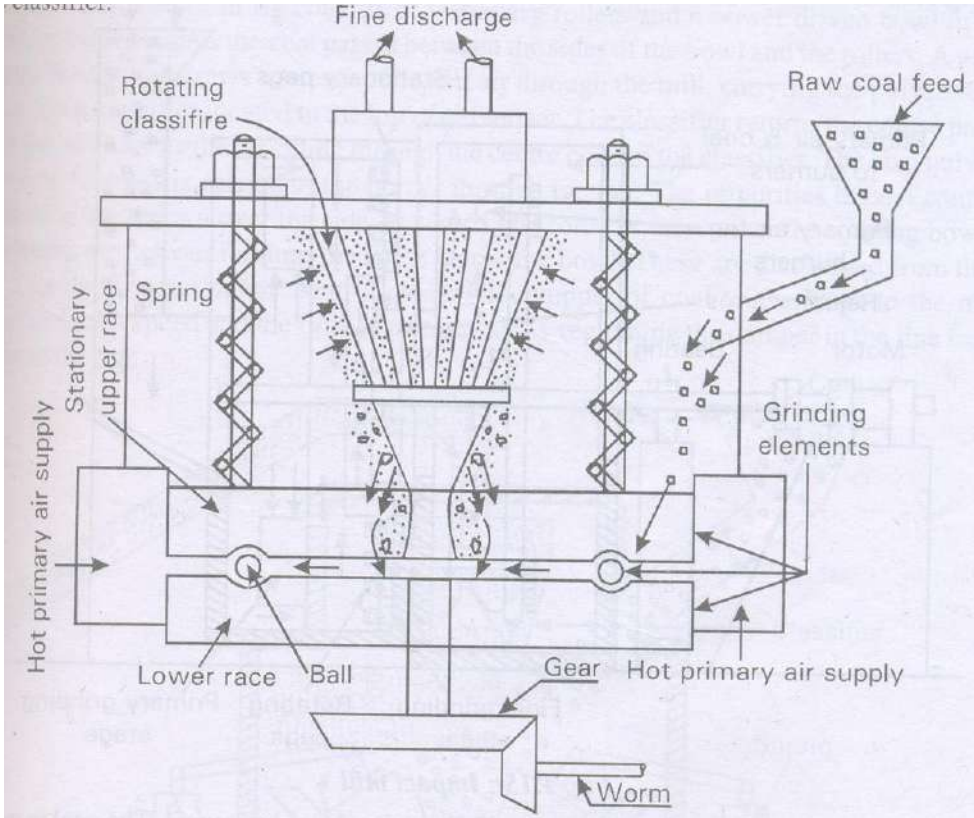


Fig. 1.14 : Ball and race mill

The diagram of a ball mill using two classifiers is as shows in figure1.14. It consists slowlyrotatinghorizontalcylinderordrumwhichispartlyfilledwithvarioussizedsteelballs.Sizes vary from 2.5 to 5cm in diameter. The feeders, feed the raw coal (6mm in size) in to theclassifiersfrom where it passes over a screw conveyor to move in to the cylinder. As the cylinderrotatest, thecoal mixes with the steel balls and gets pulverised due to the attrition and impact. HotIprimaryair is blown over it, to cany the pulverised coal to the classifiers, where sharp changes inthedirectionof themixture throw out thecoarse (over sized) particlesfor regrinding.Classifier, coalandair mixture movesto theexhausterfanandthensuppliedto theburners", mill is reliableandrequireslessmaintenance, butit isbulky andheavyin construction.It consmorepower andis not suitablefor wet coalsdueto poor air circulation. In this mill, rnetallotherforeignmatterpresentin thecoalwill notaffectthegrindingelements.Themill containsufficientquantityof coal,thereby formsacoalreservoir.This preventsfire from out due to slight interruption in fuelfeedcausedbycoa1clogginginbunkersorspouts. Thissuitable for awide range of coalssuchasanthraciteandbituminous coa1s, which aredifficult pulverise.

Advantages

1. It maybedirectlycoupledto themotor andhenceoperatesat high speed.
2. Thepowerrequiredto drive thepulveriserisnearlyproportionalto thecoal pulverized overawiderangeof rating
3. It requiresminimumfloor areaasfan is theintegralpart of mill.

1.8 Coal handling

Coalhandlingequipmentisoneofthemajorcomponentsofplantcost.Thecoalhandling Equipment shouldsatisfysomeoftherequirementsuchasminimummaintenancereliability, simplicityandshouldwearlessdueto abrasiveactionof coalparticles.

Thevariousstepsinvolvedincoalhandlingareasfollows.

1. Coaldelivery
2. Unloading
3. Preparation
4. Transfer
5. Outdoorstorage (dead storage)
6. Coveredstorage (Iive storage)
7. Inplanthandling
8. Weighingandmeasuring
9. Feedingthecoalin to furnace.

1. *Coaldelivery:*The coal may be delivered from the supply points by using ships or boatswhen thepower stationis situatednear the sea or river.The rail or trucksmay be usedto

deliverthecoal when the power station is situated away from the sea or river. The trucks are used, whentherailwayfacilities are not available near the power station.

2. *Unloading:* The type of equipment used to unload the coal in the plant depends up on howthecoal is received at the power station. i.e., by road, rail or ship. If trucks are used to deli ver thecoal, there is no need of unloading device as the same trucks are usedto dump the coal to the dead storage. Coal handling becomes easier,if lift trucks with scoop are used. If the coal is handled by railwaywagons, ships or boats, unloading may be done by cranes, rotarycardumpers, grabbuckets, coal accelerators, portable conveyors, selfunloading boats etc.

3. *PreparaJion:* When the coal recieved at the site is in the fonn ofbig lumps (not of proper size), it is to be prepared before feeding tothe combustion chamber by using the equipments i) Breakers ii)Crushers iii) Sizers iv) Dryers v) Magnetic seperators

The coal crushers are used to prepare the coal of rquired size beforesupplying to the furnace. The coal which does not require sizing istobe by passed. The sizers seperates the unsized coal particles andreturns to the crushers. The driers are used to remove the excess freemoisture from the coal by passing hot flue gases through the coalstorage. The magnetic seperators are used to remove the iron scrapand other foreign particles from the coal, before supplying to thestorage hopper.

4. *Transfer:* Transfer of coal includes handling of coal between the unloading point and the storage site. The equipments used for transfer of coal are

a. Belt conveyors

b. Screw conveyors

c. Bucket elevators

d. Grab bucket elevators

e. Skip hoists

f. Flightconveyors.

(a) **Belt conveyors**:

It is a methodof transportinglargequantitiesof coal over a large distance and used in mediumand largepower plants. The figure1.26 shows aover a pair of end drums or rollers. The belt ismadeof rubber,canvas, or balata.Theenddrumsare supported by a series of rollers provided atregularintervals. These conveyorscan carry thecoalwithaninclinationupto 200to horizontalwithanaveragespeedof 60 to 100mlmin.Theload carrying capacity of the belt mayrangesfrom 50 to 100 tonnes/hour. It cantrasferthe coal over a distance of 400m

(b) **Screwconveyor**:

Thescrewconveyorconsistsof anendlesshelicoidscrewfittedto a shaft.Thescrewshaftisdrivenbysomemechanismatoneend andthe otherend of whichis supported in abearing.Thescrew while rotating in atroughorhousing,transfersthecoalfromfeedinto thedischargeendThisconveyordischarges125tonnesof coalper hour.The screw diameter rangesfrom15cmto50cmandits speedvariesfrom 70 to 120rpm.Thissystemis suitableto transfer coal over short distance and wherethe enough space isnotavailablefor theuse of otherequipments.

Advantages

1. Theinitialcostis low
2. Itrequiresminimumspace
3. It dischargescoal at elevated places

Disadvantages

1. It is not suitablefor largecapacitystations.
2. It consumesmore power
3. There is considerablewearof screwand this reduces life of conveyor

(c) **Bucket elevators**: This elevator is used to carry the coal from bottom to the top. Thebuckets of the elevator are fixed to a chain which moves over two wheels. It can lift the coal toa maximum height of 30.5m and maximum inclination to the horizontal is 600. The elevatorcapacity is about 60 tonnes per hour and the chain speed is limited to 75m / min.

(d) Grab bucket conveyor: The purpose of grab bucket elevator is to lift and transfer coal ona single rail or track from one point to the other. It can be used with crane or tower and transfercoal to overheadbunker or storage. It h as the capacity of 50 to 100tonnes/hr rceoqnIts useisjustified only when noother.

6. **Inplant handling**

Thecoal may be brought from dead storage to covered or live storage. It also refers tohandling of the coal between final storage and the firing equipment. It includes the equipmentssuchasbeltconveyors, screw conveyors, bucket elevators etc.,

7. Weighing and measuring

The methods used to weigh the coal are 1) Mechanical 2) Pneumatic and 3) Electronic. I equipmentsused to weight the quantity of coal are i) Weight bridge ii) Belt scale iii) Weight lorry.

1.9 Ash handling

All types of coal have some percentage of ash. When the coal is burnt, about 10 to 20'% of total quantity of coal produce ash. In modem power stations, huge quantity of coal is used whichresultsinthousandtonnes of ash per year. A 200MW capacity power plant using indiancoalsThearrangementshown in figure1.31and is generally used for lowcapacity power plantwhichuses coal as the fuel

1.9.1*Mechanical handling system* .

Thehotash released from the boiler furnace is first cooled by passing through water troughandthenit is transported to an ash bunker by using belt conveyor. The trucks are used to carrytheashfrombunker to the dumping site. The life of this system is 5 to 10 years and maximum

1.9.2 *Hydraulic system* Advandages

In *this*system,ashis canied withtheflowof waterwith*high*velocitythrougha channel.finally discharged in to the sump. This system is again subdivided in to 2.

a) Low pressure (low velocity) system 3

b) High pressure (high velocity) system 4

a) Low pressure system

In this system, ash from *the* furnace grate, falls into a water trough provided below.

boilers and is made to flow through the trough with low velocity. The water flow in thetrcarries ash to pass through a screen where water gets seperated from ash. The separated is again pumped back to the trough for reuse and ash is carried to the sump. This systemcapacity of 50 tonnes/hr and carries ash over a distance of 500m.Boilers

AdvantagesofHydraulicsystem

1. Itiscleananddust less andtotallyenclosed.
2. Thesystemis alsosuitableto handlestreamof moltenash.
3. Itscapacityis largeand there foremoresuitablefor large thermalpowerplants.

4. Thecomponentsof the systemdonotcome in contact with ash

5. Itcandischargethe ash at a large distancefrom the power plant.

Advantages:

1. It ensures dust less operation as the materials are handled in an enclosed conduit andhence eliminates the dust nuisance while handling flyashand dust.

2. The system is free from spillage and rehandling

3. The materials are handle4 in the drYstate and discharged to th~ storage bin in the samestate.Thiseliminatis thechance*of*ashfreezingor stickingin the storagebin and the materialcanbedischargedfree1yby gravity. '

4. Thesystmis highlyflexible.

Disadvantages:

1. Labourandmaintenancechargesarehighdueto largeamountof wear andtearintheconveyingpipe. '

2. The operation is noisier than *other* systems.

1.10 **Chimneys**

The natural draught is obtained by a tall Chimney or a stack. The natural draught is udedinboilers of smaller capacities. It is created by the density difference between the atmospheric airand hot gas in the stack, i.e., it is caused by the difference in height of a column of cold atmospheric air and that of a similar column of hot gases in the Chimney. The system is dependent uponlChimney height and average temperature of hot gases in the Chimney. The draught obtained mafbe insufficient to overcome the losses in the system.AChimney is a vertical tubular structure of masonry, concrete, brick or steel. It is builenclose a column of hot gases to produce the draught and carries the products of combustion tosucha heightwhichis enoughto preventair pollution.The ChimneydraughtdependsupontheItemperature difference of hot gases in theChimney and cold air outside the chimney.The Chimneymainly serves two purposes (i) It produces the draught and make the air and gas to flow through,the fuel bed,furnance, boiler passes andvarious other equipments. (ii) It C 1discharges products of combustion to 0o~certain height to prevent air pollution.In modem steam power plants,

Chimney is only used to discharge gasesat certain height and is not used forcreating draught. The use of Chimneydraught increases, the flue gastemperature leaving the combustionchamber and there by reduces overallefficiency of the power plant.Furnace

Forced Draught

Thefigure 2.12 shows the an-angementof various components in a forced draught system.Itusesa blower or a fan near the base of the boiler to force the air to pass through the furnace,flues, economiser, air preheater and to the stack. As the air pressure throughout the system isaboveatmospheric, the system is known aspositi ve draught or forced draught system. In thissystem, Chimney is used only to discharge the fluegases at certain height in to the atmosphere to preventcontamination.Thedraughtproducedby Chimneyisnot significant,hencetall ChimneyISnot required.Most of highratingcombustionequipmentsusesforceddraughtfansfor supplyingtothefurnace. It is used in underfeed stoker which is carrying a thick fuel bed.

Induced Draught System

Induced draught is created by a fan and chimney to cause the air to flow into the furnace and, combustionproducts to be discharged to the atmosphere. The pressure in the furnace is belowthat of the atmosphereto inducethe flow of combustion air.As the fan is located at thebast.the stack,it has to handlehot combustiongases.Henceit requiresgreaterpowerthanthe draughtfans.In addition,it hasto withstandthecorrosive actionof combustionproductsanolash.

Balanced Draught.

It is a combination of forced and induced or forcedandnaturaldraught.Theforcedfan delivers air to the furnace and-an induced draught fan or a chimney produces draught remove the gases from the unit.

In forced draught system, furnace opening for insp~tion or firing is not possible, furnace opens, the air inside furnace which is at high pressure, tends to blowout andthiscauses blowingoutof thefire completely andthusthe furnace'stops

In induceddraught system, the furnace opening for firing odnspection is not possible, as the atmosphere airenters into the furnace due to lower pressure inside the furnace. This reduceseffective draught and dilutes the combustion.

Furnace

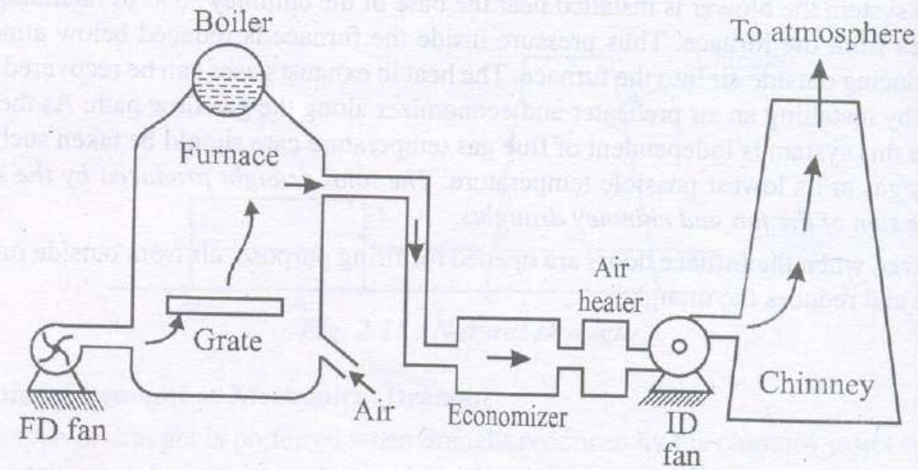


Fig. 2.14 : Balanced draught

A- Inlet pressure to forced fan

B- Outlet pressure to forced fan

C- Pressure below the Grate

D- Pressure above the Grate

E- Inlet pressure of Induced fan

F - Outlet pressure of Induced fan

The figures 2. 14(a) and 2. 14(b) shows the arrangement of various components in balanceddraughtsystem and pressure distribution through the system. The forced draught fan pushes theatmosphericair through the fuel bed on to the top of the grate, thus over comes the resistance offuelbed. This also provides sufficient air supply to the fuel bed for complete combustion. Theinduceddraught fan sucks in the gases from the furnace and discharge them to the atmosphereThroughchimney. This maintains a pressure in the furnace just below atmosphere. This preventsblow-offof flames as the air leakage is inwards. In the furnace, the pressure is near to atmosphericandhence there is no chance of blowout of flames. Below the graty, the pressure is greater thanatmospheric and it helps for proper and uniform combustion.

Advantages of Mechanical draught over natural draught

1. Easy control of combustion and evaporation.

2. The draught available is independent of the atmospheric temperature.

3. It also useslow grade fuels, as the intensity of draught is high.

4. The regulation of airflow asper requirement is possibleby changing the draught pressure.

5. Plant efficiency can be improved.

1.11 **Cooling Towers and Ponds**

Themodem steam power plants rejects 10 to 15% of heat input to the atmosphere throughboilecrhimneys. At least 50% of the heat input is rejected as unavailable energy to a cooling watersystemthroughthe steam condensers. In nuclear power plants, about67% to 68% of the heatgeneratedwithin the reactor is rejected to the water through steam condensers. The main steamcondenserserves two purposes, one is to remove the rejected heat from the plant cycle and otheristokeepthe turbine back pressure at the lowest possible leveLIt transfers latent heat of theexhaust steam to water, which is exposed to the atmosphere. Therefore, the steam condensersrequirehuge quantity of water for cooling purposes. In an open system, the water requirement isabout 5.°timesthe flow of steam to the condenser. Approximately, a condenser uses 50 gallons ofwaterperKWh for cooling and about 5% additional quantity is required for other purposes such asashquenching,beating cooling and boiler make-up water etc. The high cost of the water makes ittousecooling towers for water cooled condensers. A 1000 MW capacity plant pses about 100thousantdons of circulating water per day even with the use of cooling towers. Thus, the source ofcooling water should supply this huge quantityof cooling water.

The coolingwater may be obtained from:

1) Riveror Sea 2) Cooling Ponds 3) Spray Ponds 4) Cooling Towers.

Condenser water cooling systems

Open or once through or River water system: In this system, a pump draws wateron the up stream side of the river and delivers it to a condenser.The condenser dischargeswater at 5 to 10°C greater than inlet temperature, to the down stream side of the ri ver. Thissystemis used,when the plant is locatedon the bank of river or lake.The inlet and dischargepointsshouldbe kept as large as one kilometer or even more to avoid recirculation of water,which affects the efficiency of the condensing plant.

Closed system

This system is suitable when adequate quantity of cooling water is not available from river In this system, the required quantity of water is col~ected from river during flood or when sufficient water is available. The condenser discharges hot water to a spray pond or cooling towercooling purpose and uses same water again and again.Additional water is required fromsource to compensateevaporation losses andcarryover losses in towers.

Cooling ponds

Thespraypondsor cooling towers are recommended when the power plant is not located.Thesimplesttypeof coolingwatersystemis thepondor spraypond,whichrelyuponwindsthat blow across the ponds and cool fine sprays of water by evaporation. Thehowis dischargedthrough apipeline to apond, which is a large shallow pool and is exposedtotheatmosphericair.The cooling of hot water is effected by the air blowing across the surface Ofthe pond.The hot water dissipates heat to the air by convection and evaporation processes.Some waterparlticles evaporate by absorbing latent heat of vaporization to cool the remainingWaterevaporationand windage loss is about 2 to 3%. The rate of cooling may be increasedbyincreasintghe areaof the pond. The useof spraying system overcomes such difficulty. Thesprayisnygstemincreasesthe contact of water with atmosphere by spraying the water into the airover pond.Anozzle is used for this purpose and the pond is known as spray pond and apond withoutspray or any other cooling device is simply termed as "cooling pond".

Directed flow natural cooling pond:

Design requirements of cooling ponds

1. To obtain maximum cooling, the distance between spray nozzles and water surface about 1 to 2m.
2. Thenozzlesarearrangedin suchawaythat thereisno interferencebetweenthesprays produced.
3. The nozzle pressure should be 1.5 bar to obtain better atomization of water.
4. The spacing between the distributing pipes may be 6 to 7m apart.

Spray ponds

A cooling pond is converted into spray pond by locating a series of sprays above;surface of water.The waterpressure in the nozzles is from 0.21 to 1.5 bar.The hot waterthe condenser is sprayed through the nozzle over a ~ondof large area. The nozzles break waterinto a spray.The whirlingmotionof the nozzlesresultsin better atomizationof theweand produces cooling effect, which is mainly due to evaporation from the surface oJ waterspraynozzlesareplacedto 2m distance between nozzles should be such that, there is no interference between the diffenspraysproducedby nozzles.

Cooling Towers:

The cooling towers are effectively used to cool the condenser water so that the powerstationmay be located near the load centre to meet increased demand of electric power. Thecooling towers are used when positive cont~ol on the temperature of water is required, spaceoccupation is a considerable factor and the power station is located near the load centre andforawayfrom the river. The purpose of cooling towers is to cool the hot water discharged from condenser andfeed the cooled water back to the condenser. They reduce the quantity of cooling water requiredin the power plant.

Thefactorswhichaffectthe coolingof waterin a cooling tower are

1) Temperatureof air
2) Airhumidity
3) Temperatureof hot air
4) Dimensionsof the tower (size and height)
5) Airvelocity entering the tower
6) Platearrangements in towers
7) Air accessibility over all parts of tower
8) Uniformityin descending water.

Dependingupon design and plant loading, the quantity of cooling water required is 18 x 107Kgperhour.In order to cool such .huge quantity of water, large volumes of air are required. ForExample in, a750MW plant, in order to dissipate the condenser heat 10<¥1th, e air mass flow raterangesfrom38.5x 106kg/hour to 45 x 106kgfhourfor a mechanical draughtcooling tower

natural draught cooling towers: It is further classified into three types:

Natural draught spray filled tower:

In this type, the airflows in thetransverse direction and thecirculation of whichdependson thewind velocity. The water droplets are made to fallandtheflowof airiscrosswiseto theflow of water.BThe water is cooledby air flowingacrossthe tower.Theuse of spray nozzles increases rateof cooling.Thecooledwateris thencollected in a tank below the towerand then supplied to condenser.These towers are suitablefor dieselplants and small capacity powerplants. Due to the limitation in thecoolingrange,suffers from the problems of highwindagelossesandthereisnocontrolovertheoutlettemperatureof water.The capacityof this toweris limitedto 50to 100liters/minperm2ofbasearea and again it depends on thevelocityof air.

Packed atmospheric cooling tower

Natural draught packed type tower:

Theworkingof thistower is similarto thatof previousonexcept that theuse of packings.The waterdescendsverticallyand airflow is cross wise, while descendingwateris brokeninto small droplets by packings. These towers are rarely used as the initial and maintenance costs are high.

High Pressure Boilers, Draught Cooling Towers and Accessaries:

Disadvantages:

1) Its initial cost is high.

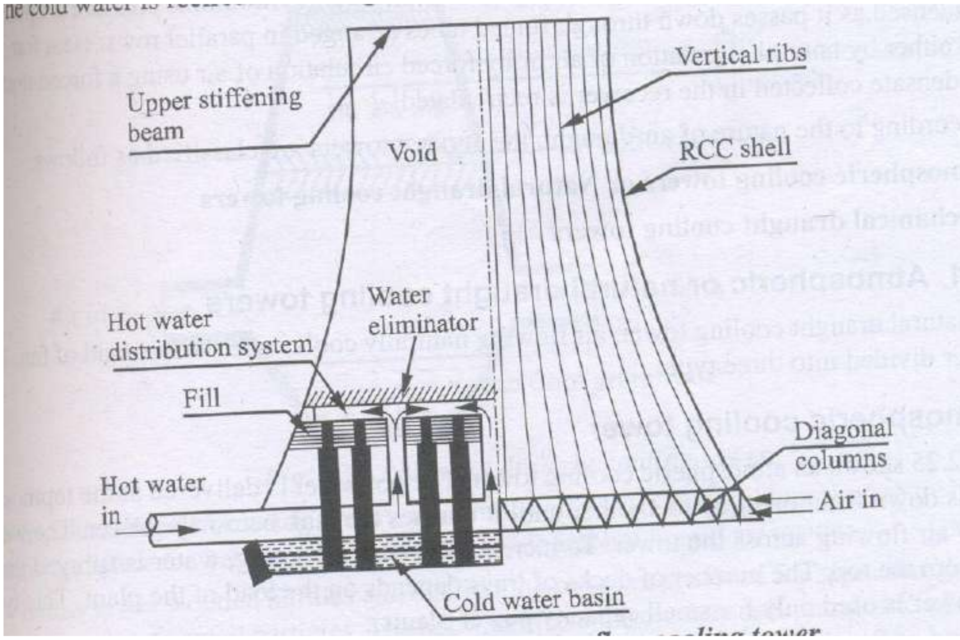
2) Seasonal changes in DBT and RH of air influence the performance oftowers.

Theuse of this towedslavorable over mechanical towers in terms of saving in fan power, Longerlifeand less maintenance. It is mainly used for large capacity plants.

Mechanical draught cooling towers

In this type, the air is moved by one or more mechanically driven fans. It provides closerApproachto WBT, gives higher efficiency, requires less floor area and reduces windage andSpraylosses. Inspite of higher initial and operating cost, the mechanical draught tower boost upOverall plant economy. These towers are constructed in cells or units and the number of cells inThetower decides the capacity of the tower.Themechanicaldraught towers are independent of natural draughtor wind velocity,andairflowiscreatedby fans. Theflow of air with high velocity increases efficiency of tower and rate of cooling.

Forced draught towers:



Thearrangementof the forced draught tower is the interior structure issimilar to natural draught tower, but the sides areclosedtoform an air and water tight structure. Theair enters through an opening, which is waterprovidedat the base of the tower and leaves thetowerat the top. The fans provided at the base of the tower create airflow through thedescending water in the tower. This type ispreferredbecause the fans would operate oncoolerair side and hence consumes less powerThehot water from the condenser enters the ColdNozzlesand is sprayed over the packings as waterout shownin figure. The raising air, cools the waterandat the top, the draught eliminators removesentrainedwater from the air.

Induced draught cooling tower (counter flow type)

The forced draught towers have some disadvantages because of air distribution problem leakages, recirculation of hot and moist exit air back to the tower and local fogging at the fan induringwinterseasons.Therefore,*for* utilityapplicationsinduced draughttypetowers areuse in this type, the fan is located at th~ top of the tower where it exhausts the hot humid airthe atmosphere. Air enters the tower *from* the sides through large openings with low velocity flows through the tower in the upward direction. The hot water *from* the condenser enters nozzles and is sprayed over the packings as shown in figure. As the air moves up, it cools water and the cooled water is collected in a tank at the bottom of the tower. are providedat the top of the tower to eliminatethe water entrained *from* the air.

The factors, which influence the effective cooling of water are: f

1) DBTandWET of atmosphericair
2) Inlettemperatureof water
3) Sizeandheightof tower
4) Airvelocityanditsquantity
5) Ammgementof thefill
6) Waterdistributionsystem

Indirect dry cooling towers

Thissystemis alsoknownasHellercoolingsystemas itwasfirstpresentedbyLazloHeller1956.

The arrangement of the components is as shown in fig. 2.31. In this type, the condensationof exhaust steam takes place in a spray condenser by means of circulating water. The condenserdischarges a major portion of water to the cooling coils and remaining which is equal to theexhaust steam from the turbine, is supplied to the boiler feed water circuit. Afan induces flow ofair in the system as shown in figure cools the hot condensate in the cooling coils. The cooledwater is then spread through the nozzle into the condenser. The steam from the turbine is condensedby coming in direct contact with water sprayed through the nozzle. Some of the'pressure andelevation head is recovered by using water turbine between cooling coils and condenser.Asthere is no direct contact between circulating water and cooling air, no evaporation loss occurs inthe system.

HighPressure Boilers, Draught Cooling Towers and Accessaries

Advantagesof Drycoolingtowers

1. Thereisnothermalpollution andevaporationloss of water.

2. Iteliminates the necessity of locating the plant near the water source. The plant may besituatednear to load centre. .

3. Theair pollution is reduced to a great extent.

4. Itisfree from windage loss, fog problem, evaporation loss etc.

Disadvantages of dry cooling towers

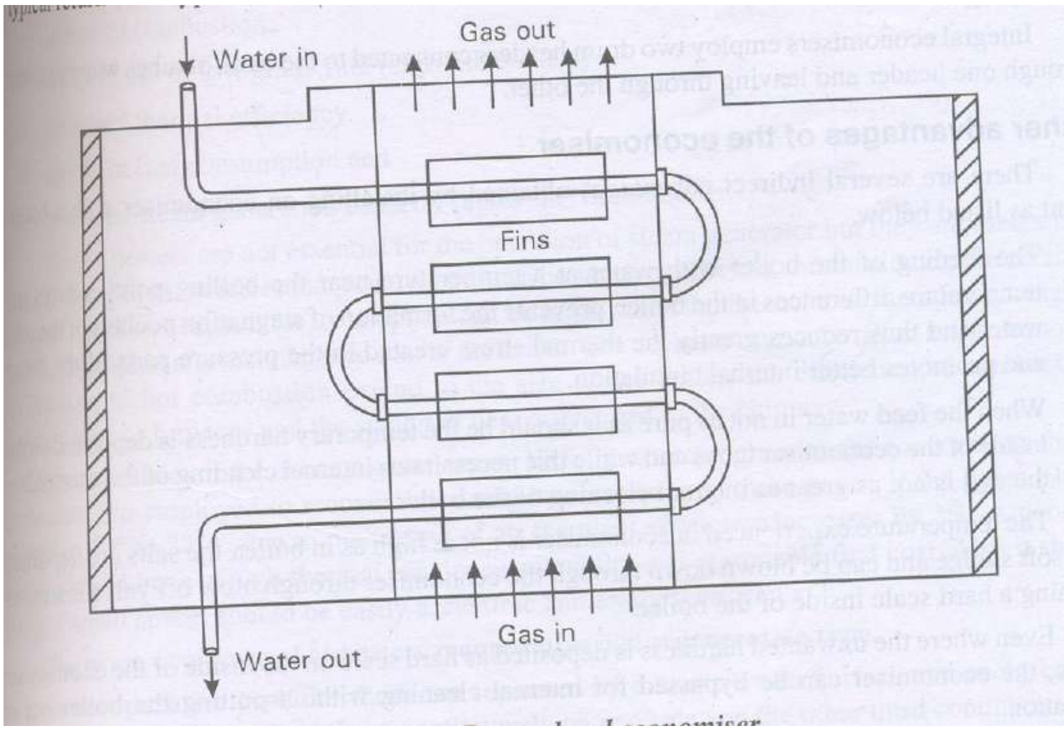
1. Ituses large volume of air with large surface areas due to low heat transfer co-efficient

2. Athigh natural air temperatures, these towers are less effective.

3. The performance of these towers is limited by DBT and hence turbine exhaust temperatures are much higher which leads to loss of turbine efficiency.

1.12 Accessories for the Steam generators

Economizers



The Economizeris a heat exchanger whichraises temperature of feed waterby deriving heat from the flue gases discharged from the boiler.It raises feed water temperature to its saturation temperature corresponding to the boiler pressure. The heat is derived from the hot gases the last super heater or reheater at a temperature varying from 370°C to 540°C. The useleconomizer improves the theITnal efficiency of the plant and better economy can be achieved the justifiable cost depends on the total gain in efficiency, which in turn depends upon theexittemperature leaving the boiler and feed water temperature to the boiler. Economizers are introduced before feed water heating. The cost benefits achieved with the use of economic depend upon the boiler size, type of the fuel used and flue gas temperature leaving the boiler.for every 6°C raise in temperature of feed water, 1% of the fuel cost can be saved and savingu~maximum of 20% is possible. In the economizer, the stearn fOITnationcan be avoided by heat the feed water less than or within 25°C of the temperature corresponding to saturation temperature of the steam .

Economizer tubes are made of steel either smooth or covered with fins. Generallyeconomizer tubes are 45-7Omm in outside diarneter and are made in vertical coils of continutubes connected between inlet and outlet headers with each section fOITnedinto several horizontal paths connectedby 180°verticalbends for properdraining.The coils are installedat apitchof 45 to 50 mm spacing, which depends upon the type of fuel and ash characteristics.

Advantages:

1) The temperaturerange between variousparts of the boiler is reduced. This decreasesStressesdueto unequalexpansion.

2) The useof economizer preventsthe cold waterto enter into boiler and hence,prevents chillingoftheboiler.

3) It reducestheconsumptionof fuel.

4) Itreducesheatloss with flue gases thereby,increasesthermalefficiencyof the plant.

5) It increasesthe evaporationcapacity of theboiler.

6) A largeamountof soot and fly ash is depositedon the economizer tubes and scrappedoff intothe sootchamber.This reducestheemissionof soot and fly ash.

Disadvantages:

1) Sometimeis installation costis high.

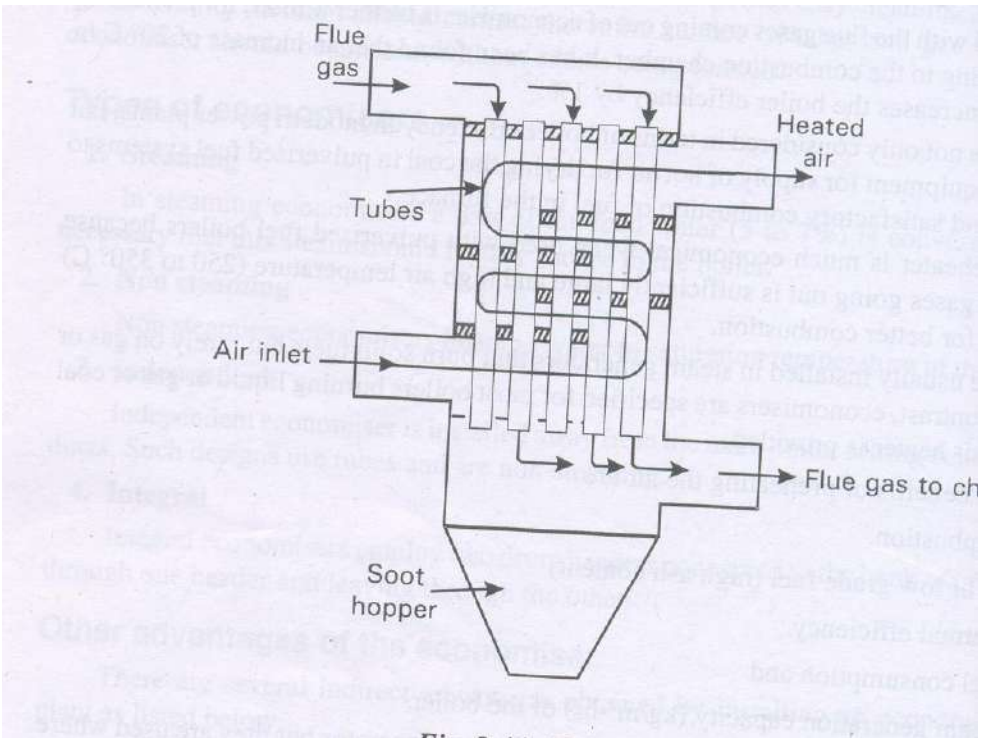
2)Itisexpensivein terms of maintenance and regular cleaning.

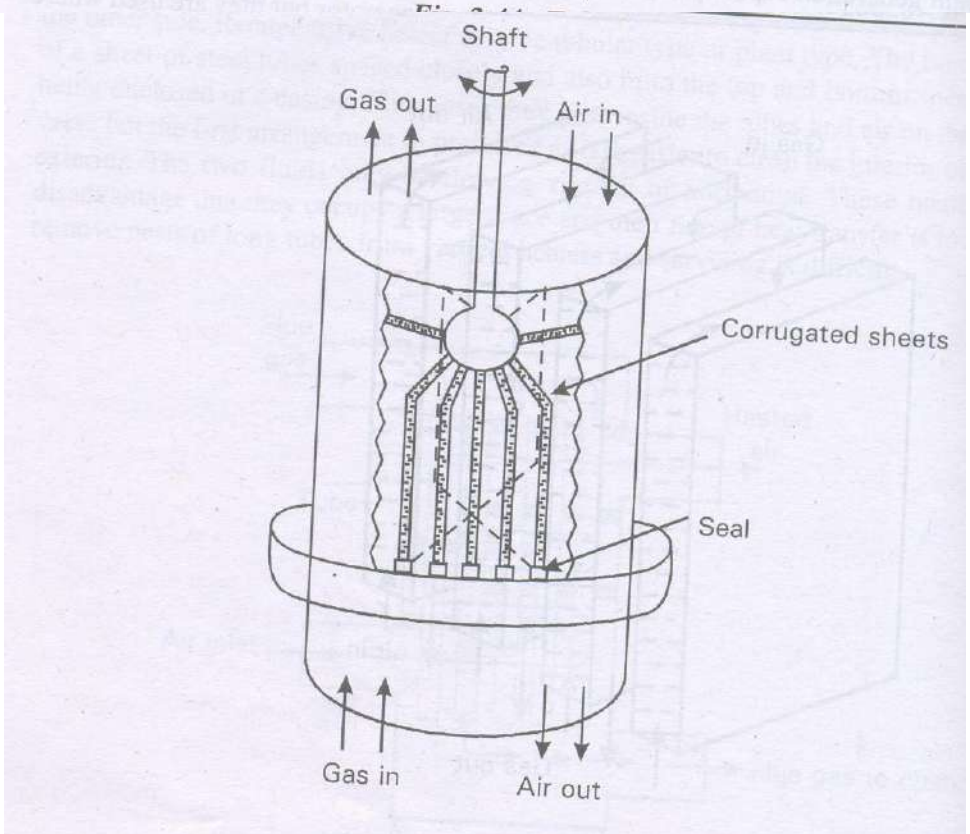
3)Itusesextrafloor space in the boiler. a simplified view of a return bend economizer. It consists of a seriesofsteeltubesthroughwhich the feed water flows.

Air preheaters

Therearetwo types of air preheaters: 1)Tubular type 2) Plate Type.

Tubular Type Air Preheater:





Itconsistsof series of tubes through whichthecombustiongases pass with air passingaroundthe outside of the tubes. Thecombustiongases transfer heat to the air and heatedthispreheated air is supplied to the furnace.Thebaffleplates deflect the direction of airtraveals,therebyincreasesheatransferby increasing the time of contactbetweenhot gas and air. Steel tubes of 6 to 8cmindiameter and 3 to 10 meter heights arecommonlyused. The air preheater may beprovidedwith one or more passes for bothairandgas in counter or cross flow, in verticalorhorizontalarrangements. The smaller thetubediameter, larger the number of tubes, thegreater the surface area for a given overall size.Smallerdiametertubesresultsinmore compactheaters. Tube diameter to be usedSuper heatersTheboilerproducessteamin thesaturatedcondition.Thesteamin thisconditionshouldbe used in the turbinebecause,thedryness fraction of the steam decreases due to expansion inIthe turbine and the resulting moisture content in the steam may corrode the turbine blades.This difficulty is solved by raising the temperature of steam above its saturation temperature and superheaters are used for this purpose. The super heated steam contains more heat than that of saturaterd steam at the same pressure and the added heat provides more energy for the turbine for conversion'to electric power.

Super heaters

The boiler produces steam in the saturated condition. The steam in this condition shouldnalbe used in the turbine because, the dryness fraction of the steam decreases due to expansionin'the turbine and the resulting moisture content in the steam may corrode the turbine blades.Thudifficulty is solved by raising the temperature of steam above its saturation temperature andsuper *heaters* are used *for this purpose.* The *super heated steam contains* more *heat* than *that* of *saturatml*steam at the same pressure and the added heat provides more energy for the turbine for conversioolto electric power.

The super heater is one type of heat exchanger in which heat is transferred to the saturated~steam to increase its temperature sufficiently above the saturation temperature and to removethelast traces of moisture (about 1to 2%) from the saturated steam. It incre(J.sesthe overall cycleefficiency and prevents blade erosion by avoiding too much condensation in the last stages oftheturbine. This also increases internal efficiency of turbine. The moisture is to be removed by using heat of flue gases in the super heaters.

The advantages of using the super heated steam are:

1) Reduction in steam consumption in turbine or engine.

2) Reduction in condensation losses in the cylinders and steam pipes.

3) The use of super heated steam eliminates turbine blade erosion.

4) Increases the efficiency of the steam power plant.

In utility boilers, super heater tubes are 50 to 75 mm in outer diameter. The smaller diametertubes have lower pressure stresses and withstand them better. The pressure drop in the steamflow is lower in larger diameter tubes. The super heater surface has steam on one side and hotgases on the other side. Therefore, the tubes are dry except for the steam which circulatesthrough them. Tubes overheating is prevented by designing the superheater to accommodate theheat transfer required for a given steam velocity based on the desired exit temperature.

Super heaters are referred to as convection, radiant or combined types, depending on howheat is transferred from the hot gases to steam. In convective super heaters, the main mode ofheat transfer between combustion gases and the super heater tubes is convection and these arelocated in convecti ve zone of the furnace, usually ahead of the economizer. The convective super heaters are also referred as "primary super heaters" as the saturated steam from the boiler directlyenters into these super heaters. .

1.13 Question Bank

1. List the different types of fuels used in thermal Power plants
2. With the help of a neat sketch explain the furnace for combustion of fine coal.
3. Enumerate and explain the steps involved in the handling of the coal
4. Explain with a neat sketch overfeed and underfeed firing of coal
5. List the requirements of pulverized coal burners.
6. Sketch and explain cyclone burner. State its advantages and Disadvantages
7. Describe the multi retort stoker with a help of a neat sketch
8. With a neat sketch explain the principle of Spreader stoker
9. Draw a line diagram of Pneumatic ash Handling System
10. What are the factors to be considered for the establishment of thermal power plant? Explain them Briefly
11. Draw a general layout of a thermal power plant and explain various circuits
12. Why pulverization is required? Explain any one method with help of a neat sketch.

13. List the various boiler Accessories.
14. Derive an expression to find the height of a chimney for a given Static Draught
15. Determine the height of a chimney to produce a static draught of 20mm of water. The mean flue gas temperature in the chimney is 270^0Cand atmospheric air temperature is 23^0C. Barometer reads 760mm of Hg. The gas constant for air is 287 N-m/kg K and for the chimney gas is 255 N-m/Kg K
16. Explain the working of forced draught and induced draught with help of a neat sketch.
17. What are cooling ponds? Exaplin the double deck system of cooling pond
18. What are the benefits of air pre heater?

1.14 Outcomes:

Student should be able to understand the

1. Properties of different fuels used for steam generation.
2. Main Components and working of steam power plant

1.15 Further reading:

1. Power Plant Engineering, P. K. Nag Tata McGraw Hill 2nd edn 2001

2. Power Plant Engineering, Domakundawar, Dhanpath Rai sons. 2003

3. https://cracku.in/blog/list-of-thermal-power-plants-in-india-with-capacity-pdf

Module 2: DIESEL ENGINE POWER SYSTEM, HYDRO ELECTRIC ENERGY

Structure

Objectives

After studying this unit, student should be able to

- Know about layout diesel engine power plant,
- Understand about cooling and lubricationsystem in diesel engine plant
- Know about intake and exhaust system in diesel engine power plant

2.1 Introduction

We know that, all types of automobiles including tractors, trucks and buses use internalcombustionengines. These internal combustion engines can also be used for power generationwherethesupplyofcoalandwateris not available in abundantquantity.Theseplantsaresuitableforsmalland medium out puts and can be used as stand by plants to hydro electric power plantsandthermalpower plants. These can also be used to meet peak load demand in some powerplants andcan be used to supply the seasonal electric loads.Low capacity plants uses petrolengines and are meant primarily for emergency service. A large capacity plant uses diesel enginesforpowergeneration. The capacity of these plants ranges from 2 to 50MW and are used asstandbysetsin hospitals, cinemas, telephone exchanges, radio stationsetc. It is one of themosteconomicmeans of generating electricity in a small scale where cheap fuels are not available andloadfactorsareconsiderablyhigh.

Ina steam plant, one or more diesel generating units may be installed to serve as stand by ortosupplypeak loads of small duration. As stand bys, these units may provide for the totalresidentialload of the power plant. In thermal plant, the diesel generators suppl y power forauxiliaries in case of failure of main working units. In industrial plant where the steam is used forprocesswork, fliesel engines supplies power during seasons when steam for process work is notrequired.

2.2 Advantages and disadvantages of diesel Power Plants;

Advantages

1. Verysimplein designandeasyto install
2. The plant can be located very near to the load centre.
3. The overall capital cost per unit of installed capacity is lesser than thermal or hydelplant.
4. Theplantrequireslesseroperatingandsupervisingstaff.
5. Fuel handlingis easierandno ashdisposalproblem.
6. The cooling waterrequirementis less.
7. It canbequickly installedandcommissionedandcanbeput on loadquickly.
8. It canmeetsuddenchangesin theloadwithoutmuchdifficulty.

Disadvantages

1. The size of the unit is limited and very large capacity plants are not possible.

2. The operating cost is high.

3. Lubricating cost and maintenance costs are high.

4. The plant cost per KW is comparatively more.

5. Noise*from* the exhaust is a seriousproblem.

6. The life of theplant is limitedto 2 to 5 yearswhencomparedto thermalplants

.

Applications of diesel Power Plants

1. It can be used as peak load *or* stand by unit *for* hydel plants.

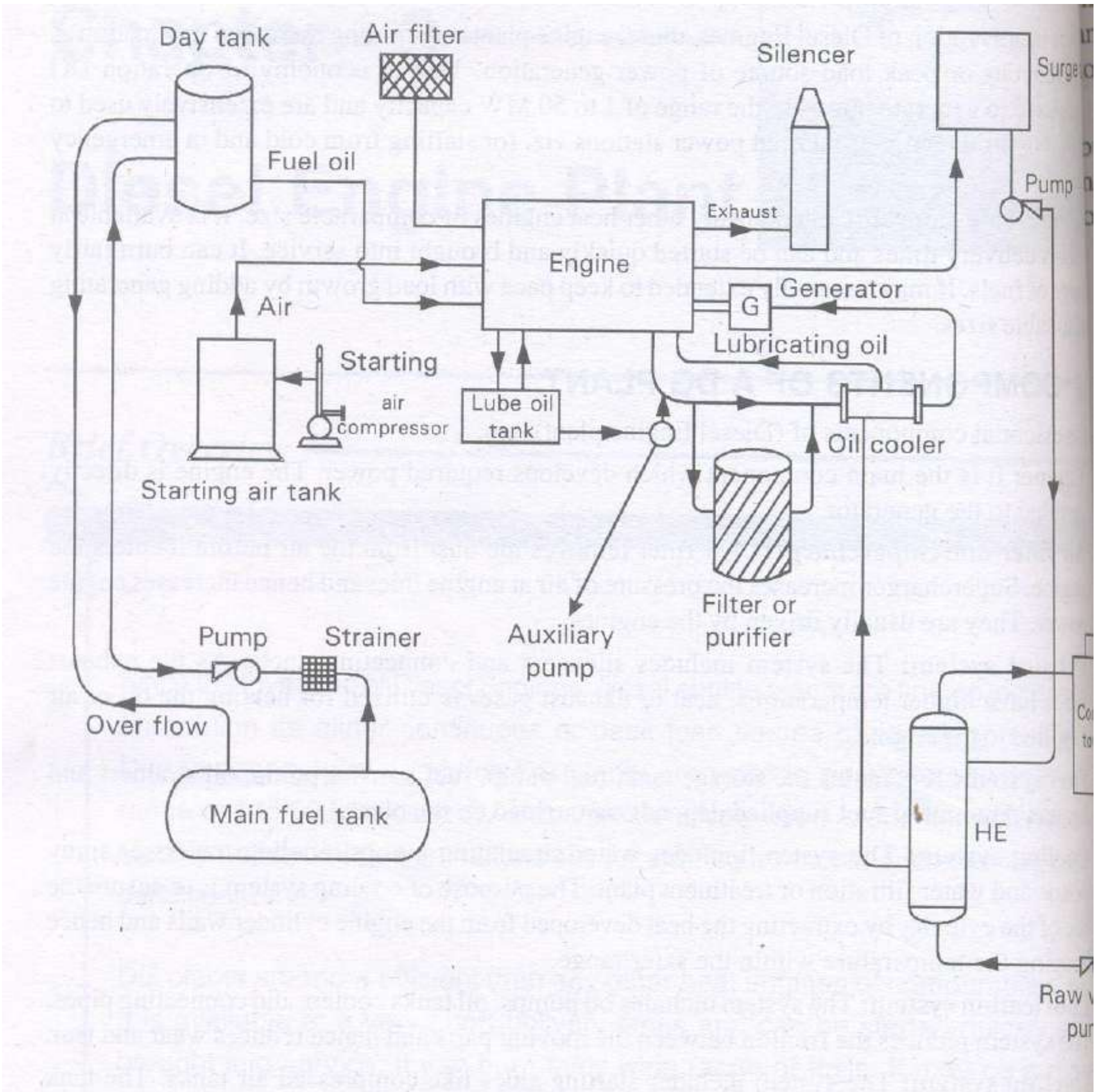
2. It can be used as mobile plants *for* temperory *or* emergency purposes (for large civillengineering works etc..)

3. Thesecanbeusedin emergencycaseswherepowerinterruptionwould result in financialloss *or* danger, in key industrial processes, tunnel lighting and operating rooms of hospitals,

4. It can be used as a Nursery station. The plant supplies power to a small town in absenceof main grid and can be moved to another area which needs power in a small scale whenthe maingridis availableisknown as "Nurserystation".

5. It can alsobe used as startingstation.The plantruns the auxiliaries*for* starting the largethermal plants.

2.3 Layout of a diesel power plant



2.4 Engine Intake system

A large diesel engine requires 0.076 to 0.114 m3/ min of airperkW of power developed, the air intake system supplies required quantity of air for combustion. The system consists ofapipe line which connects source of fresh air and engine manifold. Filters are reprovided toremove dust from the air, otherwise dust particles may cause wear and tear of the engine. Thesefilters may be of dry type (made up of cloth, felt, glass, wool etc.,) or oil bath type. ElectrostaticPrecipitator filters can also be used. In oil bath type of filters the air is swept over or throughabath of oil, so that the dust particles are gets coated. The intake ducts are made up of light weightsteel. Some times, a silencer may be used between the engine and intake since the noise maybetransmitted back to the outside air via the air intake system. In the air intake system, pressure lossshould be minimum. If pressure loss is high, it reduces engine capacity and increases specific fuelConsumption.There fore in total,the functionsof air intakesystemare:

i) Toclean the air suppliedto theengine

ii) Tosilencethe intakeair.

iii) Tosupplyair for supercharging.

2.5 Engine exhaust system

Engine exhaust system including ducts, mufflers, water heaters, silencers etc.,

The exhaust system is used to convey the exhaust gases to the atmosphere out side thebuilding.It alsoconsistsof a silencerto reducethenoiselevel.Amufflerprovidedin theexhaustpipe reduce the pressure in the exhaust line and reduce the noise.Some times, a device maybeused in the path of exhaust gases to recover heat of exhaustgases.Theexhaustpipecomingout of buildingshouldhaveoneor two flexibletubingsectionsinorder to isolate the systemfrom vibrationby taking the effect of vibration.Its length shouldbeshorterand should have minimumnumber of bends. Every engine should be provided withanindependentexhaustsystem.

The points to be consideredin the design of exhaustsystem are;

1. Thenoiselevel shouldbeminimum.

2. Thesystemshoulddischargetheexhausfsufficientlyabovethegroundlevel.

3. The duct should take up effect of expansionand contraction due to temperaturevariation.

4. As back prssureimposedon the enginereducesenginepower, it shouldbekept minimum

5. Theflexibletubing sectionsareto be used in the exhaustpipe in orderto isolatethesystemfromvibration.

2.6 *Fuel System*

The fuel system includes fuel storage tanks, fuel transfer pumps, strainers, heaters andconnectingpipes. The trucks, rail road tank cars, or barge and tankers are used to deliver thefueloilto the plant site.Then, fuel oil is delivered to main storage tanks through unloading facility.Thenthe transfer pumps are used to deliver fuel oil to smaller service storage tanks (day tanks).Forthemainflow, piping arrangementis made with necessary heaters,by - passes, shut offs,drainlines,reliefvalves,strainers,filters,flowmeters,andtemperatureindicators.Theminimumsto ragecapacityof maintance should satisfy at least a month'srequirementofoil.Butin order to availthe advantageof price fluctuationsof the fuel, it is essential to provide storage or few months requirement.The capacity of the daily consumption tank should be atleasthe8 hoursrequirementof the plant.Usuallythesetanks arelocatedabovetheenginelevelsothat theoil mayflow to the enginesundergravity.

Thefueloil supplysystemhasto satisfycertainrequirements for it'ssatisfactoryworking;

1. Provisionshouldbe madeforcleaningandchangingover of linesduringemergency.
2. Tight pipejoints shouldbe usedin allsuctionlines.
3. The oil flushing is done through the piping between filter and engine before beingplaced in service.
4. High grade filters are to be used to hold water, dirt, metallic chips and other foreignmatter.

2.7 Cooling System

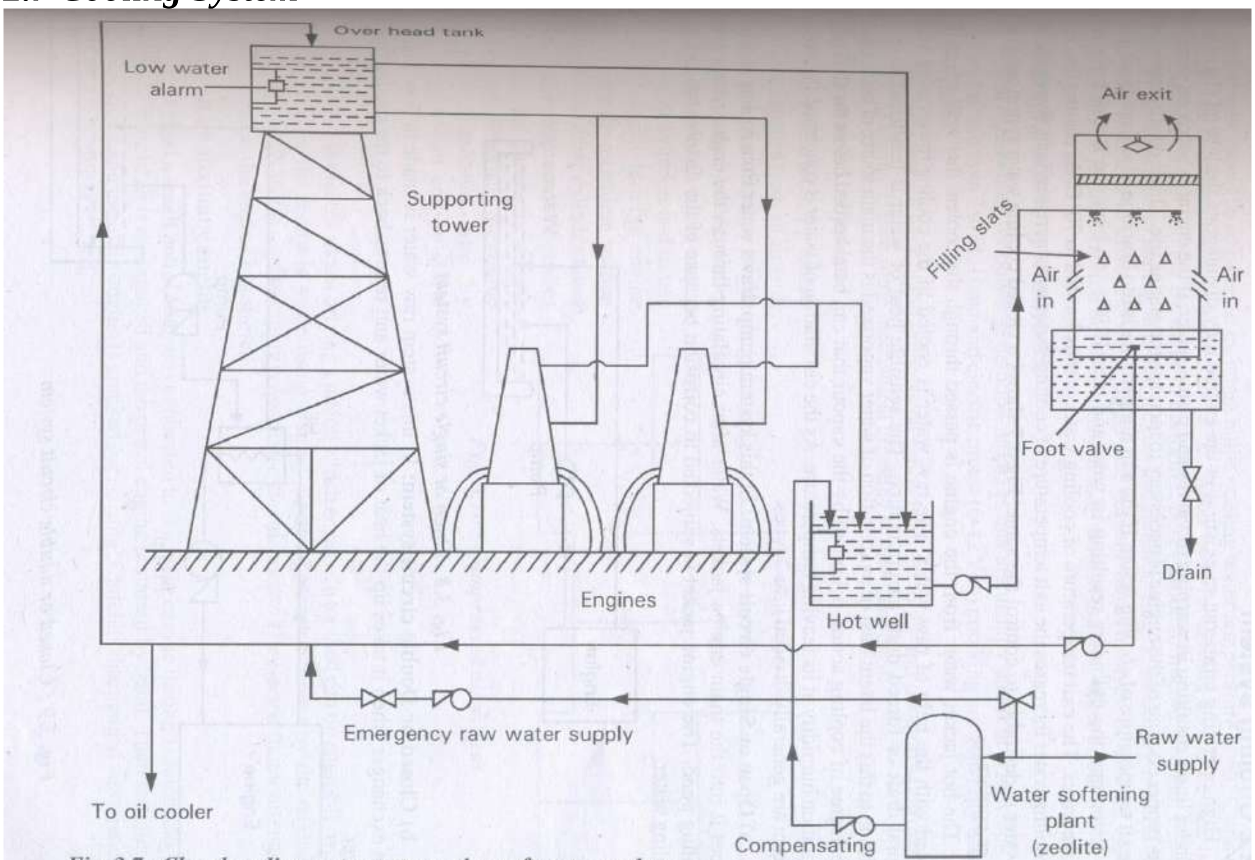


Fig. 3.7 : Closed cooling water system using soft water coolers

Thecoolingsystemin a dieselplantincludescoolantpumps, coolingtowersor sprayponds,waterfiltrationplantandpipes.The purposeof cooling systemis to provideproper circulationof cooling water all around. Theenginestokeepthetemperatureat reasonablylowerlevel.Iftheengineis not cooledproperly,thehigh temperatureexistingin theengines (cylinder and piston are exposed to hightemperatureof theorderof 1000to 15000C) woulddisintegratethefilm oflubricating oil, causeswarpingofvalves, piston etc., The overheatingof engine would cause damage to the piston, piston rings,head andcytinder liners. A pump circulates water through cylinder and headjackets to carryaway the heat. Some heat is also taken away by the lubricating oil. Same water should be usedagain and again and hence a method of cooling the cooling water is required. This is achieved bypassingwater through radiators, evaporative coolers, cooling towers, spray ponds etc., nearly25%to35% of total heat of the fuel is removed by the cooling system.The heattakenawayby Oilandradiation heat lost accounts to 3% to 5% of total heat supplied.

3.8 Cooling system for diesel engine

The cooling system in a diesel plant includes coolant pumps,coolingtowers or spray ponds, water filtration plant and connecting pipes. The function of coolingsystem is to provide proper circulation of cooling water all around the engines to keep thetemperatureat safe level. Under cooling raises engine temperature, decreases engine performance and its life. Excessive cooling makes the combustion poor and affects the fuel economy. It increasesviscosity of oil due to low temperature and hence increases power loss due to friction. Basical there are two methods of cooling,

i. Air cooling

ii. Liquid cooling

Air cooling: In thismethod,engine cylinderis directlyexposed to atmosphericairwhich carries the heatfrom the cylinder. The cylinder is finned, particularly heavily nearthe exhaust.Theuse of fins over engine cylinder provides additional heattransfer surfaces, there by increasesrate'WaterorLiquidcooling: In thismethod, thecylinderwallsandheadsaresurroundedwith cooling water jackets. The water while circulating through jackets, take the heat from cylinderwalls by convection and conduction. The heated water itself is cooled by circulating it throughaircooledradiatorsystem. In stationary diesel engine plants the watercooling systemsare used and areas follows;

i) Open or single circuit system

Water is pumped from cooling pond to the mainenginejackets.Aftercirculation,wateris returnedto thecoolingpondby sprayingthrough nozzles.Thedissolved gassesin the cooling water may corrode thecylinderjackets.

ii) Closed or double circuit cooling system

Double circuit cooling system

In this system, heatxchangeris used inbetweenengineand coolingpond.The waterfromthe pondispumpedthrough the heat exchanger,whereit takes the heat fromjacket waterand isreturnedtothecoolingpond. The cooled water is again pumped back to the engine side.Thismethodeliminatesinternaljacket corrosion.

3Evaporativecooling: In this method, a large swface of the hot water is exposed to an airflowt,herebyhumidifies the air and cool the remaining water.This can be done by providingcooling towers,evaporativewatersetc., Thecoolingactionis samein allof them.Theatmosphereisamixtureof air and water vapour in proportion and is described by humidity. Proper latentheatofevaporation must be supplied for vapourization of water. The source of heat may beinternaelnergy of the liquid water from which the vapour is being produced. During the process Ofhumidification,some off the warm water goes off inJOthe atmosphere and make up water of2.5%ofwater flow must be added to the system.

Atmospherictowers are long and having narrow structures with considerable height. Theaxis(vertical)of the tower is normal to the prevailing wind and are built to utilize horizontal windmovementsF.rom the top of the towers, waterfalls through the air currents a'ndevaporativelycooled.Thesetowers are not used in diesel power plants.For effective cooling, tower should be sufficientlyhigh. The cooling water is collected and pumped from the bottom of the tower andsuppliedto the engine for cooling.Afanis provided in mechanicaldraughctoolingtower.The use of fanreducesthe height of tower. Dependingonlocation, the fan used could be aforceddraught type or Induced draught type.The faIling water meets the air which is flowing in the oppositedirection..

An evaporative cooler is one inwhichthe cooler is constructed fromsteelincluding a heat exchanger forcoolingthe water. This type is notsuitablefor diesel plants.Theevaporative cooling is also known as steam or vapour cooling in which the coolingwatertemperaturereaches to a temperature of 100°C.The cooling of water can be done withminimumof waterby usinghigh latentheatof vapourization.Thecoolantis alwaysin theliquidstate,but the steam formed is flashed off in a separate vessel. The fresh water so formed is,returnedback for cooling. This system is used many industrial engines.Spray eliminators

Radiator in place of cooling towers, cooling ponds and spray ponds are used. But these are inefficientfor bigger power plants.

Lubrication for the diesel engine: As discussed, the roleof lubricationsystemis moreimportantin dieselpowerplant thananyother plantbecause of veryhigh pressuresand small clearancesin these engines.

The lubrication system influences theenginelife, efficiencyandthe extentto whichtheengineisput incontinuousservice.

In a dieselengine, thefollowing gare themainpartswhichrequirelubrication,

1. Pistonandcylinders.

2. Crankshaftandconnectingrod bearings.

3. Gearsandothermechanismused forpower transmission.

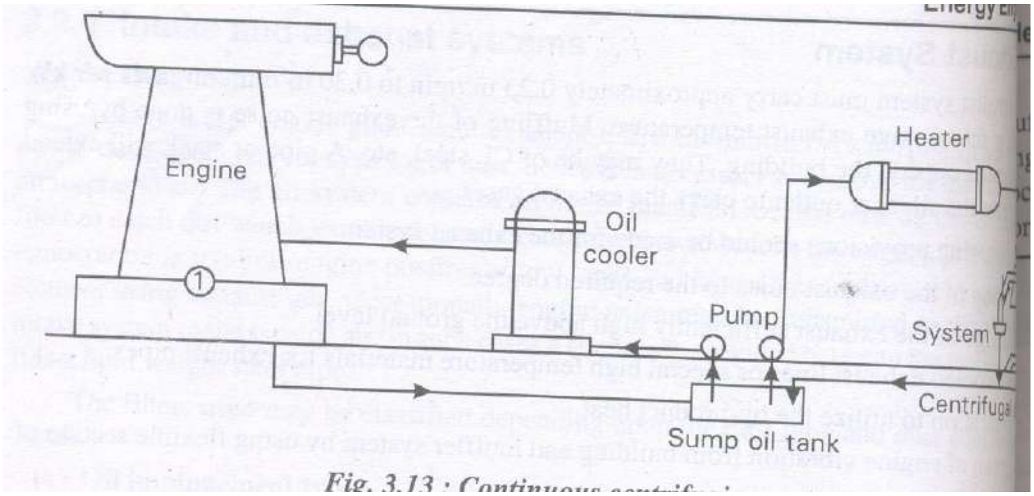
4. Integralinjectionor scavengingaircompressors.

Lubrication may beclassifiedinto

1. Full pressurelubricationsimilarto thatusedin automobileengines.

2. Mechanical force-feeds lubricationandgravitylubricationfromanover headtank.In pressurelubricationsystem,anoilpumpisusedto deliver the lubricantunderpressuretovariousparts of the enginethrougha duct systemandto the crankshaft and wristpin bearingsbydrilledpassagesintheshaftandrods.Forlubricationofcylinderwalls,oilmistslungoutwardfrom the connectingrod bearingsor splashlubricationmethod is used. Mechanical force-feedlubricationis usedto effect the lubricationof cylindersof large and slowspeed engines.The crankcase serves the purpose of oil sump from where the oil may be withdrawn by apump.Thelubricating oil, duringitscirculationthroughthelubricationcycleaccumulatesimpuritiessuch as carbonparticles, waterandmetal scrapandis cleanedby settling,centrifuging,filteringor chemical reclaiming. Mechanical filters such as cloth bags, wool felt pads, paper discsandcartridges of porous material are used for cleaning the oil. In centrifugal cleaning, first screenfilters are used to clean the oil and then the oil is passed through high speed centrifuges forultimatecleaning. The oil shouldbe heated, before it enters to the centrifugal cleaner.The oilconsumption is in the range of 2.27xl 0-6to 4.1Ox10-6m3per kW hour. In chemical reclaimingmethoadf, terfiltering, a combination of heat and activated clay are used. In settling method,impuritieasre made to settle down by allowing the hot oil to enter in to a large tank. Clean oil isthenusedfromthe top of the tank.Thelubricatingoil gets heated due to friction between rubbing surfaces and should be cooledbeforerecirculation. The lubricating oil absorbs about 2.5% of the heat of the fuel. The hotlubricatin oil may be cooled with the help of cooling water used for engine cooling. The lubricating oilconsumptionis about 1% of fuel consumption (3 litres per 1000 kWhr generated at full loadconditions).

2.8 Lubrication system



Thelubricationsystem includes oil pumps, oil tanks, filters, coolers, purifiers and connecting, thepurpose of lubrication system is to reduce the friction and wear of the rubbing

Lubricating oil is used to

1. Lubricate the moving parts

2. Remove heat from cylinder and bearings '-

3. Carryawaysolid matter from rubbing moving parts.

4. Absorbthe shock between bearings and other parts and consequently reduce noise.Pumpsare used to deliver the oil to the engine and the oil is recirculated under pressure.

Thelubricationsystem has to effect the lubrication of following engine parts.

1. Maincrank shaft bearings

u. Big-endbearing

iii. Smallend or gudgeon pin bearings

iv. Cylinderwalls and piston rings

v. Tuninggears.

vi. Carnshaft and its bearings

vii.Valvemechanism

Viii.Valveguides, valve tappets and rocker arms.

3.9 Lubricating system (continuous centrifuging system)

The lubricating oil in use is subject to changes in operating temperature and results information of sludge and varnish. Therefore, it is necessary to use the oil with engine cleaningproperties. In order to improve the oil characteristics, additives such as anti oxidants, detergents,corrosion inhibitors are added with straight mineral oils.Anti oxidants are used to prevent chemical reactionwith oxygen and due to heating. The addition of detergents keep the engine clean bycontrollinglacquer and preventing the deposition of carbon, soot, dirt and combustion productsonpistonand rings. Aprotective filw is formed on engine parts due to the addition of corrosion inhibitorsand this film protects the engine parts from corrosion acids, which is due to presence ofsulphur in the fuel.

Filters and centrifuges

Filtersand centrifugesareused to arrest dirt, metallicchips or other foreign substancesinthefuel.Filtersmay be of drytypeand madeup of cloth, felt, glass,filterpaper,somecellulosematerialwooletc.,or oil bath type. In the later type, the oil is sweptover or through an oilbathfilter, whichretainsthe oil coated dust particles. The clean fuel oil provides trouble free operation of theengine.Theuseof bulk storagetanksremovesmostof thesuspendedimpurities, waterdirtetcted from theoil, if it is light andallowedto standin thestoragetankfor sometime.This methodis too effective,if heavieroilsareusedorif thetemperatureof oils isbelow10°C.Hencecleaningdoneby filteration andcentrifugingwhentheoilistransferredfrom bulk storagetankstothetanks.Filteringmeanspassingtheoil throughfilterswhicharemostlyof absorbenttypeandretain the oil contaminants and allow clean oil to pass through. The filterscanbecleaned andreused and replacement ofcartidge is not very frequent. In other type of filters, ie., inoilimpingement type, a frame filled with crimped wire or metal shaving is used. A special oilcoated, so that when the air passing through the frame, is broken up in to a number of smallfilamentsandthesefilamentsmakescontact withtheoil.Thepropertyof oil is to seizeandholdanydustparticlescarriedbytheair.Thesefiltersrequireperiodiccleaningbyremoving,wat erand re oiling. Some times, engine noise may be transmitted back to the out side air through theairintakesystem.In suchcases,a silencerisprovidedbetweentheengineandintake.Atypicalfilterandsilencerinstallationfor a dieselengine.

Acentrifugeis adevicein which thesuspended impurities in the oil are removedby givingarapidwhirling motion.Thisprocessis known as"centrifuging". This processremovesimpurities by separating heavierparticlesfrom light cleanoil. Theviscosityof oil isthefactorwhichinfluencet thedegreeof cleanlinessandit canbeimprovedby heatingtheoil. But whentheoil is heatedtohigh temperature, thecontaminant water may go in to the solution with oil andhenceavoidsseperation.Soin orderto obtaingood results, the oil temperature in the range of 15°Cto 38°Cis considered to be optimum. The centrifuge requires periodic servicing to ensure cleanliness ofoil after centrifuging.

2.9 Starting System

Thestartingsystem includes storage battery, self starter, and compressed air supply etc., theautomobileenginesare generally started by cranking. But in power plants, large capacity enginesareusedandarestartedby, i) Using compressed air ii) By using an auxiliary engine iii) By usingelectricmotors or self starters.

Governing System

Thepurpose of this system is to regulate the engine speed constant irrespecti ve of load on theplant.usually, this is done by varying the supply of fuel to the engine according to load.

Enginesfor power generation

Internal combustion engines are used for power generation, where the supply of coal andwateris not available in abundant quantity. An internal combustion engine is one in whichcombustionoffueltake place inside a cylinder. Areciprocating piston inside a cylinder developspower. Aconnectingrod connects piston to the crank shaft and converts reciprocating motion ofpistonintotherotarymotion of the crank shaft.

Petrol enginesareusedin low capacity plantsandareprimarily intendedfor emergency service. Diesel engines are suitable for large capacity plants and theseengines are mainly usedfor'power generation. The capacity of diesel plants ranges from 2 to 50MW and are used as standby units in hospitals, cinema halls, telephone exchanges, radio stations, etc., It is one of themosteconomic means of generating electricity in a small scale where cheap fuels are not availableandload factors are considerably high. ;

The diesel plants are more efficient than any other heat engines of comparable size. It iseas~to start and can bum wide variety of fuels. The advantages of diesel engine over petrol engineare

1. At partloadand full load,the specificfuelconsumptionis low.
2. For samecylinderdimensions,highcompressionratio yieldsmorepower
3. Longeroperatinglife. ,
4. Reducedfire hazardsl
5. The vibrationand balancingproblemsarenot severe at mediumspeed operation. In an internal combustion engine, the following steps are followed in the production ofpower.

1. Air/ Airfuelmixtureisdrawninto thecylinderthroughvalves/ portswhichisrefeITredas suction.
2. Compressionof air/airfuelmixtureduringtheupwardmovementof piston.
3. Combustionby fuelinjectionintothehighlycompressedairorbyproducingaspark in thecompressedair fuelmixturewhichinitiatesthecombustion.
4. Expansionof combustiongaseswhichthrustthe piston to performpower stroke.
5. Exhaustof burnt gasesfromtheenginecylinder.

Thedieselengines are moresuitablefor smalland mediumoutputpowerplants due tothereasons as

Methods of starting the diesel engine

In powerplants, large capacityenginesare used and are startedby the following devices.

1) By compressed air.

2) By anauxiliaryengine(petrolengine)

3) By electricmotors.

Compressedair system: Largestationarydieselengines are startedwith compressedair.In thissystemcompressed air at a pressureof about 17bar is suppliedfrom an air tank or bottleto theengineinletvalvethroughthedistributororAtroughinletmanifoldTwoormorecompressedair storage tanks are provided.Asmallcompressoris installed for supplyof compressed airtothestoragetanks.Duringstartingofamulticylinderengine,compressedairisadmittedto oneormorecylindersand forces the pistonto movedownward which in turn rotatestJ1eengine shaft. Theinjectionor fuel pumps are inoperative while the speed is gained under air power.ThisPowerstheenginemuchthe same as steamworksin a steamengine.The air is turnedoff andoilInjectioinsstartedandtheenginegainsthemomentumandby supplyingfuel,theenginewillstartruning.

Byan auxiliary engine: In this method, a small petrol engine is mounted close to theMainengineandis connectedto it throughclutchandgear arrangements.Firstly theclutchis toBedisengagedand petrol engine can be easily started by manual operations. When it has warmedup,theclutch is to be gradually engaged to transmit power to the main engine i.e., the mainengineis cranked for starting. The clutch of auxiliary engine automatically dis engages after themainenginehasstarted.Thecapacityof auxiliaryengineisjust sufficienttoovercomethefriction ofthemainengine.

By electric motors or self starters: Electric motors or self starters are employed for smallgasoline and diesel engines. The engine consists of an electric motor which is used forstartingpurpose. Astorage battery of 12 to 36 volts is used to supply power to an electric motorwhichdrivesa pinion which engages a toothed rim on engine fly wheel. A small electric generator,drivenbyenginemay also'be used to drive the motor.The motor is engaged continuouslyforabout30 seconds only, after which it is required to cool off for a minute and then re engaged.

Thisistobe continued till the engine starts up. After the engine has started, the electricmotorAutomaticallydisengages. This method is more simple and effective than other method.

Methodof starting or starting procedure

Beforestarting the engine, it is necessary to go through all precautions supplied by manufacturers.

Theprocess of starting the engine is different for various engines. Some common steps are Aslistedhere;

1. Before starting the engine, it is necessary to'check air pressure and any possible air Leakagein theairsystem.In case of electricmotorstarting,thebatteryconditionshouldbe checkedregularly.
2. It is necessaryto checkfuel system,lubricatingsystemandcooling watersystem.
3. Theengineis crankedafter ensuringno loadonthe engine and decompressiondevice is use
4. By running the engine at slow speed, the workingof fuel pump is to be checked.The Inspectionis to be made for fuel andoil pressures,lubricatingoil systemetc.,

HYDRO-ELECTRIC ENERGY

2.10 Introduction to hydro power

Wateris the cheapest source of power. In the earlier days, it was used to run the waterwheels generate electric power. The power generation by hydro electric plant is nothing butthe utilization of the part of hydrological cycle. These plants utilize the energy of water to drive theturbinewhich intum run the electric generators. In 1882, the first hydro-electric station wasstarted inAmerica.In India, these plants contributenearly half of the total power requirementandplaysaveryimportantrole in the developmentof country.In India, a hydro electricpower stationwasinitiatedwith run of river schemenear Darjeling and the first major hydro electricplant wasdevelopednear Mysore in 1902(SivaSamudram of 4.5 MWcapacity)Thepotential energy of

rain falling on earth's surface, relative to the ocean is converted in toMechanicalenergy by using suitable prime movers i.e., hydraulic turbines. In hydro powergenerationth, e kinetic or potential energy of water may be used. The kinetic energy of water is itsenergyin motion and is a function of mass and velocity. The potential energy is nothing but thedifferenceof water level between two points i.e., head. In both the cases, water should be
available continuously and in ample quantity. The past history of the place oflocation of the plantmustbe known to estimate minimum and maximum quantity of water which is available forpowergeneration. The water from natural lakes and reservoirs at high altitudes may be used orstoragereservoirs may be constructed to store the water during peak periods and utilise thesameduring off peak periods. The dams constructed across the flowing stream serves thispurpose.A significant amount of rain fal goes in the form of direct evaporation and a major portionof rail fal seeps in to the soil to form the under ground storage. The remaining smallportionof rainfal is utilised for power generation.

Hydro or water power is a con ventional renewable source of energy. This energy source isclean,pollution free and environmental friendly. The hydro projects controls floods in the rivers,storesthe water for irrigation and for drinking purpose. The capital cost of the plant is high. Astheplants are situated in hilly areas, away from the load centre, the erection and transmissioncostsare also high. Hence, the cost of power generation is also high in comparision with steam,oilor gas plants. But inspite of these factors, a number of advantages favours the use of hydro projects.

2.11 Main Elements of hydro electric power plant

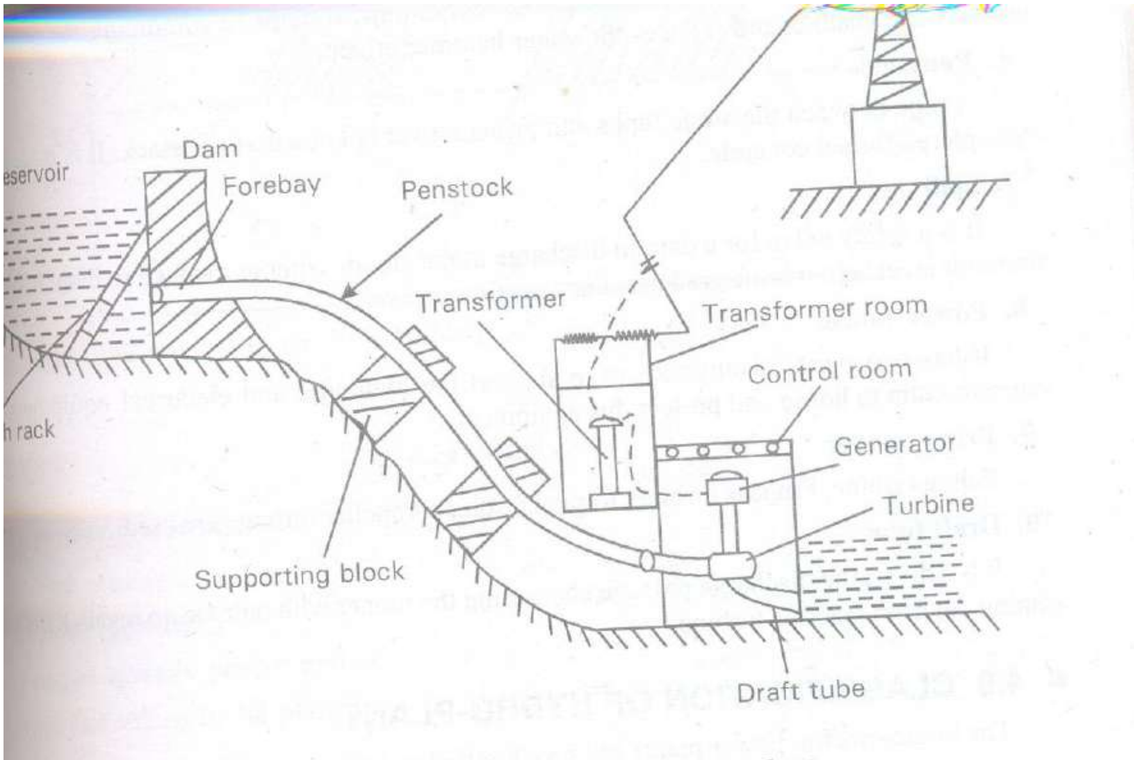


Fig. 4.25 : *Arrangement of hydro-electric power plant*

The hydroelectricpowerplantessentiallyconsistsof hydraulicstructures,powerplantetc.In the plant, hydraulicstructuremeansdams, Spillways,head work,diversion works,forebaysor surge tanks, penstocksand conduits.The essential elementsof waterpower plant are

i) Catchmentarea

ii) Reservoir

iii) Dam

iv) Spillways

v) Conduits

vi) Surgetanks

vii) Prime movers

viii) Drafttubes

ix) Power houseandequipments.

Catchment area: The catchment areaisthewhole area behind the dam which is builtacrossariverat a suitable place.

Reservoir: Itisthe basic requirementofahydro-electricpower plant and the ofwhich is to collect and store wholeofthewateravailablefrom the catchmentareabehind the dam.The stored water is usedlonmtl1tuerbines to produce electric powerimdulisyieldsuniform power out put through outtheyear.Areservoir may be natural typesuchaslakeor artificial one which is built byerectingdam across the river. Water held inupstreamreselvoiris called storage and waterbehindthedam,at the plant is called pondage.

Dam:The dam is the most importanteJemenotf the water power plant. It is aban'ierbuiltacrossthe riverto increasetheheightofwaterlevel behind it (to increase thereservoircapacity) and creates the necessaryheadtobeutilized in the water turbines.Economy and safety are the basicrequirements of the dam. The dam should resist water pressure and should be stable under conditions.In hydro - electric plants, several types of dams are used such as concrete or stonemasonry,earth and and/or rock fill and timber. Timber and steel are used for dams of height 6mto12monly.Earth dams are constructed upto about 100m.)he foundation must provide stabilityUnderdifferent forces and has to support the weight. It must be impervious to prevent seepage ofWaterunder the dam.

Forebay: It acts as a sort of regulating reservoirtemporarily store the water when the load on the plant isreduced and there is with drawl of water from it whenloadis increased. The river water is diverted away fromthemain stream. The enlarged portion at the end of canal forms the forebay.

Trashrack: It is provided on the way of waterfrom the dam or from the fore bay to prevent the entry ofdebris which might damage the wicket gates and turbinerunners or may choke up the nozzles of the impulse turbine.Manual or mechanical cleaning may be done to remove

Spill ways: It is a safety device for the dam, discharges the surplus water from the storagereservoir in to the river on the down stream side of the dam. It is arranged in the dam ornearthedam or on the periphery of the reservoir basin. This should provide structural stability tothedarnunder all conditions of floods. There are several designs of spill ways such as simple spillway,sidechannel spillway,saddlespillwaysiphonspillway,solidgravityspillway,chuteor troughspill way, emergency spill way etc.

Conduits: Inlet water way or head race is the passage of water from dam to the turbinesand tail race (outer water way) is the passage of water from the wheels. The inlet waterwayconsists of tunnels, canals, flumes, fore bays, penstocks and surge tanks. The tunnels aremadebycuttingthemountains where topography prevents the use of canalorpipeline.Headworkincludes, gates valves and trash rack etc.. The conduit may be open (canals and flumes)orclosed one (tunnels, pipe lines and penstocks).

Pen stock: A penstock is a closed pressure pipe (supplying water under pressure)
made of reinforced concrete or steel, used to supply water to the turbines. It is a pipe of shorterlength used to connect turbine and main water way. The penstocks are used where the slopeistoo great for a canal, especially where the land pitches steeply to the power house. As the working pressure or head of water increases, the thickness required in the penstock also increases,

Apenstock of larger diameter, gives lesser frictional loss. The flow of water through the penstockdecides the diameter, and the product of discharge and head gives the horse power whichthepenstock can carry. It indicates strength of the penstock. In the location of a penstock, economicalshortest route is always desired. It is desirable to locate the penstock always sloping towardsthepower house, but the extent of slope may be varied to suit the topography. In order to provideadequate water seal under all conditions, especially at low water, at the dam or fore bay.Theintake of penstock should be at a lower level. Generally penstocks are not covered, becauseexposed pipes are cheaper and maintenance and repair becomes very easy. Covered penstocksare used in the places where there is achance of sliding of snow, rock andearth etc. In the penstock, velocity of water ranges from 2 to 6 mlsec.lf thewater velocity increases, size of thepenstock required decreases andconsequently it's cost also reduces,butfrictional lossesincreases.Thelifeof the penstock may be increased byusing a protectivecorrosionresistantcoating on the steel penstock.penstocks may be burried orsupported on the piers and craddles.

2.12 **Classification of Hydro Plant**

The hydro electricpowerplants are classified according to Head of water available

a) Low head Plants:

These power plants are also known as canal power plants. In these plants, the water headavailable is less than 30 metres. The necessary water head is created by constructingadamacross the river and the water is diverted in to a canal which allows the water to flowinloaforebay, from wherethewateris madeto flowthroughturbines.Thenthewaterisdischargeidnto the river through a tail race. The power house is located near the dam itself and doesnotrequiresurgetank.Thisplantuses verticalshaftFrancisturbineor Kaplan turbine.

(b): Medium Head Plants:

In these plants, the operating head of water ranges from 30m to 100 metres. The forebay isprovided at the beginning of penstock, serves as water reservoir and conveys water to theturbines through penstocks. Open canals are used to carry the water from main reservoir to theforebay which it self acts as a surge tank. Forebay also stores the rejected water when the loadon the turbine decreases. Francis turbines are used in these type of plants.factor is less than one. Therefore, forsatisfactory working of the plant, it is tobe designedfor averageloadandthistypeisknownasbaseloadplant.Asmallplant known as peak loadplant peak load plant is usedto satisfytheloadwhichiscorningabove the mean load.

c) High head plants

Whenthe available water head for power generation exceeds 100 metre, the plant is knownAshighheadplant.During rainy season,usually the water is stored in lakes or high mountains. Fromthereservoirs, water is passed through tunnels which distribute the water to penstockThroughwhichthe wateris conveyedto the turbines.Asurgetank is attachedto the penstock toReducethe water hammer effect on the penstock. Waterflow is regulated by head gates at thetunnelintake, butterfly valves at the entry to the penstocks and gate valves at the turbines. Theseplantsareusuallyprovidedwithpeltonturbinesforpowergeneration.

d) Peak load plants

These plants are mainly intended to supply power during peak loads. Somepeakplants, deliver power during average and also peak load as and when it is there.Runofplants with pondage and pumped storageplants are used as peak load plants.In thefirstit uses a largepond which provides extensive seasonal storage.These work onrelativelhyIt.heads and load factor is considerably low.

According to quantity of water available for power generation

(a) : Run otTriver plant without pondage

This type of plant has no control over the river flow.The plant does not store waterand usethe water as it comes. During low load and high flood conditions, water will be wasted by over thedam spill ways.During dry seasons,the low flow of water reducesthe plantcapacl~.These plants are usually used to supply peak load. The non-uniformity of supply makes itsutili~ veryless in comparisionwith othertypeof plants.

(b) : Run of river plant with pondage

In theplant,additionof apond increasestheusefulnessof the run off riverplant.The wateris stored behind a daIrl and this increases the stream capacity for a short period. The conditionsat the tail race should be such that the water level in the tail race should not be increased duringfloodsas it decreasesthe effectiveheadof theplant.This plant can be used as base loador peakload plant. This plant is more reliable and its generating capacity is not fully dependent on the waterflowrates available.

(c): Storage type plants

This type of plant stores the water during rainy season in the reservoir and it is releasedduring dry season.The reservoir incorporatedis of a sufficiently large size to allowcarryoverstorage from the wet season to dry season. The power generation in dry seasons will notbe affected.

According to nature of load

The load on the power plant varies depending on seasons and every hour in a day. Consideraloadcurve as shown in figure 4.9 for an industrial town. The peak load is the plant capacity tosatisfythe demand. If the plant is designed for peak load capacity, then the working of the plantnot economical as most of the time the plant is working under low load conditions and the loadaffectplantcanbeusedasbaseload plant aswell aspeak load plant aswater is availablewithcontralsrequiredMostof thehydro-electricplantsinIndiaanaswellasin theworldareGeneraylltheseplantsareusedto supply thepeakloadfor the baseloadpower plantsandTosupply thesuddenpeakloadfor ashduration ie., afew hoursor few daysin ayear.Theseareusedintheplaceswherethewaterisnot availablein sufficient quantity for powergeneration.

Inthisplant,apenstockconnectsthe headwater pond andtail water pond. The generating Pumping plantis locatedonthelower sideasshown.Thebaseloadplant,generatessome surpluselectricenergyduring off peakhours.This energyis beingusedto pumpthewaterfromtailwaterpondto theheadwaterpondandthisenergywillbe storedthere.Duringpeakloadtime,this energy will be released by allowing waterto flow from head water pondthrough
theturbineof the pumped storage plant.
Pumpedstorage plant is a special type of hydroelectric plant works in combination withplantsto improvetheoverallefficiencyof thecombinedsystem.Theplantusesverylittle
Rateforitsoperationandhence decreases the operatingcost of the thermal plant.

2.13 Storage and pondage

Storage means, collection of water in the upstream reservoirs to increase the capacitystream over an extended period of several months. The water is stored in a reservoir forcontinuous generation of power through out the year and the power generation is not affected by thevariationin the rainfall during the year. The excess water is stored in the reservoir during rainy seasonan and it is released during run off (dry) periods. Storage plants may work satisfactorilly asbaseload Sand peak load plants. Maximum storage should be provided with economic expenditure.Thereare two types of storage.
i) The storage of water is provided for one year only (considering losses also),sothatthere is no carry over water for the next season.
ii) The water is stored, so as to be useful even during the worst dry periods.
Pondage means, collection of water behind a dam at the plant and increases the streamcapacity for a short period, ie., for a week. The generating capacity of the plant is less dependenton the flow rates of water available and the plant with pondage is more reliable than that withoutpondage.Arunof riverplantwithoutpondageuseswaterjust as it comes,withoutstoring.Thereis no controlon flow of waterso that wateris wastedduringhigh floods or low loads.Theplantcapacity is reduced during low run off period. The capacity of pondage should be such that,itshould take care of hour to hour fluctuations in load on the plant through out the period.

2.14 Hydrology

Hydrology is the science that deals with the depletion and relplenishment of water resourceson and beneath the surface of earth. It is the natural science in which rain fall and run off canbeanalysed and studied and occurence and availablity of water can be studied. It also deals withal formsof wateri.e., solid,liquidand vapour.Thestudyofhydrologyprovidesinformationabouttransportationof waterfromoneplace to onother,andfromoneform to another.The scienceofhydrologyis very importantin the design of irrigationstructures,planning and constructionofbridges and flood control works etc.

Hydrologic cycle

We know that, the cloulds are formed due to evaporation of water from plants, rivers andoceans and the evaporated water is carried with air in the form of vapour. In the atmosphere, thevapour falls in the form of water or snow depending on atmospheric temperature, when these arecooled below the dew point temperature. This evaporation (water lost in atmosphere as vapour)and precipitation (vapour condensed back in the form of rain, snow, hail, dew, sleet or frost)continues for ever and there by maintains a balance between these two. This is known as"Hydrologic cycle".

The Hydro logical cycle involves various processes such as transfer of moisture from thesea to the land and back to the sea again. The hydro logic equation is expressed asevaporation

P = R+E

P = Precipitation

R = Runoff

E = Evaporation

Precipitation (Rain fall); It includes all the water that falls from atmosphere to the earth surfacei.e.,vapourcondensed in the fonn of rain, snow, hail, dew, sleet, or frost. It consists of i) Liquid

precipitation (rain fall) and ii) Solid precipitation (snow, hail etc).

Runoffand surface run off: The portion of rain fall or precipitation, flows through the catchment areaonthesurfaceof theearthisknownas runoff.or dischargeorstreamflow.It includesalltheWaterflowingin the streamchannelatanygivensection.Theramainingportionof the rainfallis directlyevaporated by the sun, taken by the vegetation and growing crops and some percolates intotheground. Run off occurs when the rate of precipitation exceeds the rate at which water infiltratesin to the soil. The factors which in influence the rate and volume of runoff are duration,intensityand distribution of rain fall.

The surface run off means the water that reaches the stream channel without first percolatingdownto the water table (WT).

Evaporation: The change of phase of water from liquid to vapour state is called evaporation

Transpiration: *It* is the process by which the plant releases water to the atmosphere.

Run off can be measured daily, monthly seasonally or annually by using the following methods

i) Fromrain fall records

ii) Byusingempiricalequations

iii) By using runoff curvesandtablesand

iv) Dischargeobservationmethod.

2.15 Hydrograph

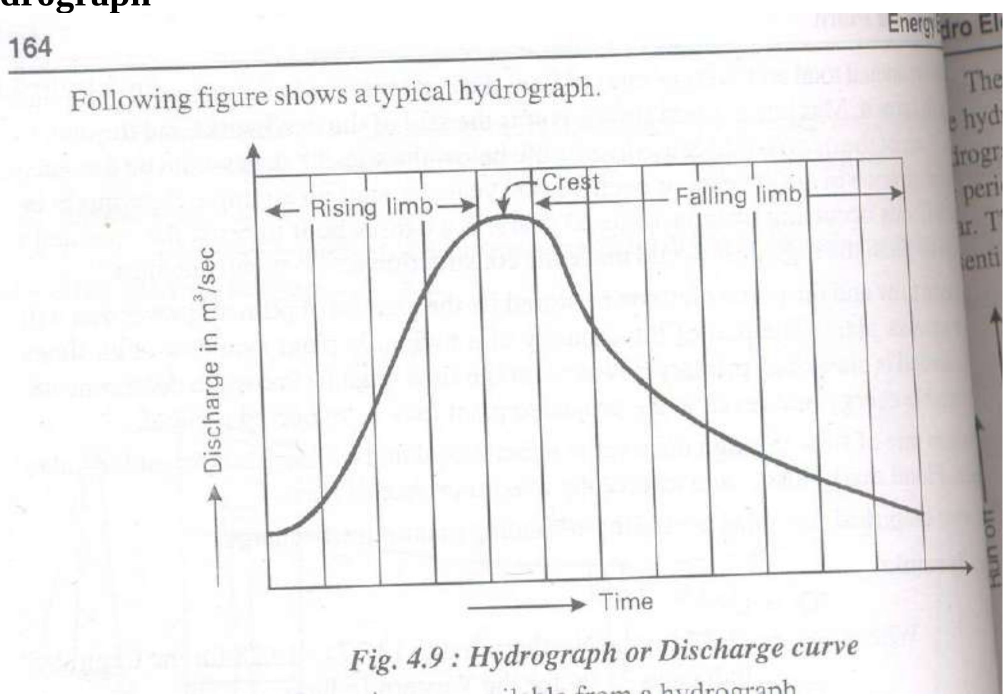


Fig. 4.9 : Hydrograph or Discharge curve

A hydrograph is a graphical representationshowing discharge (run off)offlowing water withrespect to time for a specified time. It indicatesvariation of flow or discharge with time. Ahydrographmay be plotted for hours, days,weeksor several months. It is plotted with flow as theordinate (inm3/sec)andtimeintervalas abscissas(in hours, days etc). Besides the variation of flow,indicatedbyahydrograph~italsoindicatesthepoweravailablefrom the stream at different times of theday, week or year. A hydrograph also indicatesextremeconditionsof flow and helps in analyzing theeffectof storage onflow.The characteristicsofthe catchment andprecipitationoverit, will effectthe nature of hydrograph of stream of river. Flodflow of the rivers can also be assessed and hencefora givenstorm,anticipatedhydrographofthegivenriver could be drawn.

A hydrograph is used to determine

1. Flow rate atanyinstantduring thedurationperiod.
2. Asareaunderhydrographgivesvolumeofwaterin a particularduration,thetotalvolumeof flow duringthat periodcan be determined.
3. The meanannualrun offor meanrunoff for each monthof the year.
4. Themaximumandminimumrunoff for theyearandforeachmonth.
5. Flooddurationandfrequencyandmaximumrate of runoff duringthe floods.

The peakflow shows only a momentaryvalue.There fore it is required to analysethefullHydrographofflowandtheconceptof unithydrographhasbeenintroduced.ie.,Thetwoidenticalstormsproduces same hydrographsfor the run off. Usually identical stormsrarely occursandgenerallyrainfallvariesin duration.Hencefor thebasin,a typicalhydrograhis tobe constructedwhichcouldbe used as a unitof measurementof run off.A unit hydrographis onewhichrepresentsunit run off resultedfrom an intenserain fallofUnitdurationandspecificarealdistribution.

2.16 Flow duration curve

Curveshowstherelationbetweenflows,plottedastheordinateandlengthsthey are available and plotted on abscissa. This curve represent the run offtime in the another form and is obtained from a hydrograph. The flow duration between flow available during a period and the fraction of time. If the potential flow is plotted on the ordinate, then the curve is known as "Power durationuseful to analyse development of water power. The flow duration curve gives at the site, and may be used to find maximum and mirlimum flow conditions.drawn by using hydrograph from the available run off data and it is required to time during which certain flows are available. This information is obtained eitheror from hydro graph and is tabulated. Then the flow duration curve can be00% time on the x axis and run off on Y axis. Durationcurveisthegraphicalrepresentationofitsflowarrangedin thedescending meanmonthlydischargeata siteis asshown.Drawthehydrographcurve by takingtime in monthson abcissa ordinate.Fromthisdrawflowdurationcurvebyfindinglengthsoftime

Uses offlowduration curve

i) Usefidfor comparisionbetweenstreams

iI) Usefidforprelimiruuystudies

ill)It evaluateslowlevelflows.

iv) It helps inplanningand design of water resourceprojects.

v) It helpsin designingdrainagesystemsandin floodcontrolstudies.

Disadvantages of flow duration curve

i) It does not present the flows in natural sequenceof occurence

ii)Thecurvewillnotgiveanyideawhetherthelowestflowsoccuredinconsecutiveperiods or were scatteredthrough out the consideredperiod.

2.17 Mass curve

In a hydrostationthe capacityof the reservoiris computedbyusing a plotknownas "masscurve".This plot givesthe storage requirement that is needed to produce a certain dependable

flowfrom fluctuating dischargeof a river bya reservoir.Amass curve is defined as a graph ofcummulativevolumesof waterthatcan be storedfromstreamflowagainsttime indays,weeksormonths. The integral curve of the hydrograph leads to mass curve and this expresses the areaunder hydrograph from one time to another. In the mass curve atany point, the curve slope represents the change of volume perchange of time or the flow rate at that moment. Hence, when theflow of the river is large, the curve is steep and when the flow issmall, it gives flat curve. By storage for the same mass flow, theplant generating capacity can be increased by modifying the waterflow as per plant requirements.

Advantages

1. Thepeak load capacityof the plant is increasedat comparatively lowcapital cost.
2. Theoperatingefficiencyishigh
3. Theplant ispartlyindependentof streamflowconditions.
4. Theplant loadfactor is improved.

5. Loadon thehydroelectricplantremainsuniform.

6. There is an overallgain in thepumped storageplant as theenergy available duringpeakload durationis higherthan thatof duringoffpeakload duration.

2.18 Surge tanks

A surge tank is an additional storage reservoir fitted to the penstock, asnear aspossibleto the turbine. Usually surge tanks are provided in high head or medi urn headplantswhenthere is a considerable distance between the water source and turbine, necessitating alongpenstock. It reduces the distance between free water surface and turbine and hence Reducethe effectof waterhammeronpenstock of turbine.Therefore the surge tank furnishesthefollowing functions.

1) Itstoresthe water during load rejection by the turbine and provides additional water during Additionalload on the turbine.

2) Duringsudden changes in the conditions of water flow, it relieves the waterhammer pressureswithin the penstock. Thus it regulates the water flow to relieve water hammer pressures and to improve the performance of the machines by providing better speed regulation.

3) It reduces the distance between free watersmface of the reservoirandturbineandoflllt'Reservoirhencereduce theeffect of waterhammer

During goveming of the turbine, when load on turbine decreases, the govemerc\oseslltgates of the turbine partly to adjust water flow rate in order to maintain constantspeedoft~1runner.Underthis condition, watermovingto theturbinehasto movebackwardandisstoredmthe surgetank.In absenceof surgetank,thisbackwardmovementof watermayresultin sudOOtpressure rise in the penstock resulting in water hammer phenomenon. The strengthofthepl~~to be increased, other wise penstock may burst.

Waterhammer: It is defined as the change in pressure rapidly aboveor below normIalpressure caused by sudden changes in the rate of water flow through the pipe accordingtodemandof turbine.It occurs at all the points in the penstockbetween forebayor surgetankandturbines.During turbine goveming, the gates (valves) supplying water to the turbines aresuddenl)closed when the load on turbine decreases. This sudden retardation of the flow in the penstockresults in sudden pressure rise. its fluctuations in the penstocK dunng reduction of load on turbme ISknown as Water hammer When the load on theturbine increases,itneedmorewaterandhenceturbinegatessuddenlyopenscausingrushofwaterthroughpipe.This createsa vacuumin thepipe carryingwater.

Types of surge tanks: At the top, the surge tanks may be opened or closed. In case of open type, it should be lower than the level of water in the reservoir. The various types of surgetanks are

(a) Simple surge tank: Asimple surge tank is a plaincylindrical tank connected by a veltical branch of pipe to thepenstock.In thistype, ifoverflow is allowed,it eliminatesliseofpressurein thepipe,butoverflowsurgetankisuneconomical.surge tanks arebuilt in large size, sothateven during full loadconditiononturbine,water cannotoverflow.Usuallysurgetankis locatedongroundsurface,abovethepenstockline.Thistypeof tank is more expensive and uneconomical due to its largesize and hencerarely used whencompared to other types.The effective water surface inclinedat an angle '8' to the horizontal. This reduces size ofthe tank requiredi.e..incase of Inclinedsurgetanks, height of surge tank canbe reduced for the samediameteror diameterofthetank can be reducedforthe sameheight.Butthis typeismorecostlierthanothertypesdueto difficultyinconstructionandisalso rarelyused unlessthetopographicalconditionsareinfavour.

(c) Expansion chamber and gallary type surge tank

Expansiontimberlower gallery-Expansion chamber surge tank

This type of tank consists of an expansion tank at the top and expansion at thebottom to limit the extreme surges. The expansion chamber absorbs rising surger, and lowergallary reserve the water for starting the turbine or to meet increasing load on the turbine. Theupper one must be above the maximum reservoir level and lower one must be below the loweststeadyrunning level inthe surge tank.

(d) Restricted orifice or throttled surge tanks

The simple surge tanks are not suitable for medium and large head plants. There fore somemodifications are incorporated in the restricted orifice surge tank.

In this type, a restricted orifice is provided between the conduit and the tank. AconsiderableAn10unt of fiiction loss is created when the water flows in and out of the tank through the orifice.

During low load conditions of the turbine, the surplus water passes through the restricted orificeand immediatly a retarding head, equal to the loss due to restricted orifice, is built up in theconduit. The size of the restricted head can be designed for any desired retarding and acceleratingheads. If the area of restricted orifice is equal to or greater than conduit area, the tank is said tobe a simple tank and retarding head is negligible. If an infinitely small restricted orifice isused.then the retarding head becomes equal to the water hammer in the conduit without The size of the restricted orifice selectedin such a way that the initial retarding headis equal to the rise of water surface in the tank during rejection of full load by the turbine. This typeis moreefficient and economical than simple tank, but the main disadvantage is that the considerableportion of water hammer pressure is directly transmitted to the low pressure conduit and alsoinducessuddenfluctuationsof headonthe turbine.

(e) Differentinl surge tank

This type of surge tank is the compromise between simple and restricted orifice surge tanlIn this type, an internal riser whose area equal to that of conduit is provided in the cylindricalchamber. An outer chamber connects the riser at it's base through ports. When the load changes,the water level in the riser also changes rapidly and produces sudden deceleration or accelerationofthe conduit flow. In the outer chamber, water level moves more slowly and thus lagsbehind
that in the riser. In differential surge tank, even though the action is very rapid, it gives reasonablylowpressurerises and surges oflow amplitude.

2.19 Gates

i) Vertical lift gate: cross section ofvertic1e lift gate. On the crest ofthe dam, vertical guides on peirs provides path for sliding motion of steel gates. These steel gatesare used for small power plants. The gate lifting mechanism must be able to over come highfrictional losses developed in the guides due to high hydro static force on the gate. Agate of 5m2area weights 150 tonnes and has to with stand 2000 tonnes of water load.

ii) Radial gate: cross section of a radial or tainter gate. A steel framework supports the gate which is in the form of a segment of a cylinder as shown in figure. Theframe is pivoted on trunnions. The gate is also attacl1ed with hoisting cables and other end ofcables are attached to the winches on the plat form above the gate. A motor drives the winches.for the sliding gate and for the same size of sliding gates, the hoist load is also much less.

iii) RoUinggate: cross section of rolling gate. It consists of cylindricaldrum made of steel. The lower portion of gate is a cylindrical segment and touches ~ spill waycrest. The rolling cylinder rolls on the rack provided, with the help of hoist cable. These arepreferredfor longspans and moderateheight. .

iv)Drum gate: The figure 4.17(d)showscross section of drumgate. It is also suitable for longspans.The gate is a segment of a cylinder which can fit in the recess provided in the top of thespillway.When water entersunder force to the recess,the hollow drum gaterasiesup to theclosedpositionflap gate.The lower edgeoftheflapishingedto theupstreampartofthedamandtheupperedgepositionbychainsorscrewedrodssupportedby an over headbridge. The flood wateris passed overcrest of the sizeopenings.

2.20 Advantages and disadvantages of hydro electric plants

Advantages

1.

2. The operating cost including auxiliaries is considerably low (RS 120perKWat1001load factor).

3. Maintenance and running cost of the plant is low.

4. No nuisance of smoke, exhaust gases, soot etc., and hence the atmosphere is notpoulluted

5. No ash disposal problem.

6. In addition to electric power generation, plants are also used for irrigationandfloodcontrol.

7. These plantsare moreeconomicalthan othertype of plantsas it involvesnofuelcharges.

8. Theplant life is more andplantefficiencydoes not changewithageofplant.

9. No fueltransportationproblem.

10. There are no stand by losses.

11. The plants are located away from developed areas, and hence the cost oflandisnot amajorproblem.

12. Theplant requires less skilledoperators.

13. Theseplantscan meet suddenchangesofload withoutloss of efficiency.

Disadvantages

1. The initialcost of the plantis high,as it includesconstructionofdam

2. The power generation depends only on the quantity of water availablewhichinturndepends Uponrainfall. '

3. These plants are usually locatedawayfrom the load centres anduseslongtransmissionlines.There fore, thecost of transmissionlines andlosses inthemaremore.

4. Planterectiontime is more.

2.21 Question bank

1. What are the applications of Diesel power plant?
2. What are the advantages and disadvantages of aircooling System
3. For a diesel power station briefly describe the Lubrication system
4. Draw the general schematic of Diesel power plant
5. Why cooling of diesel engine is necessary?
6. Sketch and briefly explain the working of Exhaust System
7. Give any four important applications of Lubrication Sysytem
8. List six advantages and Disadvantages of Diesel power plant
9. Draw the general layout of Diesel power plant and Explain the working of different systems
10. With the help of a neat digram explain (i) thermostat cooling and (ii) thermosyphon cooling
11. State the important factors considered while selecting a site for hydo-electric power plant
12. Draw a neat flow sheet diagram of a hydro electric powerplant indicating the essential elements
13. At a particular site the mean dischargeof a river (in millions of m^3) in 12 months from January to December are 30, 25, 20, 0, 10, 50, 80, 100, 110, 65, 45 and 30 respectively. Draw the flow duration curve on a graph sheet. Also estimate the power developedin MW if the available head is 90m and the overall efficiency of generation is87.4%. Assume each month of 30 days.
14. Define hydrograph and unit hydro graph and explain its importance in the design of storage in the hydro electric power plant
15. Explain the working of hydro electric powerplant with the help of a neat sketch
16. With the help of a neat sketch explain pumped storage plant

2.22 Outcomes:

Student should be able to understand the

1. Main Components and working of diesel engine power plant.
2. Basic concepts, working and applications of hydro electric power plant

2.23 Further reading:

1. Non Conventional Energy sources, G D Rai, Khanna Publishers.
2. Non Conventional Resources, B H Khan, TMH – 2007

3.http://www.indiawris.nrsc.gov.in/wrpinfo/index.php?title=Hydro_Electric_ojects_in_Karnataka

4. http://indianpowersector.com/wp-content/uploads/2010/09/diesel-gas-engine-power-plants-in-india1.pdf

MODULE-3: SOLAR ENERGY

Structure

3.1 Introduction :

Through out the world, the energyconsumption has been growing withadvancecivilization. Today, energy consumption is directl y related to the standard of living of thepeople of nationanddegree of Industrialization of the country. The existing energy sources of fossil fuels may. not~ Iadequate to meet the ever increasing energy demands. These energy resources are also depletingin nature and may be exhausted in a short time. Thus.a necessary exists to look for otherformof energy sources i.e., non-conventional energy sources such as geothermal, ocean tides,wind,solar, etc. Among all these energy sources, solar energy is the most promising alternativeener~source which will meet considerable part of energy demand. The solar energy has itsOwnadvantages such as its availability at free of cost, inexhaustible, free from polution, availablem'\almost all parts of the world, and is available in abundence. Solar water heaters, spaeeheaters,solar cookers, solar photo-voltaic cells, solar refrigerators and solar thermal power plantsare

used for various purposes and in all these devices, solar energy is used either for the purposeof waterheating,spaceheatingor cooling or forconversionto otherformofenergy.Theenergycomes from the sun, keeps the temperature of the earth higher, causes current in the atmosphereand ocean. The differential heating of the earth's surface by the sun produces the wind andenergy of the wind may be used to run wind mills which in turn drives a generator to produce

electricity.Solar energy is a renewable resource and cannot be depleted. It has the greatest potentialof all renewable energy sources. The sun constantly delivers 1.36 kW (1360 joules/see) ofenergy per square meter to the earth. It is one of the promising alternative energy source anditsnature and magnitude available on earth's surface varies depending on the location and weatherconditions.

The earth's surface receives 106watts of solar power which is 1000times more thantheactualpower needed through out the world.The 5 percentutilizationof solarenergy willbe 50imeswhatthe worldwillrequire.

Theapplications of solar energy are:

i. Spaceheatingor coolingfor residentialbuilding.

ii. Solarwaterheating

iii. Solarcookers

iv. Solardistillationon a smallscale

v. Dryingof agriculturaland animalproductsby suitablesolar driers.

vi. Foodrefrigeration

vii. Electricpowergeneration

viii. Solar ponds

ix. Directconversionof solarenergyintoelectricityby usingphoto-voltaiccells

x. Bio-conversionand windenergy,whichare indirectsourceof solarenergy

Solar radiation outside the earth's atmosphere

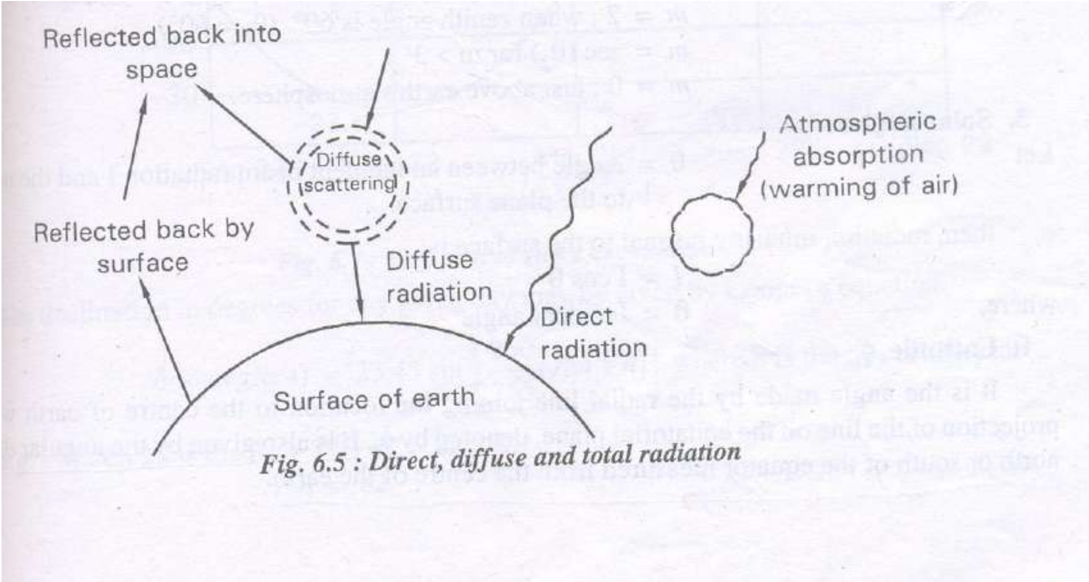


Fig. 6.5 : Direct, diffuse and total radiation

Thesunisconsideredas alargesphereofdiameter1.39x 106km,consistingofveryhotgases. Theearth's diameteris 1.27x 104km andthe averagedistancebetweentheearthandsun is1.496x 108km.The earth receives beamradiationfrom the sun, almost parellel,becauseofverylargedistancebetweenthesunandtheearth.Eventhoughsun'sbrightnessvariesfromcentreto its edge, we assume that the brightness is uniform all over the solar disc. It is to be notedthatthe radiationcoming from the sun is almostequal to that of radiationcomingfrom a Blacksurfacewhich is at 5762 K.Theenergy flux radiated from the sun outside the earth's atmosphere is consideredto beconstantandthis yieldsthe definitionof solar constant.Solar constant is the rate at whichsolarenergyreaches at the top of the atmosphereand is denotedby Isc.This is the amountof energyreceivedfrom the sun in unit time on a unit areaperpendicular to the sun's directionand at theMeandistance of the earth from the sun.The distance between the earth and the sun varies asearthrevolvesaroundthe sun in an ellipticalorbitwitha smalleccentricityandsunatoneof thefoci.Thischangesthesolarradiationandhence then ergyflux reachingtheearth's atmosphere.

Thusthe solarconstant value obtained is the average one and a standard value of 1353W/m2
was adopted in 1971. Later, the solar constant value was revised to 1367 W/m2,throughmeasurements.The variationin the extra terrestrialflux, outsidethe earth's atmospheredueto change indistance between earth and the sun produces a sinusoidal variation in the intensity of solarradiation thatreachestheearth.Thevalueof thisextraterrestrialfluxon anydayof theyearcanbe obtainedby using the equation
The figure 6.1 showsthe spectral distributionof extra terrestrial solar radiation.It is seenfrom the figure that the spectral beam radiation first increases shortly with wave lengthandreachesa maximum value of 2074 W/m2 at 0.48 Ilm wave length and then decreases. It is to benotedthat,upto a wave lengthof 4 Ilm,99 percent of sun's radiationis obtained.

3.2 Solar radiation at the Earth's surface

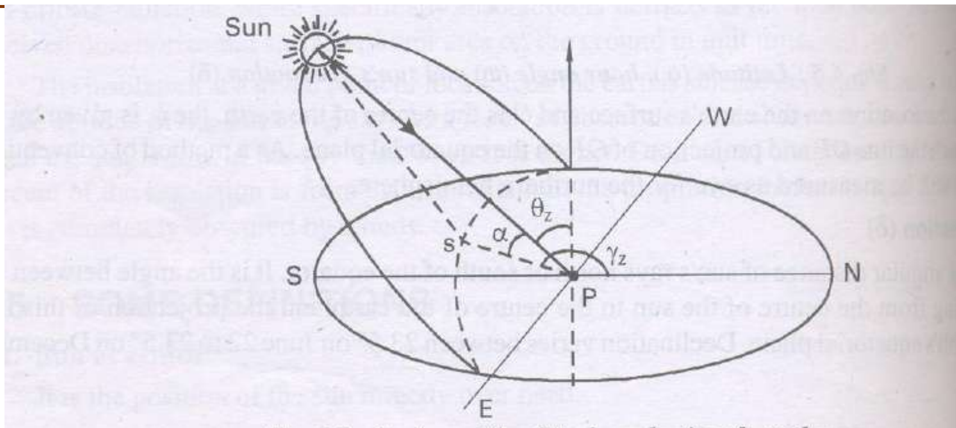


Fig. 6.8 : Sun's zenith, altitude and azimuth angles

The solarenergyreceivedatthe earth's surfacedependsonthetime of day,thetimeofyear, Locallatitudeandamountofcloudcover,amountof atmosphericpollutionetc.Thesolarradiation Receivedat theearth's surfaceisin attenuatedformandiscomposedofbeamanddiffuseradiation, Scatteredcomponentandthereflectedshortwavelengthradiationfromthe surroundingterrestrial

surfacesafter subjectedto themechanismsof absorptionandscatteringduring its travelthroughthe earth's atmosphere. The ozone, water vapour and to some extent other gases (like CO2,N02, CO, °2 and CH4)and particulate matter, absorb all the ultraviolet solar radiation andenergy in the infraredrange.This absorptionof solarradiationby the atmosphereincreasesitspresenceof allgaseous molecules andparticulatematter or dust particlesin the atmosphere, scatters the solarradiationi.e.,changesitsdirection.The scatteredradiationisredistributedin allthe directions,aportion of whichgoes back in to the space and remainingreaches the earth's surface as diffuseradiation.Thustheradiationfinallyreach theearth'ssurfaceconsistspartlyofbeamradiationandItis obvious that the solar radiation recei ved at earth's surface is maximum when theatmospheiresnotcoveredorpartlycoveredwithcloud.However,themechanismsof absorptionandscatteringare similar under the conditions of cloudless sky or atmosphere with clouds.Solaradiation which is not scattered or absorbed and reaches the earth's surface directlyfromthesun without changing its direction is called "Beam or Direct radiation". The solar radiationreceivedat the earth's surface after scattering absorption and reflection by the atmosphere iscalled"DIffuseradiation". It is the radiation at the earth's surface from all parts of the sky'shemispheraend its direction has been changed by scattering, absorption and reflection. Thereforethetotalradiation received at the earth's surface is the sum of beam and diffuse radiation and isknownastotalor globalradiation.Reflected radiation

The intensity of diffuse radiation is not isotropic in nature, but it changes with respect tolatitudetime of the year, time of the day, content in the atmosphere and many other factors.

A term called air mass (AM}is often used to indicate the distance travelled by beam radiationthrough the atmosphere to reach a location on the surface of the earth. The air mass (AM) is thetermrepresents the ratio of atmospheric mass through which beam radiation passes to the massof the atmosphere, ifthe position of the sun is directly overhead (i.e., at its zenith).

3.3 Solar Radiation Measurement

It isnecessarytomeasuresolarradiationbecauseofuseof solarheatingandcoolingdevicesand the results of the measurements are used to predict the performance of the devices. Theinstrument used for measurement of solar radiation includesmeasurementof directsolarradiationanddiffuse solar adiationor totalsolarradiation.Theinstrumentsusedformeasurementofsolarradiationincludesmeasurementof direct solarradiationanddiffusesolarradiationor totalsolarradiation.Theinstrumentswhichare commonly used formeasuringthesolarradiationare

1.*Pyrheliometer:* Aninstrumentwhichmeasuresbeam radiationintensityasafunctionof incidentangle,and

2. *Pyranometer:* Aninstrumentused to measuretotal solarradiation.

3.4Pyrheliometers

This instrumentis used to measurebeamradiationand operatesonthenopileeffect.Theinstrument consists of a tube whose axis is aligned with the direction of sun's rays by usingtwo axis tracking mechanism and alignment indicator. The tube contains a sensor disc at itsbasenmthe arrangement is made such that the diffuse radiation is blocked from the sensor surlaceandhence the device measures only Beam radiation. The use of shading ring also gives measurementof direct solar radiation, the value of which is obtained by subtracting the shaded (diffuse) readingfromthe unshaded(global)reading. .

Thepyrheliometerswhicharecommonlyused are

i) Angstromcompensationpyrheliometer

ii) Abbot silverdiskpyrheliometerand

iii) Eppleypyrheliometer

Questions

1. Explain briefly the application of Solar pond
2. Draw the sketch and label the parts (i) Horizontal wind mill (ii) Vertical wind mill
3. Define terms: (i) solar radiation (ii) diffused radiation (iii) Direct radiation and (iv)Extra terrestrial radiation.
4. Classify solar radiation measuring instruments. Explain any one instrument with Sketch
5. With the help of a neat sketch describe the photovoltaic cell
6. With a neat sketch explain the flat plate solar collector.
7. List the problem associated woth solar power

Module 4: WIND ENERGY& TIDAL POWER

Wind energy is another potential source of energy. Winds are the motion of air caused by un- even heating of the earth‘s surface by the sun and rotation of the earth. It generates due to various global phenomena such as ‗air-temperature difference associated with different rates of solar heating. Since the earth‘s surface is made up of land, desert, water, and forest areas, the surface absorbs the sun‘s radiation differently. Locally, the strong winds are created by sharp temperature difference between the land and the sea. Wind resources in India are tremendous. They are mainly located near the sea coasts. Its potential in India is estimated to be of 25 × 10^3 MW. According to a news release fromAmerican Wind Energy Association the installed wind capacity in India in the year 2000 was 1167 MW and the wind energy production was 2.33 × 10^6 MWh. This is 0.6% of the total electricityproduction.

Availability of wind energy in India

The development of wind power in India began in the 1990s, and has significantly increased in the last few years. Although a relative newcomer to the wind industry compared with Denmark or the United States, India has the fifth largest installed wind power capacity in the world. In 2009- 10 India's growth rate was highest among the other top four countries.
As of 31 Jan 2013 the installed capacity of wind power in India was 19051.5MW, mainly spread across Tamil Nadu (7154 MW), Gujarat (3,093 MW), Maharashtra (2976 MW), Karnataka(2113 MW), Rajasthan (2355 MW), Madhya Pradesh (386 MW), Andhra Pradesh (435 MW), Kerala (35.1 MW), Orissa (2MW), West Bengal (1.1 MW) and other states (3.20 MW) It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2012. Wind power accounts for 8.5% of India's total installed power capacity, and it generates 1.6% of the country's power. India's wind atlas isavailable.

Forces on the Blades. There are two types of forces operating on the blades of a propeller-type wind turbine. They are the circumferential forces in the direction of wheel rotation that provide the torque and the axial forces in the direction of the wind stream that provide an axial thrust that must be counteracted by proper mechanical design.

The circumferential force, or torque, T is obtained from

$$T = \frac{P}{\omega}$$

whereT = torque, N or lb,

ω = angular velocity of turbine
wheel, m/s D = diameter of turbine
wheel = $\sqrt{4}$ A/π,m

N = wheel revolutions per unit time, s-1

For a turbine operating at power P, the torque is given by

$$T = \eta \frac{1}{8g_c} \frac{\rho D V_1^3}{N}$$

For a turbine operating at maximum efficiency ηmax = 16/27, the torque is given by Tmax,

$$T_{max} = \frac{2}{27g_c} \frac{PDV_1^3}{N}$$

The axial force, or axial thrust, is

$$F_a = \frac{1}{2g_c} \rho A(V_1^2 - V_2^2) = \frac{\pi}{8g_c} \rho D^2 (V_1^2 - V_2^2)$$

The axial force on a turbine wheel operating at maximum efficiency where V_e = 1/3; $V_i$is given by

$$F_{a,max} = \frac{4}{9g_c} \rho A V_1^2 = \frac{\pi}{9g_c} \rho D^2 V_1^2$$

The axial forces are proportional to the square of the diameter of the turbine wheel which makes them difficult to cope with in extremely large-diameter machines. There is thus an upper limit of diameter that must be determined by design and economic considerations

The performance of a wind mill rotor stated as coefficient of performance is expressed as:

Cp = A/Pmax

= A/ (1/2 ρV^3)

whereρ = Density of air A

= Swept area

V = Velocity of the wind

Further the tip speed ratio being the function of speed at the tip of the rotor to the windspeed, i.e. U/V and in most of the parts of India, the wind velocity being low (through the wind energy average around 3 kWh/m2 day) The exploitation of wind mills in India is feasible. Depending upon the survey of velocity in a region the appropriate value of design parameter may becomputed

Wind Turbine Classification

Horizontal Axis Machines: Machines with rotors that move in a plane perpendicular to the direction of the wind.

A farmer‘s windmill, for example.

Vertical Axis Machines: Machines that have the working surfaces traveling in the direction of the wind.

Horizontal axis type wind mill

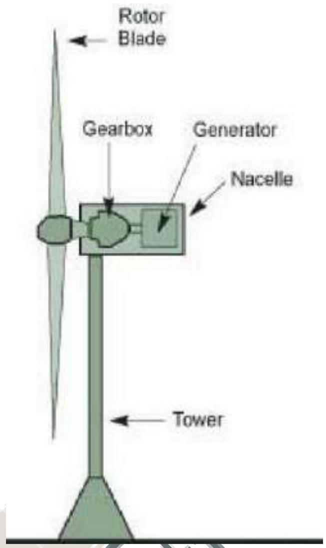


Fig: Horizontal-axis wind turbines

Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a servo motor. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator. Since a tower produces turbulence behind it, the turbine is usually positioned upwind of its supporting tower. Turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted forward into the wind a small amount. Downwind machines have been built, despite the problem of turbulence (mast wake), because they don't need an additional mechanism for keeping them in line with the wind, and because in high winds the blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since cyclical (that is repetitive) turbulence may lead to fatigue failures, most HAWTs are of upwinddesign.

Vertical Axis wind mill

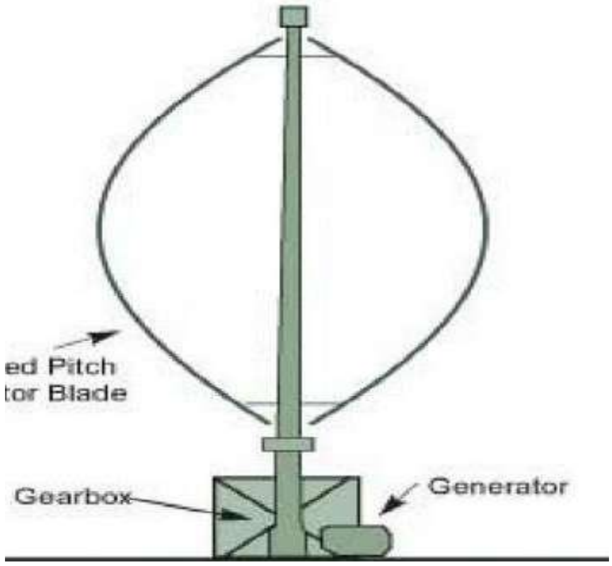


Fig: Vertical-axis wind turbine

Vertical-axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically. Key ad-vantages of this arrangement are that the turbine does not need to be pointed into the wind to be effective. This is an advantage on sites where the wind direction is highly variable, for example when integrated into buildings. The key disadvantages include the low rotational speed with the consequential higher torque and hence higher cost of the drive train, the inherently lower powercoefficient, the 360 degree rotation of the aerofoil within the wind flow during each cycle and hence the highly dynamic loading on the blade, the pulsating torque generated by some rotor designs on the drive train, and the difficulty of modelling the wind flow accurately and hence the challenges of analysing and designing the rotor prior to fabricating aprototype

With a vertical axis, the generator and gearbox can be placed near the ground, using a direct drive from the rotor assembly to the ground-based gearbox, hence improving accessibility for maintenance.

When a turbine is mounted on a rooftop, the building generally redirects wind over the roof and these can double the wind speed at the turbine. If the height of the roof top mounted turbine tower is approximately 50% of the building height, this is near the optimum for maximum wind energy and minimum wind turbulence.

COEFFICIENT PERFORMANCE OF WIND MILL ROTOR

As WECS is a capital intensive technology it is desirable for the overall wind electric plant to have the highest efficiency possible optimally utilizing capital resources and minimizing the electric energycost

$$\eta = \frac{\text{Useful output power}}{\text{Wind power input}}$$

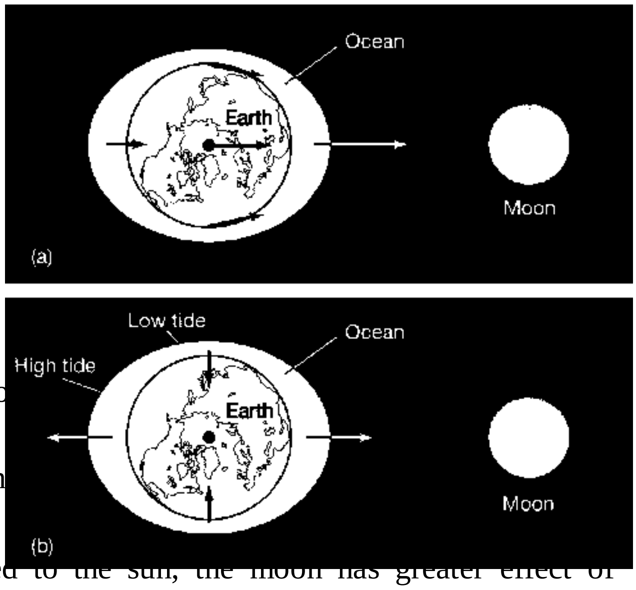
This eqn is an application of cascaded energy conversion, where in overall efficiency will be strongly determined by the lowest efficiency convertor in the cascade. For the aerogenerator this is the aeroturbine; the efficiency of the remaining three elements can be made quite high but less than 100%

TIDAL POWER

TIDAL POWER PLANT

- The periodic rise and fall of the water level of sea which are carried away by the gravitational action of sun and moon is calledtide.
- The energy generated by these tides is called tidalenergy.
- To harness the tidal energy, the difference in water surface elevations at high tide and low tide is utilized to operate a hydraulicturbine.
- A generator is attached to the turbine to generateelectricity.
- The rising water or high tides are called floods and low tides are calledebbs.

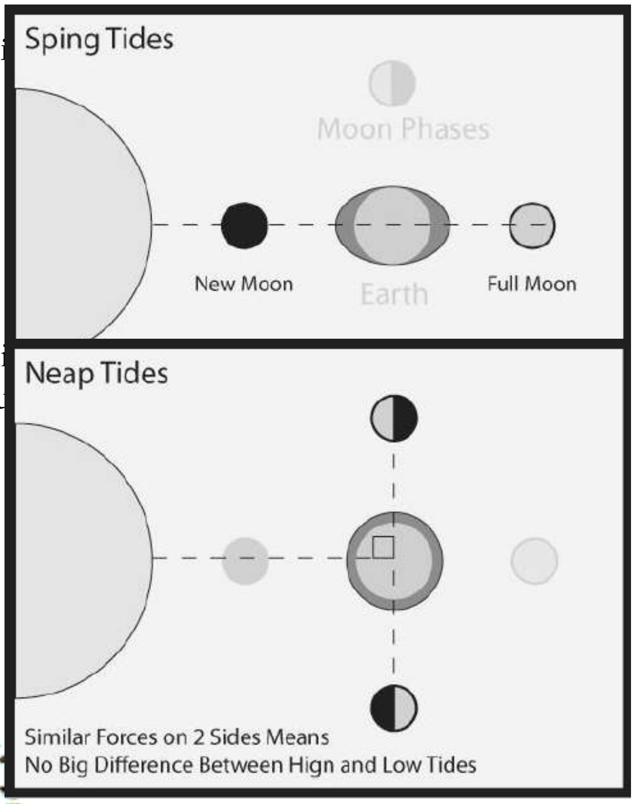
BASIC PRINCIPLE OF TIDAL POWER



- The gravitational attraction of moon and the sun on the water present on the earth produces tides.
- The magnitude of attraction depends on the mass and its distance.
- This is given by Newton's law of gravitation
- It states that "every object in the universe attracts the other object with aforce"
- The gravitational force of attractio proportional to the product of theirmasses.
- The gravitational force of attraction between square of the distance between theircenters.
- Though the moon has less mass compared to the sun, the moon has greater effect of attraction than sun because the distance between the moon and earth is veryless.

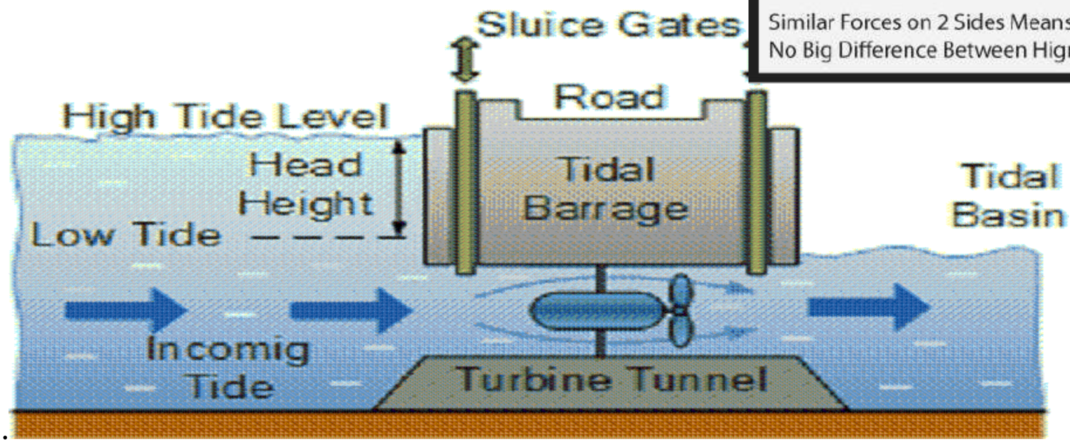
- The gravitational force of the moon causes the oceans to bulge along an axis pointing directly at the moon as shown in thefigure.

When the sun and the moon are in line, their gravitati attraction on the earth combine and cause a spring tide.



When the sun and moon are at 90˚, their gravitati attraction each pulls water in different directions and cau neaptide.

HARNESSING TIDAL ENERGY



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The major components of tidal power plant are:

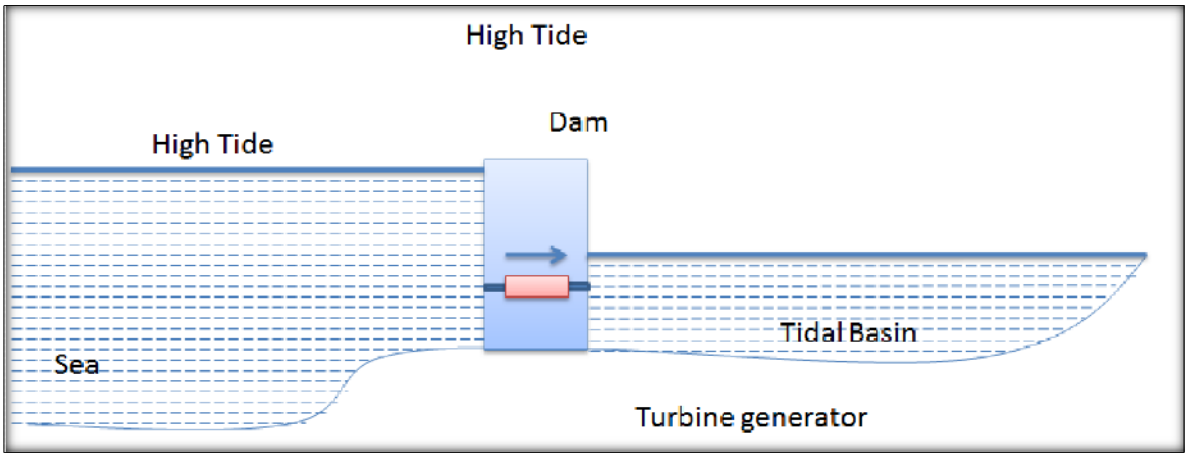
1. Power house- It has turbines, electric generators and other auxiliary equipments.
2. The dam or barrage- The function is to form barrier between sea and basin or between twobasins.
3. Sluice ways- The function is to fill basin during high tides and empty basin during lowtides.

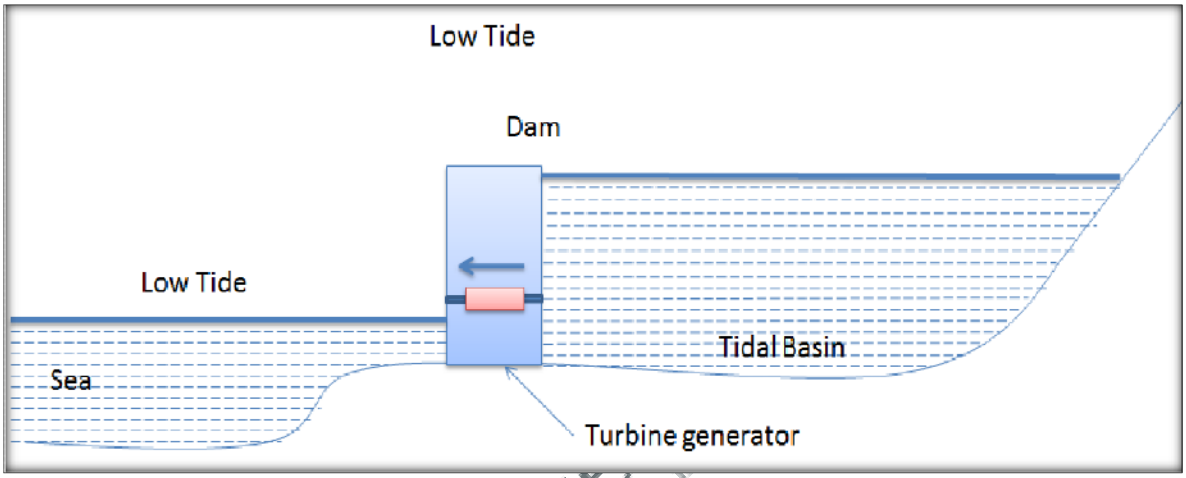
CLASSIFICATION OF TIDAL POWER PLANT

- Single basinarrangement

- Double basinarrangement

SINGLE BASIN ARRANGEMENT





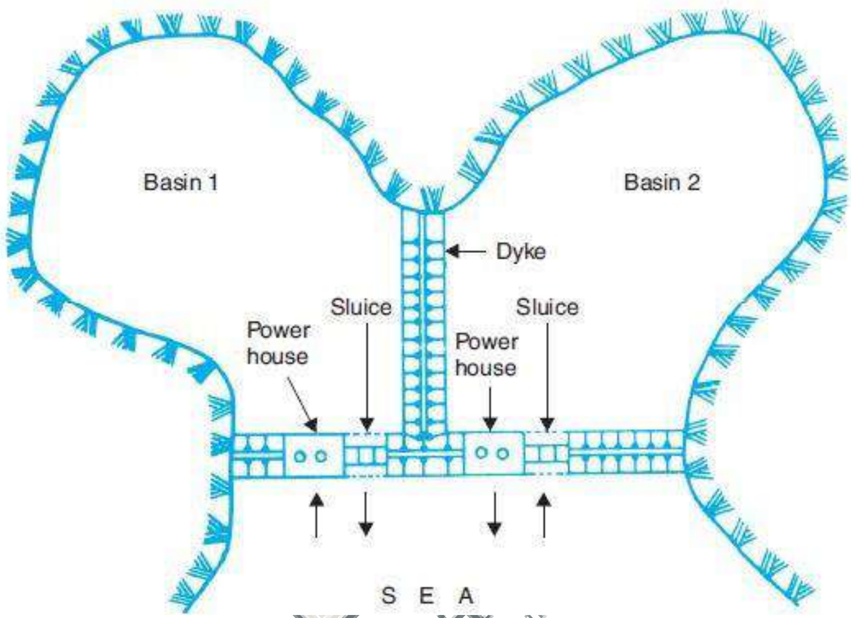
- The general arrangement of a single basin system is shownabove.
- Since only one basin interacts with the sea, power can be generated at regular intervals.
- A dam separates basin and sea. The power house is installed inside thedam.
- During High Tide, i.e., when the sea level rises, the turbine valves are opened and the sea water flows into the basin through the turbine generatingpower.
- The power is generated till the level of sea water and basin isequal.
- The water is allowed to pass into the basin, till the level reaches its maximum position.
- During low tide, the level of basin is more than the level of seawater.
- After attaining sufficient head, the turbine valves are opened and water flows from basin to sea through the turbine generatingpower.
- Tidal power plants normally use reversible water turbines, such that power is generated in both thedirections.

A Single basin arrangement system can be classified as:

1) *Single-ebb system*: Water is stored during High tide in the basin and power is generated only during lowtide.
2) *Single-Tide system*: Power is generated only during High tide and it fills the basin. The water is drained out during lowtide.
3) *Double cycle system*: Power is generated during both high tide and low tide as explainedabove.

DOUBLE BASIN ARRANGEMENT

Two Basin system



- Figure above shows a schematic diagram of two-basinsystem.
- In the system, the two basins close to each other operatealternatively.
- One basin generates power when the tide is rising (basin getting filled up) and the other basin generates power while the tide is falling (basin getting emptied).
- The two basins may have a common power house or may have separate power house for eachbasin.
- In both the cases, the power can be generatedcontinuously.

ADVANTAGES OF TIDAL POWER PLANT

- It is independent of rain, andinexhaustible.
- Large area of valuable land is notrequired.
- When a tidal power plant works in combination with thermal or hydro-electric power plant, peak power demand can be meteffectively.
- Free frompollution.

DISADVANTAGES OF TIDAL POWER PLANT

- Power generation is notuniform.
- Life of turbines reduces due to corrosive seawater.
- Construction of dams in sea isdifficult.
- The power transmission cost is high as it is located away from loadcentres.
- The plant efficiency is notuniform.
- Sedimentation and siltation ofbasins.

Module 5: BIOMASS& GREEN ENERGY

Biomass is biological material derived from living, or recently living organisms. It most often refers to plants or plant-derived materials which are specifically called biomass. As a renewable energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel. Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into: thermal, chemical, and biochemicalmethods.

5.1 Benefits of Using Biomass

1) Biomass used as a fuel reduces need for fossil fuels for the production of heat, steam, and electricity for residential, industrial and agriculturaluse.

2) Biomass is always available and can be produced as a renewableresource.

3) Biomass fuel from agriculture wastes maybe a secondary product that adds value to agricultural crop.

4) Growing Biomass crops produce oxygen and use up carbondioxide.

5) The use of waste materials reduce landfill disposal and makes more space for everythingelse.

6) Carbon Dioxide which is released when Biomass fuel is burned, is taken in byplants.

7) Less money spent on foreignoil.

5.2 Biofuels

A biofuel is a fuel that uses energy from a carbon fixation. These fuels are producedfromlivingorganisms. Examples of this carbonfixation are plants and microalgae. These fuels are made from a biomass conversion.

This biomass conversion‘s can being solid, liquid, or gas form. This new biomass can be used for bio fuels. Bio fuels have increased in popularity because of the raisingoil prices and need for energysecurity.

Bio ethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn or sugarcane. Cellulosic, derived from non-food sources, such as trees and grasses, is also being developed as a feedstock for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a gasolineadditive to increase octane and improve vehicle emissions.

Biodiesel is made from vegetable oils and animal fats. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as adiesel additive to reduce levels of particulates, carbonmonoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats using transesterification

5.3 Biopower

Biopower, or biomass power, is the use of biomass to generate electricity. Biopower system technologies include direct-firing, cofiring, gasification, pyrolysis, and anaerobic digestion.

Most biopower plants use direct-fired systems. They burn bioenergy feedstocks directly to produce steam. This steam drives a turbine, which turns a generator that converts the power into electricity. In some biomass industries, the spent steam from the power plant is also used for manufacturing processes or to heat buildings. Such combined heat and power systems greatly increase overall energy efficiency. Paper mills, the largest current producers of biomass power, generate electricity or process heat as part of the process for recovering pulpingchemicals.

Co-firing refers to mixing biomass with fossil fuels in conventional power plants. Coal-fired power plants can use co-firing systems to significantly reduce emissions, especially sulfur dioxide emissions. Gasification systems use high temperatures and an oxygen-starved environment to convert biomass into synthesis gas, a mixture of hydrogen and carbon monoxide. The synthesis gas, or "syngas," can then be chemically converted into other fuels or products, burned in a conventional boiler, or used instead of natural gas in a gas turbine. Gas turbines are very much like jet engines,

only they turn electric generators instead of propelling a jet. High-efficiency to begin with, they can be made to operate in a "combined cycle," in which their exhaust gases are used to boil water for steam, a second round of power generation, and even higher efficiency.

Using a similar thermochemical process but different conditions (totally excluding rather than limiting oxygen, in a simplified sense) will pyrolyze biomass to a liquid rather than gasify it. As with syngas, pyrolysis oil can be burned to generate electricity or used as a chemical source for making fuels, plastics, adhesives, or otherbioproducts.

Bio products

The processes are similar. The petrochemical industry breaks oil and natural gas down to base chemicals and then builds desired products from them. Biochemical conversion technology breaks biomass down to component sugars, and thermochemical conversiontechnology breaks biomass down to carbon monoxide and hydrogen. Fermentation, chemical catalysis, and other processes can then be used to create new products.
Bioproducts that can be made from sugars include antifreeze, plastics, glues, artificial sweeteners, and gel for toothpaste. Bioproducts that can be made from carbon monoxide and hydrogen of syngas include plastics and acids, which can be used to make photographic films, textiles, and synthetic fabrics. Bioproducts that can be made from phenol, one possible extraction from pyrolysis oil, include wood adhesives, molded plastic, and foaminsulation.

5.4 Photosynthesis

Photosynthesis is the process by which plants, some bacteria, and some protistans use the energy from sunlight to produce sugar, which cellular respiration converts into ATP, the "fuel" used by all living things. The conversion of unusable sunlight energy into usable chemical energy, is associated with the actions of the green pigment chlorophyll. Most of the time, the photosynthetic process uses water and releases the oxygen that we absolutely must have to stay alive. Oh yes, we need the food as well!

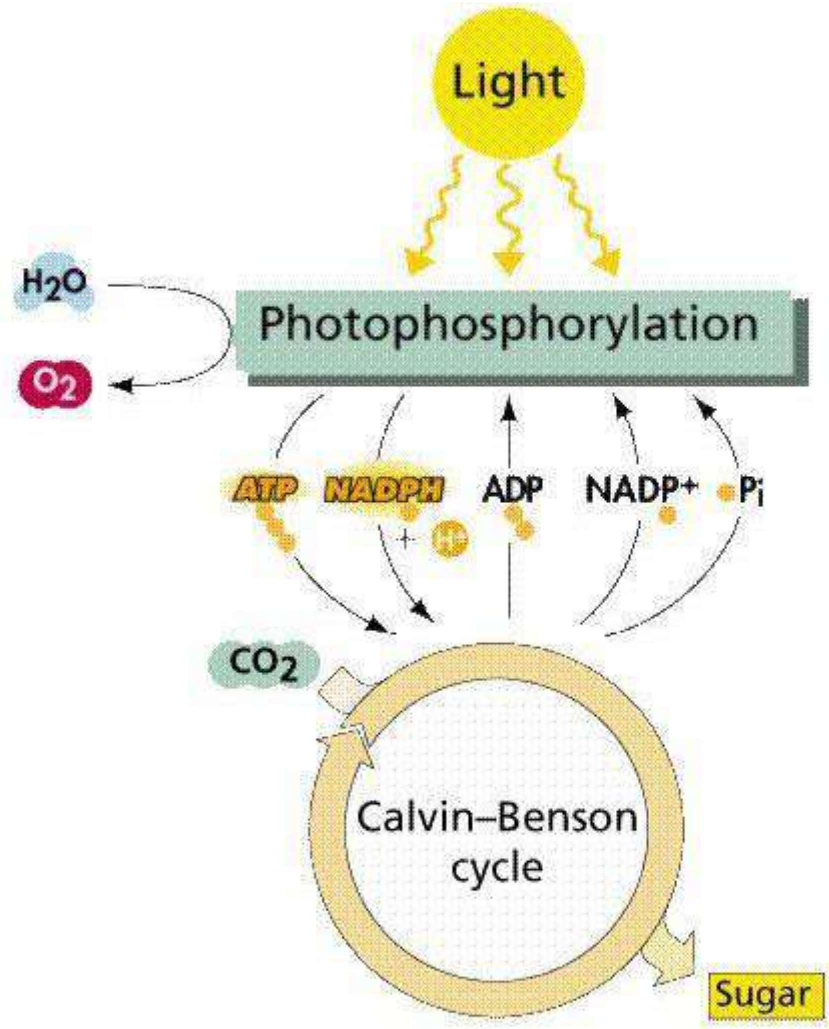
We can write the overall reaction of this process as:

$6H_2O + 6CO_2$ --------- > $C_6H_{12}O_6 + 6O_2$

six molecules of water plus six molecules of carbon dioxide produce one molecule of sugar plus six molecules of oxygen

Photosynthetic Oxygen production

Photosynthesis is a two stage process. The first process is the Light Dependent Process (LightReactions), requires the direct energy of light to make energy carrier molecules that are used in the second process. The Light Independent Process (or Dark Reactions) occurs when the products of the Light Reaction are used to form C-C covalent bonds of carbohydrates. The Dark Reactions can usually occur in the dark, if the energy carriers from the light process are present. Recent evidence suggests that a major enzyme of the Dark Reaction is indirectly stimulated by light, thus the term Dark Reaction is somewhat of a misnomer. The Light Reactions occur in the grana and the Dark Reactions take place in the stromaof the chloroplasts.



Light Reactions

In the Light Dependent Processes (Light Reactions) light strikes chlorophyll a in such a way as to excite electrons to a higher energy state. In a series of reactions the energy is converted (along an electron transport process) into ATP and NADPH. Water is split in the process, releasing oxygen as a by-product of the reaction. The ATP and NADPH are used to make C-C bonds in the Light Independent Process (Dark Reactions).

Energy Plantation:

The need to grow Energy Plantations to meet fuel wood needs without affecting agricultural lands is a pressing priority. Energy plantations on waste lands is one of the most economic and versatile ways of harnessing solar energy through the photosynthetic process. In addition to making fuel wood availability, it can also improve the fertility of degraded lands. Gujarat has over 67 lakh hectares of wastelands (almost 10% of the 63 million hectares of waste land in the country) which

could be productively used to grow energy plantations.GEDA had taken up energy plantation programme in 1985-86 and continued till 1998-99 linking to energy supply, food & fodder, soil regeneration, ecological development, and employment generation through efficient utilisation of wasted, unproductive and neglected lands in AbdasaTaluka of Kutch District.

Decomposition process

The process of decomposition — the breakdown of raw organic materials to a finished compost — is a gradual complex process, one in which both chemical and biological processes must occur in order for organic matter to change intocompost.

there are two processes that yield compost:

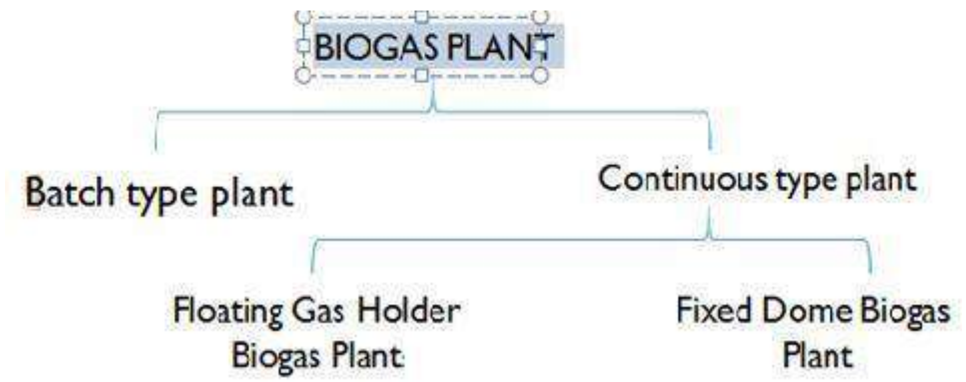
ANAEROBIC (without oxygen)

decomposition.AEROBIC (with oxygen) decomposition

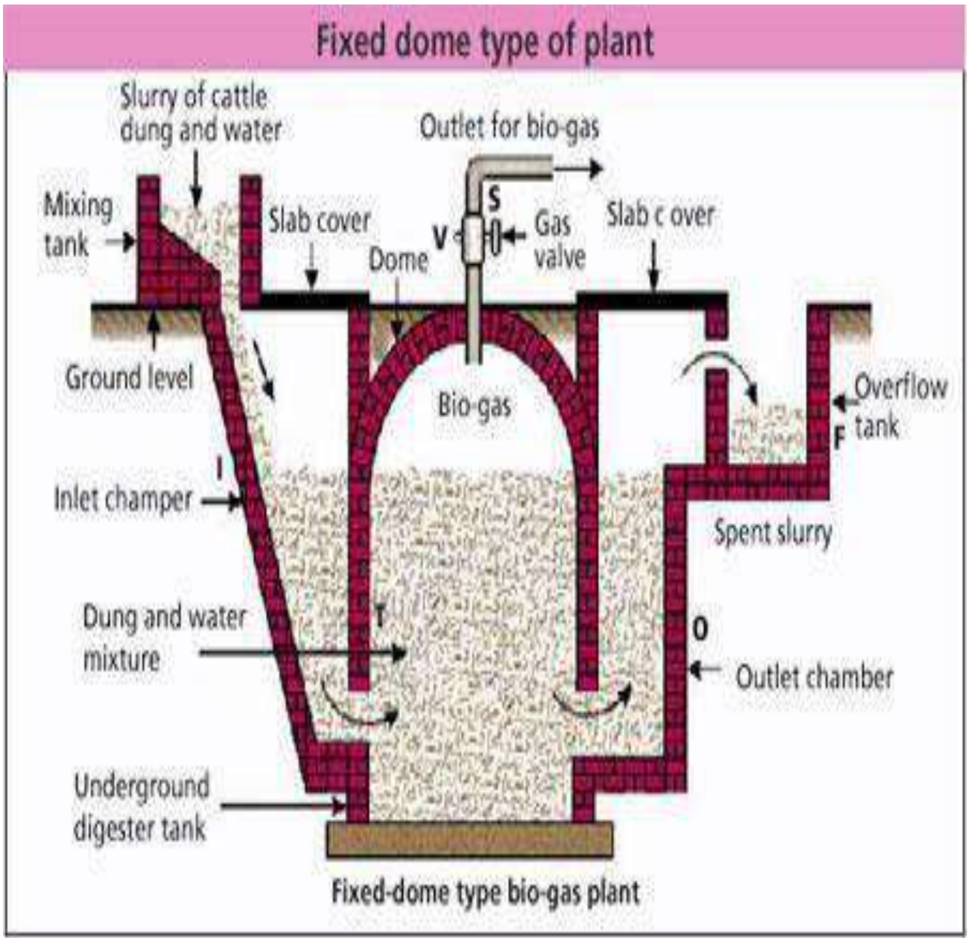
and stabilization.

In these processes, bacteria, fungi, molds, protozoa, actinomycetes, and other saprophytic organisms feed upon decaying organic materials initially, while in the later stages of decomposition mites, millipedes, centipedes, springtails, beetles and earthworms further breakdown and enrich the composting materials. The organisms will vary in the pile due to temperature conditions, but the goal in composting is to create the most favorable environment possible for the desired organisms. Differences between aerobic and anaerobic composting are discussed below.

5.5 CLASSIFICATION OF BIO GAS PLANTS



Fixed dome type of biogas plant



Raw materials required

Forms of biomass listed below may be used along with water.

- Animal dung
- Poultrywastes
- Plant wastes (Husk, grass, weedsetc.)
- Humanexcreta
- Industrial wastes(Saw dust, wastes from food processingindustries)
- Domestic wastes (Vegetable peels, waste foodmaterials)

Principle

Biogas is produced as a result of anaerobic decomposition of biomass in the presence of water.

Construction

The biogas plant is a brick and cement structure having the following five sections:

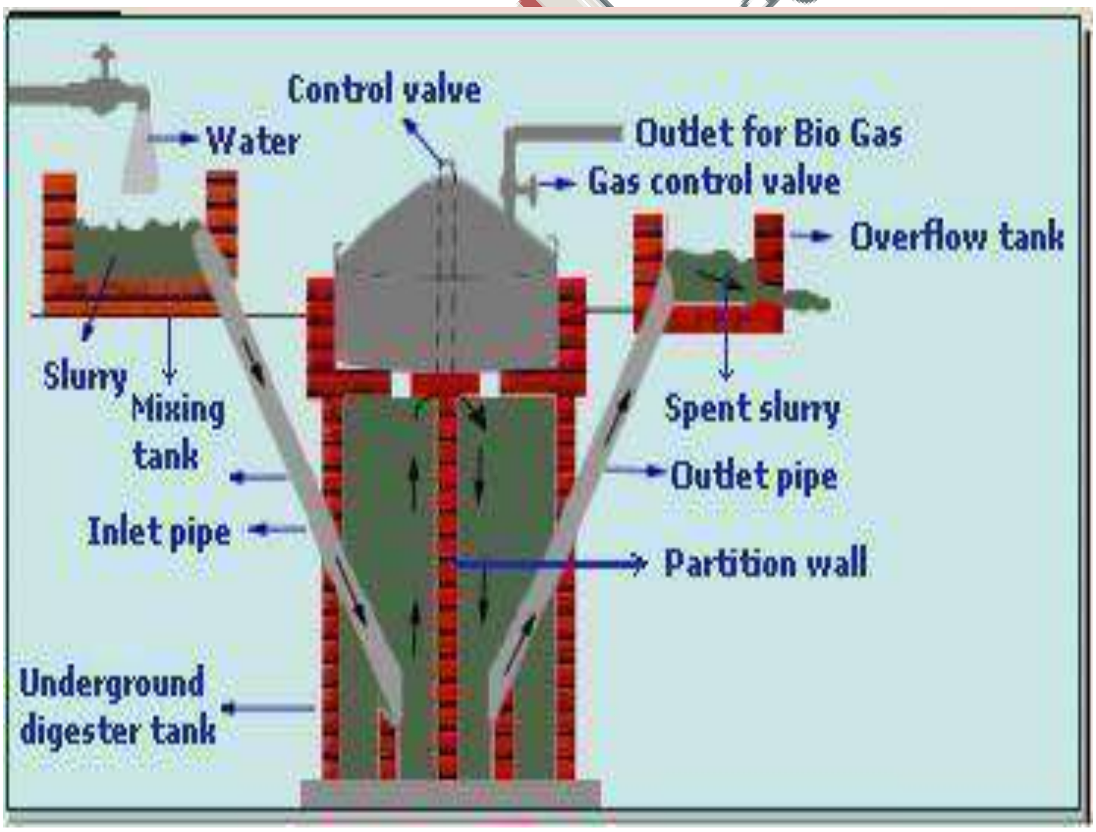
- Mixing tank present above the groundlevel.
- Inlet chamber: The mixing tank opens underground into a sloping inletchamber.
- Digester: The inlet chamber opens from below into the digester which is a huge tank with a dome like ceiling. The ceiling of the digester has an outlet with a valve for the supply ofbiogas.

- Outlet chamber: The digester opens from below into an outletchamber.
- Overflow tank: The outlet chamber opens from the top into a small over flowtank

Working

- The various forms of biomass are mixed with an equal quantity of water in the mixing tank. This forms theslurry.
- The slurry is fed into the digester through the inletchamber.
- When the digester is partially filled with the slurry, the introduction of slurry is stopped and the plant is left unused for about twomonths.
- During these two months, anaerobic bacteria present in the slurry decomposes or ferments the biomass in the presence of water.
- As a result of anaerobic decomposition, biogas is formed, which starts collecting in the dome of thedigester.
- As more and more biogas starts collecting, the pressure exerted by the biogas forces the spent slurry into the outletchamber.
- From the outlet chamber, the spent slurry overflows into the overflowtank.
- The spent slurry is manually removed from the overflow tank and used as manure forplants.
- The gas valve connected to a system of pipelines is opened when a supply of biogas isrequired.

Floating gas holder type of biogas plant



The raw materials used and the principle involved are common to both the types of biogas plants.

Construction

- The floating gas holder type of biogas plant has the following chambers/sections:
- Mixing Tank - present above the groundlevel.
- Digester tank - Deep underground well-like structure. It is divided into two chambers by a partition wall inbetween.
- It has two long cementpipes:

  i) Inlet pipe opening into the inlet chamber for introduction ofslurry.

  ii) Outlet pipe opening into the overflow tank for removal of spentslurry.

- Gas holder - an inverted steel drum resting above the digester. The drum can move up and down i.e., float over the digester. The gas holder has an outlet at the top which could be connected to gas stoves.
- Over flow tank - Present above the groundlevel.

Working

- Slurry (mixture of equal quantities of biomass and water) is prepared in the mixingtank.
- The prepared slurry is fed into the inlet chamber of the digester through the inletpipe.
- The plant is left unused for about two months and introduction of more slurry isstopped.
- During this period, anaerobic fermentation of biomass takes place in the presence of water and produces biogas in thedigester.
- Biogas being lighter rises up and starts collecting in the gas holder. The gas holder now starts movingup.
- The gas holder cannot rise up beyond a certain level. As more and more gas starts collecting, more pressure begins to be exerted on theslurry.
- The spent slurry is now forced into the outlet chamberfrom the top of the inletchamber.
- When the outlet chamber gets filled with the spent slurry, the excess is forced out through the outlet pipe into the overflow tank. This is later used as manure forplants.
- The gas valve of the gas outlet is opened to get a supply ofbiogas.
- Once the production of biogas begins, a continuous supply of gas can be ensured by regular removal of spent slurry and introduction of freshslurry.

Thermochemical conversion on biomass

There is increasing recognition that low-cost, high capacity processes for the conversion of biomass into fuels and chemicals are essential for expanding the utilization of carbon neutral processes, reducing dependency on fossil fuel resources, and increasing rural income. While much attention has focused on the use of biomass to produce ethanol via fermentation, high capacity processes are also required for the production of hydrocarbon fuels and chemicals from lignocellulosicbiomass.

5.6 Types of Gasifiers

Up draught or counter current gasifier

The oldest and simplest type of gasifier is the counter current or updraughtgasifier shown schematically in Fig

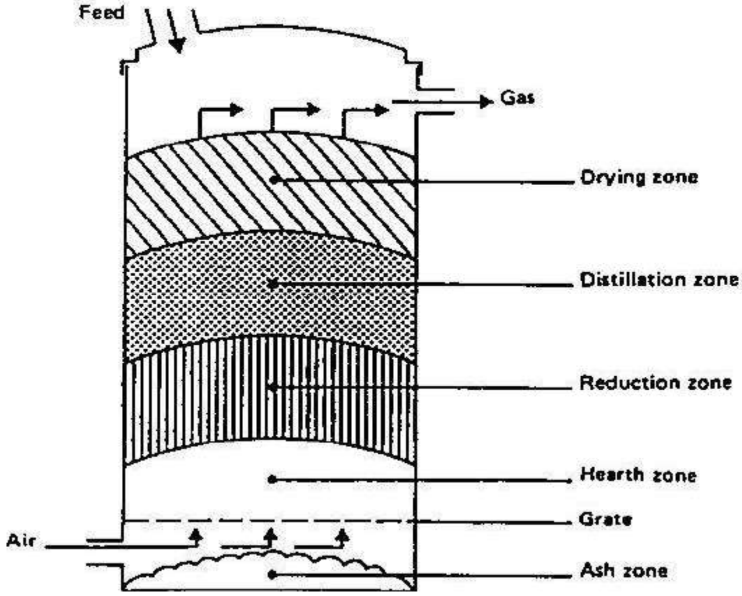


Fig:Updraught or counter current gasifier

The air intake is at the bottom and the gas leaves at the top. Near the grate at the bottom the combustion reactions occur, which are followed by reduction reactions somewhat higher up in the gasifier. In the upper part of the gasifier, heating and pyrolysis of the feedstock occur as a result of heat transfer by forced convection and radiation from the lower zones. The tars and volatiles produced during this process will be carried in the gas stream. Ashes are removed from the bottom of thegasifier.

The major advantages of this type of gasifier are its simplicity, high charcoal burn-out and internal heat exchange leading to low gas exit temperatures and high equipment efficiency, as well as the possibility of operation with many types of feedstock (sawdust, cereal hulls, etc.) .

Major drawbacks result from the possibility of "channelling" in the equipment, which can lead to oxygen break-through and dangerous, explosive situations and the necessity to install automatic moving grates, as well as from the problems associated with disposal of the tar-containing condensates that result from the gas cleaning operations. The latter is of minor importance if the gas is used for direct heat applications, in which case the tars are simply burnt.

Downdraught or co-current gasifiers

A solution to the problem of tar entrainment in the gas stream has been found by designing co-current or downdraught gasifiers, in which primary gasification air is introduced at or above the oxidation zone in the gasifier. The producer gas is removed at the bottom of the apparatus, so that fuel and gas move in the same direction, as schematically shown inFig.

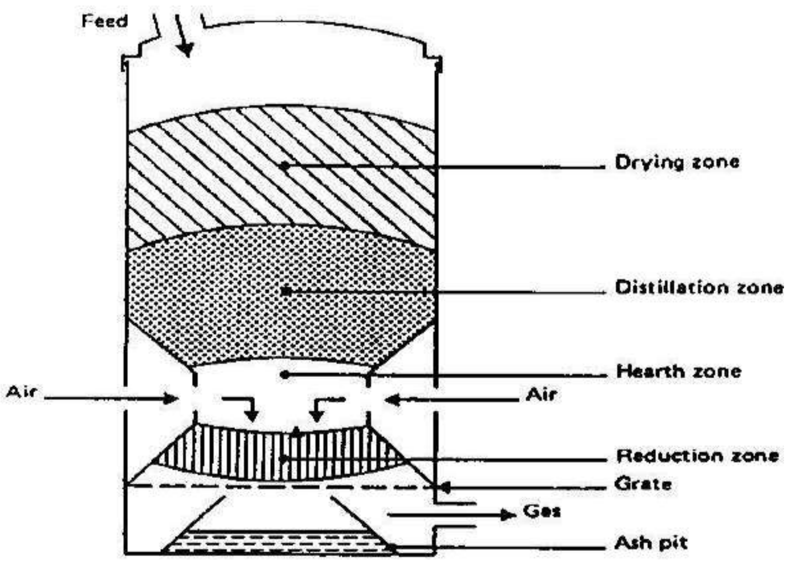


Fig: Downdraught or co-current gasifier

On their way down the acid and tarry distillation products from the fuel must pass through a glowing bed of charcoal and therefore are converted into permanent gases hydrogen, carbon dioxide, carbon monoxide and methane.

Depending on the temperature of the hot zone and the residence time of the tarry vapours, a more or less complete breakdown of the tars isachieved.

The main advantage of downdraught gasifiers lies in the possibility of producing a tar-free gas suitable for engine applications.

In practice, however, a tar-free gas is seldom if ever achieved over the whole operating range of the equipment: tar-free operating turn-down ratios of a factor 3 are considered standard; a factor 5-6 is considered excellent.

Because of the lower level of organic components in the condensate, downdraught gasifiers suffer less from environmental objections than updraughtgasifiers.

A major drawback of downdraught equipment lies in its inability to operate on a number of unprocessed fuels. In particular, fluffy, low density materials give rise to flow problems and excessive pressure drop, and the solid fuel must be pelletized or briquetted before use. Downdraught gasifiers also suffer from the problems associated with high ash content fuels (slagging) to a larger extent than updraughtgasifiers.

Minor drawbacks of the downdraught system, as compared to updraught, are somewhat lower efficiency resulting from the lack of internal heat exchange as well as the lower heating value of the gas. Besides this, the necessity to maintain uniform high temperatures over a given cross-sectional area makes impractical the use of downdraught gasifiers in a power range above about 350 kW (shaft power).

Cross-draught gasifier

Cross-draught gasifiers, schematically illustrated in Figure 2.9 are an adaptation for the use of charcoal. Charcoal gasification results in very high temperatures (1500 °C and higher) in the oxidation zone which can lead to material problems. In cross draught gasifiers insulation against these high temperatures is provided by the fuel (charcoal) itself.

Advantages of the system lie in the very small scale at which it can be operated. Installations below 10 kW (shaft power) can under certain conditions be economically feasible. The reason is the very simple gas-cleaning train (only a cyclone and a hot filter) which can be employed when using this type of gasifier in conjunction with small engines.

A disadvantage of cross-draught gasifiers is their minimal tar-converting capabilities and the consequent need for high quality (low volatile content) charcoal.

It is because of the uncertainty of charcoal quality that a number of charcoal gasifiers employ the downdraught principle, in order to maintain at least a minimal tar-cracking capability.

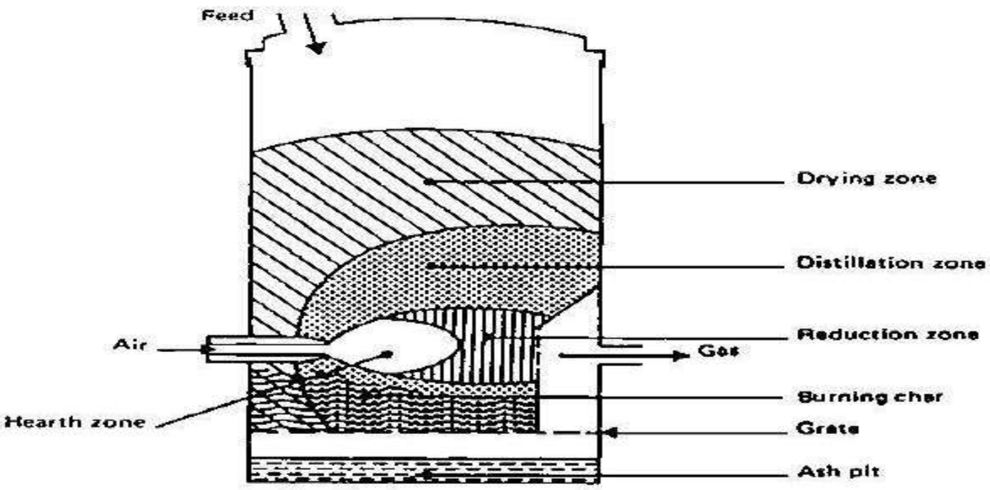


Fig:Cross draught gasifier

Fluidized bed gasifier

The operation of both up and downdraught gasifiers is influenced by the morphological, physical and chemical properties of the fuel. Problems commonly encountered are: lack of bunkerflow, slagging and extreme pressure drop over the gasifier

A design approach aiming at the removal of the above difficulties is the fluidized bed gasifier illustrated schematically in Fig

Air is blown through a bed of solid particles at a sufficient velocity to keep these in a state of suspension. The bed is originally externally heated and the feedstock is introduced as soon as a sufficiently high temperature is reached. The fuel particles are introduced at the bottom of the reactor, very quickly mixed with the bed material and almost instantaneously heated up to the bed temperature. As a result of this treatment the fuel is pyrolysed very fast, resulting in a component mix with a relatively large amount of gaseous materials. Further gasification and tar-conversion reactions occur in the gas phase. Most systems are equipped with an internal cyclone in order to minimize char blow-out as much as possible. Ash particles are also carried over the top of the reactor and have to be removed from the gas stream if the gas is used in engine applications.

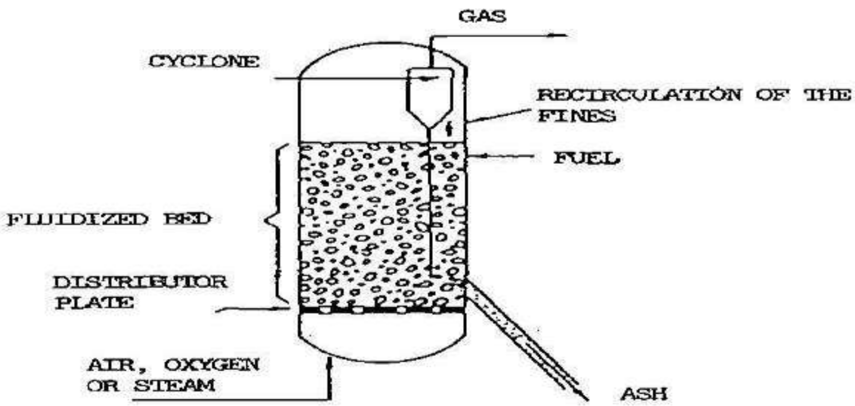


Fig ;Fluidized bed gasifier

The major advantages of fluidized bed gasifiers, as reported by Van der Aarsen (44) and others, stem from their feedstock flexibility resulting from easy control of temperature, which can be kept below the melting or fusion point of the ash (rice husks), and their ability to deal with fluffy and fine grained materials (sawdust etc.) without the need of pre-processing. Problems with feeding, instability of the bed and fly-ash sintering in the gas channels can occur with some biomass fuels.

Other drawbacks of the fluidized bed gasifier lie in the rather high tar content of the product gas (up to 500 mg/m³ gas), the incomplete carbon burn-out, and poor response to load changes.

Particularly because of the control equipment needed to cater for the latter difficulty, very small fluidized bed gasifiers are not foreseen and the application range must be tentatively set at above 500 kW (shaft power).

5.7 Ocean Thermal Energy

Principle of OTEC

Ocean Thermal Energy '(OTE) has its main source in the oceans, which in turn is originated from the sun. Absorption of solar energy at the surface of the ocean creates a relatively warm layer of water (27 to 29°C) that remains above the colder (4 to 7°C), more dense water layer in the lower depths of the ocean. Rotation of the earth causes the cold water coming from the direction of the poles to flow slowly along the ocean b~se towards the tropics. In the tropical region, the cold water density decreases. The water warmed in this manner, flows at the surface in another current toward the polar regions. The cycle is *i* repeated as the water cools and starts a return trip towards the tropics. These broad currents of water carry great amounts of thermal energy. The temperature difference between the , two streams is of the order of 20 to 25°C, which is an attractive and potential source for the generation of electric power. This thermal energy is used for running a turbine (using open or closed cycle) and generate electric energy.

These broad currents of water carry great amounts of thermal energy and represent potential sources *of* electric power. The feasibility of converting ocean thermal energy into electrical energy is dependent upon the existence of two broad currents of water, one warm and the other cold, flowing in close proximity to each other. There are numerous such locations near tropical waters, such as Caribbean sea and the gulf stream

OTE Power Plant Development

In 1882,D'Arsonval suggested that it is possible generate power based on the ocean thermal energy, by utilising the energy in the warm surface water of the ocean and rejecting heat to the colder water of the lower layer.

The first attempt to utilize the GTE was made in 1926 by G. Claude, a French scientist. He construded a 40 kW land-based GTEC power plant near Cuba. In his plant, a part of the warm surface water was converted into steam in a low-pressure flash evaporator operating at a high vacuum. In tfie flash evaporating process, sensible (heat) energy in the water gets converted into latent energy. The steam produced in the evaporator was expanded in a turbine and subsequently condensed by direct contact with the cold sea water piped from the lower layer in the ocean. .

However, Claude's system to utilize the GTE for power generation was not successful, mainly due to reasons like corrosive nature of the sea water (corrosion resistance materials were expensive), the pressure was low as water was evaporated at low temperature, high pumping work required for operations, requirement of very large turbine, and conveying the cold sea-water to the power plant over a long distqnce.

Thus, Claude's experiment demonstrated that the GTE power plant will inherently require large components, have a relatively low -power output, and operate at a high vacuum when the working fluid is water.

Problems Encountered in Harnessing OTEC

1) The sea water is more corrosive, thus the life of the plant is less.
2) The water can be evaporated (in a flash evaporator) at low temperatures only, thus the corresponding pressure is low, thus only smaller outputs are possible.
3) Much pumping work is required to remove the non- condensable gases.
4) The specific volume is more due to low pressure and temperature. This necessitates a large turbine.
5) The plants have to be based at lands, some distance away from the GTE source. This requires long pipelines to convey cold sea water to the power plant. 6) Due to low output and large components the cost of the GTE power plant is high. 7) The plant requires expensive and large size structures for installation and operation.generator to generate electric energy. In this fashion, ocean thermal energy is converted into electric energy in open OTEC system.

5.8 Geo-thermaI Energy

Geothermal energy is the thermal energy stored in under ground deposits as steam, hot water and hot dry rock. The inner core of the earth is highly radioactive, and as a consequence a natural flow of heat occurs from the core to t~e surface of earth, which can be harnessed into useful energy.

Geothermal energy is normally found in two basic forms, namely, in subterranean hot water or hot dry rock. In some locations, the vapour phase of the hot water is predominant, hence the geothermal energy source is described as steam. Where the hot water is entirely in the liquid phase, the term geo-hydrothermal or geo~pressurized, is applied. .

Utilization of Geothermal Energy (GTE)

Among the nonconventional energy sources, today the utilization of GTE is being investigated through a number of research and ~evelopment programs. Like the solar and wind energy, GTE is quantitatively significant, but the extraction of this energy from the ground and subsequent conversion to electrical energy is not cost free and not without certain operating problems. But, geothermal energy generation is not subject to interruptions that are inherent in solar and wind power generation. The Geothermal power plant is capable of continuous operation, provided that the generating capability properly matches the energy supply.

IAt the Geysers, the turbines operate with inlet steam pressures of 450 and 690 kPa. IBoiler

There are many locations in the world where geothermal steam and water (hot) are utlized for heating buildings. Even it can be used for industrial processing.

Geothermal Power Plant Operation - General Discussions

The geothermal power plant operates on a simple, low-pressure steam power cycle.

and fuel handling' equipment are not required. Also, since there is no need to lconserve the condensate, a direct~contact condenser can be used

The geothermal steam discharged from a well contains a quantity of non-condensable gases that can cause operating difficulties, including corrosion in the condensing system. These gases are removed from the steam in the condenser by the vacuum pump, usually a steam jet ejector, and expelled into the atmosphere.

Most of the wells drilled for geothermal power production dischMge a mixture of steam and water. If the hydrostatic pressure is sufficiently high at the bottom of the well, the water will flow, unaided to the surface. Hot water rising in the well and subjected to reduced pressure, partially flashes into vapour. At the well head the water is mechanically removed from the mixture in cyclone separators, and the relatively dry steam is transported to the power station.

The steam and water mixture flowing from the geothermal wells contains dissolved solids that are particularly trouble some. It ranges from 1 to 20 gm per kg of water. In addition to the dissolved solids some wells may give out the mixture containing some acids. In general, the dissolved solids and acids in geothermal water cause scaling anp corrosion. Scale formation can be particularly severe in the outflow pipeline in which the discarded water is carried away from the separator.

Geothermal power production cause air and water pollution in operation. Ear splitting noise caused by escaping steam and the escape of radioactive gases are other objectionable characteristics that have been observed.

Advantages & Disadvantages of GTE

Advantages

1) GTE is available free of cost, in large quantities.
2) There are no interruptions in GTE conversion as in solar and wind energy conversions.

3) It is capable of continuous operation. ,

4) Boiler and Fuel handling equipment are not required.

5) There is no need to conserve the condensate, thus a direct contact condensate can be used.

6) Operation and maintenance costs are less.

Dis.advantages

1) Such plants will always be located far away from the load centres.

2) Erection and installation costs are high.

3) It causes air, water, thermal and noise pollution. Ear-splitting noise caused by the escaping steam causes noise pollution.

4) The hot water geothermal sources have higher mineral contents and their disposal is a probl~m. .'

5) Seismic activities are caused, if water is injected into hot rocks to recover the thermal energy.

SOURCES OF GEOTHERMAL ENERGY

The various sources of geothermal energy are as follows

1) *Hydrothermal systems:* In these, water is heated by contact with hot-rock in the earth's crust. The temperature of the steam raised by this is in the range of 150 to 200°C.

2) *Geopressure system:* These .sources are similar to hydrothermal systems, and are reservoirs of high temperature water under high pressures (50 to 100 MPa).

3) *Hot dry rocks (HDR):* Also termed *petrothermal systems,* are very hot solid rocks available in the earth's crust at medium depths (2 to 5 km). The temperature is of the order of 300°C. .

4) *Magma source:* These are molten rocks with temperature much above 750°C, available in deep earth's crust.

Presently, the hydrothermal systems and hot dry rocks are more feasible for geothermal energy harnessing.

Hydrothermal Systems

In these, water is heated by contact with hot-rock in the earth's crust. These are two types of hydrothermal systems: .

a) *Steam dominated systems*

In this type of geothermal system, water is vaporised into steam at the lower level in the earth's crust. The steam rises to the earths surface in a dry state (about 200°C and more than 2 MPa pressure). This dry steam can be used conveniently and directly to run steam turbines and generate electric power. The schematic of such a system is illustrated

b) Water dominated systems

In this type of geothermal system, hot water slightly above l50°C under high pressure available under the earth's crust is utilised. Since the water is under pressure, it does not boil even above 100°C. When trapped by wells, the water rises to the surface and looses

(5) *Subsidence*

The removal of huge quantities of underground water causes land subsidence (collapse of ground layers, and *iallln .tb2.f}IOJ.JDO~). Subsidence* causes stre~C\f,

pij:>effnes and *~joJhe...w~ e#~ccm 6e* great(y reduced

6y reinjection of *the used* water. **(6) *Seismic Activity***

It is also possible that earth quakes may take place, if continuous underground water exploitation is done. One cause could be the large underground land subsidence. Even the reinjection of used water may cause seismic activity due to high temperature difference.

(7) *Fog due to escaping steam*

The entry of steam from the cooling towers, separators into the environment may lead to the formation of dense fog which many drift to the nearby busy living areas and cause problems. Also the temperature of the environment may increase leading to thermal pollution and cause discomfort in the surrounding areas due to increases in humidity.

(8) *Sand &other solid particles*

The high pressure water from the geothermal system usually carries sand and other solid particles. These cause separation problem, erosion and scaling problems in the equipments. This causes a lot of maintenance problems for the plant and loss of efficiency.

then extracted by circulating water to produce steam and then run turbines

Problems in Geothermal Conversion Systems

To generate the power the heat energy of the magma has to be tapped by drilling holes close to the magma chamber, where the temperature is around 1800°C. The energy There are a number problems associated with the operation of geothermal systems. Some of the major problems are discussed here.

(1) *Solid particles and non-condensable Gases*

The steam/water from hydrothermal reservoirs contain solid particles and non: condensable gases. The solid particles ar~ removed using centrifugal separators at the well exit and by strainers before the turbine entry. This leads to pressure and temperature loss and hence loss of the thermal efficiency of the complete system.

The main non-condensable gases in the geothermal sources are COz (70 to 80%) and small amounts of methane, Hz, Nz, NH3 and HzS. These gases along with the fluid enter equipments and also escape to the atmosphere through condenser, ejectors and cooling towers. These gases in the equipments cause corrosion and scaling problems. The gases, particularly HzS (a poisonous gas), are also harmful to the living beings.

(2) *Discharge of Used Water*

Discharging large quantities of used water from the geothermal systems to rivers and seas will cause water pollution (both thermal and chemical). This may make the water toxic and becomes hazardous to the animals and users. A possible solution to this problem is to reinject the used water into the well so that land subsidence can be minimised and also avoid environmental pollution.

(3) *Noise Pollution*

In geothermal systems noise pollution is also a major problem. Exhaust~, blow down and centrifugal separators work always with high noise, which is hazardous to the working people. The noise can be minimised by using silencers and its effect on working people can be reduced by using noise protective devices.

4) *Atmospheric Pollution*

The harmful gases in the geothermal water after use will escape (from the cooling tower, separator, etc.) and cause atmospheric pollution. Hydrogen sulphide (HzS) is highly toxic and harmful to the living beings.

Air pollution is severe due to the emission of heavy radioactive gases and hydrogen sulphide gas from the wells. Due to its poor steam condition, geothermal plant discharges. more thermal energy into environment (3 times that of a conventional thermal plant) causing thermal pollution. The stearn-water from well brings many corrosive substances which when mixed with atmospheric water, cause water pollution.

5.9Summary

Tidal turbines are a new technology that can be used in many tidal areas. They are basically wind turbines that can be located anywhere there is strong tidal flow. Because water is about 800 times denser than air, tidal turbines will have to be much sturdier than wind turbines. They will be heavier and more expensive to build but will be able to capture more energy.

5.10 Question bank

1. With the sketch Explain the open cycle OTEC system
2. Enlist the different geothermal resources
3. With the help of a sketch explain the “Hot dry Rock” geothermal plant
4. List any six advantages and disadvantages of Geothermal Energy