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..

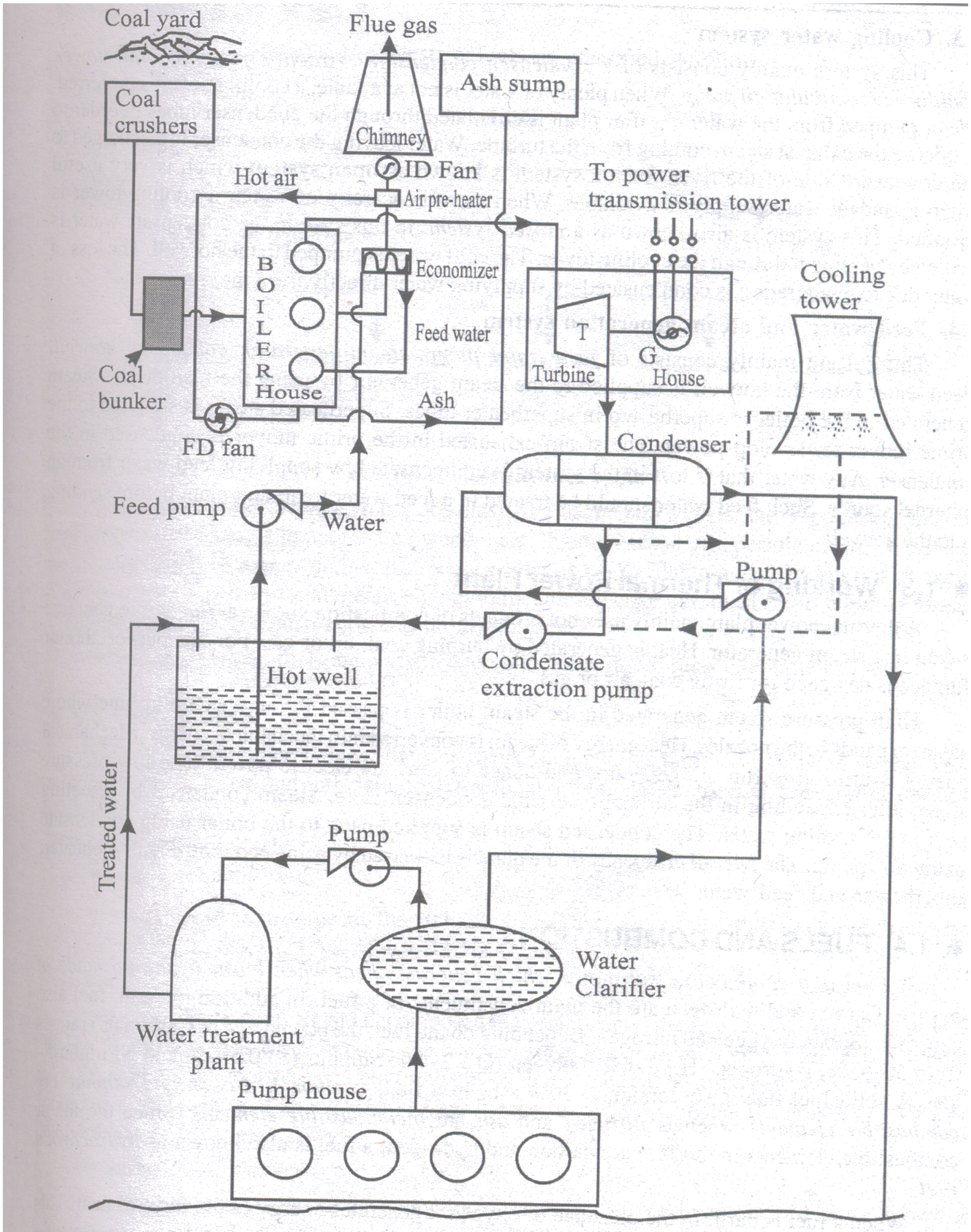


Fig 1.1 : General layout of a steam power plant

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:

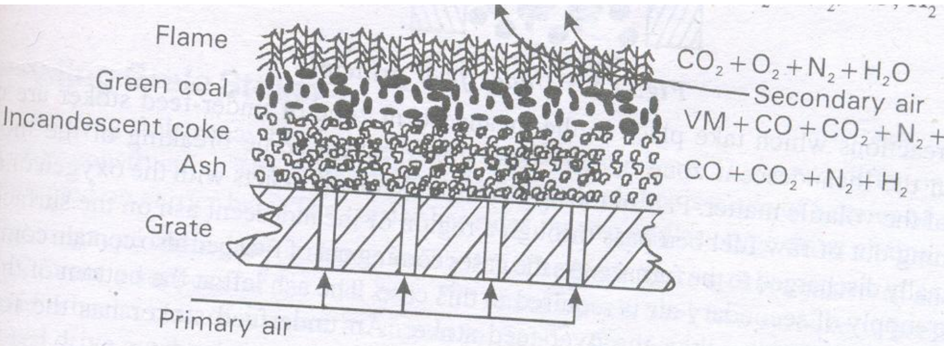


Fig 1.4 : Over feed stoker principle

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

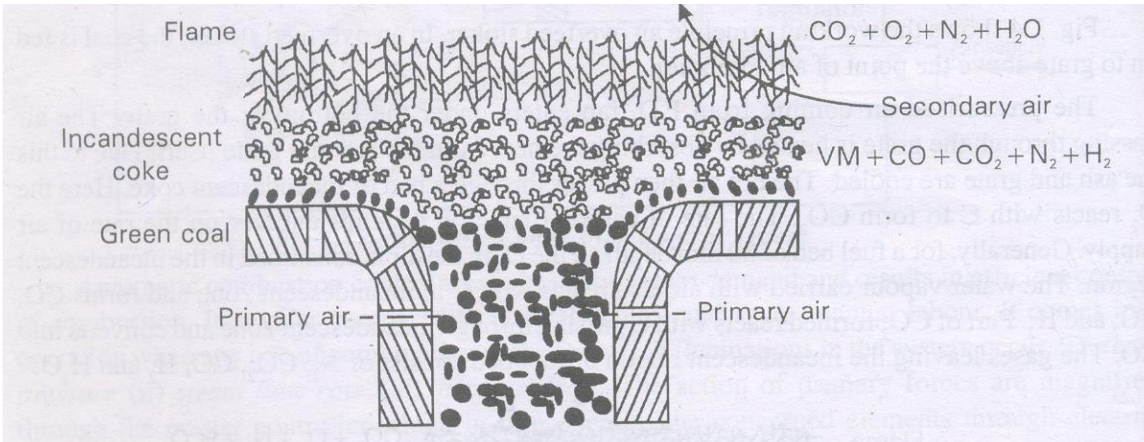


Fig. 1.5 : Under feed principle

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:

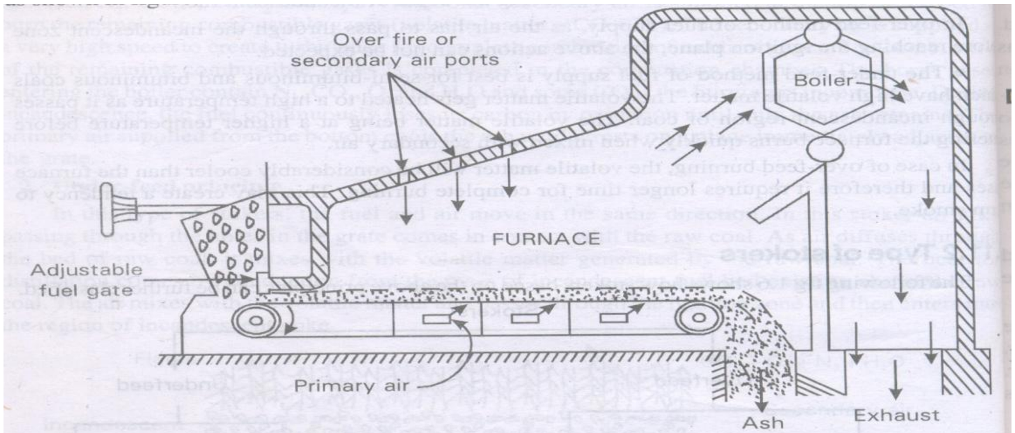


Fig. 1.7 : Chain Grate Stoker

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)*

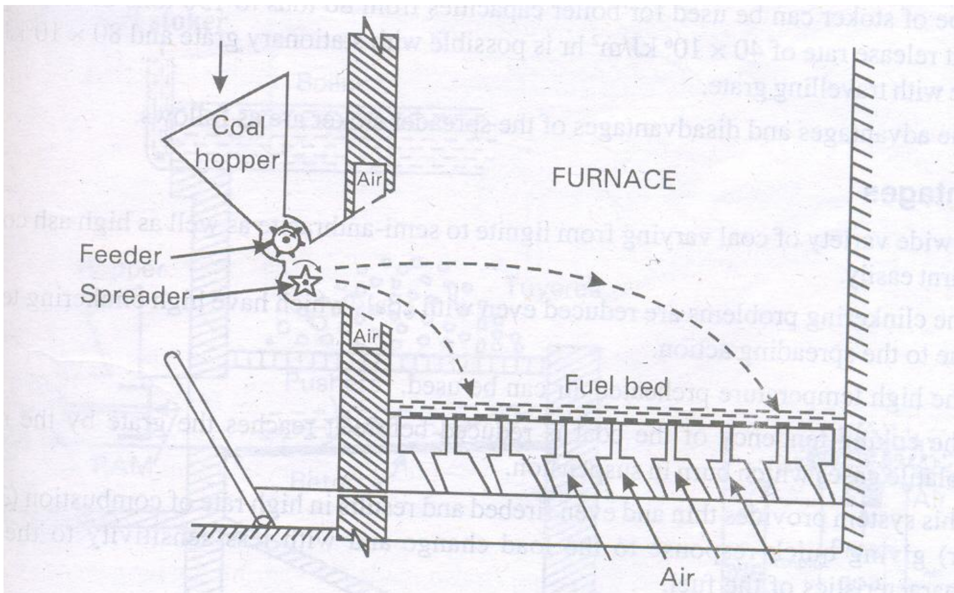


Fig. 1.8 : Spreader stoker

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

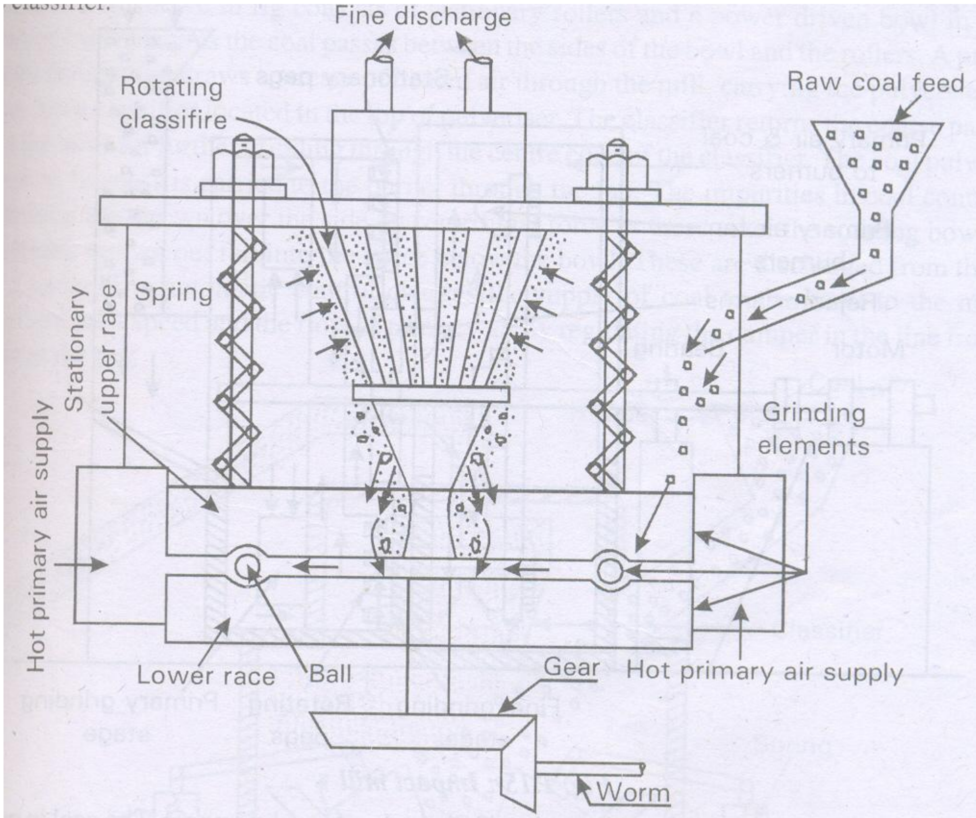


Fig. 1.14 : Ball and race mill

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

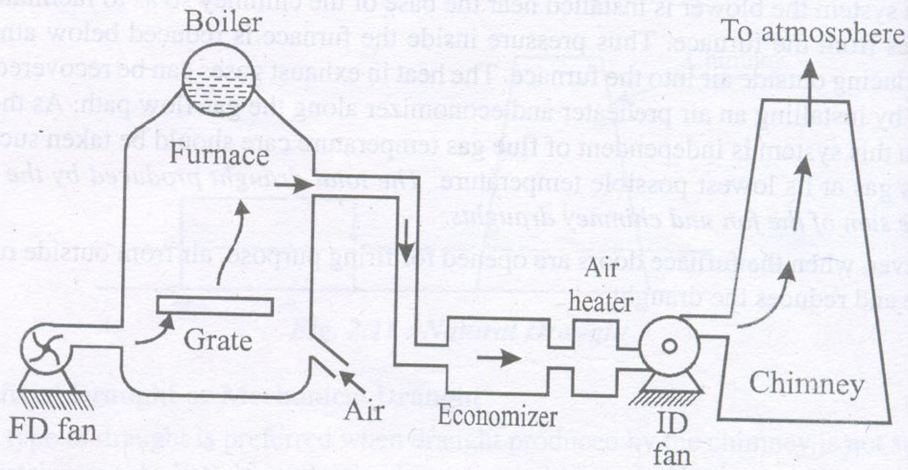


Fig. 2.14 : Balanced draught

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.

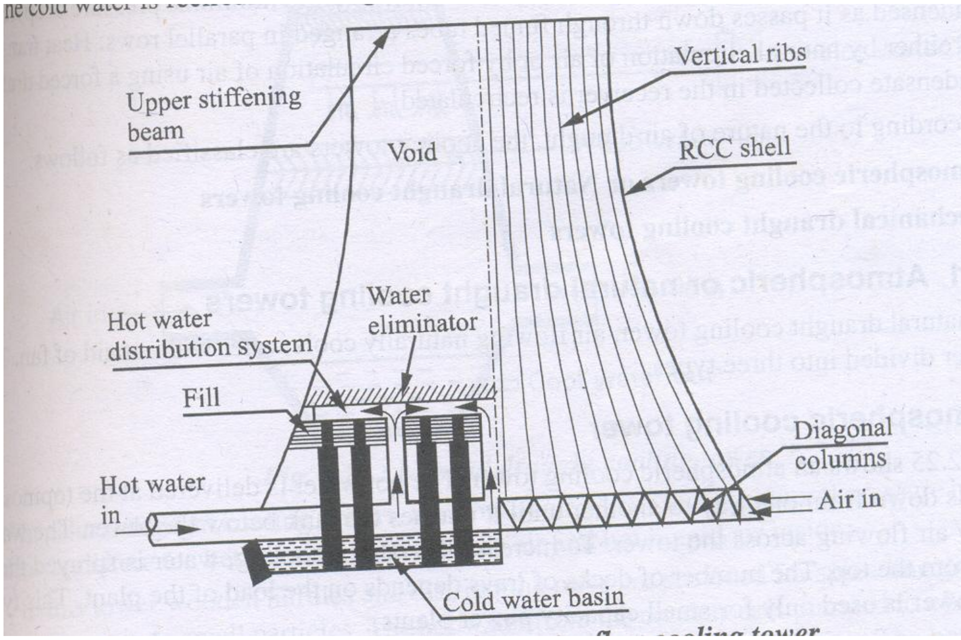
Theuse of this towedslavorable over mechanical towers in terms of saving in fan power,

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

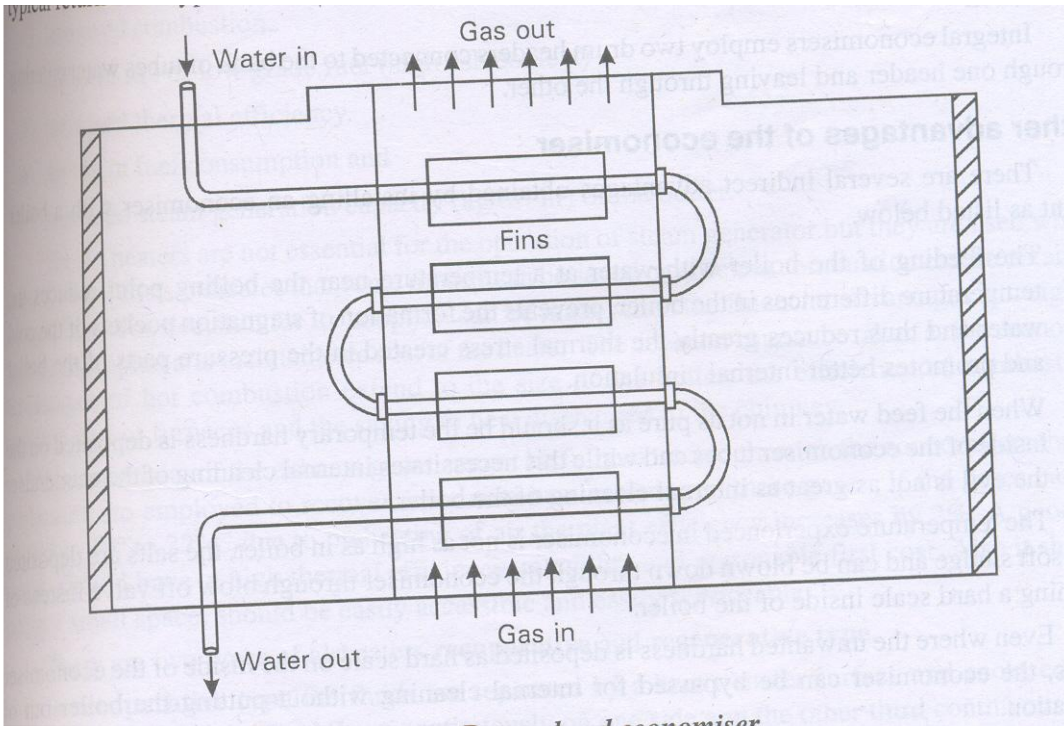
1. Ituses large volume of air with large surface areas due to low heat transfer co-efficient

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.

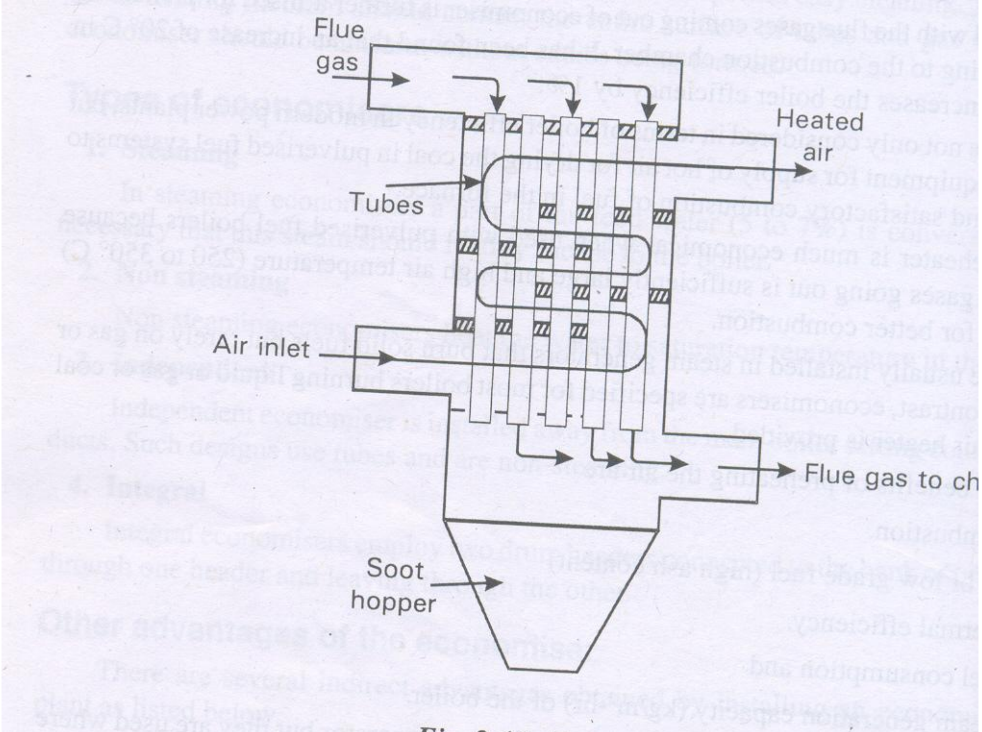
2)Itisexpensivein terms of maintenance and regular cleaning.

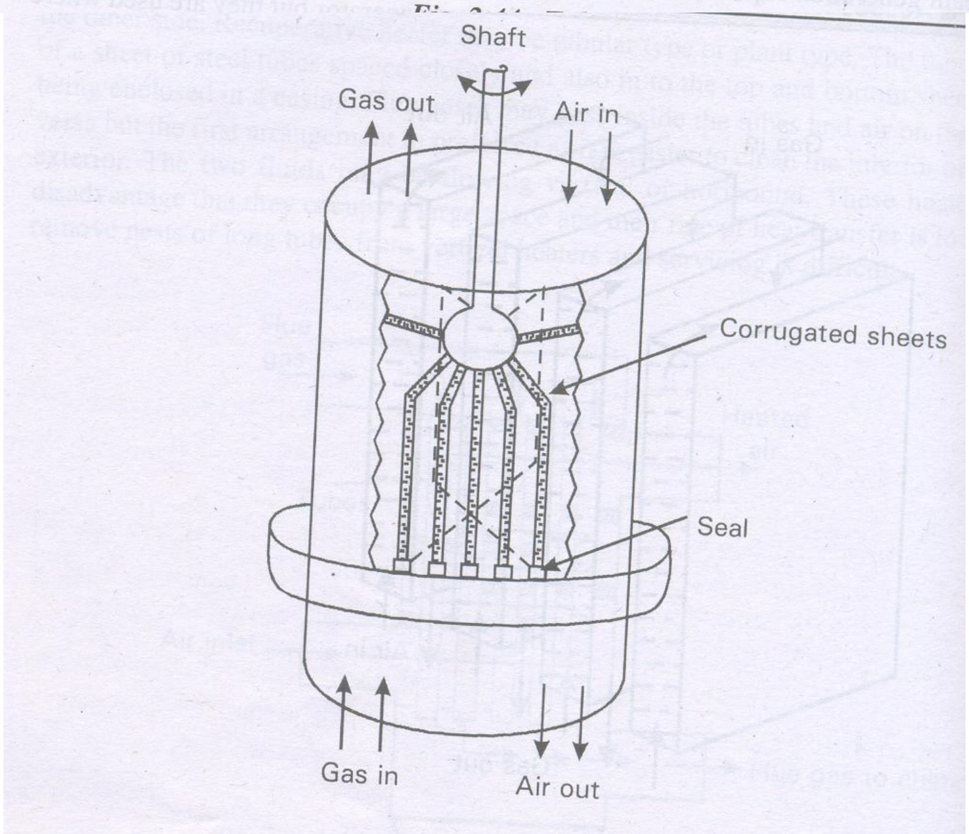
3)Itusesextrafloor space in the boiler. a simplified view of a return bend economizer. It consists of a seriesofsteeltubesthroughwhich the feed water flows.

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