3

Coal and Ash Handling Systems

Course Contents

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3. Coal & Ash Handling Systems

3.1 Introduction

Different types of fuels used for steam generation: Generally there are three types of fuels can be burnt in any type of steam power plant. They are 1) Solid fuels 2) Liquid fuels 3) Gaseous fuels.

Gaseous fuels:
The gaseous fuels widely used in steam power plants are natural gas, Blast furnace gas. Gaseous fuels may be either natural gases or manufactured gases. Since the cost of manufactured gases is high only natural gases are used for power generation. Natural gas is colorless, odorless and is non-poisonous its calorific value lies between 25000KJ to 50000 KJ/m$^3$.

The various manufactured gases are coal gas, Coke oven gas, Blast furnace gas and producer gas. These manufactured gases plays less important role in the steam generation.

Advantages:
1) Excess air required is less
2) Uniform mixing of fuels and air is possible
3) Handling is much more easier compared to the coal
4) The load changes can be met easily
5) There is no problem of ash disposal.
6) Operational labourer required is less.

Disadvantages:
1) Storage of gaseous fuels is not easy compared to liquid fuels due to the risk of explosions.
2) The plant must be located near the natural gas field otherwise transportation cost increases.

Liquid fuels:
The liquid fuels used in the thermal plant to generate the steam instead of coal as it offers the following advantages over the coal.
1) The calorific value of liquid fuels is about 40% higher than that of coal or solid fuels
2) The storage space required for liquid fuels is less
3) Instantaneous ignition and extinction of fire is possible
4) Stand by losses are minimum
5) Efficiency of the boiler is high
6) Ash handling system can be eliminated
7) Oil can be easily metered. The rate of fuel supply to furnace is easy to control.
1) The overall combustion efficiency of the liquid fuel fired power plant is less compared to the coal fired power plants

2) The availability of the liquid fuel resources are very limited as compared to the coal resources

Ex. Heavy oils, Bunker Coil, Viscous residue oil, Petroleum and its byproducts.

**Solid Fuels:**
Example for solid fuels is Coal. The term coal refers to the rocks in the earth’s crust, produced by the decaying of the plant materials accumulated over the millions of years ago. Different types of coals that are used for steam generation are

1) Lignite
2) Sub Bituminous
3) Bituminous coal
4) Semi Anthracite coal
5) Anthracite coal.

1) **Lignite:**
It is lowest grade of coal. Its having 30% of moisture calorific value is about 14650 to 19300 KJ/ Kg. Due to the high moisture content and low calorific value lignite is not easy to transport over long distances. It is usually burnt by the utilities at the mine sites.

2) **Sub Bituminous:**
Its calorific value is slightly less than that of the Bituminous coal. Its calorific value is in between 193000 to 26750 KJ / Kg. The moisture content is about 15 to 30%. It is brownish black in colour. These coals usually burned in the pulverized form.

3) **Bituminous coal:**
Bituminous coal is widely used in all purposes. It is used in steam generation and in the production of the coal gas and producer gas. Its moisture content may vary from 6 to 12 %. Its calorific value ranges from 25600 KJ/Kg to 32600 KJ /Kg. Bituminous coal burn easily especially in pulverized form.

4) **Semi Anthracite**
It is an intermediate coal between Bituminous and Anthracite coal. It ignites more easily than anthracite to give a short flame changing from Yellow to Blue. It is having the following properties:

- Moisture content = 1 to 2%
- Volatile matter = 10 to 15%
- Calorific value= 36000 to 36960 KJ / Kg

5) **Anthracite:**
It is the most mature and hard form of solid fossil fuel. It is having a fixed Carbon content ranging from 92 to 98%. Anthracite is good domestic fuel for heating and is sometimes used for steam generation.

**Selection of coal for steam generation**

Selecting a suitable coal for steam generation is a very difficult task. The firing qualities of coal are very important when we are considering a combustion equipments. Slower burning coal generates high fuel bed temperatures and therefore requires forced draught fan. The fast burning coals require large combustion chambers. Such coals are suitable for meeting a sudden demand for steam. The most important factors which are to be considered in the selection of coal are sizing and caking, Swelling properties and ash fusion temperature. Sometimes the selection of coal depends on the ash content also.

The following properties of the coal are to be considered for the selection of the coal for steam generation in steam power plants.

1) Burning rate of coal
2) Sizing, Caking, Swelling properties of coals
3) Finess of coal

**3.2 Coal handling**

The coal handling plant needs extra attention, while designing a thermal power station, as almost 50% to 60% of the total operating costs consists of fuel purchasing and handling. Fuel system is designed in accordance with the type and nature of fuel. Plants may use coal oil or gas as the fuel. The different stages in coal handling are shown below.
1. **Coal delivery**  
The method of transporting coal to a power station depends on the location of the plant, but may be one or more of the following: rail, road, river or sea. Plants situated near river or sea may make use of the navigation facilities. Stations which cannot make use of these facilities may be supplied coal either by trucks or by rail. Transportation of trucks is usually used in case the mines are not available. In case rail transport is to be adopted, the necessary siding for receiving the coal should be brought as near the station is possible.

2. **Unloading**  
Just what kind of equipment will do the best job for unloading depends first of all on how the coal is received. If the coal is delivered in dump trucks and if the plant site is favorable we may not need additional unloading equipment. When coal transported by using by sea or rivers unloading bridge or tower and portable conveyors are used. In case the coal received by rail in hoppers cars, again the coal may be unloaded quickly by using any of the facilities such as car shakers, Car throwing equipments, Car dumpers (Rotary), coal accelerators.

3. **Preparation**  
If the coal is brought to the site unsized and sizing is desirable for storage or firing purposes. The coal preparation plant may be located either near the coal receiving point or at the point of actual use. The coal preparation plant may include the following equipments:
   a. Crushers
   b. Sizers
   c. Dryers
   d. Magnetic separators

Coal preparation plant is as shown below in fig. 3.3.

The raw coal is crushed in to required size using crushers. The crushed coal is passed over the sizer who removes unsized coal and feeds back to the crusher. The crushed
coal is further passed to the drier to remove the moisture from the supplied coal. Before supplying the coal to the storage hopper, the iron scrap and particles are removed with the help of magnetic separators.

![Coal Preparation Plant Diagram](image)

**Fig. 3.3 Coal Preparation Plant**

### 4. Transfer

Transfer means the handling of the coal between the unloading point and the final storage point from where it is discharged to the firing equipment. The equipments used for the transfer of coal may be any one of the following or a suitable combination thereof:

- a) Belt conveyors
- b) Screw conveyors
- c) Bucket Elevators
- d) Grab bucket Elevators
- e) Skip hoists and
- f) Flight conveyors

**Belt conveyor**

The belt conveyors are suitable for transporting large quantities of coal over large distances. It consists of endless belt made up of rubber, canvas or balata running over a pair of end drums or pulleys and supported by series of rollers provided at regular intervals. The return idlers which support the empty belt are plain rollers and are spaced wide apart. Belt conveyors can be used successfully up to 20 degree inclination to the horizontal. The load carrying capacity of the belt may vary from 50 to 100 tons /h and it can easily be transported through 400 meters.
Advantages
It is most economical method of coal transfer.
The rate of coal can be regulated by varying the speed of the belt.
The repair and maintenance charges are minimum
The coal can be protected.
The power consumption is minimum

Disadvantages
It is not suitable for short distances and greater heights.

Screw conveyor
It consists of a helicoids screw fitted to a shaft as shown in the figure. The driving mechanism is connected to one end of the shaft and the other end of the shaft is supported in an enclosed ball bearing. The screw while rotating in a trough transfers coal from one end to the other end as shown in figure. The diameter of screw is 15 cm to 50 cm and its speed varies from 70 to 120 rpm and the maximum capacity is 125 tones per hour.

Advantages:
It requires minimum space and is cheap in cost
It is most simple and compact
It can be made dust tight

Disadvantages:
The power consumption is high
The maximum length limited to 30 meters
The wear and tear is very high therefore life of the equipment is less
**Bucket elevators**

These are used extensively for vertical lifts, through the horizontal runs is not ruled out. These elevators consist of relatively small size buckets closely spaced on an endless chain. The coal is carried by the buckets from the bottom and discharged at the top. Centrifugal type and continuous type bucket elevators are most commonly used. The maximum height of the elevator is limited to 30.5 m and maximum inclination to the horizontal is limited to 60 degree. The speed of the chain required in first case is 75 m/min and continuous type is 35 m/min for 60 tones capacity per hour.

![Bucket elevators](image)

*Fig. 3.6 Bucket elevators*

**Advantages:**
- Less power is required
- Coal can be discharged at elevated places
- Less floor area is required

**Disadvantages:**
- Its capacity is limited to 60 tons per hour and hence not suitable for large capacity stations

**Grab bucket**

Grab bucket conveyor is form of hoist which lifts and transfers the load on a single rail or track form one point to another. This can be used with crane or tower as shown in figure A 2-3 cu-m bucket operating over a distance of 60 m transfer nearly 100 tons of coal per hour. Its initial cost is high but operation cost is less.
Flight conveyor
This type of conveyor is generally used for transfer of coal when filling of number of storage bins situated under the conveyor is required. It consists of one or two strands of chain to which steel scrappers are attached the scraper scraps the coal through a trough and the coal is discharged in the bottom of the trough as shown in fig. 3.8.

![Flight conveyor](image)

**Fig. 3.7 Flight conveyor**

**Advantages:**
- It requires small head room
- The speed can be regulated.
- It can be used for as well as coal transfer.
- It requires less attention.

**Disadvantages:**
- There is excessive wear and tear and hence the life of the conveyor is less.
- The repair and maintenance charges are high.
- The restricting the operating speed to 300m/min is required to reduce the abrasive action.
- Power consumption is high per unit of coal or ash handled.

Skip hoist:
It is used in high lifts and handling is not continuous. It consists of vertical or inclined hoist way, a bucket or a car guided by the frame, and a cable for hoisting the bucket.

**Advantages:**
- It requires very low maintenance.
- Power requirement is low.
- It can handle larger size clinkers.
- It can be used for handling ash as well as coal
- It needs minimum floor area.

**Disadvantages:**
- The initial cost is high
- This is not suitable for continuous supply of coal.
There is excessive wear of skips and ropes which need frequent replacements.

5. **Outdoor storage**
Whether the storage is large or small, it needs protection against losses by weathering and by spontaneous combustion. With proper methods adopted even larger outdoor storage can remain safe. In order to avoid the oxidation of coal the compact layers are formed. To avoid spontaneous combustion air is allowed move evenly through the layers.

6. **Indoor storage or live storage**
This is usually a covered storage provided in plants, sufficient to meet day's requirement of the boiler. Storage is usually done in bunkers made of steel or reinforced concrete having enough capacity to store the requisite of coal. From the coal bunkers coal is transferred to the boiler grates.

7. **Weighing**
A frequent part of in plant handling is keeping tabs on quantity and quality of coal fired. For weighing weigh bridge is used. Coal is weighed in transit also by using belt scale.

8. **Fuel firing methods**
Selection of firing method adopted for a particular power plant depends on the following factors.
   a) Characteristics of fuel available
   b) Capacity of the plant
   c) Load factor of the power plant
   d) Nature of load fluctuations
   e) Reliability and efficiency of the various combustion equipments

Depending upon the combustion equipments used boilers can be classified as:
   a) Solid fuel fired
   b) Liquid fuel fired
   c) Gaseous fuel fired

**Solid fuel firing**
The classification of combustion system used for coal burning given below:
Hand firing system is the simplest method for solid fuel firing but it cannot be used in modern power plant. The most commonly used methods for firing the coal are:

1) Stoker fire
2) Pulverized fire

**Stoker fire:**
Stoker is fuel burning mechanism used for burning fuel on grate. This type of burning mechanism is suitable where the coal is burned. Stokers are classified as

a. Over feed stokers
b. Under feed stoker.

In over feed stoker the direction of air and coal are opposite to one another. The coal is supplied on to the grates above the point of air admission.

In under feed stoker coal is fed from underneath the grate between the two tuyers. The direction of fuel and air is same.

**Over feed stoker**
Typical overfeed stoker is as shown in the fig. 3.9. Coal is fed on to the grate above the point of air admission.
The pressurized air coming from the FD fan enters under the bottom of the grate. The air passing through the grate opening is heated by absorbing the heat from the ash and grate itself, whereas the grate and ash get cooled.

As hot air passes through the incandescent coke layer $O_2$ reacts with Carbon to form Carbon dioxide. This is an exothermic reaction and releases heat required for continuation of combustion process. It continues till all the oxygen is consumed. If the incandescent layer thick, $CO_2$ may be partly reduced to $CO$ ($CO_2 + C \rightarrow 2CO$). The gasses leaving the incandescent layer are $N_2$, $CO$, $CO_2$, $H_2$.

A slight water reaction may take place with the moisture in air ($H_2O + C \rightarrow H_2 + CO$). This is an endothermic reaction and may bring down the temperature of the bed and gas. Stream of gases then passes through the distillation zone where volatile matter is added from raw coal and then moisture is picked up in the drying zone and finally emerges above the fuel bed. The gases leaving the upper surface of the fuel bed contain combustible volatile matter, $N_2$, $CO_2$, $CO$, $H_2$ and $H_2O$, if the combustion of Carbon, Hydrogen and volatile matter is to be completed following have to provide.

a. Sufficient fresh air or secondary air is supplied.

b. Ignition point should be in the range $1000^0C - 1300^0C$.

c. Creating turbulence by supplying secondary air at right angles to the up flowing gas stream from fuel bed.

It does not help supplying if the secondary air supplied along with primary air, since more primary air produces only more carbon monoxide. The presence of the Carbon monoxide in the exhaust gases indicates the incomplete combustion leads to decrease in the efficiency of combustion equipments.

**Types of over feed stoker**

A. Traveling grate stoker

B. Spreader stoker

**Traveling grate stoker**
The traveling grate stoker is as shown in the figure. This type of stoker has the grate which is moving from one end of the furnace to the other end. This grate may be chain grate type or bar grate type chain grate stoker is made up of series of Cast Iron chain links connected by pins to form an endless chain.

The bar grate stoker is made up of a series of Cast Iron sections mounted on a carrier bars. The carrier bars are mounted and ride on two endless drive chains.

The traveling grate stoker consist of an endless chain which forms support for the fuel bed. The chain travels over the two sprocket wheels which are at the front and rear end of the furnace. The front end sprocket wheel is connected to variable speed drive mechanism.

The grate can be raised or lowered as needed. Simultaneous adjustment of great speed, fuel bed thickness, and air flow control, the burning rate so that nothing but ash remains on the grate by the time it reaches furnace rear.

The ash falls on to the ash pit, as the grate turns to make the return trip. A coal gate at the rear of the coal hopper regulates coal. As the raw coal or green coal on the grate enters the furnace, surface coal gets ignited from heat of furnace flame and radiant heat rays reflected by ignition arch.

The fuel bed becomes thinner towards the rear of furnace as combustible matter burns off. The secondary air supplied helps in mixing the gases and supplies oxygen to complete combustion. The coal should have minimum ash content which will form a layer on the grate. It helps in protecting grate from overheating.

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**Fig. 3.10 Travelling grate stoker**
Advantages:
Simple and initial cost is low
Its maintenance costs are low
It is self-cleaning stoker
Heat release rates can be easily controlled
It gives high heat release rates per unit volume of furnace

Disadvantages
This cannot be used for high capacity boilers 200 t/hr or more
The temperature of preheated air is limited to 1800°C
The clicker troubles are common
The ignition arches are required
The loss of fuel in ash cannot be avoided

Spreader Stoker
The coal from coal hopper is fed by a rotating feeder, a drum fitted with short blades on its surfaces, to the spreader or distributor below. Which projects the coal particles on to the grate holding an ignited fuel bed? The finer particles burn in suspension and the coarse particles are consumed on the grate.

The speed of the feeder directly proportional to the steam output of the boiler. The secondary air helps in creating turbulence and completing combustion. In high capacity boilers may have traveling grate stoker in addition to spreader stoker.

The grate consists of Cast Iron links underneath the grate connect all the bars to a lever. Moving lever makes the ash fall through to the ash pit below. Spreader stokers are capable of burning any type of coal.

Fig. 3.11 Spreader stoker

Advantages:
Almost any type of the coal can be burnt
Clinkering problem is less
It is having quick response to varying load
The quantity of excess air required is less
The operation cost is low

Disadvantages:
The problem of fly ash is high. It requires a dust collector to prevent the environment pollution
Coal particles trapping mechanism is necessary to prevent their escape with excess air
Its operating efficiency decreases with varying sizes of coal

**Under feed stoker**
In this type of stokers the fuel and air move in the same direction. In this case coal is fed from underneath the grate by screw conveyor or by a ram.

Primary air after passing through the holes in the grate meets the raw coal. As the air diffuse through the bed of raw coal picks up moisture and then pass through the distillation zone where volatile matter is added.

When gas stream next passes through the incandescent coke region, volatile matter burns readily with the secondary air fed at the top. The gases in this type stoker are at higher temperature than over feed stoker.

The under feed method is best suited for burning semi Bituminous and Bituminous coals high in volatile matter.

**Types of under feed stokers**
A. Single retorts Stoker
B. Multi retort stoker

![Diagram of underfeed feeders](image-url)
**Single retort stoker**
The arrangement of single retort stoker is shown in figure in the form of two views. The fuel is placed in large hopper on the front of the furnace and then further fed by reciprocating ram or screw conveyor in to the bottom of the horizontal trough. Air is supplied through the tuyers provided along upper edge of the grate. The ash and clicker are collected on the ash plate provided with dumping arrangement. The coal feeding capacity of a single retort stoker varies from 100 to 2000 Kg / Hr.

![Fig. 3.13 Single retort stoker](image)

**Multi retort stoker**
Multi retort stoker is as shown in figure. It consists of series of alternate retorts and tuyers boxes for supply of air. Each retort is fitted with reciprocating ram for feeding and pusher plates for uniform distribution of coal. Coal falling from hopper is pushed forward during inward stroke of the stoker ram. Then distributing ram pushes the entire coal down length of the stoker. The ash formed is collected at the end as shown in the figure. The number of retorts may be varying from 2 to 20 with burning capacity varying from 300 kg to 2000 Kg/hr/retort.
Fig. 3.14 Multi retort stoker

Advantages
High thermal efficiency compared to chain grate stoker
Combustion rate is high
Combustion is continuous
Grate is self-cleaning
Smoke less operation
Stokers are suitable for non-clinker high volatile and low ash content coal

Disadvantages
It requires large building space
Clicker problems are high
Low grade coals with high ash content cannot be burn economically
Initial cost of the unit is high

Pulverized fuel firing system
In pulverized fuel firing system the coal is grinded in to a fine powder form with the help of grinding mill and then projected in to the combustion chamber with the help of hot air current. This hot air is known as the primary air.

The amount of the air required for complete combustion is supplied separately in the combustion chamber. It helps in creating turbulence, so that uniform and intimate mixing of coal particles and air can take place inside combustion chamber.
The efficiency of the pulverized fuel firing system mostly depends upon the size of the particles of the coal in the coal powder. The finesse of the coal particles should be such that 70% of it would pass through 200 mesh sieve and 98% through a 50 mesh sieve.

![Diagram of pulverizing coal system](image)

**Fig. 3.15 Elements of pulverizing coal system**

**Advantages:**
- Any grade of coal can be used
- Stand by losses are reduced and banking losses are eliminated
- Efficiency of combustion is high compared to other methods of solid fuel firing methods.
- Boiler unit can be started up from cold rapidly and efficiently
- Practically free from slagging and clinker troubles
- Furnace has no moving parts subjected high temperatures
- The furnace volume required is less
- This system works successfully with or in combination with gas and oil
- Greater capacity to meet the peak loads
- Practically no ash handling problems
- The structural arrangements and flooring are simple
- The external heating surfaces are free from corrosion

**Disadvantages:**
- Coal preparation plant is necessary
- High capital cost
- Handling of fly ash makes the system uneconomical
- Special equipment is needed to start this system
- Larger building space is needed especially with central system
- Skilled operators are required
- Refractory material surfaces are affected by high furnace temperatures
- Atmospheric pollution created by the fly ash is cannot be completely eliminated
➢ The possibility of explosion is more as coal burns like gas
➢ The maintenance of furnace brick work is costly

There are two methods of pulverized fuel firing.

1) Unit system
2) Central or Bin system.

In unit system each burner of the plant has its own Pulveriser and handling units. In central or Bin system fuel is pulverized in the central plant and then distributed to each burner with the help of high pressure air current.

**Unit system**

In unit system each burner of the plant has its own Pulveriser and handling units. The Pulveriser an together with feeder, separator and fans may be arranged to form an complete unit or mill.

The number of units required depends on the capacity of the boiler. Raw coal from coal hopper fed to the pulverizing mill through feeder. Hot air from or flue gases passed through the feeder to dry the coal before feeding to the Pulveriser.

The pulverized coal is carried from the mill with the help of induced draught fan as shown in figure. This further carries the coal through the pipes to the burner.

Secondary air supplied to the burner before fuel entry in to the combustion chamber is as shown in figure helps in creating the turbulence as well as supplying additional air required for completing the combustion of the coal particles in the furnace.

**Advantages:**

➢ It is simple in layout and cheaper than central system
➢ It allows direct control of combustion rate from the Pulveriser
➢ Maintenance charges are less
➢ The coal transportation is simple

**Disadvantages:**

➢ The performance of pulverizing mill is poor.
➢ Degree of flexibility is less than central system.
➢ The fault in the preparation unit may put entire steam generator out of use.
➢ There is excessive wear and tear of the blades of fan as it handles air and coal particles.
➢ Strict maintenance of the mill is required because the entire plant operation depends on it
Central or Bin system
The central system or Bin system fuel is pulverized in the central plant and then distributed to each burner with the help of high pressure air current. Crushed and sized coal is fed to the drier from coal bunker by gravity as shown in fig. 3.17.

The dried coal fed to the pulverizing mill with the help of air, as shown in figure, separated in the cyclone separator. The separated pulverized coal is transferred to the central bunker using conveyor as shown in fig. 3.17.

Oversized coal particles are fed back to the pulverizing mill for further processing. The storage bin may contain 12 to 24 hours of supply of pulverized coal. The energy consumption is 15 to 25 KW-Hr / Ton of coal pulverized.

Advantages:
➢ The reliability of plant is high
➢ The central system is flexible. Supply of the coal can be maintained to the burners without any interruption.
➢ Burner operation is independent of coal preparation
➢ The pulverizing mill may work at the part load because of storage capacity available in the storage bin.
➢ Power consumption per ton of coal handled is less
➢ As the fans handle only air there is no problem of excessive wear and tear
➢ The laborers required is less

Disadvantages:
➢ Initial cost is high and occupies a larger space
➢ The overall power consumption per ton of coal handled is higher than unit system due to high power consumption by auxiliaries.
➢ The operation and maintenance charges are higher than unit system of same capacity.
➢ There is possibility of fire hazard due to the stored pulverized coal

3.3 Components of the pulverized coal fired plant

The main equipments used in the pulverized coal fires plant are

1. Primary crushers
2. Magnetic separators
3. Coal driers
4. Pulverizing mill
5. Burners

1. Primary crushers

Crushing of coal is required when we are handling un sized coal. Plant using pulverized coal generally specifies the top size, larger than what cannot be handled by the pulveriser, making crushing necessary to prepare coal for pulverization following types of crushers are used.

a) Ring crushers
b) Hammer mill crushers
c) Bread ford breaker
d) Rotary breaker
e) Single roll crushers

Ring crushers

In this type of crushers coal is fed at top of crushers and is crushed by the action of ring that pivots off centre on a rotor. Adjustable plate helps in varying the size of discharge coal. It can be used as off or on plant site.
**Hammer coal crusher**

In this type of coal crusher also the coal is fed from the top and is crushed by the action of swinging hammers that are pivoted on a rotor. Swinging hammers are attached to the central drum. As the drum rotates coal particles coming in between the swinging hammers and adjustable plates crushed. The crushed sized coal falls out of the crusher through the opening provided at the bottom. The adjustable plates used to vary the size of discharge coal.

**Brad ford crushers**

It is used in large capacity plant. It comprises of large cylinder consisting of perforated steel screen plates to which lifting shelves are attached inside. The cylinder rotates slowly at about 20 rpm and receives feed at the one end. The coal is lifted by the shelves, the breaking action is accomplished by the repeated lifting and dropping of the coal until its size permits it to discharge through the perforation made. The size of the perforation determines the size of crushed coal. The main advantage is rejection of the foreign matter and to produce relatively uniform size coal particles.
Rotary breakers
The crushing of coal takes place between the rotating cylinder and rollers. The crushing action is combination of both lifting and dropping of the coal and also by the crushing action of coal between rollers and rotating cylinder.

Single roll crushers
The crushing of coal takes place between adjustable plate and rotating single roller having teeth on the circumference. The size of the coal particle can be varied by varying the gap between adjustable plates and rotating roller.

2. Pulveriser
Pulverisers are devices that are used to produce coal in the powder form. They are also called as pulverizing mills. The pulverizing process consists of three stages namely i) Feeding ii) Drying iii) Grinding.

Feeding system controls automatically air required for drying and transporting pulverized fuel to the burner depending on the boiler demand. For pulverization of
Coal has to be dry and dusty. Dryer are an integral part of the pulverizing equipment. For drying coal part of primary air passing through the air preheated at 3500°C is utilized. The third stage of pulverization process is the grinding and equipment used for this action is known as the grinding mill.

Four different types of pulverizing mills are used.

a) Ball and race mill  
b) Bowl mill  
c) Ball mill  
d) Hammer mill

**Ball and race mill**

![Fig. 3.22 Ball and race mill](image)

This is also known as the contact mill.

The coal is crushed between two moving surfaces ball and race. The upper race is stationary and the lower race is driven by worm and gear, holds the steel balls between them. The coal is allowed to fall on the inside of the race from feeder or hopper.

Moving balls and race catches coal between them to crush into a powder. Springs are used to hold down the upper race and adjust the force needed for crushing.

Hot air supplied picks up the coal dust as it flows between the ball and races and then enters into the classifier, moving and fixed vanes make the entering air to form a cyclonic flow which helps to through the oversized particles on to the wall of classifier.
The oversized particles slide down for further grinding in the mill. The coal particles of required size carried to burners with air from the top of the classifier.

**Bowl mill**

The bowl mill grinds the coal between a whirling bowl & rollers mounted on pivoted axis.

The Pulveriser consists of stationary rollers and power driven balls in which pulverization takes place as the coal passes between the bowl and rollers.

The hot primary air supplied in to the bowl picks up coal parcels and passes through the classifier. Where oversized coal particles falls back to bowl for further grinding. The required size coal particles along the primary air supplied to the burner.

**Ball Mill**

The line diagram of the ball mill is as shown in fig. 3.24. It consists of a large cylinder partly filled with varying sized steel balls.
The coal from coal hopper fed in to the cylinder with the help of crew conveyor. At the same time required quantity of hot air from air preheater is also enters. As the cylinder rotates pulverization takes place between the balls and the coal. The streams of hot air pick up the pulverized coal and pass through the classifier.

The oversized coal particles thrown out of the air stream in the classifier and fine coal particles are passed to the burner through exhaust fan.

Ball mill capable of pulverizing 10 tons of coal / hr containing 4% moisture requires 28 tons of steel balls and consumes 20-25 KW – Hr energy per ton of coal pulverized.

![Fig. 3.24 Ball mill](image)

**Hammer mill**

The hammer mills have swinging hammers connected to an inner ring and placed within the rotating drum. The coal to be pulverized is fed in to the path of hammers.

Grinding is done by the combination of impact on large particles and attrition on small particles. The hot air is supplied to dry the coal as well as carrying coal particles to burners.

It is compact low in cost and simple in operation. However its maintenance is costly and its capacity is limited. The power consumption is high when fine powder is required.

![Fig. 3.25 Hammer mill](image)
3.4 Pulverised fuel burners

Burners are devices use to burn coal particle by uniform mixing of coal and air and creation of turbulence within the furnace. The air which carries pulverized coal in to the furnace through the burner is primary air. The secondary air required for completing combustion is supplied separately around the burner or elsewhere in the furnace.

The main requirements of pulverized fuel burners are.

a. It should mix thoroughly primary air with coal particles and secondary air.

b. It should create turbulence and maintain stable combustion.

c. It should control the flame shape and it travel in the furnace.

d. The velocity of primary air and coal particles should be same as that of flame velocity to avoid flash back.

The burner should have ability to withstand overheating due internal fires and excessive abrasive wear.

Types of pulverized burners are

1) Long flame or U-Flame burners or streamlined burners.
2) Turbulent burners
3) Tangential burners
4) Cyclone burners

**Long flame burners**

The tertiary air supplied around the burner to provide better mixing of primary air and fuel.

The burner discharges air and fuel mixture vertically downwards with no turbulence to provide long flame. Heated secondary air supplied at right angles to the flame creates turbulence that required rapid combustion.

These types of burners are suitable for burning low volatile slower burning coal particles.
Turbulent Burners
These burners are also called as short flame burners. Turbulent burners can project flame horizontally or at small inclination to the furnace.

The fuel – primary air mixture and secondary hot air are arranged to pass through the burner in such a way that there is good mixing and the mixture is projected in highly turbulent form in to the furnace.

The mixture burns intensely and combustion is completed in a short distance. The burning rate of turbulent burners is high compared to other types of burners. Turbulent burners are preferred for high volatile coal and they are used in modern power plants.

Tangential burners
It consists of four different burners located at 4 corners of the furnace. The discharge of fuel and air mixture directed tangentially to an imaginary circle in the centre of the furnace.
The swirling action creates necessary turbulence required for completing the combustion in short period. The tips of the burners can be angled through a small vertical arc. So raise or lower the position of turbulent combustion region in the furnace. It helps in maintaining constant super heat temperature of steam as load varies. This arrangement can provide 100⁰c difference in furnace gas exit temperature.

**Fig. 3.28 Tangential burner**

**Cyclone Burner**

It consists of horizontal cylinder of water cooled construction, 2 to 3 meters in diameter and 2.5 m in length. The horizontal axis of the burner is slightly deflected downward towards the boiler. These burners are externally attached to the furnace.

The cyclone burner receives pulverized coal carried by the primary air tangentially to the cylinder at outer end creates strong and highly turbulent Vortex. Secondary air enters in to the cylinder tangentially to complete the combustion. These burners can be rotated by ±30 degree up and down it helps in controlling the super heater temperature.

The fuel supplied burns quickly with high heat liberate rates with temperature around 2000 ⁰C. The ash forms the molten film over the inner wall surface and molten ash flows to an ash disposal system. The cyclone burners give best results with low grade fuel.

**Fig. 3.29 Cyclone burner**
3.5 Ash handling system

Large quantity of ash is produced by the power plants due to burning coals having high ash content. The ash should be discharged and dumped at sufficient distance from the power plant because of the following reasons.

a) The ash content is dusty
b) It is very hot when it comes out of the furnace
c) It produces poisonous gases and corrosive acids when mixed with water

The amount of ash produced is as large as 20% of total coal burnt during the day. In order to handle this large quantity of ash use of mechanical handling equipment becomes necessary. Any ash handling system consists of the following operations.

a) Removal of ash from the furnace.
b) Carrying of ashes from ash hopper to storage with the help of conveyor.
c) Quenching of hot ash before carrying is desirable and necessary as it offers the following advantages.
   i. Reduces the temperature.
   ii. Reduces dustiness of ash.
   iii. Reduces the corrosive action.
   iv. Disintegrate large clinkers in to smaller one.
   v. It act as sealing against the air entering in to boiler.

Requirements of Ash handling equipment

The main requirements of good ash handling plants are listed below:
1. It should be capable of handling large volume of ash.
2. It should be capable of handling large clickers with minimum attention.
3. The plant should have high rates of handling.
4. The operation should be noise less as much as possible.
5. It should deal effectively both hot and wet ash.
6. The initial cost, operating and maintenance charges should be minimum as per as possible.

The generally used ash handling systems are classified into four groups:
1) Mechanical handling system
2) Hydraulic handling system
3) Pneumatic handling system
4) Steam jet system

**Mechanical ash handling system**

This system of handling ash is used in low capacity power plants. The hot ash coming out of furnace allowed falling on to the belt conveyor moving through the water trough.

Cooled ash carried continuously by belt conveyor to the ash bunker. The ash is removed from the ash bunker to the dumping site with the help of trucks.

**Hydraulic handling system**

In this system ash is carried with the flow of water. The hydraulic system is subdivide into low velocity system and high velocity system

**Low velocity system**

In this system water trough is provided just below the boiler and water is made to flow through the trough. The ash falling directly into the drain and it is carried by water to the sump. In the sump ash is separated from water, separated water is used again while the ash collected in the sump is removed to the dumping yard. The capacity of this system is 50 tons/hr.
3. Coal & Ash Handling Systems

High velocity or high pressure system
The ash hoppers below the boilers are fitted with water nozzles at the top and on the sides. The top nozzle quench ash and side nozzle provide driving force to carry the ash through a trough. The cooled ash with high velocity water is carried to the sump. The water is re-circulated again after separating it out from the ash. Capacity of the system is 120 tons/hr and distance is 1000 meters.

Pneumatic handling system
In primary and secondary separation working on cyclone principle and then it is collected in the ash hopper as shown in the figure. The clean air is discharged from the top of the secondary air separator in to the atmosphere through the exhauster.
Exhauster may be mechanical type with filter or washer to ensure that the exhauster handles clean air or it may use steam jet or water jet for its operation.

Mechanical exhausters are used in large power stations. While steam exhausters are used in small and medium power stations. The pneumatic system can handle abrasive as well as fine materials such as fly ash as soot.

The capacity of system varies from 15 -25 tons/hr.

Fig. 3.34 Pneumatic Ash handling system

**Advantages:**
- The system is flexible.
- There is no spillage and re handling.
- No chances of ash freezing and sticking of the materials, ash can be discharged freely by gravity.
- Dustless operation as the system is totally closed.
- Cost / ton of ash handled is comparatively less.

**Disadvantages:**
- Wear and tear of pipes is high and hence the maintenance costs are high.
- The operation is noisy compared to other systems

**Steam jet system**

In this type of ash handling system, a jet of high pressure steam is passed in the direction of ash travel through a conveying pipe in which ash from the boiler ash hopper is fed. The ash is deposited in the ash hopper. The velocity is given to the steam by forcing it through the pipe under pressure greater than that of atmosphere.

**Advantages:**
- It does not requires any auxiliary drivers
➢ Capital coat and maintenance costs are low
➢ It requires less space
➢ Equipment can be installed in any position

**Disadvantages**
➢ Noisy operation
➢ Wear and tear of pipes is high
➢ Capacity of this system is limited to 15 tons/hr.

### 3.6 Dust Collection

Any gas borne matter larger than 1 micron (0.001mm) in diameter we called it as dust. If the particles are mainly ash particles then it is called fly ash. If the particles are in turn mixed with some quantity of carbon, then the matter is known as the cinders. The size of cinders is usually greater than 100 micron. Incomplete combustion volatile components of fuel produces smoke, consists of particles smaller than 10 micron. The removal of dust and cinders from flue gas can be achieved by using dust collectors. These are classified as:

1) Mechanical dust collectors
2) Electrical dust collectors

**Mechanical dust collectors**

The basic principle used in the mechanical dust collection is as shown in the fig. 3.35.

![Mechanical dust collector](image)

*Fig. 3.35 Mechanical dust collector*

a) Sudden velocity decreasing method: Enlarging cross sectional area off the dust carrying pipe helps in slow down of the gas so that dust particles will have the chance to settle out are allowed to fall down.

b) Abrupt change of flow direction. When gas makes a sharp change in flow direction the heavier particles tend to keep going in original direction and so settle out.
c) Impingement upon small baffles: The larger dust particles may be knocked out of the gas stream by impingement on baffles. These are used to drop large cinders from the gases.

Mechanical dust collectors can be further classified as wet type and dry type. The wet type dust collectors are also called as scrubbers. Scrubbers operate with water sprays to wash dust from the air. Large quantity of wash water is required for central power stations and this system is rarely used. This also produces waste water that may require chemical neutralization before it may be discharged into the natural water bodies. Scrubbers may be 1) Packed type 2) Spray type 3) Impingement type.

**Electrostatic precipitator**

Electrostatic precipitators are extensively used in removal of fly ash from electric utility boiler emissions.

The dust laden gas is passed between oppositely charged conductors and it becomes ionized. As the dust laden gas passed through these charged electrodes, both negative and positive ions are formed. The ionized gas is further passed through the collecting unit which consists of set of vertical plates.

Alternates plates are charged and earthed. As the alternate plates are grounded, high intensity electrostatic field exerts a force on positively charged dust particles and drives them towards the grounded plate.

The deposited dust particles are removed from the plates by giving the shaking motion to the plates. Dust removed collected in the dust hoppers.

![Electrostatic precipitator](image)

**Advantages**

➢ It is more effective in removing small particle
➢ Its efficiency is high
➢ The drought losses are least
➢ It provides ease of operation.

**Disadvantages:**
➢ Use of electrical equipment for converting AC in to DC is necessary
➢ The space required is larger than wet system
➢ Collectors must be protected from sparking
➢ The running costs are high