Module-2

Steam Power plants

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2.1 Introduction

- A steam power plant is a thermal power station where the heat energy of the fuel is converted into electricity. The fuel used can be coal, oil, gas, etc.
- In a steam power plant, the boiler utilizes the heat of fossil fuel combustion to raise steam at high pressure and temperature. The generated steam is used to drive a steam turbine and produce electricity.

2.2 Efficiency

This type of power station has very high energy losses due to great heat loss in the boiler and condensor. the following equation is used to calculate power station efficiency:

$$\text{Thermal Efficiency, } \eta_{thermal} = \frac{\text{Heat equivalent of mechanical energy transmitted to turbine shaft}}{\text{Heat of coal combustion}}$$

The **thermal efficiency of thermal power plant** is nearly 30%. It means, if 1000 calories of heat energy is produced by coal combustion then only 300 calories will be flow to the turbine shaft. Maximum energy is lost by condenser and rest of energies are lost in flue gases, ash etc.

$$\text{Overall Efficiency, } \eta_{overall} = \frac{\text{Heat equivalent of electric power}}{\text{Heat of coal combustion}}$$

Overall efficiency =thermal efficiency × electrical efficiency

The overall efficiency of a thermal power plant is nearly 29% and it is less than the thermal efficiency because some energy is lost by alternator. Now some heat sharing device is used in modern super-critical-pressure steam power plant to increase the overall efficiency and the efficiency is reached nearly 50% using this device.

2.3 Selection of site for steam power plants

- To achieve overall economy in power generation, the following factors should be considered while selecting a site for a thermal power plant −

1.Supply of Fuel (Coal)

- The thermal plant should be located near the coal mines so that the transportation cost is minimum. Although, if the thermal power plant is to be installed at a place where coal is not available near the site, then care should be taken that adequate facilities exist for the transportation of coal.

2.Water Availability

- Since in a thermal power plant, huge amount of water is required for the operation. Hence, a thermal power plant should be located near a river or canal to ensure the continuous supply of water.

3.Transportation Facilities

- As a modern thermal power plant requires transportation of material (ex. coal) and machinery. Hence, the power plant should be well connected to the other parts of the country by rail, road, etc. so that adequate transportation facilities are available.

4.Type and Cost of Land

- The thermal power should be located at a place where land is cheap and the further extension is possible. As in a thermal power plant, heavy equipment are to be installed, therefore the bearing capacity of the land should be adequate.

5.Near to the Load Centres

- The thermal power plant should be located near to the centres of the load, so that the transmission cost is reduced. It is more important if DC supply system is adopted rather than AC supply system.

6.Distance from the Populated Area

- The thermal power plant should be located at a considerable distance from the populated area. Because, a large amount of coal is burnt in a thermal power station, which produces smoke and fumes that pollute the surrounding environment and may have adverse effects on the health.

7.Ash disposal facilities

As a huge quantity of coal is burnt, this results in a huge quantity of ash too. The ash handling problem is more serious as compared to handling of coal because it comes out very hot and is very corrosive. If not disposed properly it will result in environmental pollution and other hazards. Therefore there must be sufficient space to dispose this large quantity of ash.

8. Availability of workforce

During construction of plant, enough labour is required. The labour should be available at the proposed site at cheap rate.

9.Public problems

The plant should be away from the town or city in order to avoid nuisance from smoke, ash, heat and noise from the plant.

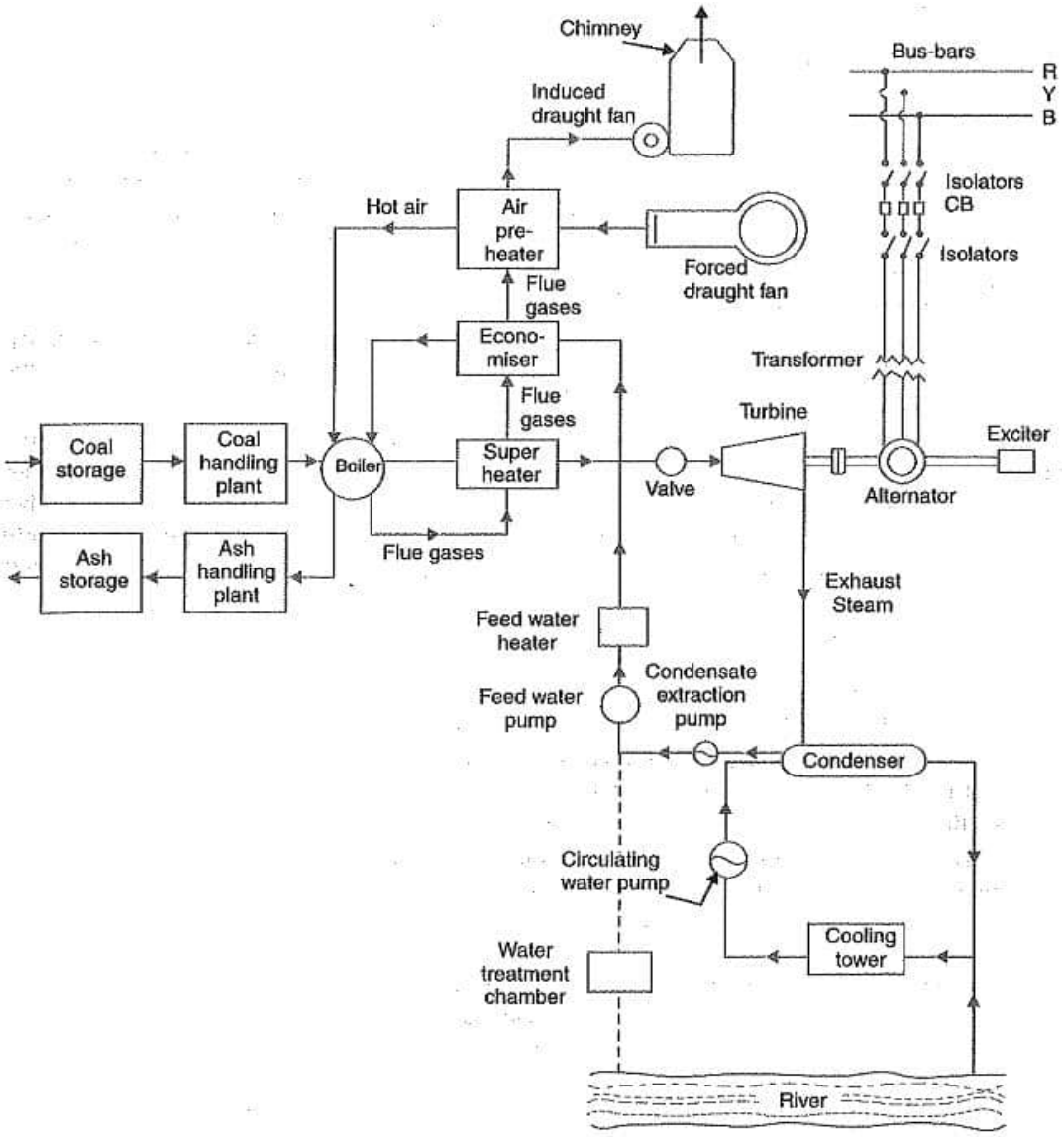
10.Future extension

A choice for future extension of the plant should be made in order to meet the power demand in future.

2.4Schematic Arrangement of Steam Power Plant:

The whole arrangement can be divided into the following stages for the sake of simplicity :

1.Coal and ash handling arrangement
2.Steam generating plant
3.Steam turbine
4.Alternator
5.Feed water
6.Cooling arrangement



Schematic arrangement of Steam Power Station

Fig. 2.1

1.Coal and ash handling plant:

The coal is transported to the power station by road or rail and is stored in the coal storage plant.

Storage of coal is primarily a matter of protection against coal strikes, failure of transportation system and general coal shortages.

From the coal storage plant, coal is delivered to the coal handling plant where it is pulverized (i.e., crushed into small pieces) in order to increase its surface exposure, thus promoting rapid combustion without using large quantity of excess air.

The pulverized coal is fed to the boiler by belt conveyors. The coal is burnt in the boiler and the ash produced after the complete combustion of coal is removed to the ash handling plant and then delivered to the ash storage plant for disposal.

The removal of the ash from the boiler furnace is necessary for proper burning of coal. It is worthwhile to give a passing reference to the amount of coal burnt and ash produced in a modern thermal power station.

A 100 MW station operating at 50% load factor may burn about 20,000 tons of coal per month and ash produced may be to the tune of 10% to 15% of coal fired i.e., 2,000 to 3,000 tolls.

In fact, in a thermal station, about 50% to 60% of the total operating cost consists of fuel purchasing and its handling.

2.Steam generating plant: The steam generating plant consists of a boiler for the production of steam and other auxiliary equipment for the utilisation of flue gases.

Boiler: The heat of combustion of coal in the boiler is utilised to convert water into steam at high temperature and pressure. The flue gases from the boiler make their journey through super-heater, economiser, air pre-heater and are finally exhausted to atmosphere through the chimney.

Superheater: The steam produced in the boiler is wet and is passed through a superheater where it is dried and superheated (i.e., steam temperature increased above that of boiling point of water) by the flue gases on their way to chimney. Superheating provides two principal benefits. Firstly, the overall efficiency is increased. Secondly, too much condensation in the last stages of turbine (which would cause blade corrosion) is avoided. The superheated steam from the superheater is fed to steam turbine through the main valve.

Economiser: An economiser is essentially a feed water heater and derives heat from the flue gases for this purpose. The feed water is fed to the economiser before supplying to the boiler. The economiser extracts a part of heat of flue gases to increase the feed water temperature.

Air preheater: An air preheater increases the temperature of the air supplied for coal burn-ing by deriving heat from flue gases. Air is drawn from the atmosphere by a forced draught fan and is passed through air preheater before supplying to the boiler furnace. The air preheater extracts heat from flue gases and increases the temperature of air used for coal combustion. The principal benefits of preheating the air are : increased thermal efficiency and increased steam capacity per square metre of boiler surface.

3.Steam turbine: The dry and super heated steam from the super heater is fed to the steam turbine through main valve. The heat energy of steam when passing over the blades of turbine is converted into mechanical energy. After giving heat energy to the turbine, the steam is exhausted to the condenser which condenses the exhausted steam by means of cold water circulation.

4.Alternator: The steam turbine is coupled to an alternator. The alternator converts mechanical energy of turbine into electrical energy. The electrical output from the alternator is delivered to the bus bars through transformer, circuit breakers and isolators.

5.Feed water. The condensate from the condenser is used as feed water to the boiler. Some water may be lost in the cycle which is suitably made up from external source. The feed water on its way to the boiler is heated by water heaters and economizer. This helps in raising the overall efficiency of the plant.

6.Cooling arrangement: In order to improve the efficiency of the plant, the steam exhausted from the turbine is condensed* by means of a condenser. Water is drawn from a natural source of supply such as a liver, canal or lake and is circulated through the condenser. The circulating water takes up the heat of the exhausted steam and itself becomes hot. This hot water coming out from the condenser is discharged at a suitable location down the river. In case the availability of water from the source of supply is not assured throughout the year, cooling towers are used. During the scarcity of water in the river, hot water from the condenser is passed on to the cooling towers where it is cooled. The cold water from the cooling tower is reused in the condenser.

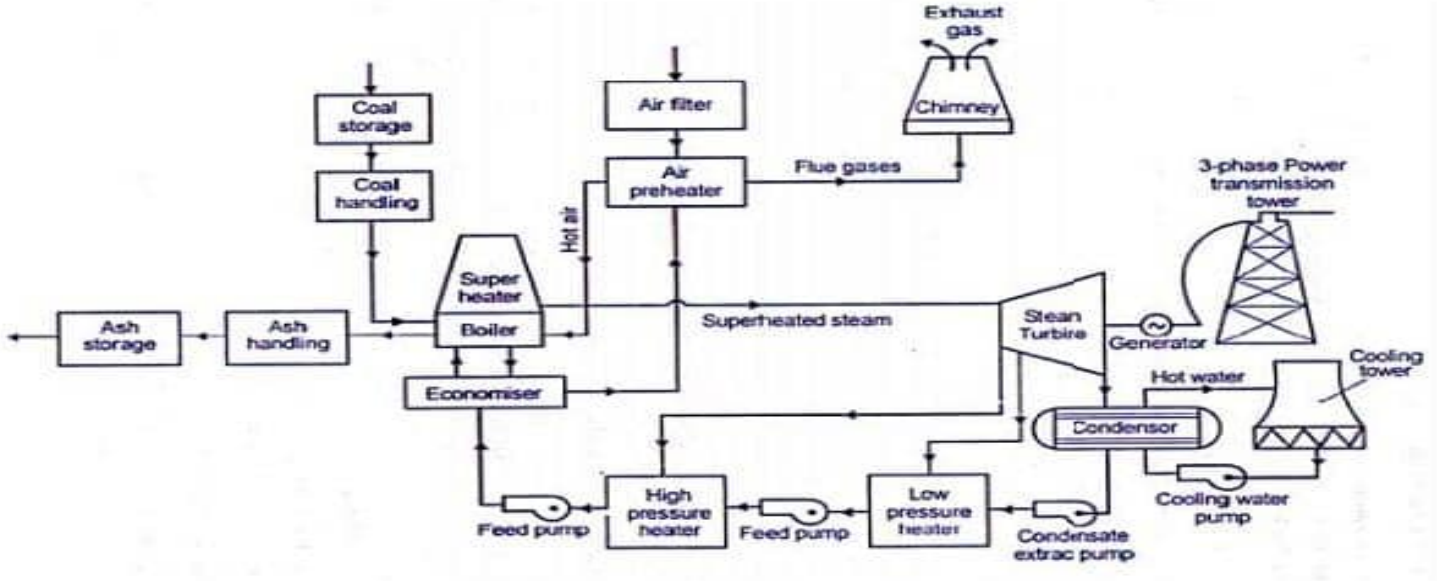
2.5 Advantages of Steam Power Plants :

- Fuel used is cheaper.
- They can respond quickly with changes in load on the plant.
- Space required is less compared to hydro power plants.
- A portion of steam can be used as process steam for various industries.
- They can be overloaded upto 20% without difficulty. Cost of electric power generation and its initial cost is less compared to diesel plants.
- Can be located near the load centre conveniently thus reduces the transmission line cost and loss of energy in transmission lines.

Disadvantages of Steam Power Plants :

- Operation and maintenance cost is high.
- Time needed for erecting of plant is high before it is put to operation.
- Large quantity of water is needed.
- Coal and ash handling poses a serious problem.
- The part load efficiency is low.
- Pollution causes health problems to workers and habitants near the thermal power plant.

2.6 Steam power plant equipment & layout



1.Steam Generator:

•A steam generator, also known as a once-through boiler, is a type of boiler that does not have a large water reservoir like traditional boilers.

•Instead of storing water, a steam generator passes water through tubes and heats it externally using a combustion process or electric heating elements.

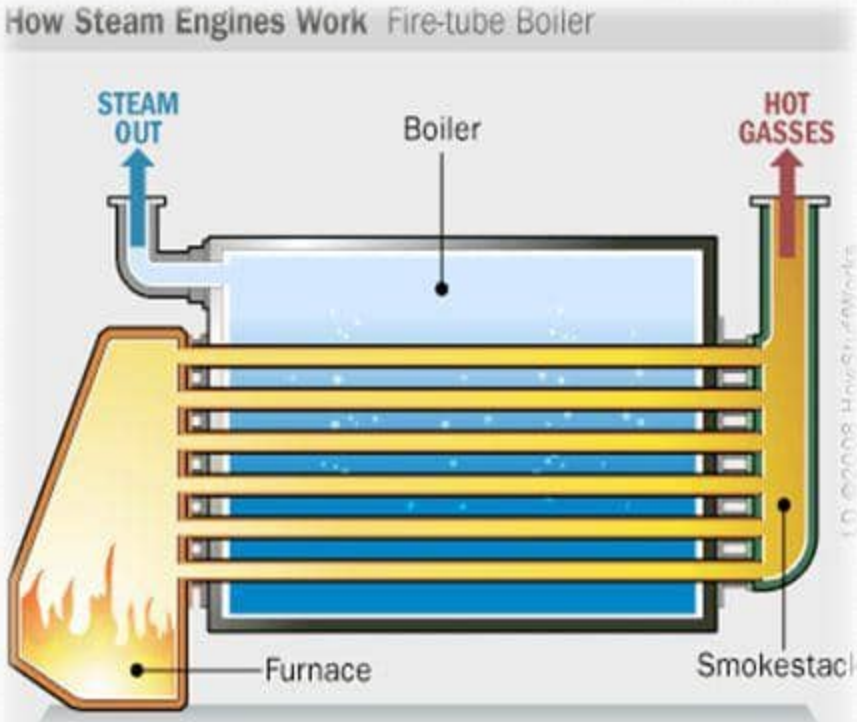
•As water flows through the tubes, it is quickly heated and converted into steam. This makes steam generators more compact and quicker to start compared to traditional boilers.

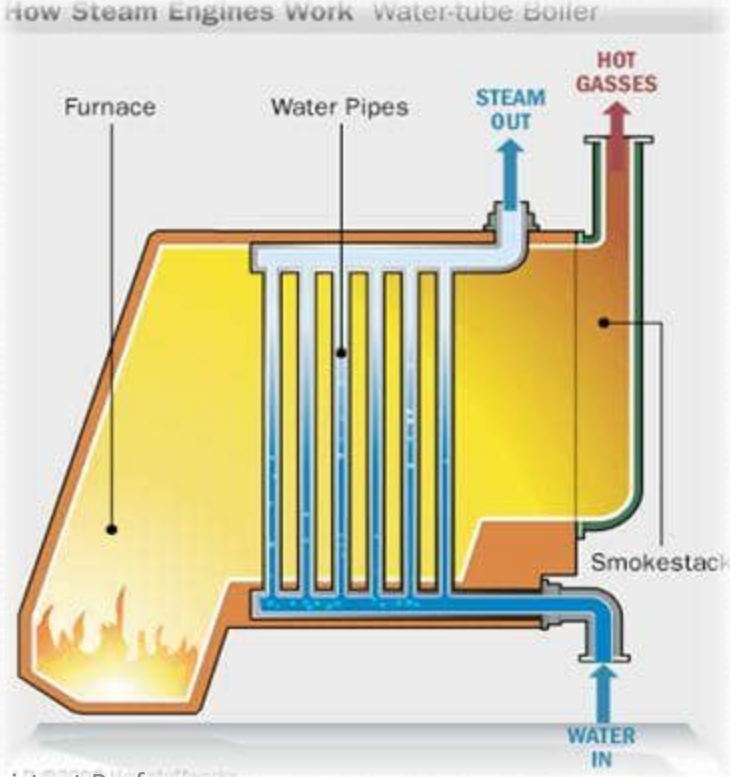
•Steam generators are commonly used in applications where rapid steam production and response time are critical, such as in nuclear power plants, industrial processes, and some marine applications.

Types Of Boilers

By Method of steam generation :

- Fire tube boiler.
- Water tube boiler.





Fire Tube Boiler:

•In a fire tube boiler, the hot gases produced by combustion pass through tubes surrounded by water in a cylindrical shell.

•The heat from the gases is transferred to the surrounding water, heating it and generating steam in the process.

•Fire tube boilers are typically used for low to medium pressure(18kg/cm2) applications and are known for their simple design and ease of maintenance.

•They are commonly used in small-scale industrial processes, heating systems, and locomotives.

•Relatively small steam capacities(12000 kg/hr)

•Operates with oil, gas or solid fuel

Water Tube Boiler:

•In a water tube boiler, water flows through tubes that are surrounded by hot gases produced by combustion.

•The heat from the gases is transferred to the water through the walls of the tubes, generating steam.

•Water tube boilers are known for their higher efficiency and ability to handle higher pressures compared to fire tube boilers.

•They are commonly used in power plants, industrial processes, and marine applications where high-pressure steam is required.

•Water tube boilers can be further classified into several types based on their design, such as package boilers, D-type boilers, and O-type boilers.

•Capacity range-120000kg/hr

2.Boiler furnaces:

•A boiler furnace is a chamber in which fuel is burnt to liberate the heat energy .

•It provides support & enclosures for the combustion equipment

•The boiler furnace walls are made of refractory materials such as fire clay, silica, kaolin etc.

Such materials have the property of resisting change of shape, weight or physical properties at High temperatures.

•The construction of boiler furnace varies from plain refractory walls to completely water cooled walls, depending upon characteristics of fuel used & ash produced, firing methods, nature of load demand, combustion space required ,excess air used, operating temperature, initial &Operating costs.

3. Superheater

Function:

•The primary function of a superheater is to increase the thermal efficiency of the power plant by raising the temperature of the steam.

•It achieves this by passing the saturated steam generated in the boiler through additional heating surfaces, typically coils or tubes, located in the path of the flue gases.

•As the steam passes through these heating surfaces, it absorbs more heat from the combustion gases, leading to an increase in temperature above the saturation point.

Significance:

•Superheated steam has higher energy content compared to saturated steam at the same pressure and is therefore more efficient for driving turbines.

•Higher steam temperatures result in increased turbine efficiency and power output, leading to improved overall plant efficiency and reduced fuel consumption.

•Superheating also helps to prevent erosion and corrosion in turbine blades by ensuring that steam remains dry and free of condensate.

Types:

Superheaters can be classified into two main types: radiant superheaters and convection superheaters.

- •Radiant superheaters are located in the combustion chamber or directly above the furnace and are exposed to high-temperature radiant heat from the burning fuel.
- •Convection superheaters are located in the path of the hot flue gases downstream of the boiler, where they absorb heat through convection from the gases.

The common methods used for controlling the superheat temperature of the steam are

1.Bypassing the furnace gas around the superheater
2.Tilting burners in the furnaces.
3.Auxiliary burners
4. Desuperheater using water spray
5. pre-condesing control
6.Gas recirculation
7. Twin furnace arrangement
8. Coil immersion in the boiler drum

4.Reheater:

•A reheater is a heat exchanger located in the steam path after the high-pressure turbine and before the intermediate-pressure turbine.

•Its primary function is to reheat the steam exhausted from the high-pressure turbine to a higher temperature before it enters the intermediate-pressure turbine.

5. Economizer:

•An economizer is a heat exchanger located in the boiler flue gas exhaust stack.

•It preheats the boiler feedwater using heat recovered from the hot flue gases exiting the boiler.

•Economizers are commonly used in steam boilers to recover waste heat and reduce fuel consumption, especially in large industrial boilers and power plants.

•Advantages of Economizer:

1.Feed water to the boiler is supplied at high temperature.hence fuel consumption is less

2. Thermal efficiency of the plant is increased.

3. Life of boiler is increased

4. Loss of heat in flue gases is reduced

5.Steam capacity is increased.

6.Air Preheater:

•An air preheater is a heat exchanger that preheats the combustion air supplied to the boiler furnace using heat recovered from the flue gases leaving the boiler.

•Preheating the combustion air reduces the energy required to raise the air temperature to the combustion level, resulting in improved boiler efficiency and reduced fuel consumption

- There are two main types of air preheaters: recuperative air preheaters, which use heat exchange surfaces to transfer heat from flue gases to the combustion air, and regenerative air preheaters, which use rotating heat storage media to achieve the same purpose.

Benefits:

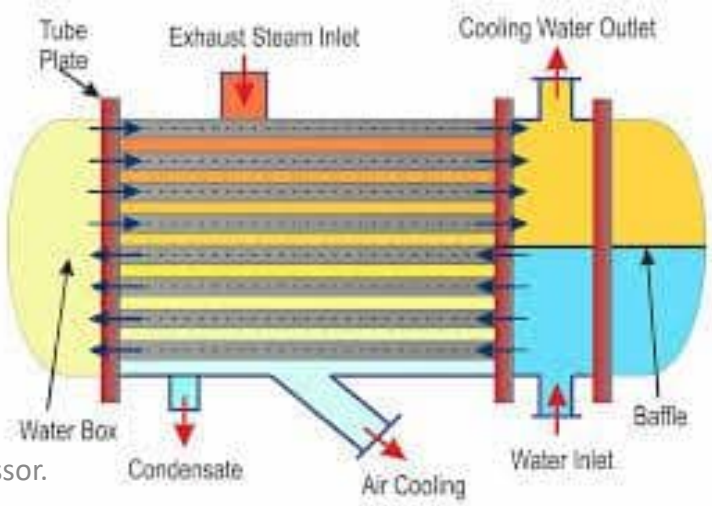
1.Improved combustion
2. Successful use of low grade fuel
3. Increased thermal efficiency
4. Saving in fuel consumption
5. Increased steam generating capacity of the boiler

7. Condenser

The primary function of a condenser in a thermal power plant is to convert the exhaust steam from the turbine back into water, ready to be reused in the boiler.After passing through the turbine, the steam loses its energy and becomes low-pressure, low-temperature steam. The condenser removes this heat from the steam, causing it to condense into water.

Surface condensers use a large surface area of tubes to facilitate heat transfer between the exhaust steam & the cooling water. These are the most common type of condenser used in modern power plants.

Jet condensers use a jet of cooling water to directly contact & condense the exhaust steam. While less common than surface condensers, jet condensers are still used in certain applications, particularly in smaller power plants & marine propulsion systems.



8.Evaporators

Evaporators convert the impure feedwater into vapor which is to condensed in a part of the system & added to the main condensate as pure distilled water.

Classified as : 1. Flash type 2. Film type & 3. Submerged type

9. Feed water Heaters

Feedwater heaters preheat the water that will enter the boiler, thereby reducing the amount of fuel needed to heat the water to its operating temperature. By utilizing waste heat from the power plant cycle, they improve the overall efficiency of the system.

Types: There are typically two types of feedwater heaters used in steam power plants: open and closed.

Open Feedwater Heaters: In open heaters, the extracted steam from the turbine comes into direct contact with the feedwater. Heat is transferred from the steam to the feedwater, raising its temperature.

Closed Feedwater Heaters: Closed heaters utilize a series of tubes or plates to separate the extracted steam and the feedwater. Heat is transferred through these surfaces without direct contact between the two fluids.

10. spray ponds and cooling towers

Function: Spray ponds, also known as cooling ponds or cooling lagoons, are large bodies of water designed to absorb waste heat from the condenser coolant (usually water) through evaporation.

Operation: Hot water from the condenser is circulated through pipes or channels and sprayed over a large surface area in the pond. As the water spreads out and comes into contact with the atmosphere, heat is transferred from the water to the air through evaporation.

Evaporative Cooling: The heat absorbed by the water causes it to evaporate, carrying away the excess heat. This process cools down the water, which can then be recirculated back to the condenser to absorb more heat from the steam cycle.

Cooling towers

Function: Cooling towers are heat rejection devices that transfer waste heat from the condenser coolant (usually water) to the atmosphere through evaporative cooling.

Operation: Hot water from the condenser is pumped to the top of the cooling tower and distributed over a fill material. As the water cascades down through the fill material, it is exposed to air moving upward through the tower.

Types: Cooling towers can be of various types, including natural draft (which relies on the buoyancy of heated air to induce airflow) and mechanical draft (which uses fans to force air through the tower). Mechanical draft towers are more common in large industrial applications.

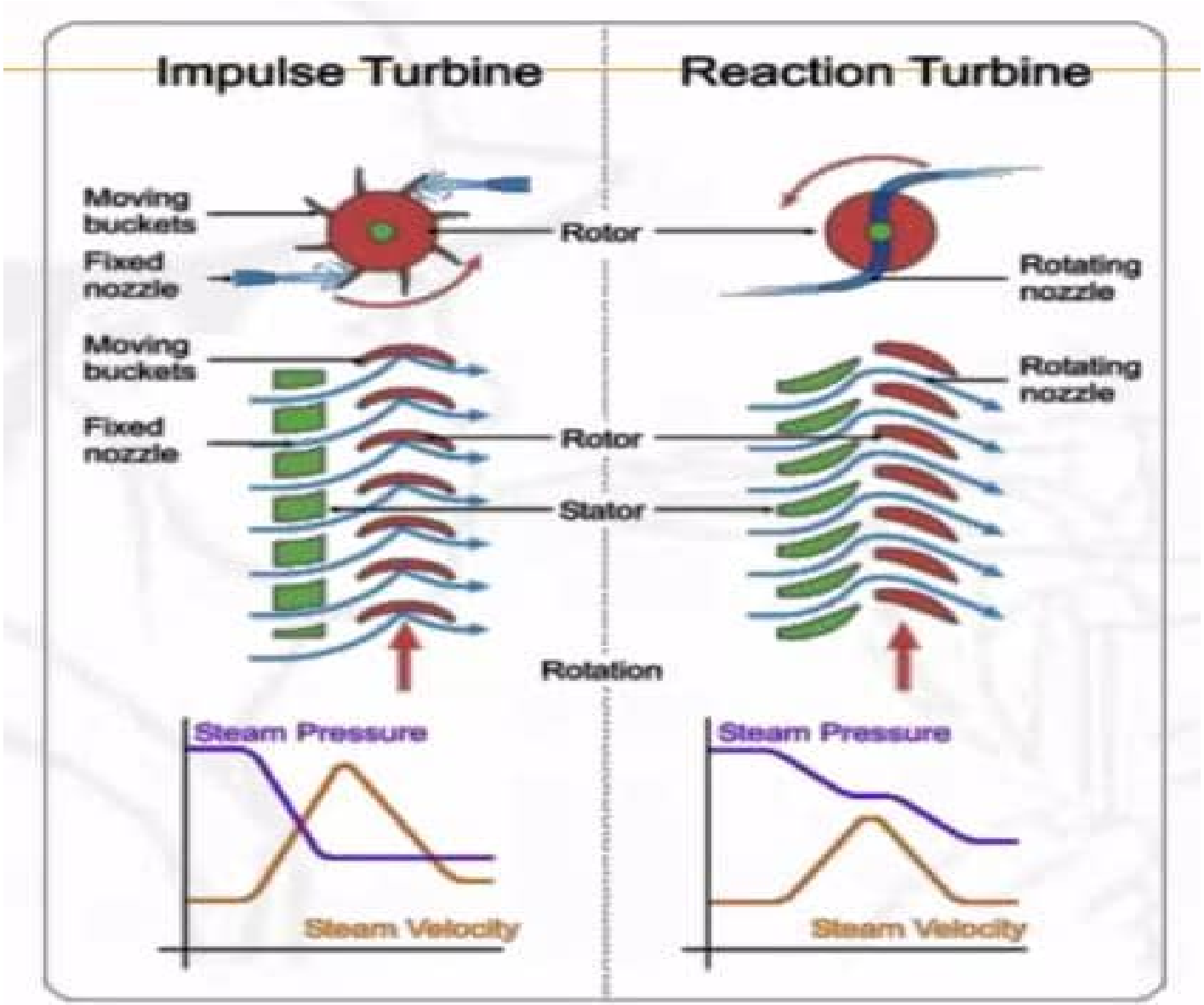
Efficiency and Size: Cooling towers are generally more efficient than spray ponds in terms of heat rejection per unit of water, which can be advantageous in areas where water availability is limited. They also occupy less space compared to spray ponds, making them suitable for densely populated areas.

11. Prime mover: converts the stored energy in steam into rotational mechanical energy

7. Steam Turbines

According to the action of steam:

- *Impulse turbine:* In impulse turbine, steam coming out through a fixed nozzle at a very high velocity strikes the blades fixed on the periphery of a rotor. The blades change the direction of steam flow without changing its pressure. The force due to change of momentum causes the rotation of the turbine shaft. Ex: De-Laval, Curtis and Rateau Turbines
- *Reaction turbine:* In reaction turbine, steam expands both in fixed and moving blades continuously as the steam passes over them. The pressure drop occurs continuously over both moving and fixed blades.
- *Combination of impulse and reaction turbine*


Impulse Turbine
Reaction Turbine
Moving buckets
Fixed nozzle
Rotor
Rotating nozzle
Moving buckets
Fixed nozzle
Rotor
Rotating nozzle
Stator
Rotation
Steam Pressure
Steam Velocity
Steam Pressure
Steam Velocity

According to the number of pressure stages:

- *Single stage turbines:* These turbines are mostly used for driving centrifugal compressors, blowers and other similar machinery.
- *Multistage Impulse and Reaction turbines:* They are made in a wide range of power capacities varying from small to large.

According to the type of steam flow:

- *Axial turbines:* In these turbines, steam flows in a direction parallel to the axis of the turbine rotor.
- *Radial turbines:* In these turbines, steam flows in a direction perpendicular to the axis of the turbine, one or more low pressure stages are made axial.

According to the heat drop process:

- *Condensing turbines with generators:* In these turbines, steam at a pressure less than the atmospheric is directed to the condenser. The steam is also extracted from intermediate stages for feed water heating). The latent heat of exhaust steam during the process of condensation is completely lost in these turbines.
- *Condensing turbines with one or more intermediate stage extractions:* In these turbines, the steam is extracted from intermediate stages for industrial heating purposes.
- *Back pressure turbines:* In these turbines, the exhaust steam is utilized for industrial or heating purposes. Turbines with deteriorated vacuum can also be used in which exhaust steam may be used for heating and process purposes.
- *Topping turbines:* In these turbines, the exhaust steam is utilized in medium and low pressure condensing turbines. These turbines operate at high initial conditions of steam pressure and temperature, and are mostly used during extension of power station capacities, with a view to obtain better efficiencies.

Impulse turbine	Reaction turbine
➢ The steam completely expands in the nozzle and its pressure remains constant during its flow through the blade passages	➢ The steam expands partially in the nozzle and further expansion takes place in the rotor blades
➢ The relative velocity of steam passing over the blade remains constant in the absence of friction	➢ The relative velocity of steam passing over the blade increases as the steam expands while passing over the blade
➢ Blades are symmetrical	➢ Blades are asymmetrical
➢ The pressure on both ends of the moving blade is same	➢ The pressure on both ends of the moving blade is different
➢ For the same power developed, as pressure drop is more, the number of stages required are less	➢ For the same power developed, as pressure drop is small, the number of stages required are more
➢ The blade efficiency curve is less flat	➢ The blade efficiency curve is more flat
➢ The steam velocity is very high and therefore the speed of turbine is high.	➢ The steam velocity is not very high and therefore the speed of turbine is low.

8.Fuels & fuel handling

- Thermal power plant use fossil fuels, i.e.
  1) Solid fuel such as coal
  2) Liquid fuel such as oil
  3) Gaseous fuel such as gas

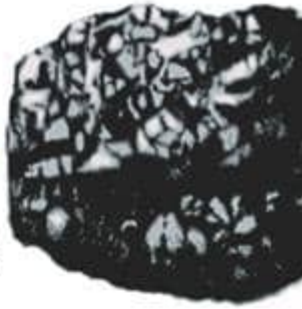
- The choice of fuels, their preparation and feeding, and their methods of firing deserve special attention for a power plant.

Natural Fuels	Manufactured Fuels
Solid Fuels	
Wood Coal Oil shale	Tanbark, Bagasse, Straw Charcoal Coke Briquettes
Liquid Fuels	
Petroleum	Oils from distillation of petroleum Coal tar Shale-oil Alcohols, etc.
Gaseous Fuels	
Natural gas	Coal gas Producer gas Water gas Hydrogen Acetylene Blast furnace gas Oil gas

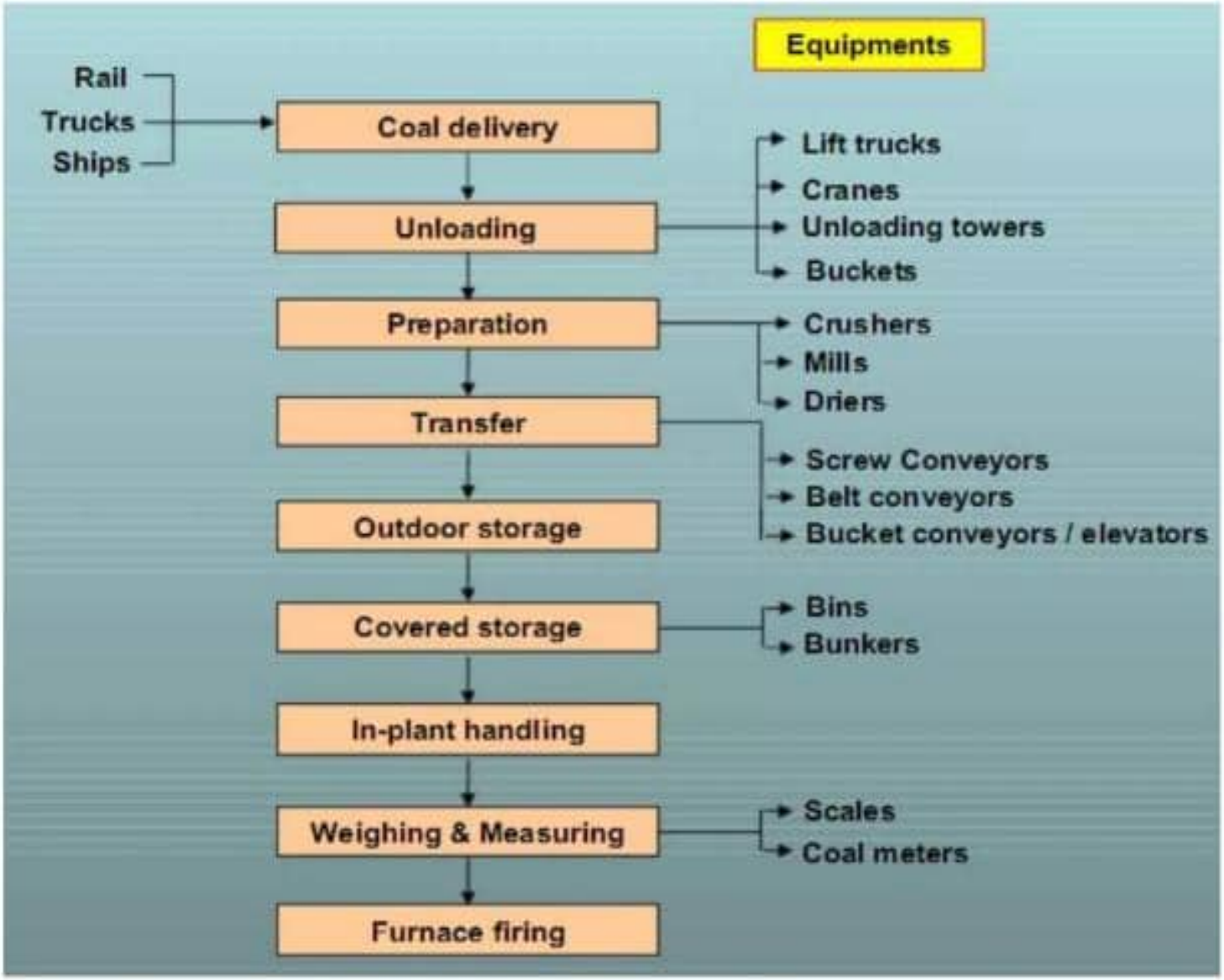
•**Lignite**: Lignite, also known as brown
• coal, is the lowest rank of coal with the least carbon content and the highest moisture content. It has a lower heating value compared to other types of coal and is often used in power plants for electricity generation.
•**Sub-bituminous**: Sub-bituminous coal has a higher carbon content than lignite but lower than bituminous coal. It typically has a lower moisture content compared to lignite, making it a preferred choice for electricity generation and industrial applications.
•**Bituminous**: Bituminous coal is the most common type of coal and is widely used in various industries due to its relatively high energy content and lower moisture content compared to lignite and sub-bituminous coal. It is used in electricity generation, steel production, and as a fuel for heating and industrial processes.

Increasing heat and carbon content

Increasing moisture content

Peat (not a coal)	Lignite (brown coal)	Bituminous (soft coal)	Anthracite (hard coal)
			
Heat, Pressure	Heat, Pressure	Heat, Pressure	
Partially decayed plant matter in swamps and bogs; low heat content	Low heat content; low sulfur content; limited supplies in most areas	Extensively used as a fuel because of its high heat content and large supplies; normally has a high sulfur content	Highly desirable fuel because of its high heat content and low sulfur content; supplies are limited in most areas

Coal Handling System



i) Coal delivery

The coal from supply points is delivered by ships or boats to power stations situated near to sea or river whereas coal is supplied by rail or trucks to the power stations which are situated away from sea or river. The transportation of coal by trucks is used if the railway facilities are not available.

ii) Unloading

The type of equipment to be used for unloading the coal received at the power station depends on how coal is received at the power station. If coal delivered by trucks, there is no need of unloading device as the trucks may dump the coal to the outdoor storage. Coal is easily handled if the lift trucks with scoop are used. In case the coal is brought by railways wagons, ships or boats, the unloading may be done by car shakes, rotary car dumpers, cranes, grab buckets and coal accelerators. Rotary car dumpers although costly are quite efficient for unloading closed wagons.

(iii) Preparation

When the coal delivered is in the form of big lumps and it is not of proper size, the preparation (sizing) of coal can be achieved by crushers, breakers, sizers, driers and magnetic separators.

iv)Transfer

After preparation coal is transferred to the dead storage by means of the following systems.

1. Belt conveyors
2. Screw conveyors
3. Bucket elevators
4. Grab bucket elevators
5. Skip hoists
6. Flight conveyor

Coal Preparation

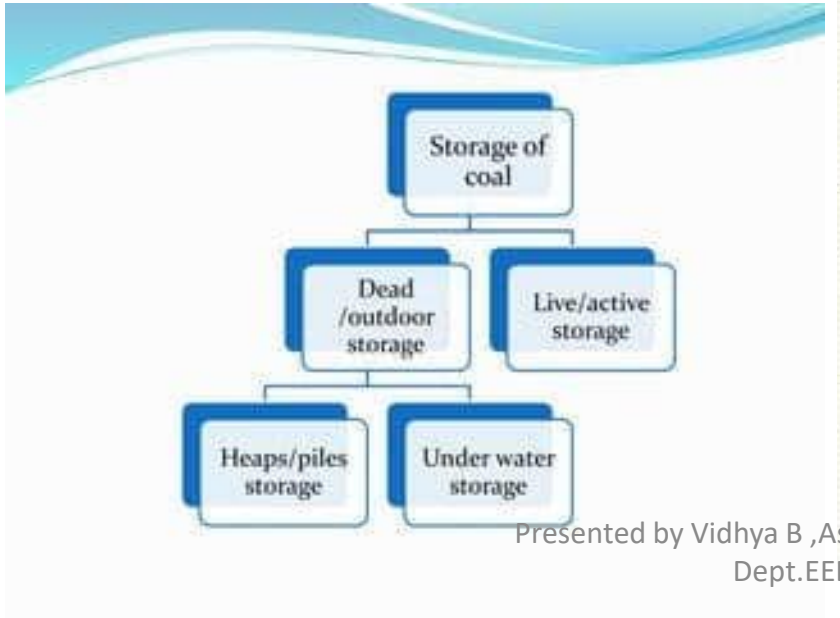
It is necessary to prepare the coal of required size before supply to the combustion chamber. It is done with the help of following equipments : i) Crushers ii) Sizers iii) Dryers and iv)Magnetic seperators.

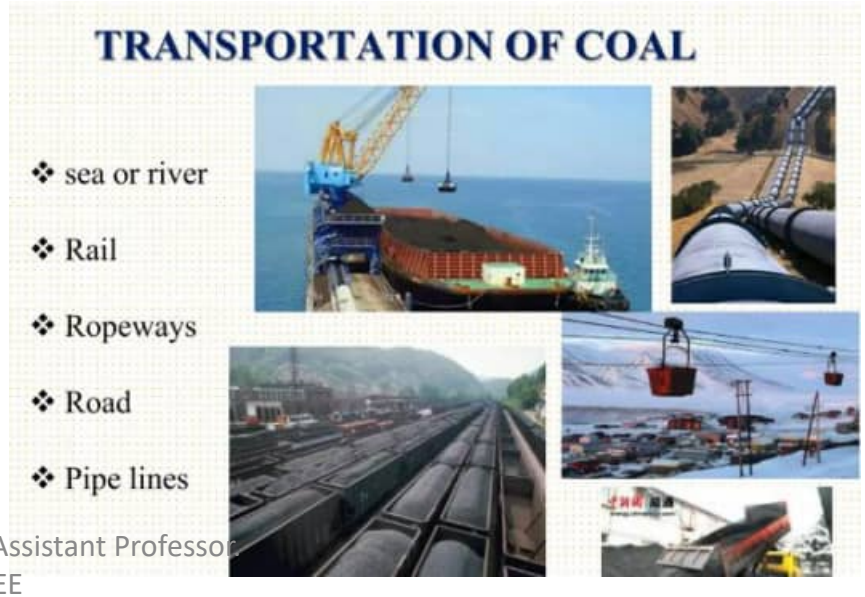
The capacity of the coal crushing plant must be sufficient to meet the maximum load demand.

The crushed coal is passed over the sizers which removes unsized coal and feeds back to the crusher the sized coal is further supplied to the dryers to remove the moisture.

Sometimes hot flue gases are passed through the closed coal storage to remove the moisture.

The iron scrap and particles are removed with the help of magnetic seperators. The prepared coal is then supplied to the storage hoppers.





STORAGE OF COAL...

Purpose of coal storage

- To store the coal for a period of 30-90 Days, therefore the plant is not require to be shut down due to failure of coal supply.
- To permit choice of the date of purchase allowing the management to take advantage of seasonal market conditions in price of coal

DEAD/OUTDOOR STORAGE...

- In this storage, the coal required at the power plant is stored in dead storage in the form piles lid directly on the ground.
- The coal stored has tendency to combine with oxygen of air & during this process call loss sum of its heating value and ignition quality.
- Due to oxidation the coal may ignite spontaneously.

❑ DEAD STORAGE:

- ❖ Supplies the coal where there is a **shortage** of coal in the plant **due to failure of normal supply** of coal.
- ❖ This is **long term storage** and **10% of annual consumption**, so it requires projection against **weathering** and **spontaneous consumption.**

❑ LIVE STORAGE:

- ❖ Supplies coal to plant for **day to day to usage**. **Capacity** of live storage is **less** than dead storage.
- ❖ Usually stored in **vertical cylindrical bunkers** or **coal bins** or **silo**, from where coal is transferred to the boiler grate.
- ❖ Bunkers are normally **diamond-shaped cross section** storage area, made up of **steel** or **reinforced concrete**.

INPLANT COAL HANDLING

- The In-Plant coal handling system deals with **feeding of coal from live storage** to the furnace.
- It includes various equipment's for transfer of coal like belt conveyor, screw conveyor etc. & the equipment needed to weigh the quantity of coal for feed.
- In case of pulverized coal firing system, it requires large no. of equipment's like chutes, pulverized mills, feeders, weighing machine, hoppers & automatic scales.

9.Fuel combustion & combustion equipment

Combustion equipment for burning coal

Coal burning methods are classified into two types:

- Stoker firing – used for solid coal
- Pulverized fuel firing – used for pulverized coal

Selection of one of the above methods depends upon

1. Characteristics of the coal available
2. Capacity of the plant
3. Load fluctuations
4. Efficiency / Reliability of combustion equipments.

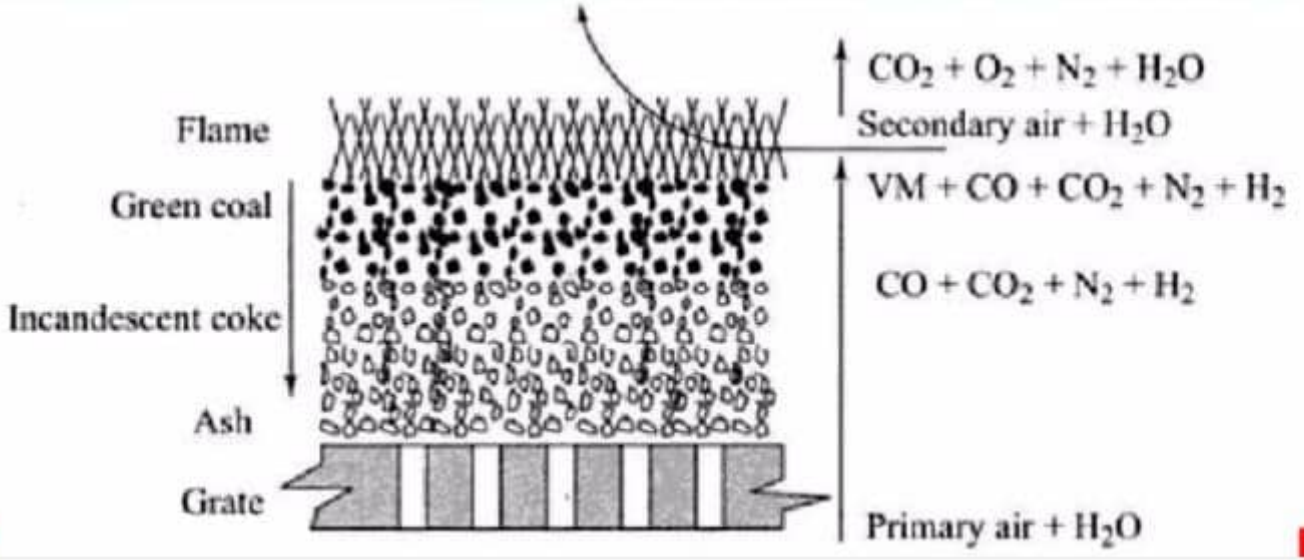
The boiler furnaces that burn coal can be classified as follows:

- Fuel bed furnaces (coarse particles)
- Pulverized coal furnaces (fine particles)
- Cyclone furnaces (crushed particles)
- Fluidized bed furnaces (crushed small particles)

- **Stoker firing**
- **In small boilers, coal is fed manually on to a stationary grate. But in large boilers, to attain uniform operating condition, higher burning rate and better efficiency, mechanical stokers are employed.**
- **A stoker consists of a power operated coal feeding mechanism and grate.**
- **Mechanical stokers are of two types:**

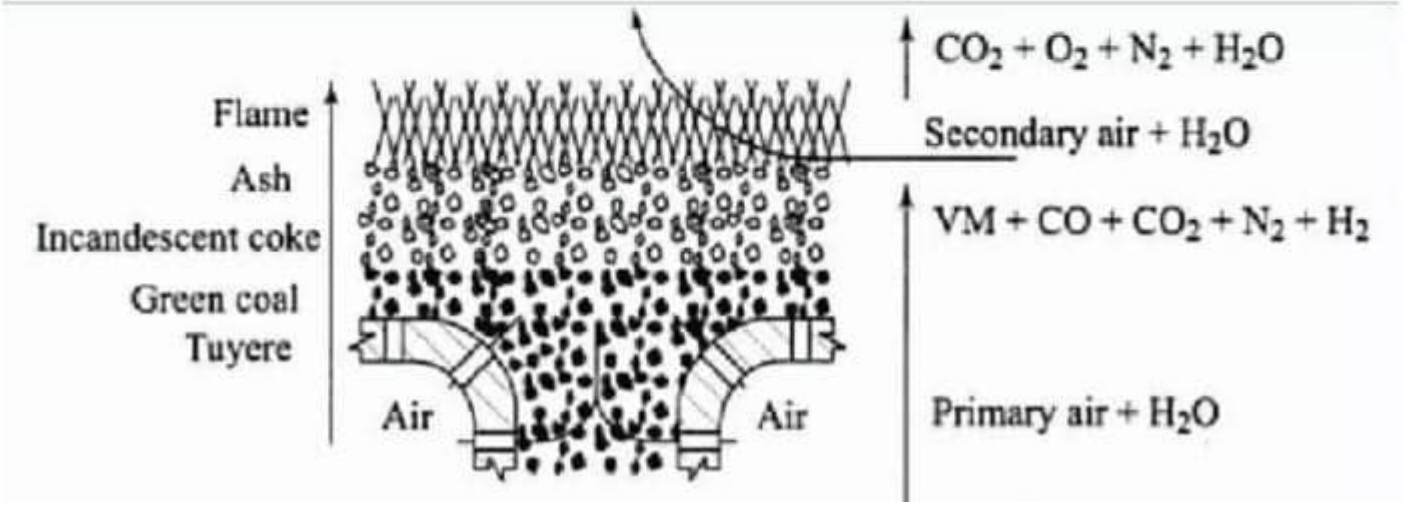
1.Overfeed stoker 2.Underfeed stoker

- **Overfeed stoker**
- **Overfeed stokers are used for large capacity boilers where coal is burnt as lumps (i.e., without pulverization). In this type of stoker, the fuel bed receives fresh coal on top surface; ignition plane lies between green coal and incandescent coke**



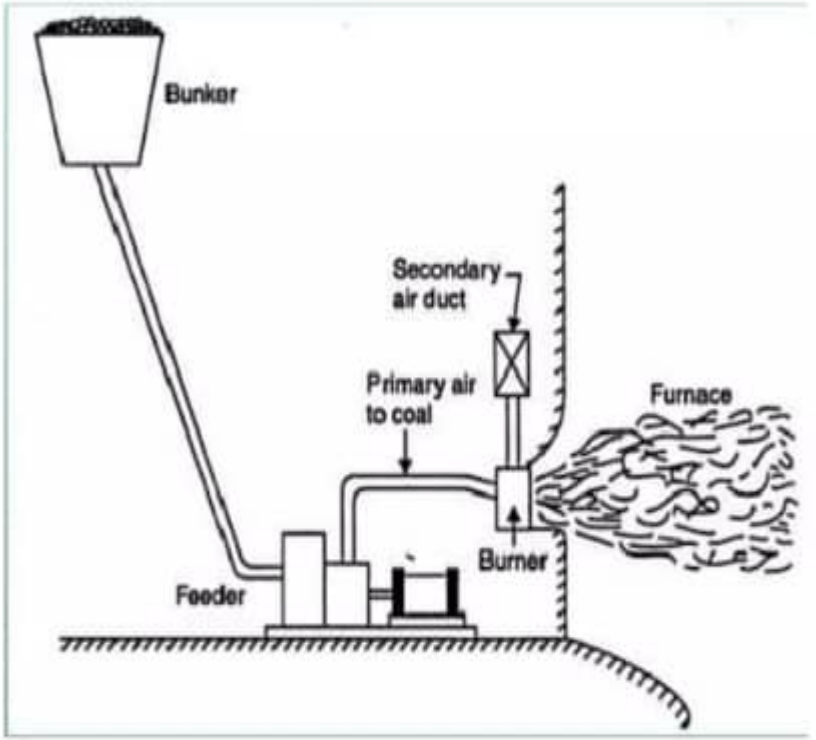
- **Overfeed stoker - Processes**
- **In the first layer (top layer), fresh coal is added**
- **Second layer is the drying zone, where coal loses moisture**
- **Third layer is distillation zone, where coal loses volatile matter**
- **Fourth layer is the combustion zone, where the fixed carbon in coal is consumed.**
- **Fifth layer is the ash cooling zone**

- **Underfeed stoker**
- **In the case of underfeed stoker, the coal is fed into the grate below the point of air admission, or air entering the stoker comes in contact with fresh coal before reaching the incandescent coke.**



Pulverized coal firing system

- In the pulverized coal firing system, the coal is reduced to a fine powder with the help of grinding mill and then admitted into the combustion chamber with the help of primary hot air.
- The primary air also helps to dry the coal before entering the combustion chamber.
- Secondary air required to complete the combustion process is supplied separately to the combustion chamber.
- The resulting turbulence in the combustion chamber helps in uniform mixing of fuel and air and good combustion.
- Elements of a pulverized coal firing system



Pulverized coal

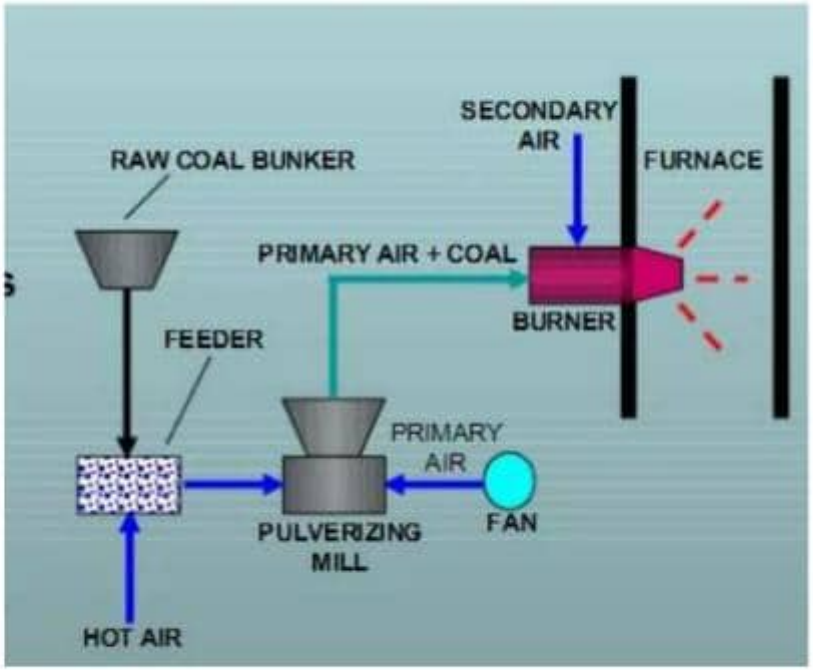
- Coal is pulverized (powdered) to increase its surface area (and therefore exposure) thus permitting rapid combustion.
- The pulverized coal is obtained by grinding the raw coal in pulverizing mills. Various types of pulverizing mills are:
- Ball mill
- Ball and race mill
- Hammer mill
- Bowl mill

Essential functions of pulverizing mills are:

- Drying of the coal
- Grinding
- Separation of particles of a desired size.
- Coal pulverizing mills reduce coal to powder by any (or all) action such as
- Impact, Abrasion and Crushing

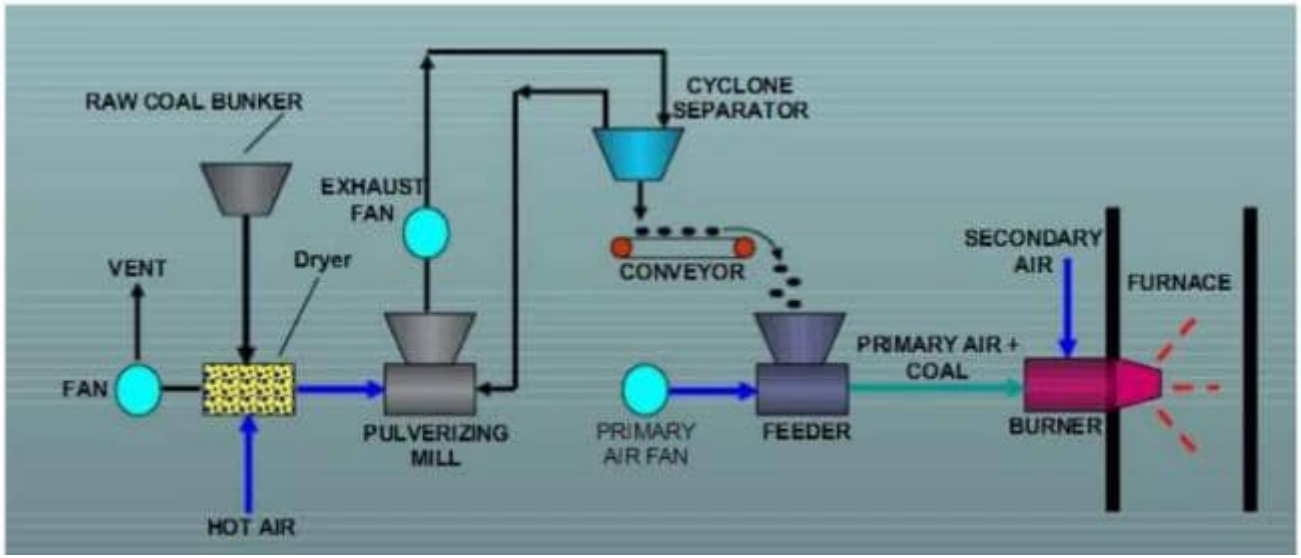
Basically, pulverized fuel plants may be divided into two systems based on the method used for firing the coal:

- Unit System or Direct System
- Bin System or Central System
- Unit or Direct System: This system works as follows:
- Coal from bunker drops on to the feeder.
- Coal is dried in the feeder by passage of hot air.
- The coal then moves to a mill for pulverizing.
- A fan supplies primary air to the pulverizing mill.
- Pulverized coal and primary air are mixed and sent to a burner where secondary air is added.



• Bin or Central System:

- Coal from bunker is fed by gravity to a dryer where hot air is admitted to dry the coal.
- Dry coal is then transferred to the pulverizing mill.
- Pulverized coal then moves to a cyclone separator where transporting air is separated from coal.
- Primary air is mixed with coal at the feeder and supplied to the burner.
- Secondary air is supplied separately to complete the combustion



Advantages of Pulverized coal firing system

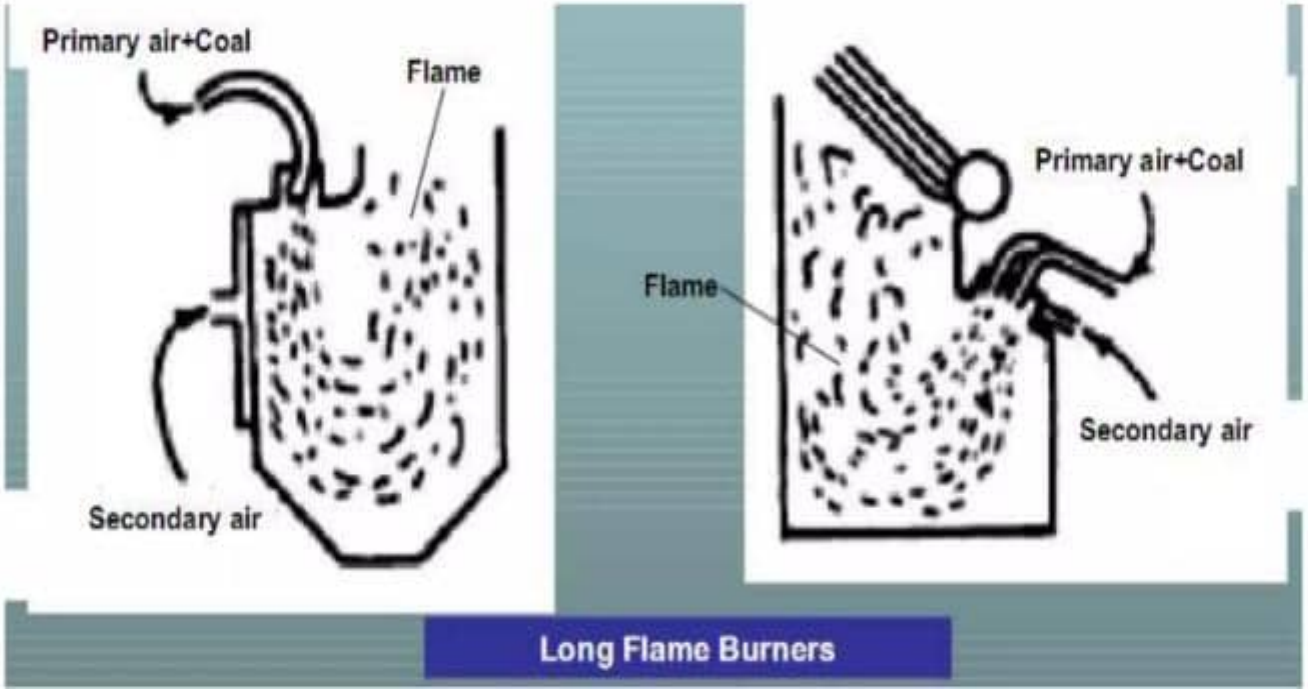
- Any grade of coal can be used because coal is powdered before use.
- Rate of feed of fuel can be easily regulated – better fuel economy.
- Since there is almost complete combustion of fuel, there is increased rate of evaporation and hence better boiler efficiency.
- Greater capacity to meet peak load.
- System is free from sagging and clinkering troubles associated with lump coal.
- Practically no ash handling problems.
- No moving parts within the furnace that is subjected to high temperatures.
- This system works successfully in combination with gas and oil.
- Requires much less air compared to stoker firing
- Furnace volume is considerably small.

Disadvantages of Pulverized coal firing system

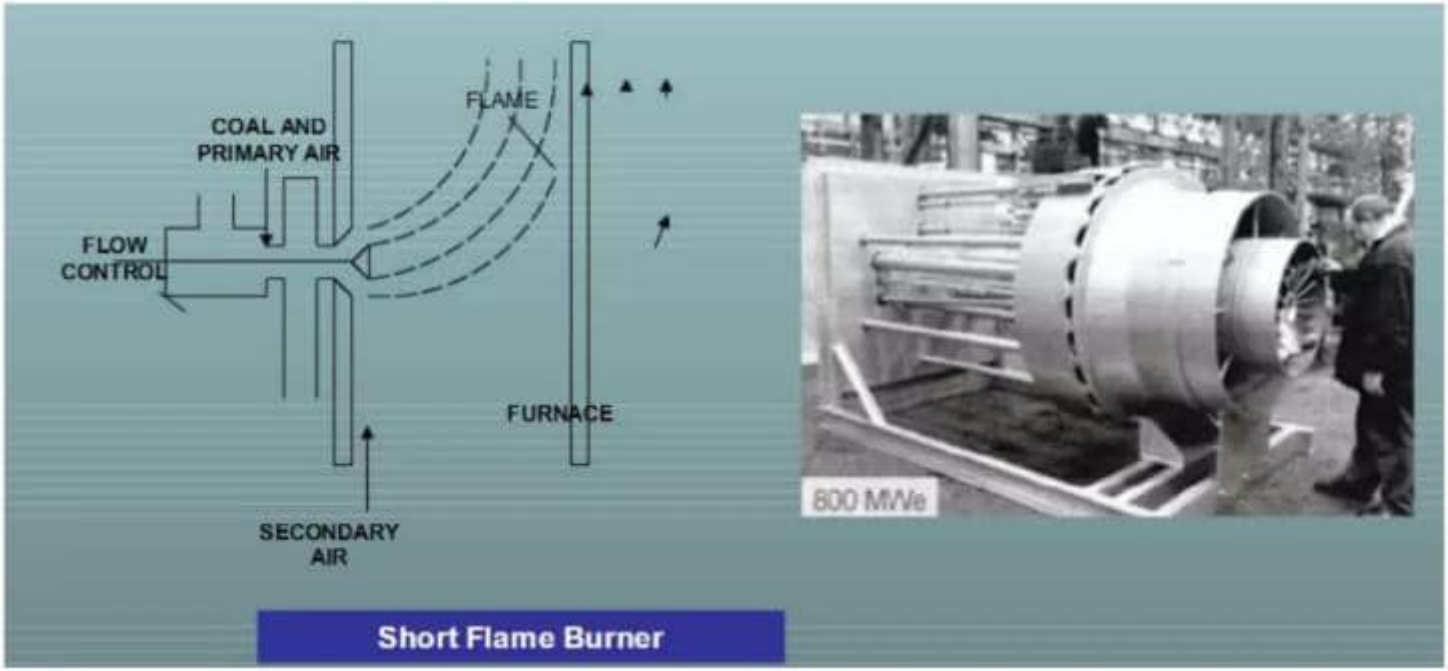
- High capital cost.
- Lot of fly-ash in the exhaust – removal of fine dust is expensive.
- Possibility of explosion is high because pulverized coal burns like gas.
- Maintenance of furnace brickwork is costly because of high temperatures.
- Special equipment's required to start the system.
- Skilled operators are required.
- Separate coal preparation plant is necessary.
- Periodic maintenance of pulverized coal dispensing system is needed.

10.Coal Burners

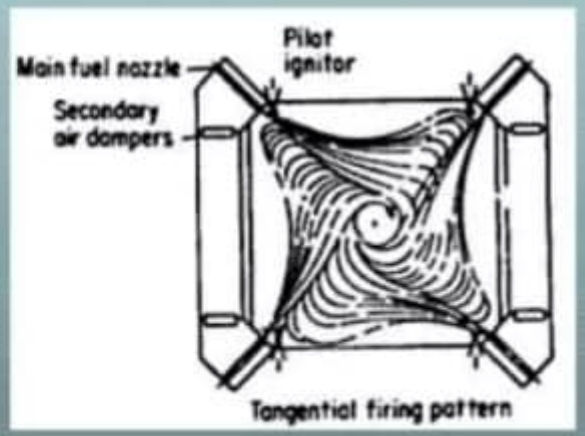
- Types of Burners for Pulverized Coal
- Various types of burners are used for combustion of pulverized coal.
- Long Flame (U-Flame) Burner: In this burner, air and coal mixture travels a considerable distance thus providing sufficient time for complete combustion



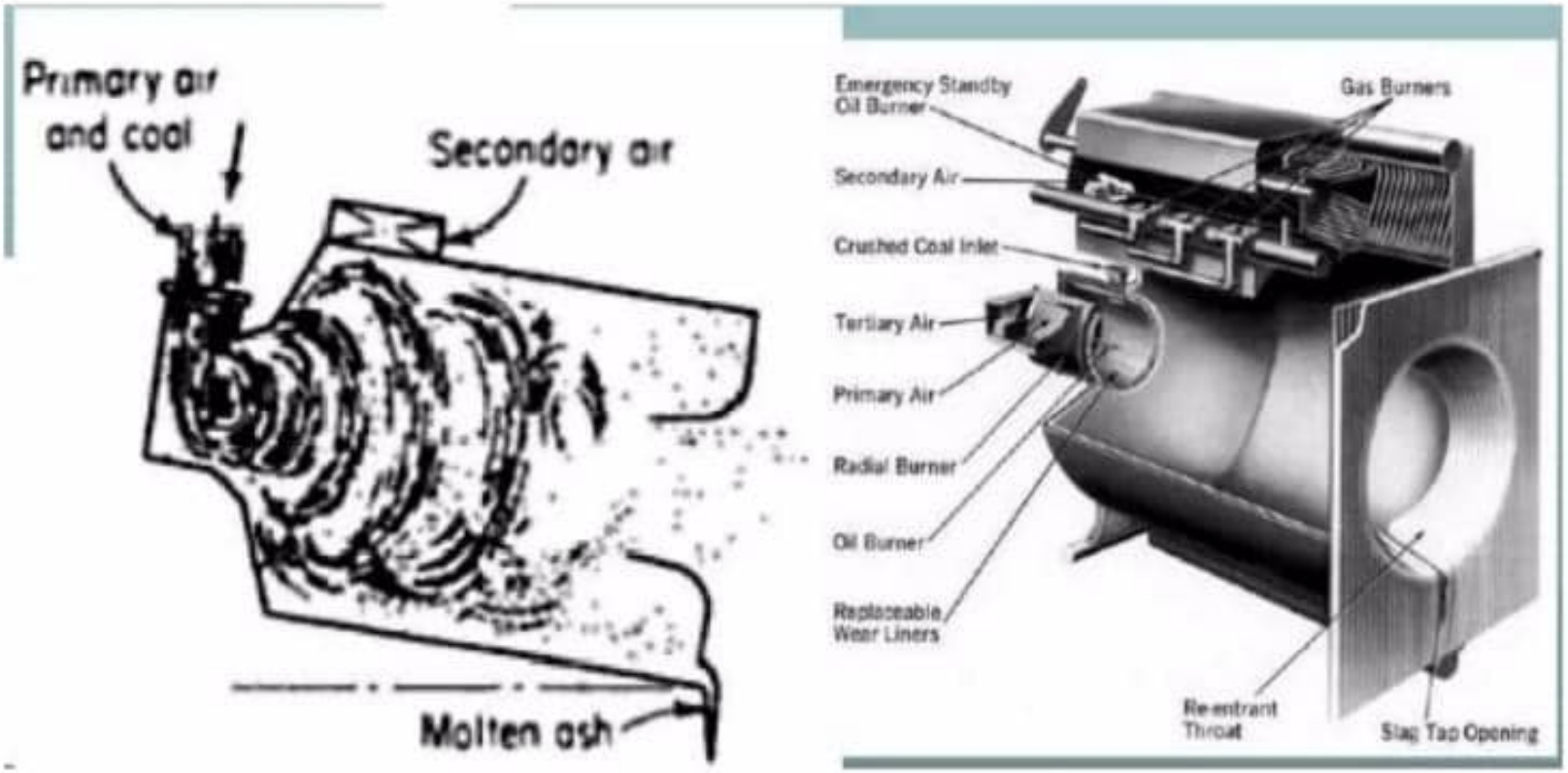
- **Types of Burners for Pulverized Coal**
- **Short Flame (Turbulent) Burner: The burner is fitted in the furnace wall and the flame enters the furnace horizontally with great turbulence**



- **Tangential Burner: In this system, one burner is attached at each corner of the furnace. The inclination of the burners is so made that the flame produced is tangential to an imaginary circle at the centre.**



- **Cyclone Burner: In this system, the cyclonic action whirls coal and air against the wall of the furnace to facilitate thorough mixing of coal and air. Advantage of this burner is that it can also use crushed coal in addition to pulverized coal thus providing an option. When crushed coal is used, ash is collected in molten form for easy disposal.**



11.Fluidized bed combustion

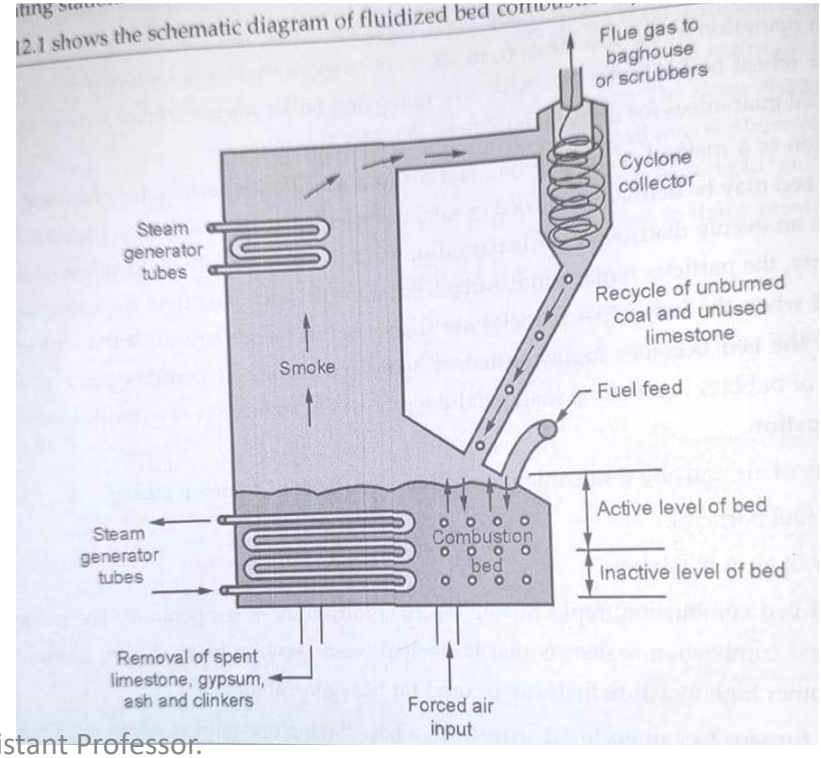
Fluidization is a way to mix fuel and air to get combustion. A **fluidized bed** is defined as a bed of solid particles that behave like a fluid. It works by passing air evenly through the particles; at low air velocity, the particles stay still, but as the air flow increases, the particles become suspended.

High Heat Transfer: Evaporator tubes in FBC systems are immersed in the fluidized bed, ensuring high heat transfer rates and efficient combustion.

The velocity of air, causing fluidization depends on a number of parameter, like :-

Size of fuel particles.

Density of air fuel mixture.



Types of Fluidized Bed Combustion

Fluidized bed combustion (FBC) can be in 2 variants, namely:

Vertical type FBC: These are generally used in smaller plant, and has the capacity to produce steam of up to 6 tonnes per hour only. Their vertical shape reduces the overall dimension of the steam boiler, and is extremely efficient in plants, where space provision is limited.

Horizontal type FBC: There are almost 10 times in capacity when compared to vertical type fluidized bed combustion. They can produce as much as 60 tonnes of steam per hour, and are placed horizontally with respect to the boiler tubes. The high capacity of the horizontal type Fluidized boilers coupled with their high efficiency, makes them an extremely desirable choice for the coal fired thermal power generating station.

Advantages and Dis-advantages of Fluidized Bed Combustion

1.High thermal efficiency.
2.Easy ash removal system, to be transferred for made cement.
3.Short commissioning and erection period.
4.Fully automated and thus ensures safe operation, even at extreme temperatures.
5.Efficient operation at temperatures down to 150^{o}C (i.e. well below the ash fusion temperature).
6.Reduced coal crushing etc. (pulverised coal is not a necessity here).
7.The system can respond rapidly to changes in load demand, due to quick establishment of thermal equilibrium between air and fuel particles in the bed.
8.The operation of fluidized bed furnace at lower temperature helps in reducing air pollution. The low temperature operation also reduces the formation of nitrogen oxides. By adding either dolomite (a calcium-magnesium carbonate) or lime stone (calcium carbonate) to the furnace the discharge of sulphur oxides to the atmosphere can also be reduced if desired.

The **main drawback** of fluidized bed combustion is the high fan power needed. The air must be supplied continuously at high pressure to support the bed, raising the operating cost. However, this cost is offset by the high efficiency of FBC.

12. Combustion control

Automatic combustion control is used for large power plants. it regulates automatically changes in demand of steam & also affects quick & stable changes in other variables So as to maintain constant steam pressure & pressure & proper combustion conditions. For controlling rate of combustion the conditions to be regualted are draught, air supply & fuel supply.

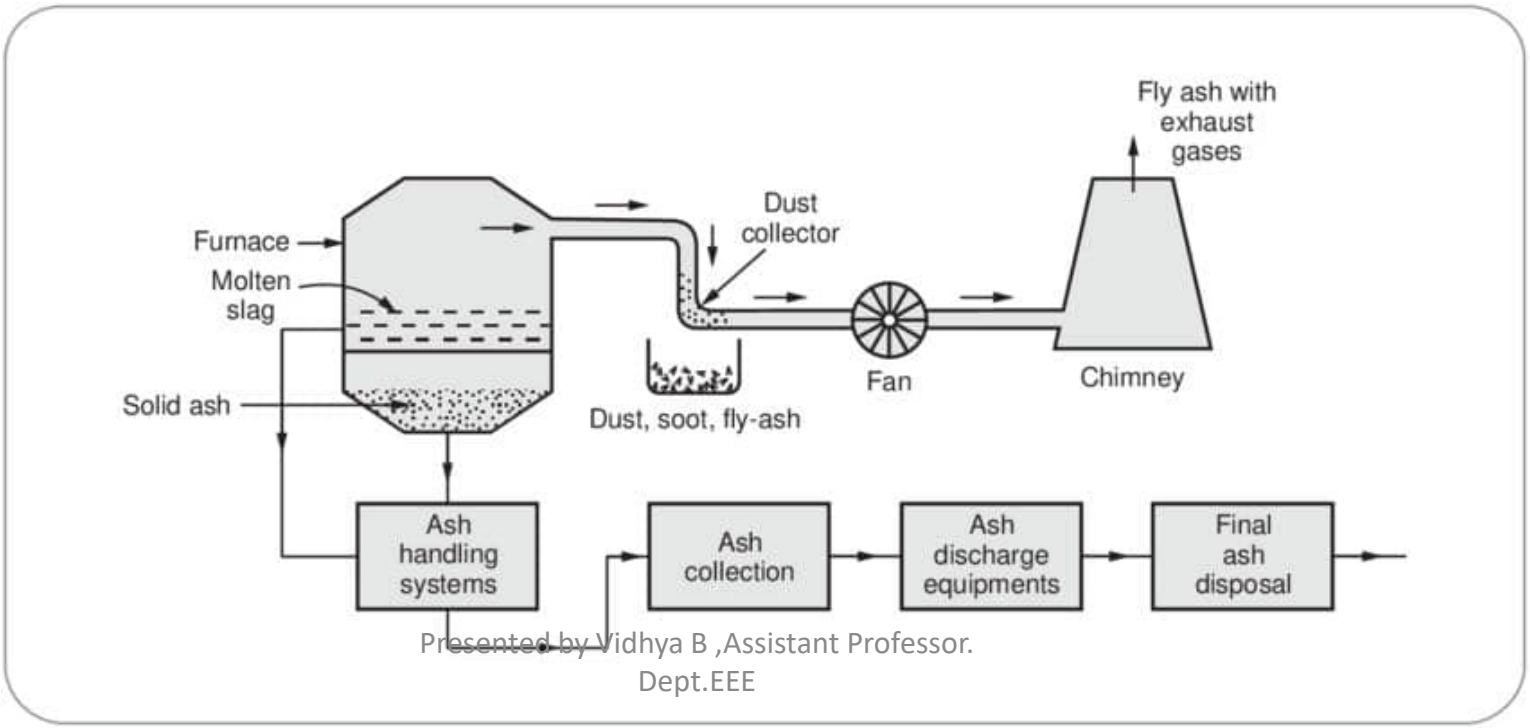
13. Ash Handling System

In a thermal power plant the quantity of ash produced is 10-20 % of the coal used. For a 200 MW capacity power plant approximately 60000 tons of ash is produced per annum. It requires very huge area at the site of plant to dump this ash. Therefore the disposal of ash and dumping it at a sufficient distance from the Power Plant is important for the following additional reasons :

1) The ash is very hot when it comes out of the boiler furnace.

2) The ash is dusty, therefore it is irritating and annoying to handle.

3) When mixed with water, the ash produces poisonous gases and corrosive acids.



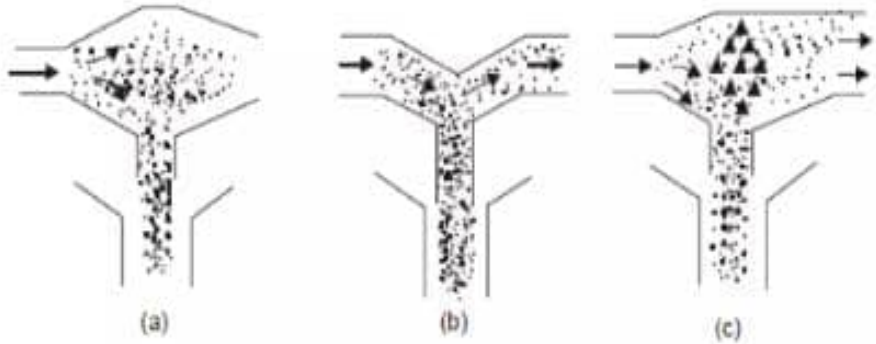
Requirements of a Good Ash Handling System

1) It should be able to handle required quantity of ash daily.
2) It should be able to handle large clinkers, soot and dust.
3) It should have minimum maintenance.
4) Its operating cost and capital investment must be minimum.
5) The plant shut down should not occur because of failure in the ash-handling plant.
6) It should be able to adopt any sudden changes in boiler operating conditions.
7) It should be able to operate efficiently under all variable load conditions.
8) It should have noiseless operation.
9) It should deal with hot and wet ashes.
10) It should be flexible.
11) It should be able to operate effectively and efficiently in case of variation in ash characteristics due to change in fuel used.

14. Dust Collection

Dust Collectors

- ***Mechanical Dust Collectors***: *by increasing the cross-sectional area of duct through which dust laden gases are passing, the velocity of gases is reduced and causes heavier dust particles to fall down.*
- *Changing the direction of flow of flue gases causes the heavier particles of settle out.*
- *Sometime baffles are provided, to separate the heavier particles.*
- *Mechanical dust collectors may be* ***wet type*** *or* ***dry type****. Wet type dust collectors called scrubbers make use of water sprays to wash the dust from flue gases.*



Dust Collectors

- ***Electrostatic Precipitators***: *It has two sets of electrodes, insulated from each other that maintain an electrostatic field between them at high voltage. The flue gases are made to pass between these two sets of electrodes.*
- *The electric field ionizes the dust particle; that pass through it attracting them to the electrode of opposite charge.*
- *The dust particles are removed from the collecting electrode by rapping the electrode periodically.*
- *The electrostatic precipitator is costly but has low maintenance cost and is frequently employed with pulverized coal fired power stations for its effectiveness on very fine ash particles and is superior to that of any other type.*

15.Draught System

Draught is an essential part in thermal power plant.

The functions of the draught system are:

1.To supply required quantity of air to the furnace for combustion of fuel.

2.To draw the combustion products through the system.

3.To remove burnt products from the system.

Draught is defined as the small pressure difference required between the fuel bed (furnace) and out side air to maintain constant flow of air and to discharge the gases through chimney to the atmosphere. Draught can be obtained by using chimney fan, steam (or) air jet (or) combination of these.

Classification of Draught System:

1. Natural draught: In this, only chimney is used for producing the draught.

2. Artificial draught: In this, the draught is produced by steam jet or by fan.

- **Steam jet draught:** Steam jet is used for creating draught in the system.
- **Mechanical draught:** Fan or blower is used for creating draught in the system.
- **Induced draught:** The flue gas is sucked through the system by a fan or steam jet.
- **Forced draught:** The air is forced into the system by a blower or steam jet.

•**16. Feedwater**

•In order to generate steam on a constant basis, boiler should be continuously supplied with water, called as feed water.

•Feed water consists of condensate, which gets collected after the steam gets condensed by losing heat to the process or radiation losses, flash steam and make up water.

•Condensate and flash steam are pure in form without any impurities.

•As we can see, the quality of feed water depends solely on the quality of makeup water. If feed water is not treated properly, it can result in multiple problems like scale formation or corrosion. It can also increase the amount of blow down required and hence can result in wastage of fuel.

•The different impurities in the feed water can be grossly classified into three classes, namely **dissolved gases, dissolved solids and suspended solids**. Each of these impurities affects the boiler system in a different way.

1.Natural and drinking water are in equilibrium with the air, and so will contain **dissolved gases** such as nitrogen, oxygen and carbon dioxide. Oxygen scavengers can also be added to reduce the dissolved oxygen levels in the feed water. Carbonic acid can be removed from feed water by neutralization with alkalis.

2. Suspended solids are sediments or organic matter which comes along with the makeup water. If not removed prior to their entry in the boiler, they can result in multiple issues like sludge formation, foaming, corrosion, clotting etc. Methods like clarification, filtration, and chemical treatment are used to limit suspended solids from the feed water.

3. Dissolved solids

As we have seen in the previous article, dissolved solids form scales which can be extremely difficult to be removed. Hence, it is quite essential that they are restricted from going inside the boiler. Dissolved solids include impurities like Hardness, sulfates carbonates etc. Natural water also has silica dissolved in it which can form hard scales. Hardness basically means excess amounts of Magnesium (Mg++) and calcium (Ca++) ions in the water. Hard water can be converted into soft water by using a softener which removes these ions from the water by the process of ion exchange. Along with this, water also has chlorides and sulfates which can be removed by the process of de-ionisation.

17. Steam power plant controls

•Automation technologies such as Supervisory Control and Data Acquisition (SCADA), Programmable Logic Controllers (PLCs), and Distributed Control Systems (DCS) have helped power plants operate more efficiently and reduce downtime.

•Whether it's for monitoring, decision-making, responding, controlling, collaborating, or communicating, control room solutions are an essential component to daily operations, allowing for more efficient work and better decision-making.

18. Steam Power Plant Auxiliaries

•Boiler auxiliaries: depend upon the type of fuel firing employed.
In case of stoker firing, stoker drivers are essential along the forced & induced draught fans, boiler

•Coal & ash auxiliaries: wagon tripplers, elevators, skip hoist, conveyors, cranes, pumps, exhausters etc.

•Turbo alternator auxiliaries: circulating water pumps condensate extraction pumps, governor control, evaporator, sludge & distillate pumps, ventilating fans, oil pumps, workshop machines & equipment

•Plant auxiliaries can be divide into two classes

1. Essential auxiliaries include forced & induced draught fans,feedwater pumps, circulating water pumps, condensate pumps, auxiliary oil pumps, Ventilating fans for alternators, lighting & switchgear tripping equipment
2. Non essential auxiliaries include coal & ash handling , service pumps, exciter field rheostat,hoist & overhead cranes, valves, governor control, evaporators auxiliaem

Methods of feed water treatment:

1. **Mechanical treatment**

a. Sedimentation b. coagulation

c. Filteration d. Interior painting

2. **Thermal treatment**

a.Deaeration b. distillation by evaporators

3.**Chemical treatment**

a. Cold-lime soda softening process

b. Hot-lime soda softening process

c. Lime- phosphate

d. Ion exchange process (sodium zeolite / hydrogen zeolite process)

4. Demineralization
5. Blow Down

Hot lime soda & hot zeolite process

Adding acid to control alkalinity & vice versa

Diesel Electric Plant

Introduction to diesel power plant

- A generating station in which the *diesel engine* is used as the *prime mover* for the *generation of electrical energy* is called as Diesel Power Station.
- The *diesel burns* inside the engine & the product of this combustion act as the *working fluid* to produce *mechanical energy*.
- The diesel engine drives *Alternator* which converts mechanical energy into electrical energy.

Introduction to diesel power plant

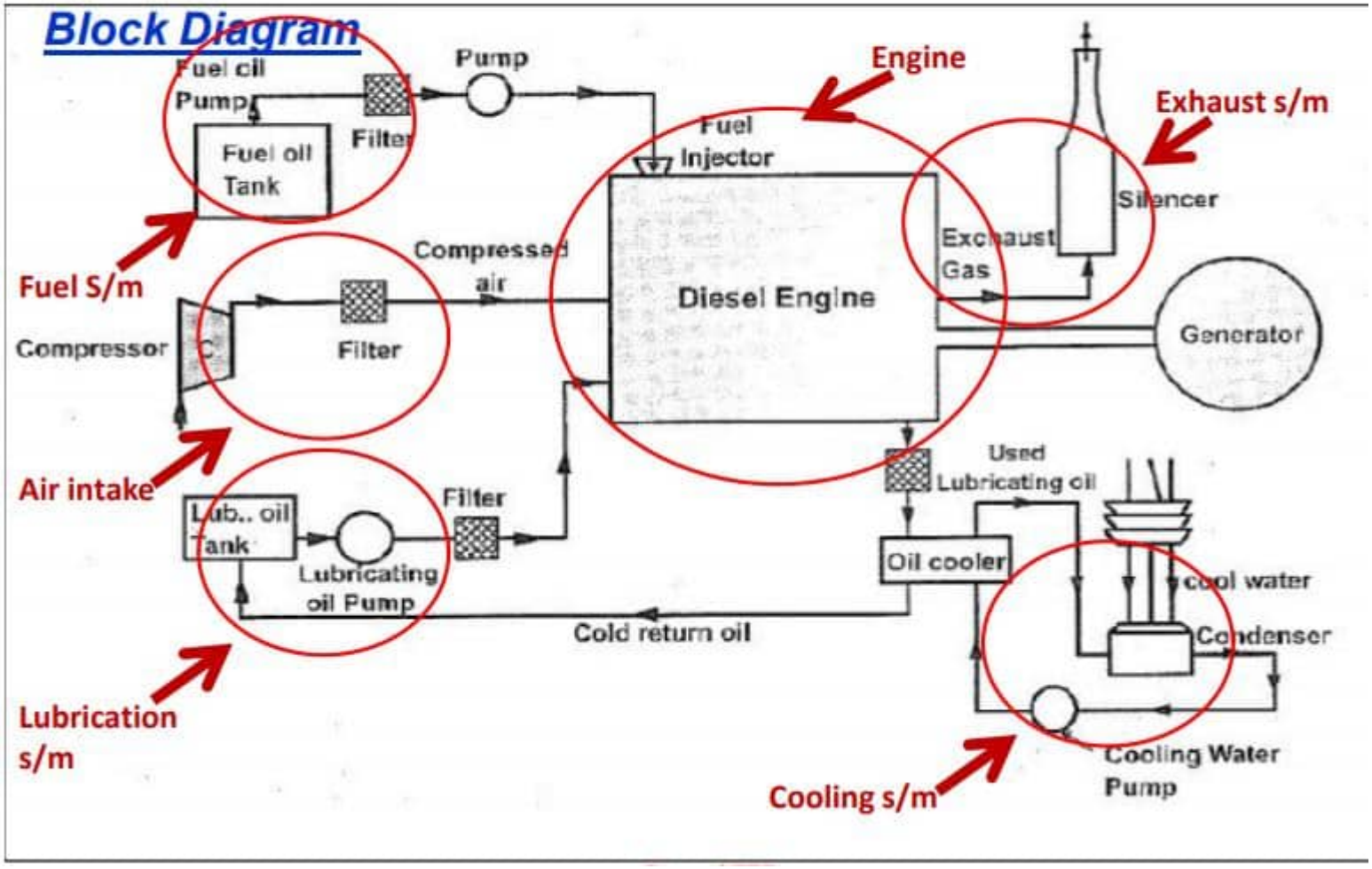
Diesel power plant is used when

- Demand of power is less.
- Sufficient quantity of coal & water is unavailable.
- Transportation facilities are inadequate.
- This plant supply power to hospitals, radio station, cinema houses & telephone exchanges.
- Peak demand problems in Industries.

Introduction to diesel power plant

- Diesel power station produces power in the range of ***2MW to 50MW.***
- They are used as a stand by sets for continuity of supply such as hospitals, telephone exchanges , radio station, cinema theater & industries (peak load).
- ***Diesel engine*** is the main component of diesel power plant.
- Alternator convert mechanical energy to electrical energy.
- Both two stroke & four stoke diesel engines are available. However two stroke engines are preferable for diesel power plant.

Diesel Electric Plant



1.Fuel Supply System

• It consists of storage tank, strainers, fuel transfer pump and all day fuel tank.

•The fuel oil is supplied at the plant site by rail or road.

• The oil is stored in the storage tank. From the storage tank, oil is pumped to smaller all day tank at daily or short intervals.

•From this tank, fuel oil is passed through strainers to remove suspended impurities.

• The clean oil is injected into the engine by fuel injection pump.

2. Air Intake System

•This system supplies necessary air to the engine for fuel combustion.

• It consists of pipes for the supply of fresh air to the engine manifold.

• Filters are provided to remove dust particles from air which may act as abrasive in the engine cylinder.

3. Exhaust System

This system leads the engine exhaust gas outside the building and discharges it into atmosphere.

A silencer is usually incorporated in the system to reduce the noise level.

4. Cooling System

•The heat released by the burning of fuel in the engine cylinder is partially converted into work.

• The remainder part of the heat passes through the cylinder wall, piston, rings etc. and may cause damage to system.

•In order to keep the temperature of the engine parts within the safe operating limits, cooling is provided.

• The cooling system consists of a water source, pump and cooling towers.

• The pump circulates water through cylinder and head jacket.

•The water takes away heat form the engine and it becomes hot.

• The hot water is cooled by cooling towers and re circulated for cooling.

5. Lubricating System

• The system minimizes the wear of rubbing surfaces of the engine.

• It comprises of lubricating oil tank, pump, filter and oil cooler.

•The lubrication oil is drawn from the lubricating oil tank by the pump and is passed through filter to remove impurities .

•The clean lubrication oil is delivered to the points which require lubrication.

•The oil coolers incorporated in the system keep the temperature of the oil low

6. Engine starting system

•This is an arrangement to rotate the engine initially while starting until firing starts & the unit runs with its own power.

•Compressed air is used for starting.

Diesel power plant

Advantages: The advantages of diesel power plants are listed below: 1. Diesel power plant design is simple for installation.

2. The layout of the diesel power plant is quite simple.

3. The limited quantity of cooling water required.

4. Standby losses are very less as compared to other Power plants.

5. Low fuel cost for operation.

6. Smaller storage is needed for the fuel.

7. There is no problem of ash handling.

8. Less time monitoring is sufficient required.

9. For small capacity power generation, diesel power plant is more efficient than the steam power plant.

10.Quickly started and put on load.

11.They can respond to varying loads without having any difficulty

Disadvantages:

1. High Maintenance and operating cost.

2. The plant cost per kW power is comparatively more.

3. The working life of diesel power plant is small due to high maintenance.

4. The plant produces too much noise.

5. Diesel power plants are tough to construct for large scale.

Selection of Site for a Diesel Power Station:

1. Near to Load Center: As far as possible the plant should be installed near to load center, to reduce transmission & distribution cost of electrical energy.
2. Availability of Land: For erection of diesel power plant, land should be available near to load center at low cost.
3. Availability of Water: The soft water is freely available for the purpose of cooling.
4. Foundations: As we know that, the diesel engines or a machine produces vibrations. So provide good foundation to erect the diesel engine.
5. Fuel Transportation: The diesel plant is far away from fuel mines. So to provide fuel to the plant arrange good transportation facility like road, rail etc.
6. Local Conditions: For increasing the demand of power & future expansion space available.
7. Noise Pollution: The plant should away from populated areas, because it produces noise.

Diesel Electric Plant

Layout

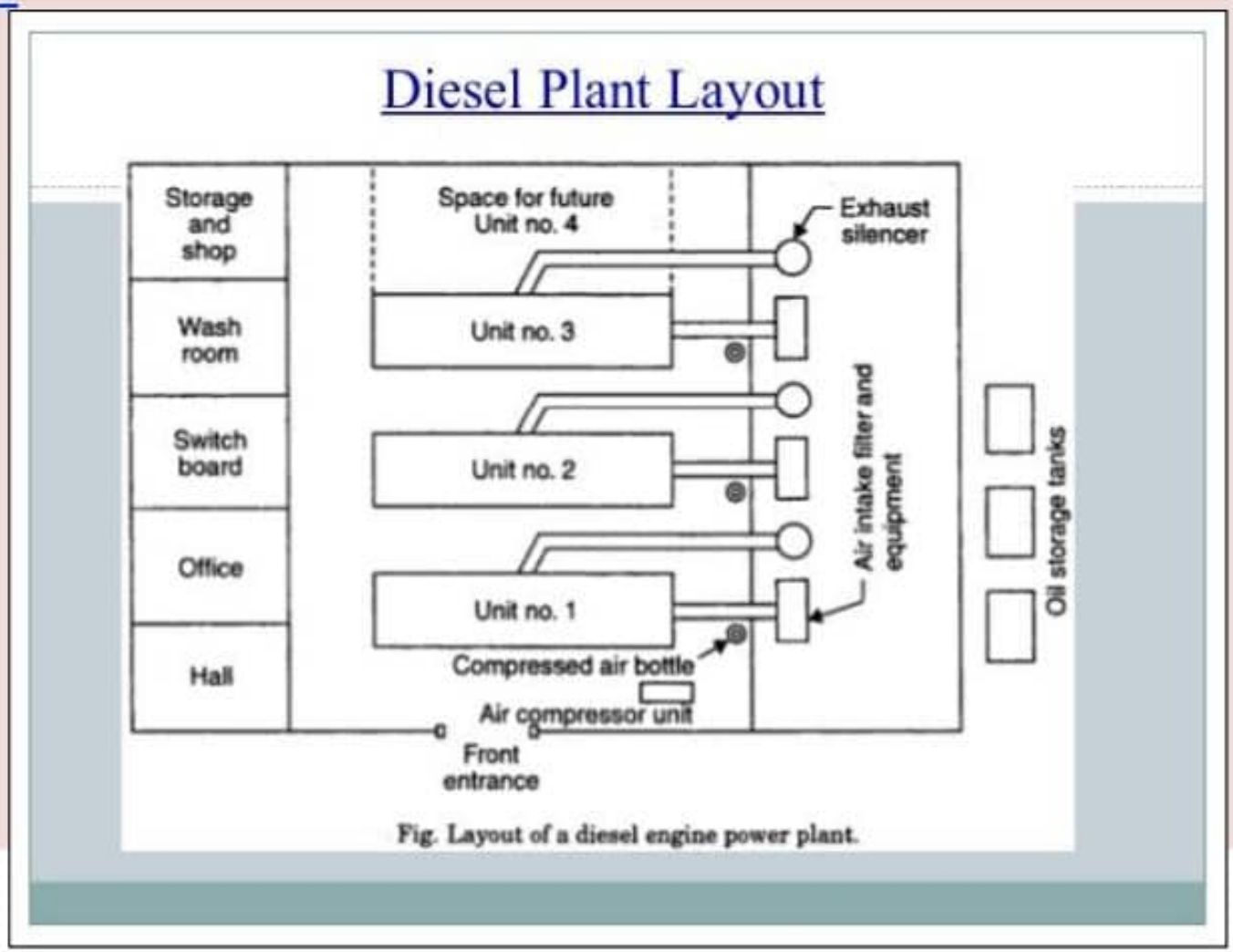


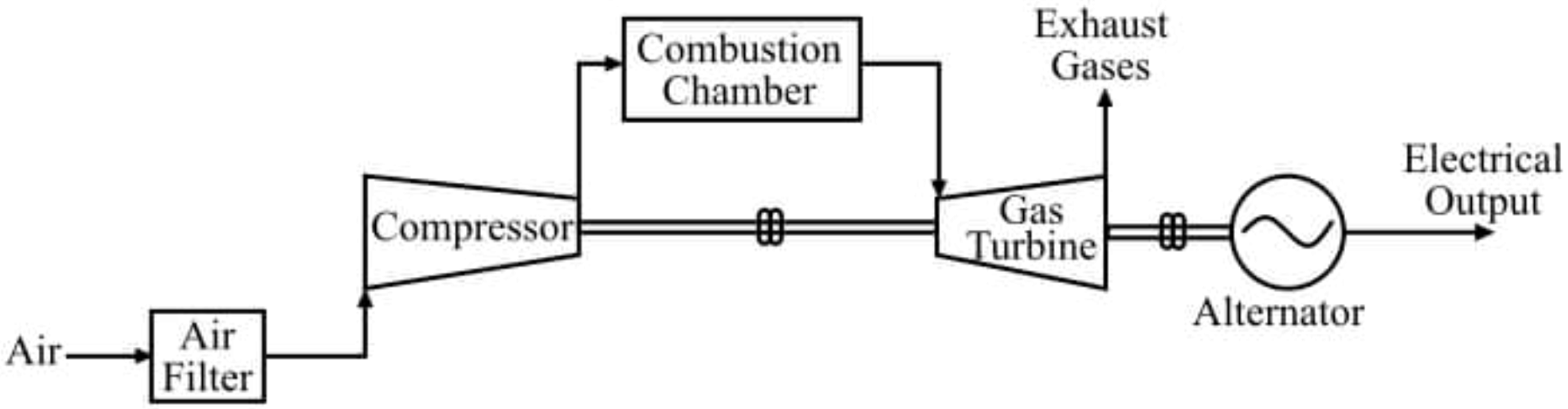
Fig. Layout of a diesel engine power plant.

Applications of diesel power plant

- Suitable for small or medium capacity range of 2 to 50 MW.
- Used in industries where power equipment's is up to 500 kW.
- Used as standby plants to hydro and steam power plant.
- Used as mobile power generation system such as automobile, ship, aeroplane, railways and road transport.
- Used as peak load plants in combination with thermal or hydro-plants to meet the power demands during peak hours.
- Diesel units can be used to run the auxiliaries for starting a large steam power plant
- Diesel plants can be used a central station where the capacity required is small

Module-2.3
Gas Turbine Power Plant

A power generating plant which has gas turbine as the prime mover for the generation of electrical energy, is called the **gas turbine power plant.**



Advantages of Gas Turbine Power Plant

1. They are small in size, weigh less and have low initial cost per unit output.
2. They are easy to install within short periods.
3. They are quick-starting and smooth running.
4. They offer flexibility by supplying electricity for power generation as well as by supplying compressed air for process needs.
5. They are capable of using a range of liquid and gaseous fuels including synthetic fuels.
6. They are subjected (put) to fewer environmental restrictions than other prime movers.
7. Water consumption is less compared to steam power plant.

Disadvantages

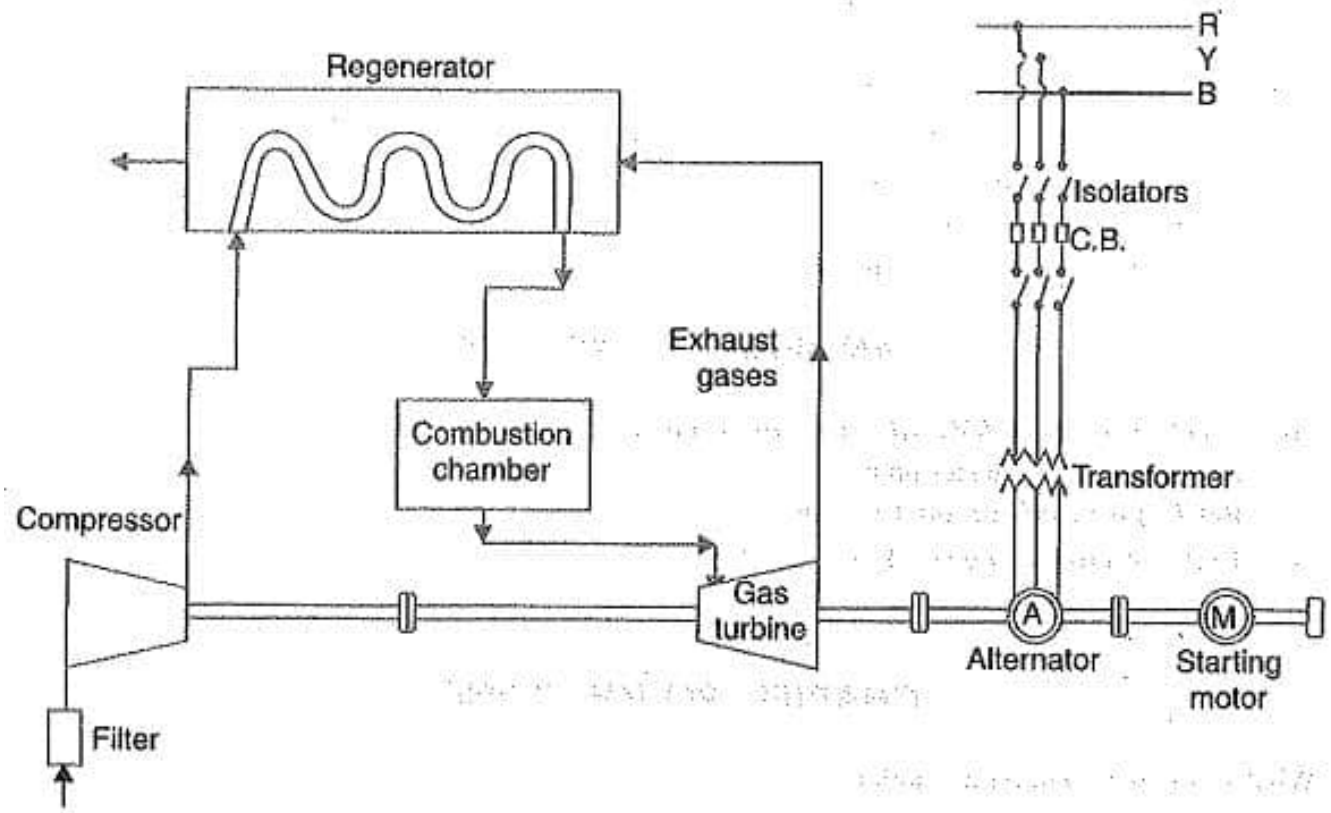
1. High temperatures impose severe restriction on the servicing conditions of the plant.
2. Overall efficiency is low since two-thirds of the total power output is used for driving the compressor.
3. Gas turbine plants have less vibrations when compared with reciprocating engines of the same speed. However the high frequency noise from the compressor is objectionable.
4. They are incompatible with solid fuels.

Gas Turbine Power Plant

Site selection criteria:-

- **Distance from the load centre:-**
- **Availability of land:-** Available at cheap rate
- **Availability of fuel:-** Reasonable rate
- **Availability of transportation facility:-**
- **Distance from the populated area:-** Away from thickly populated area.
- **Type of land:-** Load bearing capacity & resist against vibration of turbine.

Schematic Arrangement of Gas Turbine Power Plant:



Schematic arrangement of gas turbine power plant.

Fig. 2.9

1.Compressor: The compressor is responsible for drawing in and compressing air before it enters the combustion chamber. It increases the pressure of the air, which is necessary for efficient combustion.

2.Regenerator. A regenerator is a device which recovers heat from the exhaust gases of the turbine. The exhaust is passed through the regenerator before wasting to atmosphere. A regenerator consists of a nest of tubes contained in a shell. The compressed air from the compressor passes through the tubes on its way to the combustion chamber. In this way, compressed air is heated by the hot exhaust gases.

3.Combustor: This is where the fuel is mixed with compressed air and ignited to produce high-temperature, high-pressure gases that drive the turbine. The result is that the chamber attains a very high temperature (about 3000˚F). The combustion gases are suitably cooled to 1300˚F to 1500˚F and then delivered to the gas turbine.

4.Gas Turbine:

- This is the primary component responsible for converting the chemical energy of the fuel into mechanical energy through combustion.
- The gas turbine consists of a compressor, combustion chamber, and turbine.
- Air is compressed by the compressor, mixed with fuel, and ignited in the combustion chamber.
- The expanding gases then drive the turbine, which is connected to a generator to produce electricity.

•**Turbine**: The turbine is driven by the high-pressure, high-temperature gases produced in the combustion chamber. As the gases expand through the turbine, they lose energy, which is transferred to the turbine blades, causing them to rotate. This rotation drives the shaft connected to the generator, producing electricity.

5 Generator: The generator converts the mechanical energy from the turbine into electrical energy. It typically consists of a rotor and a stator, with the rotation of the rotor inducing an electrical current in the stator windings.

6 Exhaust System: After passing through the turbine, the exhaust gases are expelled from the system through the exhaust system. In some cases, these gases may be treated to reduce emissions before being released into the atmosphere.

7.Starting motor. Before starting the turbine, compressor has to be started. For this purpose, an electric motor is mounted on the same shaft as that of the turbine. The motor is energised by the batteries. Once the unit starts, a part of mechanical power of the turbine drives the compressor and there is no need of motor now.

8.Control System: A sophisticated control system is essential for monitoring and regulating various parameters such as fuel flow, air flow, temperature, and pressure to ensure efficient and safe operation of the gas turbine power plant.

•**Auxiliary Systems**: These include systems for fuel supply, lubrication, cooling, and air intake filtration, among others, which are essential for the proper functioning of the gas turbine power plant.

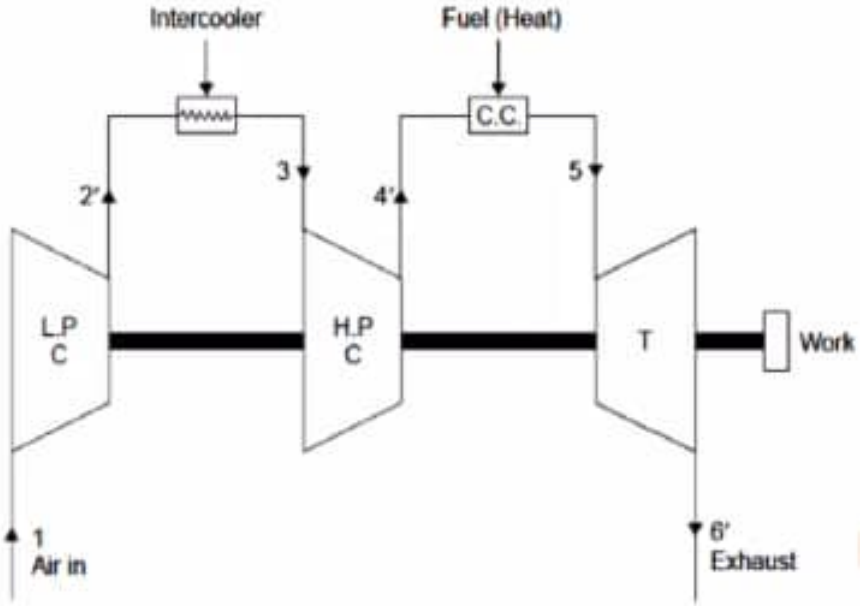
Methods of improving thermal efficiency of open cycle gas turbine

1. Intercooling
2. 2. Reheating
3. 3. Regeneration

Intercooling

A compressor in a gas turbine cycle utilizes the major percentage of power developed by the gas turbine. The work required by the compressor can be reduced by compressing the air in two stages and incorporating an intercooler between the two as shown in Fig.

1-2' Low Pressure Compression
2'-3 Intercooling
3-4' High Pressure Compression
4'-5 Heat addition in combustion chamber
5-6' Expansion in turbine



Reheating

- The output of gas turbine can be improved by expanding the gasses in two stages with a reheater between the two turbines.
- The H.P. turbine drives the compressor and the LP turbine provides useful power output.

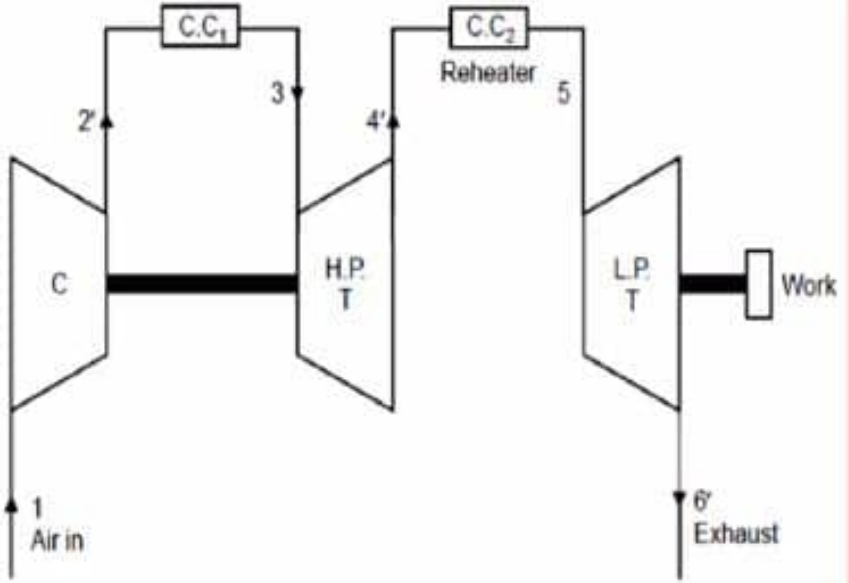
1-2' Compression in compressor

2'-3 Heat addition in CC

3-4' Expansion in HP turbine

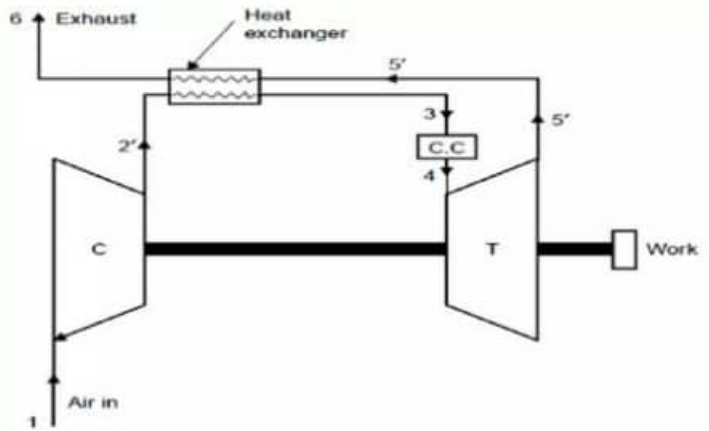
4'-5 Heat addition in reheater

5-6' Expansion in LP turbine



Regeneration

- The temperature of exhaust gases leaving the turbine of a gas turbine engine is considerably higher than the temperature of air delivered by the compressor.
- Therefore, high pressure air leaving the compressor can be heated by hot exhaust gases, thereby reducing the mass of fuel supplied in the combustion chamber. Hence the thermal efficiency can be increased.
- The heat exchanger used to transfer the heat from exhaust gases to compressed air is known as regenerator.



1-2' ---- Compression in compressor

2'-3 ---- Heat addition into the compressed air during its passage through the heat exchanger

3-4 ---- Heat addition in the combustion chamber

4-5' ---- Expansion in turbine

5'-6 ---- Heat rejection in heat exchanger to the compressed air

Sr.no	Factors	Open cycle gas turbine	Closed cycle gas turbine
1.	**Pressure**	Lesser pressure	Higher pressure
2.	**Size of the plant for given output**	Larger size	Reduced size
3.	**Output**	Lesser output	Greater output
4.	**Corrosion of turbine blades**	Corrosion takes place due to contaminated gases	No corrosion since there is indirect heating.
5.	**Working medium**	Loss of working medium	No loss of working medium.
6.	**Filtration of incoming air**	It may cause severe problem.	No filtration of air is required.
7.	**Part load efficiency**	Less part load efficiency	More part load efficiency
8.	**Thermal efficiency**	Less thermal efficiency	More thermal efficiency
9.	**Requirement of cooling water**	No Requirement of cooling water	Larger amount of cooling water required
10.	**Weight of system for given power**	Less	More
11.	**Response to the changing load**	Good response	Poor response
12.	**Fluid friction**	More Fluid friction	Less Fluid friction

Gas turbines usually operate on an open cycle. Air at ambient conditions is drawn into the compressor, where its temperature and pressure are raised. The high pressure air proceeds into the combustion chamber, where the fuel is burned at constant pressure. The high-temperature gases then enter the turbine where they expand to atmospheric pressure while producing power output.

Some of the output power is used to drive the compressor.

The exhaust gases leaving the turbine are thrown out (not re-circulated), causing the cycle to be classified as an **open cycle.**

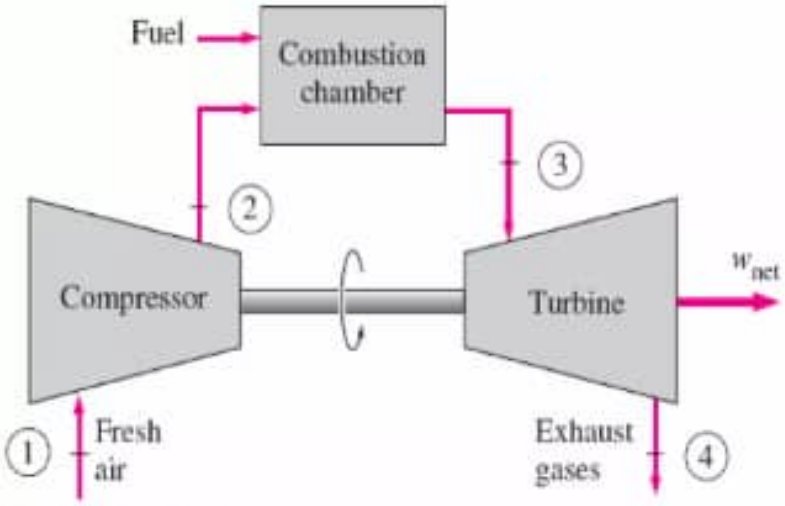


FIGURE 9–29

An open-cycle gas-turbine engine.

CLOSED CYCLE GAS TURBINE POWER PLANT AND ITS CHARACTERISTICS

- The compression and expansion processes remain the same, but the combustion process is replaced by a **constant-pressure heat addition** process from an external source.
- The exhaust process is replaced by a **constant-pressure heat rejection** process to the ambient air.

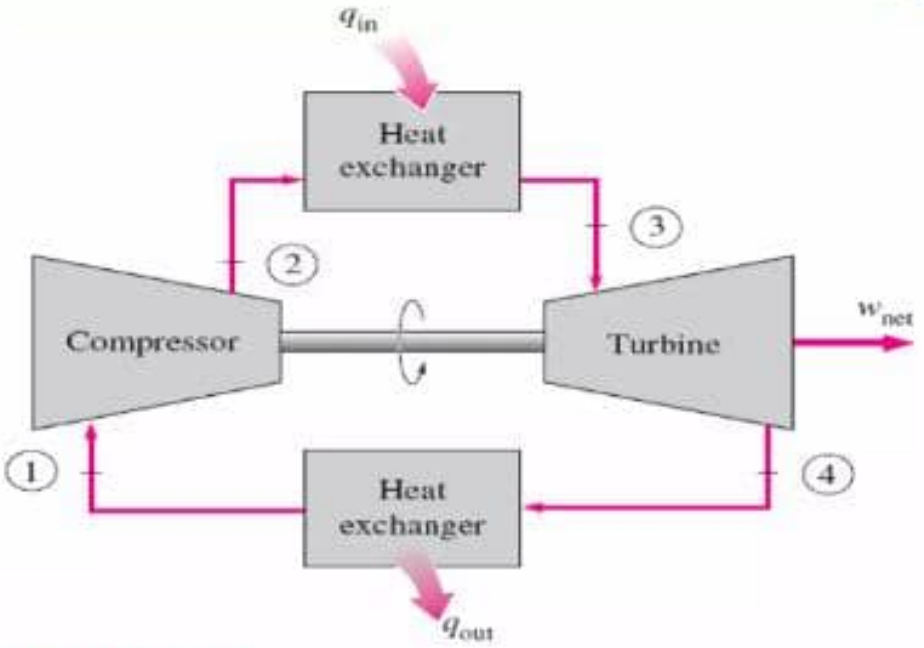


FIGURE 9–30
A closed-cycle gas-turbine engine.

Merits and Demerits of Closed Loop Cycle Turbine over Open Loop Cycle turbine

- Merits:
- Higher thermal efficiency
- Reduced size
- No contamination
- Improved heat transmission
- Lesser Fluid friction
- No loss in working medium
- Greater output
- Inexpensive fuel.

- Demerits:
- Complexity
- Large amount of cooling water is required.
- Dependent System
- Not economical for moving vehicles as weight /kW developed is high.
- Requires the use of very large air heater.

S.no	Gas Turbine	Steam Turbine
1.	In gas turbine the compressor and combustion chamber are the important components.	In steam turbine the steam boiler and accessories are the important components.
2.	Less space for installation is required.	More space for installation is required.
3.	The mass of gas turbine per kW produced is less.	The mass of the steam turbine per kW produced is more.
4.	Less installation and running cost.	More installation and running cost.
5.	With the changing load conditions, its control is easy.	Its control is difficult, with the changing load condition.
6.	The starting of this turbine is easy and quick.	The starting of steam turbine is not easy and takes long time.
7.	A gas turbine does not depend on water supply.	A steam turbine depends upon water supply.
8.	Its efficiency is less.	Its efficiency is high.

Aspect	Diesel Power Plant	Gas Power Plant	Steam Power Plant
Fuel	Diesel	Natural Gas, Propane, etc.	Coal, Natural Gas, Biomass
Efficiency	Medium to High	High	Medium to High
Initial Cost	Moderate to High	Moderate to High	High
Operating Cost	Moderate to High	Moderate to High	Moderate to High
Emissions	Higher emissions of CO2, NOx	Lower emissions	Higher emissions of CO2
	and particulates		and other pollutants
Start-up Time	Quick	Quick	Long (hours)
Flexibility	Moderate	High	Low
Maintenance	Moderate to High	Moderate to High	High
Size	Medium to Large	Medium to Large	Large
Applicability	Standby or Peak Power	Baseload, Peak, Combined	Baseload, Peak