Module 1: THERMAL ENERGY CONVERSION SYSTEM

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Objectives
After studying this module, the student should be able to

- Understand the importance of energy resources for the production of electricity.
- 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 country depends. Apart from its use in industrial organisations and domestic purposes, electricity is needed in agriculture for pumping water for irrigation and in defence for improving production methods and other various operations. Our modern life is much dependent on electric power and its 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 forms, 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 unit of 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 electrical energy.

1.2 Energy Resources

The various sources 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. Nuclear energy  
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 used for steam generations in power plants are; coal, oil and gas. A Coal is the oldest fuel and still used in large scale throughout the world for power generation. Coal is a heterogeneous compound and its constituents are always carbon, hydrogen, oxygen, sulphur, nitrogen and certain mineral non-combustibles. The phenomenon by which the buried vegetation consisting of wood, grass, shrubs etc., transformed into coal is known as metamorphism. The nature of coal will depend upon the type of vegetation buried, and nature and duration of metamorphism. The classification of coal is based on the physical and chemical composition of the coal and therefore it is required to study the chemical composition of the coal. 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, nitrogen, sulphur and ash. It also gives an indication about fusion temperature and the heating value of 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 form with oxygen known as inherent moisture which comes 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.

Oxygen: Coal contains oxygen 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 silica, 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 into following types.

1. Peat: It is a low grade coal and first stage in the progress of transformation of buried vegetation in to coal. It contains huge amount of moisture (90%) and small percentage of volatile matter and 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 to remove greater 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 comparison 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. Bituminous coal: It is most popular form and has low moisture content and non disintegrating properties. It may possess 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 is driven 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 low caking coals are suitable for gas making purposes

Sub Bituminous coal is similar to lignite and contains less moisture than lignite. It is used in briquettes or pulverised.

Semi Bituminous coal is intermediate between Anthracite and Bituminous coals and is the highest grade of Bituminous coals. It releases less smoke, and has high carbon content and heating value. It possess 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 carbon content 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 good fuel**

A good coal should possess

1. High calorific value and low ash content.
2. Less sulphur content (less than 1%)
3. Good burning characteristics to ensure complete combustion.
4. High grindability index (in ball mill grinding)
5. High weatherability.

Grading of coal can be done on the basis of i) Size ii) Ash content iii) Sulphur content iv) V) Heating value.

**Liquid Fuels:** The liquid fuels of powerplant are always by product of petroleum. Crude petroleum oil contains mainly carbon and hydrogen with small amounts of oxygen, nitrogen and sulphur. The chemical composition of petroleum and its derivatives is; carbon 83-87%, hydrogen-10-14% and various percentages of sulphur, nitrogen, oxygen etc., The hydrogen is present in the form of hydrocarbon mixtures. The hydrogen and carbon are combined as hydrocarbons into specialised products like gasoline, fuel oil etc., The liquid fuels have a higher 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.
Natural gas is found under the earth's surface and mainly contains methane (CH₄) and ethane. The calorific value is nearly equal to 21000 KJ/m³ and is colourless and odourless. The manufactured gases are coal gas, coke-oven gas, blast furnace gas, producer gas, and water or illuminating gas. First two are produced by carbonizing high volatile bituminous coal. These gases are used in boilers and sometimes used for commercial purposes. The blast furnace gas is used in steel industry and is the by-product of blast furnace. The heating value of this gas is very low. Producer gas is manufactured from the partial oxidation of coal, coke, or peat when they are 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 and ash circuit
2. Air and gas circuit
3. Feed water and steam circuit
4. Cooling water circuit

1. Coal and 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 air 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 steam generated in the boiler. Then a condenser is used to condense the steam coming out of the 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 water between low and high temperature sections. A super heater is used to super heat the wet steam 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 the steam is large and is taken either from lake, river or sea. The cooling water is taken from the 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 in river or cooling pond or in cooling tower and the system is known as closed system.

1.5 Equipment for burning coal in lump form

Early boilers were set very close to the grates and the combustion space was limited and hence resulted in smoke and poor efficiency. Later, furnaces were made larger and the boilers were set at higher level above the grates. A hand fired furnace with large combustion space is used to burn a wide variety of coal.

The following aspects are considered while selecting combustion equipments.

1. Initial cost of the equipment
2. Combustion space available and its ability to withstand high temperature
3. Grate area
4. Operating cost.

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

- Stokers
- Solid Fuel Firing
- Chain grate stokers
- Travelling system

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. Load fluctuations.
5. Reliability and 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
Mechanical stokers are used to fire almost all kinds of coal. A stoker consists of a power feeding mechanism and grate. Stokers are mainly classified into spreader stokers, underfeed stokers, vibrating grate stokers and travelling grate stokers. Among these types, spreader stokers are receiving the greatest interest and sales effort of any stoker type.

#### Advantages of stoker firing
1. All variety of coals can be fired
2. System is reliable and requires less maintenance.
3. It produces less smoke.
4. A greater flexibility of operations assured
5. Generally, it requires less building space.

#### Disadvantages
1. Construction is complicated
2. In case of larger units, the initial cost may be higher than that of pulverised fuel.
3. The system cannot meet any sudden changes in the steam demand

### 1.5.2 Classification of stoker firing

Automatic stokers are classified as
1. Over feed stokers
2. Under feed stokers.

**Overfeed stokers:**
In case of overfed stokers, the coal is fed in to the grate above the point of air admission. These are used for large capacity boilers where pulverized coal is being used. The mechanism of combustion in overfeed stokers is described below.

1. The air from ED fan with its water vapour content from atmosphere enters the bottom of the cograte under pressure. As air passes through the grate, it absorbs heat from ash and grate itself; hence cools both of them. Then the hot air passes through a bed of incandescent coke, where O2 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 O2 present in the air disappears in the incandescent region for a fuel bed of 8 cm deep. Hence no free oxygen will be present in the gases leaving the incandescent zone. Water vapour entering with air also reacts with carbon to form CO, CO2 and free H2. While travelling through incandescent region, some of the CO2 reacts with coke.

**Underfeed stokers**
In this type, the coal is admitted into the furnace below the point of air admission. i.e., both coal and air move in the same direction. This type is suitable for burning the semi-bituminous and bituminous coals.

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 bed of the 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 into the incandescent zone by passing through the ignition zone.

**Principle of underfeed stoker**

In incandescent zone, the reactions are similar to overfeed system except some breaking of the 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 is discharged into the furnace. It contains the constituents similar to overfeed stokers. This secondary air is supplied at a very high speed to create turbulence in order to facilitate complete combustion. At the bottom of the stoker, the ash is at higher temperature than the overfeed system.

**1.5.3 Types of over feed strikers**

The over feed stokers are mainly classified into two types.

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

The travelling grate stoker may be of chain grate type or bargrate type. These two, differ only in the construction of grate. The chain grate stoker employs an endless chain which is constructed to form a support for the fuel bed. The travelling grate stoker consists of grate bars carried by steel chains. In both the cases, the chain travels over two sprockets, one at the front end and other at the rear end of the furnace. The front sprocket is connected to a variable speed driving mechanism. Depending up on the type of the coal burned, the grate has air openings in the range of 20 to 40 percent of the total area. Exhaust air required for combustion is admitted through the air inlet situated below the grate. A travelling type chain grate stoker is as shown in figure. It consists of an end less chain which forms support for the fuel bed. The two sprockets, one at the front end of the furnace and connected to variable speed driving mechanism and other at the rear end, carries an end less chain as explained earlier. The speed of the stoker is 15 cm to 50 cm per minute. Coal is fed by gravity from a hopper located at the front of the stoker. The fuel depth on the grate is regulated by a hand adjusted gate. The fuel bed thickness can be regulated either by adjusting the opening of the fuel grate or by controlling the speed of the stoker driving motor i.e., the grate speed changes the rate of coal feeding into the furnace. The combustion control automatically regulates the grate speed to maintain steam pressure. The ash with combustible matter is carried over the rear end of the stoker and then disposed into the ash pit. The air required for combustion is admitted from the under side of the grate and the secondary air is supplied above the grate as shown in figure. Air dampers are used to control the supply of air to various zones. The grate should be saved from being over heated. For this, the coal should have sufficient ash content which will form a layer on the grate. Practically there is no agitation of the fuel bed, non caking coals are best suited for this type of stoker. These can burn about 150 kg of
coal per m² per hour with natural draught and from 200 to 300 kg of coal per m² per hour with forced draught.

2 *Spreader stoker (Sprinkler stoker)*

This type of stoker can burn any type of coal from lignite to semi anthracite. In this type of stoker, the grate is used only to support an ash bed and move it out of the furnace. The coal burns partly in suspension and partly on the grate. It consists of a variable feeding mechanism which throws the coal uniformly on the grate. The air required for combustion is supplied through the holes in the grate. The spreader distributes coal in the furnace and fine particles of coal burn in suspension and remaining falls on the grate.

**Furnace**

The FD fan is used to supply primary air to burn coal on the grate, volatile matter and finesuspended particles of coal. The secondary air or over fire air to create turbulence for proper combustion of fuel through nozzles which are located directly above the ignition arch. The unburnt coal and ash are deposited on the grate and are removed periodically to remove the ash from the grate.
The feeder used in the feeding mechanism may be a reciprocating mm or endless belt which supplies coal to the spreaders in a continuous stream. The feeder speed may be varied to control the combustion as per load on the plant.

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

This stoker can be used for boiler capacities from 70000 kg to 140000 kg of steam per hour. The coal size used should range between 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 action of oxygen and consequently accelerating combustion. The conventional or stoker firing methods were 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. Wide variety and low grade coal can be burnt easily.
3. Practically, it is free from slagging and clinkering problems.
4. The rate of coal feed can be regulated properly resulting in fuel economy.
5. The combustion rate is faster due to greater surface area of coal per unit mass of coal. It means more coal surface is exposed to heat and oxygen. This decreases, excess air required for complete combustion and also decreases fan power.
6. The external heating surfaces are free from corrosion and fouling.
7. The use of highly preheated secondary air (3500°C), results in rapid flame propagation.
8. There are no stand by losses due to banked fires.
9. In the furnace, moving parts are not subjected to high temperature. Increases system life.
10. There is an increased rate of evaporation and higher boiler efficiency due to complete combustion of 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. The flame length is less due to turbulence created by the burners in the furnace. Thus the Volume of furnace required is considerably less.
Disadvantages
1. The system requires many additional equipments and also coal preparation plant, thus increasing the capital and operating cost.
2. This system requires skilled operators.
3. As coal burns like a gas, there will always be danger of explosions.
4. A special equipment is required to start the system.
5. It requires large buildings space, especially in case of central system.
6. High working temperature causes rapid deterioration of the refractory surface of the furnace.
7. A special care is to be taken while storing coal in powdered form to protect it from fire hazards.

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

**Unit system or Direct firing system**
Most of the power plants with pulverised coal as the fuel are being installed with un pulveriser. In this system each burner or a group of burners and the pulveriser constitute a unit. The overhead bunker supplies raw coal by gravity into a feeder where it is dried with the help of hot air. Then the coal passes on to the pulverising mill where it is crushed to the required size (fine powder). The feeder supplies coal to the pulverising mill at a variable rate governed by the combustion requirement of the furnace and steam generating rate required in the boiler. The primary air from the ID fan carries pulverised coal from the mill to the burner through delivery pipe. In the separator, the big coal particles are separated from the fine dust and the slag again falls down in to the mill. Before the fuel enters in to combustion chamber, the secondary air is supplied to the burner as shown in figure.

Advantages
1. It has greater simplicity and permits easy operation.
2. It requires less space, less capital and operating costs.
3. It is cheaper than central system.
4. It permits direct control of combustion from the pulveriser.
5. In case of replacement of stokers, the old conveyor and bunker equipment may be used.
6. Better fuel feed into the furnace is possible.
**Disadvantages**

1. The power consumption is high per ton of the load at part load. The mill operates at variable load, a condition not conducive to best results.
2. When compared to central system, it has less flexibility.
3. With load factors common in practice, total mill capacity must be higher than for central system.
4. The fan handles air and coal particles and results in excessive wear and tear of the fan blades.
5. In case of failure of auxiliaries of one of the burners, the burner has to put off as there is no reserve capacity.

**Central system (Bin system):** This system employs a limited number of large capacity pulverisers at a central point to prepare coal for all the burners. The bin system was widely used before pulverising equipment became reliable enough for continuous steady operation. As it consists of many stages of drying, storing, transporting etc., the bin system is subject to fire hazards. Nevertheless, it is still in use in many plants. The arrangement of the system is shown in the next paragraph. The crushed coal from the raw coal bunker is passed to the drier by the action of gravity. The coal is dried either by using hot gases, preheated air or bled steam. Then the feeder supplies coal to the pulveriser. The air supplied from J.D. fan carries pulverized coal from the pulveriser mill and the pulverised coal is separated in the cyclone separator. A fabric bag filter is used to separate and exhaust the moisture-dried air to the atmosphere and discharge the pulverised coal to storage bins (central bunker), through conveyor. This system uses all the equipments as used in unitsystem with higher capacity of each part. In addition to other equipments, the system also uses storage bins. The pulverised coal is fed to the various burners through separate feeders. The bin may contain from 12 to 24 hours of supply of pulverised.

**Advantages**

1. The system is more reliable, as the failure of the coal preparation unit does not immediately affect the plant operation.
2. The quantities of fuel and air can be regulated accurately and separately. This leads to greater degree of flexibility.
3. The system offers good control of coal fineness.
4. Due to the presence of storage bin between mill and burner, the pulveriser may work at constant load.
5. It requires less labour.
6. It consumes less power per tonne of coal handled.
7. The fan handles only air, hence there is no problem of excessive wear and tear of the fan blades.
8. Burners can be operated independently of the operation of the coal preparation plant.

**Disadvantages**
1. The initial cost is high and it occupies a large space.
2. The auxiliaries used in the system consume large power.
3. There is possibility of fire hazard of stored pulverised coal.
4. The system uses driers.
5. For the same capacity, operation and maintenance costs are higher than unit system.
6. The coal transportationismuch more complex.

### 1.6.1 Pulverised Coal burners

The function of coal burner is to fire the pulverised coal from the mill, along with the primary air in to the furnace. The coal is pulverised in a mill and is carried by the primary air to the furnace and the primary air is only about 20% of the total air required for combustion. Before the coal enters in to the furnace, additional air known as secondary air is to be supplied for proper and complete combustion of coal. The secondary air is supplied separately around the burner or elsewhere in the furnace. The proper utilization of pulverised coal depends upon the ability of burners to produce uniform mixing of coal and air and turbulence within the furnace. Ignition take place: by means of radiation and flame propagation from the fuel, already burning in the furnace. The burner should maintain stable ignition of the mixture and control the shape of flame and its travel in the furnace. The mixture must move away from the burner at the rate of flame front travel.

The pulverized coal burners should satisfy the following requirements.
1. There should be thorough mixing of coal and primary air and the mixture is to be fired into the furnace properly with secondary air.
2. It should create proper turbulence and maintain stable ignition of the mixture in the furnace.
3. It should control the flame shape and its travel in the furnace.
4. The coal and air mixture should move away from the burner at the rate equal to flame travel in order to prevent flash back in the burner.
5. The burner must have adequate protection against overheating, internal fires and excessive abrasive wear. The performance of the pulverised coal burner is depends up on the
Pulverised coal burners may be classified as follows:

1. Longflame burners
2. Turbulent burners
3. Tangential burners

**Longflame burners:** These are also known as U flame or stream lined burners. These burners are suitable for furnaces with low volatile coal, and produces a long flame path for slower burning particles. The arrangement of primary air and coal flow and the supply of secondary air is as shown in figure. The supply of tertiary air near the burner forms an envelope around the primary air and fuel and helps in better mixing. The mixture is discharged vertically in one stream from the burner without turbulence and forms a long flame. The supply of secondary air at a right angle to the flame helps in better and rapid combustion of the mixture.

**Turbulent burners**

It is also known as shortflame burner. These burners are set into the furnace walls and horizontally or at some inclinations as shown in the figure. The fuel-air mixture and secondary hot air arranged to pass through the burner in such a way that there is good mixing and mixture is projected in highly turbulent form in the furnace. Due to this, there is an intense burning of the mixture and combustion is completed in a short distance. In comparison with other burners, bituminous coal and a long penetrating flame or short intensely hot flame may be obtained. This burner suitable for high volatile coals and is used in all modern power plants.

**Tangential burners**

In this case, four burners are arranged at four corners of the furnace and they discharge the fuel air mixture stream tangent to an imaginary circle in the centre of the furnace. The swirling action produces intense turbulence and thorough mixing of fuel and air so that combustion is completed 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. Sometimes the burner tip may be angled through a small vertical arc (120°). This arrangement helps to raise or lower position of molten ash in the turbulent combustion region in
the furnace. The gas temperature at the furnace aperture can be controlled with this method, so that a constant super heat temperature of steam can be maintained. The furnace is completely filled with flame by tilting the burners downward. This decrease of furnace exit gas temperature and heat given to the super heater. When burners are tilted upward, the heat given to superheaters, of that depending on the load, a constant steam superheat temperature can be maintained.

1.7 Pulverisers: (Pulverising mills)
The function of pulveriser is to grind the raw coal to increase its surface exposure and hence to accelerate the combustion without using large quantities of excess air. It is the most important part of the pulverised coal system. The satisfactory performance of the pulverised fuel system depends on the performance of the pulverisers. The pulveriser should deliver the rated tonnage of coal, and should consume nominal rate of power. It should be quiet in operation and should pulverise the fuel to satisfactory fineness over a wide range of capacities. Coals with low volatile content should be pulverised to a higher degree of fineness than those with higher volatile. It is wasteful to energy to pulverise coals finer than required to obtain satisfactory combustion. The three stages of pulverizing process of coal are i) feeding, ii) drying and iii) grinding. The feedingsystem regulates the fuel feed rate as per load on the plant and required air rate (primary air)for drying and then projects the pulverized fuel and primary air stream into the combustion chamber through burner. Dryers are the integral part of pulverising unit to remove moisture content of the coal. The air preheater forces hot air at temperature of 350°C into the pulveriser. Then it is mixed with coal as it is being circulated and ground. Pulverisers are the heart of the equipment for preparing pulverized coal. The grinding is performed by impact, attrition, crushing or combination of these. Based on the method of achieving grinding, the pulverisers are classified into:

1. Attrition mills
   i. Bowl mills, ii. Ball mills
2. Impact mills
   i. Ball mills, ii. Hammer mills,
1.7.1 Bowl mills

The bowl mill is widely used for grinding coal. The pulveriser shown in figure 1.21 has grinding elements consisting of stationary rollers and a power driven bowl in which pulverization and intermediate sizes of coal are picked up from the top by a stream of heated primary air and is carried into the classifier above for classification. The vanes of the classifier return the coarse particles of coal. Through the centre cone of the bowl for further grinding, the coal which has been pulverized to the desired fineness passes out of the mill, through the fan and is carried to the burner. The automatic control changes the coal supply to the bowl of the mill by adjusting feederspeed and the flow of primary air by regulating a damper in the line from the pulveriser to the fan. The heavier coal particles are thrown over the side into the space below the bowl due to centrifugal force and are discharged to a separate place.

This is also known as a contact mill and it crushes coal between two moving surfaces, balls and races, by attrition. It consists of stationary and power driven elements, which are arranged to obtain a rolling action with respect to each other. The coal passes between the rotating elements again and again, until it has been pulverized to the desired fineness. The grinding pressure is maintained by adjustable springs. The coal is crushed between two moving surfaces namely balls and races. The balls roll in a race running over a surface. The upper race is a stationary one and a worm and a gear drives the lower rotating race. The coal is to be fed in to the inner side of the races. The coal is crushed to the powdered form between the moving balls and races. The hot air supplied picks the coal dust as it flows between the balls and races, and then enters the classifier. The classifier separates the oversized particles and returns them for further grinding and the coal required size are discharged from the top of the classifier.

The grinding elements of these mills are protected from excessive wear and possible breakage by heavy foreign objects in the coal. These heavy particles resist the upward thrust of the stream of primary air and collect in a compartment in the base and are to be removed periodically.

The coal supply to the burner is automatically regulated by the combustion control. Additional coal is required, the flow of primary air is increased and its high velocity in the burner carries additional coal to the burner.

Advantages
1. Lower capital cost
2. Lower power consumption
3. Lesser space required
4. Lower weight.

**Disadvantages**
  1. These mills have greater wear compared to other types.

### 1.7.2 Ball mills

The diagram of a ball mill using two classifiers is as shown in figure 1.14. It consists of slowly rotating horizontal cylinder or drum which is partly filled with various sized steel balls. Sizes vary from 2.5 to 5 cm in diameter. The feeders feed the raw coal (6 mm in size) into the classifiers from where it passes over a screw conveyor to move into the cylinder. As the cylinder rotates, the coal mixes with the steel balls and gets pulverised due to the attrition and impact. Hot primary air is blown over it, to carry the pulverised coal to the classifiers, where sharp changes in the direction of the mixture throw out the coarse (over sized) particles for
regrinding. Classifier, coal and air mixture moves to the exhauster fan and then supplied to the burners. The mill is reliable and requires less maintenance, but it is bulky and heavy in construction. It consumes more power and is not suitable for wet coals due to poor air circulation. In this mill, metal and other foreign matter present in the coal will not affect the grinding elements. The mill contains sufficient quantity of coal, thereby forms a coal reservoir. This prevents fire from out due to slight interruption in fuel feed caused by coal clogging in bunkers or spouts. This is suitable for a wide range of coals such as anthracite and bituminous coals, which are difficult to pulverise.

**Advantages**
1. It may be directly coupled to the motor and hence operates at high speed.
2. The power required to drive the pulveriser is nearly proportional to the coal pulverized over a wider range of rating.
3. It requires minimum floor area as the fan is the integral part of the mill.

**1.8 Coal handling**
Coal handling equipment is one of the major components of plant cost. The coal handling equipment should satisfy some of the requirements such as minimum maintenance, reliability, simplicity and should wear less due to abrasive action of coal particles.

The various steps involved in coal handling are as follows:
1. Coal delivery
2. Unloading
3. Preparation
4. Transfer
5. Outdoor storage (dead storage)
6. Covered storage (live storage)
7. In-plant handling
8. Weighing and measuring
9. Feeding the coal in to furnace.

1. **Coal delivery:** The coal may be delivered from the supply points by using ships or boats when the power station is situated near the sea or river. The rail or trucks may be used to
deliver the coal when the power station is situated away from the sea or river. The trucks are used, when railway facilities are not available near the power station.

2. Unloading: The type of equipment used to unload the coal in the plant depends up on how the coal is received at the power station, i.e., by road, rail, or ship. If trucks are used to deliver the coal, there is no need of unloading device as the same trucks are used to dump the coal to the dead storage. Coal handling becomes easier, if lift trucks with scoop are used. If the coal is handled by railway wagons, ships or boats, unloading may be done by cranes, rotary cardumpers, grab buckets, coal accelerators, portable conveyors, self-unloading boats, etc.

3. Preparation: When the coal received at the site is in the form of big lumps (not of proper size), it is to be prepared before feeding to the combustion chamber by using the equipments:
   i) Breakers
   ii) Crushers
   iii) Sizers
   iv) Dryers
   v) Magnetic separators

   The coal crushers are used to prepare the coal of required size before supplying to the furnace. The coal which does not require sizing is to be passed. The sizers separate the unsized coal particles and return to the crushers. The driers are used to remove the excess freemoisture from the coal by passing hot flue gases through the coal storage. The magnetic separators are used to remove the iron scrap and other foreign particles from the coal, before supplying to the storage 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. Flight conveyors.

(a) Belt conveyors:
It is a method of transporting large quantities of coal over a large distance and used in medium and large power plants. The figure shows a pair of end drums or rollers. The belt is made of rubber, canvas, or balata. The end drums are supported by a series of rollers provided at regular intervals. These conveyors can carry the coal with an inclination up to 200°.
horizontal with an average speed of 60 to 100 ml/min. The load carrying capacity of the belt may range from 50 to 100 tonnes/hour. It can transfer the coal over a distance of 400m.

(b) Screw conveyor:
The screw conveyor consists of an endless helicoid screw fitted to a shaft. The screw shaft is driven by some mechanism at one end and the other end of which is supported in a bearing. The screw while rotating in a trough or housing, transfers the coal from feed into the discharge end. This conveyor discharges 125 tonnes of coal per hour. The screw diameter ranges from 15 cm to 50 cm and its speed varies from 70 to 120 rpm. This system is suitable to transfer coal over short distance and where the enough space is not available for the use of other equipments.

Advantages
1. The initial cost is low
2. It requires minimum space
3. It discharges coal at elevated places

Disadvantages
1. It is not suitable for large capacity stations.
2. It consumes more power
3. There is considerable wear of screw and this reduces life of conveyor

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

(d) Grab bucket conveyor: The purpose of grab bucket elevator is to lift and transfer coal on a single rail or track from one point to the other. It can be used with crane or tower and transfer coal to overhead bunker or storage. It has the capacity of 50 to 100 tonnes/hr. Its use is justified only when no other.

6. Inplant handling
The coal may be brought from dead storage to covered or live storage. It also refers to handling of the coal between final storage and the firing equipment. It includes the equipment such as belt conveyors, 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
equipments used 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 modern power stations, huge quantity of coal is used
which results in thousand tonnes of ash per year. A 200MW capacity power plant using
indian coals The arrangements shown in figure 1.31 and is generally used for low capacity power
plant which uses coal as the fuel

1.9.1 **Mechanical handling system**
The hot ash released from the boiler furnace is first cooled by passing through water
trough and then it is transported to an ash bunker by using belt conveyor. The trucks are used to
carry the ash from bunker to the dumping site. The life of this system is 5 to 10 years and
maximum

1.9.2 **Hydraulic system Advantages**
In this system, ash is carried with the flow of water with high velocity through a channel.
finally discharged into the sump. This system is again subdivided into 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 the trough carries
ash to pass through a screen where water gets separated from ash. The separated is again pumped
back to the trough for reuse and ash is carried to the sump. This system capacity of 50 tonnes/hr
and carries ash over a distance of 500m. Boilers

Advantages of Hydraulic system
1. Its clean and dust less and totally enclosed.
2. The system is also suitable to handle stream of molten ash.
3. Its capacity is large and there fore more suitable for large thermal power plants.
4. The components of the system do not come in contact with ash
5. It can discharge the ash at a large distance from the power plant.

**Advantages:**
1. It ensures dust less operation as the materials are handled in an enclosed conduit and hence eliminates the dust nuisance while handling fly ash and dust.
2. The system is free from spillage and rehandling.
3. The materials are handled in the dry state and discharged to the storage bin in the same state. This eliminates the chance of ash freezing or sticking in the storage bin and the material can be discharged freely by gravity.
4. The system is highly flexible.

**Disadvantages:**
1. Labour and maintenance charges are high due to large amount of wear and tear in the conveying pipe.
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 used in boilers of smaller capacities. It is created by the density difference between the atmospheric air and 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 upon chimney height and average temperature of hot gases in the chimney. The draught obtained may be insufficient to overcome the losses in the system. A chimney is a vertical tubular structure of masonry, concrete, brick or steel. It is built close to a column of hot gases to produce the draught and carries the products of combustion to such a height which is enough to prevent air pollution. The chimney draught depends upon the temperature difference of hot gases in the chimney and cold air outside the chimney. The chimney mainly serves two purposes (i) It produces the draught and makes the air and gas to flow through the fuel bed, furnace, boiler passes and various other equipments. (ii) It discharges products of combustion to a certain height to prevent air pollution. In modern steam power plants, chimney is only used to discharge gases at a certain height and is not used for creating draught. The use of chimney draught increases, the flue gas temperature leaving the combustion chamber and thereby reduces overall efficiency of the power plant.
Forced Draught
The figure 2.12 shows the arrangement of various components in a forced draught system. It uses a 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 is above atmospheric, the system is known as positive draught or forced draught system. In this system, Chimney is used only to discharge the flue gases at a certain height into the atmosphere to prevent contamination. The draught produced by Chimney is not significant, hence tall Chimney is not required. Most of high rating combustion equipments use forced draught fans for supplying to the furnace. 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, combustion products to be discharged to the atmosphere. The pressure in the furnace is below that of the atmosphere to induce the flow of combustion air. As the fan is located at the base, the stack, it has to handle hot combustion gases. Hence, it requires greater power than the draught fans. In addition, it has to withstand the corrosive action of combustion products and ash.

**Balanced Draught.**
It is a combination of forced and induced or forced and natural draught. The forced fan delivers air to the furnace and an induced draught fan or a chimney produces draught to remove the gases from the unit.
In forced draught system, furnace opening for inspection or firing is not possible, furnace opens, the air inside furnace which is at high pressure, tends to blow out and this causes blowing out of the fire completely and thus the furnace stops.
In induced draught system, the furnace opening for firing or inspection is not possible, as the atmosphere enters into the furnace due to lower pressure inside the furnace. This reduces effective draught and dilutes the combustion.

Furnace
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 balanced draught system and pressure distribution through the system. The forced draught fan pushes the atmospheric air through the fuel bed on to the top of the grate, thus over comes the resistance of fuel bed. This also provides sufficient air supply to the fuel bed for complete combustion. The induced draught fan sucks in the gases from the furnace and discharge them to the atmosphere through chimney. This maintains a pressure in the furnace just below atmosphere. This prevents blow-off of flames as the air leakage is inwards. In the furnace, the pressure is near to atmospheric and hence there is no chance of blowout of flames. Below the grate, the pressure is greater than atmospheric 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 uses low grade fuels, as the intensity of draught is high.
4. The regulation of airflow as per requirement is possible by changing the draught pressure.
5. Plant efficiency can be improved.

1.11 Cooling Towers and Ponds

The modern steam power plants rejects 10 to 15% of heat input to the atmosphere through boiler chimneys. At least 50% of the heat input is rejected as unavailable energy to a cooling watersystem through the steam condensers. In nuclear power plants, about 67% to 68% of the heat generated within the reactor is rejected to the water through steam condensers. The main steam condensers serve two purposes, one is to remove the rejected heat from the plant cycle and other is to keep the turbine back pressure at the lowest possible level. It transfers latent heat of the exhaust steam to water, which is exposed to the atmosphere. Therefore, the steam condensers require a huge quantity of water for cooling purposes. In an open system, the water requirement is about 5 times the flow of steam to the condenser. Approximately, a condenser uses 50 gallons of water per KWh for cooling and about 5% additional quantity is required for other purposes such as ash quenching, beating cooling, and boiler make-up water etc. The high cost of the water makes it use cooling towers for water cooled condensers. A 1000 MW capacity plant uses about 100 thousand tons of circulating water per day even with the use of cooling towers. Thus, the source of cooling water should supply this huge quantity of cooling water.

The cooling water may be obtained from:
1) River or 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 water on the upstream side of the river and delivers it to a condenser. The condenser discharges water at 5 to 10°C greater than inlet temperature, to the downstream side of the river. This system is used when the plant is located on the bank of river or lake. The inlet and discharge points should be 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 collected from river during flood or when sufficient water is available. The condenser discharges hot water to a spray pond or cooling tower cooling purpose and uses same water again and again. Additional water is required from source to compensate evaporation losses and carryover losses in towers.

Cooling ponds

The spray ponds or cooling towers are recommended when the power plant is not located. The simplest type of cooling water system is the pond or spray pond, which rely upon winds that blow across the ponds and cool fine sprays of water by evaporation. The heat is discharged through a pipeline to a pond, which is a large shallow pool and is exposed to the atmospheric air. The cooling of hot water is effected by the air blowing across the surface of the pond. The hot water dissipates heat to the air by convection and evaporation processes. Some water particles evaporate by absorbing latent heat of vaporization to cool the remaining water. Evaporation and windage loss is about 2 to 3%. The rate of cooling may be increased by increasing the area of the pond. The use of spraying system overcomes such difficulty. The spray system increases the contact of water with atmosphere by spraying the water into the air over the pond. A nozzle is used for this purpose and the pond is known as spray pond and a pond without spray 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. The nozzles are arranged in such a way that there is no interference between the sprays 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 the surface of water. The water pressure in the nozzles is from 0.21 to 1.5 bar. The hot water from the condenser is sprayed through the nozzle over a large area. The nozzles break water into a spray. The whirling motion of the nozzles results in better atomization of the water and produces cooling effect, which is mainly due to evaporation from the surface of the water spray. Nozzles are placed to 2m...
distance between nozzles should be such that, there is no interference between the
differssprays produced by nozzles.

Cooling Towers:
The cooling towers are effectively used to cool the condenser water so that the powerstation may be located near the load centre to meet increased demand of electric power. The cooling towers are used when positive control on the temperature of water is required, space occupation is a considerable factor and the power station is located near the load centre and far away from the river. The purpose of cooling towers is to cool the hot water discharged from condenser and feed the cooled water back to the condenser. They reduce the quantity of cooling water required in the power plant.

The factors which affect the cooling of water in a cooling tower are

1) Temperature of air
2) Air humidity
3) Temperature of hot air
4) Dimensions of the tower (size and height)
5) Air velocity entering the tower
6) Plate arrangements in towers
7) Air accessibility over all parts of tower
8) Uniformity in descending water.

Depending upon design and plant loading, the quantity of cooling water required is 18 x 107 Kg per hour. In order to cool such huge quantity of water, large volumes of air are required. For example in a 750 MW plant, in order to dissipate the condenser heat 10<Y1th, e air mass flow rate ranges from 38.5 x 106 kg/hour to 45 x 106 kg/hour for a mechanical draught cooling tower.

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

Natural draught spray filled tower:
In this type, the airflows in the transverse direction and the circulation of which depend on the wind velocity. The water droplets are made to fall and the flow of air is crosswise to the flow of water. The water is cooled by air flowing across the tower. The use of spray nozzles increases the rate of cooling. The cooled water is then collected in a tank below the tower and then supplied to
condenser. These towers are suitable for diesel plants and small capacity power plants. Due to the limitation in the cooling range, suffers from the problems of high windage losses and there is no control over the outlet temperature of water. The capacity of this tower is limited to 50 to 100 liters/min per m² of base area and again it depends on the velocity of air.

Packed atmospheric cooling tower

*Natural draught packed type tower:*

The working of this tower is similar to that of previous ones except that the use of packings. The water descends vertically and airflow is crosswise, while descending water is broken into small droplets by packings. These towers are rarely used as the initial and maintenance costs are high.

High Pressure Boilers, Draught Cooling Towers and Accessories:

*Disadvantages:*

1) Its initial cost is high.
2) Seasonal changes in DBT and RH of air influence the performance of towers.

The use of this tower is favorable over mechanical towers in terms of saving in fan power, longer life and 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 closer approach to WBT, gives higher efficiency, requires less floor area and reduces windage and spray losses. Inspite of higher initial and operating cost, the mechanical draught tower boosts up overall plant economy. These towers are constructed in cells or units and the number of cells in the tower decides the capacity of the tower. The mechanical draught towers are independent of natural draught or wind velocity, and airflow is created by fans. The flow of air with high velocity increases efficiency of tower and rate of cooling.

*Forced draught towers:*
The arrangement of the forced draught tower is the interior structure is similar to natural draught tower, but the sides are closed to form an air and water tight structure. The air enters through an opening, which is water provided at the base of the tower and leaves the tower at the top. The fans provided at the base of the tower create airflow through the descending water in the tower. This type is preferred because the fans would operate on cooler air side and hence consume less power. The hot water from the condenser enters the Cold Nozzles and is sprayed over the packings as water out shown in figure. The raising air, cools the water and at the top, the draught eliminators remove entrained water 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 inlet during winter seasons. Therefore, for utility applications induced draught type towers are used in this type, the fan is located at the top of the tower where it exhausts the hot humid air to the 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 provided at the top of the tower to eliminate the water entrained from the air.
The factors, which influence the effective cooling of water are:

1) DBT and WET of atmospheric air
2) Inlet temperature of water
3) Size and height of tower
4) Air velocity and its quantity
5) Ammagement of the fill
6) Water distribution system

**Indirect dry cooling towers**

This system is also known as Heller cooling systems as it was first presented by Lazlo Heller in 1956.

The arrangement of the components is as shown in fig. 2.31. In this type, the condensation of exhaust steam takes place in a spray condenser by means of circulating water. The condenser discharges a major portion of water to the cooling coils and remaining which is equal to the exhaust steam from the turbine, is supplied to the boiler feed water circuit. A fan induces flow of air in the system as shown in figure cools the hot condensate in the cooling coils. The cooled water is then spread through the nozzle into the condenser. The steam from the turbine is condensed by coming in direct contact with water sprayed through the nozzle. Some of the pressure and elevation head is recovered by using a water turbine between the cooling coils and condenser. As there is no direct contact between circulating water and cooling air, no evaporation loss occurs in the system.

High Pressure Boilers, Draught Cooling Towers and Accessories

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**Advantages of Dry cooling towers**

1. There is no thermal pollution and evaporation loss of water.
2. It eliminates the necessity of locating the plant near the water source. The plant may be situated near to load centre.
3. The air pollution is reduced to a great extent.
4. It is free from windage loss, fog problem, evaporation loss etc.

**Disadvantages of dry cooling towers**

1. It uses large volume of air with large surface areas due to low heat transfer co-efficient
2. At high 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 Economizer is a heat exchanger which raises temperature of feed water by 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 use of an economizer improves the thermal 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 the exit temperature 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 an economizer 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 saving—maximum of 20% is
possible. In the economizer, the steam formation can be avoided by heating 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. Generally, economizer tubes are 45-70 mm in outside diameter and are made in vertical coils of continuous tubes connected between inlet and outlet headers with each section fed into several horizontal paths connected by 180° vertical bends for proper draining. The coils are installed at a pitch of 45 to 50 mm spacing, which depends upon the type of fuel and ash characteristics.

Advantages:
1) The temperature range between various parts of the boiler is reduced. This decreases stresses due to unequal expansion.
2) The use of economizer prevents cold water to enter into boiler and hence, prevents chilling of the boiler.
3) It reduces the consumption of fuel.
4) It reduces heat loss with flue gases thereby, increases thermal efficiency of the plant.
5) It increases the evaporation capacity of the boiler.
6) A large amount of soot and fly ash is deposited on the economizer tubes and scrapped off into the soot chamber. This reduces the emission of soot and fly ash.

Disadvantages:
1) Sometimes installation cost is high.
2) It is expensive in terms of maintenance and regular cleaning.
3) It uses extra floor space in the boiler. A simplified view of a return bend economizer. It consists of a series of steel tubes through which the feed water flows.

**Air preheaters**

There are two types of air preheaters: 1) Tubular type 2) Plate Type.

**Tubular Type Air Preheater:**
It consists of series of tubes through which the combustion gases pass with air passing around the outside of the tubes. The combustion gases transfer heat to the air and heated this preheated air is supplied to the furnace. The baffle plates deflect the direction of
airtraveals, thereby increases heat transfer by increasing the time of contact between hot gas and air. Steel tubes of 6 to 8 cm in diameter and 3 to 10 meter heights are commonly used. The air preheater may be provided with one or more passes for both air and gas in counter or cross flow, in vertical or horizontal arrangements. The smaller the tube diameter, larger the number of tubes, the greater the surface area for a given overall size. Smaller diameter tubes result in more compact heaters. Tube diameter to be used:

Super heaters

The boiler produces steam in the saturated condition. The steam in this condition should not be used in the turbine because, the dryness fraction of the steam decreases due to expansion in the 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 superheated steam contains more heat than that of saturated steam at the same pressure and the added heat provides more energy for the turbine for conversion to 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 remove the last traces of moisture (about 1 to 2%) from the saturated steam. It increases the overall cycle efficiency and prevents blade erosion by avoiding too much condensation in the last stages of the turbine. 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 diameter tubes 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 hot gases on the other side. Therefore, the tubes are dry except for the steam which circulates through them. Tubes overheating is prevented by designing the superheater to accommodate the heat 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 how heat is transferred from the hot gases to steam. In convective super heaters, the main mode of heat transfer between combustion gases and the super heater tubes is convection and these are located in convective 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 directly enters 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
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°C and atmospheric air temperature is 23°C. 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? Explain 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:
2. Power Plant Engineering, Domakundawar, Dhanpath Rai sons. 2003