IV B.Tech II Semester

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16MEC421 POWER PLANT ENGINEERING

Course Educational Objectives:

CEO1: Describe the basic principles of steam power plant and combustion process.

CEO2: Demonstrate the nuclear power station and types of reactors

CEO3: Apply the principles of internal combustion engine plant, gas turbine plant and direct energy conversion.

CEO4: Analyze the gas turbine power plant, Renewable Energy Sources plants and power energy sources

CEO5: Apply the power plant economics and environmental considerations

UNIT – 1: STEAM POWER PLANT

Introduction to the sources of energy – Resources and development of power in India. **Steam Power Plant**: Plant layout – Working of different circuits – Types of coal – Properties of coal – Coal handling system – Ash handling system – Feed water treatment. **Combustion Process**: Stages of combustion – Overfeed and underfeed stoker firing – Stoker firing of coal – Pulverized coal firing system – Cyclone furnace – Fluidized bed combustion system – Cooling towers and heat rejection.

UNIT – 2: NUCLEAR POWER PLANT

Layout and subsystems – Fuels and nuclear reactions – Pressurized water reactor (PWR) – Boiling water reactor (BWR) – Gas cooled and liquid metal fast breeder reactor – Heavy water reactor – Working and comparison – Safety measures.

UNIT – 3: DIESEL AND HYDROELECTRIC POWER PLANT

Diesel Power Plant: Introduction – IC Engines, types, construction – Plant layout with auxiliaries – Fuel supply system, air starting equipment, lubrication and cooling system – Super charging. **Hydroelectric Power Plant**: Water power – Hydrological cycle – Hydrographs – Storage and pondage – Classification of dams and spill ways – Classification of hydroelectric plant – Pumped storage power plants – Typical layout and associated components – Selection of turbines.

UNIT – 4: GAS TURBINE POWER PLANT AND RENEWABLE ENERGY SOURCES

Gas Turbine Power Plant: Introduction – Classification – Construction – Layout with auxiliaries – Principles of working of closed and open cycle gas turbines – Combined cycle power plants and comparison. **Renewable Energy Sources:** Principle, construction and working of solar energy, utilization of solar energy and solar energy collectors – Wind energy – horizontal and vertical axis wind turbine (HAWT & VAWT) – Geo thermal – Tidal energy – Ocean thermal – Biogas – Fuel cell, thermoelectric and thermionic generation.

UNIT – 5: ENERGY MANAGEMENT, ECONOMICS AND ENVIRONMENTAL ISSUES

Power tariff types – Load distribution parameters – Load curve – Comparison of site selection criteria – Capital and operating cost of different power plants – Pollution control technologies including waste disposal options for coal and nuclear power plants.

Course Outcomes:

Course Outcomes		POs related to COs
CO1	Understand the concept of generation of power by using various types of fuels, layout of power plant, coal, fuel & ash handling	PO1, PO3
CO2	Acquire basic knowledge of different types of nuclear power plants, Reactors its operation advantages, disadvantage and application.	PO1, PO3
CO3	Understand of diesel power plants, construction, and fuel supply system and cooling systems its equipments and hydroelectric plants,	PO1, PO2,
CO4	Understand of gas turbine power plants, construction, and classified different types of layouts and Renewable Energy Sources power	PO1, PO2,PO3
CO5	Developed Capital and operating cost of different power plants and Pollution control technologies.	PO1,PO3.PO7

Text books:

1. Power Plant Engineering, P.K.Nag, 4/e, 2015, McGraw-Hill Education Pvt. Ltd., New Delhi.
2. A Course in Power Plant Engineering, Arora and S. Domkundwar, 6/e, 2012, Dhanpat Rai Publishing Company (P) Ltd., New Delhi.

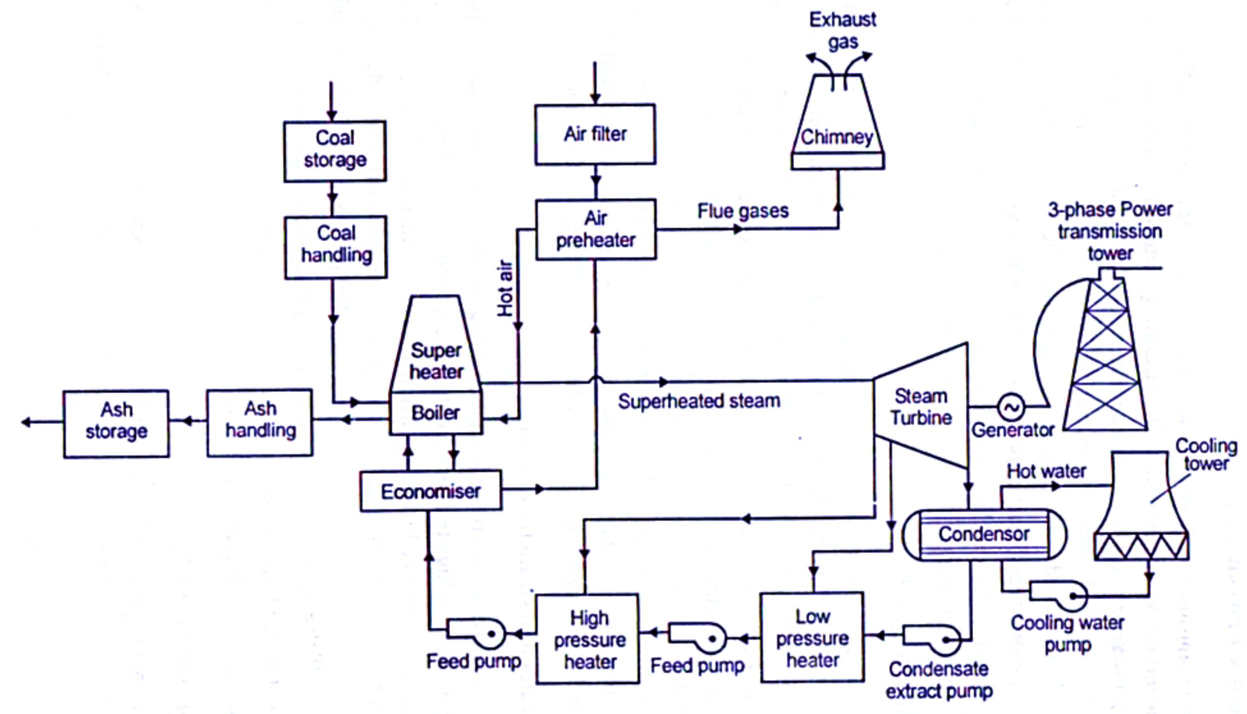
Reference books:

1. Powerplant Technology, Mohamed Mohamed El-Wakil, 2010, Tata McGraw-Hill, New Delhi.
2. A Text Book of Power Plant Engineering, R.K.Rajput, 4/e, 2012, Laxmi Publications (P) Ltd., New Delhi.
3. Power Plant Engineering, K.K.Ramalingam, 1/e, 2010, Scitech Publishers, Chennai.
4. Power Plant Engineering, Nagpal G. R, n/e, 2004, Khanna Publisher, New Delhi.
5. Introduction to Power Plant Technology, G.D.Rai, 3/e, 2012, Khanna Publishers, New Delhi.

STEAM POWER PLANTS

A thermal power station is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated; this is known as a **Rankine cycle**. The greatest variation in the design of thermal power stations is due to the different fuel sources. Some prefer to use the term *energy center* because such facilities convert forms of heat energy into electricity. Some thermal power plants also deliver heat energy for industrial purposes, for district heating, or for desalination of water as well as delivering electrical power. A large proportion of CO_2 is produced by the worlds fossil fired thermal power plants; efforts to reduce these outputs are various and widespread.

LAYOUT OF STEAM POWER PLANT:



The four main circuits one would come across in any thermal power plant layout are

- Coal and Ash Circuit
- Air and Gas Circuit
- Feed Water and Steam Circuit
- Cooling Water Circuit

Coal and Ash Circuit

Coal and Ash circuit in a thermal power plant layout mainly takes care of feeding the boiler with coal from the storage for combustion. The ash that is generated during combustion is collected at the back of the boiler and removed to the ash storage by scrap conveyors. The combustion in the Coal and Ash circuit is controlled by regulating the speed and the quality of coal entering the grate and the damper openings.

Air and Gas Circuit
Air from the atmosphere is directed into the furnace through the air preheated by the action of a forced draught fan or induced draught fan. The dust from the air is removed before it enters the combustion chamber of the thermal power plant layout. The exhaust gases from the combustion heat the air, which goes through a heat exchanger and is finally let off into the environment.
Feed Water and Steam Circuit
The steam produced in the boiler is supplied to the turbines to generate power. The steam that is expelled by the prime mover in the thermal power plant layout is then condensed in a condenser for re-use in the boiler. The condensed water is forced through a pump into the feed water heaters where it is heated using the steam from different points in the turbine. To make up for the lost steam and water while passing through the various components of the thermal power plant layout, feed water is supplied through external sources. Feed water is purified in a purifying plant to reduce the dissolve salts that could scale the boiler tubes.
Cooling Water Circuit
The quantity of cooling water required to cool the steam in a thermal power plant layout is significantly high and hence it is supplied from a natural water source like a lake or a river. After passing through screens that remove particles that can plug the condenser tubes in a thermal power plant layout, it is passed through the condenser where the steam is condensed. The water is finally discharged back into the water source after cooling. Cooling water circuit can also be a closed system where the cooled water is sent through cooling towers for re-use in the power plant. The cooling water circulation in the condenser of a thermal power plant layout helps in maintaining a low pressure in the condenser all throughout.
All these circuits are integrated to form a thermal power plant layout that generates electricity to meet our needs.

Advantages

- Generation of power is continuous.
- Initial cost low compared to hydel plant.
- Less space required.
- This can be located near the load centre so that the transmission losses are reduced.
- It can respond to rapidly changing loads.

Disadvantages

- Long time required for installation.
- Transportation and handling of fuels major difficulty.
- Efficiency of plant is less.
- Power generation cost is high compared to hydel power plant.
- Maintenance cost is high.

Types of coal
Coal is a non-renewable resource which is being used by humans as their primary source of energy for industrial needs and generation of electricity. Though coal is rarely used nowadays in industries, it still forms a major part(about 37%) of producing electricity.

1. Coal is essentially carbon, a blackish mass which is being used for powering our homes, though the rate of renewal is slim.
2. Coal is formed from decaying matter under the action of high pressure and temperature under the surface of Earth, which took millions of years.
3. Though coal is made of carbon, other elements such as hydrogen, oxygen, nitrogen and sulphur do form some parts.
4. Capacity of coal to give energy depends upon the percentage of carbon content.
5. So older the coal, more is its carbon content.

- Coal quality can be ascertained from the % of carbon content it has.
- Good coal will have greater carbon content, greater calorific value and less to minimum moisture & dust.
- The coal is primarily divided into four components, yet humans use six of their variants:-
  - Peat
  - Lignite
  - Bituminous
  - Steam coal
  - Anthracite
  - Graphite

Properties of coal

Peat

- Peat is the accumulation of partially decayed matter or vegetation, which can be found in peat mines.
- Peat is also a fossil fuel, so it is a non-renewable resource.
- It has the potential of becoming coal.
- Carbon content:- 40-55%
- Moisture:- 45%
- Calorific value:- 5430 kcal/hr
- Uses:- electricity generation
- It can also be used to absorb oil and fuel spills on land & water, when dry.

Lignite

- Formed from compressed peat, also called the brown coal.
- It is also the youngest geological coal
- It is low ranking and highly volatile
- Carbon content—40-55 %
- Moisture- 35%
- Calorific value- 6300kcal/hr
- Uses- Used primarily in power generation.

Bituminous

- It is the most abundantly form of coal available in the world.
- They are dense black sedimentary rocks, but can be light brown
- Carbon content- 40-80%
- Moisture- 15-40%
- Calorific value- 8000 kcal/Hr
- Uses- In power generation and for producing coke in steel industry

Steam coal

- It is the stepping stone between bituminous and anthracite
- Once used to power steam locomotives for pulling trains, the gradual decrease of steam coal also led to the decrease of steam coal.

Anthracite

- It has the highest rank of ignitable coal.
- It is hard, black and glossy
- Carbon content- 80-95%
- Moisture- 8-15%
- Calorific value- 8600kca;/hr
- Uses:- Residential and commercial place heating

Graphite

- Highest ranking coal
- Graphite is difficult to ignite
- Rarely used as a fuel
- Used mainly for pencils and a lubricant in powdered form.

Coal Handling Systems

Coal handling systems for coal fired boilers. Coal handling at utilities requires specialized technology and equipment from unloading to crushing and dust control to fire protection.

Coal from the coal wagons is unloaded by Tipplers in the coal handling plant. This coal is transported up to the coal storage bunkers through conveyor belts.

Coal is then transported to the Crush house by conveyor belts where it is crushed to small pieces and light dust is separated. The crushed coal is then transported to the bowl mill by coal feeders.

In the bowl mill, coal is grounded to a powder form. The mill consists of a round metallic table on which coal particles fall. The crushed coal is then taken to the Boiler through coal pipes with the help of hot and cold air mixture.

ASH HANDLING EQUIPMENT

Ash Handling means are required for the disposal of ash. The handling equipment should perform the following functions:

(1) Capital investment, operating and maintenance charges of the equipment should be low.
(2) It should be able to handle large quantities of ash.
(3) Clinkers, soot, dust etc. create troubles, the equipment should be able to handle them smoothly.
(4) The equipment used should remove the ash from the furnace, load it to the conveying system to deliver the ash to a dumping site or storage and finally it should have means to dispose of the stored ash.
(5) The equipment should be corrosion and wear resistant.

Fig. 4.33 shows a general layout of ash handling and dust collection system. The commonly used ash handling systems are as follows

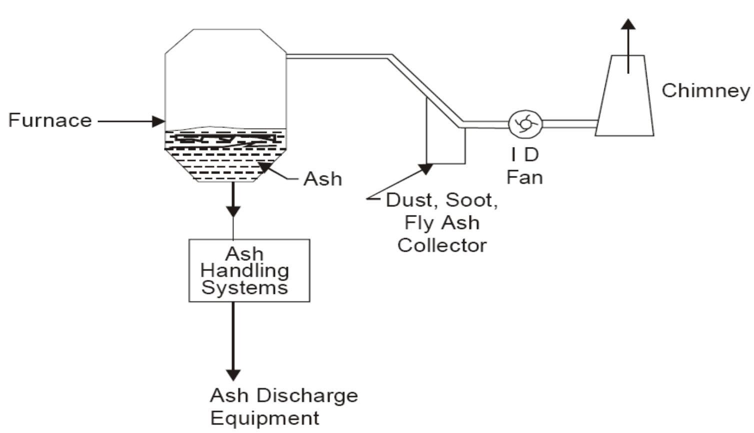


Fig. 4.33. Ash Handling and Dust Collections System.

(*i*) Hydraulic system
(*ii*) Pneumatic system
(*iii*) Mechanical system.
The commonly used ash discharge equipment is as follows:
(*i*) Rail road cars
(*ii*) Motor truck
(*iii*) Barge.
The various methods used for the disposal of ash are as follows :
(*I*) **Hydraulic System.** In this system, ash from the furnace grate falls into a system of water Possessing high velocity and is carried to the sumps. It is generally used in large power plants. Hydraulic system is of two types namely low pressure hydraulic system used for continuous removal of ash and high pressure system which is used for intermittent ash disposal. Fig. 4.34 shows hydraulic system.

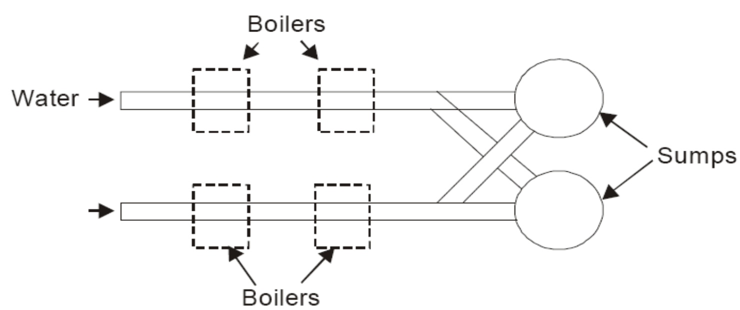


Fig. 4.34. Hydraulic System.

In this method water at sufficient pressure is used to take away the ash to sump. Where water and ash are separated. The ash is then transferred to the dump site in wagons, rail cars or trucks. The loading of ash may be through a belt conveyor, grab buckets. If there is an ash basement with ash hopper the ash can fall, directly in ash car or conveying system.

(ii) Water Jetting. Water jetting of ash is shown in Fig. 4.35. In this method a low pressure jet of water coming out of the quenching nozzle is used to cool the ash. The ash falls into a trough and is then removed.

(iii) Ash Sluice Ways and Ash Sump System. This system shown diagrammatically in Fig. 4.36 used high pressure (H.P) pump to supply high pressure (H.P.) water-jets which carry ash from the furnace bottom through ash sluices (channels) constructed in basement floor to ash sump fitted with screen. The screen divides the ash sump into compartments for coarse and fine ash. The fine ash passes through the screen and moves into the dust sump (D.S.). Dust slurry pump (D.S. pump) carries the dust through dust pump (D.P), suction pipe and dust delivery (D.D.) pipe to the disposal site. Overhead crane having grab bucket is used to remove coarse ash. A.F.N represents ash feeding nozzle and S.B.N. represents sub way booster nozzle and D.A. means draining apron.

(iv) Pneumatic system. In this system (Fig. 4.37) ash from the boiler furnace outlet falls into a crusher where larger ash particles are crushed to small sizes. The ash is then carried by a high velocity air or steam to the point of delivery. Air leaving the ash separator is passed through filter to remove dust etc. so that the exhauster handles clean air which will protect the blades of the exhauster.

(*v*) **Mechanical ash handling system.** Fig. 4.38 shows a mechanical ash handling system. In this system ash cooled by water seal falls on the belt conveyor and is carried out continuously to the bunker. The ash is then removed to the dumping site from the ash bunker with the help of trucks.

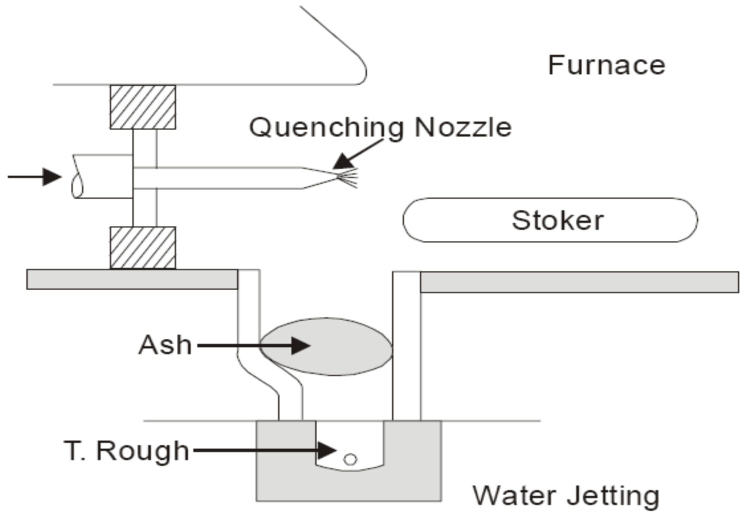


Fig. 4.35. Water Jetting of Ash.

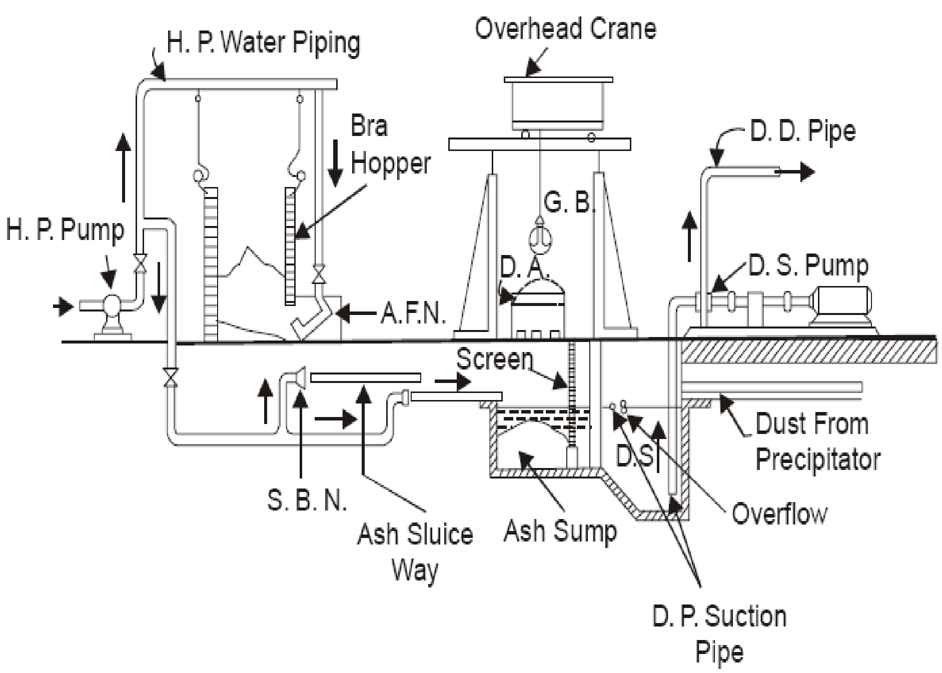
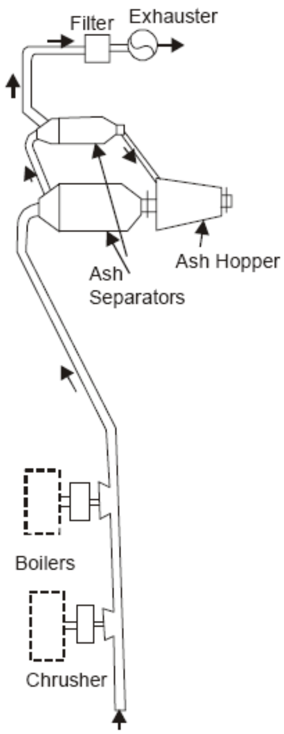


Fig. 4.36. Ash Sump System.



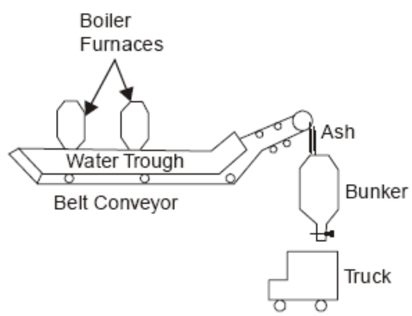


Fig. 4.37. Pneumatic System. **Fig. 4.38.** Mechanical Ash Handling.

METHOD OF FUEL FIRING

The solid fuels are fired into the furnace by the following methods:

1. Hand firing. 2. Mechanical firing.

HAND FIRING

This is a simple method of firing coal into the furnace. It requires no capital investment. It is used for smaller plants. This method of fuel firing is discontinuous process, and there is a limit to the size of furnace which can be efficiently fired by this method. Adjustments are to be made every time for the supply of air when fresh coal is fed into furnace.

Hand Fired Grates. A hand fired grate is used to support the fuel bed and admit air for combustion. While burning coal the total area of air openings varies from 30 to 50% of the total grate area. The grate area required for an installation depends upon various factors such as its heating surface, the rating at which it is to be operated and the type of fuel burnt by it. The width of air openings varies from 3 to 12 mm. The construction of the grate should be such that it is kept uniformly cool by incoming air. It should allow ash to pass freely. Hand fired grates are made up of cast iron. The various types of hand fired grates are shown in Fig. 4.10. In large furnaces vertical shaking grates of circular type are used.

In a hand fired furnace the fuel is periodically shovelled on to the fuel bed burning on the grate, and is heated up by the burning fuel and hot masonry of the furnace. The fuel dries, and then evolves gaseous matter (volatiles combustibles) which rise into the furnace space and mix with air and burn forming a flame. The fuel left on the grate gradually transforms into coke and burns-up. Ash remains on the grate which drops through it into ash pit from which it is removed at regular intervals. Hand fired furnaces are simple in design and can burn the fuel successfully but they have some disadvantages also mentioned below:

(*i*) The efficiency of a hand fired furnace is low.

(*ii*) Attending to furnace requires hard manual labour.

(*iii*) Study process of fuel feed is not maintained.

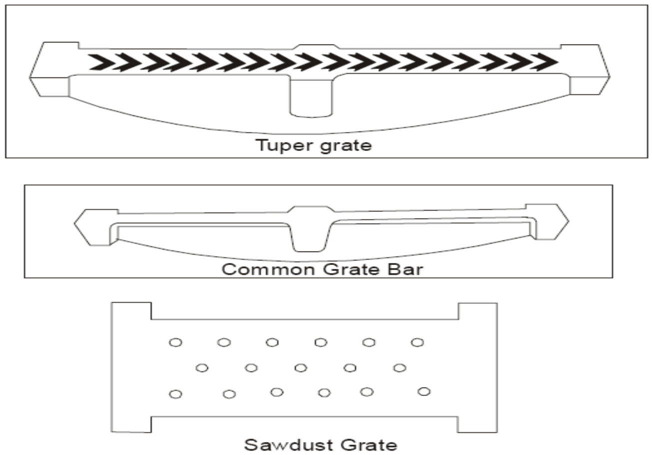


Fig. 4.10. Various Types of Hand Fired Grates.

MECHANICAL FIRING (STOKERS)

Mechanical stokers are commonly used to feed solid fuels into the furnace in medium and large size power plants.

The various advantages of stoker firing are as follows :

(*i*) Large quantities of fuel can be fed into the furnace. Thus greater combustion capacity is achieved.

(*ii*) Poorer grades of fuel can be burnt easily.

(*iii*) Stoker save labour of handling ash and are self-cleaning.

(*iv*) By using stokers better furnace conditions can be maintained by feeding coal at a uniform rate.

(*v*) Stokers save coal and increase the efficiency of coal firing. The main disadvantages of stokers are their more costs of operation and repairing resulting from high furnace temperatures.

Principles of Stokers. The working of various types of stokers is based on the following two principles:

1. Overfeed Principle. According to this principle (Fig. 4.13) the primary air enters the grate from the bottom. The air while moving through the grate openings gets heated up and air while moving through the grate openings gets heated up and the grates cooled.

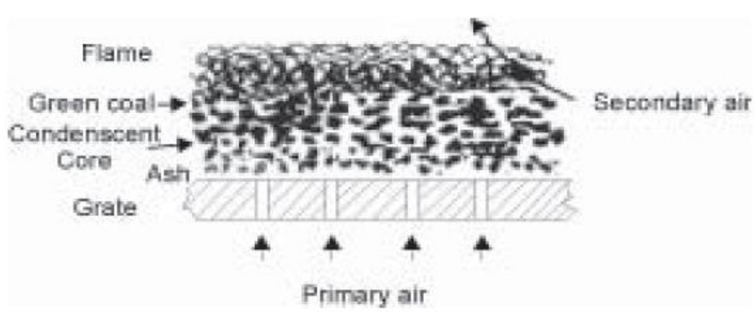


Fig. 4.13. Stokers

The hot air that moves through a layer of ash and picks up additional energy. The air then passes through a layer of incandescent coke where oxygen reacts with coke to form-C02 and water vapours accompanying the air react with incandescent coke to form CO_2, CO and free H_2. The gases leaving the surface of fuel bed contain volatile matter of raw fuel and gases like CO_2, CO, H_2, N_2 and H_2O. Then additional air known as secondary air is supplied to burn the combustible gases. The combustion gases entering the boiler consist of N_2, CO_2, O_2 and H_2O and also CO if the combustion is not complete.

2. Underfeed Principle. Fig. 4.14 shows underfeed principle. In underfeed principle air entering through the holes in the grate comes in contact with the raw coal (green coal).

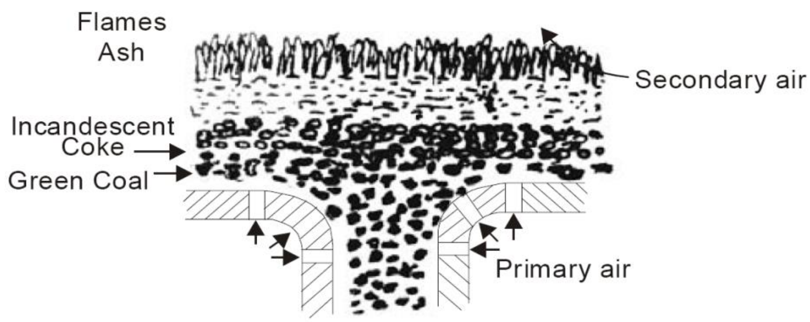


Fig. 4.14. Underfeed Principle.

Then it passes through the incandescent coke where reactions similar to overfeed system take place. The gases produced then passes through a layer of ash. The secondary air is supplied to burn the combustible gases. Underfeed principle is suitable for burning the semi-bituminous and bituminous coals.

Types of Stokers The various types of stokers are as follows:

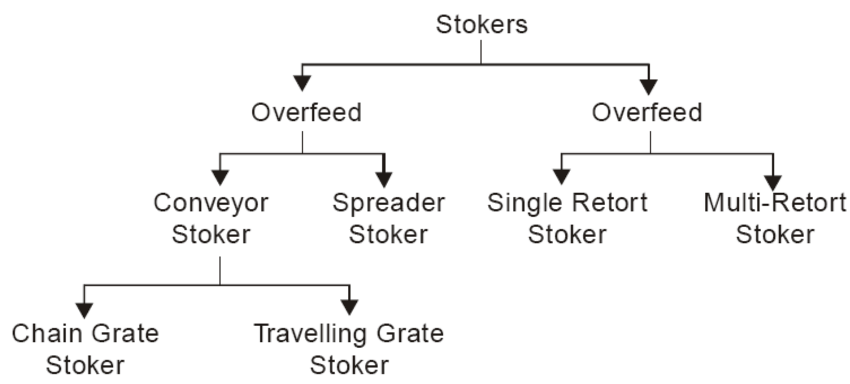


Fig. 4.15. Various Tyles of Stokers.

Charging of fuel into the furnace is mechanized by means of stokers of various types. They are installed above the fire doors underneath the bunkers which supply the fuel. The bunkers receive the fuel from a conveyor.

(*i*) **Chain Grate Stoker.** Chain grate stoker and traveling grate stoker differ only in grate construction. A chain grate stoker (Fig. 4.16) consists of an endless chain which forms a support for the fuel bed.

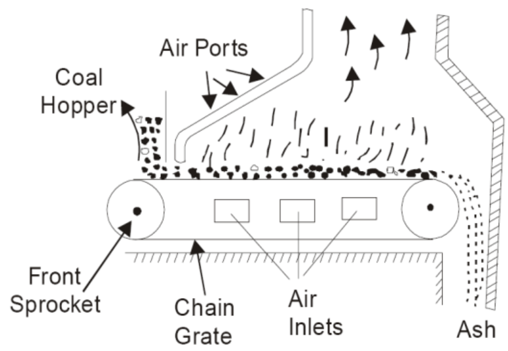


Fig. 4.16. Chain Grate Stoker.

The chain travels over two sprocket wheels, one at the front and one at the rear of furnace. The traveling chain receives coal at its front end through a hopper and carries it into the furnace. The ash is tipped from the rear end of chain. The speed of grate (chain) can be adjusted to suit the firing condition. The air required for combustion enters through the air inlets situated below the grate. Stokers are used for burning non-coking free burning high volatile high ash coals. Although initial cost of this stoker is high but operation and maintenance cost is low.

The traveling grate stoker also uses an endless chain but differs in that it carries small grate bars which actually support the fuel fed. It is used to burn lignite, very small sizes of anthracites coke breeze etc.

The stokers are suitable for low ratings because the fuel must be burnt before it reaches the rear of the furnace. With forced draught, rate of combustion is nearly 30 to 50 lb of coal per square foot of grate area per hour, for bituminous 20 to 35 pounds per square foot per hour for anthracite.

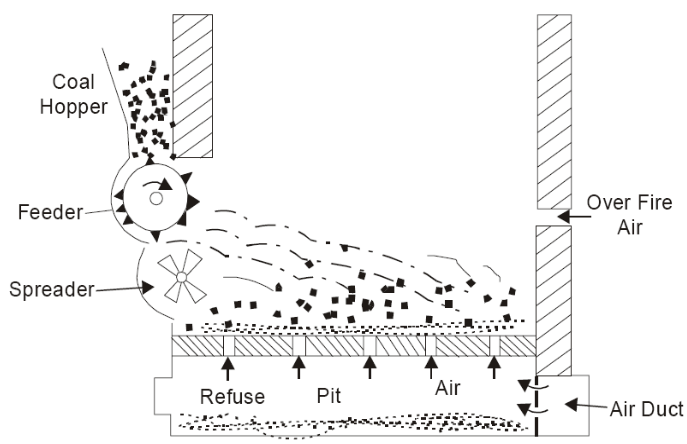


Fig. 4.17. Spreader Stoker.

(*ii*) **Spreader Stoker.** A spreader stoker is shown in Fig. 4.17. In this stoker the coal from the hopper is fed on to a feeder which measures the coal in accordance to the requirements. Feeder is a rotating drum fitted with blades. Feeders can be reciprocating rams, endless belts, spiral worms etc. From the feeder the coal drops on to spreader distributor which spread the coal over the furnace. The spreader system should distribute the coal evenly over the entire grate area. The spreader speed depends on the size of coal.

Advantages

The various advantages of spreader stoker are as follows :

1. Its operation cost is low.

2. A wide variety of coal can be burnt easily by this stoker.
3. A thin fuel bed on the grate is helpful in meeting the fluctuating loads.
4. Ash under the fire is cooled by the incoming air and this minimizes clinkering.
5. The fuel burns rapidly and there is little coking with coking fuels.

Disadvantages

1. The spreader does not work satisfactorily with varying size of coal.
2. In this stoker the coal burns in suspension and due to this fly ash is discharged with flue gases which requires an efficient dust collecting equipment.

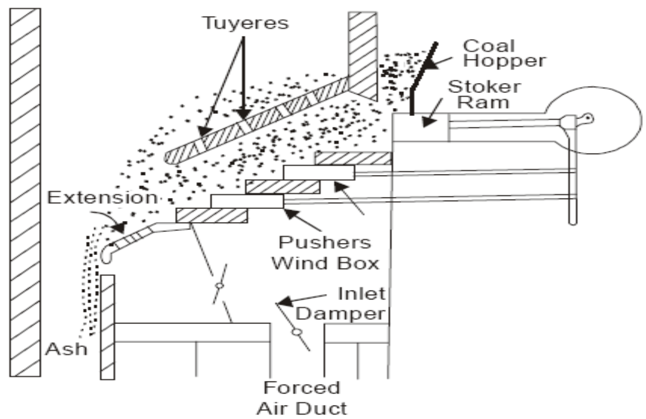


Fig. 4.18. Multi-retort Stoker.

(*iii*) **Multi-retort Stoker.** A multi-retort stoker is shown in Fig. 4.18. The coal falling from the hopper is pushed forward during the inward stroke of stoker ram. The distributing rams (pushers) then slowly move the entire coal bed down the length of stoker. The length of stroke of pushers can be varied as desired. The slope of stroke helps in moving the fuel bed and this fuel bed movement keeps it slightly agitated to break up clinker formation. The primary air enters the fuel bed from main wind box situated below the stoker. Partly burnt coal moves on to the extension grate. A thinner fuel bed on the extension grate requires lower air pressure under it. The air entering from the main wind box into the extension grate wind box is regulated by an air damper.

As sufficient amount of coal always remains on the grate, this stoker can be used under large boilers (upto 500,000 lb per hr capacity) to obtain high rates of combustion. Due to thick fuel bed the air supplied from the main wind box should be at higher pressure.

PULVERIZED COAL

Coal is pulverized (powdered) to increase its surface exposure thus permitting rapid combustion.
Efficient use of coal depends greatly on the combustion process employed.

For large scale generation of energy the efficient method of burning coal is confined still to pulverized coal combustion. The pulverized coal is obtained by grinding the raw coal in pulverising mills. The various pulverising mills used are as follows:

(*i*) Ball mill (*ii*) Hammer mill
(*iii*) Ball and race mill (*iv*) Bowl mill.

The essential functions of pulverising mills are as follows: (*i*) Drying of the coal (*ii*) Grinding (*iii*) Separation of particles of the desired size.

Proper drying of raw coal which may contain moisture is necessary for effective grinding.
The coal pulverising mills reduce coal to powder form by three actions as follows:
(*i*) Impact (*ii*) Attrition (abrasion) (*iii*) Crushing.

Most of the mills use all the above mentioned all the three actions in varying degrees. In impact type mills hammers break the coal into smaller pieces whereas in attrition type the coal pieces which rub against each other or metal surfaces to disintegrate. In crushing type mills coal caught between metal rolling surfaces gets broken into pieces. The crushing mills use steel balls in a container. These balls act as crushing elements.

(i) BALL MILL

A line diagram of ball mill using two classifiers is shown in Fig. 4.21. It consists of a slowly rotating drum which is partly filled with steel balls. Raw coal from feeders is supplied to the classifiers from where it moves to the drum by means of a screw conveyor.

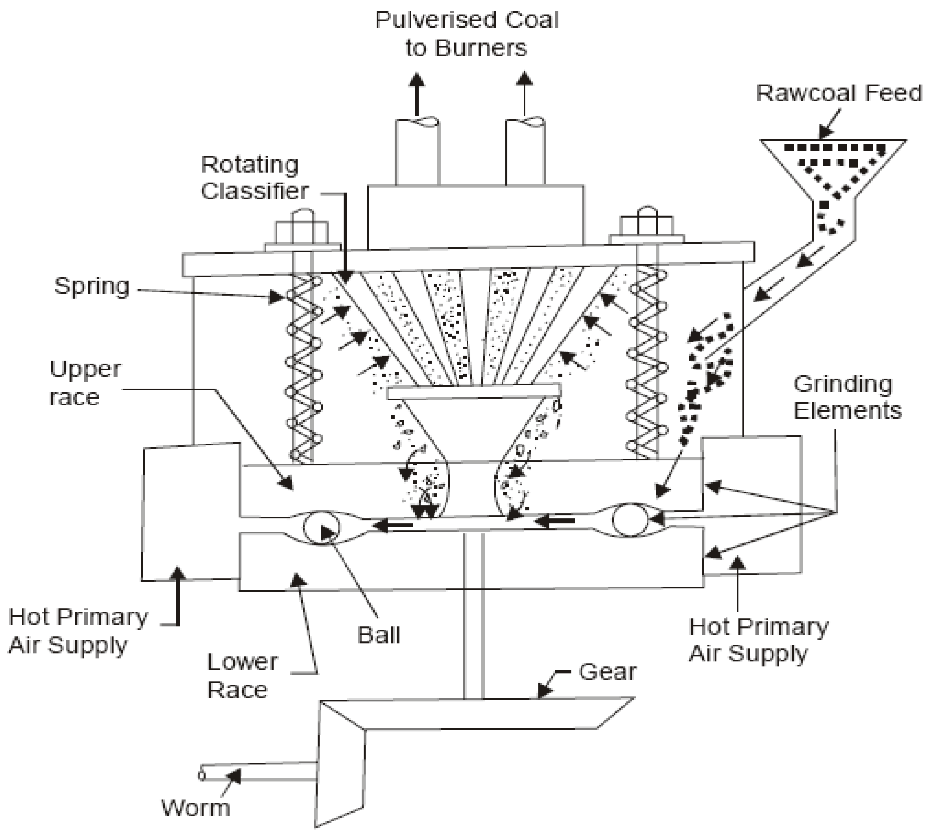


Fig. 4.21. Ball Mill.

As the drum rotates the coal gets pulverized due to the combined impact between coal and steel balls. Hot air is introduced into the drum. The powdered coal is picked up by the air and the coal air mixture enters the classifiers, where sharp changes in the direction of the mixture throw out the oversized coal particles. The over-sized particles are returned to the drum. The coal air mixture from the classifier moves to the exhauster fan and then it is supplied to the burners.

(ii) BALL AND RACE MILL

Fig. 4.22 shows a ball and race mill. In this mill the coal passes between the rotating elements again and again until it has been pulverized to desired degree of fineness. The coal is crushed between two moving surfaces namely balls and races. The upper stationary race and lower rotating race driven by a worm and gear hold the balls between them. The raw coal supplied falls on the inner side of the races. The moving balls and races catch coal between them to crush it to a powder. The necessary force needed for crushing is applied with the help of springs. The hot air supplied picks up the coal dust as it flows between the balls and races, and then enters the classifier. Where oversized coal particles are returned for further grinding, where as the coal particles of required size are discharged from the top of classifier.
In this mill coal is pulverized by a combination of' crushing, impact and attrition between the grinding surfaces. The advantages of this mill are as follows :

(*i*) Lower capital cost (*ii*) Lower power consumption
(*iii*) Lower space required (*iv*) Lower weight.
However in this mill there is greater wear as compared to other pulverizes.
The use of pulverized coal has now become the standard method of firing in the large boilers.
The pulverized coal burns with some advantages that result in economic and flexible operation of steam boilers.
Preparation of pulverized fuel with an intermediate bunker is shown in Fig. 4.22. The fuel moves to the automatic balance and then to the feeder and ball mill through which hot air is blown. It dries the pulverized coal and carries it from the mill to separator.

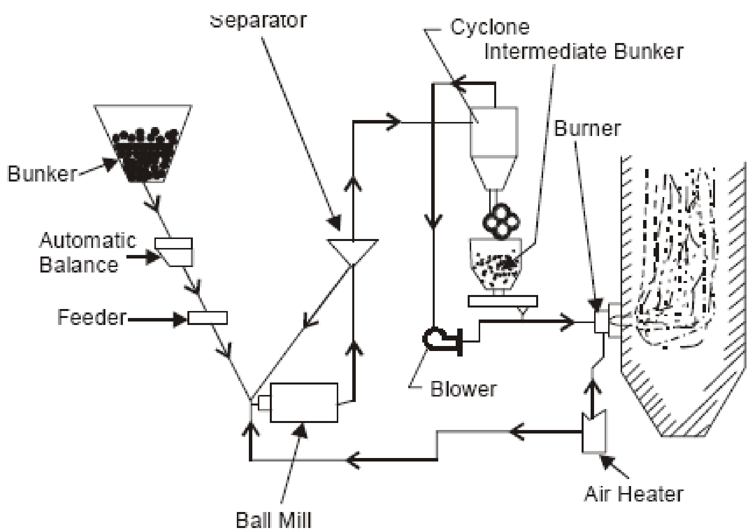


Fig. 4.22. Ball and Race Mill.

The air fed to the ball mill is heated in the air heater. In the separator dust (fine pulverized coal) is separated from large coal particles which are returned to the ball mill for regrinding. The dust moves to the cyclone. Most of the dust (about 90%) from cyclone moves to bunker. The remaining dust is mixed with air and fed to the burner.

Coal is generally ground in low speed ball tube mill. It is filled to 20-35% of its volume. With steel balls having diameter varying from 30-60 mm. The steel balls crush and ground the lumps of coal. The average speed of rotation of tube or drum is about 18-20 r.p.m. [Fig. 4.23].

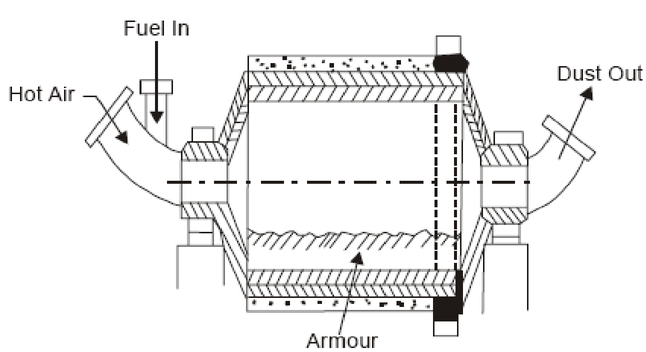


Fig. 4.23

Advantages

The advantages of using pulverized coal are as follows :
1. It becomes easy to burn wide variety of coal. Low grade coal can be burnt easily.

2. Powdered coal has more heating surface area. They permits rapids and high rates of combustion.
3. Pulverized coal firing requires low percentage of excess air.
4. By using pulverized coal, rate of combustion can be adjusted easily to meet the varying load.
5. The system is free from clinker troubles.
6. It can utilize highly preheated air (of the order of 700°F) successfully which promotes rapid flame propagation.
7. As the fuel pulverising equipment is located outside the furnace, therefore it can be repaired without cooling the unit down.
8. High temperature can be produced in furnace.

Disadvantages

1. It requires additional equipment to pulverize the coal. The initial and maintenance cost of the equipment is high.
2. Pulverized coal firing produces fly ash (fine dust) which requires a separate fly ash removal equipment.
3. The furnace for this type of firing has to be carefully designed to withstand for burning the pulverized fuel because combustion takes place while the fuel is in suspension.
4. The flame temperatures are high and conventional types of refractory lined furnaces are inadequate. It is desirable to provide water cooled walls for the safety of the furnaces.
5. There are more chances of explosion as coal burns like a gas.
6. Pulverized fuel fired furnaces designed to burn a particular type of coal can not be used to any other type of coal with same efficiency.
7. The size of coal is limited. The particle size of coal used in pulverized coal furnace is limited to 70 to 100 microns.

PULVERISED COAL FIRING

Pulverised coal firing is done by two systems:
(*i*) Unit System or Direct System.
(*ii*) Bin or Central System.
Unit System. In this system (Fig. 4.25) the raw coal from the coal bunker drops on to the feeder.

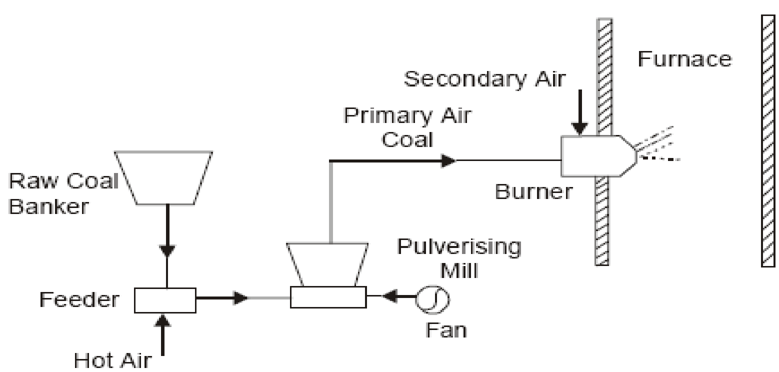


Fig. 4.25. Unit or Direct System.

Hot air is passed through coal in the feeder to dry the coal. The coal is then transferred to the pulverising mill where it is pulverised. Primary air is supplied to the mill, by the fan. The mixture of pulverised coal and primary air then flows to burner where secondary air is added. The unit system is so called from the fact that each burner or a burner group and pulveriser constitute a unit.

Advantages

(*i*) The system is simple and cheaper than the central system.
(*ii*) There is direct control of combustion from the pulverising mill.
(*iii*) Coal transportation system is simple.

Bin or Central System. It is shown in Fig. 4.26. Crushed coal from the raw coal bunker is fed by gravity to a dryer where hot air is passed through the coal to dry it. The dryer may use waste flue gases, preheated air or bleeder steam as drying agent. The dry coal is then transferred to the pulverising mill. The pulverised coal obtained is transferred to the pulverised coal bunker (bin). The transporting air is separated from the coal in the cyclone separator. The primary air is mixed with the coal at the feeder and the mixture is supplied to the burner.

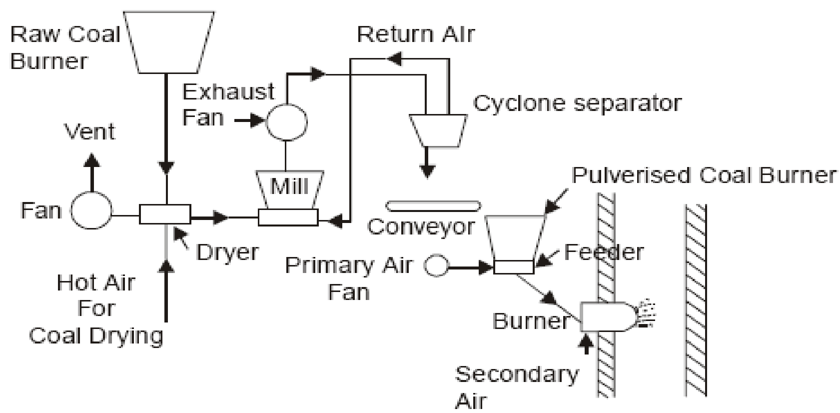


Fig. 4.26. Bin or Central System.

Advantages

l. The pulverising mill grinds the coal at a steady rate irrespective of boiler feed.
2. There is always some coal in reserve. Thus any occasional breakdown in the coal supply will not effect the coal feed to the burner.
3. For a given boiler capacity pulverising mill of small capacity will be required as compared to unit system.

Disadvantages

1. The initial cost of the system is high.
2. Coal transportation system is quite complicated.
3. The system requires more space.

To a large extent the performance of pulverised fuel system depends upon the mill performance.

The pulverised mill should satisfy the following requirements:

1. It should deliver the rated tonnage of coal.
2. Pulverised coal produced by it should be of satisfactory fineness over a wide range of capacities.
3. It should be quiet in operation.
4. Its power consumption should be low.
5. Maintenance cost of the mill should be low.

SMOKE AND DUST REMOVAL

In coal fed furnaces the products of combustion contain particles of solid matter floating in suspension. This may be smoke or dust. The production of smoke indicates that combustion conditions are faulty and amount of smoke produced can be reduced by improving the furnace design.
In spreader stokers and pulverised coal fired furnaces the coal is burnt in suspension and due to this dust in the form of fly ash is produced. The size of dust particles is designated in microns (1 μ = 0.001 mm). Dust particles are mainly ash particles called fly ash intermixed with some quantity of carbon ash material called cinders. Gas borne particles larger than 1μ in diameter are called dust and when such particles become greater in size than 100p they are called cinders. Smoke is produced due to the incomplete combustion of fuels, smoke particles are less than 10p in size.
The disposal smoke to the atmosphere is not desirable due to the following reasons :

1. A smoky atmosphere is less healthful than smoke free air.
2. Smoke is produced due to incomplete combustion of coal. This will create a big economic loss due to loss of heating value of coal.
3. In a smoky atmosphere lower standards of cleanliness are prevalent. Buildings, clothings, furniture etc. becomes dirty due to smoke. Smoke corrodes the metals and darkens the paints.

To avoid smoke nuisance the coal should be completely burnt in the furnace.

The presence of dense smoke indicates poor furnace conditions and a loss in efficiency and capacity of a boiler plant. A small amount of smoke leaving chimney shows good furnace conditions whereas smokeless chimney does not necessarily mean a better efficiency in the boiler room.

To avoid the atmospheric pollution the fly ash must be removed from the gaseous products of combustion before they leaves the chimney.

The removal of dust and cinders from the flue gas is usually effected by commercial dust collectors which are installed between the boiler outlet and chimney usually in the chimney side of air preheater.