S.J.P.N. Trust's,
HIRASUGAR INSTITUTE OF TECHNOLOGY, NIDASOSHI
Department of Mechanical Engineering

Power plant Engineering

Course content 10ME833

PART – A

UNIT – 1

STEAM POWER PLANT

Different types of fuels used for steam generation, Equipment for burning coal in lump form, stokers, different types, Oil burners, Advantages and Disadvantages of using pulverized fuel, Equipment for preparation and burning of pulverized coal, unit system and bin system. Pulverized fuel furnaces, cyclone furnace.

7Hour

UNIT – 2

COAL, ASH HANDLING AND DIFFERENT TYPES OF BOILERS

Coal and Ash handling, Generation of steam using forced circulation, high and supercritical pressures, A brief account of LaMount, Benson, Velox, Schmidt, Loeffer and Ramson steam generators.

6 Hours

UNIT – 3

CHIMNEYS, ACCESSORIES FOR THE STEAM GENERATOR COOLING TOWERS AND PONDS

Natural, forced, induced and balanced draft, Calculations involving height of chimney to produce a given draft. Accessories For The Steam Generator such as super-heaters, desuperheater, control of super heaters, Economisers, Air Pre-heaters Study of different types of cooling towers and ponds.

.

6 Hours

UNIT-4

DIESEL ENGINE AND GAS TURBINE POWER PLANT

Method of starting diesel engines, Cooling and lubrication system for the diesel engine. Filters, centrifuges, Oil heaters, Intake and exhaust system, Layout of a diesel power plant.Advantages and disadvantages of the gas turbine plant, Open and closed cycle turbine plants with the accessories

7 Hours

PART – B

UNIT – 5

HYDRO-ELECTRIC PLANTS

Storage and poundage, flow duration and mass curves, hydrographs, Low, medium and high head plants, pumped storage plants, Penstock, water hammer, surge tanks, gates and valves, power house, general layout. A brief description of some of the important Hydel Installations in India.

7 Hours

Powerplant Engineering, HIT, Nidasoshi

UNIT – 6

NUCLEAR POWER PLANT

Principles of release of nuclear energy Fusion and fission reactions. Nuclear fuels used in the reactors. Multiplication and thermal utilization factors. Elements of the Nuclear reactor, Moderator, control rod, fuel rods, coolants. Brief description of reactors of the following types - Pressurized water reactor, Boiling water reactor, Sodium graphite reactor, Homogeneous graphite reactor and gas cooled reactor, Radiation hazards, Radioactive waste disposal.

7 Hours

UNIT – 7

CHOICE OF SITE

Choice of site for power station, load estimation, load duration curve, load factor, capacity factor, use factor, diversity factor, demand factor, Effect of variable load on power plant, selection of the number and size of units.

6 Hours

UNIT – 8

ECONOMIC ANALYSIS OF POWER PLANT

Cost of energy production, selection of plant and generating equipment, performance and operating characteristics of power plants, tariffs for electrical energy

6 Hours

Text Books

1. **Power Plant Engineering**, P.K Nag, 3rd Ed. Tata McGraw Hill2nd ed 2001,
2. **Power Plant Engineering.** Morse F.T., Van Nstrand.1998

Additional References

1. **Water Power Engg**., Edition 3, Barrows, TMH, New Delhi. 1998
2. **Plant Engg. Hand Book**, Stanier, McGraw Hill. 1998
3. **Hydraulic Machines**, Jagadish Lal, Metropollitan Co 1996.
4. **Principles of Energy Conversion**, A.W. Culp Jr., McGraw Hill.1996
5. **Power Plant Technology**, M.M. EL-Wakil, McGraw Hill,International. 1994
6. **Power Station Engg. Economics**, Skrotizke and V opat. 1994
7. **Power Plant Engineering,** Domakundawar, Dhanpath Raisons.2003

Powerplant Engineering, HIT, Nidasoshi

UNIT – 1
STEAM POWER PLANT

Introduction

Steam power plants are producing about half of the total power requirement in India. In a steam Power plant, thermal energy is used to raise steam that is used to run steam turbines to produce mechanical energy. This mechanical energy is converted into electrical energy in a generator. Steam power plants are suitable for large scale production of electrical power. **Selection of site for steam power plants** There are many factors that are to be considered while selecting site for a hydel power plant. The important factors are as follows:

1) **Availability of fuel**

2) **Transportation**

3) **Availability of water**

4) **Ash Disposal**

5) **Nature of land**

6) **Space Area**

1. Availability of fuel: The site selected should have abundant sources of fuel (generally coal, petroleum or natural gas). A steam power plant using Coal as fuel needs about **1,500 tons of coal for every 100 MW** of power produced.

2. Transportation: Though having a plant at the fuel source does not require transportation for fuel, it may be away from the place of use. This leads to high transmission costs and loss of power, hence possible to locate a site for economical power transmission and fuel transmission. Rope-ways or railway is the better choices of transportation at the interior places. Sea transportation is economical for plants and fuel source near sea shores.

3. Availability of water: A steam power plant requires **high volumes** of water for use as feed water, ash handling and mainly for condensing. About **50 to 60 thousand tones** of water **per hour** is required for every **100 MW** of power developed, as cooling water and makeup water for the feed. A good quality of drinking water is also essential for the use of employees.

4. Ash Disposal: Generally the steam power plants produce ash about **20 to 30%** of fuel burnt. The ash to be disposed may be **several thousand tons a day.** Hence the site selected should have **provision** for proper disposal of ash.

5. Nature of land: The soil of the site selected should have a **good bearing capacity** as it has to support huge structures and **dynamic forces** in operating conditions. A bearing capacity of **10 kgf/cm2**is essential to set up a steam power plant.

6. Space Area: Steam power plants need the **maximum space** area all other power plants. They require larger space areas for coal yards, buildings, machinery & equipment, cooling

Powerplant Engineering, HIT,Nidasoshi

towers, ash disposal and for residential purpose. About **500 acres** of land is necessary for every **100 MW** of power produced.

Layout of a Steam Power Plant Essential components and systems of a steam power plant-

1) Turbine Generator

2) Furnace Boiler

3) Fuel Handling System

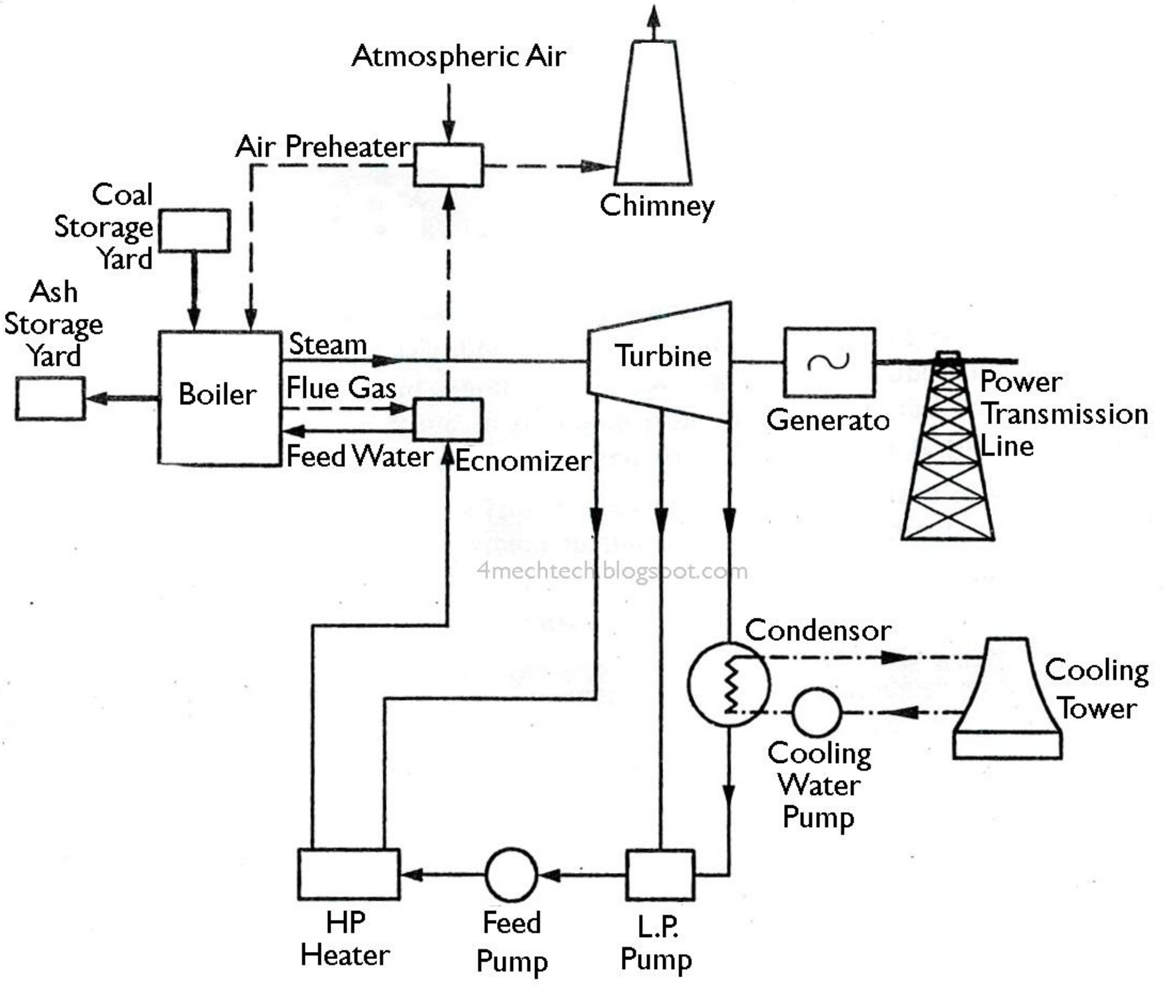
4) Ash Handling System

5) Draught System

6) Condensing System

7) Water Cooling System

8) Lubrication System



Fuels for steam Generation

Steam power plant uses fossil fuels to generate steam. The fuel may be in different form such as solid, liquid, pulverized or gaseous. The selection of the type of fuel depends on the availability of fuels and economical conditions. **Types of Fuels** The important fuels are as follows-

1) **Solid fuels**

2) **Liquid fuels**

3) **Gaseous fuels**

1) Solid fuels: Coal is the major fuel used for thermal power plants to generate steam. Coal occurs in nature, which was formed by the decay of vegetable matters buried under the earth millions of years ago under pressure and heat.

The chemical substances in the coal are

• Carbon, -50-95%

• Hydrogen, 1-5.5%

• Nitrogen, 0.5-7%

• Oxygen, 2-40%

2) Liquid Fuels:

All types of liquid fuels used are derived from crude petroleum and its by-products. The **petroleum or crude oil** consists of **80-85% C**, **10-15% hydrogen**, and varying percentages of sulphur, nitrogen, oxygen and compounds of vanadium.The fractions from light oil to heavy oil are naphtha, gasoline, kerosene, diesel and finally heavy fuel oil. The heavy fuel oil is used for generation of steam.

The use of liquid fuels in thermal power plants has many advantages over the use of solid fuels. **Some important advantages are as follows:**

1) The storage and handling of liquid fuels is much easier than solid and gaseous fuels.

2) Excess air required for the complete combustion of liquid fuels is less, as compared to the solid fuels 3) Fire control is easy and hence changes in load can be met easily and quickly.

4) There are no requirements of ash handling and disposal.

5) The system is very clean, and hence the labour required is relatively less compared to the operation with solid fuels.

3) Gaseous Fuels:

For the generation of steam in gas fired thermal plants, either **natural gas** or **manufactured gaseous fuels** are used. However, manufactured gases are costlier than the natural gas. Generally, natural gas is used for power plants as it is available in abundance. The natural gas is generally obtained from gas wells and petroleum wells. The major constituent in natural

Powerplant Engineering, HIT,Nidasoshi

gas is methane, about 60-65%, and also contains small amounts of other hydrocarbons such as **ethane**, **naphthene** and **aromatics**, **carbon dioxide** and **nitrogen.** The natural gas is transported from the source to the place of use through pipes, for distances to several hundred kilometers. The natural gas is **colourless, odourless** and **non-toxic.** Its calorific value ranges from 25,000 to 50,000.KJ/m3, the artificial gases are **producer gas**, **water gas coke-oven gas**; and the **Blast furnace gas**. Generally, power plants fired with artificial gases are not found. The gaseous fuels have advantages similar to those of liquid fuels, except for the storage problems. The major disadvantage of power plant using natural gas is that it should be setup near the source; otherwise the transportation losses are too high. **Fuel Feeding & Firing Systems** In India, steam power plants use coal as the fuel, since coal is the major source and also it is available in abundance. Power plants with smaller outputs are using liquid fuels like diesel oil and heavy fuel oils. All major steam power plants are run by burning coal. Coal is generally referred to as fuel, which is used either in solid or powdered form. The coal in powdered form is termed the pulverized coal.

The different firing methods are:

1. Solid fuel
    a) Hand firing
    b) Mechanical stoker firing
2. Pulverized fuel
    a) Unit system,
    b) Bin or central system

Hand Firing:

Though hand firing is simple and cheaper it is not generally used, because of the following reasons: 1) It has low combustion efficiency.

2) Slow response to the load fluctuations.

3) Combustion control is difficult.

4) Suitable only for small power plants.

Mechanical Stoker Firing:

Even though it is costlier, generally they are used to feed the solid fuels in small and medium size power plants, because of the following reasons:

1) Combustion is more efficient.

2) Fuel handling is automatic and combustion control is easier.

3) Faster response to load fluctuations.

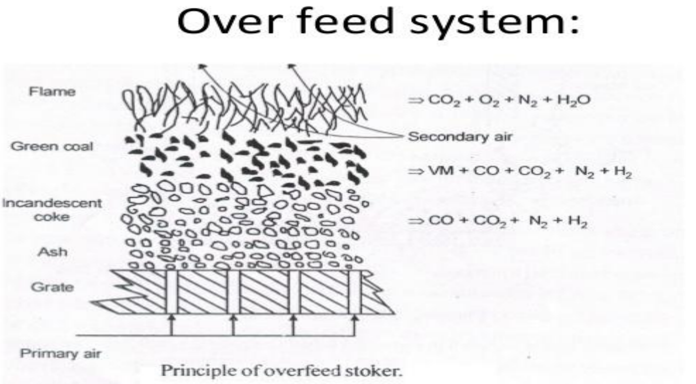
4) Low quality fuels can be successfully burnt. 5) Suitable for small to high capacity plants.

Powerplant Engineering, HIT, Nidasoshi

Principle of Stokers

The different types of stokers work on the following principles.

a) **Principle of overfeed stokers** b)**Principle of under feed stoker**



Principle of overfeed stoker.

A fully built up overfeed stoker will have the beds of green coal (raw coal), incandescent coke and ash over the grate. In this the primary air enters the grate from the bottom, which cools the grate while moving up and gets heated as it passes through hot ash bed. The hot air then passes through the bed of incandescent coke, where oxygen reacts with the carbon in the coke to form carbon dioxide, carbon monoxide and hydrogen. Part of carbon dioxide formed reacts with carbon in the fuel to form carbon monoxide. The gases leaving the bed of incandescent coke consist of nitrogen, carbon dioxide, carbon monoxide, hydrogen and water. To these gases, then an additional air termed the secondary air is supplied from the sides to burn the combustible gases like the carbon monoxide, hydrogen and other volatile matters. The burnt hot gases **entering** the boiler consist of carbon dioxide, nitrogen, oxygen, and water. It may also contain carbon monoxide, if the combustion is incomplete. The primary and secondary air to the stoker is supplied under pressure with the help of blowers.

Principle of under feed stoker

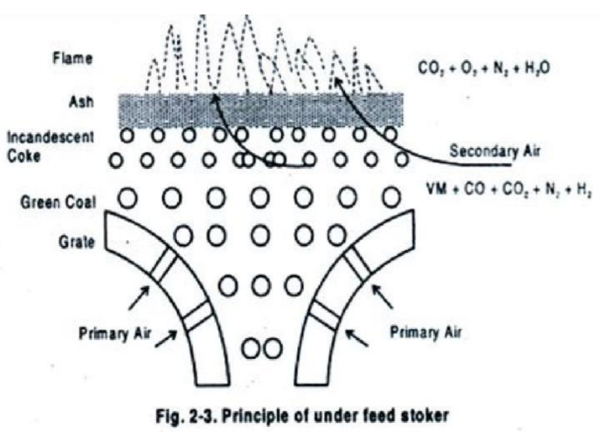


Fig. 2-3. Principle of under feed stoker

In this the coal is charged from the bottom, and the primary air under pressure also moves from the bottom through the holes in the grate. This stoker has the layers of ash, incandescent coke bed and raw coal, in the reverse direction as compared to that of the overfeed stoker. In operation the primary air entering from the bottom through the grate holes comes in contact with the coal and then passes through the bed of incandescent coke. In operation the primary air entering from the bottom through the grate holes comes in contact with the green coal and then passes through the bed of incandescent coke. Initially, air reacts with carbon in the coke to form carbon dioxide, and the moisture in the air reacts to release carbon dioxide, carbon monoxide and hydrogen. While these gases pass over the ash bed, secondary air is supplied for their complete combustion. This method is most suitable for semi-bituminous and bituminous coals which have high volatile-matter.

Types of Stokers

Different types of stokers are

1. Over feed stokers

- a) Conveyer stoker
  - i) Chain grate stoker
  - ii) Traveling grate stoker
- b) Spreader stoker

2. Under feed stokers

- a) Single retort stoker
- b) Multi-retort stoker

1) Chain & traveling grate stokers

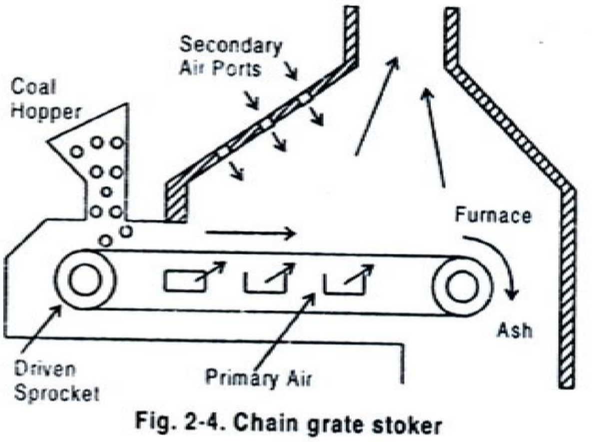


Fig. 2-4. Chain grate stoker

A chain grate stoker consists of an endless chain which forms the support for the fuel bed. The chain is made of cast iron links connected by pins. The chain is held over two sprockets as shown figure, and travels from one end of the furnace to the other end. The sprocket at the front end is driven by an electric motor. The coal is fed at the front end through a hopper which is carried by the chain to the other end, hence into the furnace. The air necessary for

Powerplant Engineering, HIT, Nidasoshi

the combustion of the fuel is supplied through the air inlets below the traveling grate. The secondary air is supplied through the openings in the top roof as shown in figure. The rate of fuel supplied to the grate and hence the heat to the boiler can be controlled by two means. The first means is to control the depth of the coal bed on the grate by controlling the feed to the hopper. In the second method, the speed of the chain grate can be adjusted to meet the boiler operation requirements. The chain grate stokers are widely used for burning non-caking (that does not form a solid mass while burning), free burning, volatile and high ash content coals.

Advantages of chain grate stokers

1) It is simple in construction and operation.

2) Its initial and maintenance costs very low.

3) It doesn't have ash cleaning problems.

4) Combustion control is simple, by control of feed or chain speed, along with the air supply.

5) Its combustion efficiency is high.

Disadvantages

1) It is suitable only for small capacity plants.

2) Coal losses are high as the un burnt coal may also move with ash.

3) If caking coal is used ash clinker problems may rise.

• In the traveling grate stoker, the chain grate is replaced by grate bars that support the burning fuel.

• Also the grate is inclined towards the inlet of the furnace.

• The fuel movement is accomplished and controlled by vibration of the grate.

Spreader or Sprinkler Stoker

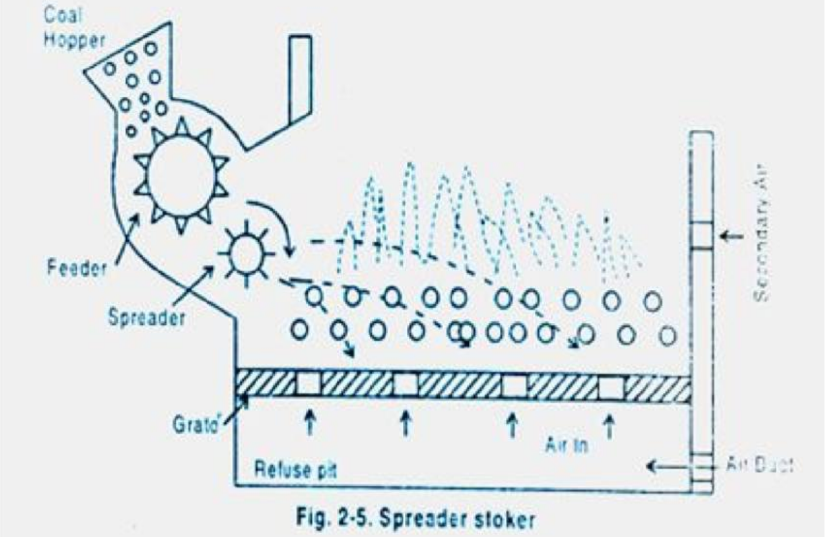


Fig. 2-5. Spreader stoker

Fig. shows the schematic arrangement of a spreader stoker. In this type stoker, coal from the hopper is fed on to a rotating feeder which in turn feeds the, to a spreader or sprinkler, and feed according to the requirements. Feeder is a rotating drum fitted with blades on its

Power plant Engineering, HIT,Nidasoshi

periphery. Other type of feeders such as reciprocating rams, endless belts or spiral worms can also be used. The feeder continuously supplies the coal on to the spreader, a fast moving drum with blades, which in turn distributes and feeds the coal on to the grate as shown in figure. The fuel feed rate and the supplied to the boiler can be controlled by controlling the feed to the hopper are by controlling the spreader speed.

Advantages of spreader stoker

1) Its operation is simple and economical.

2) A wide variety of low quality coals can be burnt successfully.

3) Preheated air can be used for improving the efficiency of operation.

4) The fuel burns rapidly and hence the caking tendency is very low, even with the use of caking coals.

5) It can respond quickly to load variations

Disadvantages

1) It is not possible to burn varying sizes of coal and only crushed, sized coal can be used.

2) A part of the charge is burnt in suspension and hence fly ash is discharged with flue gases.

3) Un burnt carbon particles may escape through the flues and reduce the combustion efficiency.

Single Retort Stoker

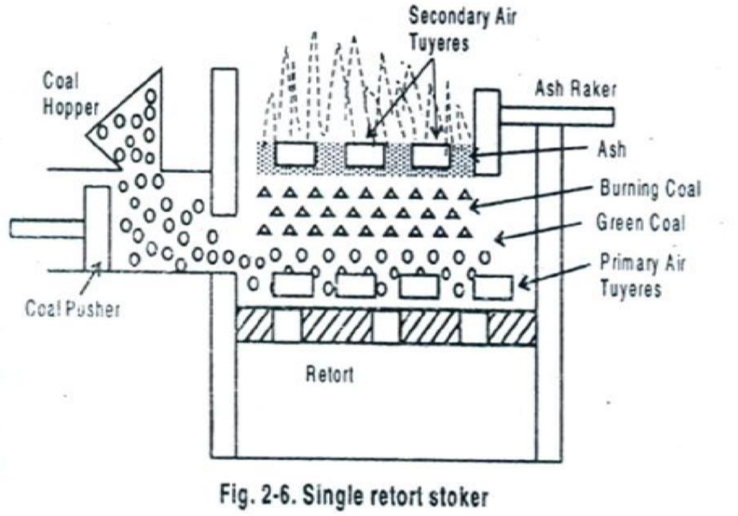


Fig. 2-6. Single retort stoker

The principle of construction of a single retort stoker is illustrated in Fig. In this stoker, fuel is burnt on a retort. The fuel is fed through a hopper and pushed on to the retort by a piston ram movement. With the feeding from the bottom, gradually the burning coat rises up. Above the green coal an incandescent coke layer is formed, and above which the ash layer is formed. With the continuous feeding of green coal, the ash level rises that is removed by ash raker.

Power plant Engineering, HIT Nidasoshi

Multi Retort Stoker

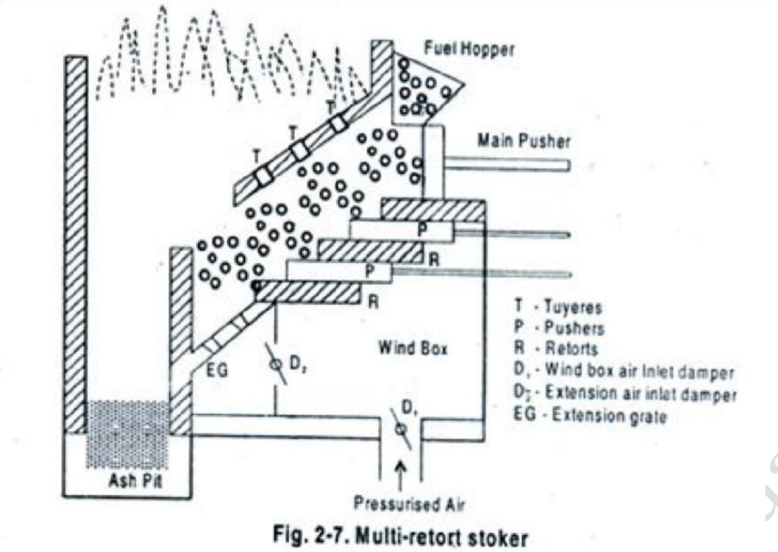


Fig. 2-7. Multi-retort stoker

It contains of a series of retorts (5 to 20) with tuyers and pushers. It also consists of a fuel hopper and a coal pusher at the hopper end as shown in figure. The coal fed through the hopper is pushed by the main pusher driven by a ram. The distributing pushers in the retorts push the coal and distribute it to all the retorts. The movement of the fuel bed by the pushers helps in minimizing the clinker formation. The primary air enters the wind box below the retorts, and flows through the retorts. An air damper is provided at the air inlet in the wind box to control the airflow to the furnace. The airflow to the extension grate at its entry is further controlled by another damper, sincethe extension grate requires small quantity of air with less fuel burning on it. The ash formed from all the retorts falls into the ash pit.

Advantages of multi retort stoker

1) Since the combustion rate is high, such a stoker is most suitable for high capacity power plants.
2) The combustion efficiency of this stoker is very high.
3) As the fuel is pushed off by the pushers, they perform the cleaning action as well.
4) Automatic combustion control can be adopted in this stoker.
5) This stoker can respond quickly to variations in demand.

Disadvantages

1) The operation and maintenance is expensive.
2) The initial investment is high.
3) Ash clinker problems may arise.
4) It needs a larger area for installation and operation.
5) Low grade, high ash fuels cannot be burnt successfully.

Powerplant Engineering, HIT Nidasoshi

Pulverized Coal Firing

In pulverised fuel firing system, the coal is powdered and then charged into the combustion chamber with the help of hot air current. The **main purpose** of pulverizing coal is to increase the surface area of exposure to the combustion process, which results in faster and efficient combustion. In burning the pulverized coal, the secondary air required for the complete combustion of fuel is supplied separately to the combustion chamber. The resulting turbulence in the combustion chamber helps for uniform mixing of fuel and air. The air required to carry the pulverized coal and dry it **before entering the combustion** chamber is termed the **Priming Air**, and the air supplied separately for complete combustion is termed the Secondary Air. Pulverized coal firing systems are universally adopted far large scale power plants. The choice of pulverized fuel firing system depends upon the **size of the boiler unit, type of coal available, cost of coal, type of load (i.e., fluctuating or constant), the load factor and availability of trained personnel**. Generally such systems are not economical for small capacity thermal power plants

Advantages of using pulverized coal

1) A wide variety of low grade fuels (coal) can be used and burnt easily.

2) Greater surface area is exposed for combustion and hence combustion is faster and efficient.

3) The system is free from clinker and slagging troubles.

4) Combustion control is easy, and hence the system gives fast response to load changes.

5) Preheated secondary air (up to 350°C) can be used, resulting in rapid flame propagation and faster heat supply to the boiler.

6) The pulverizing system can be maintained or repaired without affecting the combustion process.

7) It has a very high rate of heat release.

8) Banking losses (un burnt fuel with ash) are lower, as compared to stoker firing.

9) The boilers can be started from cold very rapidly.

10) Usually combustion will be smokeless.

Disadvantages of Pulverized system

1) The capital investment of the system is **high** as it requires additional equipments (for pulverizing, and handling).

2) Its **operation and maintenance** costs are very **high**.

3) It produces fly-ash/fine dust and needs costly fly-ash removal equipments like **electrostatic precipitators.**

4) The chances of **explosion are high as coal burns like a gas.**

Powerplant Engineering HIT, Nidasoshi

5) The storage of powdered coal requires special attention as it has possibilities of fire hazards. 6) Skilled workers are required for safe-operation and maintenance.

7) Air pollution takes place by the emission of fine particles of grit and dirt.

8) The removal of liquid slag formed from low fusion temperature ash requires special handling equipments.

Pulverized Fuel Burning System

There are two common methods of pulverized fuel burning systems-
1. Unit system

2. Central or Bin system

1. Unit System In this system, each burner and a pulveriser constitute a unit. It consists of a raw coal bunker, a feeder, pulverizing mill, separator, and the burner. In operation, the raw coal is supplied to the bunker, where it is crushed to the required sizes, the crushed coal is then fed to the pulverizing mill through the feeder at the required rate, depending upon the combustion requirements. Hot gases are passed through the feeder to dry the coal. The dried coal is pulverised in the mill and it is carried to the burner. An induced draft fan is used at the pulverizer to carry the powdered coal to the burner. A separator is provided to separate the grains of bigger size from the powder and returned to the pulverize for further crushing.

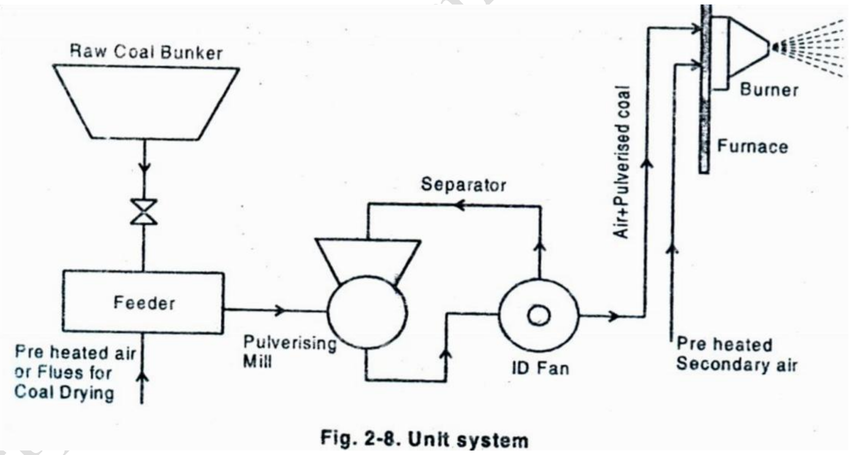


Fig. 2-8. Unit system

Advantages
1) It is simple in operation and economical than the central system.

2) Combustion is controlled directly after pulverize.
3) Maintenance cost is low.
4) Fuel supply to the burner can be controlled easily.
Disadvantages
1) The performance of the pulverizing mill is poor as the system operates at **variable loads.**

2) The total capacity of mills must be higher than the central system.

3) The unit system of fuel burning is **less flexible.**

4) Whenever any of the auxiliaries fails the burner has to be put-off.

5) **Wear and tear** of the fan blades is more since it handles hot air and coal particles.

6) Strict **maintenance** of pulverizing mill is a must for perfect operation of the system.

Central or Bin System

Fig. shows schematic arrangement and the principle of operation of a central, or bin system for burning pulverized coal. The crushed raw coal is dried using hot air or flue gases and fed to the pulverize. The pulverized coal from the pulverizing mill is passed to the **cyclone separator** where **over-sized particles are separated** and fed back to the mill.

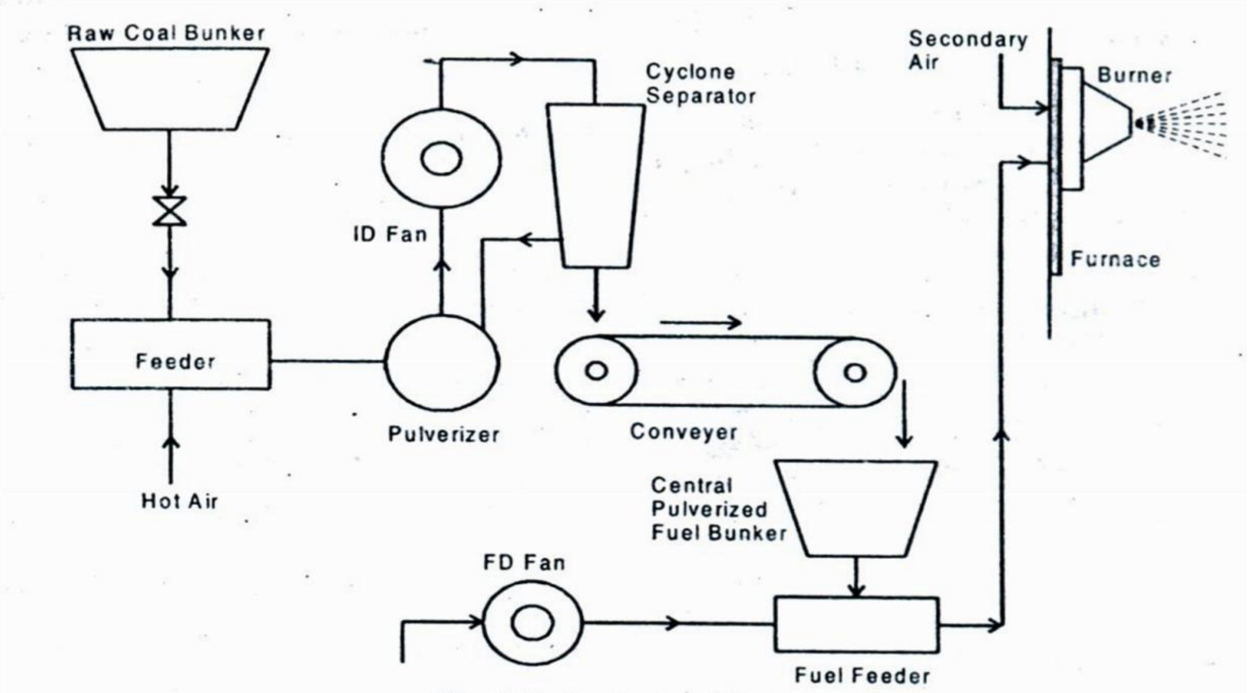


Fig. 2-9. Central or bin system

The pulverized coal is then transferred from the separator to the central bunker (bin) through a conveyer system. The pressurized air from the forced draft fan, supplies the stored coal to the burner. This air not only carries the fuel, but also acts as the primary air for the combustion of the fuel. Secondary air is supplied to the burner separately to assist in the complete combustion.

Advantages of Central system

1) Central system is highly flexible and hence can meet any quick changes in the demand
2) Burner operation is independent of coal pulverization.

3) The pulverizing mill can be stopped when there is a good stock of pulverized fuel in the bin.

4) The fan wear is less as it handles only natural air.
5) Coal size can be controlled efficiently.

Disadvantages

1) Central system is expensive, and occupies more space.

2) It requires complicated coal handling systems.

3) Power consumption in auxiliaries is high.

4) Chances of fire hazards are more since the pulverized fuel is stored.

5) Operation and maintenance costs are high.

Pulverised Coal Burners

Burners are devices that allow uniform mixing of fuel with air hence lead to efficient and complete combustion. The burner receives the fuel along with the primary air in a central passage, while the secondary air is supplied around the passage. A good design of the burner is essential to achieve complete combustion of the fuel. Thus a good burner should meet a number of design requirements. The important requirements of an efficient pulverised coal burner are as follows:

1) It should mix the fuel and primary air thoroughly and inject the mixture into the furnace.

2) It should create proper· turbulence for air-fuel mixing and maintain a stable combustion.

3) It should be able to control the flame shape and flame travel by varying the amount of secondary air.

4) Coal-air mixture should move away from the burner at a rate equal to the flame travel so as to avoid flash back.

5) It should be projected properly to avoid overheating, wear and internal fires.

Types of burners

There are four types of burners used for the pulverized fuel burning.

1) long-Flame or U-Flame or Stream lined burner

2) Short Flame or Turbulent Burner

3) Tangential Burners

4) Cyclone Burner

1) Long-Flame or U - Flame or Stream lined burner

The arrangement of a long flame, U-shaped burner is schematically shown Fig. The burner is placed such that it produces a long, u-shaped flame. The burner injects a mixture of primary air and fuel vertically downwards in thin streams practically with no turbulence and **produces a long flame.**

Powerplant Engineering, HIT, Nidasoshi

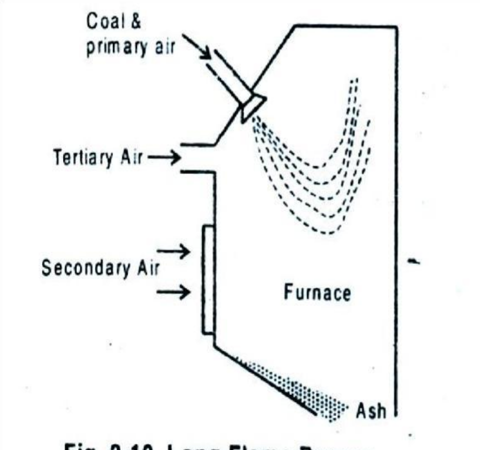


Fig. 2-10. Long Flame Burner

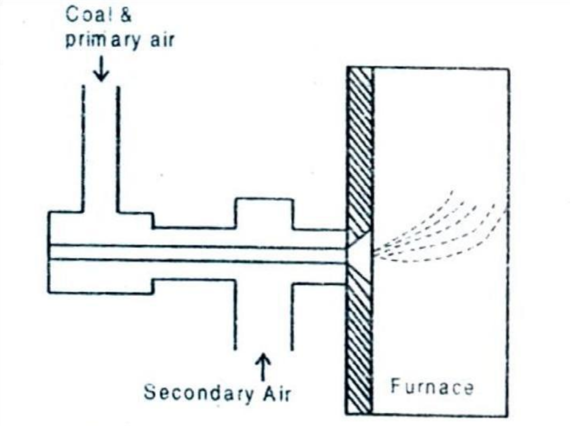


Fig. 2-11. Short Flame Burner

Secondary hot air is supplied at right angles to the flame which provides necessary turbulence and mixing for proper and rapid combustion. A tertiary air is supplied around the burner for better mixing of the fuel with air. In this burner due to long flame travel, high volatile coals can be burnt easily. Velocity of the air-fuel mixture at the burner tip is around of **25 m/sec.**

Short Flame or Turbulent Burner The schematic arrangement of a short-flame or turbulent burner is illustrated in fig. These burners are generally built into the furnace walls, so that the flame is projected horizontally into the furnace. Primary air and the fuel mixture is combined with secondary air at the burner periphery, before the entry into the furnace as shown in figure. This burner gives out a turbulent mixture which burns rapidly and combustion is completed within a short distance. Therefore, the combustion rate is high. The velocity of mixture at the burner tip is about **50 m/sec.** In such burners, the bituminous coal can be burnt easily. Modern **high capacity power** plants use such burners.

Tangential Burners

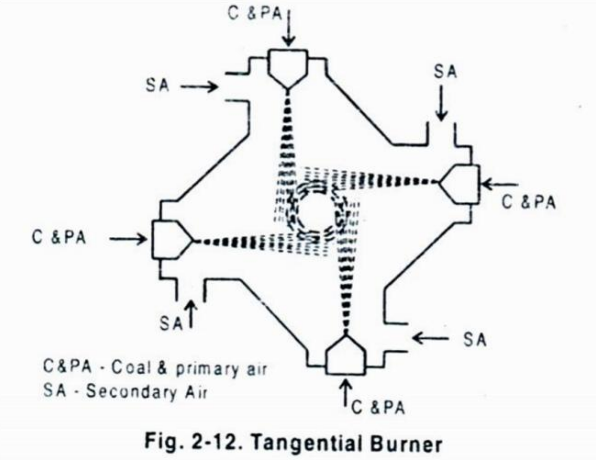


Fig. 2-12. Tangential Burner

These burners are built into the furnace walls at the corners. They inject the air-fuel mixture tangentially to an imaginary circle in the centre of furnace. As the flames intercept, it leads to a swirling action. This produces sufficient turbulence in the furnace for complete combustion. Hence in such burners, there is no need to produce high turbulence within the burners.

Powerplant Engineering, HIT, Nidasoshi

Tangential burners give fast and high heat release rates. **Avoiding fly-ash problems**, which is common in other types of burners. This burner **uses crushed coal** (about **5 to 6 mm** size) instead of pulverised coal. This burner can easily **burn low grade coal** with high ash and moisture content. Also, this can burn biofuels such as rice husk. The principle of operation of a cyclone burner is illustrated in Fig.

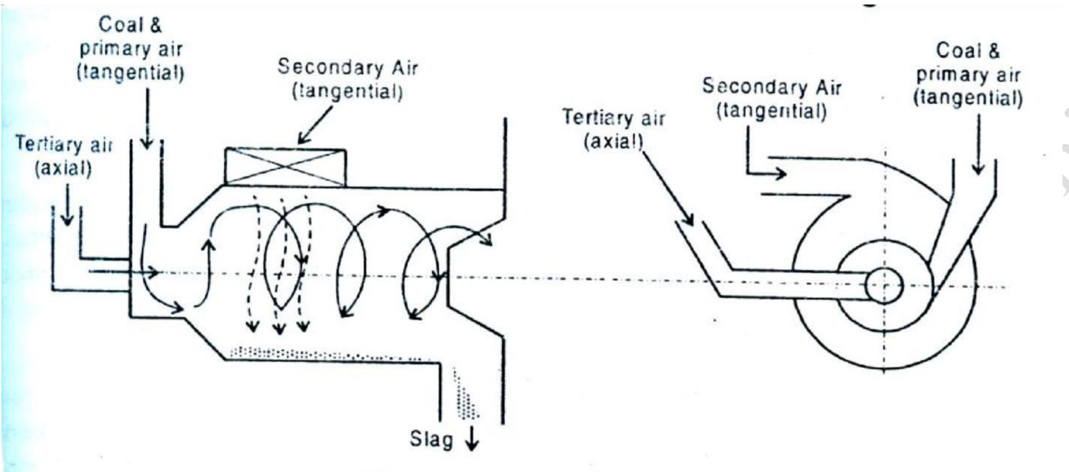


Fig. 2-13. Cyclone Burner

The cyclone burner consists of a horizontal cylinder of about **3 m diameter** and about **4 m length.** The cylinder wall is water cooled, while the inside surface is lined, with **chrome ore**. The horizontal axis of the burner is slightly inclined towards the boiler. The coal used in cyclone burner is crushed to about **6 mm size**. Coal and primary air (about 25% of the combustion or secondary air) are admitted tangentially into the cylinder so as to produce a strong centrifugal motion and turbulence to the coal particles. The primary air and fuel mixture flows centrifugally along the cylinder walls towards the furnace. From the top of the burner, the secondary air is also admitted tangentially, at a high velocity **(about 100 m/s).**The high velocity secondary air causes further increase in the centrifugal motion, leading to a highly turbulent whirling motion of the coal air mixture. Tertiary air (about **5 to 10%** of the secondary air) is admitted , axially at the centre as shown in fig, so as to move the turbulent coal-air mixture towards the furnace. The coal is burnt completely within the burner and only hot gases enter the furnace. Such burners produce **high heat and temperatures (about 1000°C).** Due to high temperature burning, the ash melts in the form of slag, and is drained out periodically at the bottom.

Advantages of cyclone burner

1) Since it uses crushed coal, it saves the cost of pulverization.

2) All the incombustible are retained in cyclone burner, and hence the boiler fouling problems are reduced.

3) It requires less excess air, as it uses forced draught.

4) Slag-recovery is around 80% and dust passing to the stack is about 10%. Thus simple equipment can be used for dust removal.

5) Fly ash problem is reduced to a great extent.

6) Low grade fuels can be used.

Disadvantages
1) It requires **high pressure** draught and consumes **higher power**.
2) It produces **more oxides of nitrogen**, which creates atmospheric pollution

Powerplant Engineering, HIT,Nidasoshi

Pulverizing Mills.

The various types of mills used for pulverising the coal are listed below :

(1) Ball mill
(2) Ball and Race mill,
(3) Impact or Hammer mill
(4) Bowl mill.

Ball Mill.

The line diagram of the ball mill is shown in Fig. It consists of a large cylinder partly filled with various sized steel balls (2.5 to 5 cm in diameter). The coal (6 mm) is fed into the cylinder and mixes with these balls. The cylinder is rotated (130 m/min peripheral velocity) and pulverization takes place as a result of action between the balls and the coal. The mill consists of coal feeder, pulveriser, classifier and exhauster. The feeders supply coal to **i** classifier and then it is passed to the pulveriser with the help of screw conveyor. A mixture of tempering air and hot air from air-preheater is introduced in the pulverize as shown in figure. These streams of airpeak up the pulverised coal and pass through the classifier. The over-sized particles are thrown out of t air stream in the classifier and fine material is passed to the burner through exhaust fan. The output of the mill is controlled by the dampers located in the exhaust fan inlet duct. These damp vary the flow of air through the mill and thereby control the rate of fuel removed from the mill. The dampers are operated by the boiler's automatic combustion control. The feeder output is regulated by the coal level in the cylinder. When the coal level in the cylinder attains sufficient height to seal off the lower channel then the differential control operates to stop the coal feed. A ball mill capable of pulverising 10 tons of coal per hour containing 4% moisture requires 28 ton of steel balls and consumes 20 to 25 kW-hr energy per ton of coal. The principal features of this pulveriser are listed below :

(1) The grinding elements in this mill are not seriously affected by metal scrap and other foreign material in the coal unlike the grinders in most other pulverisers.

(2) There is considerable quantity of coal in the mill which acts as a reservoir. This pulveriser prevents the fire from going out when there is slight interruption in fuel feed caused by coal clogging in the

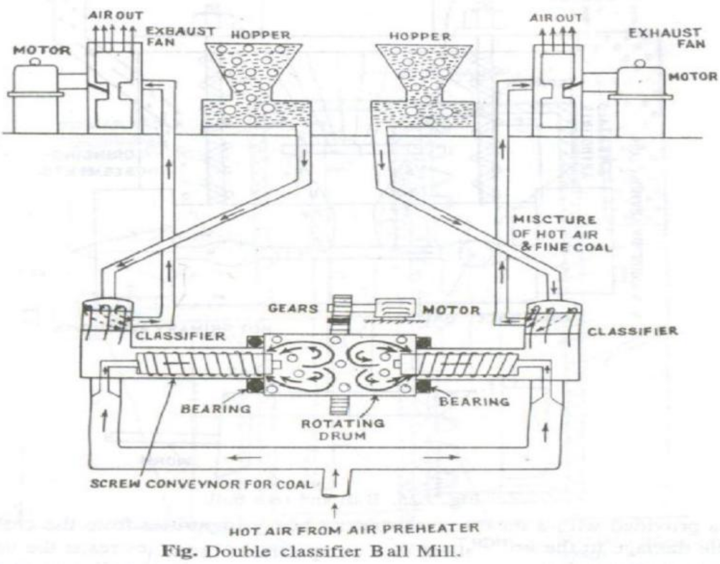


Fig. Double classifier Ball Mill.

(3)This mill can be used successfully for a wide range of fuels including anthracite and bituminous coal which are difficult to pulverise.
(4) The system is simple in operation, low in initial cost but operating cost is high.

Ball and Race Mill.

This is also known as contact mill which consists of two elements which have a rolling action with respect to each other. The coal passes between the rotating elements again and again until it has been pulverised to the desired degree of fineness. The pulverization is completed by a combination of crushing, impact and attrition between grinding surfaces. The line diagram of ball and race mill is shown in Fig.The coal is crushed between two moving surfaces: balls and races. The upper stationary race and lower rotating race driven by a worm and gear, hold the balls between them. The coal is supplied through the rotating table feeder at the upper right to fall on the inner side of the races. The moving balls and races catch coal between them to crush it to a powder. Springs hold down the upper stationary race and adjust the force needed for crushing. Hot air is supplied to the mill through the annular space surrounding the races by a forced draft fan. The air picks up the coal dust as it flows between the balls and races and then enters into the classifier above. The fixed vanes make the entering air to form a cyclonic flow which helps to throw the oversized particles to the wall of the classifier. The oversized particles slide down for further grinding in the mill. The coal particles of required size are taken to the burners with air from the top of the classifier. The mill is provided with a means of separating heavy impurities from the coal and thus reducing wear and possible damage to the grinding element. These heavy particles resist the upward thrust caused by the primary air stream and collect in a compartment in the base of mill, and then they are removed periodically. The automatic combustion control regulates the flow of primary air through the pulveriser and feeder and maintains the coal supply. When more coal is required, the primary air flow is increased automatically and its higher velocity in the mill carries additional coal in the furnace. This action reduces the amount of coal in the pulveriser and decreases the pressure drop, thus causing the feeder controller to supply more coal

Powerplant Engineering, HIT, Nidasoshi

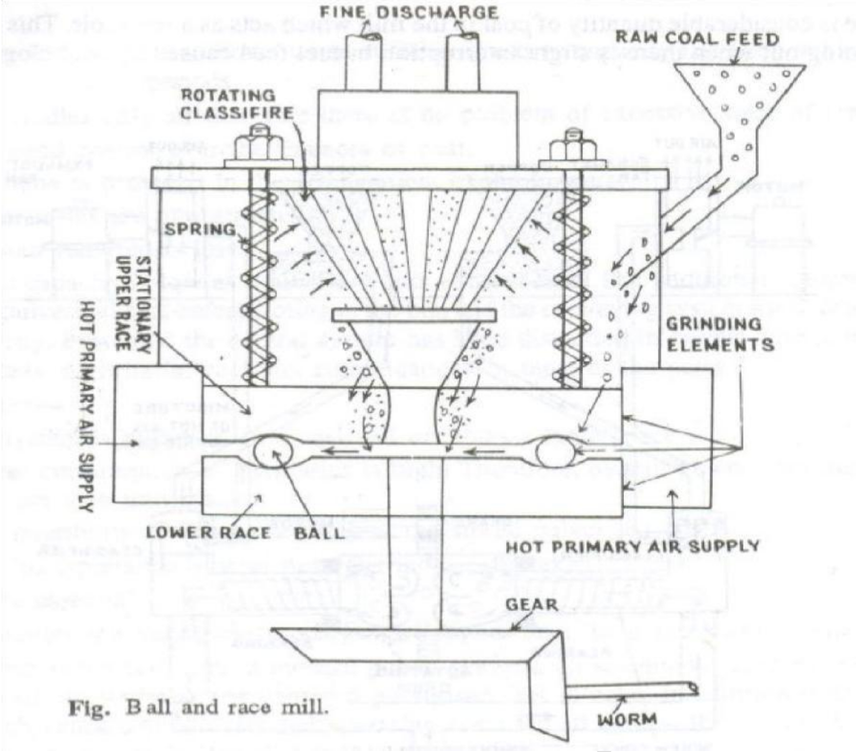


Fig. Ball and race mill.

The fan used with this mill handles only air therefore the blades erosion by coal particles is eliminated. As the casing of the pulveriser is under pressure, the leakage of fine coal through the mill casing causes the pulverised fuel to be blown out into the boiler room. This mill can handle coals containing as much as 20% moisture. Mill, feeder and fan need nearly 15 kW-hr energy per ton of coal pulverised. These pulverisers have greater wear compared to other pulverisers. The advantages of lower space occupied, lower power consumptions in kW-hr/ton of coal pulverised, lower weight and lower capital cost have outweighed the wear problem and these pulverisers found general acceptance.

Boul Mill.

The arrangement of boul mill is shown in Fig. This pulveriser consists of stationary rollers and a power driven boul in which pulverization takes place as the coal passes between the sides of the boul and the rollers. A primary air induced draught fan draws a stream of heated air through the mill, carrying the pulverised coal into a stationary classifier located in the top of the pulveriser. The classifier returns the coarse particles of coal to the boul for further grinding through the centre cone of the classifier. The coal pulverised to the desired fineness is carried to the burner through the fan. The impurities in coal containing heavy particles are thrown over the side by centrifugal force as these enter the rotating boul. These heavy particles thrown out fall into the space below the boul and are discharged from containing heavy particles are thrown over the side by centrifugal force as these enter the rotating boul. These heavy particles thrown out fall into the space below the boul and are discharged from the mill through a specially provided spout. The automatic control charges the supply of coal to the boul of the mill by adjusting the feeder speed and the flow of primary air by regulating the damper in the line from the pulverize to the fan.

Power plant Engineering, HIT, Nidasoshi

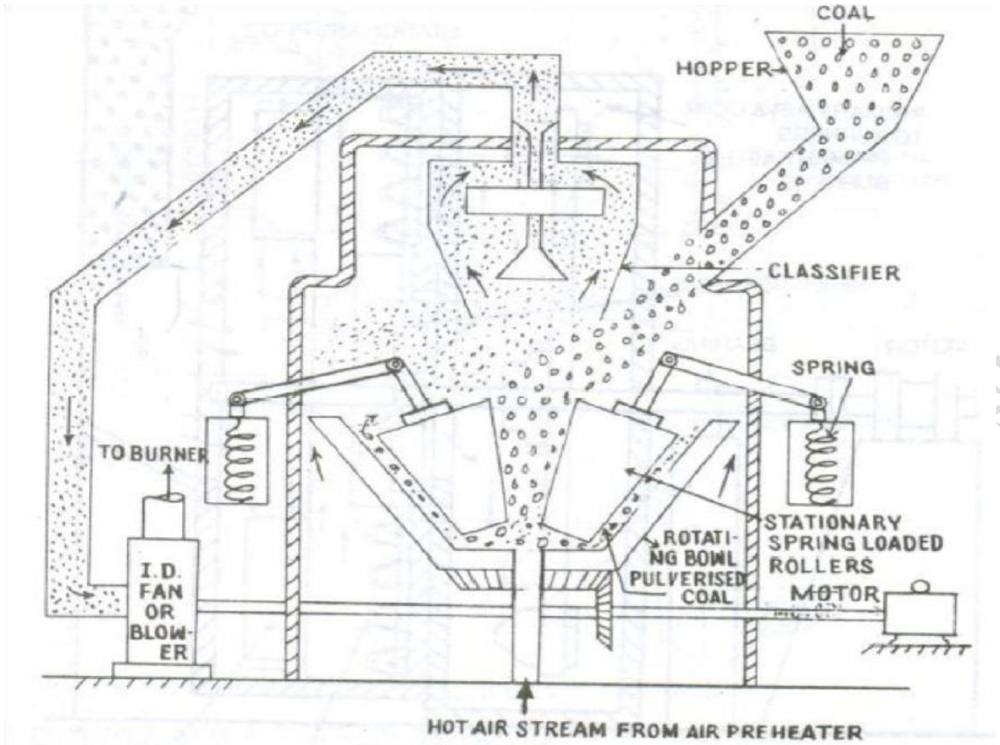


Fig . Boul mill.

The outstanding features of this pulveriser are listed below
(1) The classifier may be adjusted to change the coal fineness while the pulveriser is operating.

(2) The leakage of coal from the mill casing is completely eliminated as the mill operates under negative pressure.

In selecting the mill, the following coal characteristics and their effects on mill operation are considered:

(1) **Higher heating value of the coal,** which affects the ability of a pulveriser to meet the boiler requirement for maximum continuous rating.

(2) **Total moisture content,** used to determine the mill drying capacity.

(3) **Grindability,** used to select the mill size.

(4) **Volatile matter,** used to determine the required coal fineness.

(5) **Sulphur and mineral content,** used to determine pyrite removal sizing requirements.

The outstanding features of this pulveriser are listed below
(1) The classifier may be adjusted to change the coal fineness while the pulveriser is operating.

(2) The leakage of coal from the mill casing is completely eliminated as the mill operates under negative pressure.

In selecting the mill, the following coal characteristics and their effects on mill operation are considered:

(1) **Higher heating value of the coal,** which affects the ability of a pulveriser to meet the boiler requirement for maximum continuous rating.

(2) **Total moisture content,** used to determine the mill drying capacity.

(3) **Grindability,** used to select the mill size.

(4) **Volatile matter,** used to determine the required coal fineness.

(5) **Sulphur and mineral content,** used to determine pyrite removal sizing requirements.

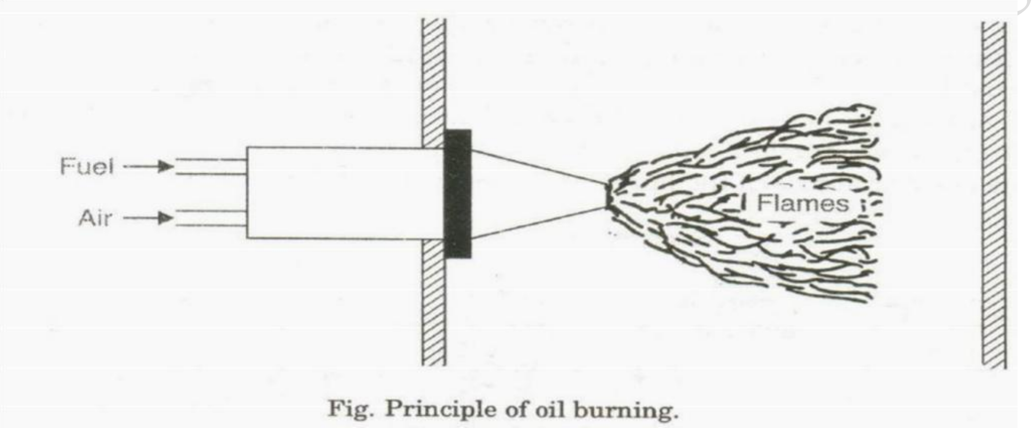


Fig. Principle of oil burning.

The fineness required in today's pulveriser differ unit to unit but most of the fuel is ground to atleast 98 - 99% passing 50 mesh and 60 - 70% passing 200 mesh.

Oil burners

Principle of oil firing.
*The functions of an oil burner are to mix the fuel and air in proper proportion and to prepare the fuel for combustion.*Fig. shows the principle of oil firing.

Classification ***of oil burners.*** The oil burners may be *classified* as:

1. *Vapourising oil burners :*
   a) Atmospheric pressure atomizing burner
   b) Rotating cup burner
   c) Recirculation burner
   d) Wick type burner
2. *Atomising fuel burners :*
   a) Mechanical or oil pressure atomising burner

Powerplant Engineering Nidasoshi

b) Rotating cup burner

c) Steam or high pressure air atomising burner

I. *Vapourising oil burners*

Following are the requirements of a vapourising/evaporation oil burner: *(i)* To vapourise the fuel before ignition.
(ii) To mix the vapourised fuel thoroughly with the air.

(iii) To minimise the soot formation.

(iv) To give high heat release by burning large quantity of oil per hour. *(v)* To allow for efficient combustion of fuel at part load operation.

(a) ***Atmospheric pressure atomizing burner.*** This burner makes use of highly volatile liquid fuels such as neptha, volatile gasoline etc. Here the *fuel at low pressure* is passed through a tube adjacent to the flame before being released through an orifice. While passing through the hot tube, most of the fuel is vapourised so that the fluid ejected from the orifice is more or less a vapour. The required quantity of primary air is supplied to burn the vapour stream in a cylindrical tube.

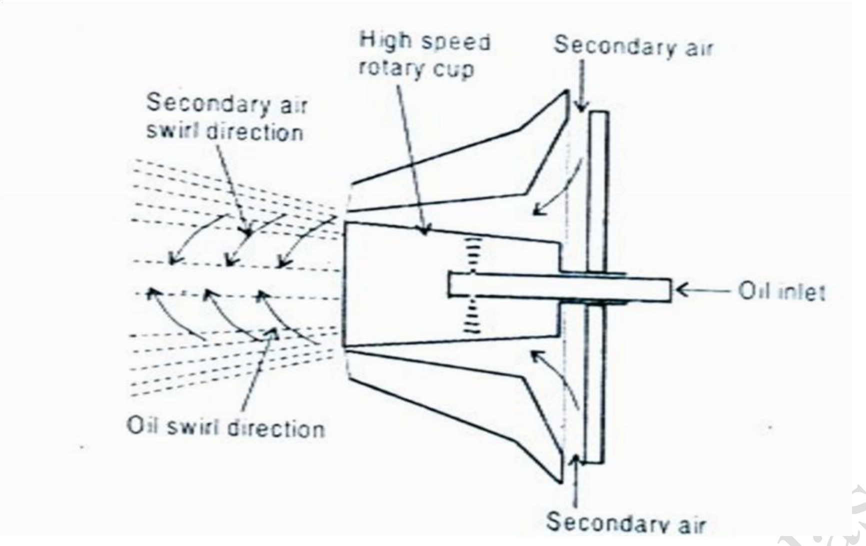
(b) ***Rotating cup burner.*** These burners are used on low as well as medium capacity boilers. In this type of burner, the fuel oil flows through a tube in the hollow shaft of the burner and into the cup at the furnace end. An electric motor or an air turbine runs the shaft and the cup at high speeds (3000 to 10000 r.p.m.). As a result of centrifugal force fuel is split into small droplets. About 10 to 15 percent of air is supplied as primary air. This air is supplied from a blower surrounding the cup. The shape of the flame is governed by the sharp edge of the cup and the position of air nozzle.

(c) ***Recirculating burner.***The part of the combustion products may be recirculated in order to heat up the incoming stream of fuel and air. Low ratio of the mass of recirculated combustion products to the mass of unburnt fuel-air mixture results in less temperature rise of the mixture, whereas, high ratio may extinguish the flame due to increased proportions of circulated products. An optimum ratio may be determined for different fuels experimentally.

In recirculation burner (utilising the above principle) circulation system is separated from the combustion by a solid wall.
(d) ***Wick burners.***In this type of a burner a cotton or asbestos wick is used which raises the liquid fuel by capillary action. The fuel from the uppermost part of the wick is evaporated due to radiant heat from the flame and the nearby heated surfaces. Air is admitted through holes in the surrounding walls.

A wick burner is suitable for models or domestic appliances
1) Rotary cup burner

Powerplant Engineering, HIT, Nidasoshi



The construction of rotary cup oil burner is schematically illustrated in Fig. It consists of a horizontal rotary cup that runs at a high speed (about 3000 rpm). The oil is supplied at the center though the inlet port and it is sprayed on the inner surface of the rim of the high speed rotary cup. The oil is spun off the high speed cup due to centrifugal force as very fine particles into the air stream entering the cup periphery, thus atomizing the oil. The direction of rotation of the cup and the direction of flow of air are opposite such that both mix thoroughly by swirling action as they leave the burner, and burn easily. Such burners have a wide capacity ranges, as the rate of oil burnt can be easily regulated by controlling the inlet port size at the centre of the cup.

2) Mechanical or oil pressure burner The construction of a typical oil pressure burner is schematically illustrated in Fig. In these burners the oil is subjected to high pressure and atomized by passing it through an orifice

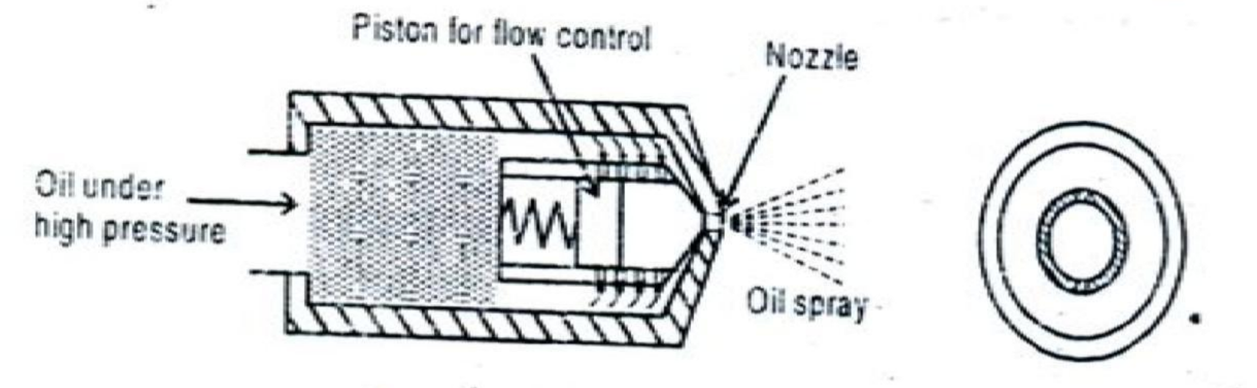


Fig. 2-16. Oil pressure burner

The oil is supplied under high pressure of 10 to 20 bar. Usually the oil passes through a swirl chamber and thoroughly get mixed with primary air. As the oil under pressure is ejected out of the

Engineering, HIT, Nidasoshi

orifice, it breaks down into fine particles, forms a conical oil mist and easily undergoes combustion. The oil flow through the orifice can be regulated with the help of control piston (plunger), which closes the tangential slots to the required level.

3) Steam or high pressure air burner In these burners the oil is atomized with the help of high pressure compressed air or steam. The high pressure air or steam enters the nozzle and mixes with the fuel. The air and oil, are supplied through two different channels, and are mixed either within the nozzle before leaving it or outside the nozzle after leaving it. The principle of such burners is schematically shown in Fig

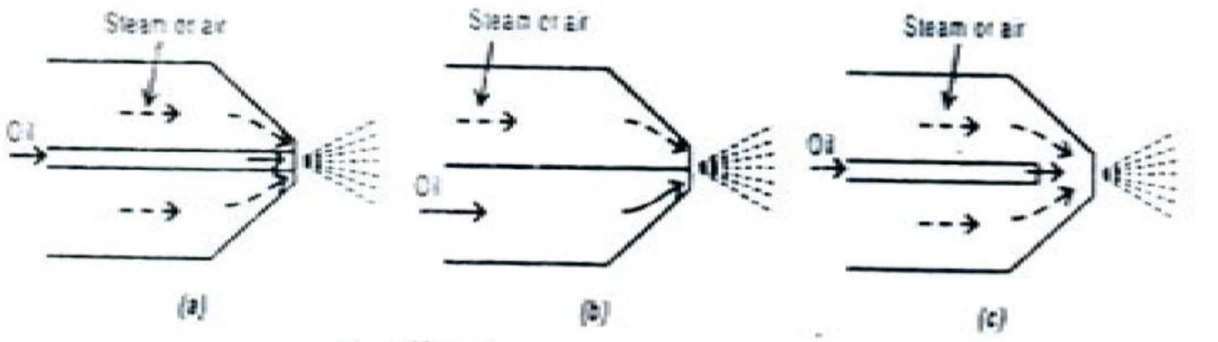


Fig. 2-19. Air or steam pressure burner

Powerplant Engineering, Nidasoshi

UNIT – 2
COAL, ASH HANDLING AND DIFFERENT TYPES OF BOILERS

Fuel Handling

Three types of fuels can be burnt in any type of steam generating plant: 1. Solid fuel such as *coal*; 2. Liquid fuel as oil and 3. Gaseous fuel as gas. Supply of these fuels to the power plants from various sources is one of the important considerations for a power plant engineer. The handling of these fuels is an important aspect. The following factors should be considered in selecting the fuel handling system:

1. Plant fuel rate.
2. Plant location in respect of fuel shipping.
3. Storage area available.

Fuel handling plant needs extra attention, while designing a thermal power station, as almost 50 to 60 percent of the total operating cost consists of fuel purchasing and handling. *Fuel system is designed in accordance with the type and nature of fuel.* Continuously increasing demand for power at lower cost calls for setting up of higher capacity power stations. Rise in capacity of the plant poses a problem in coal supply system from coal mines to the power stations. The coal from coal mines may be transported by the following means :

1. Transportation by sea or river,
2. Transportation by rail,
3. Transportation by ropeways,
4. Transportation by road, and
5. Transportation of coal by pipeline.

The pipeline coal transport system offers the following *advantages:*

1. It provides simplicity in installation and increased safety in operation.
2. More economical than other modes of transport when dealing with large volume of coal over long distances.
3. This system is continuous as it remains unaffected by the vagaries of climate and weather.
4. High degree of reliability.
5. Loss of coal during transport due to theft and pilferage is totally eliminated.
6. Manpower requirement is low.

Powerplant Engineering, HIT ,Nidasoshi

Requirements of Good Coal Handling Plant

1. It should need minimum maintenance.
2. It should be reliable.
3. It should be simple and sound.
4. It should require a minimum of operatives.
5. It should be able to deliver requisite quantity of coal at the destination during peak periods.
6. There should be minimum wear in running the equipment due to abrasive action of coal particles.

Coal Handling Systems

"Mechanical handling" of coal is preferred over *"manual handling"* due to the following *reasons :*

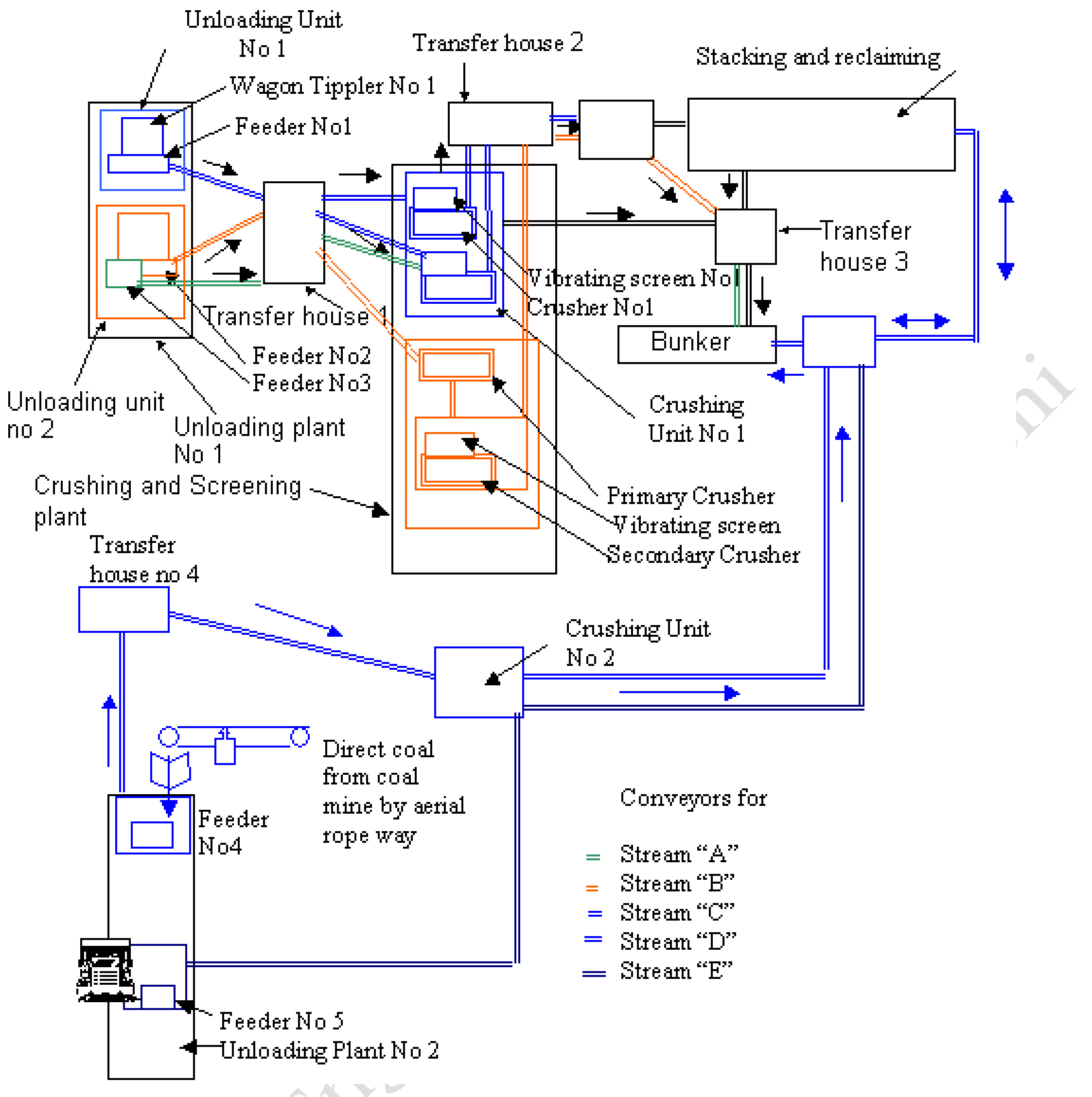
1. Higher reliability.
2. Less labour required.
3. Economical for medium and large capacity plants.
4. Operation is easy and smooth.
5. Can be easily started and can be economically adjusted according to the need.
6. With reduced labour, management and control of the plant becomes easy and smooth.
7. Minimum labour is put to unhealthy condition.
8. Losses in transport are minimised.

Disadvantages:

1. Needs continuous maintenance and repair.
2. Capital cost of the plant is increased.
3. In mechanical handling some power generated is usually consumed, resulting in less net power available for supply to consumers.

Coal Handling

Powerplant Engineering, HIT ,Nidasoshi



Coal Transfer equipments

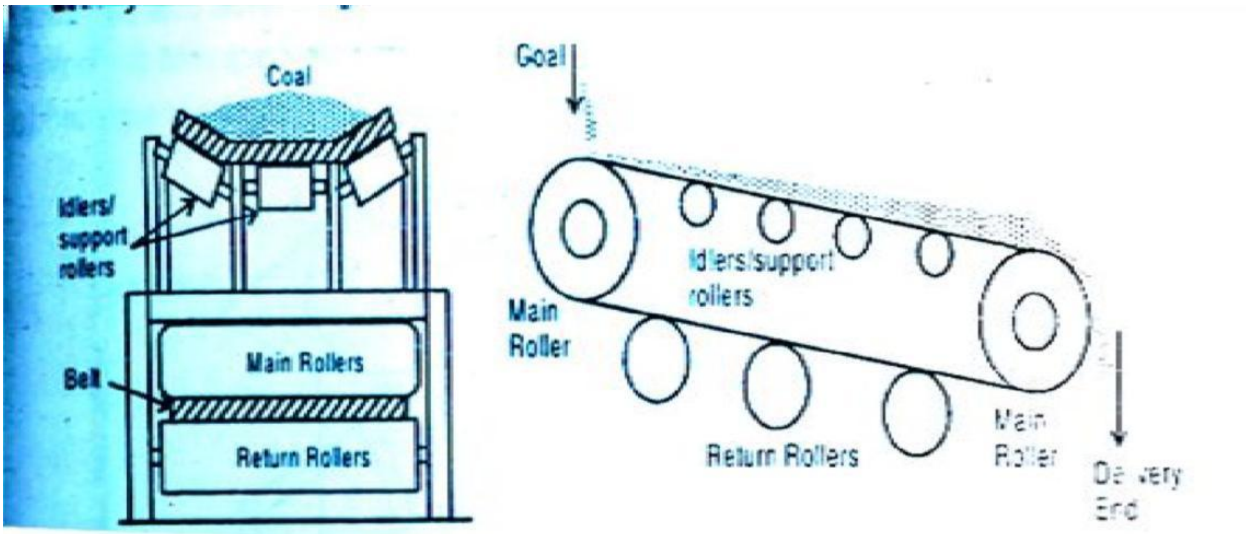
'Transfer' means the handling of coal between the unloading point and the final storage point from here it is discharged to the firing equipment.

The following equipment may be used for transfer of coal:

1 Belt conveyors
2 Screw conveyors
3 Bucket elevator and conveyor
4 Pivoted bucket conveyor
5 Grab bucket conveyor
6 Flight conveyers (or scrapers)
7 Skip hoists
8 Mass flow conveyor
9 Chutes

1) Belt Conveyor

It is basically an endless moving belt over which the coal is moved; the belt is connected to a pair of drums at the ends, and supported at the upper portion by a series of rollers (idlers) at regular intervals, as illustrated in Fig. The belt is usually made of strong and flexible materials such as rubber or canvas. Belt conveyors are useful for transportation of large quantity of coal over long distances in power plants.The belt is inclined at about 15-20 degrees from the charge end to the discharge end. The average speed of belt conveyors is in the range of 50 to 100 m/minute.



Advantages

1) It is simple in construction and operation.

2) The operation is smooth and clean.

3) It requires less power compared to other systems.

4) Large quantities of coal can be conveyed quickly and continuously. 5) It is comparatively cheaper in maintenance and operation.

(ii) ***Screw conveyor.*** Refer Fig. It consists of an endless helicoid screw fitted to a shaft. The driving mechanism is connected to one end of the shaft and the other end of the shaft is supported in an enclosed ball bearing. The screw while rotating in a trough/housing transfers coal from one end to the other end. The following particulars relate to this conveyor

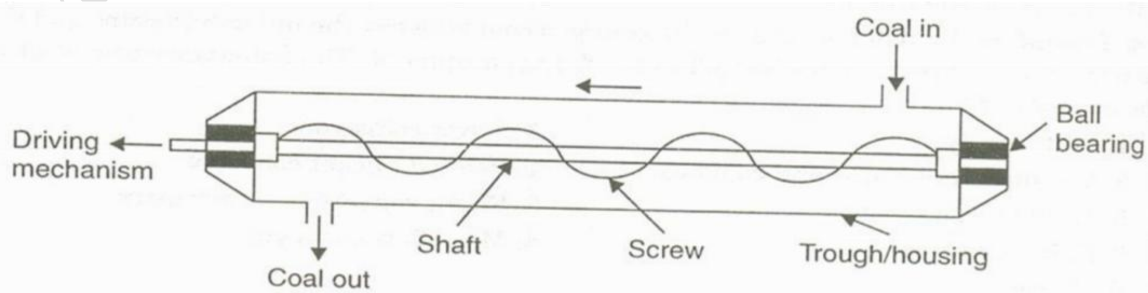
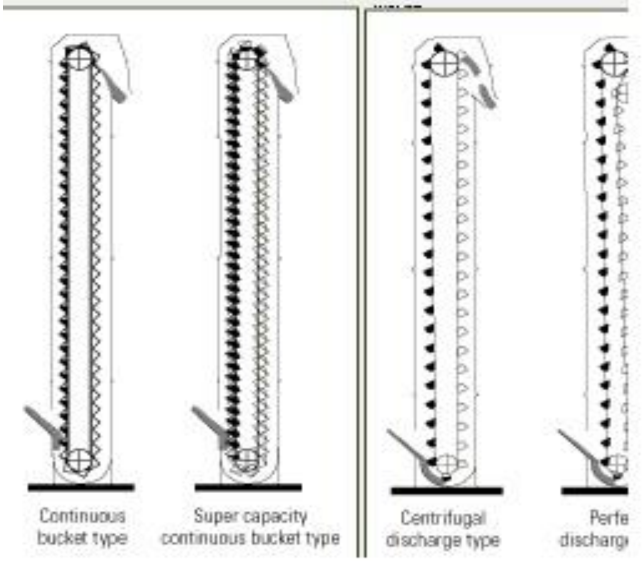


Fig. Screw conveyor.

Diameter of the screw	......15 to 50 cm
Speed	......70 to 120 r.p.m.
Maximum capacity	......125 tonnes/hour.

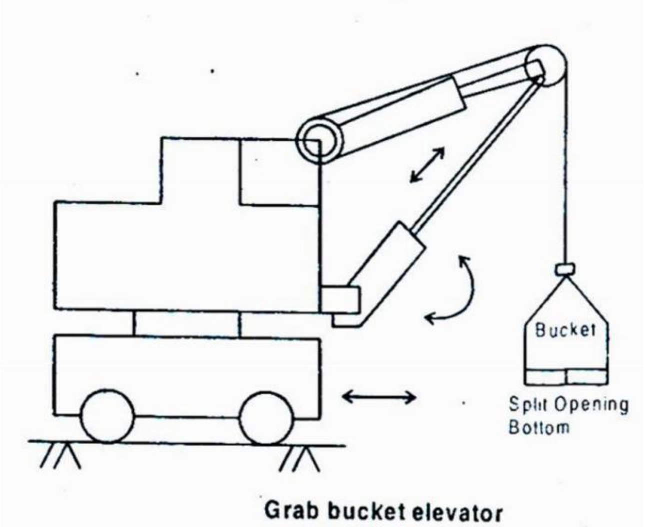
(iii) ***Bucket elevator.*** In this type of elevator, steel V-shaped buckets are rigidly fastened to an endless chain going round sprockets. The buckets are equally spaced on the chain, and receive their load by dipping into coal pocket at the lower end of the system. The material elevated in V-buckets is discharged either by centrifugal force at the top of the elevator or by drawing back the buckets on the discharged side.

Advantages: Less power is required for operating the equipment (as the coal is carried not dragged).xCoal can be discharged at elevated places. xLess floor area is required.



Disadvantages: Its capacity is limited and hence *not suitable for large capacity stations.*

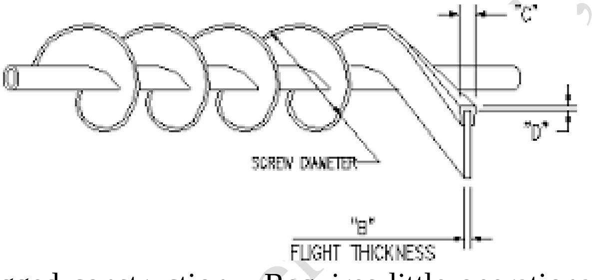
(iv) Grab Bucket Elevator



Grab bucket elevator

The construction of a grab bucket elevator illustrated in Fig. It consists of a crane which can lift the coal and move Circumferentially in a given location. This system is most suitable for handling coal at the coal store yard. Thus used to load coal from the yard to the wagon tippler, which then moves inside the plant. This elevator has the unique advantage of operating as a crane as well as moving in all directions. This helps in lifting the coal using the, grab bucket from the yard, change its direction, move to the required distance and unload it onto the wagon tippler. The grab bucket with bottom closed condition picks up the coal from the heap and when moved to the wagon opens its split opening bottom, thereby dumping the coal onto the wagon.

(vi) ***Flight conveyor (or Scraper).*** It is generally used for transfer of coal when filling of number of storage bins situated under the conveyor is required. It consists of one or two strands of chain, to which steel scrapers are attached. The scraper scraps the coal through a trough and *the* coal is discharged in the bottom of the trough as shown in fig. Capacity of a conveyor of this type may range from 10 to 100 tonnes per hour. It is used extensively for conveying coal horizontally and for inclinations up to 35°



Advantages: It has a rugged construction. xRequires little operational care. xIt can be used for transfer of coal as well as ash.
Its speed can be easily regulated.
It needs small headroom.

Disadvantages:
Excessive wear due to dragging action.
High maintenance cost.
The speed is limited to 30 m/min. to reduce the abrasive action of material handled.
Power consumption is more (due to dragging action).

Ash Handling

A huge quantity of ash is produced in central stations, sometimes being as much as 10 to 20% of the total quantity of coal burnt in a day. Hundreds of tonnes of ash may have to be handled every day in large power stations and mechanical devices become indispensable. A station using low grade fuel has to deal with large quantities of ash. Handling of ash includes :
(i) Its removal from the furnace.

(ii) Loading on the conveyers and delivery to the fill or dump from where it can be disposed off by sale or otherwise.

Handling of ash is a problem because ash coming out of the furnace is too hot, it is dusty and irritating to handle and is accompanied by some poisonous gas. Ash needs to be *quenched* before handling due to following *reasons :*

(i) Quenching reduces corrosion action of the ash.

(ii) It reduces the dust accompanying the ash.

(iii) It reduces temperature of the ash.

(iv) Ash forms clinkers by fusing in large lumps and by quenching clinkers will disintegrate

Ash Handling Equipment

A good ***ash handling plant*** should have the following *characteristics:*
1. It should have enough capacity to cope with the volume of ash that may be produced in station.

2. It should be able to handle large clinkers, boiler refuse, soot etc. with little personal attention of the workmen.

3. It should be able to handle hot and wet ash effectively and with good speed.

4. It should be possible to minimize the corrosive or abrasive action of ashes and dust nuisance should not exist.

5. The plant should not cost much.

6. The operation charges should be minimum possible.

7. The operation of the plant should be noiseless as much as possible.

8. The plant should be able to operate effectively under all variable load conditions.

9. In case of addition of units, it should need minimum changes in original layout of plant.

10. The plant should have high rate of handling.

The commonly used equipment for ash handling in large and medium size plants may comprise of:
(i) Bucket elevator

(ii) Bucket conveyor

(Hi) Belt conveyor
(iv) Pneumatic conveyor

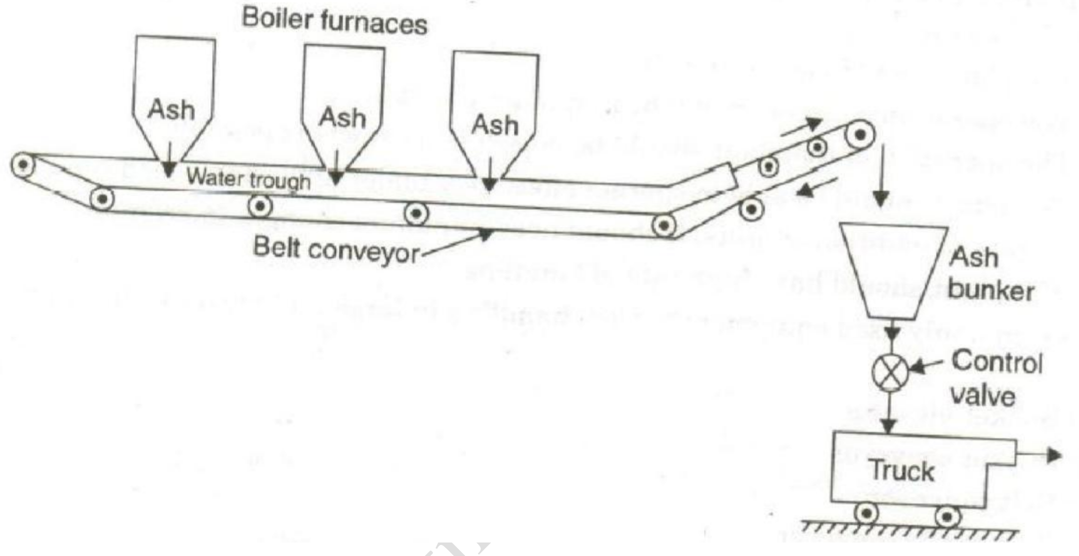
(v) Hydraulic sluicing equipment *(vi)* Trollies or rail cars etc.

Powerplant Engineering, HIT, Nidasoshi

Ash Handling System

The ever increasing capacities of boiler units together with their ability to use low grade high ash content coals have been responsible for the development of modern ash handling systems. The general layout of the components used in modern ash handling and dust collection plant is shown in Fig. 9.1. The modern ash-handling systems are mainly classified into four groups: 1. Mechanical handling system. 2. Hydraulic system. 3. Pneumatic system. 4. Steam jet system.

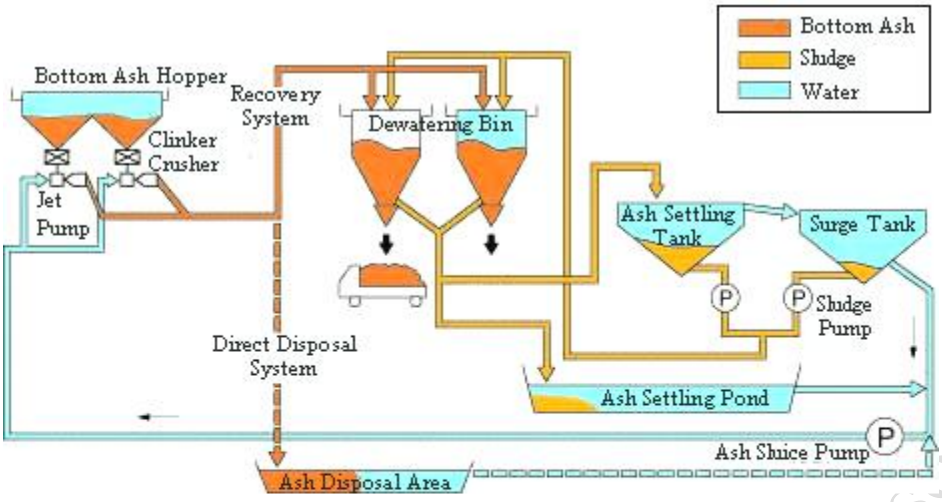
1. Mechanical Handling System. The mechanical handling system is generally used for low capacity power plants using coal as fuel. The arrangement of the system is shown in Fig.



The hot ash coming out of boiler furnace is made to fall over the belt conveyor through a water seal as shown in figure. The cooled ash falls on the belt conveyor and it is carried continuously to the dumping site or overhead bunker. The ash is carried to the dumping site from the ash bunker with the help of trucks. Control valve is opened and closed manually to load the truck. The life of this system is 5 to 10 years. The maximum capacity of this system is limited to 5 tons per hour. The major advantage of this system is low power consumption.

2. Hydraulic Ash Handling System

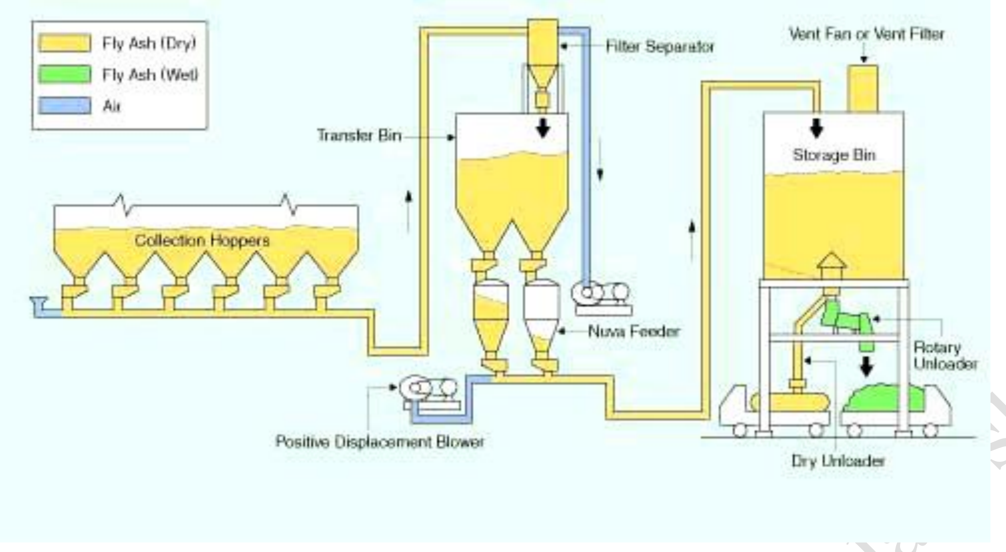
In this system, ash from the furnace grate falls into a system of water possessing high velocity and is carried to the sumps. It is generally used in large power plants. Hydraulic system is of two types namely low pressure hydraulic system used for continuous removal of ash and high pressure system which is used for intermittent ash disposal.



3. Pneumatic system

The arrangement of the system is shown in Fig. This system has been developed for handling abrasive ash as well as fine dusty materials such as fly-ash and soot. This is more suitable to the boiler plants from which ash and soot must be transported some considerable distance for final disposal. The ash and dust from all discharge points are picked up by a high velocity air stream created by an exhauster at the discharge end. The ash collected in the ash hopper is passed through the ash crushers shown in figure. The ash carried by the air is separated into the primary and secondary separators working on cyclone principle and is collected in ash hopper as shown in figure. The clean air is discharged from the top of the secondary air-separator into the atmosphere through exhauster. The exhauster used may he mechanical as I.D. fan or stream jet type or water jet type. If the mechanical exhauster is used, then it is necessary to use filter or air-washer before the air enters into the exhauster to ensure the clean air exhaust to atmosphere. The mechanical exhauster is preferred where large tonnages of material are to | be conveyed. The power requirement of mechanical exhauster is approximately 3 kW per ton of material. The steam-jet exhauster is commonly used for small and medium-sized plant. The steam consumption of this system is approximately 120 kg per ton of material discharged. The water-jet exhauster may be used more economically where large quantities of water are easily and cheaply available. The ash carrying capacity of this system varies from 5 to 30 tons per hour.

Powerplant Engineering, HIT, Nidasoshi



Steam Generator

Boiler is an apparatus to produce steam. Thermal energy released by combustion of fuel is transferred to water, which vaporizes and gets converted into steam at the desired temperature and pressure.

The steam produced is used for:

(*i*) Producing mechanical work by expanding it in steam engine or steam turbine.

(*ii*) Heating the residential and industrial buildings

(*iii*) Performing certain processes in the sugar mills, chemical and textile industries.

Boiler is a closed vessel in which water is converted into steam by the application of heat. Usually boilers are coal or oil fired. A boiler should fulfill the following requirements

(*i*) **Safety.** The boiler should be safe under operating conditions.

(*ii*) **Accessibility.** The various parts of the boiler should be accessible for repair and maintenance.

(*iii*) **Capacity.** The boiler should be capable of supplying steam according to the requirements.

(*iv*) **Efficiency.** To permit efficient operation, the boiler should be able to absorb a maximum amount of heat produced due to burning of fuel in the furnace.

(*v*) It should be simple in construction and its maintenance cost should be low.

(*vi*) Its initial cost should be low.

(*vii*) The boiler should have no joints exposed to flames.

(*viii*) The boiler should be capable of quick starting and loading.

The performance of a boiler may be measured in terms of its evaporative capacity also called power of a boiler. It is defined as the amount of water evaporated or steam produced in kg per hour. It may also be expressed in kg per kg of fuel burnt or kg/hr/m2 of heating surface.

Powerplant Engineering, HIT, Nidasoshi

Classification of boilers

1. Horizontal, Vertical or Inclined Boiler. If the axis of the boiler is horizontal, the boiler is called horizontal, if the axis is vertical, it is called vertical boiler and if the axis is inclined it is called as inclined boiler.The parts of horizontal boiler is can be inspected and repaired easily but it occupies more space.The vertical boiler occupies less floor area.

2.Fire Tube and Water Tube In the fire boilers, the hot gases are inside the tubes and the water surrounds the tubes. Examples: Cochran, Lancashire and Locomotive boilers. In the water tube boilers, the water is inside the tubes and hot gases surround them. Examples: Babcock and Wilcox, Stirling, Yarrow boiler etc.

3.Externally Fired and Internally Fired The boiler is known as externally fired if the fire is outside the shell. Examples: Babcock and Wilcox boiler,Stirling boiler etc. In case of internally fired boilers, the furnace is located inside the shell. Examples: Cochran, Lancashire boiler etc.

4.Forced circulation and Natural Circulation In forced circulation type of boilers, the circulation of water is done by a forced pump. Examples: Velox,Lamomt,Benson Boiler etc. In natural circulation type of boilers, circulation of water in the boiler takes place due to natural convention currents produced by the application of heat.
Examples: Lancashire, Babcock and Wilcox boiler etc.

5.Higher Pressure and Low Pressure Boilers The boiler which produce steam at pressures of 80 bar and above are called high pressure boilers. Examples: Babcock and Wilcox, Velox,Lamomt,Benson Boiler etc. The boilers which produce steam at pressure below 80 bar are called low pressure boilers. Examples: Cochran, Cornish, Lancashire and Locomotive boiler etc.

6. Stationary and Portable primarily, the boilers are classified as either stationary or mobile. Stationary boilers are used for power plant steam, for central station utility power plants, for plant process steam etc. Mobile boilers or portable boilers include locomotive type, and other small units for temporary use at sites.

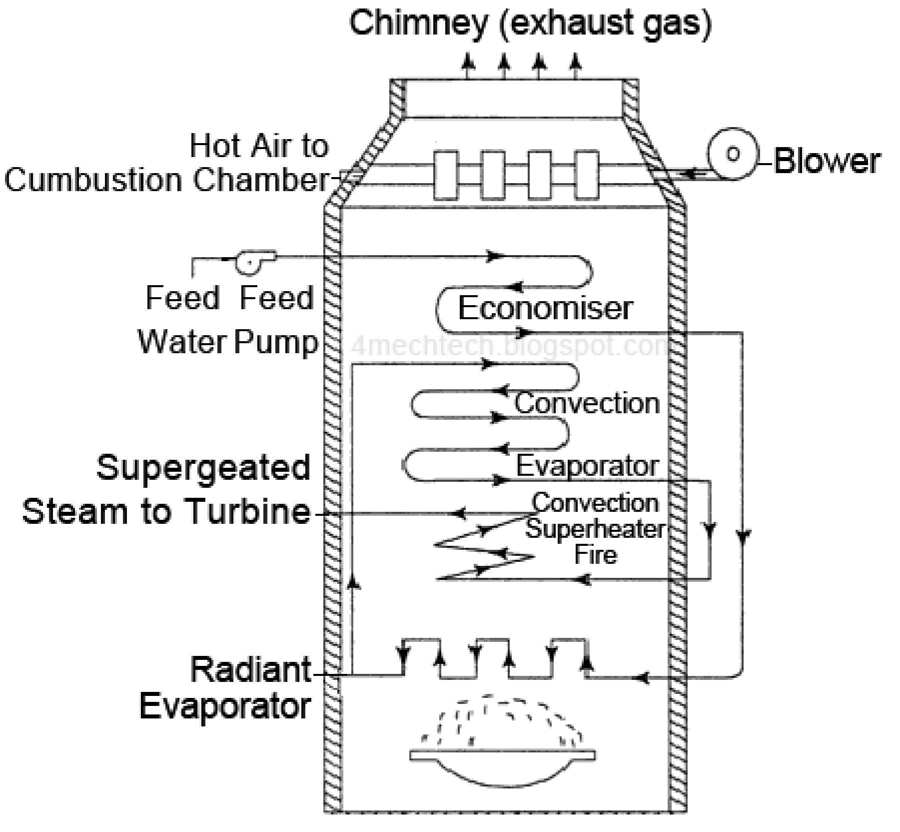
7. Single Tube and Multi Tube Boiler

The fire tube boilers are classified as single tube and multi-tube boilers, depending upon whether the fire tube is one or more than one. Examples: Cornish, simple vertical boiler are the single tube boiler and rest of the boilers are multi-tube boiler.

High Pressure boilers 1.La-mount boiler 2.Benson boiler 3.Loeffler boiler 4.velox boiler 5. Schmidt- Hartmann boiler

Powerplant Engineering, HIT, Nidasoshi

Benson Boiler



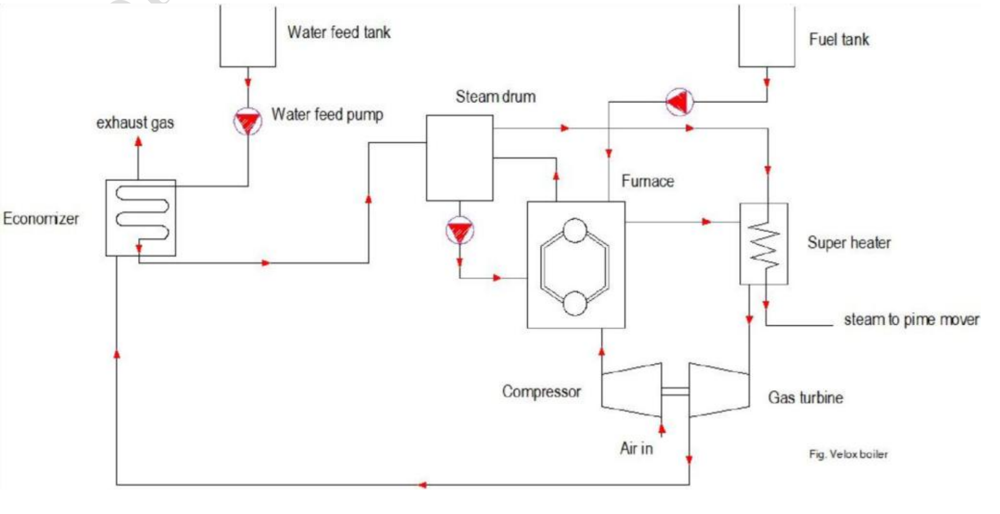
The main difficulty experienced in the La Mont boiler is the formation and attachment of bubbles
on the inner surfaces of the heating tubes. The attached bubbles reduce the heat flow and steam generation
as it offers higher thermal resistance compared to water film

1. Benson in 1922 argued that if the boiler pressure was raised to critical pressure (225 atm.), the
steam and water would have the same density and therefore the danger of bubble formation can be
completely
2. Natural circulation boilers require expansion joints but these are not required for Benson as the pipes are welded. The erection of Benson boiler is easier and quicker as all the parts are welded at
site and workshop job of tube expansion is altogether avoided.
3. The transport of Benson boiler parts is easy as no drums are required and majority of the parts
are carried to the site without pre-assembly.
4. The Benson boiler can be erected in a comparatively smaller floor area. The space problem does not control the size of Benson boiler used.
5. The furnace walls of the boiler can be more efficiently protected by using small diameter and
close pitched tubes.

6. The superheater in the Benson boiler is an integral part of forced circulation system, therefore
no special starting arrangement for superheater is required.
7. The Benson boiler can be started very quickly because of welded joints.
8. The Benson boiler can be operated most economically by varying the temperature and pressure
at partial loads and overloads. The desired temperature can also be maintained constant at any pressure.
9. Sudden fall of demand creates circulation problems due to bubble formation in the natural circulation boiler which never occurs in Benson boiler. This feature of insensitiveness to load fluctuations
makes it more suitable for grid power station as it has better adaptive capacity to meet sudden load
fluctuations.
10. The blow-down losses of Benson boiler are hardly 4% of natural circulation boilers of same
capacity.
11. Explosion hazards are not at all severe as it consists of only tubes of small diameter and has
very little storage capacity compared to drum type boiler.

During starting, the water is passed through the economiser, evaporator, superheater and back to
the feed line via starting valve A. During starting the valve B is closed. As the steam generation starts
and it becomes superheated, the valve A is closed and the valve B is opened.
During starting, first circulating pumps are started and then the burners are started to avoid the
overheating of evaporator and superheater tubes

Velox boiler



Now, it is known fact that when the gas velocity exceeds the sound-velocity, the heat is transferred from the gas at a much higher rate than rates achieved with sub-sonic flow. The advantages of this theory are taken to effect the large heat transfer from a smaller surface area in this boiler. Air is compressed to 2.5 bar with an help of a compressor run by gas turbine before supplying to the combustion chamber to get the supersonic velocity of the gases passing through the combustion chamber and gas tubes and high heat release rates (40 MW/m3). The burned gases in the combustion chamber are passed through the annulus of the tubes as shown in figure. The heat is transferred from gases to water while passing through the annulus to generate the steam. The mixture of water and steam thus formed then passes into a separator which is so designed that the mixture enters with a spiral flow. The centrifugal force thus produced causes the heavier water particles to be thrown outward on the walls. This effect separates the steam from water. The separated steam is further passed to superheater and then supplied to the prime-mover. The water removed from steam in the separator is again passed into the water tubes with the help of a pump. The gases coming out from the annulus at the top are further passed over the superheater where its heat is used-for superheating the steam. The gases coming out of superheater are used to run a gas turbine as they carry sufficient kinetic energy. The power output of the gas turbine is used to run the air compressor.

The exhaust gases coming out from the gas turbine are passed through the economiser to utilize the remaining heat of the gases. The extra power required to run the compressor is supplied with the help of electric motor. Feed water of 10 to 20 times the weight of steam generated is circulated through the tubes with the help of water circulating pump. This prevents the overheating of metal walls. The size of the velox boiler is limited to 100 tons per hour because 400 KW is required to run the air compressor at this output. The power developed by the gas turbine is not sufficient to run the compressor and therefore some power from external source must be supplied as mentioned above.

Advantages

1. Very high combustion rates are possible as 40 MJ/m3 of combustion chamber volume.
2. Low excess air is required as the pressurised air is used and the problem of draught is simplified.
3. It is very compact generating unit and has greater flexibility.
4. It can be quickly started even though the separator has a storage capacity of about 10% of the maximum hourly output.

Powerplant Engineering, HIT, Nidasoshi

UNIT – 3
CHIMNEYS, ACCESSORIES FOR THE STEAM GENERATOR COOLING TOWERS AND PONDS

FORCED DRAUGHT

In a forced draught system, a blower is installed near the base of the boiler and air is forced to pass through the furnace, flues, economiser, air-preheater and to the stack. This draught system is known as positive draught system or forced draught system because the pressure of air throughout the system is above atmospheric pressure and air is forced to flow through the system. The arrangement of the system is shown in Fig.

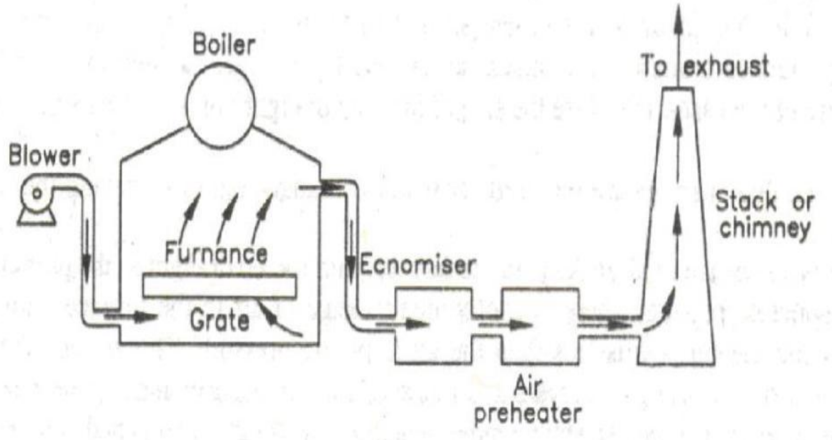


Fig. Forced draught.

A stack or chimney is also used in this system as shown in figure but its function is to discharge gases high in the atmosphere to prevent the contamination. It is not much significant for producing draught therefore height of the chimney may not be very much.

INDUCED DRAUGHT

In this system, the blower is located near the base of the chimney instead of near the grate. The air is sucked in the system by reducing the pressure through the system below atmosphere. The induced draught fan sucks the burned gases from the furnace and the pressure inside the furnace is reduced below atmosphere and induces the atmospheric air to flow through the furnace. The action of the induced draught is similar to the action of the chimney. The draught produced is independent of the temperature of the hot gases therefore the gases may be discharged as cold as possible after recovering as much heat as possible in air-preheater and economiser.

This draught is used generally when economiser and air-preheater are incorporated in the system. The fan should be located at such a place that the temperature of the gas handled by the fan is lowest. The chimney is also used in this system and its function is similar as mentioned in forced draught but total draught produced in induced draught system is the sum of the draughts produced by the fan and chimney. The arrangement of the system is shown in Fig.

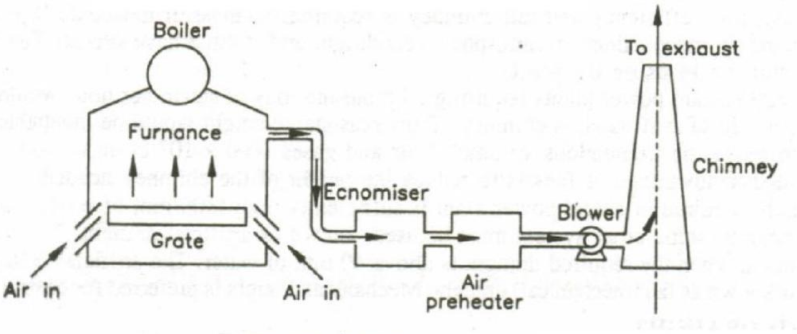


Fig. Induced draught.

COMPARISON OF FORCED AND INDUCED DRAUGHTS

The advantages of the forced draught over the induced draught are listed below :

1. The size and power required by the induced draught fan is more than the forced draught because the induced draught fan handles more gases (air and fuel) and at elevated temperature. The volume of the gas handled by induced draught fan is much larger than the volume handled by forced draught fan due to high temperature of the gases, therefore the size of induced draught fan is 1.3 times the size of forced draught fan.

2. Water cooled bearings are required for induced draught fan to withstand the high temperatures of the flue gases.

3. There is no chance of air leakage in the furnace with forced draught as the pressure inside the furnace is above atmospheric pressure. There is continuous leakage of air in the furnace with induced draught as the pressure inside the furnace is less than the atmospheric pressure. This dilutes the combustion.

4. The flow of air through the grate and furnace is more uniform and it penetrates better into the fire bed when forced draught is used. The better penetration of air through the fuel bed and uniform flow improves the rate of burning.

5. When the doors are opened for firing in case of induced draught fan, there will be rush of cold air into the furnace and this reduces the draught through the system and reduces the heat transmission efficiency of the surfaces.

BALANCED DRAUGHT

It is always preferable to use a combination of forced draught and induced draught instead of forced or induced draught alone.

If the forced draught is used alone, then the furnace cannot be opened either for firing or inspection because the high pressure air inside the furnace will try to blow out suddenly and there is every chance of blowing out the fire completely and furnace stops.

If the induced draught is used alone, then also furnace cannot be opened either for firing or inspection because the cold air will try to rush into the furnace as the pressure inside the furnace is below atmospheric pressure. This reduces the effective draught and dilutes the combustion.

To overcome both the difficulties mentioned above either using forced draught or induced draught alone, a balanced draught is always preferred. The balanced draught is a combination of forced and induced draught. The forced draught overcomes the resistance of the fuel bed therefore sufficient air is supplied to the fuel bed for proper and complete combustion. The induced draught fan removes the gases from the furnace maintaining the pressure in the furnace just below atmosphere. This helps to prevent the blow-off of flames when the doors are opened as the leakage of air is inwards.

Advantages and Limitations of Chimney Draught

Advantages :

(1) It does not require any external power for producing the draught.

(2) The capital investment is less than the capital investment required for artificial draught. The maintenance cost is nil as there is no mechanical part.

(3) Chimney keeps the flue gases at a high place in the atmosphere which prevents the contamination of atmosphere in a crowded locality and maintains the cleanliness.

(4) It has long life.

Limitations :

(1) The maximum pressure available for producing natural draught by chimney is hardly 10 to 20 mm of water under the normal atmospheric and flue gas temperatures.

(2) The available draught decreases with increase in outside air temperature and for producing sufficient draught, the flue gases have to be discharged at comparatively high temperatures resulting in the loss of overall plant efficiency.

Cooling tower

The cooling towers are desired when positive control on the temperature of water is required, the space occupied by the cooling system is considerable factor and the plant is situated near load centre and far away from the adequate natural resources of cooling water. **The rate of evaporation of water in cooling tower and subsequent reduction in water temperature depends upon the following factors :**

1. Amount of water surface area exposed.
2. The time of exposure.
3. The relative velocity of air passing over the water droplets formed in cooling tower.
4. The R.H. of air and difference between the inlet air WBT and water inlet temperature.
5. The direction of air flow relative to water.

Types of cooling tower

1. Natural draft or Atmospheric cooling towers

a. Natural Draft Spray Filled Tower

Powerplant Engi... da

b. Natural Draft Packed Type Tower

c. Hyperbolic Cooling Tower

2. Mechanical draft towers

a. Forced draft

b. induced draft.

i. Counter flow

ii. Cross-flow

1. Natural Draft

a) Natural Draft Spray Filled Tower

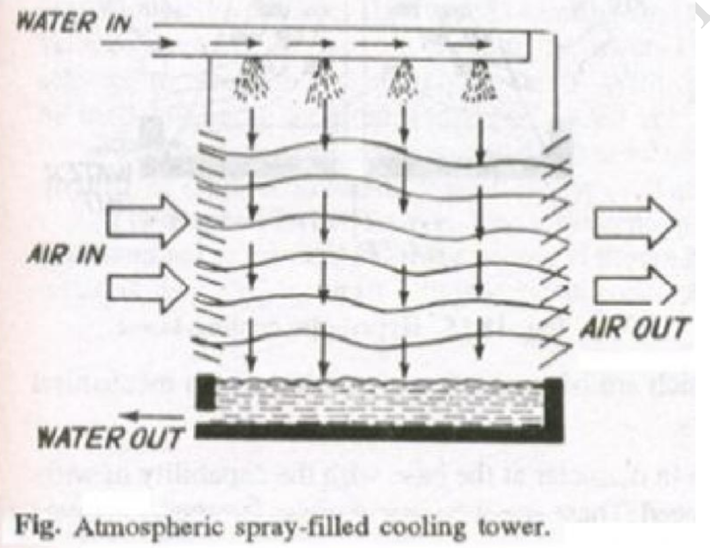


Fig. Atmospheric spray-filled cooling tower.

The air enters through the lowered sides and flows across the unit in a transverse direction. The air circulation through the tower depends on wind velocity. The capacity of this tower varies from 50 to 100 liters per minute per m2 of base area depending upon the air velocity. These towers are used only for diesel plants and where prevailing winds are not cut-off by obstructions. This is not used for high capacity thermal plants as cooling range is limited, wind losses are high and there is no control over the outlet temperature of water

Natural Draft Packed Type Tower

Powerplant E... Nidasoshi

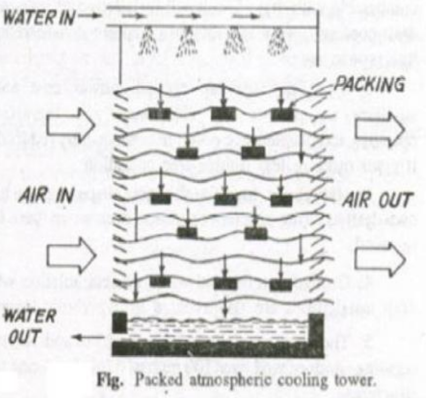


Fig. Packed atmospheric cooling tower.

The construction of this tower is similar to spray filled tower except that water distributing toughs of fills are used which helps to break the water into small droplets. In this tower also, the flow of air is cross-wise to the flow of water. These towers are also rarely used for thermal power plants as original cost (due to height requirement) and pumping head required are high. Tower's extreme length and height and narrow width require anchoring to withstand high winds.

b) Hyperbolic Cooling Tower

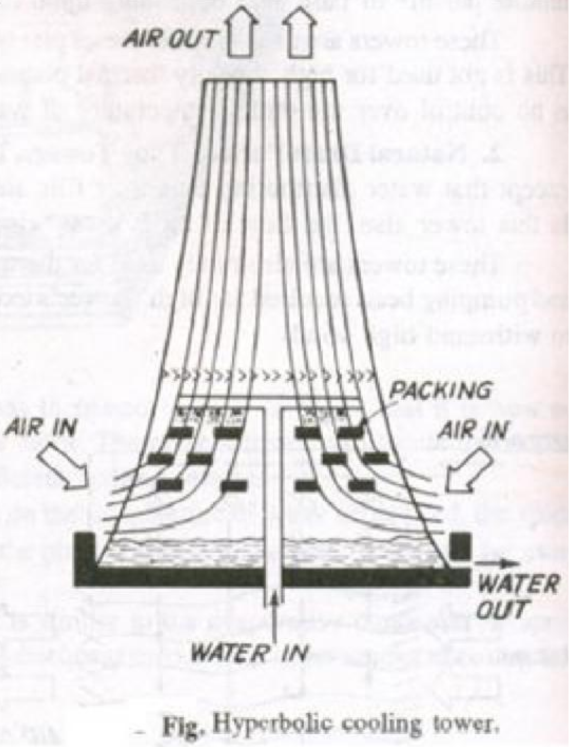


Fig. Hyperbolic cooling tower.

The arrangement of hyperbolic cooling tower is shown in Fig. It is steel reinforced concrete structure mostly slack (empty space) and the bottom 10 m above the air-intake contains packing over which warm water flows. The shape of the stack is circular in plan and hyperbolic in profile. The operation of this tower is much like that of other natural draft spray cooling towers with hot water cascading over timber splash type filling through which cooler air moves.

Powerplant HIT, Nidasoshi

The advantages of this tower over mechanical towers are listed below :

1. The hyperbolic towers have a cooling capacity comparable with that of multi cell installation
of induced draft cooling towers and they also require considerable less ground area.

2. Since, "no fans are needed, power cost and auxiliary equipments are eliminated and therefore operating and maintenance costs are consequently reduced. It gives more or less trouble-free operation.

3. Hyperbolic tower's chimney shape creates its own draft assuring efficient operation even when there is no wind Ground fogging and warm air-recirculation which are often the facing problems with mechanical draft installations are also avoided in hyperbolic towers. The towers may be as high as 125 m and 100 m in diameter at the base with the capability of withstanding winds of well over 100 mph which is hurricane speed. These structures are more or less self-supported structures.

4. The enlarged top of the tower allows water to fall out of suspension.

The major drawbacks of this tower are listed below :

1. Its initial cost is considerably high.

2. Its performance varies with the seasonal changes in DBT and RH of air.

2. Mechanical draft towers

a) Forced draft cooling tower

The arrangement of the forced draft tower is shown in Fig. The fan is located at the base of the tower and air is blown by the fan up through the descending water. The entrained water is removed by draft eliminators on top.

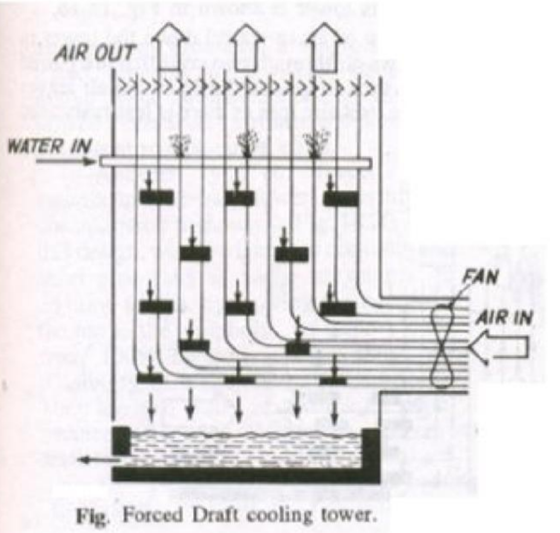


Fig. Forced Draft cooling tower.

Powerplant Engineering, HIT, Nidasoshi

b) Induced draft cooling tower

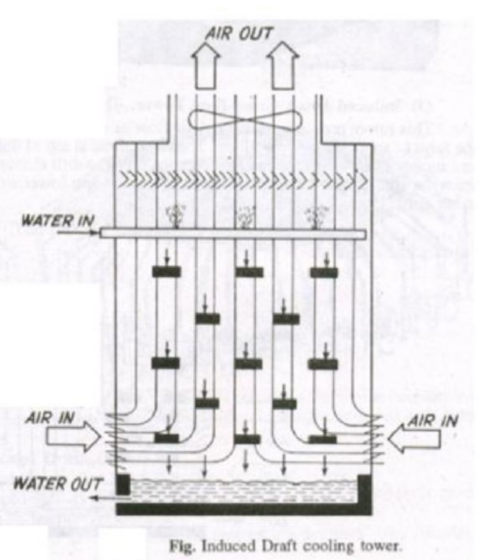
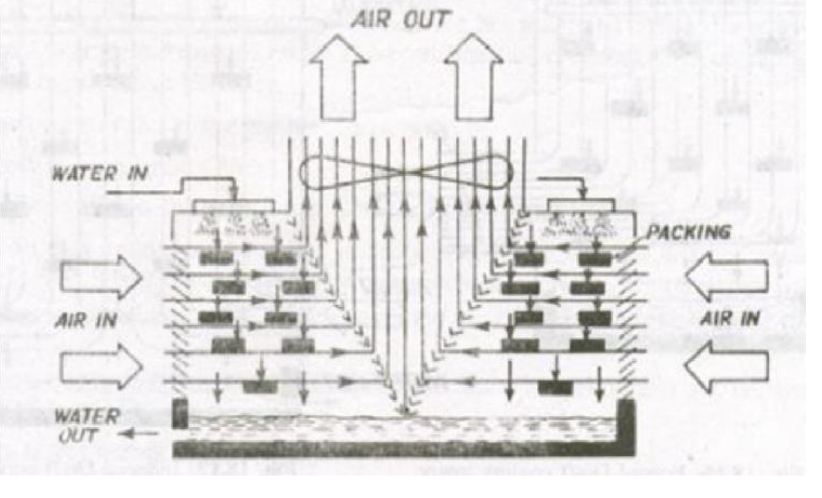


Fig. Induced Draft cooling tower.

The arrangement of the induced draft is shown in Fig. The difference lies only in supply of air. In this case the fan is located at the top of die tower and air enters through the louvers located on the tower's side as shown in figure and is drawn up and discharged through the fan casing to the atmosphere-Such type of cooling towers made with combination of fiber glass, PVC and stainless steel developed.

ii) **Induced Draft Cross-flow Tower**

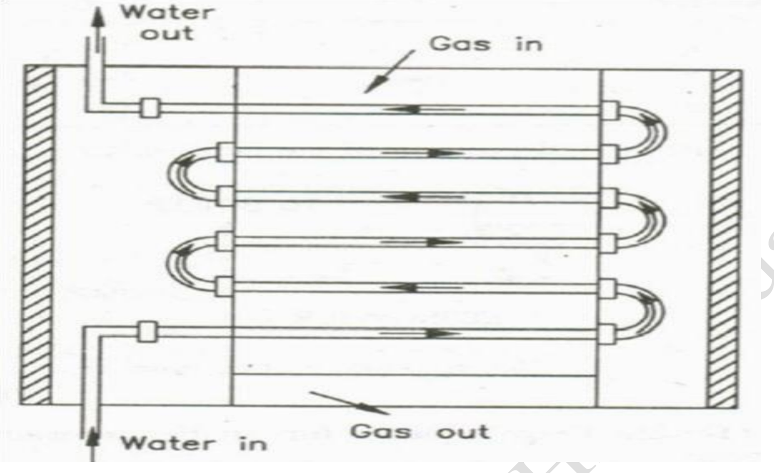


This tower provides horizontal air flow as water falls (cross-flow of air to water) down the tower in the form of small drops over filling. The fan centered at top of unit draws air through two cells that are, paired to a suction chamber partitioned beneath the fan. The drift eliminators turn air toward out-let fan as air leaves the water sprays. The outstanding feature of this tower is lower air static pressure loss as there is less resistance to air flow.

Power Plant Engineering, HIT Nidasoshi

Boiler accessories

1. Economiser



2. Air preheater

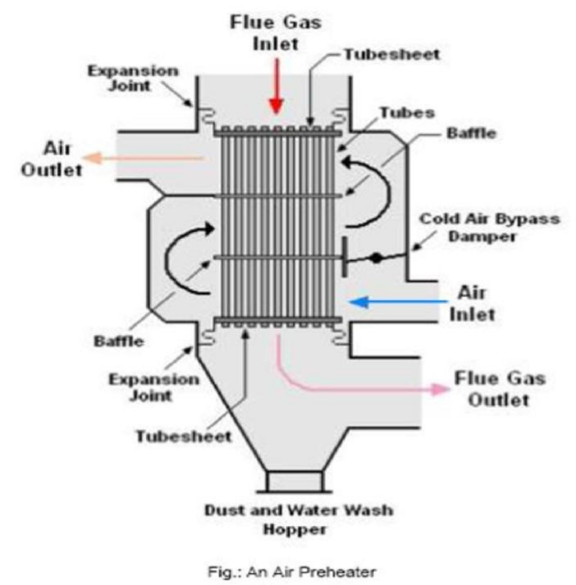
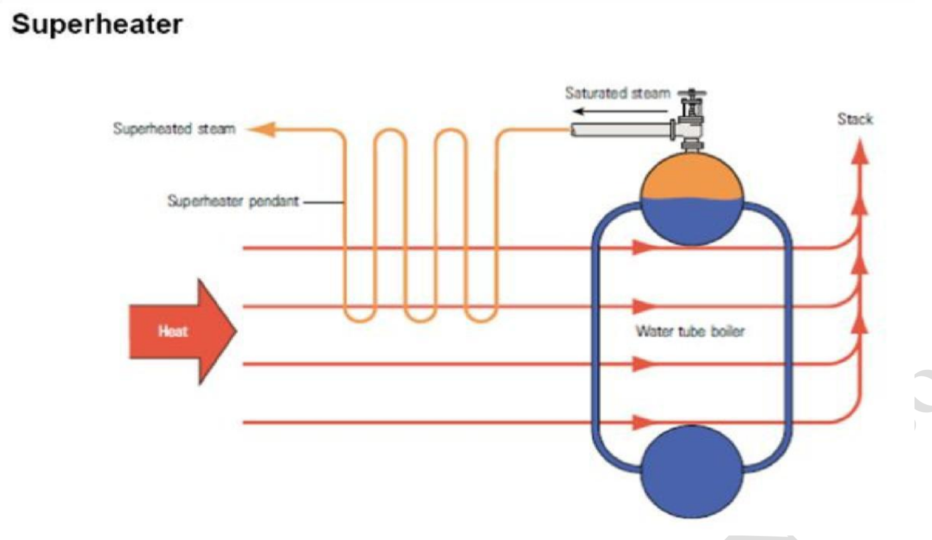


Fig.: An Air Preheater

Powerplant Engineering, HIT, Nidasoshi

3. Superheater



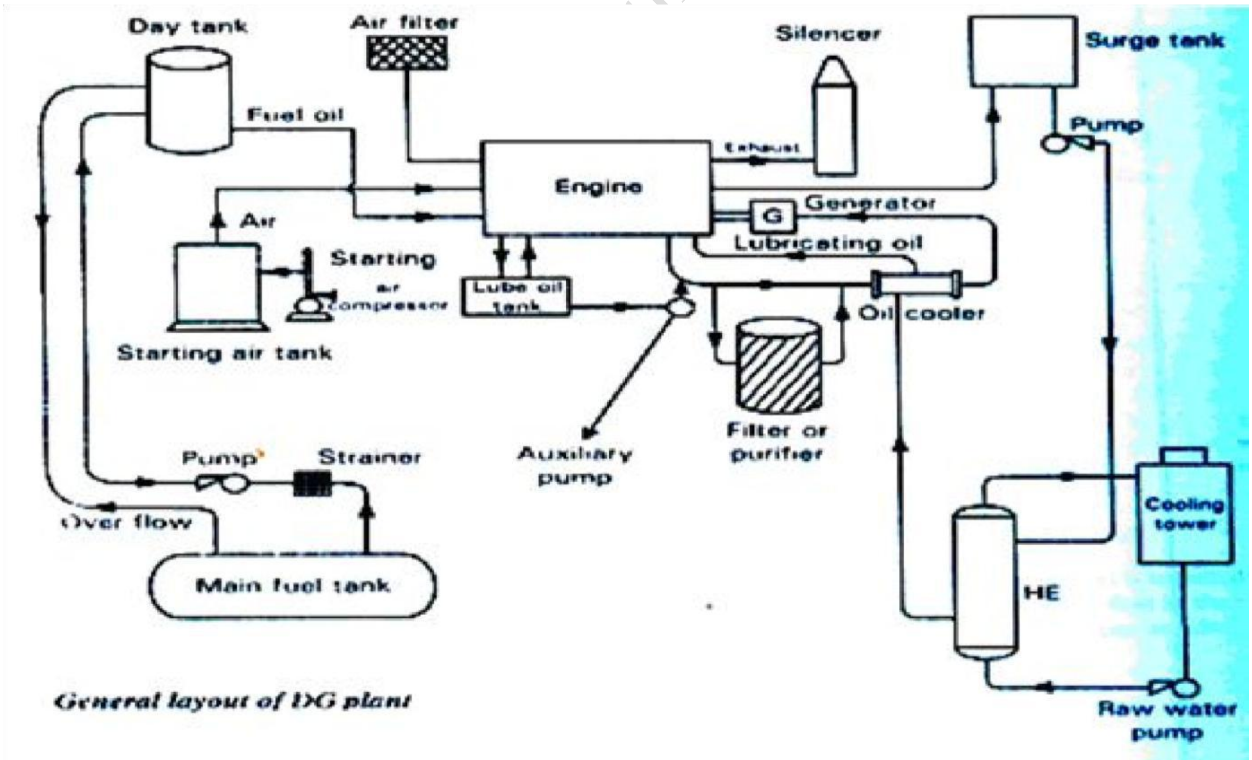
The function of the superheated in the thermal power plant is to remove the last traces of moisture (1 to 2%) from the saturated steam coming out of boiler and to increase its temperature sufficiently above saturation temperature. The super-heating raises overall cycle efficiency as well as avoids too much condensation in the last stages of the turbine (below 12%) which avoids the blade erosion. The heat of combustion gases from furnace is utilized for the removal of moisture from steam and to superheat the steam. Super-heaters usually have several tube circuits in parallel with one or more return bends, connected between headers.

Powerplant Engineering, HIT, Nidasoshi

UNIT-4
DIESEL ENGINE AND GAS TURBINE POWER PLANT

Introduction

Diesel engine plants are **finding increased application** as either **continuous or peak load source** of power generation. Due to **economy** of operation, DG plants are used to generate power in the range of **1 to 50 MW** capacities and are extensively used to supplement **hydro electric or thermal power stations.** Diesel engine plants are **finding increased application** as either **continuous or peak load source** of power generation. Due to **economy** of operation, DG plants are used to generate power in the range of **1 to 50 MW** capacities and are extensively used to supplement **hydro electric or thermal power stations.** DG plants are more efficient than any other heat engines of comparable size. It is available at a very short delivery times and can be started quickly and brought into service. It can burn fairly wide range of fuels.



General layout of DG plant

The essential components of Diesel Engine plant are,

1. Engine
2. Air Intake System (filter and Supercharger)

3. Exhaust system
4. Fuel system
5. Cooling system
6. Lubrication system
7. Engine starting system
8. Governing system

1. **Engine:**

It is the main component of the plant which **develops** required **power.** The engine is **directly coupled** to the **generator**.

2. **Air Intake System (filter and Supercharger):**

Air filterremoves the dust from the air **before it enters** the engine. **Supercharger increases the pressure** of air at engine inlet and hence **increases engine power**. They are usually **driven** by the engines.

3. **Exhaust system:**

It includes **silencers** and **connecting ducts.** As the exhaust gases **have higher temperatures**, heat of exhaust gases is **utilized** for heating the oil or air supplied to the engine.

4. **Fuel system:**

It **contains** the **storage tank, fuel pump, fuel transfer pump, oil strainers and heaters.** Amount of fuel supplied **depends** on the load on the plant.

5. **Cooling system:**

The system **includes** water circulating **pumps, cooling towers or spray ponds and water filtration or treatment plant**. The **purpose** of cooling system is to **ensure the life** of the cylinder by **extracting the heat developed** from the engine cylinder walls and hence **keeping** the **temperature within the safer range.**

6. **Lubrication system:**

The system **includes oil pumps, oil tanks coolers** and **connecting pipes**. The system **reduces the friction** between the **moving parts and hence reduces wear and tear.**

7. **Starting system**

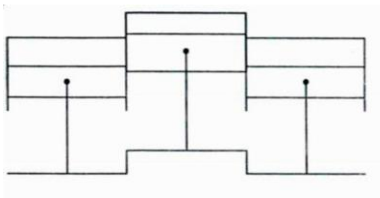
The system **includes** starting aides like **compressed air tanks**.The tank **supplies compressed air** to **start** the engine from cold.

8. Governing system: The governing engine **maintains** constant speed of the engine **irrespective of load** on the plant.This is done by **varying the fuel** supplied to the engine. **Engine starting methods** The SI engines used for power generation in DG plants are usually

Powerplant Engineering HIT, Nidasoshi

small in size which use **compression ratio from 7 to 11. Hand** and **electric motor** (6-12 V dc) cranking are generally used to **start** the engine. The CI engines use very **high compression ratios** from **20 to 22** and hence it is **difficult** to hand crank the engine. Hence some mechanical cranking systems are used.

1. Compressed Air System



Compressed air system

2. Electric Starting

3. Starting by auxiliary engine

4. 1. Compressed Air System

In this system air at a **pressure of 20 bar** is supplied from an air tank at the engine inlet **through intake manifold**. In case of **multi-cylinder engine** compressed air enters **one or more of engine cylinders** and forces down the piston to **turn the engine shaft**. During the **meantime suction stroke** of some other cylinder takes place and the **compressed air** pushes this cylinder and causes the **engine shaft to rotate.** Gradually the **engine gains the momentum** and by supplying the fuel engine starts running.

2. Electric Starting

It consists of an **electric motor** driving a pinion which engages a **toothed rim** on engine flywheel. Electric **supply** for the motor is made using a small **electric generator** driven by the engine. A storage battery, of **12 - 36V** is used to supply power to the electric motor. The electric motor **disengages** automatically **after** the **engine** has **started**. **3. Starting by auxiliary engine** In this method a **small petrol engine** is connected to the **main engine** through **clutch** and **gear** arrangement. The clutch is **disengaged** and the petrol engine is **started** by hand. Then the clutch is **gradually engaged** and the main engine is **cranked** for starting. Clutch is **disengaged automatically** when the main engine is started. **Cooling system** The cylinder walls, cylinder and piston will tend to assume the average temperature of the gases to which they are exposed, which may be of the order of 1000 to 1500°C. Obviously at such high temperature, the metals will loose their characteristics and piston will expand considerably and sieze the liner. Of course theoretically thermal efficiency of the engine will improve without cooling but actually the engine will sieze to run. If the cylinder wall temperature is allowed to rise above a certain limit, about 65°C, the lubricating oil will begin to evaporate rapidly and both cylinder and piston may be damaged. Also high temperature may cause excessive stress in some parts rendering them useless for further operation. In view of this, part of the heat generated inside the engine cylinder is allowed to be carried away by the cooling system.

Thus cooling system is provided on an engine for the following reasons :
(necessity of cooling)

- The even expansion of piston in the cylinder may result in seizure of the piston.

Powerplant Engineering, HIT Nidasoshi

- High temperatures reduce strength of piston and cylinder liner.
- Overheated cylinder may lead to pre-ignition of the charge, in case of spark ignition engine.
- Physical and chemical changes may occur in lubricating oil which may cause sticking of piston rings and excessive wear of cylinder.

Almost 25 to 35 per cent of total heat supplied in the fuel is removed by the cooling medium. Heat carried away by lubricating oil and heat lost by radiation amounts 3 to 5 per cent of total heat supplied. There are mainly two methods of cooling I.C. engine: 1. Air cooling 2. Liquid cooling (water) As the circulation of water is concerned, the cooling system is generally divided into 2 types.

1. Open or Single circuit system

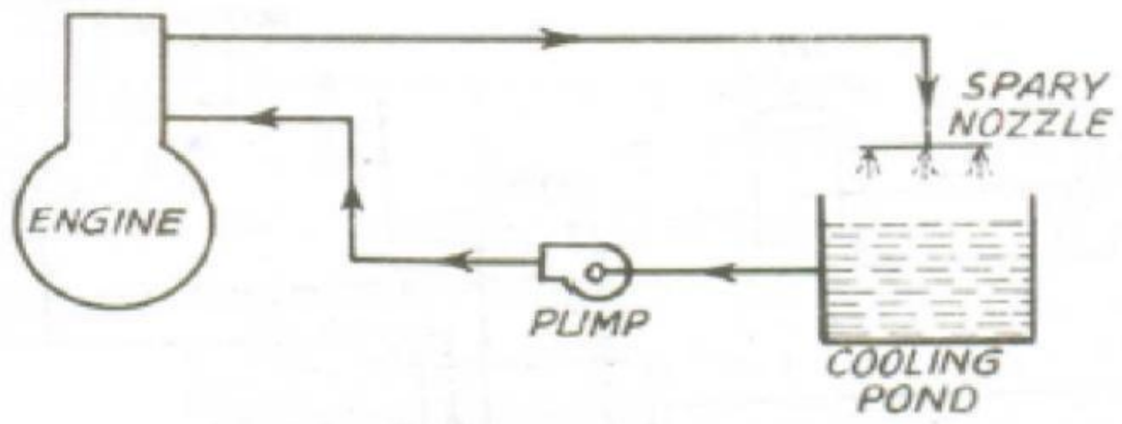


Fig. Single circuit cooling system.

In this system pump draws water from cooling pond and **forces it into the main engine jackets.**Water after circulating through the engine **returns to the cooling pond.**The **engine jacket** is subjected to **corrosion** because of the dissolved gases in the cooling water

2. Closed or Double circuit system

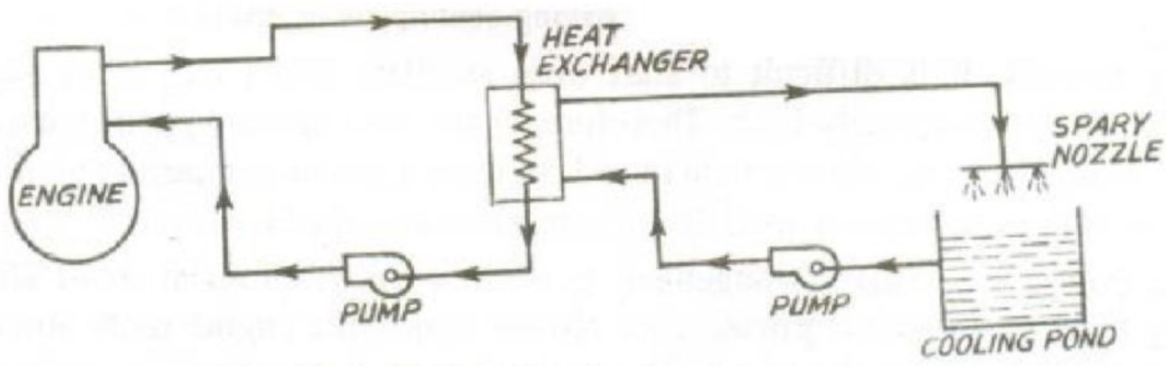


Fig. 23.4 (*b*). Double circuit cooling system.

In this system raw water is made to flow through a **heat exchanger. W**hen it **takes up the heat** of jacket water and returns back to the cooling pond or tower. About **25 to 35% heat is lost** by cooling water which is known as jacket water loss. The **rate of flow of water** should be adjusted to **maintain** outlet cooling water temperature to **600 C** and rise in temperature of cooling water is limited to **110 C.** Water used for cooling should be **free from impurities.** This type of cooling system **eliminates internal jacket corrosion** but the **corrosion may exist** in the raw water circuit.

Lubrication system Due to the presence of **friction**, **wear and tear** of the engine parts takes place **reducing** the engine life. The lubricant **introduced** forms a **thin film** between the **rubbing surfaces** and **prevents** metal to metal **contact**. The **various parts** that **require lubrication** are **cylinder walls and pistons, crank pins, gudgeon pins, big end and small end bearings etc.** Lubrication is the admittance of oil between two surfaces having relative motion. **The purpose of lubrication may be one or more of the following:** 1.To reduce friction and wear between the parts having relative motion. 2.To cool the surfaces by carrying away heat generated due to friction. 3.To seal a space adjoining the surfaces such as piston rings and cylinder liner. 4.To clean the surface by carrying away the carbon and metal particles caused by wear. 5.To absorb shock between bearings and other parts and consequently reduce noise. The main parts of an engine which need lubrication are as given below : (i) Main crankshaft bearings. (ii) Big-end bearings. (iii) Small end or gudgeon pin bearings. (iv) Piston rings and cylinder walls. (v) Timing gears.

Lubrication may be achieved in different forms:

• Full pressure (Mist) lubrication,

• Mechanical,

• Force feed lubrication (or gravity circulation from an over head tank).

Full pressure lubrication

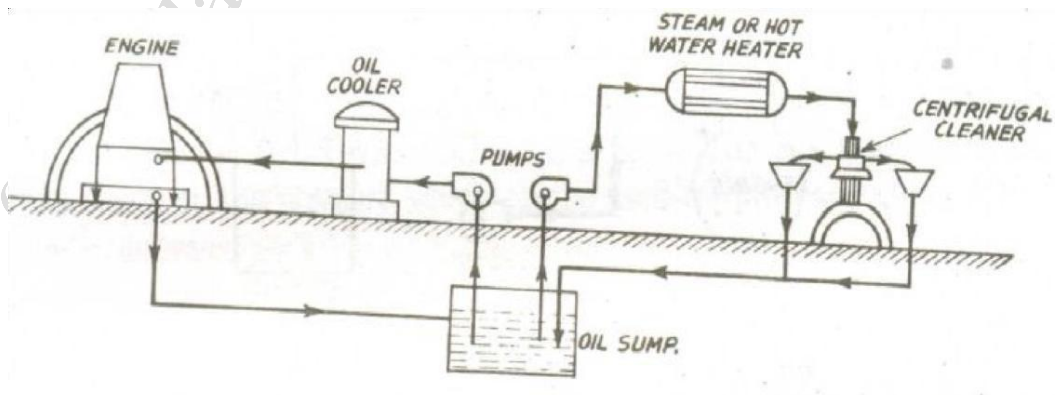


Fig. Lubrication system having continuous centrifugal cleaning.

In this system an oil pump supplies lubricating oil too many parts of the engine through duct system and to the crank shaft through drilled holes. The cylinder walls are lubricated by oil mist that is slung outward from the connecting rod bearings or by splash of rod ends into oil pools. The complete lubrication system usually includes the following auxiliaries: pump, oil cleaners, coolers, storage and sump tanks, gauges and safety devices. As oil passes through the lubrication cycle it accumulates impurities in the form of carbon particles, water and metal scrap. For continuous reliable operation attention should be given to oil cleaning. Purpose filters with centrifuges or chemical action have been employed. Mechanical filters include cloth bags, wool, felt pads, paper discs & cartridge of porous material. Rough cleaning of oil can be done by passing high speed centrifuges for final cleaning. Centrifuging can be done by periodic centrifuging of the entire lubricating oil or by continuous cleaning of a small fraction of it by splitting the oil from main flow and returning back to the main stream. Oil should be heated before passing it through the centrifuge. Oil should be cooled before supplying it to the engine. As heat is developed due to friction between the moving parts the cooling is done by using water from the cooling tower.

Air Intake system

The air intake system conveys fresh air through pipes or ducts to : (*i*) Air intake manifold of four stroke engines (*ii*) The scavenging pump inlet of a two stroke engine and (*iii*) The supercharger inlet of a supercharged engine.

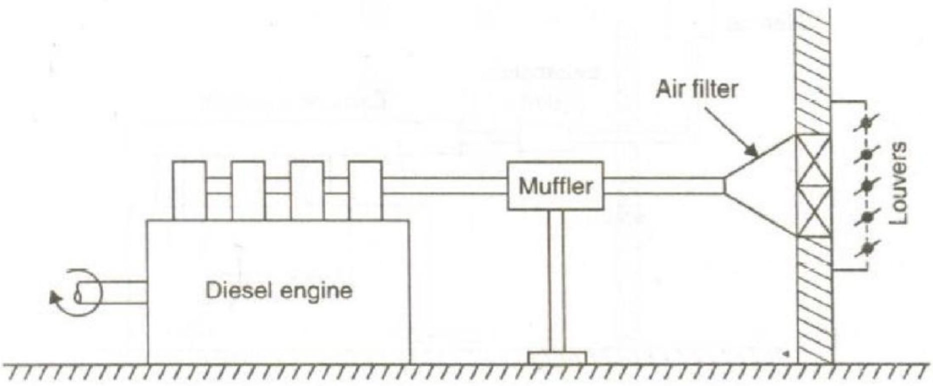


Fig. Air intake system.

The air system begins with an intake located outside the building provided with a *filter* to catch dirt which would otherwise cause excessive wear in the engine. The filters may be of *dry or oil bath*. Electrostatic precipitator filters can also be used. *Oil impingement type of filter* consists of a frame filled with metal shavings which are coated with a special oil so that the air in passing through the frame and being broken up into a number of small filaments comes into contact with the oil whose property is to sieze and hold any dust particles being carried by the air. The *dry type* of filter is made of cloth, felt, glass wool etc. In case of *oil bath type of filter* the air is swept over or through a pool of oil so that the particles of dust become coated. Light weight steel pipe is the material for intake ducts. In some cases, the engine noise may be transmitted back through the air intake system to the outside air. In such cases a silencer is provided between the engine and the intake.

Following *precautions* should be taken while constructing a suitable air intake system :

1. Air intakes may not be located inside the engine room.
2. Air should not be taken from a confined space otherwise air pulsations can cause serious vibration problems.
3. The air-intake line used should neither have too small a diameter nor should be too long, otherwise there may crop up engine starvation problem.
4. Air intake filters may not be located close to the roof of the engine room otherwise pulsating air flow through the filters can cause serious vibrations of the roof.
5. Air intake filters should not be located in an inaccessible location.

Exhaust System

Refer Fig. The purpose of the exhaust system is to discharge the engine exhaust to the atmosphere outside the building. The exhaust manifold connects the engine cylinder exhausts outlets to the exhaust pipe which is provided with a muffler to reduce pressure in the exhaust line and eliminate most of the noise which may result if gases are discharged directly into the atmosphere.

The exhaust pipe leading out of the building should be short in length with minimum number of bends and should have one or two flexible tubing sections which take up the effects of expansion, and isolate the system from the engine vibration. Every engine should be provided with its independent exhaust system.

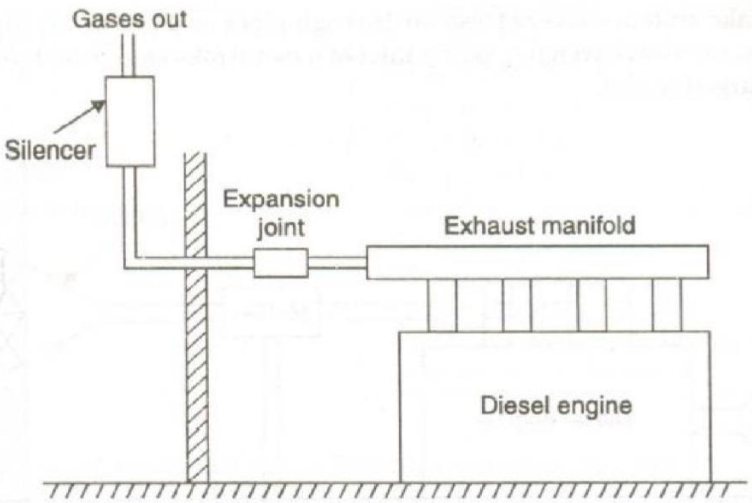


Fig. Exhaust system.

The waste heat utilisation in a *diesel-steam* station may be done by providing waste-heat boilers in which most of the heat of exhaust gases from the engine is utilised to raise low pressure steam. Such application is common on *marine plants*. On the *stationary power plant* the heat of exhaust may be utilised to heat water in gas-to-water heat exchangers consisting of a water coil placed in exhaust muffler and using the water in the plant suitably. If air heating is required, the exhaust pipe from the engine is surrounded by the cold air jacket, and transfers the heat of exhaust gases to the air.

Applications of Diesel Power Plant

Widely used in the,

1. **Peak load plant** the diesel plants are used in combination with thermal or hydro-plants as peak load plants. This plant is particularly preferable as peak load plant as it can be started quickly and it has no standby losses as in the case of thermal plants where boilers always must be kept hot.

2. **Mobile plants.** Mobile diesel plants mounted on skids or trailers can be used for temporary or emergency purposes such as for supplying power to large civil engineering works for supplementing electricity supply systems that are temporarily short of power.

3. **Stand-by Units.** This can be used as a standby unit to supply part load when required. For example, this can be used with hydro-plant as stand-by unit. If the water available is not sufficient due to reduced rainfall, a diesel station supplies power in parallel with hydro-station. The use is made temporarily till the water **is** available to take the full load.

4. **Emergency plant.** The plants used for emergency purposes are also standby units, normally idle but are used where power interruption would mean financial loss or danger in key industrial processes, tunnel lighting and operating rooms of hospitals. They are also used for telecommunication and water supply under emergency conditions.

Russia will supply 9300 kW diesel generating set to the Heavy Engineering Corporation, Ranchi, to overcome the chronic power shortage faced by the plant

5. **Nursery station.** When the diesel plant is used to supply the power to a small town in the absence of main grid and which can be moved to another area which needs power on a small scale when the main grid is available is known as "Nursery Station".

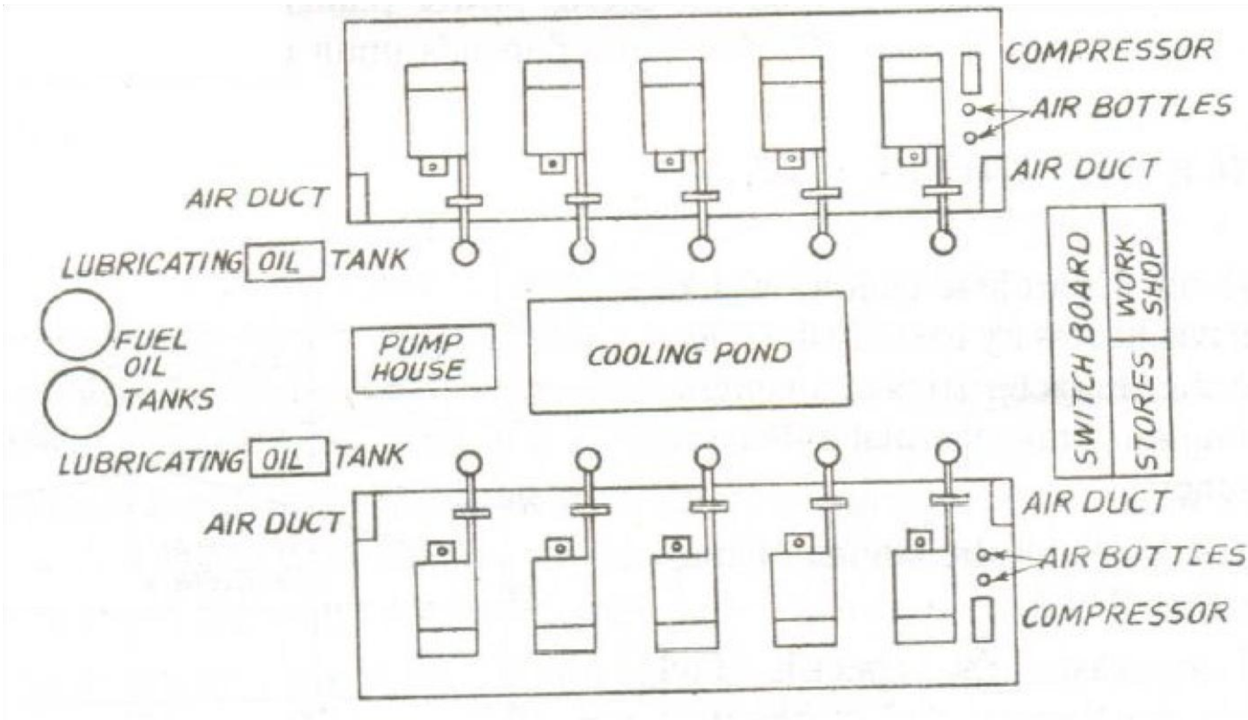
The main grid cannot extend to every corner of the country till mere is enough load. Many times the extension of grid is not possible due to the constructional difficulties as in Assam. Diesel unit of small capacity can be installed to supply the load to a small town during the process of development and it can be removed to another required place till the main grid for tapping the power is available.

6. **Starting stations.** The diesel units are used to run the auxiliaries for starting the large steam plants.

7. **Central stations.** This can be used as central station where the capacity required is small (5 to 10 MW). The limit is generally decided by the cost of the plant and local conditions regarding the availability of fuel and water, space requirements and non-availability of the grid.

Small supply units for commercial purposes and public utilities e.g., cinema hall, hospital and municipalities are commonly used in practice.

Powerplant Engineering, HIT Nidasoshi



The most common arrangement for diesel engines is with parallel centre lines, with some room left for extension in future. The repairs and usual maintenance works connected with such engines necessitate sufficient space around the units and consideration should be given to the need for dismantling and removal of large components of the engine generator set. The air intakes and filters-as well as the exhaust mufflers are located outside the building or may be separated from the main engine room by a partition wall. The latter arrangement is not vibration free. Adequate space for oil storage and repair shop as well as for office should be provided close to the main engine room. Bulk storage of oil may be outdoor. The engine room should be well ventilated. The generating units are installed parallel. Sufficient space must be provided around the various units for dismantling and repairing purposes. The fuel oil tanks are generally located outside the main buildings to avoid the fire hazards. The construction of buildings and engine layout are similar in many respects to the steam power plant although on a much smaller scale. A steel frame with brick panels and asbestos sheet roof is quite satisfactory. Good natural lighting can be provided by including large vertical or horizontal windows in the side wall and rows of skylights in the engine house roof.

Advantages and Disadvantages Of Diesel Power Plants

The advantages and disadvantages of diesel power plants are listed below:

Advantages:

1. Design and installation are very simple.
2. Can respond to varying loads without any difficulty.
3. The standby losses are less.
4. Occupy less space.

Powerplant Engineering, H

5. Can be started and put on load quickly

6. Require less quantity of water for cooling purposes. Overall capital cost is lesser than that for steam plants.

7. Require less operating and supervising staff as compared to that for steam plants. The efficiency of such plants at part loads does not fall so much as that of a steam plant. The cost of building and civil engineering works is low. Can burn fairly wide range of fuels.

8. These plants can be located very near to the load centers, many times in the heart of thetown.

9. No problem of ash handling.

10. The lubrication system is more economical as compared with that of a steam power plant. The diesel power plants are more efficient than steam power plants in the range of 150 MW capacity.

Disadvantages:

1. High operating cost.

2. High maintenance and lubrication cost.

3. Diesel unit's capacity is limited. These cannot be constructed in large size. In a diesel power plant noise is a serious problem.

4. Diesel plants cannot supply overloads continuously whereas steam power plant can work under 25% overload continuously.

5. The diesel power plants are not economical where fuel has to be imported.

Powerplant Engineering, HIT,Nidasoshi

PART B

UNIT – 5

HYDRO-ELECTRIC PLANTS

Introduction

The hydro electric plants energy is utilized to move the turbines which in turn run the eclectic generator. The energy of water utilized for power generation may be kinematic or potential. The kinematic energy of water is its energy in motion and is function of mass and velocity, while the potential energy is a function of the difference in level/head of water between two points.

Selection of Site for Hydel Plants

There are many factors that are to be considered while selecting site for a hydel power plant. The important factors are as follows:

1. **Availability of Water.**
2. **Storage of Water.**
3. **Head of Water.**
4. **Ground Water Data.**
5. **Distance from the Load Centre.**

1. Availability of Water: The site selected should be such that requisite quantity of water is be available throughout the year for economical generation of power. To estimate the availability of water, geographical, meteorological and geological investigations of the site are to be carried-out. Previous records of rainfall of the particular area are to be studied.

2. Storage of Water: The site selected should have good storage capacity, sufficient enough to use for a full year. This depends upon the reservoir capacity and the catchment area. It is always intended to store water enough to use even during dry periods, to the extent possible.

3. Head of Water: Head of water is the highest level of water at the upstream from where water flows down for power generation. Higher the head available, lesser the quantity of water required for a known power output and hence, lesser is the storage requirement. Power generated depends mainly on the head of water available, which is seen from the relation, Power = $mgH\eta / 1000$ Where, m = discharge or rate of water flow, kg/sec. H = head of water, m g = acceleration due to gravity, 9.81 m/s2 η = efficiency of the prime mover and generator (about 0.8 to 0.9) Hence, the site selected should give the highest head of water.

Powerplant Engineering, HIT ,Nidasoshi

4. Ground Water Data: It is an important factor to be considered, since it decides the stability of the ground at the reservoir and dam construction area. It is essential to select a site which has lesser ground water movement; as it provides a solid reservoir base and also seepage will be minimum. A strong reservoir base also helps in reducing the foundation costs for the dam construction.

5. Distance from the Load Centre: It is always essential that the site selected should be as nearer as possible to the load centre. Increased distances lead to increased power transmission costs and higher transmission losses. Other factors to be considered are the easy accessibility to the site by road and/ or rail, cheap cost of the land and the availability of non-polluted water for power generation.

Advantages of Hydel Plants

1) Operating cost of the plant including auxiliaries is low.

2) The maintenance of the plant is comparatively less.

3) Less labour is required to operate the plant.

4) No nuisance of smoke, exhaust gases, soot and other pollution.

5) The sites of hydel plants are usually away from the developed areas and hence the land is very cheap.

6) Load fluctuations can be met rapidly without loss of efficiency.

7) There are no stand-by losses.

8) Since no fuel used, there are no problems of handling, charging and disposal.

Disadvantages

1) Initial cost of the plant including the cost of dam is very high.

2) The feasibility of a hydel plant depends mainly on the availability of water and hence the natural phenomenon of rain and thus the problems of stopping the plant may arise during dry seasons.

3) Usually the sites will be away from the load centers, which causes loss of power and high costs in transmission lines.

4) It takes considerably long time for its erection as compared with the erection of - thermal plants.

Classification of Hydel Plants

Hydel power plants can be classified as follows:

Powerplant Engineering, HIT ,Nidasoshi

1. Quantity of water available

a) Run-off river plants without pondage

b) Run-off river plants with pondage

c) Pumped storage plant

2. Head of water

a) Low head plant

b) Medium head plant

c) High head plant

3. Nature of load

a) Base load plant

b) Peak load plant

4. Capacity of plant

a) Low capacity plant (100-999 kW)

b) Medium capacity plant (1 MW-10 MW)

c) High capacity plant (above 10 MW)

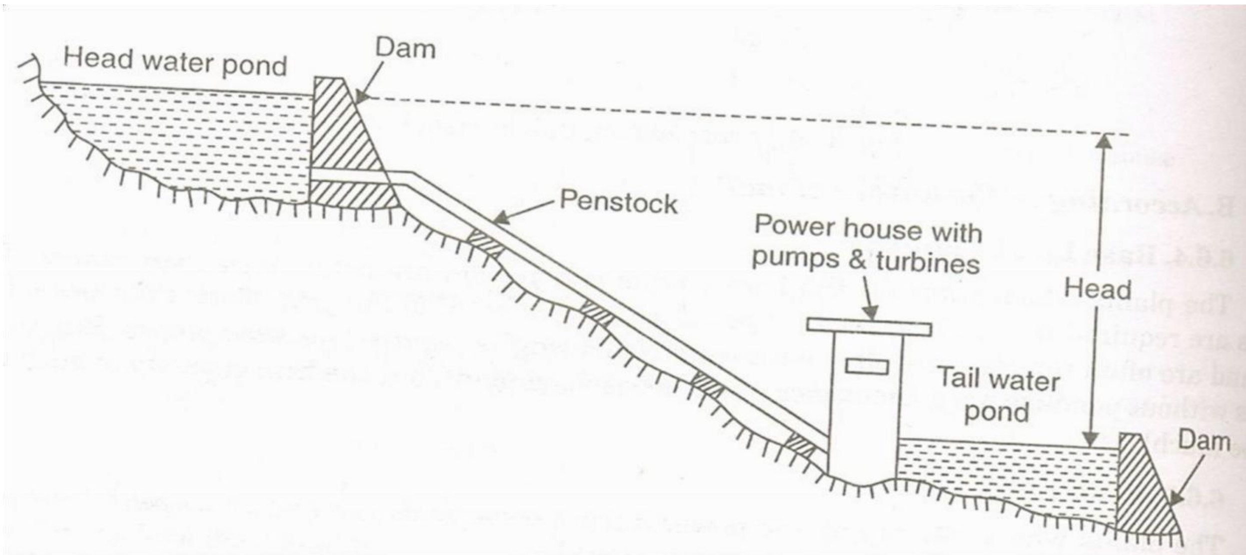
Run-off River Plants without Poundage

In such plants water is not stored, but only the running water is used for power generation. In such power plants the power generated directly depends upon the rate of flow available. Hence, during rainy seasons some excess quantity of water may run waste without doing any power generation. During dry periods the power production will be very poor, since the water flow rate will be low.

Run-off River Plants with Pondage In such plants, the excess water available during rainy seasons is stored in the reservoirs. The plant works with the normal run-off during the rainy season, while the stored water from the reservoir is utilised to supplement the low flow rate during dry periods. Power production will not be affected by the dry seasons. Hence, plants with pondage can generate a constant rate of power throughout the year.

Pumped Storage Plants Such plants are most suitable for supplying sudden peak load requirements. However, such demands can be met only for a short duration. In the normal operation they can meet the average demand only. Such type of plant consists of two storage reservoirs. The upstream reservoir is the main (head race) storage reservoir to which water flows from the catchment area.

Powerplant Engineering, HIT,Nidasoshi



The second reservoir is the downstream (tail race) reservoir, in which the used water from the upstream is collected. The water in the downstream reservoir is pumped back to the main upstream reservoir, during off peak periods. This facilitates making use of the excess water during peak hours. A pumped storage plant is a peak load plant operates in combination with other base load plants such as a thermal power plant. The off peak load capacity of the thermal plant is used for pumping water from the downstream reservoir to the upstream reservoir. The schematic arrangement of pumped storage plant operating along with a thermal plant to meet the peak load demands, is shown in Fig 4.1

Storage &Poundage

Storage plants are the plants with facilities for storing water at their sites. However, often such plants cannot store as much water as required for the full year operation for continuous operation, it is always preferred to have one or more reservoirs upstream Depending upon the place of storage and the function, the reservoirs are grouped as storage and pondage

Storage:

Storage can be defined as the collection of a large quantity of run-off during monsoon seasons, which is essentially used in the dry seasons for the plant operation. This is the main ,or the upstream reservoir, made by the construction of a dam across the stream

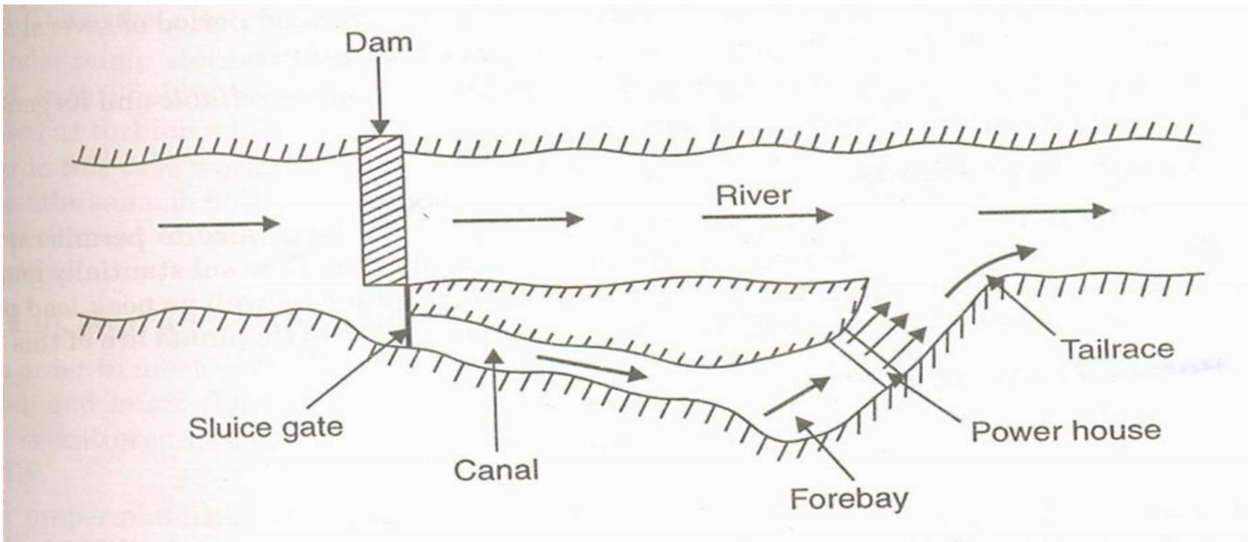
Pondage:

It is defined as a regulating means of water, and is a small reservoir that is used for the collection of the excess flow water from the dam spill ways of the main reservoir or from/the river stream. It is basically a small pond or reservoir just behind the power house.

Powerplant Engineering, HIT, Nid

Low Head Hydel Plant

A hydel plant with a water head of less than 50 meters is termed a low head plant. In such plants, a small dam is constructed across a river to obtain the necessary water head. The excess water is allowed to flow over the dam, while the water head is made use to run a hydraulic turbine.



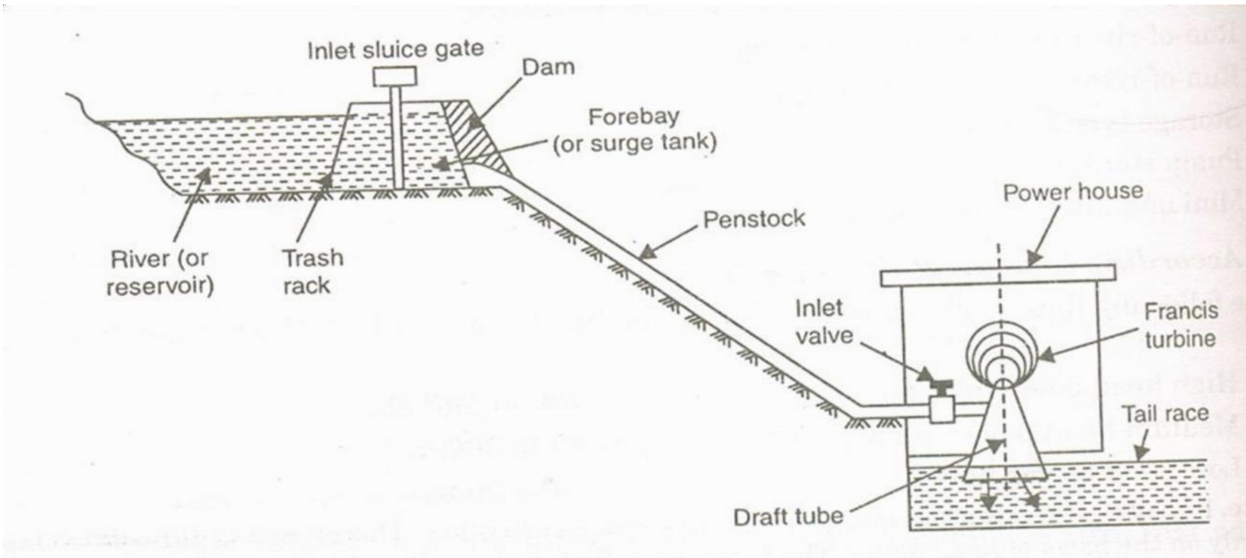
Low head power plant layout.

The water from the dam is taken through a canal to the turbine. For low head plants Francis or Kaplan turbines are used. There is no water hammer problem in such plants, hence no surge tank is provided in the water line.

Medium Head Hydel Plant

A hydel plant with a water head of in the range of 50 to 100 meters is termed a medium head plant. In this, the water is stored in a main reservoir, this water is allowed to a small pond or forebay through a canal, The water from the forebay is taken to the turbine through penstock. In such plants the forebay itself acts as the surge tank, and hence receives the excess water during the low demand periods. Francis turbine is most suitable for medium head hydel plants.

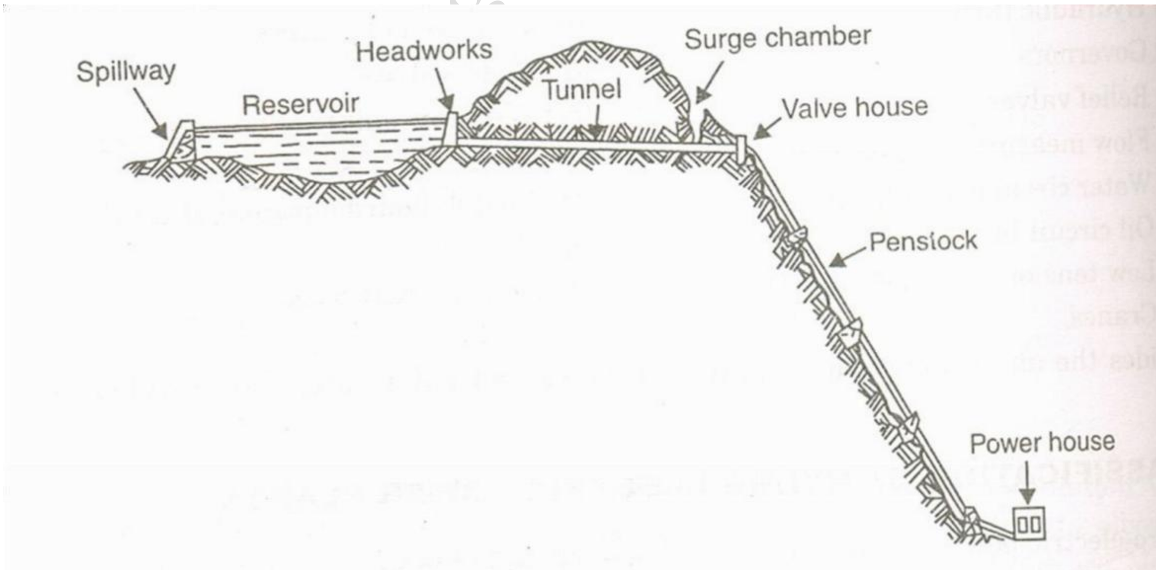
Powerplant Engineering



Medium head power plant layout.

High Head Hydel Plant

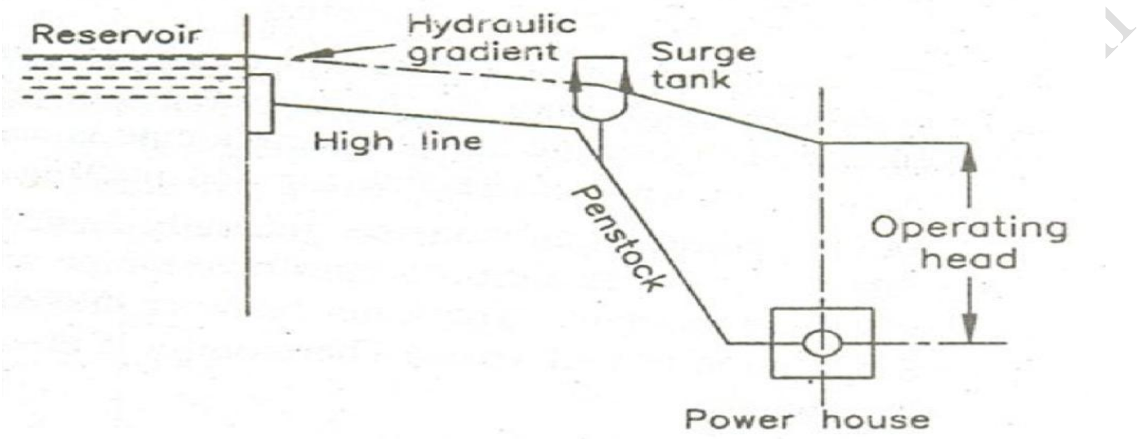
A hydel plant with a water head of more than 100 meters is termed a high head plant. In this case.The water from the main reservoir is carried through tunnels up to the surge tank, from where it is taken through the penstock. Since the water head is very high, the effect of water hammer is too severe in such plants. Thus, it is essential to provide a surge tank in the water line at appropriate location. The surge tank takes care of the increasing and decreasing water levels during the low-demand and high demand periods, respectively. The Francis and Pelton wheel turbines are most suitable for high head plants.



High head power plant layout. The main dam, spillway, and powerhouse stand at widely separated locations. Water flows from the reservoir through a tunnel and penstock to the turbines.

Penstocks

Penstocks are the pipelines that connects between the water source (such as the reservoir, forebay, water way) and the hydraulic turbine, these are usually large circular pipes with diameters ranging form 1 meter to 8 meters. Penstocks are usually made of steel or concrete pipes. Care should be taken to keep the entry to the penstock at the dam or the forebay at a low level, submerged always under the water. If the entry is open to air, it may take air along and create aeration problems in the prime mover, thus affecting the performance.



Position of Penstock.

The penstocks should be laid in such a way that there are no sharp bends. Sharp bends cause frictional losses and reduce the effective water head. Generally penstocks are exposed type, since they are economical and easy to repair and maintain. However, covered penstocks can be used when the regions are prone to sliding rocks, snow, earth and such dangers, so as to avoid damage to the pipe line.

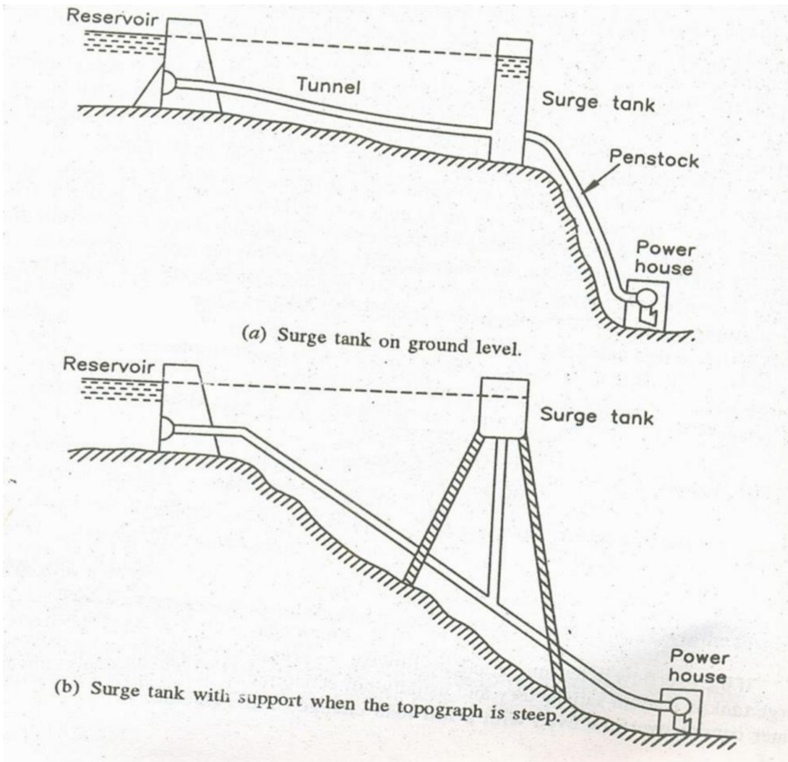
Water Hammer

Whenever there is a sudden fall in the demand, the governor closes the penstock valve to a minimum. This sudden closure-of the valve increases the pressure inside the penstock due to the kinetic energy of the water which is high enough to damage the penstock pipe. This effect is termed Water Hammer. Also, whenever there is a sudden rise in the load demand the gates are opened instantly by the governor, thereby creating vacuum in the penstock pipe. This causes to bubbling and foaming action. This leads to operational problems in the turbine. These problems can be overcome by providing a surge tank in the penstock line. Basically, a surge tank is a cylindrical open top storage unit, which connected to the penstock line and located very close to the turbine.

Powerplant Engineering

Surge tank

Surge tank is an open tank which is often used with pressure conduit of considerable length. The main purpose of providing surge tank is to reduce the distance between the free water surface and turbine there by reducing the water hammer effect on penstock and also protect upstream tunnel from high pressure raises. It also serves as a storage tank when the water is accelerating during increased load conditions and as a storage tank when the water is decelerating during reduced load conditions



Function of Surge Tank

1. Reduce the water hammer effect
2. Acts as a relief valve
3. Acts as a temporary reservoir

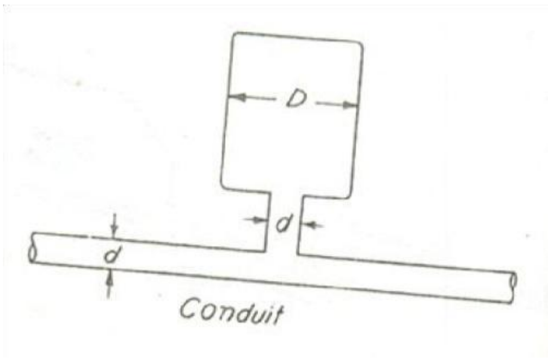
Types of Surge Tanks

1. Simple surge tank
2. Inclined surge tank
3. The expansion chamber and gallery type surge tank
4. Restricted orifice surge tank
5. Differential surge tank

Powerplant Engineering HIT Nidasoshi

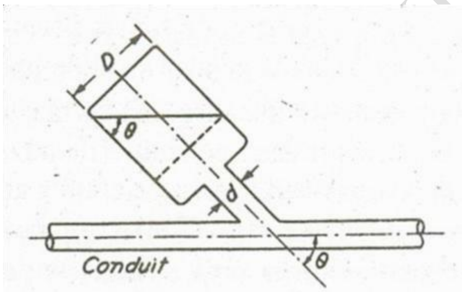
1. Simple surge tank:

The simplest type of surge tank is plain cylinder tank. It is



Connected to the conduit by a short connecting shaft as shown in fig. the diameter of the tank is governed by making a sufficient air to ensure stability.

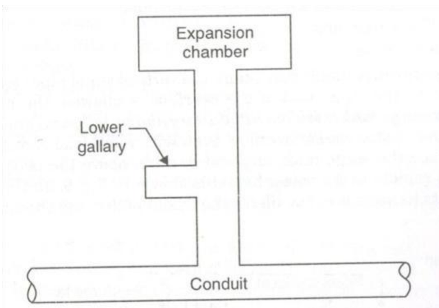
2. Inclined surge tank



Inclined simple surge tank.

If the surge tank of diameter is inclined at an angle T to the horizontal as shown, its effective water surface area increases from 3 $d^2/4$ to 3 $d^2/4$ cosec T. Therefore lesser height surge tanks are required

3. The expansion chamber and Gallery type surge tank



The expansion chamber surge tank.

The surge tank having a variable cross section with expansion tank at the top and expansion gallery at the bottom. The upper reservoir absorbs the risings buds while the lower one provides rage of water on starting the turbine or increasing the load on the turbine.

Powerplant Eng HIT ,Nidasoshi

UNIT-6
NUCLEAR POWER PLANT

Introduction Nuclear Energy:

Nuclear energy is the energy trapped inside each atom. Heavy atoms are unstable and undergo nuclear reactions. Nuclear reactions are of two types

1. Nuclear fission…the splitting of heavy nucleus

2. Nuclear fusion…the joining of lighter nuclei

Fission:

Fission may be defined as the process of splitting an atomic nucleus into fission fragments. The fission fragments are generally in the form of smaller atomic nuclei and neutrons. Large amounts of energy are produced by the fission process. **Fusion :**Fusion is a nuclear reaction whereby two light atomic nuclei fuse or combine to form a single larger, heavier nucleus. The fusion process generates tremendous amounts of energy. For fusion to occur, a large amount of energy is needed to overcome the electrical charges of the nuclei and fuse them together. Fusion reactions **do not occur naturally** on our planet but are the principal type of reaction found in stars. The large masses, densities, and high temperatures of stars provide the initial energies needed to fuel fusion reactions. The sun fuses hydrogen atoms to produce helium, subatomic particles, and vast amounts of energy. **Comparison of fission and fusion**

Fission	Fusion
• **Splitting** of heavy nucleus	• **Joining** of light nuclei
• Is a **chain reaction**	• Is **not** a chain reaction
• Can be **controlled**	• **Cannot** be controlled
• Radiations are **very harmful**	• Will **not emit** harmful radiation.

Components Of A Nuclear Reactor

The important components of a nuclear reactor are:

- Fuel rods
- Control rods
- Moderator
- Reflector
- Reactor vessel
- Biological shielding
- Coolant

Powerplant Engineering HIT ,Nidasoshi

Fuel Rod (Material): Natural Uranium with U235 contents (occurs in nature), Enriched Uranium with more than 0.71 of U235, Pu239,Pu241 or Pu239 (man made), U233 (man made). The finished fuel rods are grouped in fuel assemblies, called fuel bundles.

A typical PWR has fuel assemblies of 200 to 300 rods each, and a large reactor would have about 150–250 such assemblies with 80–100 tonnes of uranium in all. Generally, the fuel bundles consist of fuel rods bundled 14 × 14 to 17 × 17. A PWR produces on the order of 900 to 1,500 MW. PWR fuel bundles are about 4 meters in length. Refuelings for most commercial PWRs is on an 18–24 month cycle. Approximately one third of the core is replaced each refueling.

Important properties of Fuel rods

- It should withstand high temperature
- It should have high corrosion resistance
- It should have good thermal conductivity
- It should not absorb neutrons
- It should withstand radiation effects

Controls rods:

These are cylindrical shaped rods located centrally in the fuel rods which have the property of absorbing neutrons. It keeps the chain-reaction under control. It can be lowered into the chamber to absorb neutrons and to slowdown the reactions (and vice versa). Thus the rate of nuclear reactions can be controlled with the help of control rods. Ex: Cadmium, Boron, Carbon, Cobalt, Silver, Hafnium, and Gadolinium. A good control rod should have the following properties

- Good capacity to transfer heat
- Stability at high temperature
- Good corrosion resistance
- Good strength and capacity to absorb neutrons at faster rate.

Moderator:

Function of a moderator is to reduce the energy(velocity) of fast neutrons to thermal neutrons(thermal energies). A process called moderation or thermalization in order to interact with the nuclear fuel and sustain the chain reaction. In PWRs the coolant water is used as a moderator by letting the neutrons undergo multiple collisions with light hydrogen atoms in the water, losing speed in the process. **Generally used moderators are**: H2O, D2O(heavy water), He(gas), Be(beryllium) and C(graphite).

The important properties of a good moderator

Powerplant Engineering, HIT,Nidasoshi

• It should have high corrosion resistance

• It should have good thermal conductivity

• It should be stable under high temperature and pressure conditions

• It should successfully reduce the velocity of the fast moving neutrons

• A solid moderator should have machinability

Reflector:

Function of the reflector is to minimize the neutron leakage by reflecting them back into the reactor. Graphite and Beryllium are generally used as reflectors.

The important properties of good reflectors material are:

It should have good thermal conductivity

• It should have good corrosion resistance

• It should have high stability under high temperature and pressure conditions

• It should not absorb neutrons

• It should have good reflectivity.

Reactor Vessel:

It is a strong steel container in which the fuel rods,moderator,control rods and the reflector are arranged properly. It forms a strong structural support for the reactor core.

Biological Shielding:

This is a wall which surrounds the whole reactor system. It‘s mainly made of lead or concrete. Its main purpose is to avoid radiation hazards caused by the escape of radioactive radiation (like neutrons, alpha, beta and gamma rays) from the reactor core due to the nuclear reaction. Of all these radiation particles gamma rays are very hazards.

Important Properties of Good Biological Shielding

• It should have a high strength

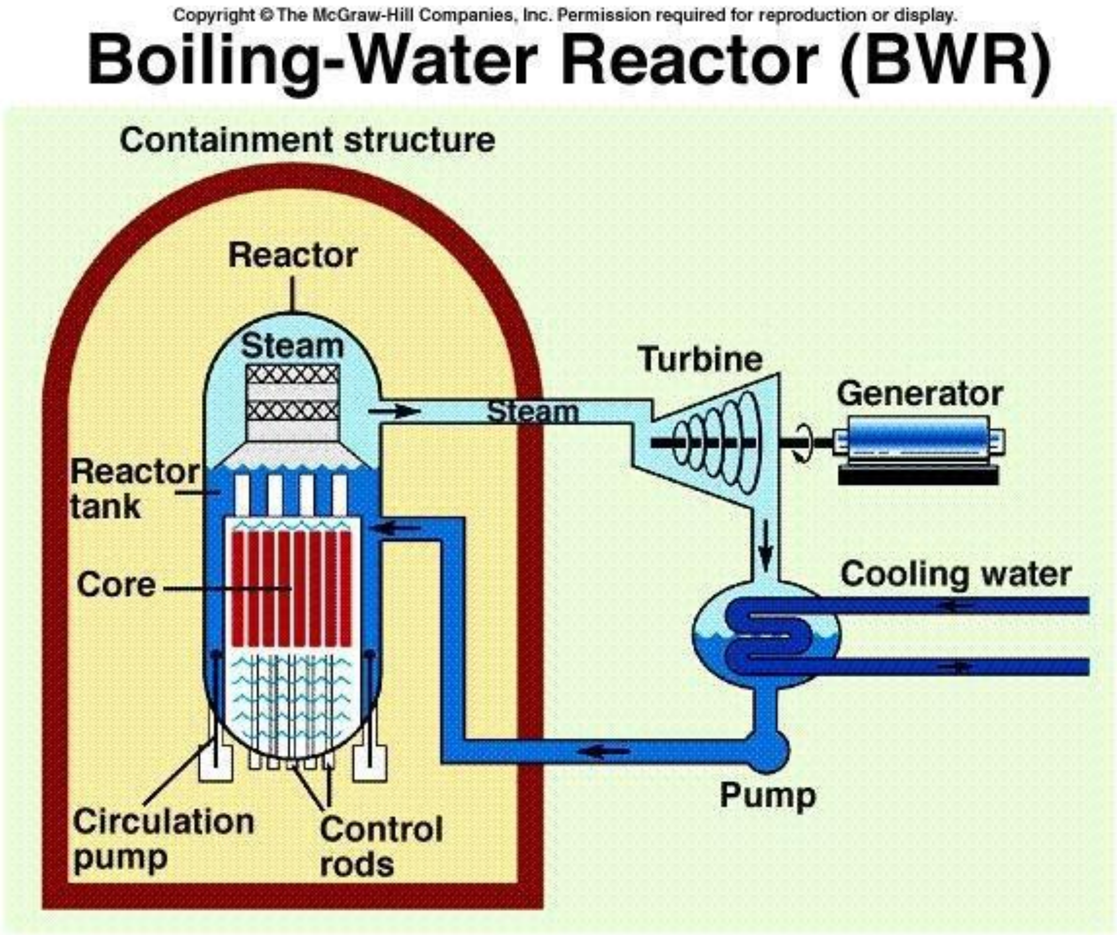
• It should not allow radioactive rays to pass through.

• It should be stable under high temperature and pressure.

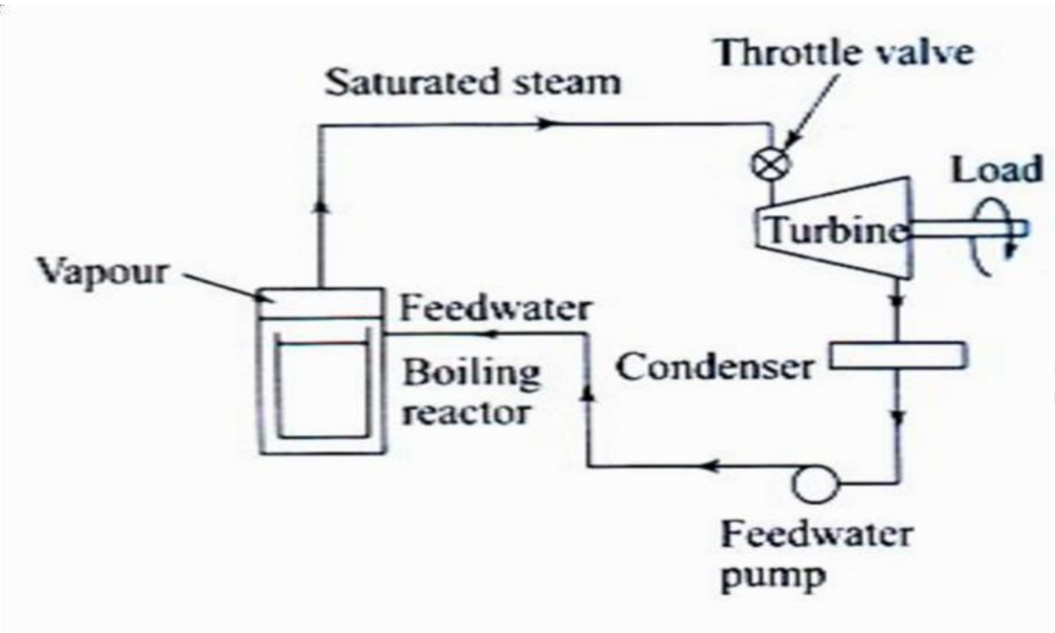
Coolant: A **Coolant** is used to remove the heat and maintain the temperature of the fuel within acceptable limits. Coolants are used both in primary and secondary circuits (cycles) in nuclear reactors. Sometimes the moderator and the coolant are the same material (e.g. water). The commonly used coolants are water, heavy water, inert gasses (helium,CO_2),air,sodium,bismuth and potassium. **Boiling water reactor (BWR)** Boiling water reactor (BWR) is the simplest of all facilities. Water absorbs heat from the reactions in the core and is directly driven to the turbines. After condensing the water is pumped back to the reactor core. In a Boiling Water Reactor **enriched fuel** is used. The BWR uses

Powerplant Engineering, HIT,Nidasoshi

dematerialized water (light water) as a coolant and moderator. Heat is produced by nuclear fission in the reactor core, and this causes the cooling water to boil, producing steam.
The steam is **directly** used to drive a turbine, after which is cooled in a condenser and Converted back to liquid water.



Powerplant



Advantages of BWR

- Heat exchanger circuit is not required so direct conduction hence more thermal efficiency.
- Use of low pressure principle hence no need of Pressurizer.
- Metal Temperature remains low.
- Outlet temp of steam is very high (as compared with PWR).
- Pressure is low, and thicker vessel is not required.

Disadvantages of BWR

- Possibility of radio active contamination in the turbine mechanism.
- More elaborate safety particulars needed which are costly.
- Wastage of steam resulting in lower thermal efficiency on part load.
- The possibility of ―burn out‖ of fuel is more.

Pressurized water reactor (PWR) PWR uses a sealed system to prevent water circulating through the core from boiling due to high pressure. The heat from this system is removed by the water in pipes to the steam generator. In a Pressurized water reactor natural and highly enriched fuel is used. PWR use ordinary water under high pressure (superheated water) as **coolant** to remove heat generated by nuclear chain reaction from nuclear fuel, and also as the **moderator** to thermalise the neutron flux so that it interacts with the nuclear fuel to maintain the chain reaction.

PWR reactor design.

Light water is used as the primary coolant in a PWR. It enters the bottom of the reactor core at about **275 °C** and is heated as it flows upwards through the reactor core to a temperature of about **315 °C.** The water remains liquid despite the high temperature due to the high pressure in the primary coolant loop, usually around 15 MPa. Pressure in the primary circuit is maintained by a **Pressurizer**(about **155 bar**), a separate vessel (boiler) that is connected to the primary circuit and partially filled with water which is heated to the saturation temperature (boiling point) for the desired pressure by submerged electrical heaters. To achieve a pressure of 155 bar, the pressuriser temperature is maintained at 345 °C, which gives a subcooling margin of 30 °C. (The difference between the pressuriser temperature and the highest temperature in the reactor core, since pressuriser temperature is higher than the primary coolant temperature). To achieve maximum heat transfer, the primary circuit temperature, pressure and flow rate are arranged such that subcoolednucleate boiling takes place as the coolant passes over the nuclear fuel rods. PWRs are the most common type of power producing nuclear reactor, and are widely used in power stations such as ships and submarines all over the world. More than 230 of them are in use in nuclear power plants to generate electric power, and several hundred more for marine propulsion in aircraft carriers, submarines and ice breakers.

Advantages

- PWR reactors are very stable due to their tendency to **produce less power** as temperatures increase; this makes the reactor easier to operate from a stability standpoint.

- PWR reactors can be operated with a core containing **less fissile material.** This significantly reduces the chance that the reactor will run out of control and makes PWR designs relatively safe from critical accidents.

- PWR reactors can use ordinary water as coolant, moderator hence less expensive and easily available. PWR turbine cycle loop is separate from the primary loop, so the water in the secondary loop is not contaminated by radioactive materials.

- A small number of control rods are required.

- There is complete freedom to inspect and maintain the turbine, feed heaters and condenser during the operation.

- Fission products remain contained in the reactor and are not circulated.

Disadvantages

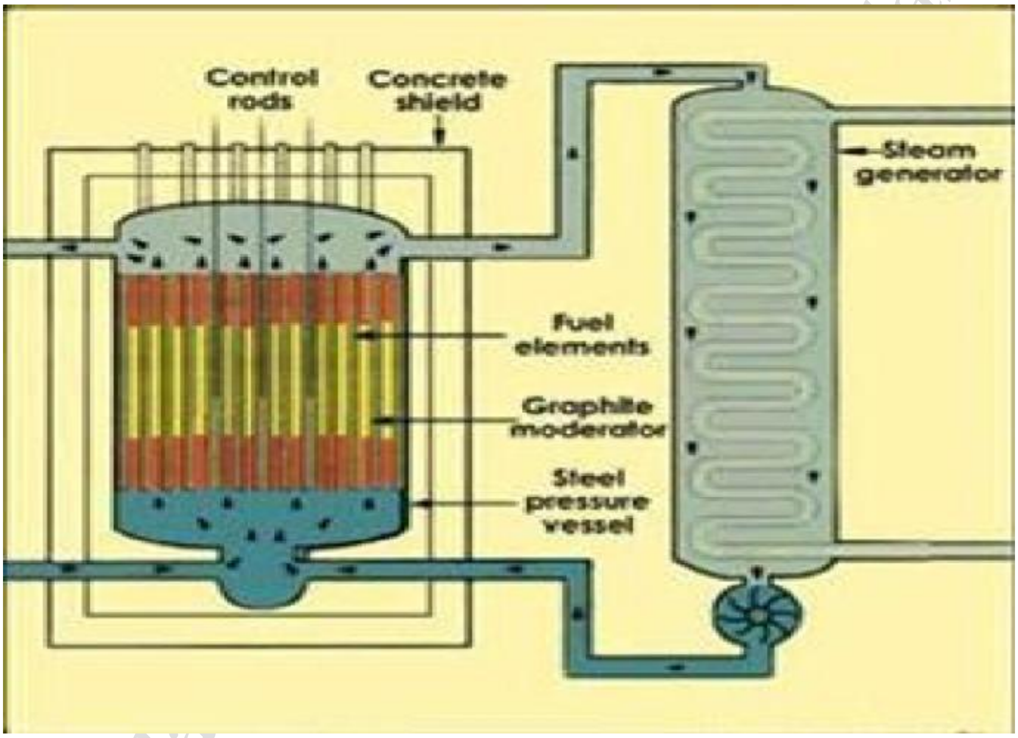
- The coolant water must be highly pressurized to remain liquid at high temperatures.This requires high strength piping and a heavy pressure vessel and hence increases construction costs.

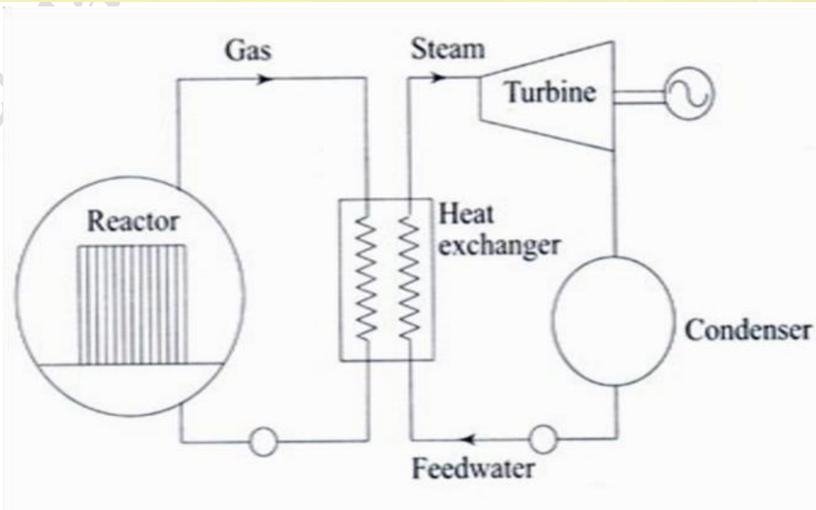
- Most pressurized water reactors cannot be refueled while operating. This decreases the availability of the reactor- it has to go offline for comparably long periods of time (some weeks).

Powerplant Engineering, HIT,Nidasoshi

- Natural uranium is only 0.7% Uranium-235, the isotope necessary for thermal reactors. This makes it necessary to enrich the uranium fuel, which increases the costs of fuel production. If heavy water is used it is possible to operate the reactor with natural uranium, but the production of heavy water requires large amounts of energy and is hence expensive.
- Severe corrosion problem

Gas cooled reactor (GCR)





GCR uses CO_2 gas as a coolant to remove heat from the core

Then it is piped through the steam generator where heat is removed from the gas and it can then recirculated to the reactor. As usual steam generated is used to drive the turbine and generate electricity, condensed then recalculated. **Graphite** is used as a moderator. Other type of Coolant used can be **air, helium and hydrogen**

- The processing of fuel is simpler.
- No corrosion problem.
- Graphite remains stable under irradiation at high temperature.
- The use of CO_2as coolant completely eliminates the possibility of explosion in the reactor (which always in water cooled plants).
- Power density is low (due to low heat transfer coefficient), therefore large vessel is required.
- If helium is used instead of CO_2, the leakage of gas is a major problem.
- More power is required for coolant circulation (pumping cost is more).
- Fuel loading is more elaborate and costly.

Breeder Reactor

A **breeder reactor converts** fertile materials into fissionable materials such as **U238** to **Pu239** and**Th232**to **U233**besides the power production. Types of Breeder reactor

• **Fast breeder reactor** or FBR

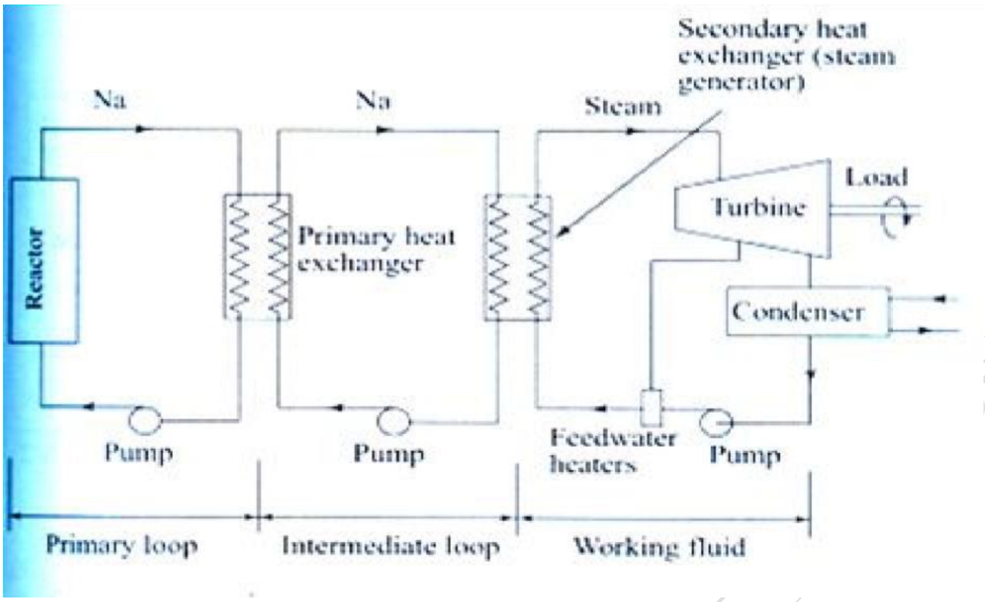
• **Thermal breeder reactor**

Fast breeder reactor or FBR

Under appropriate operating conditions, the neutrons given off by fission reactions can "breed" more fuel. Production of fissile material in a reactor occurs by neutron irradiation of fertile material, particularly Uranium-238 and Thorium-232. The most common breeding reaction is that of **plutonium-239** from nonfissionable **uranium-238.** A normal reactor can consume less than 1% of the natural uranium that begins the fuel cycle, whereas a breeder can use much more with a once-through cycle and nearly all of it with reprocessing. Also, breeders can be designed to utilize Thorium, which is more abundant than Uranium **Liquid Metal Reactor or Sodium Graphite Reactor.**

This reactor consists of **double circuit**coolant.Enriched**uranium** is used as the fuel. Liquid metal and alloys such as **sodium (and NaK)** as coolant. **Graphite** as the moderator. Here **primary** circuit uses **sodium** as coolant absorb the heat from core and transfer to the **Na** or **NaK** (uses an alloy as coolant) in the **secondary**circuit ,Na or NaK transfers heat to the boiler to raise steam, which is used to run the turbine to generate power.**Sodium** has high **thermal conductivity** which is more than **100 times** that of **water**, hence increases the thermal efficiency of the plant.

Power plant Engineering, HIT, Nidasoshi



Advantages

1. The moderator is not required

2. High breeding is possible

3. Small core is sufficient

4. High burn-up of fuel is achievable

5. Absorption of neutrons is low

6. Thermal efficiency of the plant is very high (30 – 40%).

Disadvantages

1. Requires highly enriched fuel

2. It is necessary to provide safety against - melt-down

3. Neutron flux is high at the centre of the core

4. The specific power of reactor is low.

5. There is a major problem of handling sodium as it becomes hot and radioactive.

6. Plant cost is more due to costly coolants.

Multiplication Factor & Thermal Utilization Factor In a fission reaction 2.5 neutrons released in each reaction, one neutron is used to sustain chain reaction (fast fission), about 0.9 neutron is captured by U-238 to form Pu-239 a fissionable material (in a fast breeder reactor), and about 0.6 neutron is partly absorbed by control rods, coolant, moderator and partly escape from the reactor. Finally, the fraction of 2.5 neutrons that remains for absorption by the fuel nuclei to cause further chain reaction, is termed **thermal utilisation factor (f).** Nuclear fission reaction continues or not, can be **determined** by a number termed the **Multiplication Factor.** Multiplication Factor is defined as the ratio of the number of neutrons produced by one reaction to the number of neutrons produced in an immediately preceding reaction. It is expressed by the relation ,

k = **Number of neutrons in a given reaction**

No of neutrons of produced in the immediate preceding reactionK = P / A+E where, k = Effective multiplication factor

P = Rate of neutron production

A =Rate of neutron absorption

E = Rate of neutron leakage.

The **multiplication factor k** is useful in determining whether a fission reaction will be sustained, slowed down or increasing, based on

1) Critical Reaction

2) Sub-critical Reaction

3) Super-critical Reaction

1) Critical Reaction: When, k = 1, the chain reaction will continue at a steady rate (reaction is critical).

This is the desirable condition in power plants as this releases energy at a steady rate and is easily controllable (whenever a nuclear reactor is reported to have gone critical meaning that it has successfully operating with sustainable chain reaction).

2) Sub-critical Reaction: When, k < 1, the chain reaction will **stop**, i.e., reaction is sub-critical, which is not desirable. With this state, the chain reaction dies down, and indicates that the conditions to maintain a chain reaction are not fulfilled.

3) Super-critical Reaction: When, k > 1, chain reaction will be building up, it goes super-critical, which is the most **undesirable and dangerous** condition as it is **uncontrollable**.This**condition is applied in nuclear bombs.** If this condition is reached in a nuclear reactor, reactor melts down and explodes **leading to fire and radiation hazards.**

Powerplant Engineering, HIT ,Nidasoshi

Types of Nuclear Wastes

1. Low level waste (LLW) This is generated from nuclear fuel cycle. Initially the low level solid waste is cast in cemented steel drum. After it is buried few meters below from the soil or kept on ocean bed. It get diluted as it disperse. It comprises paper, rags, tools, clothing, filters, etc., which contain small amounts of mostly short-lived radioactivity. They have low but potentially hazardous concentration of radioactive materials. They do not require any shielding and can be disposed in liquid form.

2. Intermediate level waste (ILW)
This contains higher amounts of radioactivity and in some cases requires shielding. ILW includes resins, chemical sludge and metal reactor fuel cladding, as well as contaminated materials from reactor decommissioning. It may be solidified in **concrete or bitumen for disposal.** These wastes mainly contaminated with neutron activation product isotopes. This type of waste is primarily put in a **cement concrete cylinder.** Then it is buried few meters below from the soil or kept on ocean bed.

3. High level waste (HLW)
This is produced by nuclear reactors. It contains fission products elements generated in the reactor core. It is highly radioactive and often thermally hot. HLW accounts for over 95% of the total radioactivity produced in the process of nuclear electricity generation. High-level radioactive waste is stored temporarily in spent fuel pools and in **dry cask storage**facilities. This allows the shorter-lived isotopes to decay before further handling.

Radioactive Waste Disposal Systems

a] Disposal of low level solid waste

Primarily the low level solid waste is cast in cement in steel drum. After it is buried few meters below from the soil or kept on ocean bed. It gets diluted as it disperses.

b] Disposal of medium level solid waste
These wastes mainly contaminated with neutron activation product isotopes.This type of waste is primarily put in a cement concrete cylinder. Then it is buried few meters below from the soil or kept on ocean bed.

c] Disposal of high level liquid waste
High level liquid waste is stored in steel cylinder tanks with concrete. It is water cooled to keep the temperature at 50ºc.then this cylinder is stored in salt mine. The oceans is used for permanent storage of high level waste disposal. Long-term storage of radioactive waste requires the stabilization of the waste into a form which will not react, nor degrade, for extended periods of time. One way to do this is through vitrification. The high-level waste is

Powerplant Engineering, HIT, Nidasoshi

mixed with sugar and then calcined. Calcinations involves passing the waste through a heated, rotating tube. The purposes of calcinations are to evaporate the water from the waste, and de-nitrate the fission products to assist the stability of the glass produced. The 'calcine' generated is fed continuously into an induction heated furnace with fragmented glass. The resulting glass is a new substance in which the waste products are bonded into the glass matrix when it solidifies. This product, as a molten fluid, is poured into stainless steel cylindrical containers ("cylinders") in a batch process. When cooled, the fluid solidifies ("vitrifies") into the glass. Such glass, after being formed, is very highly resistant to water. After filling a cylinder, a seal is welded onto the cylinder. The cylinder is then washed. After being inspected for external contamination, the steel cylinder is stored, usually in an underground repository. In this form, the waste products are expected to be immobilized for a very long period of time (many thousands of years).

Powerplant Engineering, HIT,Nidasoshi

UNIT-7
CHOICE OF SITE

Introduction

Selecting a proper site for a thermal power plant is vital for its long term efficiency and a lot many factors come into play when deciding where to install the plant. Of course it may not be possible to get everything which is desirable at a single place but still the location should contain an optimum mix of the requirements for the settings to be feasible for long term economic justification of the plant.

The Requirements for the Site

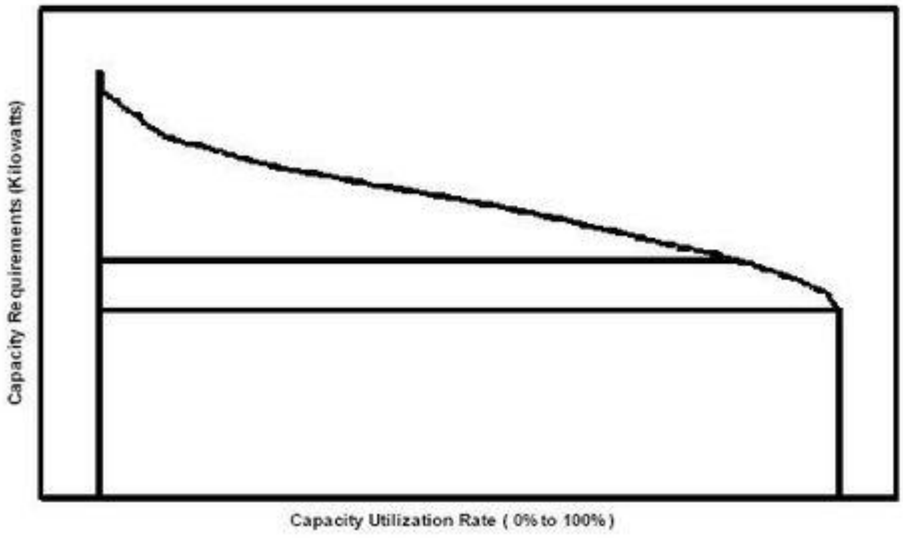
As the name implies the power plant is meant for generating power which obviously means that it will consume huge quantities of fuel. The exact quantity would depend on the size of the plant and its capacity but it is a general fact that ample quantities of fuel must be available either in the vicinity or it should be reasonably economical to transport the fuel till the power plant. Since most thermal power plants use coal (they can use other fuels as well) it must be ensured that sufficient coal is available round the clock. Just to give you a rough idea a power plant with 1000 MW capacity approximately would require more than ten thousand tons of coal per day hence the necessity for continuous supply and storage capability of coal in the power station.

Ash if the main byproduct of combustion and since the amount of coal used is huge, you can intuitively imagine the amount of ash generated and it is certainly in the region of thousand tons per day. Ash is much more difficult to handle as compared to coal since it comes out hot from the boiler and is very corrosive in nature. Disposing of such huge quantities of ash requires a large amount of empty space where it can be safely dumped.

There must be ample space for the storage of coal, disposal of ash, building of the power plant, and residential colony of workers, markets and so forth. An approximate analysis suggests that for every MW of power generated there must be at least 3 acres of land available for the purpose. Hence the power plant site needs to have good amount of land and this land should have good bearing capacity in order to survive the static and dynamic loads during the operation of the plant.

Load Duration Curve

It is the curve for a plant showing the total time within a specified period, during which the load equaled or exceeded the values shown.



Plant Capacity Factor

It is the ratio of the average loads on a machine or equipment to the rating of the machine or equipment, for a certain period of time considered. Since the load and diversity factors are not involved with 'reserve capacity' of the power plant, a factor is needed which will measure the reserve, likewise the degree of utilization of the installed equipment. For this, the factor "Plant factor, Capacity factor or Plant Capacity factor" is defined as,

Plant Capacity Factor = (Actual kWh Produced)/(Maximum Possible Energy that might have produced during the same period)
Thus the annual plant capacity factor will be,
= (Annual kWh produced)/[Plant capacity (kW) × hours of the year]
The difference between load and capacity factors is an indication of reserve capacity.

Load Factor

It is defined as the ratio of the average load to the peak load during a certain prescribed period of time. The load factor of a power plant should be high so that the total capacity of the plant is utilized for the maximum period that will result in lower cost of the electricity being generated. It is always less than unity. High load factor is a desirable quality. Higher load factor means greater average load, resulting in greater number of power units generated for a given maximum demand. Thus, the fixed cost, which is proportional to the maximum demand, can be distributed over a greater number of units (kWh) supplied.
This will lower the overall cost of the supply of electric energy.

Utility Factor

It is the ratio of the units of electricity generated per year to the capacity of the plant installed in the station. It can also be defined as the ratio of maximum demand of a plant to the rated capacity of the plant. Supposing the rated capacity of a plant is 200 mW. The maximum load on the plant is 100 MW at load factor of 80 per cent, then the utility will be
$= (100 \times 0.8)/(200) = 40\%$

Plant Operating Factor

It is the ratio of the duration during which the plant is in actual service, to the total duration of the period of time considered.

Demand Factor

The actual maximum demand of a consumer is always less than his connected load since all the appliances in his residence will not be in operation at the same time or to their fullest extent. This ratio of' the maximum demand of a system to its connected load is termed as demand factor. It is always less than unity.

Diversity Factor

Supposing there is a group of consumers. It is known from experience that the maximum demands of the individual consumers will not occur at one time. The ratio of the sum of the individual maximum demands to the maximum demand of the total group is known as diversity factor. It is always greater than unity. High diversity factor (which is always greater than unity) is also a desirable quality. With a given number of consumers, higher the value of diversity factor, lower will be the maximum demand on the plant, since,
Diversity factor = Sum of the individual maximum Demands/Maximum demand of the total Group So, the capacity of the plant will be smaller, resulting in fixed charges.

Load Curve

It is a curve showing the variation of power with time. It shows the value of a specific load for each unit of the period covered. The unit of time considered may be hour, days, weeks, months or years.

Load Duration Curve

It is the curve for a plant showing the total time within a specified period, during which the load equaled or exceeded the values shown.

Powerplant Engineering, HIT, Nidasoshi

Dump Power

This term is used in hydro plants and it shows the power in excess of the load requirements and it is made available by surplus water.

Firm Power

It is the power, which should always be available even under emergency conditions.

Prime Power

It is power, may be mechanical, hydraulic or thermal that is always available for conversion into electric power.

Cold Reserve

It is that reserve generating capacity which is not in operation but can be made available for service.

Hot Reserve

It is that reserve generating capacity which is in operation but not in service.

Spinning Reserve

It is that reserve generating capacity which is connected to the bus and is ready to take the load.

Plant Use Factor

This is a modification of Plant Capacity factor in that only the actual number of hours that the plant was in operation is used. Thus Annual Plant Use factor is,

= (Annual kWh produced) / [Plant capacity (kW) × number of hours of plant operation]

Powerplant Engineering, HIT, Nidasoshi

UNIT-8
ECONOMIC ANALYSIS OF POWER PLANT

Introduction

A power plant should be reliable. The capacity of a power plant depends upon the power demand. The capacity of a power plant should be more than predicted maximum demand. It is desirable that the number of generating units should be two or more than two. The number of generating units should be so chosen that the plant capacity is used efficiently. Generating cost for large size units running at high load factor is substantially low. However, the unit has to be operated near its point of maximum economy for most of the time through a proper load sharing programme. Too many stand bys increase the capital investment and raise the overall cost of generation. The thermal efficiency and operating cost of a steam power plant depend upon the steam conditions such as throttle pressure and temperature. The efficiency of a boiler is maximum at rated capacity. Boiler fitted with heat recovering devices like air preheater, economiser etc. gives efficiency of the order of 90%. But the cost of additional equipment (air preheater economiser) has to be balanced against gain in operating cost. Power can be produced at low cost from a hydropower plant provided water is available in large quantities. The capital cost per unit installed is higher if the quantity of water available is small. While installing a hydropower plant cost of land, cost of water rights, and civil engineering works cost should be properly considered as they involve large capital expenditure. The other factor, which influences the choice of hydropower plant, is the cost of power transmission lines and the loss of energy in transmission. The planning, design and construction of a hydro plant is difficult and takes sufficient time. The nuclear power plant should be installed in an area having limited conventional power resources. Further a nuclear power plant should be located in a remote or unpopulated are to avoid damage due to radioactive leakage during an accident and also the disposal of radioactive waste should be easy and a large quantity of water should be available at the site selected. Nuclear power becomes competitive with conventional coal fired steam power plant above the unit size of 500 mW. The capital cost of a nuclear power plant is more than a steam power plant of comparable size. Nuclear power plants require less space as compared to any other plant of equivalent size. The cost of maintenance of the plant is high. The diesel power plant can be easily located at the load centre. The choice of the diesel power plant depends upon thermodynamic considerations. The engine efficiency improves with compression ratio but higher pressure necessitates heavier construction of equipment with increased cost. Diesel power plants are quite suitable for smaller outputs. The gas turbine power plant is also suitable for smaller outputs. The cost of a gas turbine plant is relatively low. The cost of gas turbine increases as the sample plant is modified by the inclusion of equipment like

Powerplant Engineering, HIT, Nidasoshi

regenerator, reheater, and intercooler although there is an improvement in efficiency of the plant by the above equipment. This plant is quite useful for regions where gaseous fuel is available in large quantities.

In order to meet the variable load the prime movers and generators have to act fairly quickly to take up or shed load without variation of the voltage or frequency of the system. This requires that supply of fuel to the prime mover should be carried out by the action of a governor. Diesel and hydropower plants are quick to respond to load variation as the control supply is only for the prime mover. In a steam power plant control is required for the boilers as well as turbine. Boiler control may be manual or automatic for feeding air, feed water fuel etc. Boiler control takes time to act and therefore, steam powers plants cannot take up the variable load quickly. Further to cope with variable load

Factor effecting power plant design

Following are the factor effecting while designing a power plant.

(1) Location of power plant
(2) Availability of water in power plant
(3) Availability of labour nearer to power plant
(4) Land cost of power plant
(5) Low operating cost
(6) Low maintenance cost
(7) Low cost of energy generation
(8) Low capital cost

Effect of power plant type on costs

The cost of a power plant depends upon, when a new power plant is to set up or an existing plant
is to be replaced or plant to be extended. The cost analysis includes

1. Fixed Cost

It includes Initial cost of the plant, Rate of interest, Depreciation cost, Taxes, and Insurance.

2. Operational Cost

It includes Fuel cost, Operating labour cost, Maintenance cost, Supplies, Supervision, Operating taxes.

Powerplant Engineering, HIT ,Nidasoshi

Initial Cost

The initial cost of a power station includes the following:

1. Land cost
2. Building cost
3. Equipment cost
4. Installation cost
5. Overhead charges, which will include the transportation cost, stores and storekeeping charges, interest during construction etc.

Adopting unit system where one boiler is used for one turbo generator can reduce the cost on equipment. Also by simplifying the piping system and elimination of duplicate system such as steam headers and boiler feed headers. Eliminating duplicate or stand-by auxiliaries can further reduce the cost. When the power plant is not situated in the proximity to the load served, the cost of a primary distribution system will be a part of the initial investment.

Rate of Interest

All enterprises need investment of money and this money may be obtained as loan, through bonds and shares or from owners of personal funds. Interest is the difference between money borrowed and money returned. It may be charged at a simple rate expressed as % per annum or may be compounded, in which case the interest is reinvested and adds to the principal, thereby earning more interest in subsequent years. Even if the owner invests his own capital the charge of interest is necessary to cover the income that he would have derived from it through an alternative investment or fixed deposit with a bank. Amortization in the periodic repayment of the principal as a uniform annual expense.

Depreciation

Depreciation accounts for the deterioration of the equipment and decrease in its value due to corrosion, weathering and wear and tear with use. It also covers the decrease in value of equipment due to obsolescence. With rapid improvements in design and construction of plants, obsolescence factor is of enormous importance. Availability of better models with lesser overall cost of generation makes it imperative to replace the old equipment earlier than its useful life is spent. The actual life span of the plant has, therefore, to be taken as shorter than what would be normally expected out of it. The following methods are used to calculate the depreciation cost:

(1) Straight line method
(2) Percentage method
(3) Sinking fund method
(4) Unit method.

Straight Line Method. It is the simplest and commonly used method. The life of the equipment or the enterprise is first assessed as also the residual or salvage value of the same after the estimated life span. This salvage value is deducted from the initial capital cost and the balance is divided by the life as assessed in years. Thus, the annual value of decrease in cost of equipment is found and is set aside as depreciation annually from the income. Thus, the rate of depreciation is uniform throughout the life of the equipment. By the time the equipment has lived out its useful life, an amount equivalent to its net cost is accumulated which can be utilized for replacement of the plant.

Powerplant Engineering, HIT, Nidasoshi

Percentage Method. In this method the deterioration in value of equipment from year to year is taken into account and the amount of depreciation calculated upon actual residual value for each year. It thus, reduces for successive years.

Sinking Fund Method. This method is based on the conception that the annual uniform deduction from income for depreciation will accumulate to the capital value of the plant at the end of life of the plant or equipment. In this method, the amount set aside per year consists of annual installments and the interest earned on all the installments.

Let,

A = Amount set aside at the end of each year for n years.

n = Life of plant in years.

S = Salvage value at the end of plant life.

i = Annual rate of compound interest on the invested capital.

P = Initial investment to install the plant.

Then, amount set aside at the end of first year = A

Amount at the end of second year

$= A + \text{interest on } A = A + Ai = A(1 + i)$

Amount at the end of third year

$= A(1 + i) + \text{interest on } A(1 + i)$

$= A(1 + i) + A(1 + i)i$

$= A(1 + i)^2$

Amount at the end of nth year = $A(1 + i)^{n-1}$

Total amount accumulated in n years (say x)

= sum of the amounts accumulated in n years

i.e., $x = A + A(1 + i) + A(1 + i)^2 + \ldots\ldots + A(1 + i)^{n-1}$

$= A[1 + (1 + i) + (1 + i)^2 + \ldots\ldots + (1 + i)^{n-1}]$ ...(1)

Multiplying the above equation by $(1 + i)$, we get

$x(1 + i) = A[(1 + i) + (1 + i)^2 + (1 + i)^3 + \ldots\ldots + (1 + i)^n]$ ...(2)

Subtracting equation (1) from (2), we get

$x.i = [(1 + i)^n - 1]A$

$x = [\{(1 + i)^n - 1\}/i]A$, where $x = (P - S)$

$P - S = [\{(1 + i)^n - 1\}/i]A$

$A = (P - S)[i/\{(1 + i)^n - 1\}]A$

Unit Method. In this method some factor is taken as a standard one and, depreciation is measured by that standard. In place of years equipment will last, the number of hours that equipment will last is calculated. This total number of hours is then divided by the capital value of the equipment. This constant is then multiplied by the number of actual working hours each year to get the value of depreciation for that year. In place of number of hours, the number of units of production is taken as the measuring standard.

Power plant Engineering, HIT ,Nidasoshi

Operational Costs

The elements that make up the operating expenditure of a power plant include the following

(1) Cost of fuels.

(2) Labour cost.

(3) Cost of maintenance and repairs.

(4) Cost of stores (other than fuel).

(5) Supervision.

(6) Taxes.

Cost of Fuels

In a thermal station fuel is the heaviest item of operating cost. The selection of the fuel and the maximum economy in its use are, therefore, very important considerations in thermal plant design. It is desirable to achieve the highest thermal efficiency for the plant so that fuel charges are reduced. The cost of fuel includes not only its price at the site of purchase but its transportation and handling costs also. In the hydro plants the absence of fuel factor in cost is responsible for lowering the operating cost. Plant heat rate can be improved by the use of better quality of fuel or by employing better thermodynamic conditions in the plant design.

The cost of fuel varies with the following:

(1) Unit price of the fuel.

(2) Amount of energy produced.

(3) Efficiency of the plant.

Labor Cost

For plant operation labour cost is another item of operating cost. Maximum labour is needed in a thermal power plant using. Coal as a fuel. A hydraulic power plant or a diesel power plant of equal capacity requires a lesser number of persons. In case of automatic power station the cost of labour is reduced to a great extent. However labour cost cannot be completely eliminated even with fully automatic station, as they will still require some manpower for periodic inspection etc.

Cost Of Maintenance And Repairs

In order to avoid plant breakdowns maintenance is necessary. Maintenance includes periodic cleaning, greasing, adjustments and overhauling of equipment. The material used for maintenance is also charged under this head. Sometimes an arbitrary percentage is assumed as maintenance cost. A good plan of maintenance would keep the sets in dependable condition and avoid the necessity of too many stand-by plants. Repairs are necessitated when the plant breaks down or stops due to faults developing in the mechanism. The repairs may be minor, major or periodic overhauls and are charged to the depreciation fund of the equipment. This item of cost is higher for thermal plants than for hydro-plants due to complex nature of principal equipment and auxiliaries in the former.

Powerplant Engineering, HIT Nidasoshi

Cost Of Stores

The items of consumable stores other than fuel include such articles as lubricating oil and greases,
cotton waste, small tools, chemicals, paints and such other things. The incidence of this cost is also higher in thermal stations than in hydro-electric power stations.

Supervision

In this head the salary of supervising staff is included. A good supervision is reflected in lesser breakdowns and extended plant life. The supervising staff includes the station superintendent, chief engineer, chemist, engineers, supervisors, stores incharges, purchase officer and other establishment. Again, thermal stations, particularly coal fed, have a greater incidence of this cost than the hydro-electric power stations.

Taxes

The tax under operating head includes the following:
(*i*) Income tax
(*ii*) Sales tax
(*iii*) Social security and employee's security etc.

Effect Of Plant Type On Rates (Tariffs Or Energy Element)

Rates are the different methods of charging the consumers for the consumption of electricity. It is desirable to charge the consumer according to his maximum demand (kW) and the energy consumed (kWh). The tariff chosen should recover the fixed cost, operating cost and profit etc. incurred in generating the electrical energy.

Requirements Of A Tariff

Tariff should satisfy the following requirements:
(1) It should be easier to understand.
(2) It should provide low rates for high consumption.
(3) It should encourage the consumers having high load factors.
(4) It should take into account maximum demand charges and energy charges.
(5) It should provide less charge for power connections than for lighting.
(6) It should avoid the complication of separate wiring and metering connections.

Power plant Engineering, HIT, Nidasoshi

Types Of Tariffs

The various types of tariffs are as follows,

(1) Flat demand rate

(2) Straight line meter rate

(3) Step meter rate

(4) Block rate tariff

(5) Two part tariff

(6) Three part tariff.

The various types of tariffs can be derived from the following general equation:

$Y = DX + EZ + C$

where

Y = Total amount of bill for the period considered.

D = Rate per kW of maximum demand.

X = Maximum demand in kW.

E = Energy rate per kW.

Z = Energy consumed in kWh during the given period.

C = Constant amount to be charged from the consumer during each billing period.

Various type of tariffs are as follows:

(1) Flat Demand Rate. It is based on the number of lamps installed and a fixed number of hours of use per month or per year. The rate is expressed as a certain price per lamp or per unit of demand (kW) of the consumer. This energy rate eliminates the use of metering equipment. It is expressed by the expression.

(2) Straight Line Meter Rate. According to this energy rate the amount to be charged from the consumer depends upon the energy consumed in kWh which is recorded by a means of a kilowatt hour meter. It is expressed in the form

$Y = EZ$

This rate suffers from a drawback that a consumer using no energy will not pay any amount although he has incurred some expense to the power station due to its readiness to serve him. Secondly since the rate per kWh is fixed, this tariff does not encourage the consumer to use more power.

(3) Step Meter Rate. According to this tariff the charge for energy consumption goes down as the energy consumption becomes more. This tariff is expressed as follows.

$Y = EZ$ If $0 \leq Z \leq A$

$Y = E1Z1$ If $A \leq Z1 \leq B$

$Y = E2Z2$ If $B \leq Z2 \leq C$

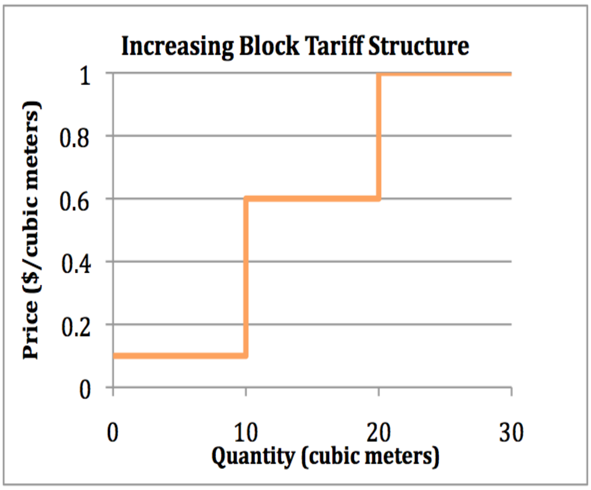
And so on. Where E, E1, E2 are the energy rate per kWh and A, B and C, are the limits of energy consumption.

(4) Block Rate Tariff. According to this tariff a certain price per units (kWh) is charged for all or any part of block of each unit and for succeeding blocks of energy the corresponding unit charges decrease.

Powerplant Engineering, HIT ,Nidasoshi

It is expressed by the expression

Y = E1Z1 + E2Z2 + E3Z3 + E4Z4 +.....



(5) Two Part Tariff (Hopkinson Demand Rate). In this tariff the total charges are based on the maximum demand and energy consumed. It is expressed as

Y = D . X + EZ

A separate meter is required to record the maximum demand. This tariff is used for industrial loads.

(6) Three-Part Tariff (Doherty Rate). According to this tariff the customer pays some fixed amount in addition to the charges for maximum demand and energy consumed. The fixed amount to be charged depends upon the occasional increase in fuel price, rise in wages of labour etc. It is expressed by the expression

Y = DX + EZ + C.

Effect Of Plant Type On Fixed Elements

Various types of fixed element are:

(1) Land

(2) Building

(3) Equipment

(4) Installation of Machine

(5) Design and planning

The fixed element means which are not movable, and for any types of power plant, the fixed elements play a major role. Since each cost is added to the final cost of our product (electricity in case of Power plant). So when a power plant is established, the first selection is fixed element. Effect of plant on land is as cost of land.

Effect Of Plant Type On Customer Elements

The costs included in these charges depend upon the number of customers. The various costs to be considered are as follows:

(1) Capital cost of secondary distribution system and depreciation cost, taxes and interest on this capital cost.

Powerplant Engineering, HIT ,Nidasoshi

(2) Cost of inspection and maintenance of distribution lines and the transformers.
(3) Cost of labour required for meter reading and office work.
(4) Cost of publicity.

Investor's Profit

If the power plant is the public property, as is the case in India, then the customers will be the taxpayers to share the burden of the government. For this purpose, there is an item in the rates to cover taxes in place of the investor's profit. The consumers in the form of electric consumption bills will pay these taxes. This amount is collected in twelve installments per year or six installments per year. The investor expects a satisfactory return on the capital investment. The rate of profit varies according to the business conditions prevailing in different localities.

Adopting the following economical measures can reduce cost of power generation:
(1) By reducing initial investment in the power plant.
(2) By selecting generating units of adequate capacity.
(3) By running the power plant at maximum possible load factor.
(4) By increasing efficiency of fuel burning devices so that cost of fuel used is reduced.
(5) By simplifying the operation of the power plant so that fewer power-operating men are required.
(6) By installing the power plant as near the load centre as possible.
(7) By reducing transmission and distribution losses.

Powerplant Engineering, HIT ,Nidasoshi