LECTURE NOTES ON

POWER PLANT ENGINEERING

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UNIT-1

STEAM POWER PLANT

Introduction:

Power Plant Engineering is a science, which deals with the complete study of different types of power plant.

Sources are divided into two types

1. Conventional sources (Non-Renewable Sources)-these are consumable sources.

   Ex: Coal, Diesel, Nuclear activity materials etc.

2. Non-conventional sources (Renewable Sources) -these are non-consumable sources

   Ex: Solar, Wind, Tidal, Water etc.

In India, the following sources are used to generate the power.

1. Water energy – It is used in Hydro-Electric Power Plant
2. Coal- It is used in Steam Plant
3. Diesel- It is used in I.C Engine plant
4. Nuclear activity materials- It is used in Nuclear Power Plant
5. Non-conventional sources- These are used in Solar, Wind & tidal power plant.

RESOURCES OF POWER IN INDIA:

The hydel power source plays a vital role in the generation of power, as it is a non-conventional perennial source of energy. Therefore the French cals it “huile Blanche”— white oil-the power of flowing water. Unlike black oil, it is a non-conventional energy source. A part of the endless cycle in which moisture is raised by the sun, formed into clouds and then dropped back to earth to feed the rivers whose flow can be harnessed to produce hydroelectric power. Water as a source of power is non-polluting which a prime requirement of power industry today is.

The world’s total waterpower potential is estimated as 1500 million kW at mean flow. This means that the energy generated at a load factor of 50% would be 6.5 million kW-hr, a quantity equivalent to 3750 million tonnes of coal at 20% efficiency. The world hydel installed capacity (as per 1963 estimate is only 65 million kW or 4.3% of the mean f l o w .

India has colossal waterpower resources. India's total mean annual river flows are about 1675 thousand million cubic meters of which the usable resources are 555 thousand million cubic meters. Out of total river flows, 60% contribution comes from Himalayan Rivers (Ganga, Indus and Brahmaputra). 16% from central Indian rivers (Narmada, Tapti and Mahanadi) and the remaining from the rivers draining the Deccan plateau (Godavari, Krishna and Cauvery). India's power potential from hydel source as per the recent estimate is 41500 mW while its present hydel capacity is only 32000 mW. Still India has got enough hydel potential to develop to meet the increasing power needs of the nation. The abundant availability of water resources, its fairly even distribution and overall economy in developing this source of energy enhanced its development in India, The other factors responsible in its rapid development are indigenous technological skill, material and cheap labor. In the IX five-year plan; the Government considering the importance of this source has included a number of hydro-projects. The major difficulty in the development of hydroelectric projects is the relatively longer time required for its hydrological, topographical and geological investigations. Lack of suitable. Site is an added problem for taking up hydro-projects.

Hydropower was once the dominant source of electrical energy in the world and still is in Canada, Norway and Switzerland. But its use has decreased in other countries since 1950s, as relatively less expensive fuel was easily available. In USA, only 10% of the total power production is water-generated. In the light of fuel scarcity and its up surging prices, the role of hydropower is again re-examined and more emphasis is being laid on waterpower development. As per Mr. Hays (Manager of Hydro Projects in USA), "It was less costly per mW to build a single 1000 mW thermal plant than 20 small hydro plants. But, with the increased fuel cost and high cost of meeting environmental criteria for new thermal plants, interest in hydro is being revived". Sma l hydro-projects ranging from 10 to 1500 kW are becoming more feasible as standardization of major equipment reduces costs. India is yet to start in the field of micro-hydro projects, which is one major way for solving the present power problem.

Hydro-projects generate power at low cost, it is non conventional, easy to manage, pollution free and makes no crippling demands on the transportation system. But the major drawback is, it operates at the mercy of nature. Poor rainfall has on a number of occasions shown the dangers of over dependence on hydropower. Let rivers flow and let rains shower the earth with prosperity is the ancient prayer chanted by Riches and continued to be chanted even now.

The development of hydropower systems as a backup for thermal systems has significant advantages:

- The flexible operation of hydraulic turbines makes them suitable for. Peak load operation. Therefore, the development of hydropower is not only economical but it also solves the major problem of peak load.

- The present Indian policy of power development gives sufficient importance for the hydel-power development.
- The next important source for power generation is fuel in the form of coal, oil or gas. Unfortunately, the oil and gas resources are very much limited in India. Only few power plants use oil or gas as a source of energy. India has to import most of the oil required and so it is not desirable to use it for power generation.
- The known resources of coal in India are estimated to be 121,000 million tonnes, which are localized in West Bengal, Bihar, Madhya Pradesh and Andhra Pradesh. The present rate of annual production of coal is nearly 140 million tonnes of which 40 million-tonnes are used for power generation.
- The coal used for power generation is mainly low-grade c o a l with high ash content (20-40%).
- The high ash content of Indian coal (40–50%) is one of the causes for bad performance of the existing steam power plants and their frequency outages, as these plants have been designed for low ash coals. Due to the large resources of coal available in the country, enough emphasis has been given for thermal Power plants in the IX plan period.
- The location of hydel-power plants is mostly determined by the natural topography available and location of thermal plants is dictated by the source of fuel or transportation facilities available if the, power plant is to be located far from coalmines.
- For nuclear power plant any site can be selected paying due consideration to safety and load. India has to consider nuclear generation in places remote from coal mines and water power sites.
- The states which are poor in natural resources and those which have little untapped conventional resources for future development have to consider the development of nuclear plants.
- The nuclear fuel which is commonly used for nuclear power plants is uranium. Deposits of uranium have been located in Bihar and Rajasthan. It is estimated that the present reserves of uranium available in country may be sufficient to sustain 10,000 mW power plants for its thorium into nuclear Indian lifetime. Another possible nuclear power source is thorium, which is abundant in this country, estimated at 500,000 tonnes.
- But the commercial use of this nuclear fuel is tied up with development of fast breeder reactor which converts energy economy must wait for the development of economic methods for using thorium which is expected to be available before the end of twentieth century.
- The major hurdle in the development of nuclear power in this country is lack of technical facility and foreign exchange required to purchase the main component of nuclear power plant. Dr. Bhabha had envisaged 8000 mW of power from nuclear reactors by 1980–81 which was subsequently scaled down to a more realistic level of 2700 mW by Dr. Sarabhai out of this only 1040MW has materialized which is less than 1.5% of the country’s insta l ed power capacity. Moreover the performance of nuclear plants has been satisfactory compared to thermal plants.

DEVELOPMENT OF POWER IN INDIA:

- The history of power development in India dates back to 1897 when a 200 kW hydro-station was first commissioned at Darjeeling. The first steam station was set up in Calcutta in 1899. By the end of 1920, the total capacity was 130 mW, comprising. Hydro 74 mW, thermal 50 mW and diesel 6 mW. In 1940, the total capacity goes to 1208 mW. There was very slow development during 1935-1945 due to Second World War. The total generation capacity was 1710 mW by the end of 1951. The development really started only after 1951 with the launching of the first five-year plan.

- During the First Plan, construction of a number of Major River Valley Projects like Bhakra-Nangal, Damodar Valley, Hira Kund and Chambal Valley was taken up. These projects resulted in the stepping up of power generation. At the end of the First Plan, generation capacity stood at 34.2 lakh kW.

- Emphasis in Second Plan (1956-61) was on development of basic and heavy industries and related need to step up power generation. Installed capacity at the end of Second Plan reached 57 lakh kW. Comprising 3800 mW thermal and 1900 MW hydel.

- During the Third Plan period (1961-66), emphasis was on extending power supply to rural areas. A significant development in this phase was emergence of Inter-state Grid System. The country was divided into Five Regions to promote power development on a Regional Basis. Regional Electricity Board was established in each region to promote integrated operation of constituent power system.

- Three Annual Plans that followed Third Plan aimed at consolidating programmes initiated during the Third Plan.

- Fourth Plan envisaged need for central participation in expansion of power generation programmes at strategic locations to supplement activities in the State Sector. Progress during the period covering

- Third Plan, three Annual Plans and Fourth Plan was substantial with installed capacity rising to 313.07 lakh kW compression; 113.86 lakh kW from Hydro-electric Projects, lakh kW from Thermal Power Projects and balance of 6.4 lakh kW from Nuclear Projects at the end of the Fifth Plan.

- During the Sixth Plan, total capacity addition of 196.66 lakh kW comprising Hydro 47.68 lakh kW, Thermal 142.08 lakh kW and Nuclear 6.90 lakh kW was planned. Achievement, however, has been 142.26 lakh kW (28.73 lakh kW Hydro, 108.98 lakh kW Thermal and 4.55 lakh kW Nuclear) 72.3 percent of thetarget.

- The Seventh Plan power programme envisaged aggregate generating capacity of 22,245 mW in utilities. This comprised 15,999 mW Thermal, 5,541 mW Hydro and 705 mW Nuclear of the anticipated 22,245 mW additional capacity. Central Sector Programme envisaged capacity addition of 9,320 mW (7,950 mW Thermal, 665 mW Hydro and 705 mW Nuclear) during the Plan Period. During the Seventh Plan, 21401.48 mW has been added comprising 17104.1 mW Thermal 3,827.38 mW Hydro and 470 mW Nuclear. Year wise commissioning of Hydro, Thermal and Nuclear Capacity added during 1985-86 to 1989-90 is given in.

- The Working Group on Power set up particularly the Planning Commission in the context of formulation of power programme for the Eighth Plan has recommended a capacity addition programme of 38,369 mW for the Eighth Plan period, out of which it is expected that the Central Sector Projects would add a capacity of 17,402 mW. The programme for the first year of the Eighth Plan (1990-91) envisages generation of additional capacity of 4,371.5 mW comprising 1,022 mW Hydro, 3,114.5 mW Thermal and 235 mW Nuclear.

- The subject 'Power' appears in the Concurrent List of the Constitution and as such responsibility of its development lies both with Central and state governments. At the Centre, Department of Power under the Ministry of Energy is responsible for development of Electric Energy. The department is concerned with policy formulation, perspective planning, procuring of projects for investment decisions, monitoring of projects, training and manpower development, administration and enactment of Legislation in regard to power generation, transmission and distribution. The department is also responsible for administration of the Electricity (Supply) Act, 1948 and the Indian Electricity Act, 191() and undertakes all amendments thereto. The Electricity (Supply) Act, 1948, forms basis of administrative structure of electricity industry. The Act provides for setting up of a Central Electricity Authority (CEA) with responsibility, inter-alia, to develop a National Power Policy and coordinate activities of various agencies and State Electricity Boards. The act was amended in 1976 to enlarge scope and function of CEA and enable of creation of companies for generation of electricity.

- The Central Electricity Authority advises Department of Power on technical, financial and economic matters. Construction and operation of generation and transmission projects in the Central Sector are entrusted to Central Power Corporations, namely, National Thermal Power Corporation (NTPC), National Hydro-Electric Power Corporation (NHPC) and North-Eastern Electric Power Corporation (NEEPCU) under administrative control of the Department of Power. The Damodar Valley Corporation (DVC) constituted under the DVC Act, 1948 and the Bhitkra Beas, Management Board (BBMB) constituted under the Punjab Reorganization. Act, 1966, is also under administrative control of the Department of Power. In addition, the department administers Beas Construction Board (BCB) and National Projects Construction Corporation (NPCC), which are construction agencies and training and research organisations, Central Power Research Institute (CPRI) and Power Engineers Training Society (PETS). Programmes of rural electrification are within the purview of Rural Electrification Corporation (REC) which is a financing agency. ''There are two joint venture Power Corporations under the administrative control of the Department of Power, namely, Nathpa jhakri Power Corporation and Tehri Hydro Development Corporation which are responsible for the execution of the Nathpa Jhakri

- Power Project and Projects of the Tehri Hydro Power Complex respectively. In addition to this, Energy Management Centre, an autonomous body, was established in collaboration with the European Economic Community, which is responsible for training, research, and information exchange between energy professionals. It is also responsible for conservation of energy programmes/activities in the Department of Power. Significant progress has been made in the expansion of transmission and distribution facilities in the Country. Total length of transmission lines of 66 kV and above increased from 10,000 ckt (circuit) km in December 1950 to 2.02 lakh ckt Km in March, 1990.

- Highest transmission voltage in the Country at present is 400 kV and above 19800 ckt km of 400 kV lines had been constructed up to March, 1990 and about 18000 ckt km of these are in actual operation. Prior to the Fourth Plan, Transmission Systems in the Country were developed more or less as state systems, as generating stations were built primarily in the State Sector. When State Transmission Systems had developed to a reasonable extent in the Third Plan, potentiality of inter-connected operation of individual state systems with other neighboring systems within the region (northern, western, southern, eastern and north-eastern) was thought of. Fairly well inter-connected systems at voltage of 220 kV with progressive overlay of 400 kV are presently available in all regions of the Country except North-eastern Region. With creation of Two Generation Corporations, namely National Thermal Power Corporation and National Hydro-Electric Power Corporation in 1975, the Centre had started playing an increasingly larger role in the development of grid systems.

- The 400 kV transmission systems being constructed by these organizations as part of their generation projects, along with 400 kV inter-state and inter-regional transmission lines would form part of the National Power Grid. National Power Grid will promote integrated operation and transfer of power from one system to another with ultimate objective of ensuring optimum utilization of resources in the Country. India now has well integrated Regional Power Systems and exchange of power is taking place regularly between a large numbers of state systems, which greatly facilitates better utilization of existing capacity.

A **power plant** may be defined as a machine or assembly of equipment that generates and delivers a flow of mechanical or electrical energy. The main equipment for the generation of electric power is generator. When coupling it to a prime mover runs the generator, the electricity is generated. The type of prime move determines the type of power plants. The major power plants are,

1. Steam power plant
2. Diesel power plant
3. Gas turbine power plant
4. Nuclear power plant
5. Hydro electric power plant

The Steam Power Plant, Diesel Power Plant, Gas Turbine Power Plant and Nuclear Power Plants are called **THERMAL POWER PLANT,** because these convert heat into electric energy.

Steam is the most common working fluid used in steam/Thermal power plant because of its many desirable characteristics, such as low cost, availability and high enthalpy of vaporization.

Classification of steam power plants:

The steam power plants may be classified as follows:

1. Central stations
2. Industrial power stations or captive power stations

STEAM POWER PLANT LAYOUT:

A steam power plant must have following equipments:

1. A furnace to burn the fuel.
2. Steam generator or boiler containing water. Heat generated in the furnace is utilized to convert water in steam.
3. Main power unit such as an engine or turbine to use the heat energy of steam and perform work.
4. Piping system to convey steam and water.

- ❖ In addition to the above equipment the plant requires various auxiliaries and accessories depending upon the availability of water, fuel and the service for which the plant is intended.

- ❖ A steam power plant using steam as working substance works basically on Rankine cycle. Steam is generated in a boiler, expanded in the prime mover and condensed in the condenser and fed into the boiler again.

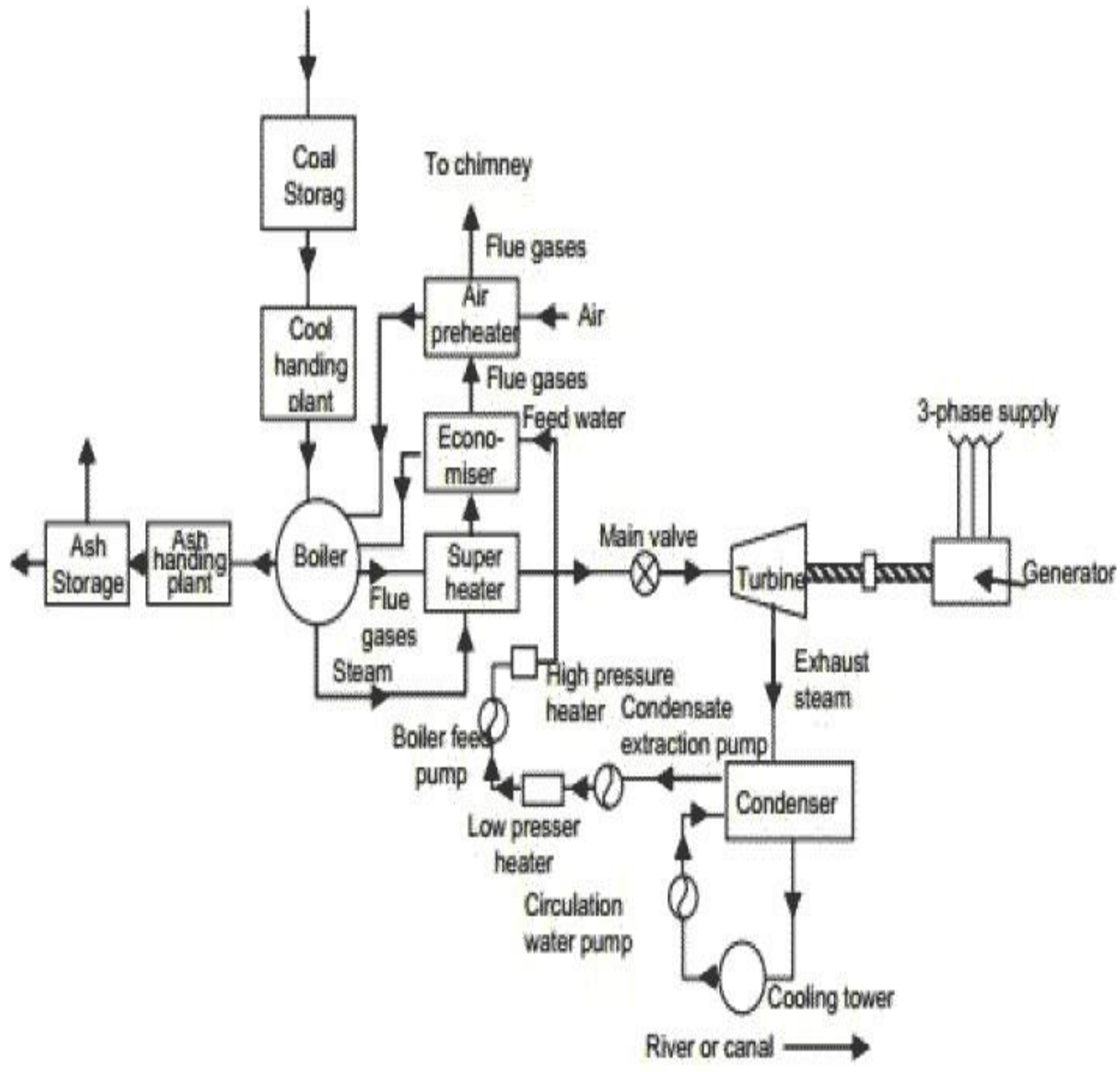

Fig-1.1- layout of steam power plant

❖ Layout of thermal plant can be easily understood by dividing the plant components into four circuits.

- Coal and ash circuit.
- Air and gas circuit.
- Feed water and steam circuit.
- Cooling water circuit

Coal and Ash Circuit:

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

Air and Gas Circuit:

Air from the atmosphere is directed into the furnace through the air preheated by the action of a forced draught fan or induced draught fan. The dust from the air is removed before it enters the combustion chamber of the thermal power plant layout. The exhaust gases from the combustion heat the air, which goes through a heat exchanger and is finally let off into the environment.

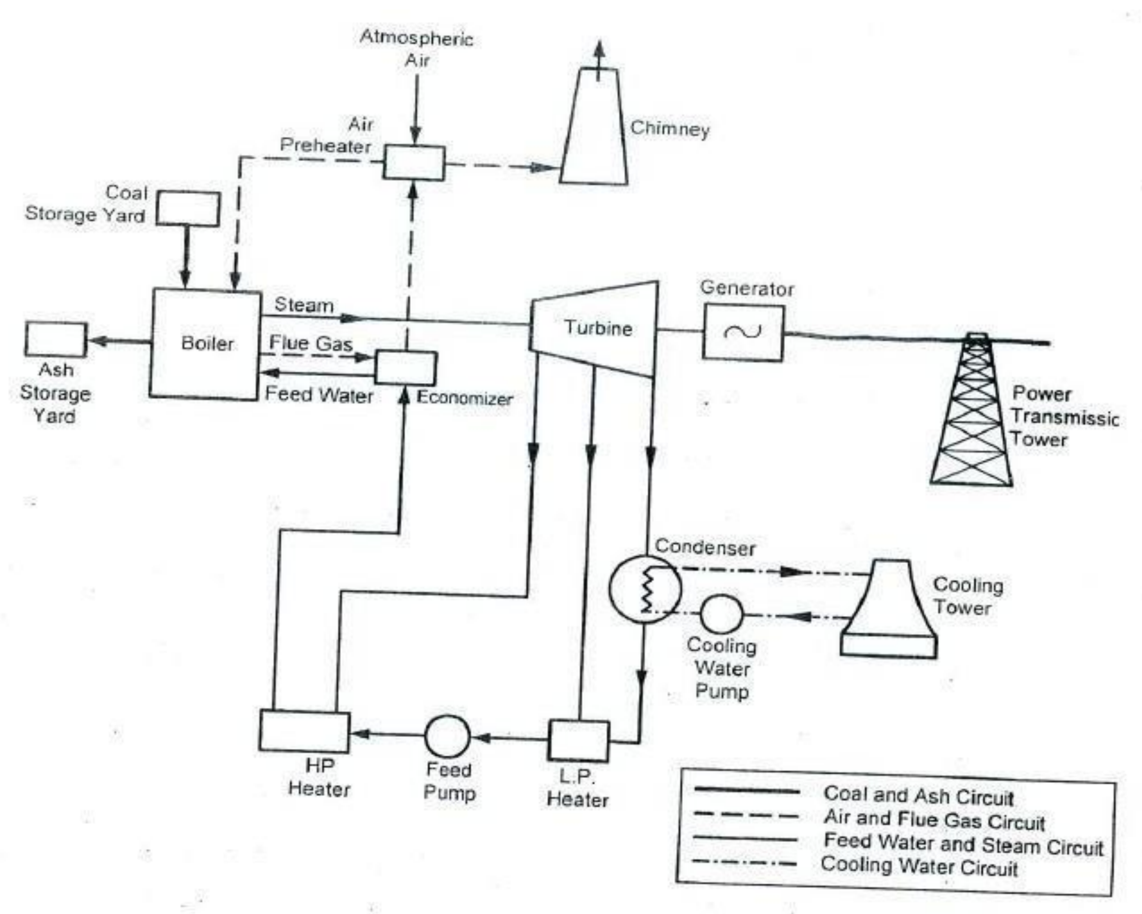

Fig-1.2-Layout of different circuits

Feed Water and Steam Circuit:

The steam produced in the boiler is supplied to the turbines to generate power. The steam that is expelled by the prime mover in the thermal power plant layout is then condensed in a condenser for re-use in the boiler. The condensed water is forced through a pump into the feed water heaters where it is heated using the steam from different points in the turbine. To make up for the lost steam and water while passing through the various components of the thermal power plant layout, feed water is supplied through external sources. Feed water is purified in a purifying plant to reduce the dissolve salts that could scale the boiler tubes.

Cooling Water Circuit:

The quantity of cooling water required to cool the steam in a thermal power plant layout is significantly high and hence it is supplied from a natural water source like a lake or a river. After passing through screens that remove particles that can plug the condenser tubes in a thermal power plant layout, it is passed through the condenser where the steam is condensed. The water is finally discharged back into the water source after cooling. Cooling water circuit can also be a closed system where the cooled water is sent through cooling towers for re-use in the power plant. The cooling water circulation in the condenser of a thermal power plant layout helps in maintaining a low pressure in the condenser allthroughout.

The different types of systems and components used in steam power plant are as follows:

(i) High pressure boiler
(ii) Prime mover
(iii) Condensers and cooling towers
(iv) Coal handling system
(v) Ash and dust handling system
(vi) Draught system
(vii) Feed water purification plant
(viii) Pumping system
(ix) Air preheater, economizer, super heater, feed heaters.

Fig-1 shows a schematic arrangement of equipment of a steam power station. Coal received in coal storage yard of power station is transferred in the furnace by coal handling unit. Heat produced due to burning of coal is utilized in converting water contained in boiler drum into steam at suitable pressure and temperature. The steam generated is passed through the super heater.

Superheated steam then flows through the turbine. After doing work in the turbine die pressure of steam is reduced. Steam leaving the turbine passes through the condenser which maintains the low pressure of steam at the exhaust of turbine.

Steam pressure in the condenser depends upon flow rate and temperature of cooling water and on effectiveness of air removal equipment. Water circulating through the condenser may be taken from the various sources such as river, lake or sea. If sufficient quantity of water is not available the hot water coming out of the condenser may be cooled in cooling towers and circulated again through the condenser.

Bled steam taken from the turbine at suitable extraction points is sent to low pressure and high pressure water heaters.

Air taken from the atmosphere is first passed through the air pre-heater, where it is heated by flue gases. The hot air then passes through the furnace.

The flue gases after passing over boiler and super heater tubes, flow through the dust collector and then through economizer, air pre-heater and finally they are exhausted to the atmosphere through the chimney.

ADVANTAGES:

1. They can be located very conveniently near the load centers.
2. Does not require shielding like required in nuclear power plants.
3. Unlike nuclear power plants whose power production method is difficult, for thermal power plants it is easy if compared.
4. Transmission costs are reduced as they can be set up near the industry.
5. The portion of steam generated can be used as process steam in different industries.
6. Steam engines and turbines can work under 25% of overload capacity.

DISADVANTAGES:

1. Large amounts of water are required.
2. Great difficulties experienced in coal handling and disposal of ash.
3. Takes long time to be erected and put into action.
4. Maintenance and operating costs are high.
5. With increase in pressure and temperature, the cost of plant increases.
6. Troubles from smoke and heat from the plant.

TYPES OF COALS:

- Peat
- Lignite
- Sub-Bituminous coal
- Bituminous coal
- Anthracite coal

Peat Starting stage of coal formation and is not useful in power plants.

Lignite is the youngest form of coal. It is soft and ranges in color from black to shades of brown. As a result, it's sometimes caled brown coal. Lignite is mainly used for power generation and accounts for 17 percent of the world's coal reserves.

Sub-bituminous coal: After millions of years, continued pressure and temperature convert lignite into sub-bituminous coal. It burns more cleanly than other types of coal due to its low sulfur content. Sub-bituminous coal has applications in power generation and also in industrial processes. This type of coal makes up 30 percent of the world's coal reserves.

Bituminous coal is harder and blacker than lignite and sub-bituminous coal, and can be divided into two types: thermal and metal urgical. Together, they make up 52 percent of the world's coal reserves. Thermal coal is mostly used for power generation, cement manufacturing and other industrial purposes, while metallurgical coal is used primarily for manufacturing iron and steel.

Anthracite is the most mature coal and thus has the highest carbon content of any type of coal. It is frequently used for home heating and, accounting for about 1 percent of the world's total coal reserves, represents a very small portion of the overall market. Anthracite coal can be used as a smokeless fuel in domestic and industrial contexts.

FUEL AND HANDLING EQUIPMENTS:

The various stages are involved in the fuel handling system from coal delivery to furnace in the steam plant

1. Coal delivery
2. Unloading
3. Preparation
4. Transfer
5. Storage
6. In plant handling
7. Weighing
8. Feeding the coal into Furnace.

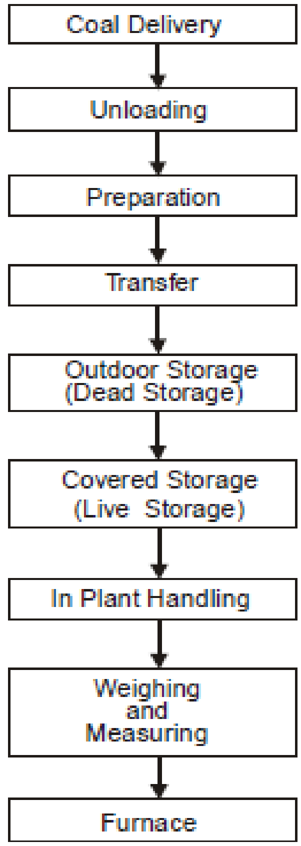

Fig-1.3-steps in coal handling

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

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

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

(iv) **Transfer.** After preparation coal is transferred to the dead storage by means of the following systems :

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

1.Belt conveyor.

Fig.1.4 shows a belt conveyor. It consists of an endless belt. Moving over a pair of end drums (rollers). At some distance a supporting roller is provided at the center. The belt is made, up of rubber or canvas. Belt conveyor is suitable for the transfer of coal over long distances. It is used in medium and large power plants. The initial cost of the system is not high and power consumption is also low. The inclination at which coal can be successfully elevated by belt conveyor is about 20. Average speed of belt conveyors varies between 200-300 r.p.m. This conveyor is preferred than other types.

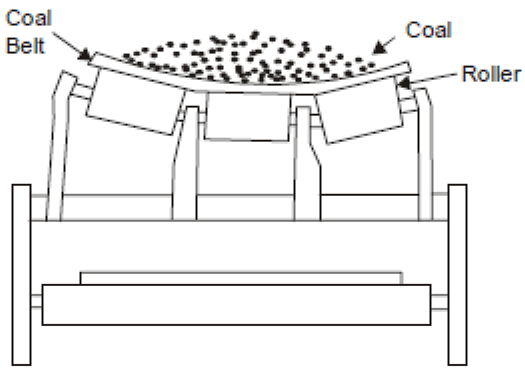

Fig-1.4-Belt Conveyor

Advantages of belt conveyor:

1. Its operation is smooth and clean.
2. It requires less power as compared to other types of systems.
3. Large quantities of coal can be discharged quickly and continuously.
4. Material can be transported on moderates inclines.

2. Screw conveyor:

It consists of an endless helicoids screw fitted to a shaft (Fig.1.5).The screw while rotating in a trough transfers the coal from feeding end to the discharge end. This system is suitable, where coal is to be transferred over shorter distance and space limitations exist. The initial cost of the system is low. It suffers from the drawbacks that the power consumption is high and there is considerable wear of screw. Rotation of screw varies between 75-125 r.p.m.

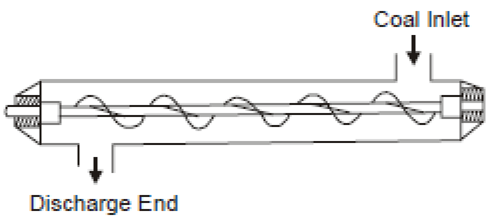

Fig-1.5-Screw conveyor

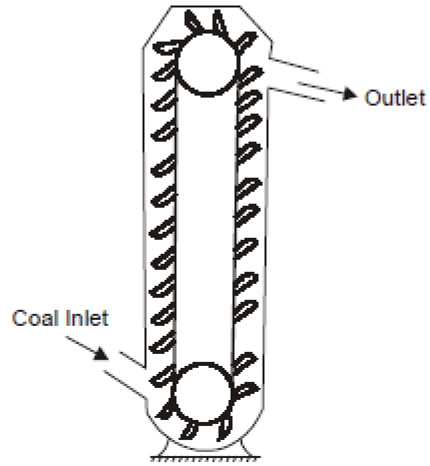

Fig-1.6- bucket conveyor

3. **Bucket elevator.** It consists of buckets fixed to a chain (Fig.1.6). The chain moves over two wheels. The coal is carried by the buckets from bottom and discharged at the top.

4. **Grab bucket elevator.** It lifts and transfers coal on a single rail or track from one point to the other. The coal lifted by grab buckets is transferred to overhead bunker or storage. This system requires less power for operation and requires minimum maintenance. The grab bucket conveyor can be used with crane or tower as shown in Fig.7. Although the initial cost of this system is high but operating cost is less.

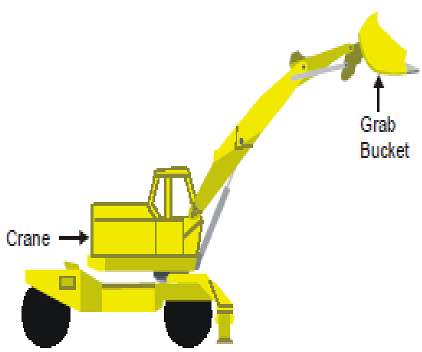

Fig-1.7- Grab bucket elevator

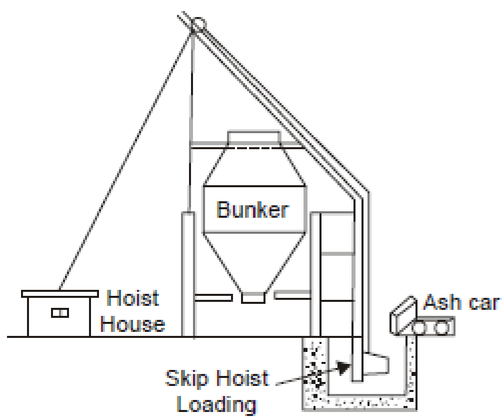

Fig-1.8-Skip Hoist

5. **Skip hoist.** It consists of a vertical or inclined hoist way a bucket or a car guided by a frame and a cable for hoisting the bucket. The bucket is held in upright position. It is simple and compact method of elevating coal or ash. Fig.1.8 shows a skip hoist.

6. **Flight conveyor.** It consists of one or two strands of chain to which steel scraper or flights are attached' which scrap the coal through a trough having identical shape. This

coal is discharged in the bottom of trough. It is low in first cost but has large energy consumption. There is considerable wear.

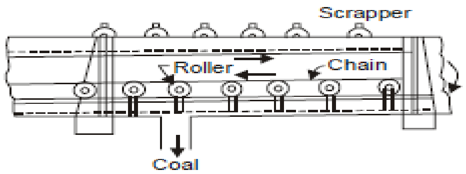

Fig-1.9-Flight Conveyor

Skip hoist and bucket elevators lift the coal vertically while Belts and flight conveyors move the coal horizontally or on inclines. Fig.9 shows a flight conveyor.

Flight conveyors possess the following **advantages.**

(i) They can be used to transfer coal as well as ash.

(ii) The speed of conveyor can be regulated easily.

(iii) They have a rugged construction.

(iv) They need little operational care.

Disadvantages.

Various disadvantages of flight conveyors are as follows:

(i) There is more wear due to dragging action.

(ii) Power consumption is more.

(iii) Maintenance cost is high.

(iv) Due to abrasive nature of material handled the speed of conveyors is low (10 to 30 m/min).

Storage of coal. It is desirable that sufficient quantity of coal should be stored. Storage of coal gives protection against the interruption of coal supplies when there is delay in transportation of coal or due to strikes in coal mines. Also when the prices are low, the coal can be purchased and stored for future use. The amount of coal to be stored depends on the availability of space for storage, transportation

facilities, the amount of coal that will whether away and nearness to coal mines of the power station. Usually coal required for one month operation of power plant is stored in case of power stations situated at longer distance from the collieries whereas coal need for about 15 days is stored in case of power station situated near to collieries. Storage of coal for longer periods is not advantageous because it blocks the capital and results in deterioration of the quality of coal.

The coal received at the power station is stored in dead storage in the form of piles laid directly on the ground. The coal stored has the tendency to whether (to combine with oxygen of air) and during this process coal loss some of its heating value and ignition quality. Due to low oxidation the coal may ignite spontaneously. This is avoided by storing coal in the form of piles which consist of thick and compact layers of coal so that air cannot pass through the coal piles. This will minimize the reaction between coal and oxygen. The other alternative is to allow the air to pass through layers of coal so that air may remove the heat of reaction and avoid burning. In case the coal is to be stored for longer periods the outer surface of piles may be sealed with asphalt or fine coal.

COAL STORAGE:

The coal is stored by the following methods:

(i) *Stocking the coal in heaps*. The coal is piled on the ground up to 10-12 m height. The pile top should be given a slope in the direction in which the rain may be drained off. The sealing of stored pile is desirable in order to avoid the oxidation of coal after packing an air tight layer of coal. Asphalt, fine coal dust and bituminous coating are the materials commonly used for this purpose.

(ii) *Under water storage*. The possibility of slow oxidation and spontaneous combustion can be completely eliminated by storing the coal under water. Coal should be stored at a site located on solid ground, well drained, free of standing water preferably on high ground not subjected to flooding.

(v) **In plant handling** From the dead storage the coal is brought to covered storage (Live storage) (bins or bunkers). A cylindrical bunker shown in Fig.1.10. In plant handling may include the equipment such as belt conveyors, screw conveyors, bucket elevators etc. to transfer the coal. Weigh Lorries hoppers and automatic scales are used to record the quantity of coal delivered to the furnace.

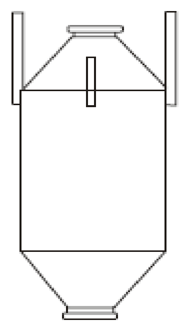

Fig-1.10-Cylindrica l Bunker

(vi) **Coal weighing methods**. Weigh Lorries, hoppers and automatic scales are used to weigh the quantity coal. The commonly used methods to weigh the coal are as follows:

(i) Mechanical (*ii*) Pneumatic (*iii*) Electronic.

The Mechanical method works on a suitable lever system mounted on knife edges and bearings connected to a resistance in the form of a spring of pendulum. The pneumatic weighters use a pneumatic transmitter weight head and the corresponding air pressure determined by the load applied. The electronic weighing machines make use of load cells that produce voltage signals proportional to the load applied.

The important factors considered in selecting fuel handling systems are as follows:

(i) Plant flue rate
(ii) Plant location in respect to fuel shipping
(iii) Storage area available.

ASH HANDLING SYSTEMS:

A large quantity of ash is, produced in steam power plants using coal. Ash produced in about 10 to 20% of the total coal burnt in the furnace. 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 gases.

It is desirable to quench the ash before handling due to following reasons:

1. Quenching reduces the temperature of ash.
2. It reduces the corrosive action of ash.
3. Ash forms clinkers by fusing in large lumps and by quenching Clinkers will disintegrate.
4. Quenching reduces the dust accompanying the ash.

Handling of ash includes its removal from the furnace, loading on the conveyors and delivered to the fill from where it can be disposed off.

ASH HANDLING EQUIPMENT:

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

(1) Capital investment, operating and maintenance charges of the equipment should be low.
(2) It should be able to handle large quantities of ash.
(3) Clinkers, soot, dust etc. create troubles; the equipment should be able to handle them smoothly.
(4) The equipment used should remove the ash from the furnace, load it to the conveying system to deliver the ash to a dumping site or storage and finally it should have means to dispose of the storedash.
(5) The equipment should be corrosion and wear resistant. Fig.1.11 shows a general layout of ash handling and dust collection system. The commonly used ash handling systems are as follows:

(i) Hydraulic system
(ii) Pneumatic system
(iii) Mechanical system

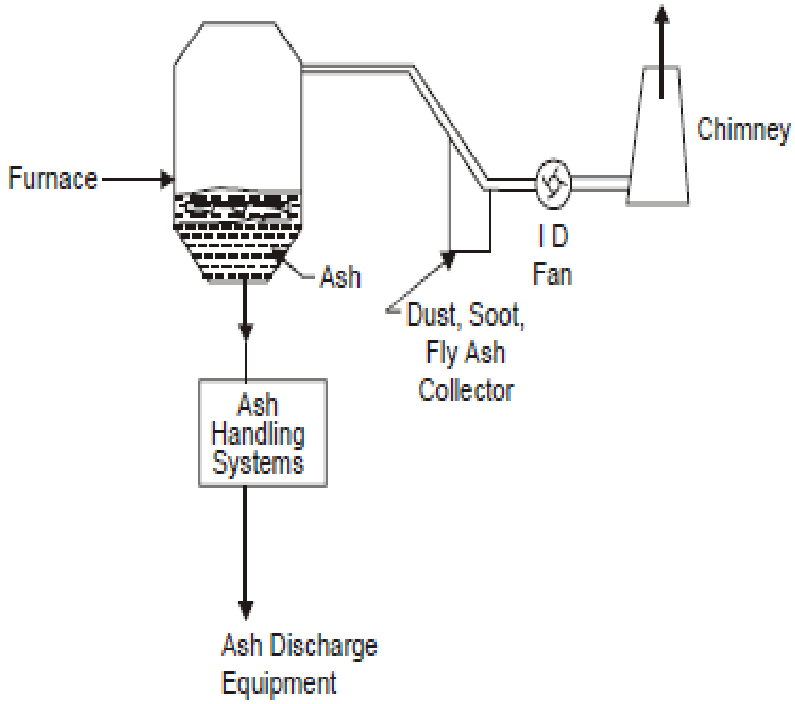

Fig-1.11-Ash handling system

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The commonly used ash discharge equipment is as follows:

(i) Rail road cars
(ii) Motor truck
(iii) Barge.

The various methods used for the disposal of ash are as follows:

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

Fig.1.12 shows hydraulic system.

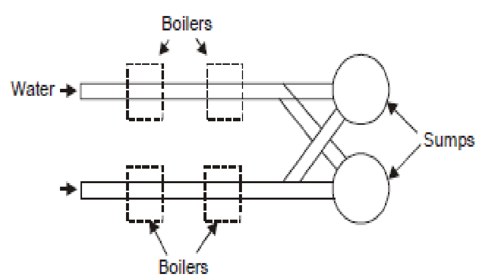


Fig-1.12-Hydraulic System

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

(i) **Pneumatic system.** In this system (Fig.1.13) ash from the boiler furnace outlet falls into a crusher where larger ash particles are crushed to small sizes. The ash is then carried by a high velocity air or steam to the point of delivery. Air leaving the ash separator is passed through filter to remove dust etc. so that the exhauster handles clean air which will protect the blades of the exhauster.

(ii) **Mechanical ash handling system.** Fig.1.14 shows a mechanical ash handling system. In this system ash cooled by water seal falls on the belt conveyor and is carried out continuously to the bunker. The ash is then removed to the dumping site from the ash bunker with the help of trucks.

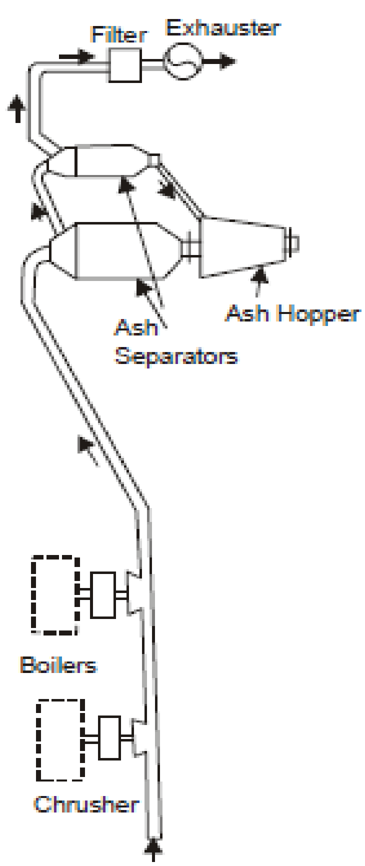


Fig-1.13-Pneumatic System

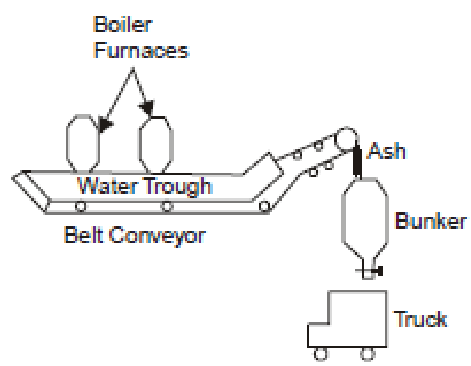


Fig-1.14-Mechanical System

COMBUSTION PROCESS:

PROPERTIES OF COAL:

The properties of coal are broadly classified as

1. Physical properties
2. Chemical properties

Proximate Analysis

Proximate analysis indicates the percentage by weight of the Fixed Carbon, Volatiles, Ash, and Moisture Content in coal. The amounts of fixed carbon and volatile combustible matter directly contribute to the heating value of coal. Fixed carbon acts as a main heat generator during burning. High volatile matter content indicates easy ignition of fuel. The ash content is important in the design of the furnace grate, combustion volume, pollution control equipment and ash handling systems of a furnace.

Significance of Various Parameters in Proximate Analysis

Fixed carbon: Fixed carbon is the solid fuel left in the furnace after volatile matter is distilled off. It consists mostly of carbon but also contains some hydrogen, oxygen, sulphur and nitrogen not driven off with the gases. Fixed carbon gives a rough estimate of heating value of coal

Volatile Matter: Volatile matters are the methane, hydrocarbons, hydrogen and carbon monoxide, and incombustible gases like carbon dioxide and nitrogen found in coal. Thus the volatile matter is an index of the gaseous fuels present. Typical range of volatile matter is 20 to 35%.

Volatile Matter

- Proportionately increases flame length, and helps in easier ignition of coal.
- Sets minimum limit on the furnace height and volume.
- Influences secondary air requirement and distribution aspects.
- Influences secondary oil support

Ash Content: Ash is an impurity that will not burn. Typical range is 5 to 40%

Ash

- Reduces handling and burning capacity.
- Increases handling costs.
- Affects combustion efficiency and boiler efficiency
- Causes clinkering and slagging.

Moisture Content: Moisture in coal must be transported, handled and stored. Since it replaces combustible matter, it decreases the heat content per kg of coal. Typical range is 0.5 to 10%

Moisture

- Increases heat loss, due to evaporation and superheating of vapour
- Helps, to a limit, in binding fines.
- Aids radiation heat transfer.

Sulphur Content:

Typical range is 0.5 to 0.8% normally.
Sulphur

Affects clinkering and slagging tendencies
Corrodes chimney and other equipment such as air heaters and economisers
Limits exit flue gas temperature.

Chemical Properties

Ultimate Analysis:

The ultimate analysis indicates the various elemental chemical constituents such as Carbon, Hydrogen, Oxygen, Sulphur, etc. It is useful in determining the quantity of air required for combustion and the volume and composition of the combustion gases. This information is required for the calculation of flame temperature and the flue duct design etc.

OVERFEED AND UNDERFEED FUEL BEDS:

1. Overfeed Principle. According to this principle (Fig. 1.15) the primary air enters the grate from the bottom. The air while moving through the grate openings gets heated up and air while moving through the grate openings gets heated up and the grate is cooled.

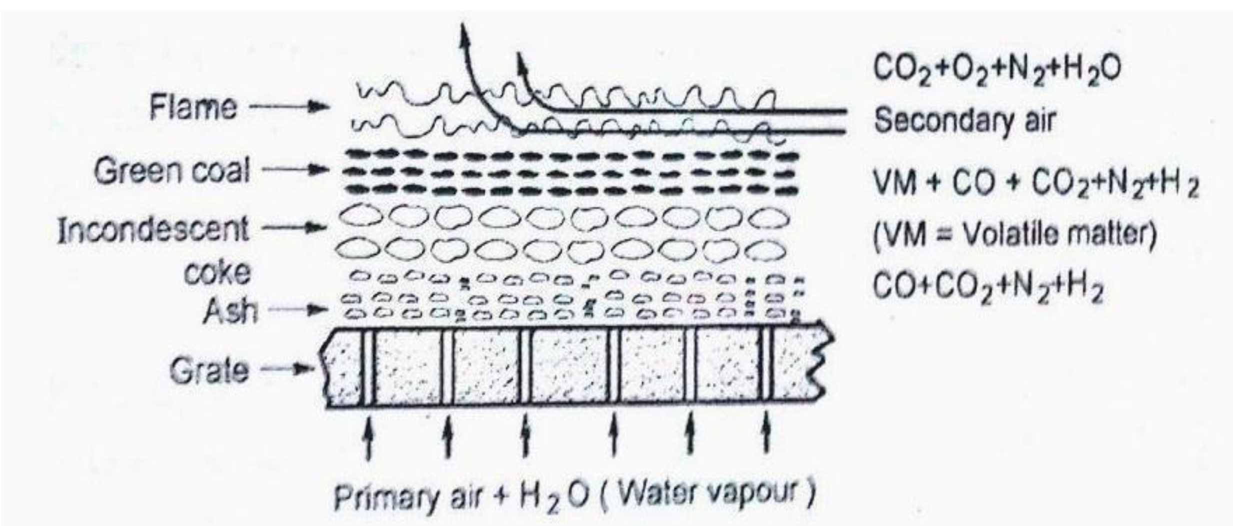


Fig-1.15-Overfeed Mechanism

The hot air that moves through a layer of ash and picks up additional energy. The air then passes through a layer of incandescent coke where oxygen reacts with coke to form-C02 and water vapors accompanying the air react with incandescent coke to form CO2, CO and free H2. The gases leaving the surface of fuel bed contain volatile matter of raw fuel and gases like CO2, CO, H2, N2 and H2O. Then additional air known as secondary air is supplied to burn the combustible gases. The combustion gases entering the boiler consist of N2, CO2, O2 and H2O and also CO if the combustion is not complete.

Underfeed Principle. Fig.1.16 shows underfeed principle. In underfeed principle air entering through the holes in the grate comes in contact with the raw coal (green coal).

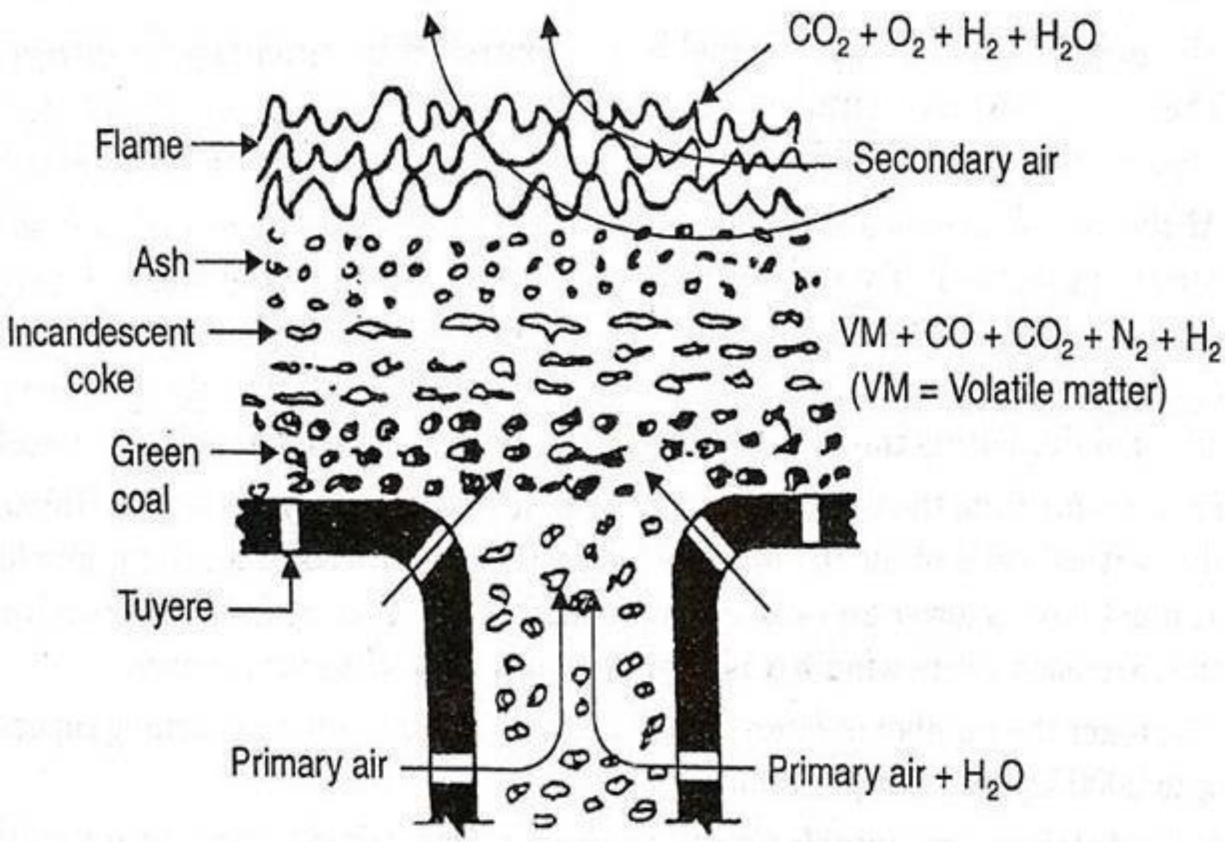


Fig-1.16- Underfeed Principle

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

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

The various advantages of stoker firing are as follows :

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

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

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

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

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

TYPES OF STOKERS:

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

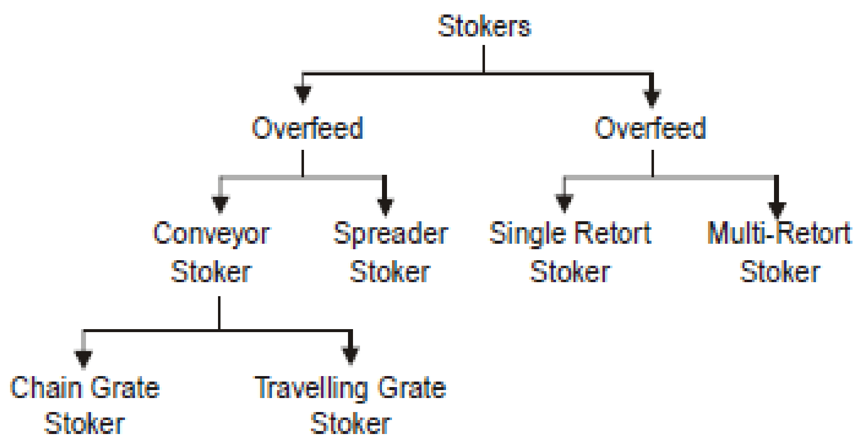


Fig-1.17- Types of Stokers

Chain Grate Stoker. Chain grate stoker and traveling grate stoker differ only in grate construction. A chain grate stoker (Fig. 1.18) consists of an endless chain which forms a support for the fuel bed.

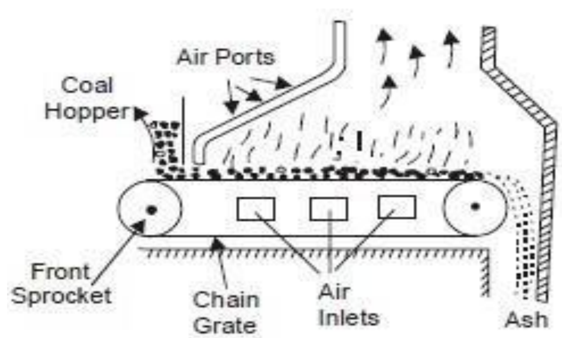


Fig-1.18-Chain grate Stoker

The chain travels over two sprocket wheels, one at the front and one at the rear of furnace. The traveling chain receives coal at its front end through a hopper and carries it into the furnace. The ash is tipped from the rear end of chain. The speed of grate (chain) can be adjusted to suit the firing condition. The air required for combustion enters through the air inlets situated below the grate.

Stokers are used for burning non-coking free burning high volatile high ash coals. Although initial cost of this stoker is high but operation and maintenance cost is low.

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

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

Spreader Stoker. A spreader stoker is shown in Fig. 1.19. In this stoker the coal from the hopper is fed on to a feeder which measures the coal in accordance to the requirements. Feeder is a rotating drum fitted with blades. Feeders can be reciprocating rams, endless belts, spiral worms etc. From the feeder the coal drops on to spreader distributor which spread the coal over the furnace. The spreader system should distribute the coal evenly over the entire grate area. The spreader speed depends on the size of coal.

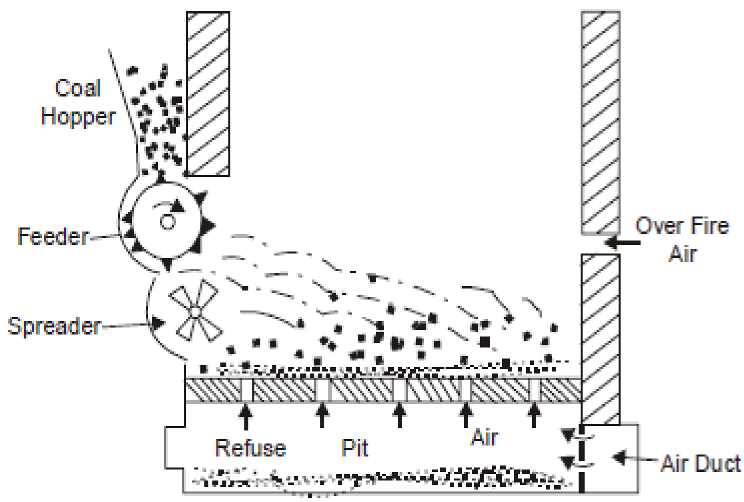


Fig-1.19-Spreader Stoker

Advantages

The various advantages of spreader stoker are as follows:

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

Disadvantages

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

Multi-retort Stoker.

A multi-retort stoker is shown in Fig.1.20. The coal falling from the hopper is pushed forward during the inward stroke of stoker ram. The distributing rams (pushers) then slowly move the entire coal bed down the length of stoker. The length of stroke of pushers can be varied as desired. The slope of stroke helps in moving the fuel bed and this fuel bed movement keeps it slightly agitated to break up clinker formation. The primary air enters the fuel bed from main wind box situated below the stoker. Partly burnt coal moves on to the extension grate. A thinner fuel bed on the extension grate requires lower air pressure under it. The air entering from the main wind box into the extension grate wind box is regulated by an air damper. As sufficient amount of coal always remains on the grate, this stoker can be used under large boilers (upto 500,000 lb per hr capacity) to obtain high rates of combustion. Due to thick fuel bed the air supplied from the main wind box should be at higher pressure.

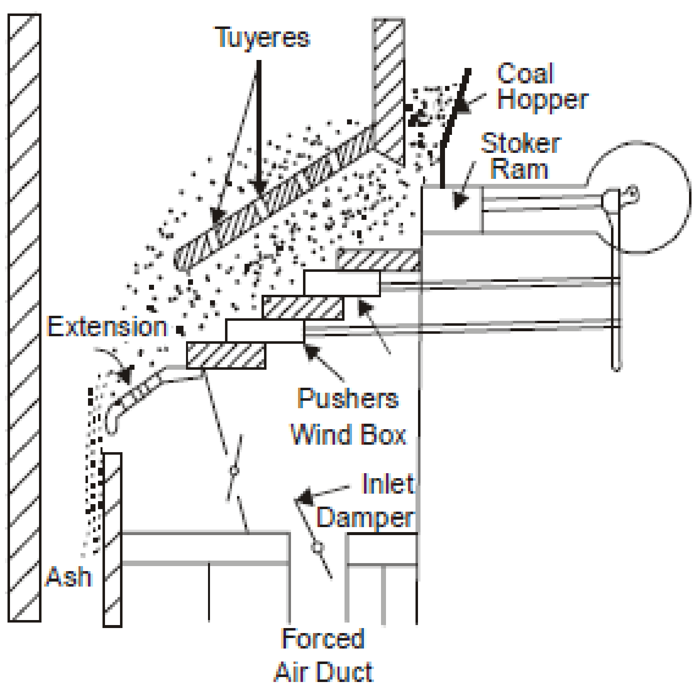


Fig-1.20-Multi retort Stoker

Pulverized Fuel Burning System and its Components:

Coal is pulverized (powdered) to increase its surface exposure thus permitting rapid combustion. Efficient use of coal depends greatly on the combustion process employed. For large scale generation of energy the efficient method of burning coal is confined still to pulverized coal combustion. The pulverized coal is obtained by grinding the raw coal in pulverizing mills.

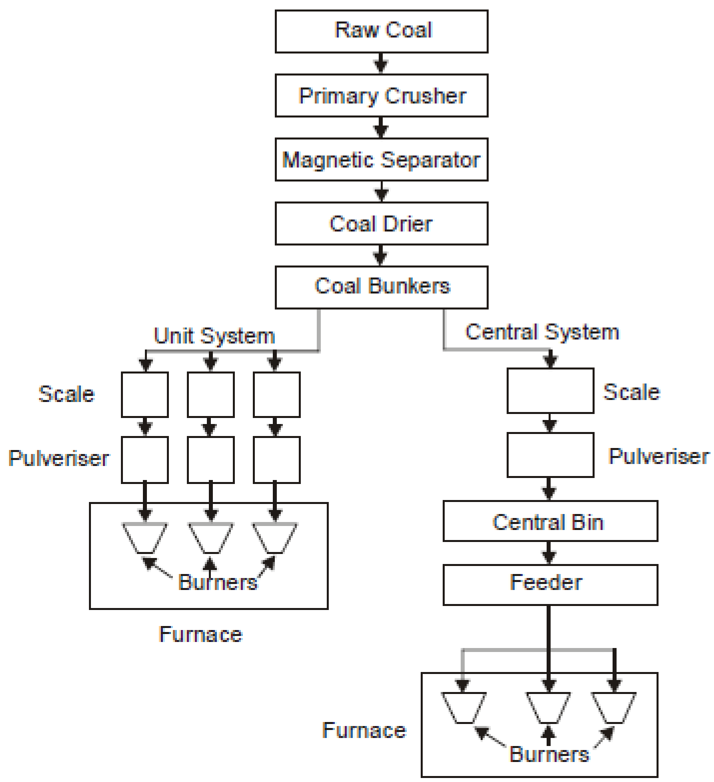


Fig-1.21- Components of pulversied fuel burning

The various pulverizing mills used are as follows:

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

The essential functions of pulverizing mills are as follows:

- *(i)* Drying of the coal
- *(ii)* Grinding
- *(iii)* Separation of particles of the desired size.

Proper drying of raw coal which may contain moisture is necessary for effective grinding. The coal pulverizing mills reduce coal to powder form by three actions as follows:

(*i*) Impact (*ii*) Attrition (abrasion) (*iii*) Crushing.

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

BALL MILL:

A line diagram of ball mill using two classifiers is shown in Fig. 1.22. It consists of a slowly rotating drum which is partly filled with steel balls. Raw coal from feeders is supplied to the classifiers from where it moves to the drum by means of a screw conveyor.

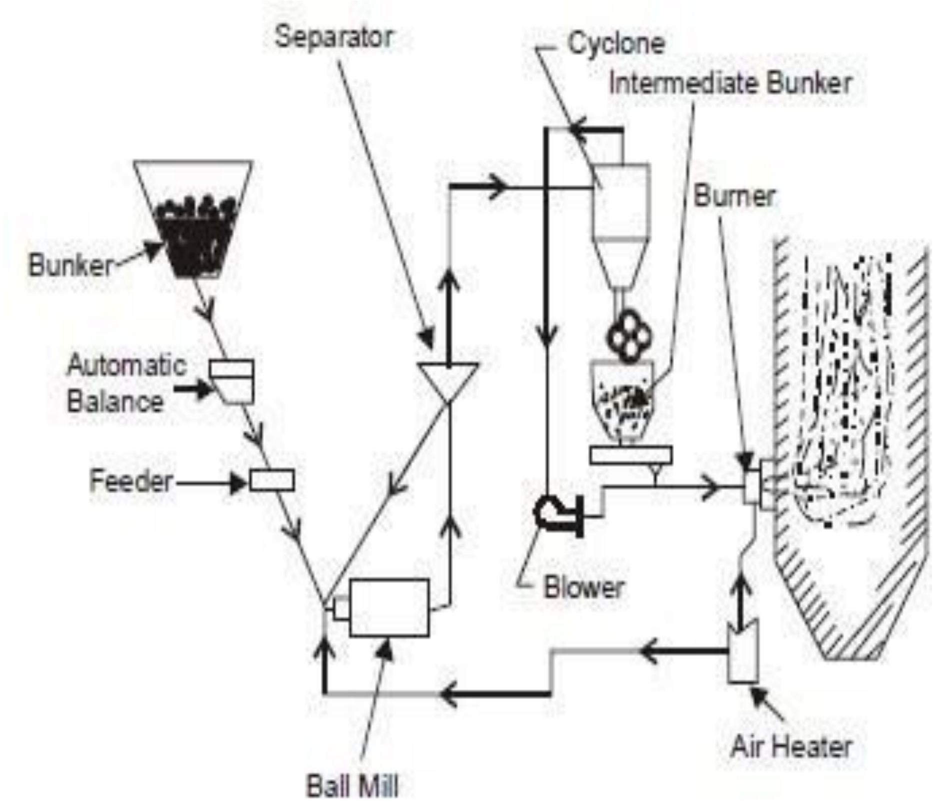


Fig-1.22-Ball Mill

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

BALL AND RACE MILL

Fig. 1.23 shows a ball and race mill. In this mill the coal passes between the rotating elements again and again until it has been pulverized to desired degree of fineness. The coal is crushed between two moving surfaces namely balls and races. The upper stationary race and lower rotating race driven by a worm and gear hold the balls between them. The raw coal supplied falls on the inner side of the races. The moving balls and races catch coal between them to crush it to a powder. The necessary force needed for crushing is applied with the help of springs. The hot air supplied picks up the coal dust as it flows between the balls and races, and then enters the classifier. Where oversized coal particles are returned for further grinding, where as the coal particles of required size are discharged from the top of classifier.

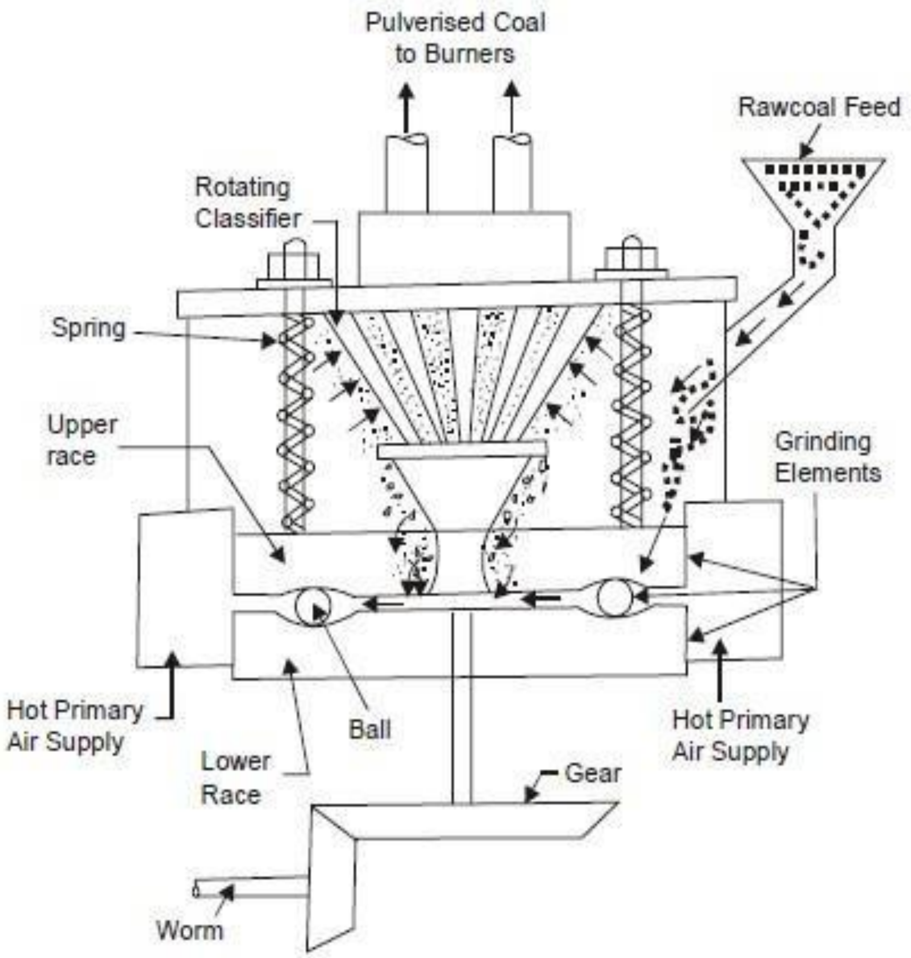


Fig-1.23-Ball and Race Mill

In this mill coal is pulverized by a combination of' crushing, impact and attrition between the grinding surfaces. The advantages of this mill are as follows:

(*i*) Lower capital cost (*ii*) Lower power consumption

(iii) Lower space required (*iv*) Lower weight.

However in this mill there is greater wear as compared to other pulverizes. The use of pulverized coal has now become the standard method of firing in the large boilers. The pulverized coal burns with some advantages that result in economic and flexible operation of steam boilers. Preparation of pulverized fuel with an intermediate bunker is shown in Fig. 1.23. The fuel moves to the automatic balance and then to the feeder and ball mill through which hot air is blown. It dries the pulverized coal and carries it from the mill to separator.

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

IMPACT/HAMMER MILL:

In impact mill coal passes through coal feeder and pulverization takes place due to impact.

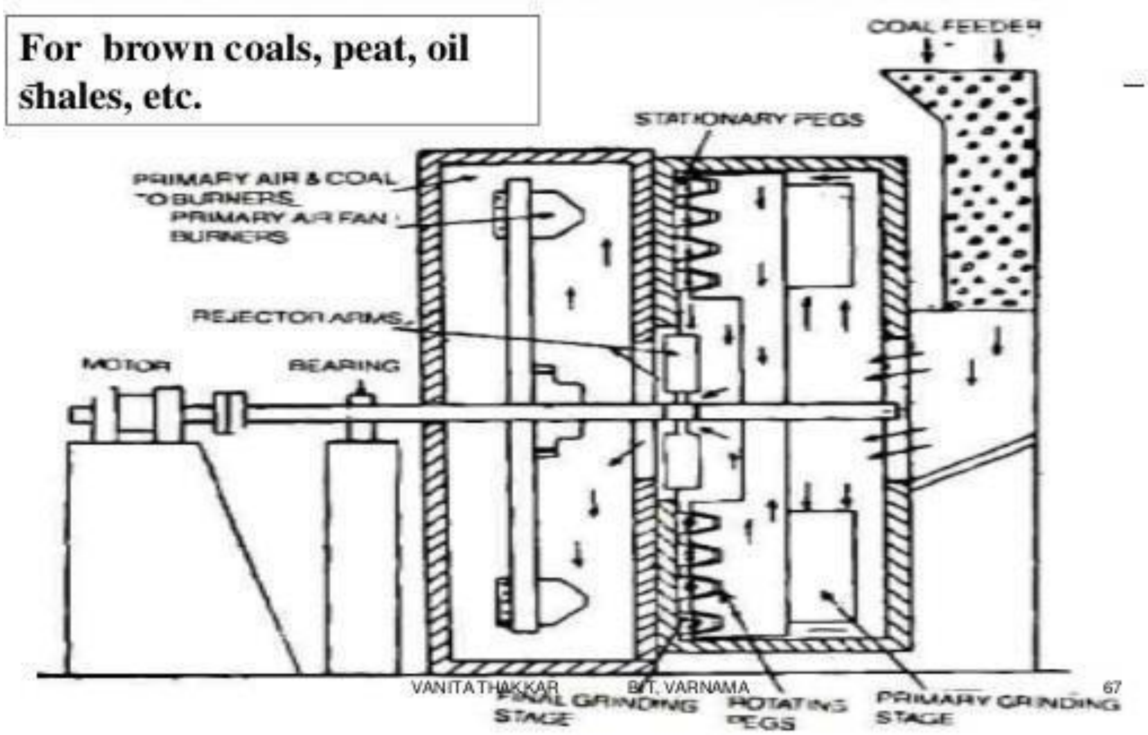


Fig-1.24-Impact mill

The coal in pulverizer remains in suspension during the entire pulverizing process. All the grinding elements and the primary air fan are mounted on a single shaft as shown in figure. The primary air fan induces flow of air through the pulverizer which carries the coal to the primary stage of grinding where the coal is reduced to fine granular state by impact with a series hammers and then into final stage where pulverization is completed by attririon. The final stage of grinding consists of pegs carried on a rotating disc and travelling between stationary pegs.

BOWL MILL:

This pulverizer consists of stationary rollers and a power driven bowl in which pulverization takes place as the coal passes between the sides of the bowl and the rollers.

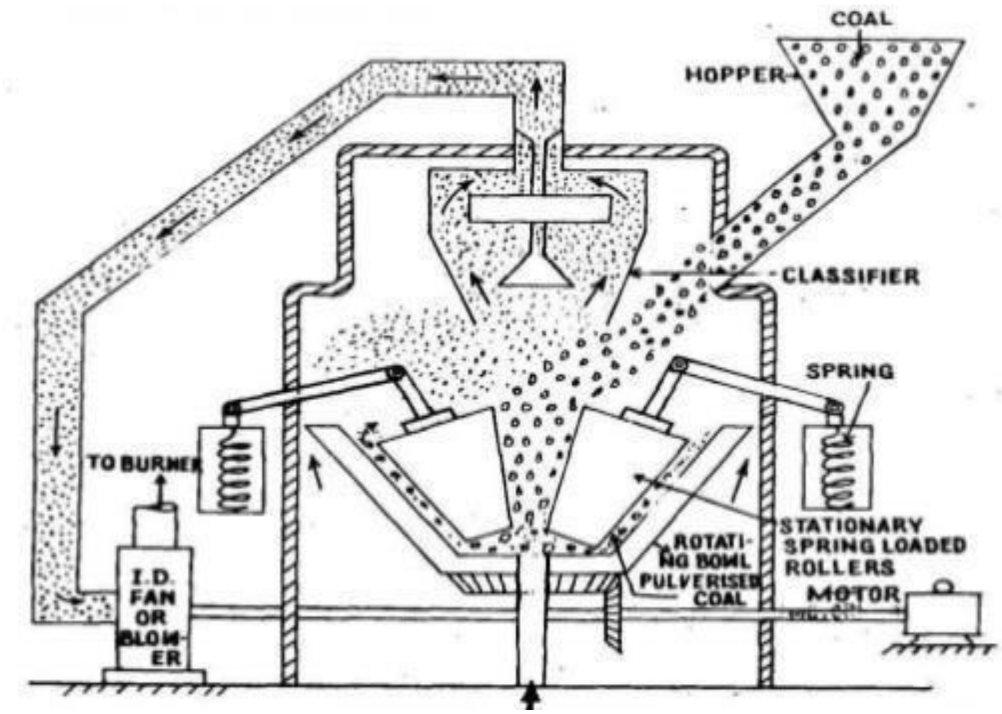


Fig-1.25-Bowl mill

Advantages:

The advantages of using pulverized coal are as follows:

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

Disadvantages

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

Pulverized coal firing is done by two systems:

(i) Unit System or Direct System.
(ii) Bin or Central System.

Unit System. In this system (Fig. 1.26) the raw coal from the coal bunker drops on to the feeder.

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

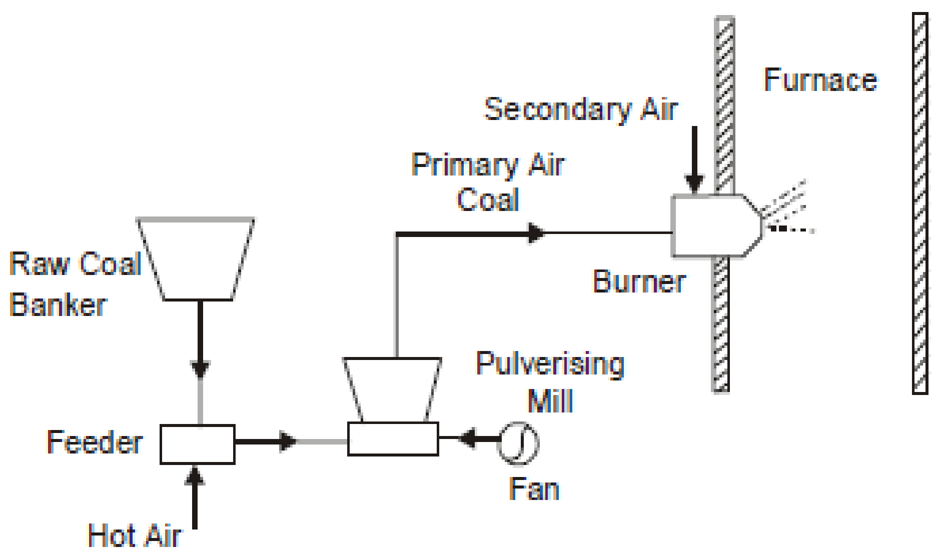


Fig-1.26- Unit System

Advantages:

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

Bin or Central System.

It is shown in Fig. 1.27. Crushed coal from the raw coal bunker is fed by gravity to a dryer where hot air is passed through the coal to dry it. The dryer may use waste flue gases, preheated air or bleeder steam as drying agent. The dry coal is then transferred to the pulverizing mill. The pulverized coal obtained is transferred to the pulverized coal bunker (bin). The transporting air is separated from the coal in the cyclone separator. The primary air is mixed with the coal at the feeder and the mixture is supplied to the burner.

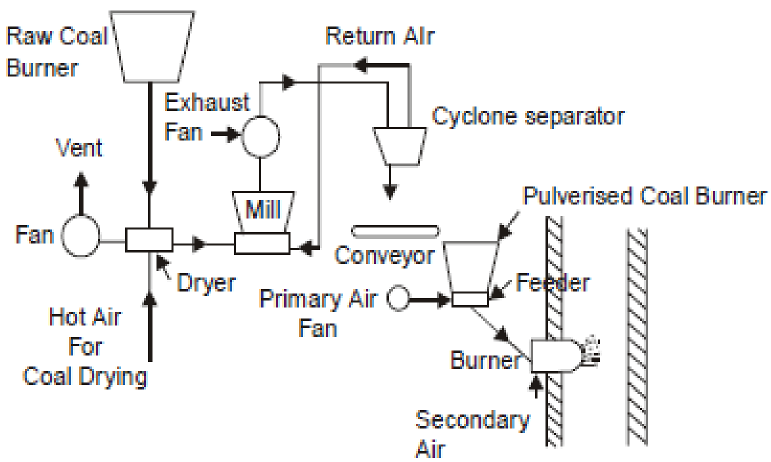


Fig-1.27-Central System

Advantages:

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

Disadvantages

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

To a large extent the performance of pulverised fuel system depends upon the mill performance. The pulverised mill should satisfy the following requirements:

- It should deliver the rated tonnage of coal.
- Pulverized coal produced by it should be of satisfactory fineness over a wide range of capacities.
- It should be quiet in operation.
- Its power consumption should be low.
- Maintenance cost of the mill should be low.

CYCLONE FURNACE:

Cyclone-furnace firing, developed in the 1940s, represents the most significant step in coal firing since the introduction of pulverized-coal firing in the 1920s. It is now widely used to burn poorer grades of coal that contain a high ash content with a minimum of 6 percent to as high as 25 percent, and a high volatile matter, more than 15 percent, to obtain the necessary high rates of combustion. A wide range of moisture is allowable with pre-drying. One limitation is that ash should not contain a high sulfur content or a high Fe_2O_3; (CaO + MgO) ratio. Such a coal has a tendency to form high ash-fusion temperature materials such as iron and iron sulfide in the slag, which negates the main advantage of cyclone firing.

The main advantage is the removal of much of the ash, about 60 percent, ao molten slag that is collected on the cyclone walls by centrifugal action and drained off the bottom to a slag-disintegrating tank below. Thus only 40 percent ash leave, with the flue gases, compared with about 80 percent for pulverized-coal firing. this materially reduces erosion and fouling of steam-generator surfaces as well as the size of dust-removal precipitators or bag houses at steam-generator exit. Other advantages are that only crushed coal is used and no pulverization equipment is needed and that the boiler size is reduced.Cyclone-furnace firing uses a range of coal sizes averaging 95 percent passing a 4-mesh screen.

The disadvantages are higher forced-draft fan pressures and therefore higher power requirements, the inability to use the coals mentioned above, and the formation of relatively more oxides of nitrogen, NO_2 which are air pollutants, in the combustion process. The cyclone is essentially a water-cooled horizontal cylinder (Fig.1.28) located outside the main boiler furnace, in which the crushed coal is fed and fired with very high rates of heat release. Combustion of the coal is completed before the resulting hot gases enter the boiler furnace.

The crushed coal is fed into the cyclone burner at left along with primary air, which is about 20 percent of combustion or secondary air. The primary air enters the burner tangentially, thus imparting a centrifugal motion to the coal. The secondary air is also admitted tangentially at the top of the cyclone at high speed, imparting further centrifugal motion. A small quantity of air, called tertiary air, is admitted at the center.

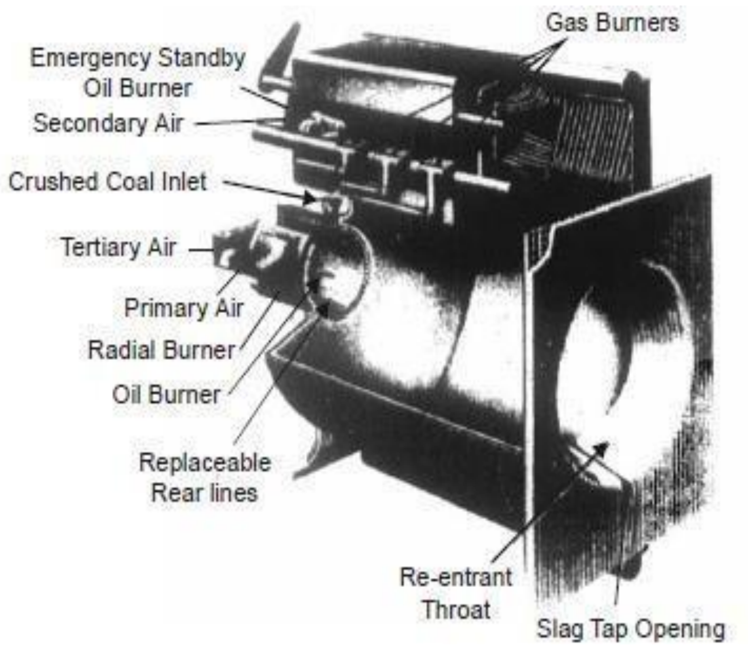


Fig-1.28-Cyclone Furnace

The whirling motion of air and coal results in large heat-release-rate volumetric densities, between 450,000 and 800,000 Btu/(h.ft) (about 4700 to 8300 kW/m3), and high combustion temperatures, more than 3000°F (1650°C). These high temperatures melt the ash into a liquid slag that covers the surface of the cyclone and eventually drains through the slag-tap opening to a slag tank at the bottom of the boiler furnace, where it is solidified and broken for removal. The slag layer that forms on the walls of the cyclone provides insulation against too much heat loss through the walls and contributes to the effi ciency of cyclone firing. The high temperatures also explain the large production of NO, in the gaseous combustion products. These gases leave the cyclone through the throat at right and enter the main boiler furnace. Thus combustion takes place in the relatively small cyclone, and the main boiler furnace has the sole function of heat transfer from the gases to the water-tube walls. Cyclone furnaces are also suitable for fuel-oil and gaseous-fuel firing. Initial ignition is done by small retractable oil or gas burners in the secondary air ports.

Like pulverized-coal systems, cyclone firing systems can be of the bin, or storage. or direct-firing types, though the bin type is more widely used, especially for most bituminous coals, than in the case of pulverized coal. The cyclone system uses either one-wall, or opposed-wall, firing, the latter being preferred for large steam generators The size and number of cyclones per boiler depend upon the boiler size and the desired load response because the usual load range for good performance of any one cyclone is from 50 to 100 percent of its rated capacity. Cyclones vary in size from 6 to 10 fv in diameter with heat inputs between 160 to 425 million Btu/h (about 47,000 to 125,Oa_ kW), respectively .

The cyclone component requiring the most maintenance is the burner, which is subjected to erosion by the high velocity of the coal. Erosion is minimized by the us; of tungsten carbide and other erosion-resistant materials for the burner liners, which are usually replaced once a year or so.

DUST COLLECTORS:

A **dust collector** is a system used to enhance the quality of air released from industrial and commercial processes by collecting dust and other impurities from air or gas. Designed to handle high-volume dust loads, a dust collector system consists of a blower, dust filter, a filter-cleaning system, and a dust receptacle or dust removal system. It is distinguished from air cleaners, which use disposable filters to remove dust.

Five main types of industrial dust collectors are:

- Inertial separators
- Fabric filters
- Wet scrubbers
- Unit collectors
- Electrostatic precipitators

Inertial separators separate dust from gas streams using a combination of forces, such as centrifugal, gravitational, and inertial. These forces move the dust to an area where the forces exerted by the gas stream are minimal. The separated dust is moved by gravity into a hopper, where it is temporarily stored.

The three primary types of inertial separators are:

- Settling chambers
- Baffle chambers
- Centrifugal collectors

Neither settling chambers nor baffle chambers are commonly used in the minerals processing industry. However, their principles of operation are often incorporated into the design of more efficient dust collectors.

Fabric filters Commonly known as baghouses, fabric collectors use filtration to separate dust particulates from dusty gases. They are one of the most efficient and cost effective types of dust collectors available and can achieve a collection efficiency of more than 99% for very fine particulates.

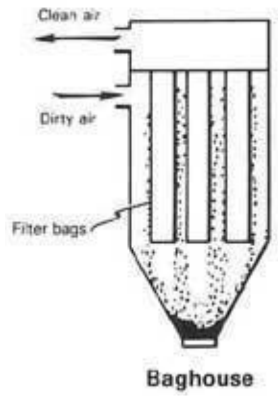


Fig-1.29- Baghouse

Dust-laden gases enter the baghouse and pass through fabric bags that act as filters. The bags can be of woven or felted cotton, synthetic, or glass-fiber material in either a tube or envelope shape.

WET SCRUBBERS:

Dust collectors that use liquid are known as wet scrubbers. In these systems, the scrubbing liquid (usually water) comes into contact with a gas stream containing dust particles. Greater contact of the gas and liquid streams yields higher dust removal efficiency.

There is a large variety of wet scrubbers; however, all have one of three basic configurations:

1. Gas-humidification - The gas-humidification process agglomerates fine particles, increasing the bulk, making collection easier.
2. Gas-liquid contact - This is one of the most important factors affecting collection efficiency. The particle and droplet come into contact by four primary mechanisms:
   a) Inertial impaction - When water droplets placed in the path of a dust-laden gas stream, the stream separates and flows around them. Due to inertia, the larger dust particles will continue on in a straight path, hit the droplets, and become encapsulated.
   b) Interception - Finer particles moving within a gas stream do not hit droplets directly but brush against and adhere to them.
   c) Diffusion - When liquid droplets are scattered among dust particles, the particles are deposited on the droplet surfaces by Brownian movement, or diffusion. This is the principal mechanism in the collection of submicrometre dust particles.
   d) Condensation nucleation - If a gas passing through a scrubber is cooled below the dewpoint, condensation of moisture occurs on the dust particles. This increase in particle size makes collection easier.

3. Gas-liquid separation - Regardless of the contact mechanism used, as much liquid and dust as possible must be removed. Once contact is made, dust particulates and water droplets combine to form agglomerates. As the agglomerates grow larger, they settle into a collector.

The "cleaned" gases are normally passed through a mist eliminator (demister pads) to remove water droplets from the gas stream. The dirty water from the scrubber system is either cleaned and discharged or recycled to the scrubber. Dust is removed from the scrubber in a clarification unit or a drag chain tank. In both systems solid material settles on the bottom of the tank. A drag chain system removes the sludge and deposits in into a dumpster or stockpile.

UNIT COLLECTORS:

Unlike central collectors, unit collectors control contamination at its source. They are small and self-contained, consisting of a fan and some form of dust collector. They are suitable for isolated, portable, or frequently moved dust-producing operations, such as bins and silos or remote belt- conveyor transfer points. Advantages of unit collectors include small space requirements, the return of collected dust to main material flow, and low initial cost. However, their dust-holding and storage capacities, servicing facilities, and maintenance periods have been sacrificed.

A number of designs are available, with capacities ranging from 200 to 2,000 ft^3/min (90 to 900 L/s). There are two main types of unit collectors:

- Fabric collectors, with manual shaking or pulse-jet cleaning - normally used for fine dust
- Cyclone collectors - normally used for coarse dust

Fabric collectors are frequently used in minerals processing operations because they provide high collection efficiency and uninterrupted exhaust airflow between cleaning cycles. Cyclone collectors are used when coarser dust is generated, as in woodworking, metal grinding, or machining.

The following points should be considered when selecting a unit collector:

- Cleaning efficiency must comply with all applicable regulations.
- The unit maintains its rated capacity while accumulating large amounts of dust between cleanings.
- Simple cleaning operations do not increase the surrounding dust concentration.
- Has the ability to operate unattended for extended periods of time (for example, 8 hours).
- Automatic discharge or sufficient dust storage space to hold at least one week's accumulation.
- If renewable filters are used, they should not have to be replaced more than once a month. Durable.
- Quiet.

Use of unit collectors may not be appropriate if the dust-producing operations are located in an area where central exhaust systems would be practical. Dust removal and servicing requirements are expensive for many unit collectors and are more likely to be neglected than those for a single, large collector.

Electrostatic precipitators use electrostatic forces to separate dust particles from exhaust gases. A number of high-voltage, direct-current discharge electrodes are placed between grounded collecting electrodes. The contaminated gases flow through the passage formed by the discharge and collecting electrodes. Electrostatic precipitators operate on the same principle as home "Ionic" air purifiers.

The airborne particles receive a negative charge as they pass through the ionized field between the electrodes. These charged particles are then attracted to a grounded or positively charged electrode and adhere to it.

The collected material on the electrodes is removed by rapping or vibrating the collecting electrodes either continuously or at a predetermined interval. Cleaning a precipitator can usually be done without interrupting the airflow.

The four main components of all electrostatic precipitators are:

- Power supply unit, to provide high-voltage DC power
- Ionizing section, to impart a charge to particulates in the gas stream A means of removing the collected particulates
- A housing to enclose the precipitator zone

The following factors affect the efficiency of electrostatic precipitators:

- Larger collection-surface areas and lower gas-flow rates increase efficiency because of the increased time available for electrical activity to treat the dust particles.
- An increase in the dust-particle migration velocity to the collecting electrodes increases efficiency. The migration velocity can be increased by:
  - Decreasing the gas viscosity
  - Increasing the gas temperature
  - Increasing the voltage field

COOLING TOWERS AND HEAT REJECTION:

Cooling towers are a very important part of many chemical plants. The primary task of a cooling tower is to reject heat into the atmosphere.

They represent a relatively inexpensive anddependable means of removing low-grade heat from cooling water. The make-up water sourceis used to replenish water lost to evaporation. Hot water from heat exchangers is sent to thecooling tower. The water exits the cooling tower and is sent back to the exchangers or to other units for further cooling. Typical closed loop cooling tower system is shown in Figure 1.30.

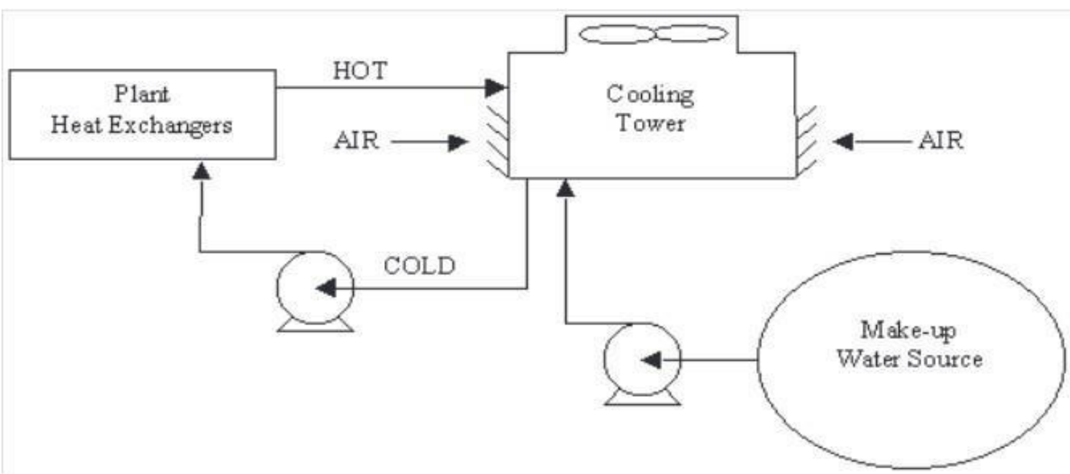


Fig-1.30-Cooling system

The amount of heat that can be rejected from the water to the air is directly tied to the relative humidity of the air. Air with a lower relative humidity has a greater ability to absorb water through evaporation than air with a higher relative humidity, simply because there is less water in the air. As an example, consider cooling towers in two different locations– one in Atlanta, Georgia, and another in Albuquerque, New Mexico. The ambient air temperature at these two locations may be similar, but the relative humidity in Albuquerque on average will be much lower than that of Atlanta's. Therefore, the cooling tower in Albuquerque wil be able to extract more process or building heat and will run at a cooler temperature because the dry desert air has a greater capacity to absorb the warm water.

Cooling towers can be split into two distinct categories: open circuit (direct contact) and closed circuit (indirect) systems.In open circuit systems the recirculating water returns to the tower after gathering heat and is distributed across the tower where the water is in direct contact with the atmosphere as it recirculates across the tower structure. Closed circuit systems differ in that the return fluid (often water, or sometimes water mixed with glycol) circulates through the tower structure in a coil, while cooling tower water recirculates only in the tower structure itself (see Figure 1). In this case, the return fluid is not exposed directly to the air.

- The cooling towers types:-

1. Natural Draft cooling tower
2. Mechanical Draught

Natural Draft Towers

Natural draft towers are designed to move air up through the structure naturally without the use of fans. They use the natural law of differing densities between the ambient air and warm air in the tower. The warm air will rise within the chimney structure because of its lower density drawing cool ambient air in the bottom portion. Often times these towers are very tall to induce adequate air flow, and have a unique shape giving them the name "hyperbolic" towers

Mechanical draught Towers — Uses power-driven fan motors to force or draw air through the tower.

- **Induced draught** — A mechanical draft tower with a fan at the discharge (at the top) which pulls air up through the tower. The fan *induces* hot moist air out the discharge. This produces low entering and high exiting air velocities, reducing the possibility of *recirculation* in which discharged air flows back into the air intake. This fan/fin arrangement is also known as *draw-through*.

- **Forced draught** — A mechanical draft tower with a blower type fan at the intake. The fan *forces* air into the tower, creating high entering and low exiting air velocities. The low exiting velocity is much more susceptible to recirculation. With the fan on the air intake, the fan is more susceptible to complications due to freezing conditions.

Another disadvantage is that a forced draft design typically requires more motor horsepower than an equivalent induced draft design. The benefit of the forced draft design is its ability to work with high static pressure. Such setups can be installed in more-confined spaces and even in some indoor situations. This fan/fill geometry is also known as *blow-through*.

- **Fan assisted natural draught** — A hybrid type that appears like a natural draft setup, though airflow is assisted by a fan.

CORROSION AND FEED WATER TREATMENT:

Necessity of Feed Water treatment

Raw water (from any water body) contains a variety of impurities.

- Suspended solids and turbidity
- Hardness
- Alkalinity
- Silica
- Dissolved gasses
- Micro-organisms

Water Softening Plant Location:

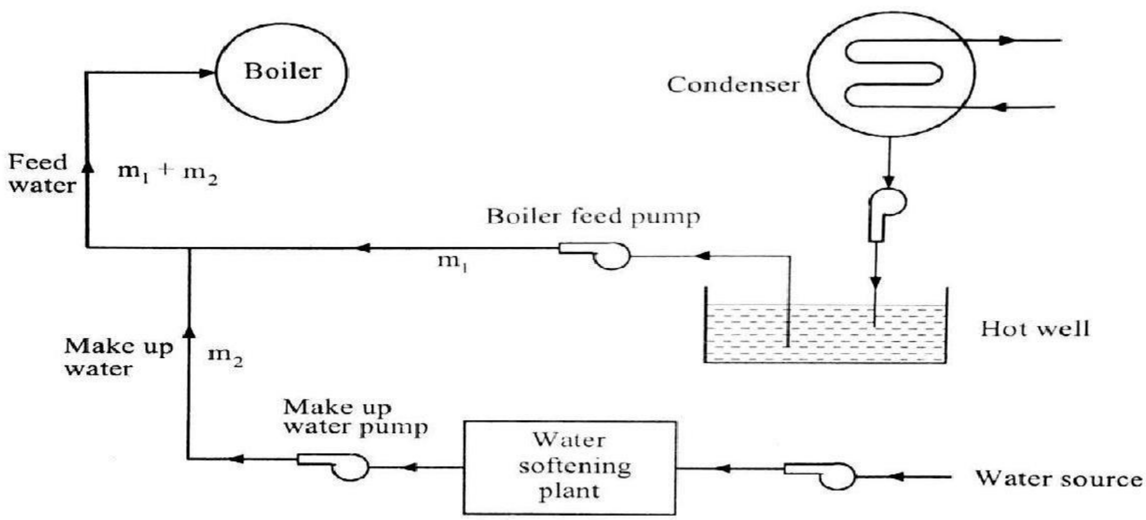


Fig-1.31-Water softening plant

Different Impurities in Feed Water:

1. Undissolved and Suspended Materials
2. **Dissolved Salts and Minerals**
   Calcium and Magnesium Salts:
   The presence of these salts is recognised by the hardness of the water. These salts are present in the water in the ***form of carbonated, bicarbonates, sulphates and chlorides*** and cannot be removed just by boiling because they ***form a hard scale on heating surfaces***.
3. **Dissolved Gases** *Oxygen* is corrosive to iron, zinc, brass and other metals. It is present in surface water in dissolved form. It causes corrosion and pitting of all metal parts with which it comes in contact **esp.** at high temperatures.

Carbon Dioxide produces corrosion and scale forming compounds by combining with other materials. Majority of water contains 2-50 ppm of CO_2

4. Other Materials

Free Mineral Acid Usually they are present in water as sulphuric or hydrochloric acid. Their presence is always undesirable as they result in corrosion. Can be reduced by neutralization with alkalies.

Oil: Generally, lubricating oil is carried with steam into the condenser and through the feed water system to the boiler. It causes sludge, scale and foaming in the boilers. It is generally removed by strainers or baffle separators.

EFFECTS OF IMPURITIES:

- Scale formation
- corrosion
- Priming and Foaming
- Caustic Embrittlement

SCALE FORMATION:

The concentration of dissolved salts in the hard water increases progressively due to continuous evaporation of water in boiler and finally these salts are precipitated on the inner walls of the boiler. The precipitated matter forms a hard adhering coating inside the boiler surface, they are called as scales. This reduces heat transfer and leads to rise in the temperature of the metal wall.

- Temp above 450^0 C may causes serious damage due to hot spots and consequently rupture of boiler temperature.
- Scaling is mainly caused due to salts of **Calcium, Magnesium, Iron, Aluminium and silicates.**
- Scales chokes the flow in the piping system and thus require increase in the pressure to maintain water delivery.
- Leads to heat transfer drop from flue gases to the water.

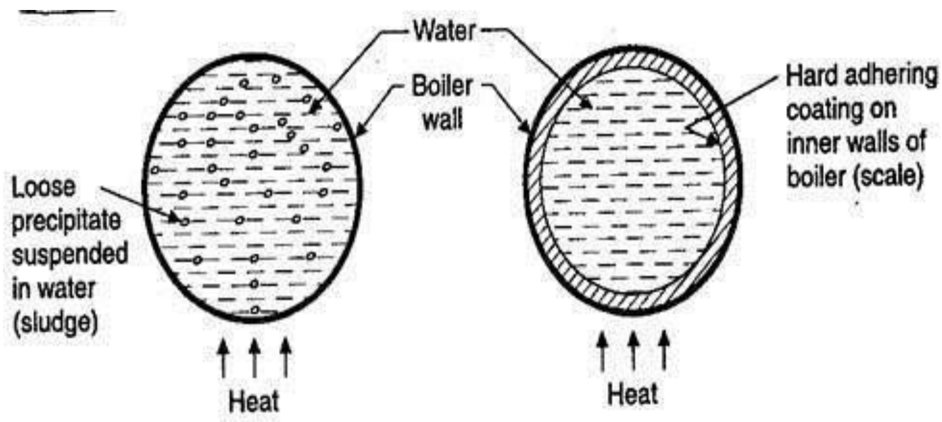


Fig-1.32- scale formation

CORROSION:

The eating away process of the boiler metal is known as Corrosion. It produces **Pits, Grooves and Cracks** on the surface of the boiler, corrosion in the boiler generally occurs when the boiler water alkalinity is low or when the metal is exposed to oxygen bearing water either during operation or idle periods.

High temperatures and stresses in the boiler metal tend to accelerate the corrosive mechanisms.

- Specific contaminants such as ammonia or sulphur bearing gases may increase attack on copper alloys in the system.
- Cracks occur due to the, cyclic stresses created due to rapid heating and cooling at points where corrosion has roughened the metal surface.

Remedies:-

The use of membrane contractors are the best and most diffused ways to avoid corrosion removing the dissolved gasses (mainly O_2 and CO_2).

PRIMING AND FOAMING:

Priming is the carryover of varying amounts of droplets of water in the steam (foam and mist), which lowers the energy efficiency of the steam and leads to the deposit of salt crystals on the super heaters and in the turbines.

- Priming may be caused by **improper construction of boiler**, **excessive ratings**, or **sudden fluctuations in steam demand**.

Boiler water carry-over is the contamination of the steam with boiler-water solids. Bubbles are build up on the surface of the boiler water and pass out with the steam. This is called **foaming** and it is caused by high concentration of any solids in the boiler water.

Substances such as **alkalis, oils, fats, greases, certain types of organic matter and suspended solids** are particularly conducive to foaming.

- To prevent foaming and priming we should **maintain the concentration of solids at reasonably low levels, Avoiding high water levels, excessive boiler loads, and sudden load changes.**

CAUSTIC EMBRITTLEMENT:

The caustic Embrittlement is caused by using **highly alkaline water** (caustic in water). It **causes the brittleness** of metal, which result in cracks formation in boiler shell below the water level. This is caused due to long exposure of boiler steel to combination of stress and highly alkaline water.

The following three conditions contribute to caustic Embrittlement:-

- Slow leakage of boiler water through a joint or steam.
- Metal is highly stressed at the point of leakage. This may be caused by **faulty riveting**, **misalignment** and **expansion**.

Measures to control :-

- Eliminating free sodium hydroxide from boiler water.
- Maintaining a definite ratio of sodium nitrate to sodium hydroxide.

METHODS OF WATER TREATMENT:

- Internal Treatment
- External treatment
    - Mechanical
    - Chemical
        - Zeolite treatment
        - Demineralization Process
    - Thermal
        - De-aeration
        - Evaporation

The internal feed water treatment is accomplished by adding chemicals to boilers water. The dissolved solids in the water are removed in the boiler itself by a chemical treatment then the method is known as internal treatment.

It is carried out to prevent scale formation and to nullify the effects of external treatment. Some important methods are listed below.

- Sodium carbonate (Na_2CO_3).
- Sodium Phosphate treatment.
- Sodium aluminate ($NaAlO_2$) treatment.
- Blow down System.

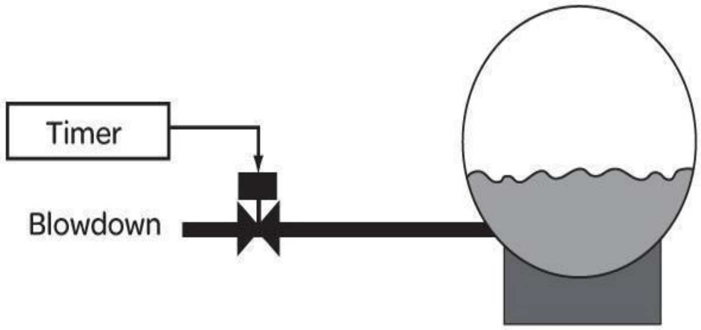


Fig-1.33- Blow Down System

EXTERNALWATER TREATMENT:

When the makeup water quantity is large and contains considerable suspended and dissolved solid material. The suspended solid material is generally removed by mechanical means. The dissolved solids are removed with the use of chemical treatment and dissolved gases are generally removed by thermal treatment.

Mechanical treatment includes **Sedimentation, Coagulation & Filtration.**

Chemical treatment includes **Zeolite ion exchange process and demineralization.**

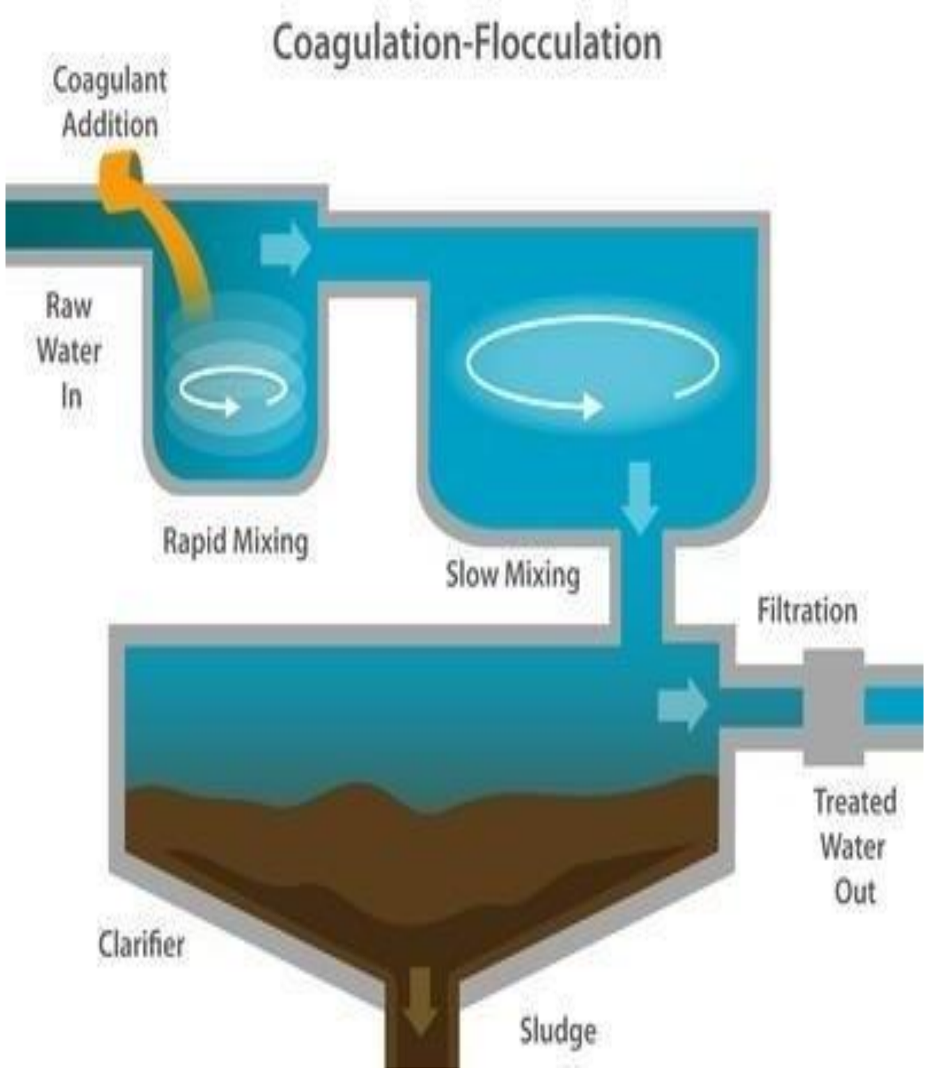


Fig-1.34-e xternal treatment

ZEOLITE TREATMENT:

Zeolite is used as catalyst in many industrial purposes such as water purification & air purification.

Zeolites are two types : 1. natural

2. artificial

Natural zeolite that is used for water softening is greensand.& artificial is used in water softening & its chemical formula is na2o, AL2O3,nsio2,xh2o. These are used as ion exchanger in water softener.

The zeolite softener is shown is shown in fig. the water sprayed at the top of the shell flows downward through the zeolite bed & the water is removed by ion exchange.

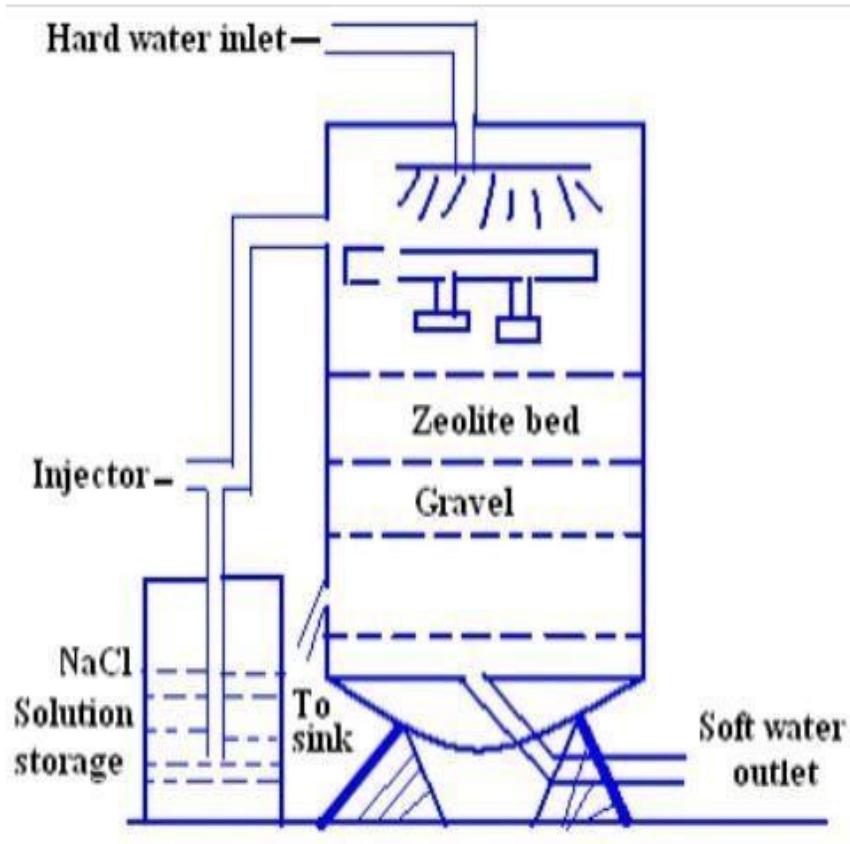


Fig-1.35- Zeolite Process

Zeolite process for water softening hasbecome a commercial success for the reason that zeolite can be easily regenerated. When ca2+& mg2+ ions containing hard water is passes through a bed of sodium zeolite, the sodium ions are replaced by the calcium & magnesium ions. The chemical reactions can be written as:

When all sodium ions are replaced by calcium & magnesium ions, the zeolite becomes inactive. Then the zeolite needs to be regenerated.

Brine solutions are passing through bed of inactivated zeolite. Regeneration process is given by equation.

Softening water by this process is used for laundry process& can not used for boiler purpose because this process contains nahco3 in water, when this water is heated, it produces co2 which is corrosive for boilerplates.

Advantages:

1. It is very effective in removing hardness
2. It is easy & inexpensive in operation
3. No problem of filtration of softened water & sludge removal
4. It is compact & occupies less space.

Disadvantages:-

1. Filtration of turbid water is required before it is passed through the process
2. Water of high or low PH value has deterious effect on zeolite
3. Treated water contains more sodium salts.

Demineralization or ion exchange process:

- Any process which results in the reversible exchange of ions contained in a fluid with those contained on a solid without a permanent change in the solid structure.
- Water is treated with an ion exchange resin.
- The mineral content of water may be removed by ***evaporation*** or by ***series of cat ion and anion exchangers*** to produce essentially distilled water.
- Demineralization is often the most economical method of producing make – up water for high pressure boiler.

The functional groups are molecules with exchangeable ions such as H^+ or OH^-, that can be safely released into the system.

Cat ion resins :

Exchange positively charged functional groups, for undesirable positive ions. With their functional groups in the hydrogen form, R – H, "R" represents the exchange resin and "H" represents the attached hydrogen ion.

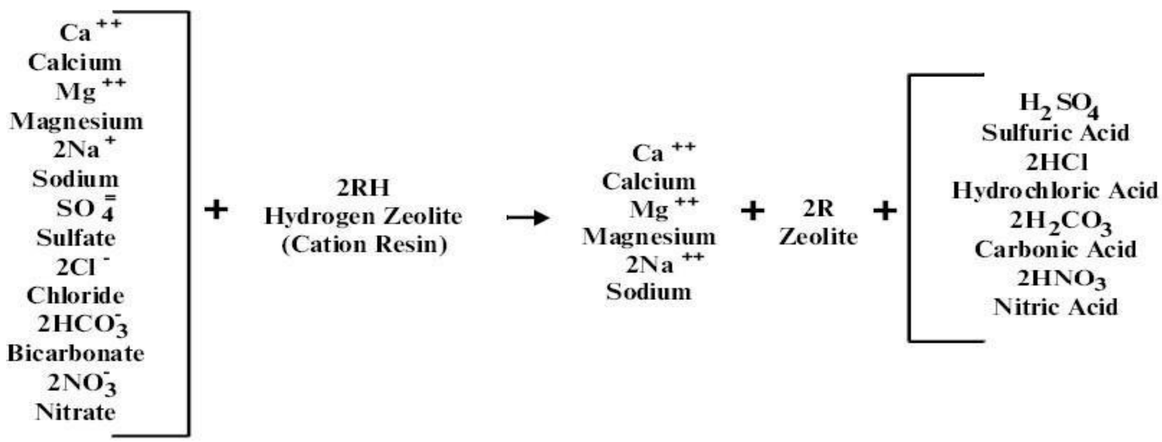
Anion resins :

Exchange negatively charged functional groups for any undesirable negative ion.

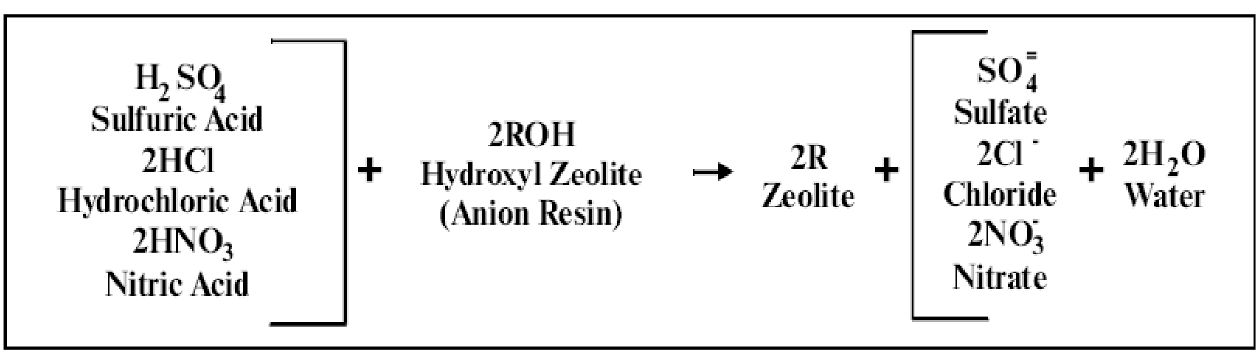
The hydroxyl ion, OH^- (R—OH) is commonly used as the functional group in an anion resin.

Process: In this system, raw water is first passed through a weak acid cat ion exchanger to remove the bicarbonates. Water coming out contains dilute carbonic acid, hydrochloric acid and sulphuric acid .

The demineralizer system consists of one or more ion exchange resin columns, including a strong cat ion unit and a strong anion unit. The cat ion resins exchange hydrogen for raw water cat ions as shown below:



- the water coming out of cat ion exchanger is passed through anion exchanger.
- In anion exchanger such as chlorides , sulphates and nitrates are removed from water with certain resinous material (RCO_3). anion exchanger also exchanges acid radicals .
- The anion resins exchange hydroxyl for raw water anions.



- The water coming out from anion exchanger is passed through a ***degasifier tower*** . Which is filled with **porcelain packing**. Water is distributed over very large surface area provided by the packing as it flows downward through the tower .

Water comes in contact with low pressure air blown in at bottom , CO2 is liberated and is vented from the top of the tower .

DIMENERALISING PROCESS:

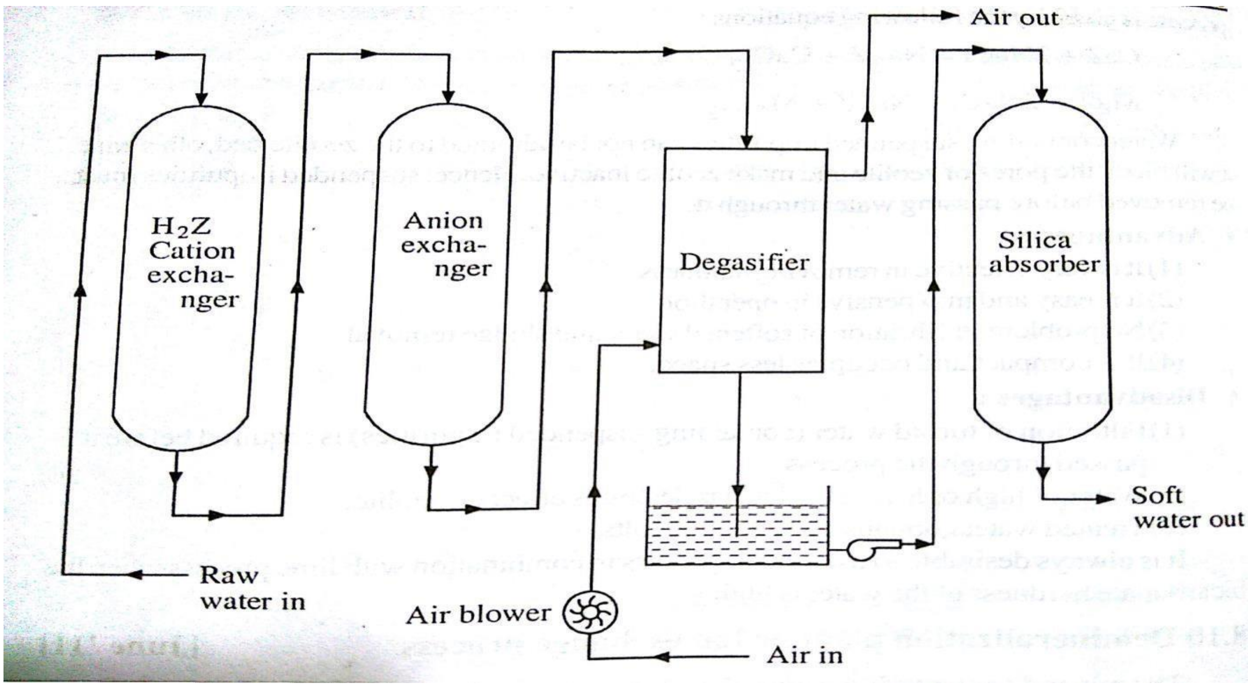


Fig-1.36-dimeneralising Process

- The degassed water containing about 2 to 5 ppm CO2 is collected in the sump.
- The water is then passed through ***base-anion resin tower***.

This resin reduces the silica to 0.02 ppm.

H_2CO_3 Carbonic Acid H_2SiO_3 Silicic Acid	+	ROH Hydroxyl Zeolite (Anion Resin)	$\rightarrow$	R Zeolite	+	HCO_3^- Bicarbonate $HSiO_3^-$ Bisilicate	+	H_2O Water

- In the example, the acids resulting from the cat ion exchange process react with the anion exchange resin. As a result we form water and the anions are embedded into the resin.

- Other weak acids are also removed because the resin is strongly basic.

- Strong base anion exchangers are specially designed to remove dissolved silica,

Purpose

Demineralization is the removal of essentially all inorganic salts. In ion exchange demineralization hydrogen cat ion exchange converts dissolved salts to their corresponding acids, and basic anion exchange removes these acids.

- Purpose
  - Removal of ionic substances
  - Reduction of conductivity
  - Control of pH

Advantages:

- It reduce boiler blow down and helps for the production of higher quality steam.
- It supplies the purest quality feed water.
- It can supply high quality feed water for the period needed to bring about an orderly shutdown to repair the condenser.

Disadvantages:

- Its equipment cost is high.
- Its operating cost is high.

Reverse Osmosis Process:

Reverse Osmosis is a pressure driven membrane process capable of removing small particles, dissolved salts and low molecular weight organics from feed water stream.

- The reverse osmosis water treatment method has been used extensively to convert brackish or seawater to drinking water, to clean up wastewater, and to recover dissolved salts from industrial processes.

- It is becoming more popular in the home market as homeowners are increasingly concerned about contaminants that affect their health, as well as about non-hazardous chemicals that affect the taste, odour, or colour of their drinking water.

Principle:

- Osmosis is a natural phenomenon which can be defined as the movement of pure water through a semi permeable membrane from a low to a high concentration solution. The membrane is permeable to water and some ions but rejects almost all ions and dissolved solids. This process (movement of water) occurs until the osmotic equilibrium is reached, or until the chemical potential is equal on both sides of the membrane.

- A difference of height is observed between both compartments when the chemical potential is equalized. The difference in height expresses the osmotic pressure difference between the two solutions.

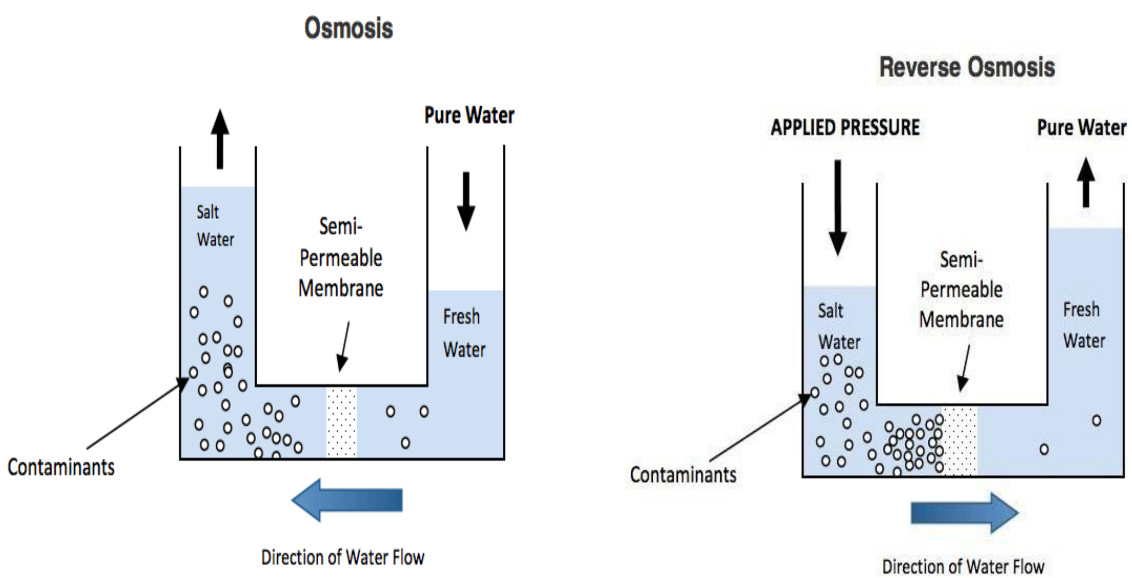


Fig-1.37- Osmosis principle

- Reverse osmosis is a process which occurs when pressure, greater than the osmotic pressure, is applied to the concentrated solution. Water is forced to flow from the concentrated to the diluted side, and solutes are retained by the membrane.

Working:

Reverse osmosis are applied as a cross-flow filtration process. With a high pressure pump, feed water is continuously pumped at elevated pressure to the membrane system. Within the membrane system, the feed water will be split into a low saline and/or purified products, called permeate, and a high saline or concentrated brine, called concentrate or reject. A flow regulating valve, called a concentrate valve, controls the percentage of feed water that is going to the concentrate stream and the permeate which will be obtained from the feed

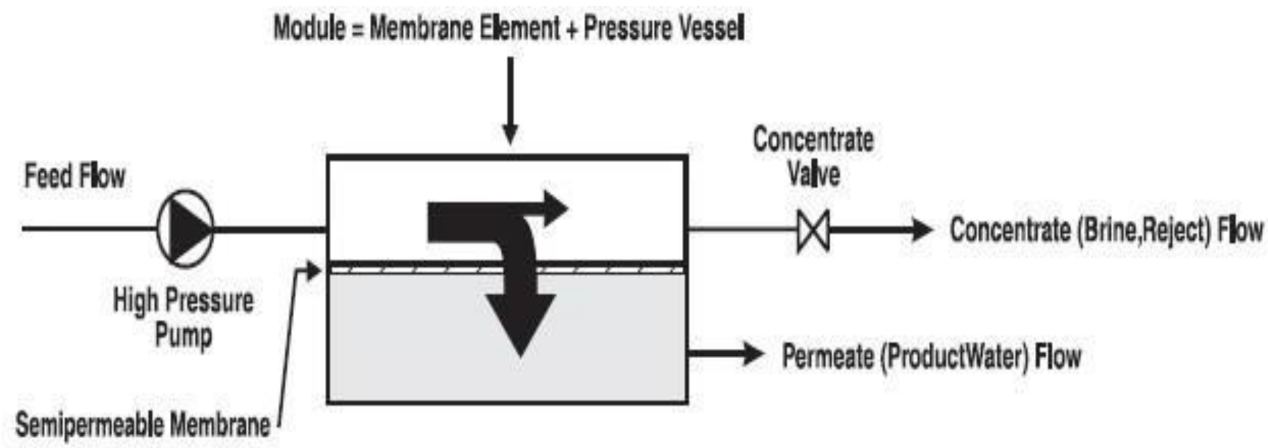


Fig-1.38- working of osmosis

DE-AERATION:

- The dissolved gases in water like O2, CO2, H2S, air, and other gases are responsible for corrosion since these react with impurities and form acids. Therefore, these gases are removed from water before supplied to the boiler by the method of **thermal treatment.**
- De-aeration is the process of removing dissolved corrosive gases from water. This process is called **degasification.** These corrosive gases make the water corrosive as they react with metal to form iron oxide.
- The removal of gases is accomplished by heating the water to 105-110 with subsequent agitation during heating.
- The arrangement of tray type de-aerator is shown in fig.
- It consists of a de- aerator column fitted on the top of the storage tank.

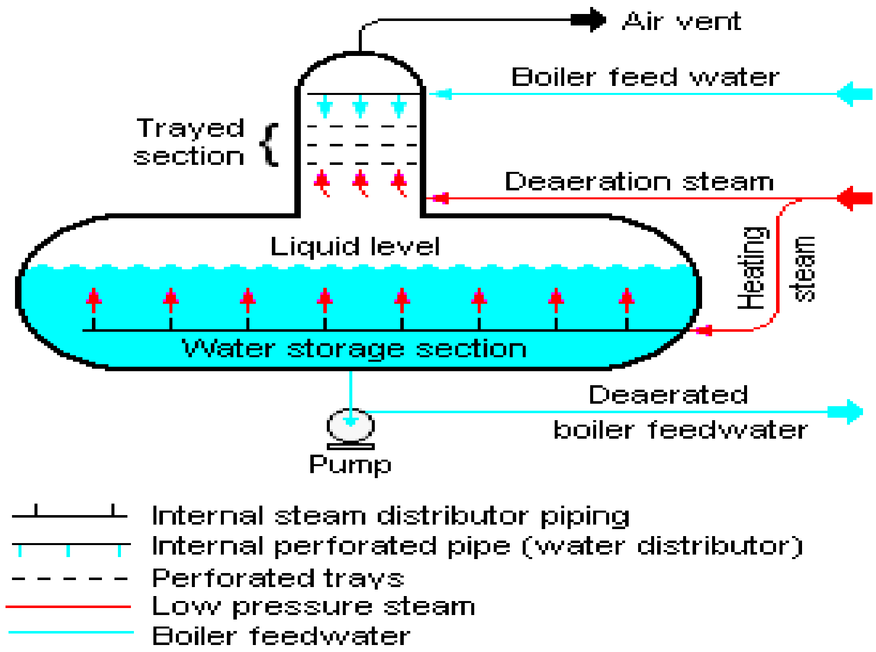


Fig-1.39- De-aeration process

- The de-aerator column is hollow cylindrical vessel provided with horizontal perforated trays, water distribution device at the top, and steam distributor at the bottom
- Feed water enters the de-aerator from the top and is evenly distributed by means of the distributing device into the perforated trays fitted at the bottom.
- Water fills the perforations and rains down and comes in contact with heating steam delivered into the lower portion of the de-aerator column through the steam distributor.
- As a result of heat exchange between the steam going up and the feed water system flowing down, the water gets heated up and its boiling points and the gases dissolved in it are transferred to the gas phase.
- These gases together with non-condensing vapour are vented into the atmosphere through a vent valve or pass into a vent condenser where the steam is condensed and the O_2 and CO_2 are vented.
- The de-aerated water is collected in the storage tank which is fitted with gauge glass and pressure gauge to avoid the formation of high pressure or vacuum in the de-aerator.
- With this type of de-aerator, the oxygen content can be reduced below 0.005 CC per litre. As CO_2 is also removed, the increase in pH value of water also gives an indication of de-aeration efficiency.

UNIT-II

INTERNAL COMBUSTION ENGINE PLANT:

DIESEL POWER PLANT:

INTRODUCTION: The oil engines and gas engines are called Internal Combustion Engines. In IC engines fuels burn inside the engine and the products of combustion form the working fluid that generates mechanical power. Whereas, in Gas Turbines the combustion occurs in another chamber and hot working fluid containing thermal energy is admitted in turbine.

Reciprocating oil engines and gas engines are of the same family and have a strong resemblance in principle of operation and construction.
The engines convert chemical energy in fuel in to mechanical energy.

A typical oil engine has:

1. Cylinder in which fuel and air are admitted and combustion occurs.
2. Piston, which receives high pressure of expanding hot products of combustion and the piston, is forced to linear motion.
3. Connecting rod, crankshaft linkage to convert reciprocating motion into rotary motion of shaft.
4. Connected Load, mechanical drive or electrical generator.
5. Suitable valves (ports) for control of flow of fuel, air, exhaust gases, fuel injection, and ignition systems.
6. Lubricating system, cooling system

In an engine-generator set, the generator shaft is coupled to the Engine shaft.

The main differences between the gasoline engine and the diesel engine are:

- A gasoline engine intakes a mixture of gas and air, compresses it and ignites the mixture with a spark. A diesel engine takes in just air, compresses it and then injects fuel into the compressed air. The heat of the compressed air lights the fuel spontaneously.

- A gasoline engine compresses at a ratio of 8:1 to 12:1, while a diesel engine compresses at a ratio of 14:1 to as high as 25:1. The higher compression ratio of the diesel engine leads to better efficiency.

- Gasoline engines generally use either carburetion, in which the air and fuel is mixed long before the air enters the cylinder, or port fuel injection, in which the fuel is injected just prior to the intake stroke (outside the cylinder). Diesel engines use direct fuel injection to the diesel fuel is injected directly into the cylinder.

- The diesel engine has no spark plug, that it intakes air and compresses it, and that it then injects the fuel directly into the combustion chamber (direct injection). It is the heat of the compressed air that lights the fuel in a diesel engine.

- The injector on a diesel engine is its most complex component and has been the subject of a great deal of experimentation in any particular engine it may be located in a variety of places. The injector has to be able to withstand the temperature and pressure inside the cylinder and still deliver the fuel in a fine mist. Getting the mist circulated in the cylinder so that it is evenly distributed is also a problem, so some diesel engines employ special induction valves, pre-combustion chambers or other devices to swirl the air in the combustion chamber or otherwise improve the ignition and combustion process.

- One big difference between a diesel engine and a gas engine is in the injection process. Most car engines use port injection or a carburetor rather than direct injection. In a car engine, therefore, all of the fuel is loaded into the cylinder during the intake stroke and then compressed. The compression of the fuel/air mixture limits the compression ratio of the engine, if it compresses the air too much, the fuel/air mixture spontaneously ignites and causes knocking. A diesel compresses only air, so the compression ratio can be much higher. The higher the compression ratio, the more power is generated.

- Some diesel engines contain a glow plug of some sort. When a diesel engine is cold, the compression process may not raise the air to a high enough temperature to ignite the fuel. The glow plug is an electrically heated wire (think of the hot wires you see in a toaster) that helps ignite the fuel when the engine is cold so that the engine can start.

- Smaller engines and engines that do not have such advanced computer controls, use glow plugs to solve the cold-starting problem.

- We recommend diesels due to their:
  (a) Longevity-think of an 18 wheeler capable of 1,000,000 miles of operation before major service)
  (b) Lower fuel costs (lower fuel consumption per kilowatt (kW) produced)
  (c) Lower maintenance costs-no spark system, more rugged and more reliable engine

Today's modern diesels are quiet and normally require less maintenance than comparably sized gas (natural gas or propane) units. Fuel costs per kW produced with diesels is normally thirty to fifty percent less than gas units. 1800 rpm water-cooled diesel units operate on average 12– 30,000 hours before major maintenance is required. 1800 rpm water-cooled gas units normally
Operate 6–10,000 hours because they are built on a lighter duty gasoline engine block. 3600 rpm air-cooled gas units are normally replaced not overhauled at 500 to 1500 hours.

Because the gas units burn hotter (higher btu of the fuel) you will see significantly shorter lives than the diesel units.

Diesel engine power plants are installed where

1. Supply of coal and water is not available in desired quantity.
2. Where power is to be generated in small quantity for emergency services.
3. Standby sets are required for continuity of supply such as in hospital, telephone exchange.

It is an excellent prime mover for electric generator capacities of from 100 hp to 5000 hp. The Diesel units used for electric generation are more reliable and long - lived piece of equipment compared with other types of plants.

OPERATING PRINCIPLE:

All the gas engines and o i l engines operate in the same general way. The working fluid undergoes repeated cycles. A thermodynamic cycle is composed of a series of sequential events in a closed loop on P-V or T-S diagram. A typical cycle has following distinct operations

1. Cylinder is charged
2. Cylinder contents are compressed
3. Combustion (Burning) of charge, creation of high pressure pushing the piston and expansion of products of combustion.
4. Exhaust of spent products of combustion to atmosphere. The route taken for these steps is illustrated conveniently on P-V diagram and T-S diagram for the cycle.

Various types of Gas Engines and Oil Engines have been developed and are classified on the basis of their operating cycles. Cycles are generally named after their Inventors e.g. Carnot Cycle; Diesel Cycle; Otto Cycle; Sterling Cycle; Brayton Cycle; Dual Cycle, etc.
New cycles are being developed for fuel saving and reduction of pollution.

Two principal categories of IC Engines are:
—Four Stroke Engines
—Two Stroke Engines

In a Four Stroke Engine Cycle, the piston strokes are used to obtain the four steps (intake, compression, expansion, exhaust) and one power stroke in two full revolutions of crankshaft.

In a Two Stroke Engine Cycle, one power stroke is obtained during each full revolution of the crankshaft.

This is achieved by using air pressure slightly above atmospheric to blow out exhaust gases out of the cylinder and fill the fresh charge (scavenging). The methods of scavenging include: Crankcase scavenging; blower scavenging. Other methods include Super Charging; Turbo Charging.

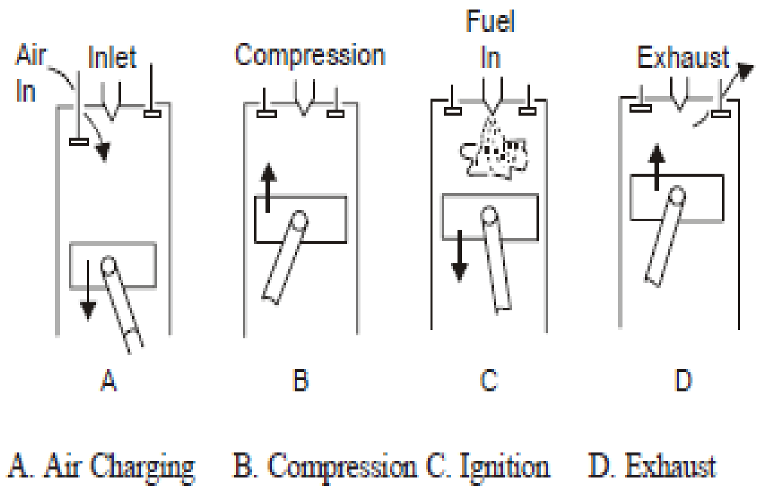


Fig-2.1-Illustrating operation of an IC Engine principle

BASIC TYPES OF IC ENGINES:

Although alike in main mechanical aspects, the oil engines differ from gas engines in fuels and fuel handling *i.e.*, when fuel and air are injected how much charge is compressed and how ignited. Many
Variants exist.

TWO-STROKE, SPARK IGNITION GAS ENGINES/PETROL ENGINES

The well-known automobile engine fueled with petrol (also called Gas) and Natural Gas Engine, Bio- gas Engine is of this category. The low compression gas engine (petrol engine/natural gas engine) mixes fuel and air, outside the cylinder, before compression. With the automobile engine, a carburetor is used for mixing the fuel and air and the mixture is injected in the cylinder. In a Natural Gas Engine, a mixing valve is used for the same purpose instead of the carburetor.

In the mixture, the gas fuel and air proportion is almost perfect to produce complete combustion without excess air. This mixture flows into the cylinder and is then compressed. Near the end of the compression stroke, an electric spark ignites the inflammable mixture, which burns rapidly.
The pressure in the cylinder rises rapidly and acts on the piston area and the piston is forced to move down on its power stroke.

Since the compressed gas mixture rises in pressure during the compression stroke, the mixture may get pre-ignited before the sparking resulting in loss of power. Hence compression pressure must be limited in this type of engine. Compression Ratio is therefore an important parameter in establishing combustion without pre-ignition.

The compression ratio is the ratio of cylinder volumes at the start and at the end of compression stroke. In general, higher the compression ratio, higher will be the maximum pressure reached during combustion and higher is the efficiency of the engine.

Although it is desirable to have a high compression ratio, the nature of fuel imposes limits in engines where a nearly perfect mixture is compressed. With natural gas for example the compression ratio might be about 5:1 and compression pressure of about 8 bar, pre-ignition being the limiting factor.

DIESEL ENGINES/HEAVY OIL ENGINES

In contrast to the engines in which the fuel and air mixes before compression, in diesel engines: air is compressed as the compression stroke begins and the fuel enters the cylinder at the end of compression stroke. Heat of compression is used for ignition of fuel. In a typical diesel engine, air is compressed to about 30 bars, which increases the temperature when finely atomized diesel fuel oil is sprayed into the heated air, it ignites and burns. High compression ratio is therefore essential for reliable combustion and high efficiency. Compression ratios above those needed to achieve ignition do not improve the efficiency.

The pressure ratio depends on engine speed, cylinder size and design factors. Typical compression pressures in diesel engines range from 30 bar to 42 bar. Small high-speed engines have higher compression pressures.

DUEL FUEL ENGINES

In a duel fuel engine, a small quantity of pilot oil is injected near the end of the compression stroke. It is ignited by the compression and the mixture burns like standard diesel fuel. The pilot oil burning provides enough heat to the mixture of gas/air. Precise control of pilot oil injection and a separate set of fuel pumps and nozzles are added. Means are provided to reduce air quantity at partial loads.

HIGH COMPRESSION GAS ENGINES

With operation solely on gas, without duel mixtures and pilot oil, the high Compression Gas Engines of today use slightly richer mixtures of fuel and air, with lower compression ratios than duel fuel engines. The compression ratios are higher than conventional gas engines and lower than duel fuel engines. There is no need of pilot oil.

The **advantages** of diesel power plants are listed below:

1. Very simple design also simple installation.
2. Limited cooling water requirement.
3. Standby losses are less as compared to other Power plants.
4. Low fuel cost.

5. Quickly started and put on load.
6. Smaller storage is needed for the fuel.
7. Layout of power plant is quite simple.
8. There is no problem of ash handling.
9. Less supervision required.
10. For small capacity, diesel power plant is more efficient as compared to steam power plant.
11. They can respond to varying loads without any difficulty.

The **disadvantages** of diesel power plants are listed below:

1. High Maintenance and operating cost.
2. Fuel cost is more, since in India diesel iscostly.
3. The plant cost per kW is comparatively more.
4. The life of diesel power plant is small due to high maintenance.
5. Noise is a serious problem in diesel powerplant.
6. Diesel power plant cannot be constructed for large scale.

LAYOUT OF DIESEL POWER PLANTS WITH AUXILLIARIES:

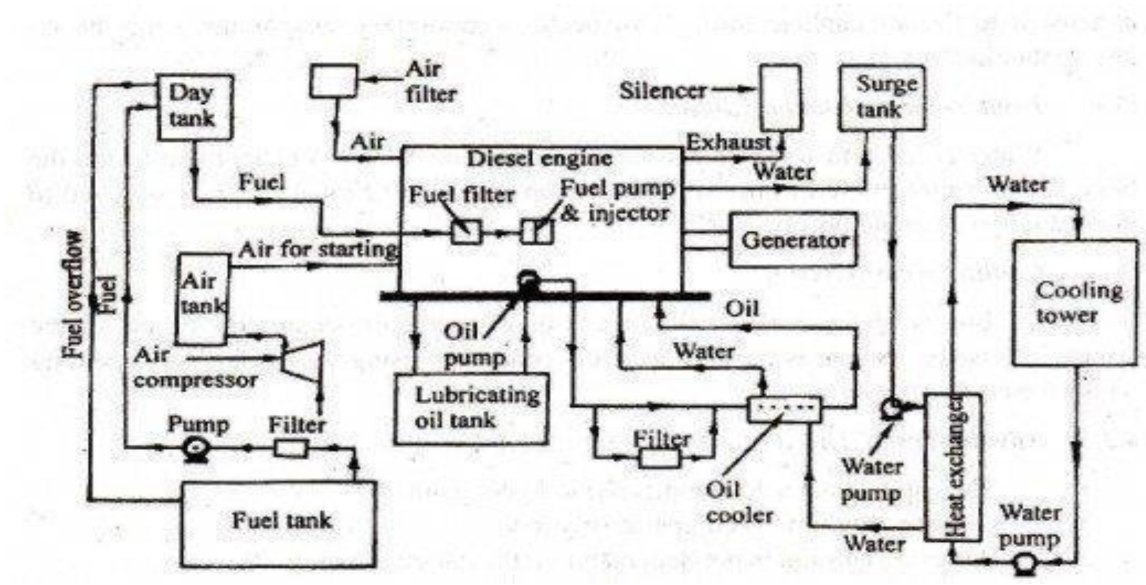


Fig-2.2-Layout of diesel plant

Since there are many disadvantage of diesel power plant, although the plant find wide **applications** in the following fields:

1. They are quite suitable for mobile power generation and are widely used in Transportation systems consisting of railroads, ships, automobiles and aeroplanes.

2. They can be used for electrical power generation in capacities from 100 to 5000 H.P.
3. They can be used as standby power plants.
4. They can be used as peak load plants for some other types of power plants.

FUEL SUPPLY SYSTEM:

The fuel is delivered to the plant by railroad tank car, by truck or by barge and tanker and stored in the bulk storage situated outdoors for the sake of safety. From this main fuel tank, the fuel oil is transferred to the daily consumption tank by a transfer pump through a filter.

The capacity of the daily consumption should be atleast the 8-hour requirement of the plant. This tank is located either above the engine level so that the fuel flows by gravity to the injection pump or below the engine level and the fuel oil is delivered to the injection pump by a transfer pump driven from the engine shaft, Fig**. 8.3**. Fuel connection is normally used when tank-car siding or truck roadway is above tank level. If it is below tank level, then, an unloading pump is used to transfer fuel form tank car to the storage tank (dotted line).

The five **essential functions** of a fuel injection system are:

1. To deliver oil from the storage to the fuel injector.
2. To raise the fuel pressure to the level required for atomization.
3. To measure and control the amount of fuel admitted in each cycle.
4. To control time of injection.
5. To spray fuel into the cylinder in atomized form for thorough mixing and burning.

The above functions can be achieved in a variety of ways. The following are the systems, which are usual on power station diesels:

1. Common Rail.
2. Individual Pump Injection.
3. Distributor.

1. COMMON RAIL INJECTION

A typical common rail injection system is shown in Fig.2.3. It incorporates a pump with built in pressure regulation, which adjusts pumping rate to maintain the desired injection pressure. The function of the pressure relief and timing valves is to regulate the injection time and amount. Spring-loaded spray valve acts merely as a check. When injection valve lifts to admit high-pressure fuel to spray valve, its needle rises against the spring. When the pressure is vented to the atmosphere, the spring shuts the valve.

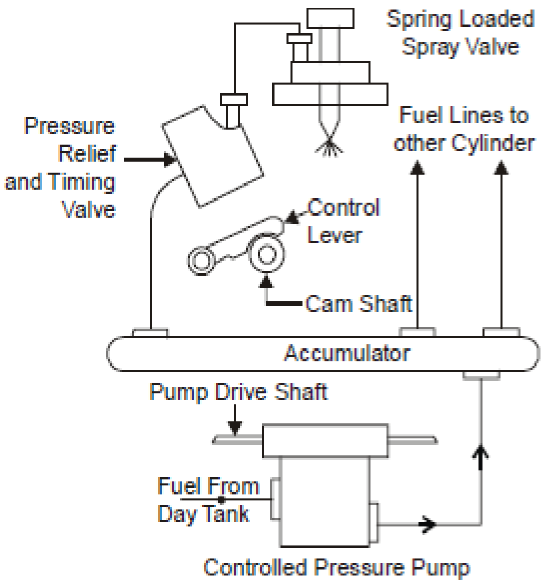


Fig-2.3- Common rail system

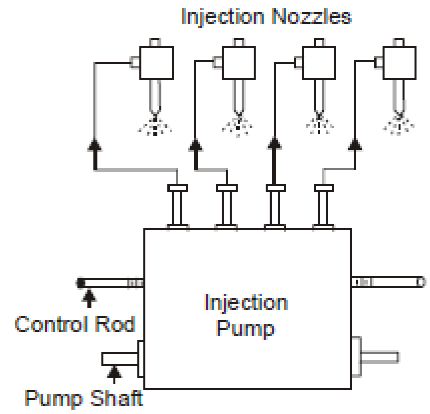


Fig-2.4- Individual system

2. INDIVIDUAL PUMP INJECTION

In this system, each fuel nozzle is connected to a separate injection pump, Fig.2.4. The pump itself does the measuring of the fuel charge and control of the injection timing. The delivery valve in the nozzle is actuated by fuel-oil pressure.

3. DISTRIBUTOR SYSTEM

This system is shown in Fig.2.5**.** In this system, the fuel is metered at a central point *i.e.*, the pump that pressurizes, meters the fuel and times the injection. From here, the fuel is distributed to cylinders in correct firing order by cam operated poppet valves, which open to admit fuel to nozzles.

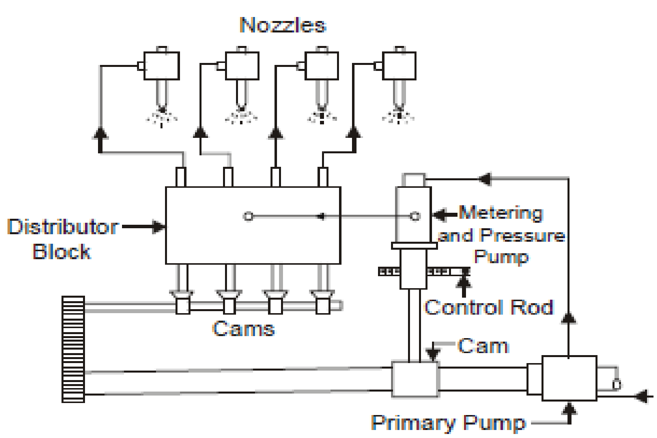


Fig-2.5-Distributor System

LUBRICATION SYSTEM OF DIESEL POWER PLANT:

Since frictional forces causes wear and tear of rubbing parts of the engine and thereby the life of the engine is reduced. So the rubbing part requires that some substance should be introduced between the rubbing surfaces in order to decrease the frictional force between them. Such substance is called lubricant. The lubricant forms a thin film between the rubbing surfaces. And lubricant prevents metalto- metal contact. So we can say "Lubrication is the admission of oil between two surface having relative motion".
The main function of lubricant is to,

1. To reduce friction and wear between the parts having relative motion by minimizing the force of friction and ensures smooth running of parts.
2. To seal a space adjoining the surfaces such as piston rings and cylinder liner.
3. To clean the surface by carrying away the carbon and metal particles caused by wear.
4. To absorb shock between bearings and other parts and consequently reduce noise.
5. To cool the surfaces by carrying away heat generated due to friction.
6. It helps the piston ring to seal the gases in the cylinder.
7. It removes the heat generated due to friction and keeps the parts cool.

The various parts of an engine requiring lubrication are:

1. Cylinder walls and pistons.
2. Main crankshaft bearings.
3. Piston rings and cylinder walls.
4. Big end bearing and crank pins.
5. Small end bearing and gudgeon pin bearings.
6. Main bearing cams and bearing valve tappet and guides
7. Timing gears etc.
8. Camshaft and cam shaft bearings.
9. Valve mechanism and rocker arms.

A good lubricant should possess the following properties:

1. It should not change its state with change in temperature.
2. It should maintain a continuous film between the rubbing surfaces.
3. It should have high specific heat so that it can remove maximum amount of heat.
4. It should be free from corrosive acids.
5. The lubricant should be purified before it enters the engine.
6. It should be free from dust, moisture, metallic chips, etc.
7. The lubricating oil consumed is nearly 1% of fuel consumption.
8. The lubricating oil gets heated because of friction of moving parts and should be cooled before recirculation.

The cooling water used in the engine may be used for cooling the lubricant. Nearly 2.5% of heat of fuel is dissipated as heat, which is removed by the lubricating oil.

The various lubricants used in engines are of three types:

1. Liquid Lubricants or Wet sump lubrication system.
2. Solid Lubricants or Dry sump lubrication system.
3. Semi-solid Lubricants or Mist lubrication system.

Liquid oils lubricants are most commonly used.

Liquid lubricants are of two types: (*a*) Mineral oils (*b*) Fatty oils.

Graphite, white lead and mica are the solid lubricants.Semi solid lubricants or greases as they are often called are made from mineral oils and fatty-oils.In this system, the oil from the sump is carried to a separate storage tank outside the engine cylinder block.

The oil from sump is pumped by means of a sump pump through filters to the storage tank. Oil from storage tank is pumped to the engine cylinder through oil cooler. Oil pressure may vary from 3 to 8 kgf/cm2. Dry sump lubrication system is generally adopted for high capacity engines.

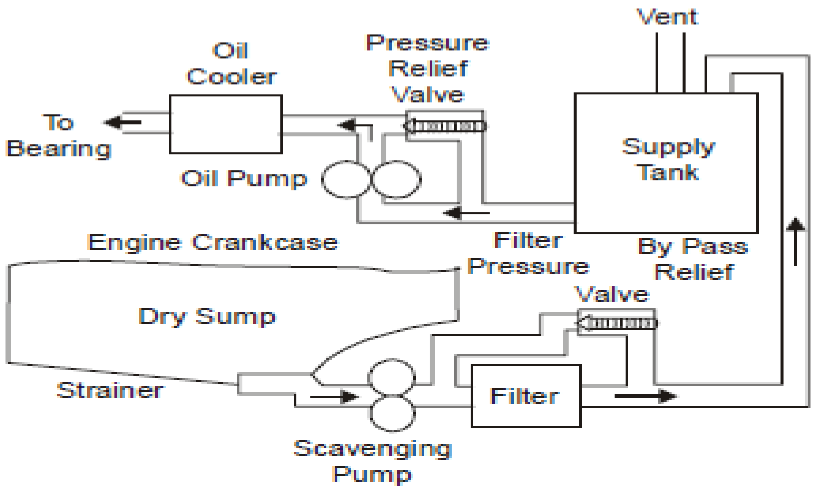


Fig-2.6-Lubrication system

AIR INTAKES AND ADMISSION SYSTEM OF DIESELPOWER PLANT

Generally a large diesel engine requires 0.076 to 0.114 m3 of air per min per kw of power developed.

The fresh air is drawn through pipes or ducts or filters. The purpose of the filter is to catch any air borne dirt as it otherwise may cause the wear and tear of the engine. The filters may be of dry or oil bath. The filters should be cleaned periodically. 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 seize 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. Lightweight steel pipe is the material for intake ducts.

Since the noise may be transmitted back to the outside air via the air intake. So, A silencer is needed in between the engine and the intake system. There should be minimum pressure loss in the air intake system, otherwise specific fuel consumption will increase and the engine capacity is reduced.

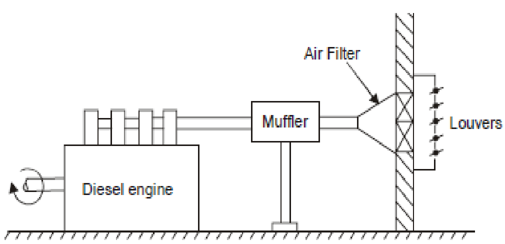


Fig-2.7-Air Intake System

The air intake system conveys fresh air through pipes or ducts to:

1. Air-intake manifold of four-stroke engine.
2. The scavenging pump inlet of a two-stroke engine.
3. The supercharger inlet of a supercharged engine.

The air intake may be located:

(a) Very Near the ground and outside the plant building.

(b) In the building roof.

(c) On the building roof.

(d) Inside the engine room.

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

1. They do not locate the air-intakes inside the engine room.
2. Do not take air from a confined space as otherwise serious vibration problems can occur due to air pulsations.
3. Do not use air-intake line with too small a diameter or which is too long, otherwise engine starvation might occur.
4. Do not install air-intake filters in an inaccessible location.
5. Do not locate the air intake filters close to the roof of the engine room since serious vibrations of the roof may occur due to pulsating airflow through the filters.

EXHAUST SYSTEM OF DIESEL POWER PLANT:

The purpose of the exhaust system is to discharge the engine exhaust to the atmosphere outside the main building.

For designing of exhaust system of a big power plant, following points should be taken into consideration.

1. Exhaust noise should be reduced to a tolerable degree.
2. To reduce the air pollution at breathing level, Exhaust should be exhausted well above the ground level

3. Pressure loss in the system should be reduced to minimum.

4. By use of flexible exhaust pipe, the vibrations of exhaust system must be isolated from the plant.

5. A provision should be made to extract the heat from exhaust if the heating is required for fuel oil heating or building heating or process heating.

In many cases, we have seen that the temperature of the exhaust gases under full load conditions may be of the order of 400°C. With the recovery of heat from hot jacket water and exhaust gases and its use either for heating oil or buildings in cold weather increase the thermal efficiency to 80%. Nearly 40% of the heat in the fuel can be recovered from the hot jacket water and exhaust gases. The heat from the exhaust can also be used for generating the steam at low pressure that can be used for process heating. Nearly 2 kg of steam at 8 kg/cm2 can be generated per kW per hour, when the mass of exhaust gases can be taken as 10 kg/kW hr.

COOLING SYSTEM OF DIESEL POWER PLANT

During combustion process the peak gas temperature in the cylinder of an internal combustion engine is of the order of 2500 K. Maximum metal temperature for the inside of the combustion chamber space are limited to much lower values than the gas temperature by a large number of considerations and thus cooling for the cylinder head, cylinder and piston must therefore be provided. Necessity of engine cooling arises due to the following facts

- During combustion period, the heat fluxes to the chamber walls can reach as high as 10 mW/m2. The flux varies substantially with location. The regions of the chamber that are contacted by rapidly moving high temperature gases generally experience the highest fluxes. In region of high heat flux, thermal stresses must be kept below levels that would cause fatigue cracking. So temperatures must be less than about 400°C for cast iron and 300°C for aluminium alloy for water cooled engines. For air-cooled engines, these values are 270°C and 200°C respectively.
- The gas side surface temperature of the cylinder wall is limited by the type of lubricating oil used and this temperature ranges from 160°C to 180°C. Beyond these temperature, the properties of lubricating oil deteriorates very rapidly and it might even evaporates and burn, damaging piston and cylinder surfaces. Piston seizure due to overheating resulting from the failure of lubrication is quite common.
- The valves may be kept cool to avoid knock and pre-ignition problems which result from overheated exhaust valves (true for S.I. engines).
- The volumetric and thermal efficiency and power output of the engines decrease with an increase in cylinder and head temperature.

Based on cooling medium two types of cooling systems are in general use. They are

(a) Air as direct cooling system.

(b) Liquid or indirect cooling system.

Air-cooling is used in small engines and portable engines by providing fins on the cylinder. Big diesel engines are always liquid (water/special liquid) cooled.

Liquid cooling system is further classified as

(1) Open cooling system

(2) Natural circulation (Thermo-system)

(3) Forced circulation system

(4) Evaporation cooling system.

OPEN COOLING SYSTEM

This system is applicable only where plenty of water is available. The water from the storage tank is directly supplied through an inlet valve to the engine cooling water jacket. The hot water coming out of the engine is not cooled for reuse but it is discharged.

NATURAL CIRCULATION SYSTEM: The system is closed one and designed so that the water may circulate naturally because of the difference in density of water at different temperatures. Fig.2.8 shows a natural circulation cooling system. It consists of water jacket, radiator and a fan. When the water is heated, its density decreases and it tends to rise, while the colder molecules tend to sink. Circulation of water then is obtained as the water heated in the water jacket tends to rise and the water cooled in the radiator with the help of air passing over the radiator either by ram effect or by fan or jointly tends to sink. Arrows show the direction of natural circulation, which is slow.

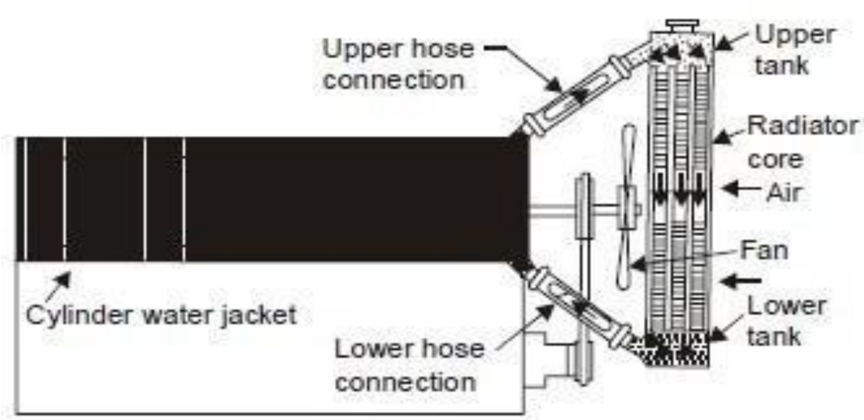


Fig-2.8-Natural Circulation Cooling System

FORCED CIRCULATION COOLING SYSTEM

Fig.2.9 shows forced circulation cooling system that is closed one. The system consists of pump, water jacket in the cylinder, radiator, fan and a thermostat.

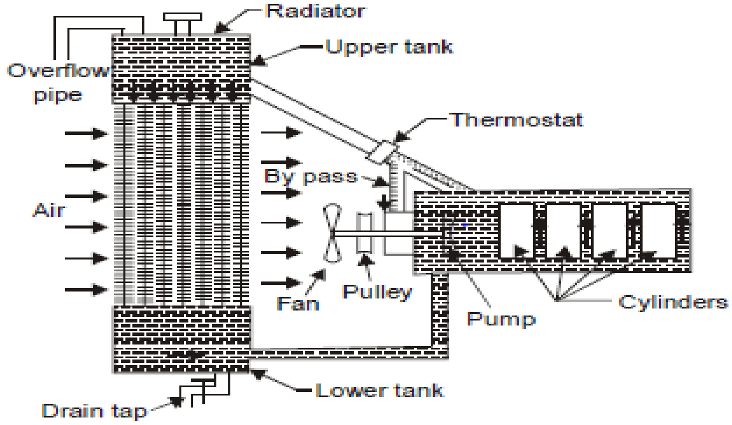


fig-2.9-forced circulation

The coolant (water or synthetic coolant) is circulated through the cylinder jacket with the help of a pump, which is usually a centrifugal type, and driven by the engine. The function of thermostat, which is fitted in the upper hose connection initially, prevents the circulation of water below a certain temperature (usually upto 85°C) through the radiation so that water gets heated up quickly.

Standby diesel power plants upto 200 kVA use this type of cooling. In the case of bigger plant, the hot water is cooled in a cooling tower and recirculated again. There is a need of small quantity of cooling make-up water.

DIESEL PLANT OPERATION:

When diesel alternator sets are put in para lel, "hunting" or "phase swing may be produced due to resonance unless due care is taken in the design and manufacture of the sets. This condition occurs due to resonance between the periodic disturbing forces of the engine and natural frequency of the system. The engine forces result from uneven turning moment on the engine crank which are corrected by the flywheel effect. "Hunting" results from the tendency of each set trying to pull the other into synchronism and is characterized by flickering of lights.

To ensure most economical operation of diesel engines of different sizes when working together and sharing load it is necessary that they should carry the same percentage of their full load capacity at all times as the fuel consumption would be lowest in this condition. For best, operation performance the manufacturer's recommendations should be strictly followed.
In order to get good performance of a diesel power plant the following points should be taken care of:

- It is necessary to maintain the cooling temperature within the prescribed range and use of very cold water should be avoided. The cooling water should be free from suspended impurities and suitably treated to be scale and corrosion free. If the ambient temperature approaches freezing point, the cooling water should be drained out of the engine when it is kept idle.

- During operation the lubrication system should work effectively and requisite pressure and temperature maintained. The engine oil should be of the correct specifications and should be in a fit. Condition to lubricate the different parts. A watch may be kept on the consumption of lubricating oil as this gives an indication of the true internal condition of the engine.

SUPER CHARGING OF DIESEL PLANT:

The purpose of supercharging is to raise the volumetric efficiency above that value which can be obtained by normal aspiration. Since the I.H.P. produced by an I.C. engine is directly proportional to the air consumed by the engine. And greater quantities of fuel to be added by increasing the air consumption permit and result in greater power produced by the engine. So, it is, therefore, desirable that the engine should take in the greatest possible mass of air. The supply of air is pumped into the cylinder at a pressure greater than the atmospheric pressure and is called supercharging. When greater quantity of air is supplied to an I.C. engine it would be able to develop more power for the same size and conversely a small size engine fed with extra air would produce the same power as a larger engine supplied with its normal air feed.

Supercharging is used to increase rated power output capacity of a given engine or to make the rating equal at high altitudes corresponding to the unsupercharged sea level rating. Installing a super charger between engine intakes does supercharging and air inlet through air cleaner super charger is merely a compressor that provides a denser charge to the engine thereby enabling the consumption of a greater mass of charge with the same total piston displacement. Power required to drive the super charger is taken from the engine and thereby removes from over all engine output some of the gain in power obtained through supercharging.

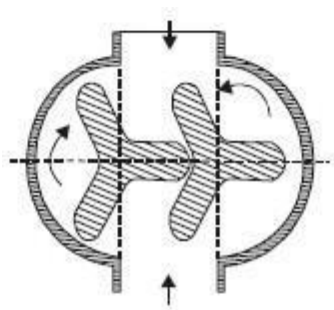
Since the main object of supercharging is to increase the power output of these engine without increasing its rotational speed or the dimensions of the cylinder. This is achieved by increasing the charge of air, which results more burning of the fuel and a higher mean effective pressure. So there are three possible methods that increase the air consumption of an engine,

- To increasing the piston displacement, but this increases the size and weight of the engine, and introduces additional cooling problems.
- Running the engine at higher speeds, which results in increased fluid and mechanical friction losses, and imposes greater inertia stresses on engine parts.
- Increasing the density of the charge, such that a greater mass of charge is introduced into the same volume or same total piston displacement.

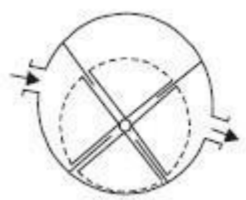
TYPES OF SUPERCHARGER

Supercharging is done by means of compressor; there are two types of compressors that may be used as super chargers. They are as follows:

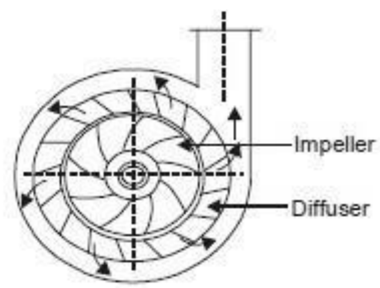
1. Positive displacement type super chargers.
   (a) Piston Cylinder type
   (b) Roots blowers
   (c) Vane blower
2. Centrifugal type super chargers or turbo type.
3. Turbo type superchargers.



Root blowers



Vane blower



Centrifugal types

The blowers are usually driven from the engine cranks shaft by mean of Spur, helical or herringbone gears, silent chains or V-belts at a speed 2-3 times the engine speed. In the case of turbo-supercharger, the super charger is coupled to a gas turbine in which the exhaust of the engine is expanded.

The positive displacement types are used for low and medium speed engines with speeds not over 4000 rev/min. Positive displacement type used with many reciprocating engines in stationary plants, vehicles and marine installations.The piston cylinder type is used on large and slow speed stationary engines, but their use is limited since they are bulkier, more expensive and less dependable than the rotary type blowers.

Centrifugal blowers are used both on low speed and high-speed engines. Centrifugal blowers driven by exhaust gas turbine are small and light and are used for stationary, locomotive, and marine and aircraft engine. The speed of the centrifugal type of blowers is high about 10000 to 15000 rev/min for low speed engines and 15000 to 30000 rev/min for high-speed engines such as aircraft engines.

Centrifugal type widely used as the supercharger for reciprocating engines, as well as compressor for gas turbines. It is almost exclusively used as the supercharger with reciprocating power plants for aircraft because it is relatively light and compact, and produces continuous flow rather than pulsating flow as in some positive displacement types.

ADVANTAGES OF SUPERCHARGING:

Due to a number of advantages of supercharging the modern diesel engines used in diesel plants are generally supercharged. The various advantages of supercharging are as follows:

1. **Power Increase.** Mean effective pressure of the engine can be easily increased by 30 to 50% by supercharging which will result in the increase the power output.
2. **Fuel Economy.** Due to better combustion because of increased turbulence, better mixing of the fuel and air, and of an increased mechanical efficiency, the specific fuel consumption in most cases, though supercharging reduces not all.
3. **Mechanical Efficiency.** The mechanical efficiency referred to maximum load is increased since the increase of frictional losses with a supercharger driven directly from the engine is quite smaller as compared to the power gained by supercharging.
4. **Fuel Knock.** It is decreased due to increased compression pressure because increasing the inlet pressure decreases the ignition lag and this reduces the rate of pressure rise in the cylinder resulting in increasing smoothness ofoperation.
5. **Volumetric Efficiency.** Volumetric efficiency is increased since the clearance gases are compressed by the induced charge that is at a higher pressure than the exhaust pressure.

GAS TURBINE PLANT:

INTRODUCTION:

The gas turbine obtains its power by utilizing the energy of burnt gases and air, which is at high temperature and pressure by expanding through the several ring of fixed and moving blades. It thus resembles a steam turbine. To get a high pressure (of the order of 4 to 10 bar) of working fluid, which is essential for expansion a compressor, is required.

The quantity of the working fluid and speed required are more, so, generally, a centrifugal or an axial compressor is employed. The turbine drives the compressor and so it is coupled to the turbine shaft. If after compression the working fluid were to be expanded in a turbine, then assuming that there were no losses in either component the power developed by the turbine would be just equal to that absorbed by the compressor and the work done would be zero. But increasing the volume of the working fluid at constant pressure, or alternatively increasing the pressure at constant volume can increase the power developed by the turbine. Adding heat so that the temperature of the working fluid is increased after the compression may do either of these.

To get a higher temperature of the working fluid a combustion chamber is required where combustion of air and fuel takes place giving temperature rise to the working fluid.

Thus, a simple gas turbine cycle consists of

(1) A compressor,
(2) A combustion chamber and
(3) A turbine.

Since the compressor is coupled with the turbine shaft, it absorbs some of the power produced by the turbine and hence lowers the efficiency. The network is therefore the difference between the turbine work and work required by the compressor to drive it.

Gas turbines have been constructed to work on the following: oil, natural gas, coal gas, producer gas, blast furnace and pulverized coal.

CLASSIFICATION OF GAS TURBINE POWER PLANT

The gas turbine power plants which are used in electric power industry are classified into two groups as per the cycle of operation.

(a) Open cycle gas turbine.
(b) Closed cycle gas turbine.

OPEN CYCLE GAS TURBINE POWER PLANT

A simple open cycle gas turbine consists of a compressor, combustion chamber and a turbine as shown in Fig. 2.10. The compressor takes in ambient air and raises its pressure. Heat is added to the air in combustion chamber by burning the fuel and raises its temperature.

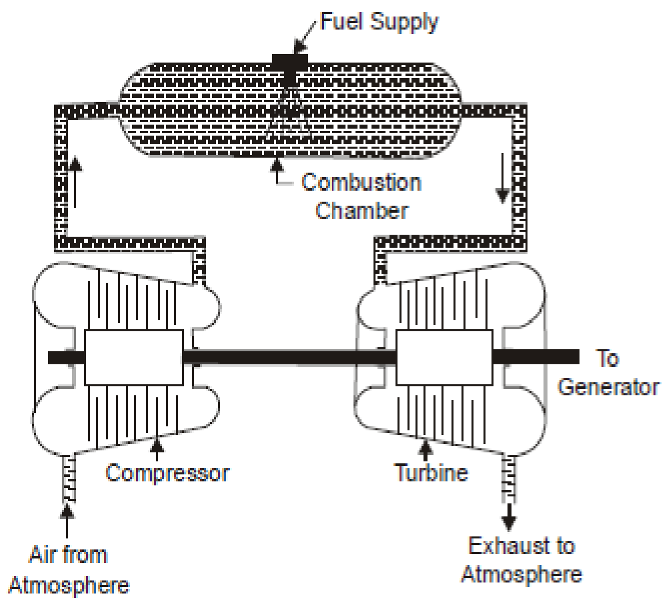


Fig-2.10-Open Cycle Gas Turbine

The heated gases coming out of combustion chamber are then passed to the turbine where it expands doing mechanical work. Part of the power developed by the turbine is utilized in driving the compressor and other accessories and remaining is used for power generation. Since ambient air enters into the compressor and gases coming out of turbine are exhausted into the atmosphere, the working medium must be replaced continuously. This type of cycle is known as open cycle gas turbine plant and is mainly used in majority of gas turbine power plants as it has many inherent advantages.

(A) Advantages

1. **Warm-up time.** Once the turbine is brought up to the rated speed by the starting motor and the fuel is ignited, the gas turbine will be accelerated from cold start to full load without warm-up time.
2. **Low weight and size.** The weight in kg per kW developed is less.
3. **Fuels.** Almost any hydrocarbon fuel from high-octane gasoline to heavy diesel oils can be used in the combustion chamber.
4. Open cycle plants occupy comparatively little space.
5. The stipulation of a quick start and take-up of load frequently are the points in favour of open cycle plant when the plant is used as peak load plant.

6. Component or auxiliary refinements can usually be varied to improve the thermal efficiency and give the most economical overall cost for the plant load factors and other operating conditions envisaged.
7. Open-cycle gas turbine power plant, except those having an intercooler, does not require cooling water. Therefore, the plant is independent of cooling medium and becomes self-contained.

(B) Disadvantages:

1. The part load efficiency of the open cycle plant decreases rapidly as the considerable percentage of power developed by the turbine is used to drive the compressor.
2. The system is sensitive to the component efficiency; particularly that of compressor. The open cycle plant is sensitive to changes in the atmospheric air temperature, pressure and humidity.
3. The open-cycle gas turbine plant has high air rate compared to the other cycles, therefore, it results in increased loss of heat in the exhaust gases and large diameter ductwork is necessary.
4. It is essential that the dust should be prevented from entering into the compressor in order to minimize erosion and depositions on the blades and passages of the compressor and turbine and so impairing their profile and efficiency. The deposition of the carbon and ash on the turbine blades is not at all desirable as it also reduces the efficiency of the turbine.

CLOSED CYCLE GAS TURBINE POWER PLANT

Closed cycle gas turbine plant was originated and developed in Switzerland. In the year 1935, J. Ackeret and C. Keller first proposed this type of machine and first plant was completed in Zurich in1944.

It used air as working medium and had a useful output of 2 mW. Since then, a number of closed cycle gas turbine plants have been built all over the world and largest of 17 mW capacity is at Gelsenkirchen, Germany and has been successfully operating since 1967. In closed cycle gas turbine plant, the working fluid (air or any other suitable gas) coming out from compressor is heated in a heater by an external source at constant pressure. The high temperature and high-pressure air coming out from the external heater is passed through the gas turbine. The fluid coming out from the turbine is cooled to its original temperature in the cooler using external cooling source before passing to the compressor.

The working fluid is continuously used in the system without its change of phase and the required heat is given to the working fluid in the heat exchanger.

The arrangement of the components of the closed cycle gas turbine plant is shown in Fig.2.11

(A) Advantages

1. The inherent disadvantage of open cycle gas turbine is the atmospheric backpressure at the turbine exhaust. With closed cycle gas turbine plants, the backpressure can be increased. Due to the control on backpressure, unit rating can be increased about in proportion to the backpressure. Therefore the machine can be smaller and cheaper than the machine used to develop the same power using open cycle plant.
2. The closed cycle avoids erosion of the turbine blades due to the contaminated gases and fouling of compressor blades due to dust. Therefore, it is practically free from deterioration of efficiency in service. The absence of corrosion and abrasion of the interiors of the compressor and turbine extends the life of the plant and maintains the efficiency of the plant constant throughout its life as they are kept free from the products of combustion.
3. The need for filtration of the incoming air which is a severe problem in open cycle plant is completely eliminated.
4. Load variation is usually obtained by varying the absolute pressure and mass flow of the circulating medium, while the pressure ratio, the temperatures and the air velocities remain almost constant.

   This result in velocity ratio in the compressor and turbine independent of the load and full load thermal efficiency maintained over the full range of operating loads.
5. The density of the working medium can be maintained high by increasing internal pressure range, therefore, the compressor and turbine are smaller for their rated output. The high density of the working fluid further increases the heat transfer properties in the heat exchanger.
6. As indirect heating is used in closed cycle plant, the inferior oil or solid fuel can be used in the furnace and these fuels can be used more economically because these are available in abundance.
7. Finally the closed cycle opens the new field for the use of working medium (other than air as argon, CO_2, helium) having more desirable properties. The ratio γ of the working fluid plays an important role in determining the performance of the gas turbine plant. An increase in γ from 1.4 to 1.67 (for argon) can bring about a large increase in output per kg of fluid circulated and thermal efficiency of the plant.

   The theoretical thermal efficiencies of the monoatomic gases will be highest for the closed cycle type gas turbine. Further, by using the relatively dense inert gases, such as argon, krypton and xenon, the advantage of smaller isentropic heat fall and smaller cross- sectional flow areas would be realised: Whether CO_2 or Helium should be adopted as working medium is matter of controversy at present. Blade material poses a problem to use helium as working fluid. In case of CO_2, a new kind of compressor must be designed to compress the fluid. The main advantage of CO_2 is that it offers 40% efficiency at 700°C whereas helium would need 850°C or more to achieve the same efficiency. A helium turbine would also need to run faster imposing larger stresses on the rotor.

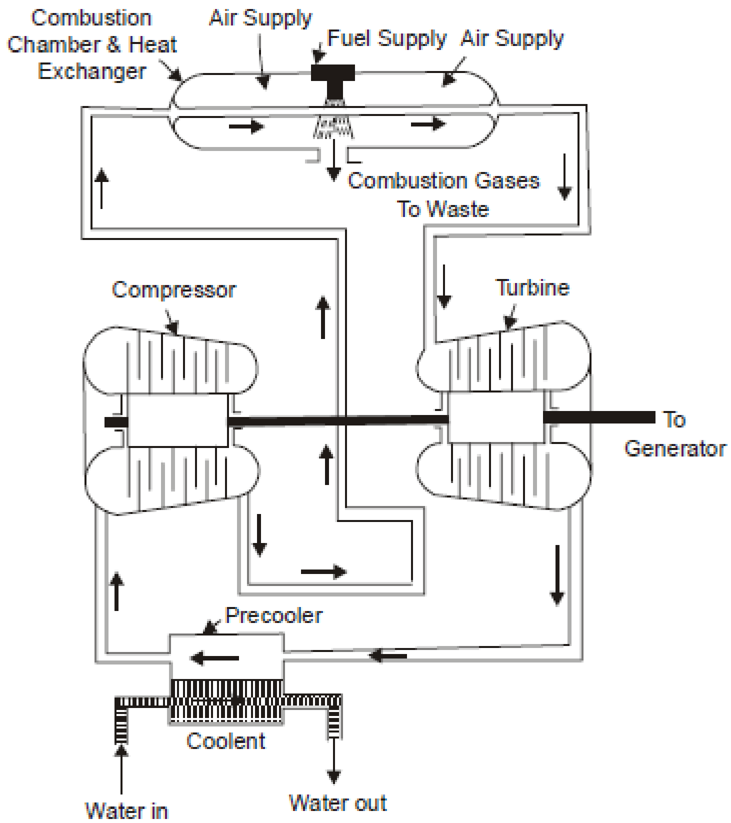


Fig-2.11-Closed Cycle

8. The maintenance cost is low and reliability is high due to longer useful life.
9. The thermal efficiency increases as the pressure ratio (R*p*) decreases. Therefore, appreciable higher thermal efficiencies are obtainable with closed cycle for the same maximum and minimum temperature limits as with the open cycle plant.
10. Starting of plane is simplified by reducing the pressure to atmospheric or even below atmosphere so that the power required for starting purposes is reduced considerably.

Disadvantages

1. The system is dependent on external means as considerable quantity of cooling water is required in the pre-cooler.
2. Higher internal pressures involve complicated design of all components and high quality material is required which increases the cost of the plant.
3. The response to the load variations is poor compared to the open-cycle plant,
4. It requires very big heat-exchangers as the heating of workings fluid is done indirectly. The space required for the heat exchanger is considerably large. The full heat of the fuel is also not used in this plant.

The closed cycle is only preferable over open cycle where the inferior type of fuel or solid fuel is to be used and ample cooling water is available at the proposed site of the plant.

COMBINED CYCLE POWER PLANTS

It has been found that a considerable amount of heat energy goes as a waste with the exhaust of the gas turbine. This energy must be utilized. The complete use of the energy available to a system is called the total energy approach. The objective of this approach is to use all of the heat energy in a power system at the different temperature levels at which it becomes available to produce work, or steam, or
the heating of air or water, thereby rejecting a minimum of energy waste. The best approach is the use of combined cycles.

There may be various combinations of the combined cycles depending upon the place or country requirements. Even nuclear power plant may be used in the combined cycles.

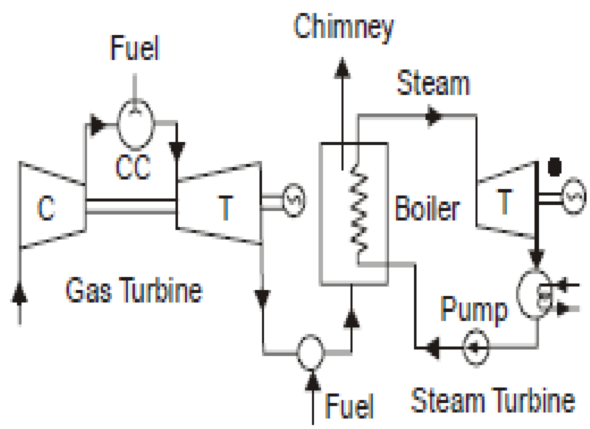


Fig-2.12-Combined Cycle

Fig.2.12 shows a combination of an open cycle gas turbine and steam turbine. The exhaust of gas turbine which has high oxygen content is used as the inlet gas to the steam generator where the combustion of additional fuel takes place. This combination allows nearer equality between the power outputs of the two units than is obtained with the simple recuperative heat exchanger. For a given total power output the energy input is reduced (*i.e.*, saving in fuel) and the installed cost of gas turbine per unit of power output is about one-fourth of that of steam turbine. In other words, the combination cycles exhibit higher efficiency. The greater disadvantages include the complexity of the plant, different fuel requirements and possible loss of flexibility and reliability. The most recent technology in the field of co-generation developed in USA utilizes the gaseous fuel in the combustion chambers produced by the gasification of low quality of coal. The system is efficient and the cost of power production per kW is less.

APPLICATIONS OF GAS TURBINE

1. Gas turbine plants are used as standby plants for the hydro-electric power plants.
2. Gas turbine power plants may be used as peak loads plant and standby plants for smaller power units.
3. Gas turbines are used in jet aircrafts and ships. Pulverised fuel fired plants are used in locomotive.

ADVANTAGES OF GAS TURBINE POWER PLANT

The economics of power generation by gas turbines is proving to be more attractive, due to low capital cost, and high reliability and flexibility in operation. Quick starting and capability of using wide variety of fuels from natural gas to residual oil or powdered coal are other outstanding features of gas turbine power plants. Major progress has been made in three directions namely increase in unit capacities of gas turbine units (50—100 mW), increase in their efficiency and drop in capital cost, (about Rs. 700 per kW installed). Primary application of gas turbine plant is to supply peak load. However gas turbine plants now-a-days are universally used as peak load, base lead as well as standby plants.

1. It is smaller in size and weight as compared to an equivalent steam power plant. For smaller capacities the size of the gas turbine power plant is appreciably greater than a high speed diesel engine plant but for larger capacities it is smaller in size than a comparable diesel engine plant. If size and weight are the main consideration such as in ships, aircraft engines and locomotives, gas turbines are more suitable.
2. The initial cost and operating cost of the plant is lower than an equivalent steam power plant. A thermal plant of 250 mW capacity cost about Rs. 250 crores. Presently whereas a gas turbine plant of that same-size cost nearly 70 crores.
3. The plant requires less water as compared to a condensing steam power plant.
4. The plant can be started quickly, and can be put on load in a very short time.
5. There are no standby losses in the gas turbine power plant whereas in steam power plant these losses occur because boiler is kept in operation even when the turbine is not supplying any load.
6. The maintenance of the plant is easier and maintenance cost is low.
7. The lubrication of the plant is easy. In this plant lubrication is needed mainly in compressor, turbine main bearing and bearings of auxiliary equipment.
8. The plant does not require heavy foundations and building.
9. There is great simplification of the plant over a steam plant due to the absence of boilers with their feed water evaporator and condensing system.

DISADVANTAGES:

1. Major part of the work developed in the turbine is used to derive the compressor. Therefore, network output of the plant is low.
2. Since the temperature of the products of combustion becomes too high so service conditions become complicated even at moderate pressures.

DIRECT ENERGY CONVERSION

SOLAR ENERGY:

Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaics, solar thermal energy, solar architecture and artificial photosynthesis.

It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

Solar power is the conversion of sunlight into electricity, either directly using photovoltaic (PV), or indirectly using concentrated solar power. Concentrated solar power systems (Unified Solar) use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic convert light into an electric current using the photovoltaic effect

FUEL CELLS:

A **fuel cell** is a device that converts the chemical energy from a fuel into electricity through a chemical reaction of positively charged hydrogen ions with oxygen or another oxidizing agent. Fuel cells are different from batteries in that they require a continuous source of fuel and oxygen or air to sustain the chemical reaction, whereas in a battery the chemicals present in the battery react with each other to generate an electromotive force (emf). Fuel cells can produce electricity continuously for as long as these inputs are supplied.

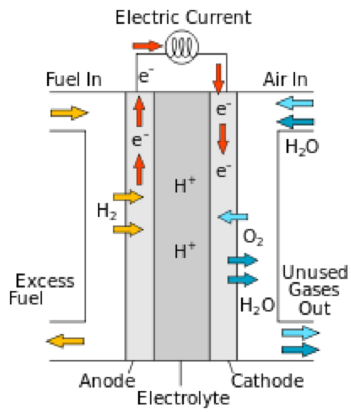


Fig-2.13-Fuel cell

There are many types of fuel cells, but they all consist of an anode, a cathode, and an electrolyte that allows positively charged hydrogen ions (or protons) to move between the two sides of the fuel cell. The anode and cathode contain catalysts that cause the fuel to undergo oxidation reactions that generate positively charged hydrogen ions and electrons. The hydrogen ions are drawn through the electrolyte after the reaction. At the same time, electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity. At the cathode, hydrogen ions, electrons, and oxygen react to form water. As the main difference among fuel cell types is the electrolyte, fuel cells are classified by the type of electrolyte they use and by the difference in startup time ranging from 1 second for proton exchange membrane fuel cells (PEM fuel cells, or PEMFC) to 10 minutes for solid oxide fuel cells (SOFC). Individual fuel cells produce relatively small electrical potentials, about 0.7 volts, so cells are "stacked", or placed in series, to create sufficient voltage to meet an application's requirements. In addition to electricity, fuel cells produce water, heat and, depending on the fuel source, very small amounts of nitrogen dioxide and other emissions. The energy efficiency of a fuel cell is generally between 40–60%, or up to 85% efficient in cogeneration if waste heat is captured for use.

THERMO ELECTRIC SYSTEM:

The **thermoelectric effect** is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference. At the atomic scale, an applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side.

This effect can be used to generate electricity, measure temperature or change the temperature of objects. Because the direction of heating and cooling is determined by the polarity of the applied voltage, thermoelectric devices can be used as temperature controllers.

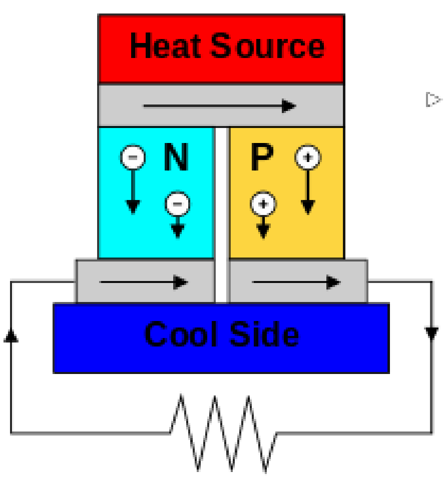


Fig-2.14- thermo electric system

The term "thermoelectric effect" encompasses three separately identified effects: the **Seebeck effect**, **Peltier effect**, and **Thomson effect**. Textbooks may refer to it as the **Peltier–Seebeck effect**. This separation derives from the independent discoveries of French physicist Jean Charles Athanase Peltier and Baltic German physicist Thomas Johann Seebeck. Joule heating, the heat that is generated whenever a current is passed through a resistive material, is related, though it is not generally termed as thermoelectric effect. The Peltier–Seebeck and Thomson effects are thermodynamically reversible,[1] whereas Joule heating is not.

THERMO IONIC SYSTEM:

A **thermionic converter** consists of a hot electrode which thermionically emits electrons over a potential energy barrier to a cooler electrode, producing a useful electric power output. Caesium vapor is used to optimize the electrode work functions and provide an ion supply (by surface ionization or electron impact ionization in a plasma) to neutralize the electron space charge.

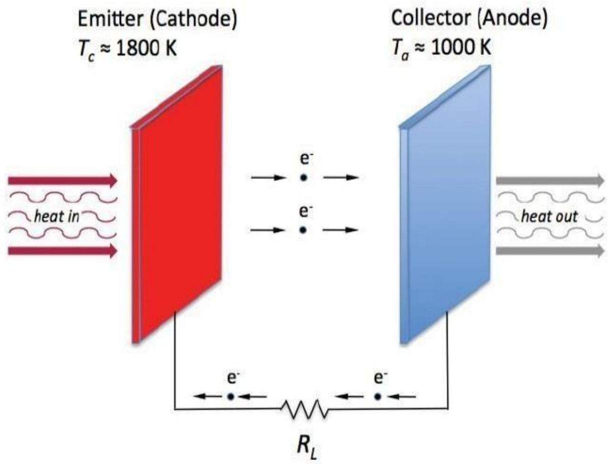


Fig-2.15- Thermo Ionic Convertor

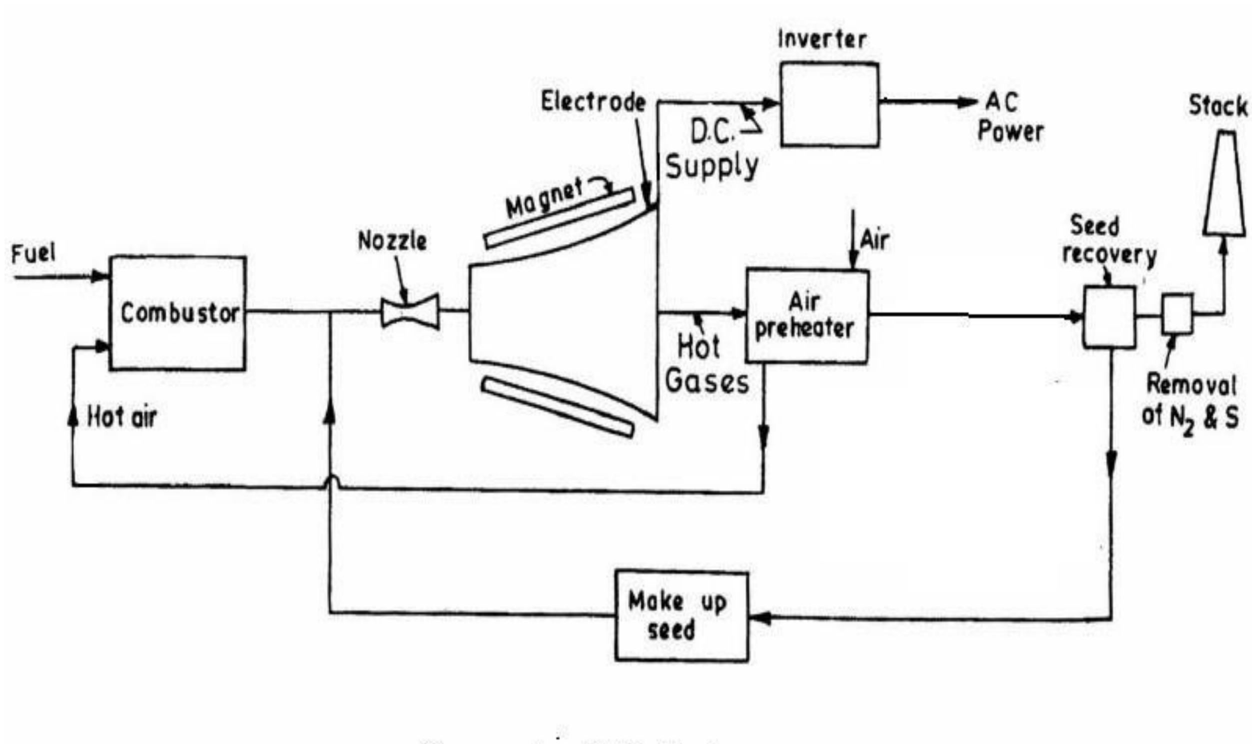
MHD GENERATION:

A **magneto hydrodynamic generator** (**MHD generator**) is a magneto hydro dynamic device that transforms thermal energy and kinetic energy into electricity. MHD generators are different from traditional electric generators in that they operate at high temperatures without moving parts. MHD was developed because the hot exhaust gas of an MHD generator can heat the boilers of a steam power plant, increasing overall efficiency. MHD was developed as a topping cycle to increase the efficiency of electric generation, especially when burning coal or natural gas. MHD dynamos are the complement of MHD propulsors, which have been applied to pump liquid metals and in several experimental ship engines.

An MHD generator, like a conventional generator, relies on moving a conductor through a magnetic field to generate electric current. The MHD generator uses hot conductive plasma as the moving conductor. The mechanical dynamo, in contrast, uses the motion of mechanical devices to accomplish this. MHD generators are technically practical for fossil fuels, but have been overtaken by other, less expensive technologies, such as combined cycles in which a gas turbine's or molten carbonate fuel cell's exhaust heats steam to power a steam turbine.

OPEN CYCLE SYSTEM:

- Working fluid after generating electrical energy is discharged to the atmosphere through a stack .
- Operation of MHD generator is done directly on combustion products .
- Temperature requirement : 2300˚C to 2700˚C.
- More developed.

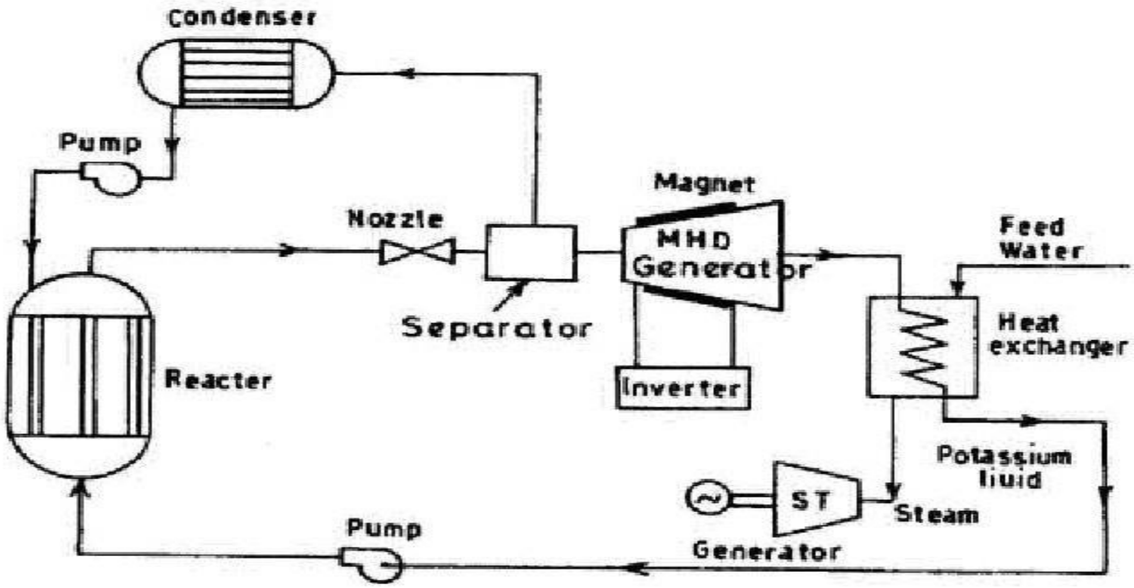


Open cycle MHD System

Fig-2.16

CLOSED CYCLE SYSTEM:

- Working fluid is recycled to the heat sources and thus is used again.
- Helium or argon(with cesium seeding) is used as the working fluid.
- Temperature requirement : about 530˚C.
- Less developed.



Closed cycle MHD generator using liquid metal as working fluid coupled with steam genarator.

Fig-2.17-Closed cycle system

ADVANTAGES:

- Conversion efficiency of about 50% . Less fuel consumption.
- Large amount of pollution free power generated . Ability to reach full power level as soon as started.
- Plant size is considerably smaller than conventional fossil fuel plants . Less overall generation cost.
- No moving parts, so more reliable .

DISADVANTAGES:

- Suffers from reverse flow (short circuits) of electrons through the conducting fluids around the ends of the magnetic field.
- Needs very large magnets and this is a major expense. High friction and heat transfer losses.
- High operating temperature.
- Coal used as fuel poses problem of molten ash which may short circuit the electrodes. Hence, oil or natural gas are much better fuels for MHDs. Restriction on use of fuel makes the operation more expensive.

UNIT-III
HYDRO ELECTRIC POWER PLANT

INTRODUCTION:

When rain water falls over the earth's surface, it possesses potential energy relative to sea or ocean towards which it flows. If at a certain point, the water falls through an appreciable vertical height, this energy can be converted into shaft work. As the water falls through a certain height, its potential energy is converted into kinetic energy and this kinetic energy is converted to the mechanical energy by allowing the water to flow through the hydraulic turbine runner. This mechanical energy is utilized to run an electric generator which is coupled to the turbine shaft.

The generation of electric energy from falling water is only a small process in the mighty heat power cycle known as "Hydrological cycle" or rain evaporation cycle". It is the process by which the moisture from the surface of water bodies covering the earth's surface is transferred to the land and back to the water bodies again. This cycle is shown in Fig.3.1. The input to this cycle is the solar energy.
Due to this, evaporation of water takes lace from the water bodies. On cooling, these water vapors form clouds.

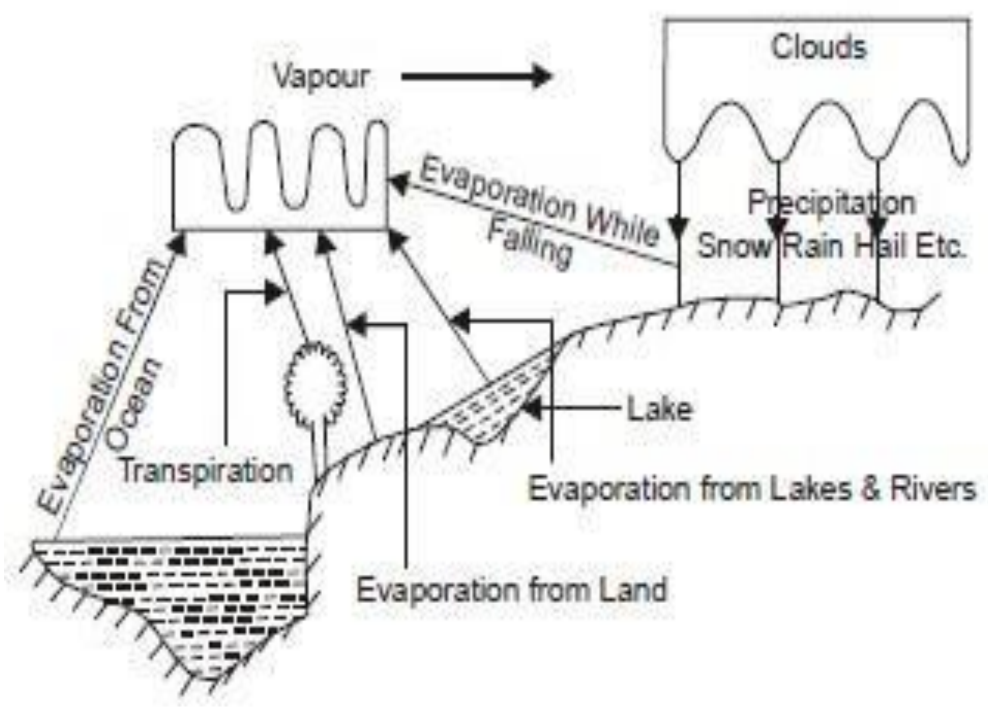


Fig-3.1- Hydrological cycle

Further cooling makes the clouds to fall down in the form of rain, snow, hail or sleet etc; known as precipitation. Precipitation includes all water that falls from the atmosphere to the earth's surface in any form.

Major portion of this precipitation, about 2/3rd, which reaches the land surface, is returned to the atmosphere by evaporation from water surfaces, soil and vegetation and through transpiration by plants. The remaining precipitation returns ultimately to the sea or ocean through surface or underground channels.

This completes the cycle. The amount of rainfall which runs off the earth's land surface to form streams or 'rivers is useful for power generation. The precipitation that falls on hills and mountains in the form of snow melts during warmer weather as run-off and converges to form streams can also be used for power generation.

Hydro projects are developed for the following purposes:

1. To control the floods in the rivers.
2. Generation of power.
3. Storage of irrigation water.
4. Storage of the drinking water supply.

FLOW MEASUREMENT:

1. **Nature of Precipitation.** Short, hard showers may produce relatively little run-off. Rains lasting a longer time results in larger run-off. The soil tends to become saturated and the rate of seepage decreases. Also, the humid atmosphere lowers evaporation, resulting in increased run- off.
2. **Topography of Catchments Area.** Steep, impervious areas will produce large percentage of total run-off. The water will flow quickly and absorption and evaporation losses will be small.
3. **Geology of Area.** The run-off is very much affected by the types of surface soil and sub-soil, type of rocks etc. Rocky areas will give more run-off while pervious soil and sub-soil and soft and sandy area will give lesser run-off.
4. **Meteorology.** Evaporation varies with temperature, wind velocity and relative humidity. Runoff increases with low temperature, low wind velocity and high relative humidity and vice versa.
5. **Vegetation.** Evaporation and seepage are increased by cultivation. Cultivation opens and roughens the hard, smooth surface and promotes seepage. Thick vegetation like forests consumes a portion of the rain fall and also acts as obstruction for run-off.
6. **Size and Shape of Area.** Large areas will give more run-off. A wide area like a fan will give greater run-off, whereas, a narrow area like a leaf will give lesser run-off. In an area whose length is more than its width, the flow along its width will give more run-off than if the flow is along its length, since in the former case, seepage and evaporation will be less.

Measurement of Run-Off or Flow : The run-off or stream flow can be determined with the help of three methods:

1. **From Rain-Fall Records.** The run-off can be estimated from rain-fall records by multiplying the rain fall with "run-off coefficient" for the drainage area.

The run-off coefficient takes into account the various losses and will depend upon the nature of the catchment area

Then, Run-off = Rain fall × run-off co-efficient

This is not an accurate method of measuring run-off since the estimation of run-off co-efficient cannot be very accurate.

2. **Empirical Formulas.** Empirical relations to determine the stream flow relate only to a particular site and cannot be relied upon for general use.

3. **Actual Measurement.** Direct measurement by stream gauging at a given site for a long period is the only precise method of evaluation of stream flow. The flow is measured by selecting a channel of fixed cross-section and measuring the water velocity at regular intervals, at enough points in the cross-section for different water levels. The velocity of flow can be measured with the help of current meter or float method. By integrating the velocities over the cross-section for each stage, the total flow for each stage can be calculated.

HYDROGRAPH:

A hydrograph indicates the variation of discharge or flow with time. It is plotted with flows as ordinates and time intervals as abscissas. The flow is in m3/sec and the time may be in hours, days, weeks or months.

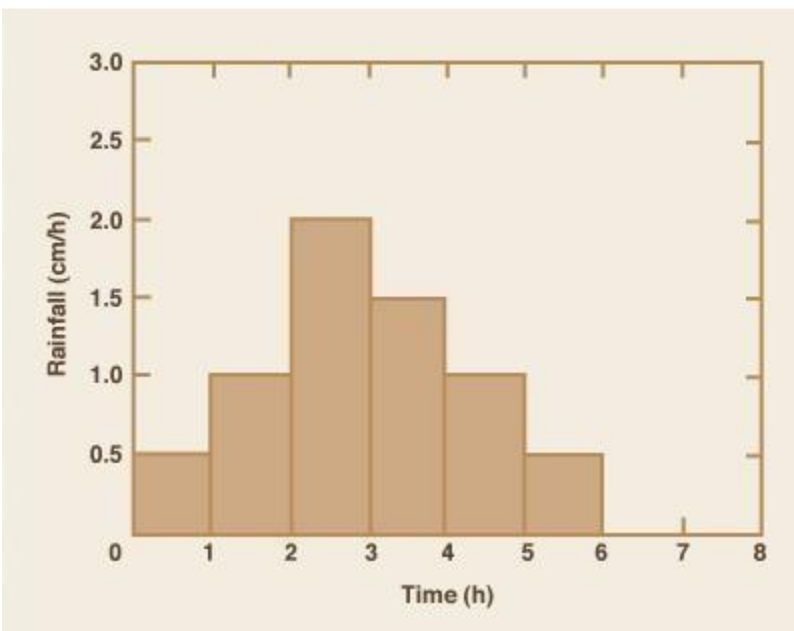


Fig-3.2-Hydro graph

PUMPED STORAGE PLANTS:

These plants supply the peak load for the base load power plants and pump all or a portion of their own water supply. The usual construction would be a tail water pond and a head water pond connected through a penstock. The generating pumping plant is at the lower end. During off peak hours, some of the surplus electric energy being generated by the base load plant, is utilized to pump the water from tail water pond into the head water pond and this energy will be stored there. During times of peak load, this energy will be released by allowing the water to flow from the head water pond through the water turbine of the pumped storage plant. These plants can be used with hydro, steam and i.e. engine plants. This plant is nothing but a hydraulic accumulator system and is shown in Fig.3.3. These plants can have either vertical shaft arrangement or horizontal shaft arrangement. In the older plants, there were separate motor driven pumps and turbine driven generators. The improvement was the pump and turbine on the same shaft with the electrical element acting as either generator or motor. The latest design is to use a Francis turbine which is just the reverse of centrifugal pump. When the water flows through it from the head water pond it will act as a turbine and rotate the generator. When rotated in the reverse direction by means of an electric motor, it will act as a pump to shunt the water from the tail water pond to the head water pond.

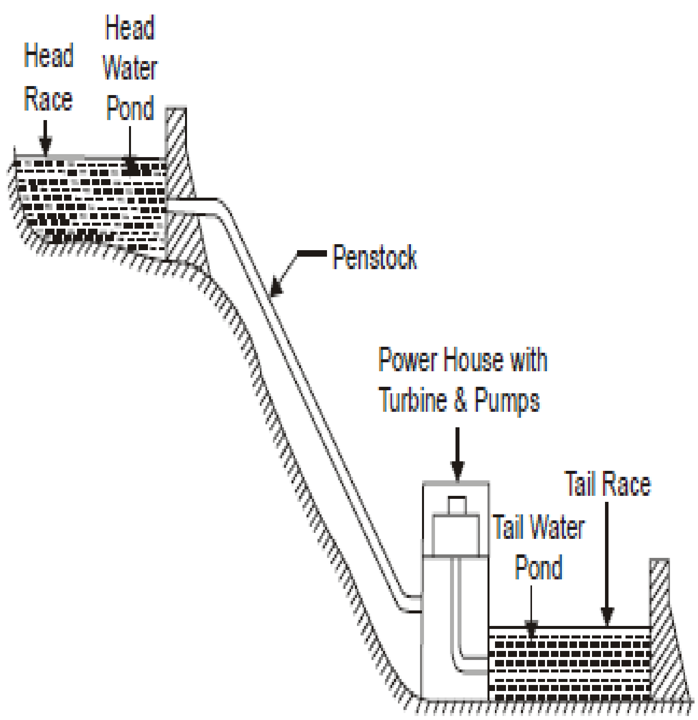


Fig-3.3-Pumped storage plant

The efficiency of such a plant is never 100 per cent. Some water may evaporate from the head water pond resulting in the reduction in the stored energy or there might be run off through the soil.

TYPES OF DAMS:

Primary purpose of a dam is to provide for the safe retention and storage of water. Structurally, a dam must be stable against overturning and sliding, either or within the foundations. The rock or soil on which it stands must be competent to withstand the superimposed loads without crushing or undue yielding. The reservoir basin is created must be watertight and seepage through the foundation of the dam should be minimal.

MASANORY DAMS

- Solid gravity dams
- Buttress dams
- Arch dams

EARTHFILL DAMS

- Earth fill dams
- Rock fill dams

SOLID GRAVITY DAMS:

A gravity dam is one which depends entirely on its own mass for stability (Fig.3.4). The basic gravity profile is triangular in shape, but for practical purposes, is modified at the top. Some gravity dams are slightly curved in plan, with the curvature being towards the river upstream. It is mostly due to aesthetic and other reasons, rather than having an arch action for providing greater stability.

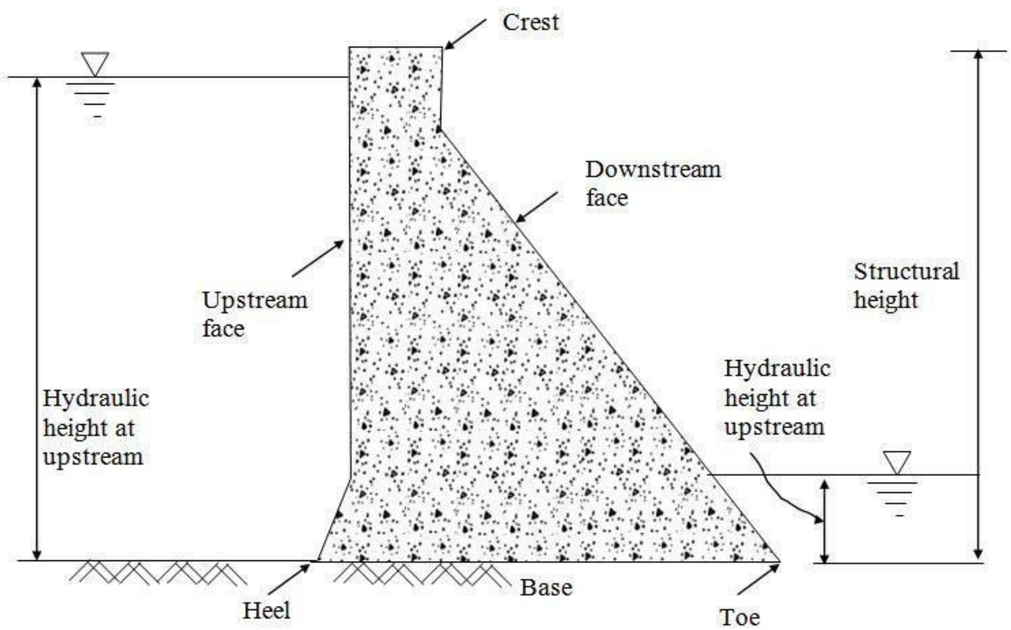
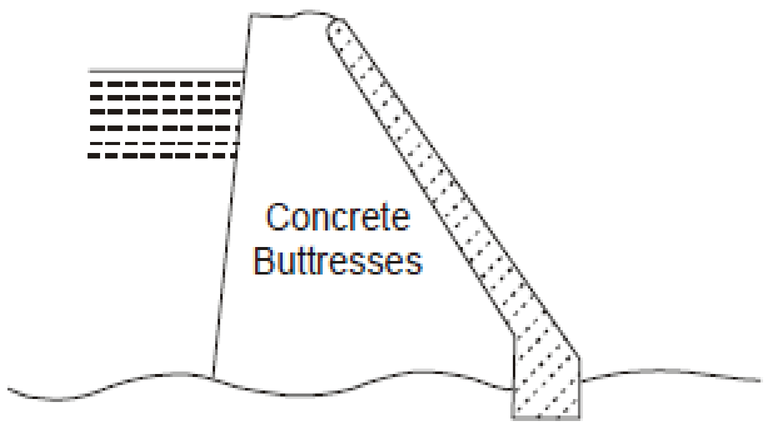


Fig-3.4- Gravity dam

BUTTRESS DAMS:

A buttress dam or hollow dam is a dam with a solid, water-tight upstream side that is supported at intervals on the downstream side by a series of buttresses or supports. The dam wall may be straight or curved. Most buttress dams are made of reinforced concrete and are heavy, pushing the dam into the ground. Water pushes against the dam, but the buttresses are inflexible and prevent the dam from falling over.
Buttress or hollow gravity dams were originally built to retain water for irrigation or mining in areas of scarce or expensive resources but cheap labour. A buttress dam is a good choice in wide valleys where solid rock is rare.



Buttress Dam

Fig-3.5

ARCH DAMS:

It resists the pressure of water partly due to its weight and partly due to arch action. An **arch dam** is a solid dam made of concrete that is curved upstream in plan. The arch dam is designed so that the force of the water against it, known as hydrostatic pressure, presses against the arch, compressing and strengthening the structure as it pushes into its foundation or abutments.

An arch dam is most suitable for narrow gorges or canyons with steep walls of stable rock to support the structure and stresses. Since they are thinner than any other dam type, they require much less construction material, making them economical and practical in remote areas.

TYPES OF SPILLWAYS:

A spillway is a structure used to provide the controlled release of flows from a dam or levee into a downstream area, typically being the river that was dammed. In the UK they may be known as overflow channels. Spillways release floods so that the water does not overtop and damage or even destroy the dam. Except during flood periods, water does not normally flow over a spillway. In contrast, an *intake* is a structure used to release water on a regular basis for water supply, hydroelectricity generation, etc. Floodgates and fuse plugs may be designed into spillways to regulate water flow and dam height.

- Overflow spillway
- Chute spillway
- Shaft spillway
- Siphon spillway

Overflow spillway:

Open channel spillways are dam spillways that utilize the principles of open-channel flow to convey impounded water in order to prevent dam failure. They can function as principal spillways, emergency spillways, or both. They can be located on the dam itself or on a natural grade in the vicinity of the dam.

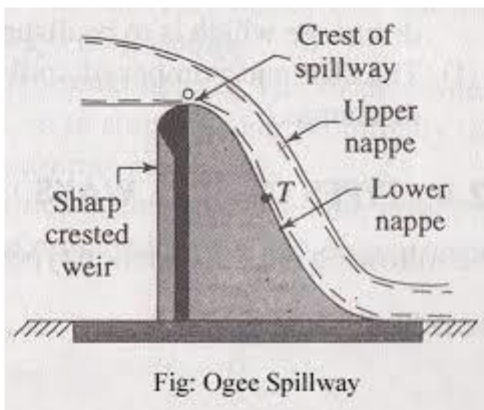


Fig-3.6- over flow spillway

Chute spillway:

A chute spillway is a common and basic design which transfers excess water from behind the dam down a smooth decline into the river below. These are usually designed following an ogee curve. Most often, they are lined on the bottom and sides with concrete to protect the dam and topography. They may have a controlling device and some are thinner and multiply lined if space and funding are tight. In addition, they are not always intended to dissipate energy like stepped spillways. Chute spillways can be ingrained with a baffle of concrete blocks but usually have a 'flip lip' and/or dissipator basin which creates a hydraulic jump, protecting the toe of the dam from erosion.

Shaft Spillway:

A vertical shaft which has a funnel-shaped mouth and ends in an outlet tunnel, providing an overflow duct for areservoir.

Siphon spillway:

A siphon makes use of the difference in the height between the intake and the outlet to create a pressure difference needed to remove excess water. Siphons however require priming or the removal of air in the bend in order for them to function and most siphon spillways are designed with a system that makes use of water to remove the air and automatically prime the siphon. One such design is the volute siphon which makes use of water forced into a spiral vortex by volutes or fins on a funnel that draw air out of the system. The priming happens automatically when the water level rises above the inlets that are used to drive the priming process

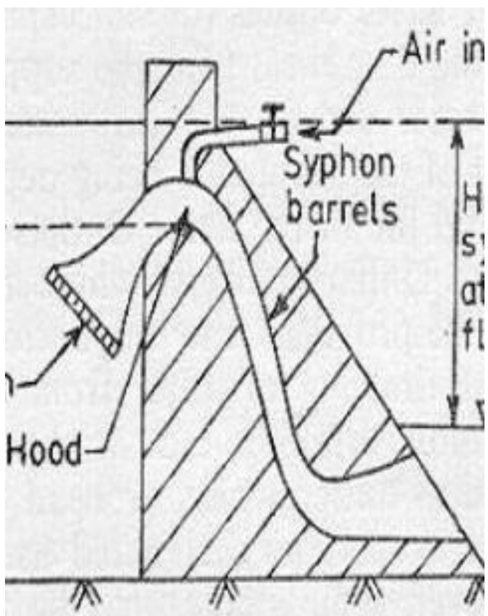


Fig-3.7- siphon spillway

POWER FROM NON-CONVENTIONAL RESOURCES:

Solar collector system It is also called solar farm power plant as a number of solar modules consisting of parabolic trough solar collectors are interconnected. This system uses a series of special y designed 'Trough' collectors which have an absorber tube running along their length. Large arrays of these collectors are coupled to provide high temperature water for driving a steam turbine. Such power stations can produce many megawatts (mW) of electricity, but are confined to areas where there is ample solar insulation.

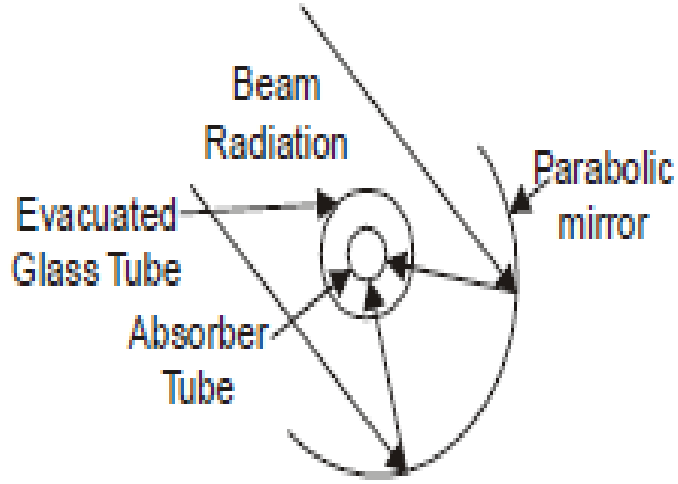


Fig-3.8- Solar collector

Wind Energy: The kinetic energy of wind converted into mechanical energy by wind turbines (*i.e.*,blades rotating from a hub) that drive generators to produce electricity for distribution.

This kinetic energy of the wind can be used to do work. This energy was harnessed by windmills in the past to do mechanical work. For example, in a water-lifting pump, the rotatory motion of windmill is utilised to lift water from a well. Today, wind energy is also used to generate electricity. A windmill essentially consists
of a structure similar to a large electric fan that is erected at some height on a rigid support . To generate electricity, the rotatory motion of the windmill is used to turn the turbine of the electric generator. The output of a single windmill is quite small and cannot be used for commercial purposes. Therefore, a number of windmills
are erected over a large area, which is known as wind energy farm. The energy output of each windmill in a farm is coupled together to get electricity on a commercial scale.
Tidal power, also called **tidal energy**, is a form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity.

Although not yet widely used, tidal power has potential for future electricity generation. Tides are more predictable than wind energy and solar power. Among sources of renewable energy, tidal power has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities, thus constricting its total availability. However, many recent technological developments and improvements, both in design (e.g. dynamic tidal power, tidal lagoons) and turbine technology (e.g. new axial turbines, cross flow turbines), indicate that the total availability of tidal power may be much higher than previously assumed, and that economic and environmental costs may be brought down to competitive levels.

UNIT-IV
NUCLEAR POWER STATION

INTRODUCTION:

There is strategic as well as economic necessity for nuclear power in the United States and Indeed most of the world. The strategic importance lies primarily in the fact that one large nuclear power plant saves more than 50,000 barrels of oil per day. At $30 to $40 per barrel (1982), such a power plant would pay for its capital cost in a few short years. For those countries that now rely on but do not have oil, or must reduce the importation of foreign oil, these strategic and economic advantages are obvious.

For those countries that are oil exporters, nuclear power represents an insurance against the day when oil is depleted. A modest start now will assure that they would not be left behind when the time comes to have to use nuclear technology.
The unit costs per kilowatt-hour for nuclear energy are now comparable to or lower than the unit costs for coal in most parts of the world. Other advantages are the lack of environmental problems that are associated with coal or oil-fired power plants and the near absence of issues of mine safety, labor problems, and transportation bottle-necks. Natural gas is a good, relatively clean- burning fuel, but it has some availability problems in many countries and should, in any case, be conserved for small-scale industrial and domestic uses. Thus nuclear power is bound to become the social choice relative to other societal risks and overall health and safety risks.

Other sources include hydroelectric generation, which is nearly fully developed with only a few sites left around the world with significant hydroelectric potential. Solar power, although useful in outer space and domestic space and water heating in some parts of the world, is not and will not become an economic primary source of electric power.

Yet the nuclear industry is facing many difficulties, particularly in the United States, primarily as a result of the negative impact of the issues of nuclear safety waste disposal, weapons proliferation, and economics on the public and government The impact on the public is complicated by delays in licensing
proceedings, court and ballot box challenges. These posed severe obstacles to electric utilities planning nuclear power plants, the result being scheduling problems, escalating and unpredictably costs, and economic risks even before a construction permit is issued. Utilities had a delay or cancel nuclear projects
so that in the early 1980s there was a de fan moratorium on new nuclear plant commitments in the United States.

NUCLEAR FUEL:

Fuel of a nuclear reactor should be fissionable material which can be defined as an element or isotope whose nuclei can be caused to undergo nuclear fission by nuclear bombardment and to produce a fission chain reaction. It can be one or all of the following U233, U235 and Pu239.

Natural uranium found in earth crust contains three isotopes namely U234, U235 and U238 and their average percentage is as follows:

U238 — 99.3%
U235 — 0.7%
U234 — Trace

Out of these U235 is most unstable and is capable of sustaining chain reaction and has been given the name as primary fuel. U233 arid Pu239 are artificially produced from Th232 and U238 respectively and
are called secondary fuel.

Pu239 and U233 so produced can be fissioned by thermal neutrons. Nuclear fuel should not be expensive to fabricate. It should be able to operate at high temperatures and should be resistant to radiation damage.

Uranium deposits are found in various countries such as Congo, Canada, U.S.A., U.S.S.R.,Australia. The fuel should be protected from corrosion and erosion of the coolant and for this it is encased in metal cladding generally stainless steel or aluminum. Adequate arrangements should be made for fuel supply, charging or discharging and storing of the fuel. For economical operation of a nuclear power plant special attention should be paid to reprocess the spent: up (burnt) fuel elements and the unconsumed fuel. The spent up fuel elements are intensively
radioactive and emits some neutron and gamma rays and should be handled carefully.

In order to prevent the contamination of the coolant by fission products, a protective coating or cladding must separate the fuel from the coolant stream. Fuel element cladding should possess the following properties :

1. It should be able to withstand high temperature within the reactor.
2. It should have high corrosion resistance.
3. It should have high thermal conductivity.
4. It should not have a tendency to absorb neutrons.
5. It should have sufficient strength to withstand the effect of radiations to which it is subjected.

Uranium oxide (UO2) is another important fuel element. Uranium oxide has the following advantages over natural uranium:

1. It is more stable than natural uranium.
2. There is no problem or phase change in case of uranium oxide and therefore it can be used for higher temperatures.
3. It does not corrode as easily as natural uranium.
4. It is more compatible with most of the coolants and is not attacked by H2, Nz.
5. There is greater dimensional stability during use.

Uranium oxide possesses following disadvantages :

1. It has low thermal conductivity.
2. It is more brittle than natural uranium and therefore it can break due to thermal stresses.
3. Its enrichment is essential.

Uranium oxide is a brittle ceramic produced as a powder and then sintered to form fuel pellets. Another fuel used in the nuclear reactor is uranium carbide (UC). It is a black ceramic used in the form of pellets.

NUCLEAR REACTOR:

A nuclear reactor is an apparatus in which heat is produced due to nuclear fission chain reaction. Fig.4.1 shows the various parts of reactor, which are as follows:

1. Nuclear Fuel
2. Moderator
3. Control Rods
4. Reflector
5. Reactors Vessel
6. Biological Shielding
7. Coolant

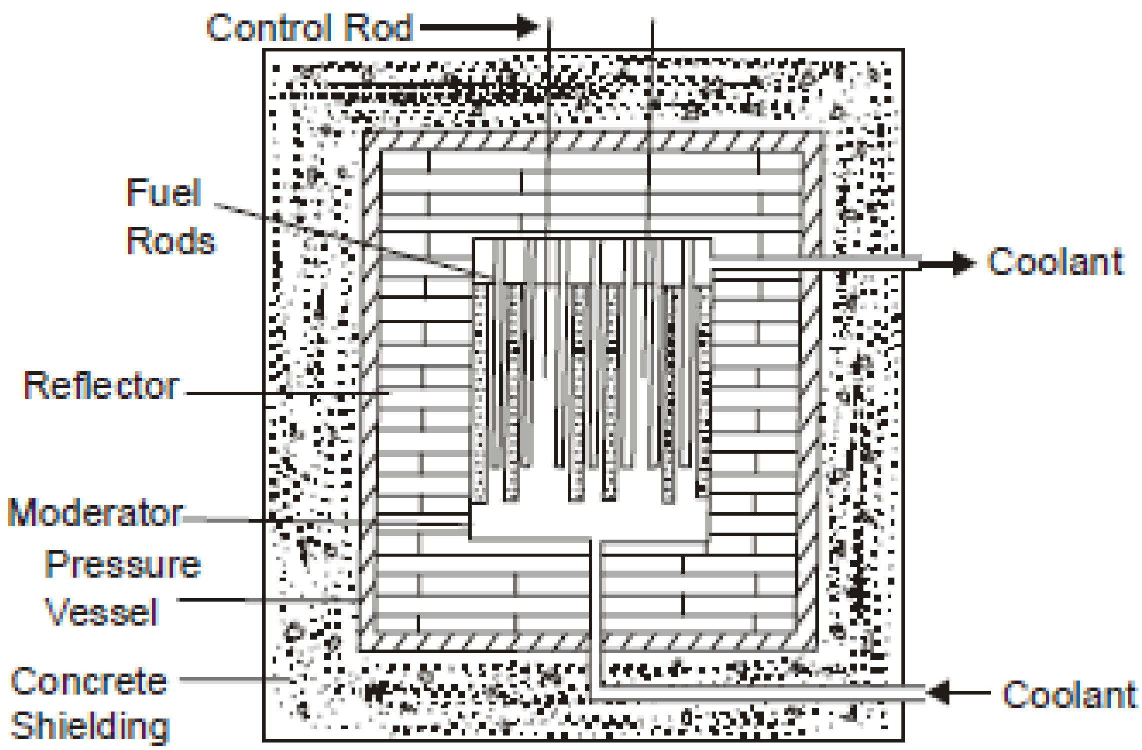


Fig-4.1- nuclear reactor

TYPES OF REACTORS:

- PRESSURISED WATER REACTOR
- BOILING WATER REACTOR
- SODIUM-GRAPHITE REACTOR
- FAST BREEDER REACTOR
- HOMOGENEOUS REACTOR
- GAS COOLED REACTOR

PRESSURISED WATER REACTOR:

The most widely used reactor type in the world is the Pressurised Water Reactor (PWR) (see Fig 4) which uses enriched (about 3.2% U^{235}) uranium dioxide as a fuel in zirconium alloy cans. The fuel, which is arranged in arrays of fuel "pins" and interspersed with the movable control rods, is held in a steel vessel through which water at high pressure (to suppress boiling) is pumped to act as both a coolant and a moderator. The high-pressure water is then passed through a steam generator, which raises steam in the usual way. As in the CANDU design, the whole assembly is contained inside the concrete shield and containment vessel.

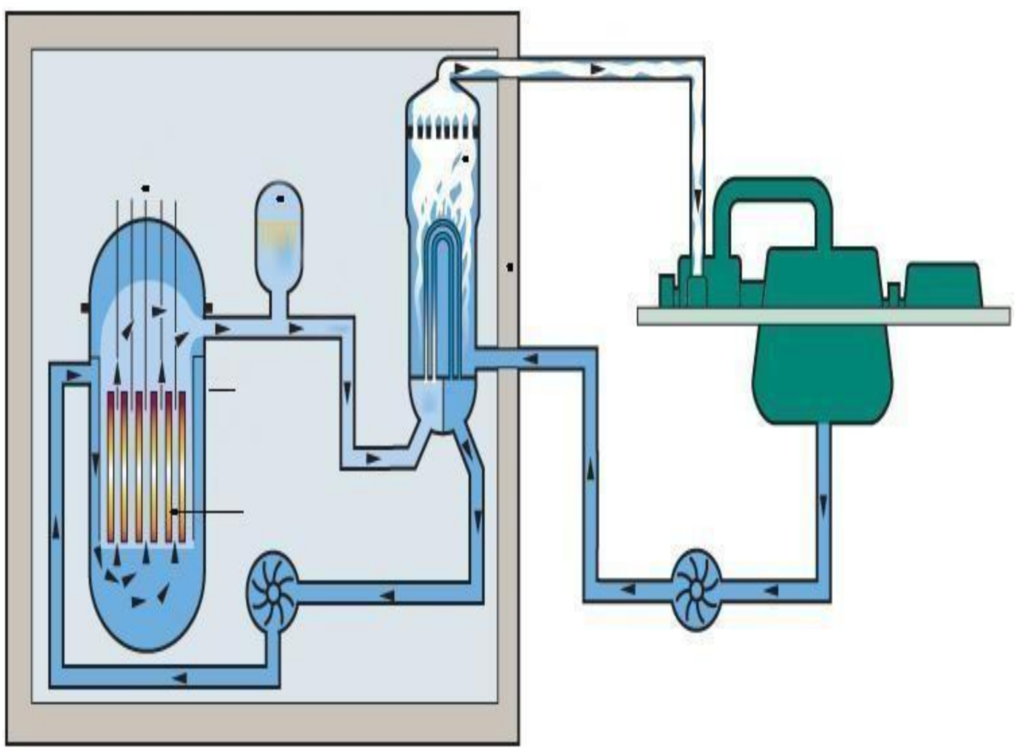


Fig-4.2- pressurized water reactor

BOILING WATER REACTOR:

The second type of water cooled and moderated reactor does away with the steam generator and, by allowing the water within the reactor circuit to boil, it raises steam directly for electrical power generation.

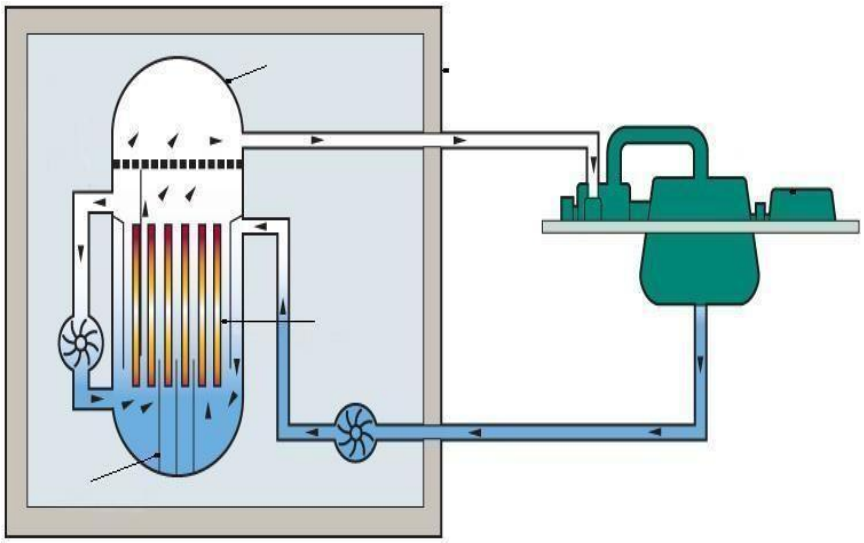


Fig-4.3- BWR

This, however, leads to some radioactive contamination of the steam circuit and turbine, which then requires shielding of these components in addition to that surrounding the reactor. Such reactors, known as Boiling Water Reactors (BWRs), are in use in some ten countries throughout the world.

FAST BREEDER REACTOR:

A breeder reactor is a nuclear reactor that generates more fissile material than it consumes. These devices achieve this because their neutron economy is high enough to breed more fissile fuel than they use from fertile material, such as uranium-238 or thorium-232. Breeders were at first found attractive because their fuel economy was better than light water reactors, but interest declined after the 1960s as more uranium reserves were found, and new methods of uranium enrichment reduced fuel costs.

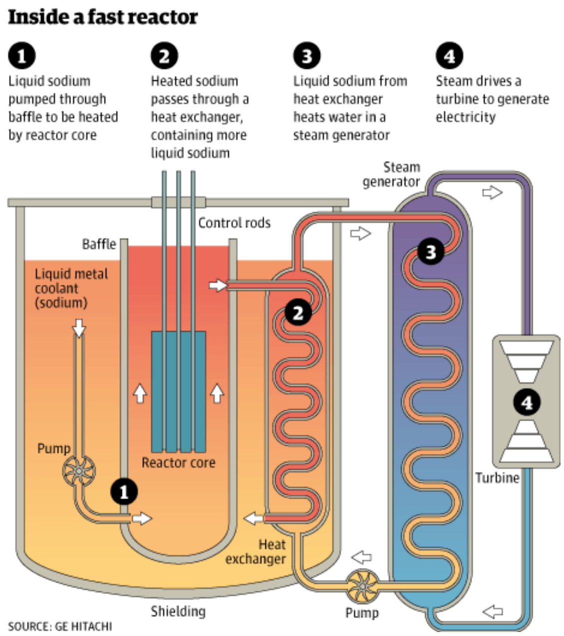


Fig-4.5-Fast breeder reactor

SODIUM- GRAPHITE REACTOR:

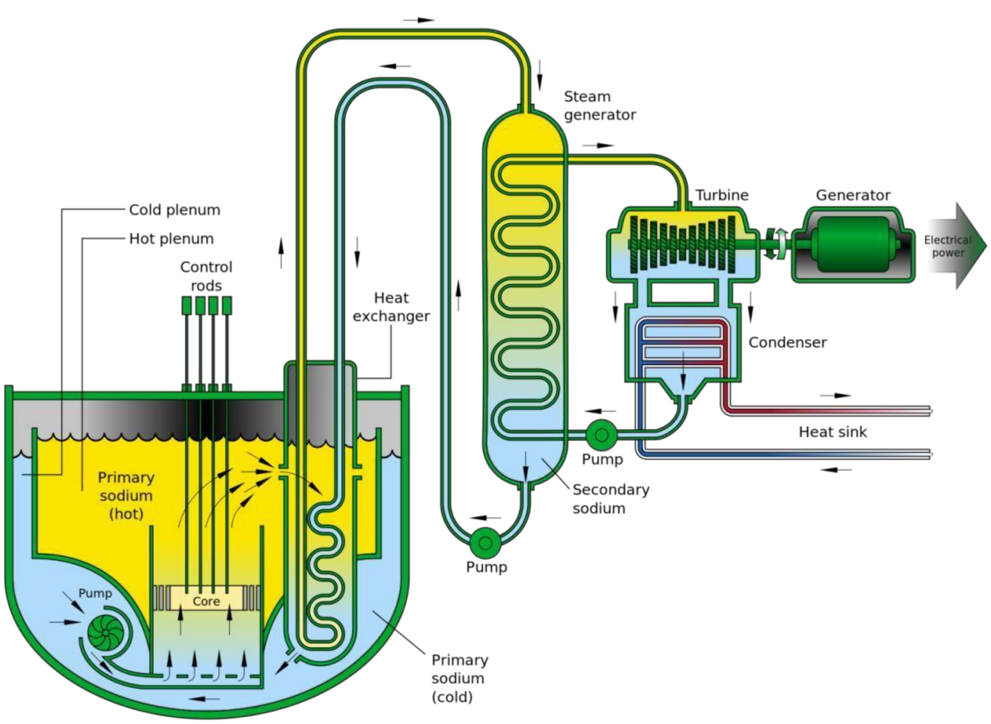


FIG.4.4-Sodium Graphite reactor

GAS COOLED REACTOR:

Magnox reactors (see Fig 1.1(a)) were built in the UK from 1956 to 1971 but have now been super seded. The Magnox reactor is named after the magnesium alloy used to encase the fuel, which is natural uranium metal. Fuel elements consisting of fuel rods encased in Magnox cans are loaded into vertical channels in a core constructed of graphite blocks. Further vertical channels contain control rods (strong neutron absorbers) which can be inserted or withdrawn from the core to adjust the rate of the fission process and, therefore, the heat output. The whole assembly is cooled by blowing carbon dioxide gas past the fuel cans, which are specially designed to enhance heat transfer. The hot gas then converts water to steam in a steam generator. Early designs used a steel pressure vessel, which was surrounded by a thick concrete radiation shield. In later designs, a dual-purpose concrete pressure vessel and radiation shield was used. In order to improve the cost effectiveness of this type of reactor, it was necessary to go to higher temperatures to achieve e higher thermal efficiencies and higher power densities to reduce capital costs. This entailed increases in cooling gas pressure and changing from Magnox to stainless steel cladding and from Uranium metal to uranium dioxide fuel. This in turn led to the need for an increase in the proportion of U 235 in the fuel.

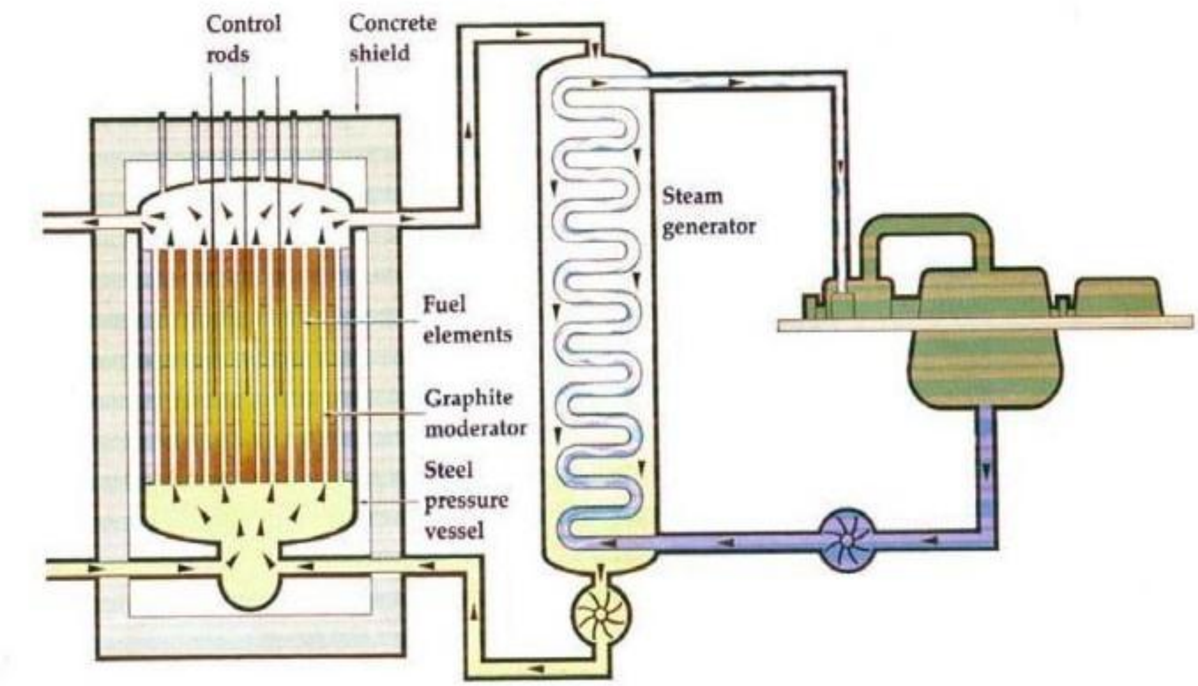


Fig-4.6- Gas cooled reactor

ADVANTAGES OF NUCLEAR POWER PLANT

The various advantages of a nuclear power plant are as follows:

1. Space requirement of a nuclear power plant is less as compared to other conventional power plants are of equal size.
2. A nuclear power plant consumes very small quantity of fuel. Thus fuel transportation cost is less and large fuel storage facilities are not needed Further the nuclear power plants will conserve the fossil fuels (coal, oil, gas etc.) for other energy need.
3. There is increased reliability of operation.
4. Nuclear power plants are not effected by adverse weather conditions.
5. Nuclear power plants are well suited to meet large power demands. They give better performance at higher load factors (80 to 90%).
6. Materials expenditure on metal structures, piping, storage mechanisms are much lower for a nuclear power plant than a coal burning power plant.

DISADVANTAGES

1. Initial cost of nuclear power plant is higher as compared to hydro or steam power plant.
2. Nuclear power plants are not well suited for varying load conditions.
3. Radioactive wastes if not disposed carefully may have bad effect on the health of workers and other population. In a nuclear power plant the major problem faced is the disposal of highly radioactive waste in form of liquid, solid and gas without any injury to the atmosphere. The preservation of waste for a long time creates lot of difficulties and requires huge capital.
4. Maintenance cost of the plant is high.
5. It requires trained personnel to handle nuclear power plants.

SHIELDING

Shielding the radioactive zones in the reactor roan possible radiation hazard is essential to protect, the operating men from the harmful effects. During fission of nuclear fuel, alpha particles, beta particles, deadly gamma rays and neutrons are produced. Out oil these nc-1utroxrs and gamma rays are of main significance. A protection must be provided against them.

Thick layers of lead or concrete are provided round the reactor for stopping the gamma rays. Thick layers of metals or plastics are sufficient to stop the alpha and beta particles.

Radioactive waste disposal:

Radioactive waste is waste that contains radioactive material. Radioactive waste is usually a by-product of nuclear power generation and other applications of nuclear fission or nuclear technology, such as research and medicine. Radioactive waste is hazardous to most forms of life and the environment, and is regulated by government agencies in order to protect human health and the environment.

Radioactivity naturally decays over time, so radioactive waste has to be isolated and confined in appropriate disposal facilities for a sufficient period until it no longer poses a threat. The time radioactive waste must be stored for depends on the type of waste and radioactive isotopes. It can range from a few days for highly radioactive isotopes to millions of years for slightly radioactive ones. Current major approaches to managing radioactive waste have been segregation and storage for short-lived waste, near-surface disposal for low and some intermediate level waste, and deep burial or partitioning / transmutation for the high- level waste.

Space disposal is attractive because it removes nuclear waste from the planet. It has significant disadvantages, such as the potential for catastrophic failure of a launch vehicle, which could spread radioactive material into the atmosphere and around the world. A high number of launches would be required because no individual rocket would be able to carry very much of the material relative to the total amount that needs to be disposed of. This makes the proposal impractical economically and it increases the risk of at least one or more launch failures.[To further complicate matters, international agreements on the regulation of such a program would need to be established. Costs and inadequate reliability of modern rocket launch systems for space disposal has been one of the motives for interest in non-rocket space launch systems such as mass drivers, space elevators, and other proposals

UNIT-V
POWER PLANT ECONOMICS AND ENVIRONMENTAL CONSIDERATIONS

Introduction to Economics of Power Generation:

The function of a power station is to deliver power at the lowest possible cost per kilo watt hour. This total cost is made up of fixed charges consisting of interest on the capital, taxes, insurance, depreciation and salary of managerial staff, the operating expenses such as cost of fuels, water, oil, labor, repairs and maintenance etc.

The cost of power generation can be minimized by:

1. Choosing equipment that is available for operation during the largest possible % of time in a year.
2. Reducing the amount of investment in the plant.
3. Operation through fewer men.
4. Having uniform design
5. Selecting the station as to reduce cost of fuel, labor, etc.

All the electrical energy generated in a power station must be consumed immediately as it cannot be stored. So the electrical energy generated in a power station must be regulated according to the demand. The demand of electrical energy or load will also vary with the time and a power station must be capable of meeting the maximum load at any time. Certain definitions related to power station practice are given below:

Load curve:

Load curve is plot of load in kilowatts versus time usually for a day or a year.

Load duration curve:

Load duration curve is the plot of load in kilowatts versus time duration for which it occurs.

Maximum demand:

Maximum demand is the greatest of all demands which have occurred during a given period of time.

Average load:

Average load is is the average load on the power station in a given period (day/month or year)

Base load:

Base load is the minimum load over a given period of time.

Connected load:

Connected load of a system is the sum of the continuous ratings of the load consuming apparatus connected to the system.

Peak load:

Peak load is the maximum load consumed or produced by a unit or group of units in a stated period of time. It may be the maximum instantaneous load or the maximum average load over a designated interval of time.

Demand factor:

Demand factor is the ratio of maximum demand to the connected load of a consumer.

Diversity factor:

Diversity factor is the ratio of sum of individual maximum demands to the combined maximum demand on power stations

Load factor:

Load factor is the ratio of average load during a specified period to the maximum load occurring during the period.

$$\textit{Load factor} = \textit{Average Load} / \textit{Maximum demand}$$

Station load factor:

Station load factor is the ratio of net power generated to the net maximum demand on a power station.

Plant factor:

Plant factor is the ratio of the average load on the plant for the period of time considered, to the aggregate rating of the generating equipment installed in the plant.

Capacity factor:

Capacity factor is the ratio of the average load on the machine for a period of time considered, to the rating of the machine.

Demand factor:

Demand factor is the ratio of maximum demand of system or part of system, to the total connected load of the system, or part of system, under consideration.

Load Factor

In a Hydro -electric power station with water available and a fixed staff for maximum output, the cost per unit generated at 100% load factor would be half the cost per unit at 50% load factor. In a steam power station the difference would not be so pronounced since fuel cost constitutes the major item in operating costs and does not vary in the same proportion as load factor.

The cost at 100% load factor in case of this station may, therefore, be about 2/3rdof the cost 50% load factor. For a diesel station the cost per unit generated at 100% load factor may be about 3/4thof the same cost at 50% load factor.

From the above discussion it follows that

(a)Hydro-electric power station should be run at its maximum load continuously on all units.
(b)Steam power station should be run in such a way that all its running units are economically loaded.
(c)Diesel power station should be worked for fluctuating loads or as a standby.

Demand Factor and Utilization Factor

A higher efficient station, if worked at low utilization factor, may produce power at high unit cost. The time of maximum demand occurring in a system is also important. In an interconnected system, a study of the curves of all stations is necessary to plan most economical operations.

The endeavor should be to load the most efficient and cheapest power producing Stations to the greatest extent possible. Such stations, caled "base load stations" carry full load over 24 hours, i.e. for three shifts of 8 hours.

- The stations in the medium range of efficiency are operated only during the two shifts of 8 hours during 16 hours of averageload.
- The older or less efficient stations are used as peak or standby stations only, and are operated rarely or for short periods of time.

Presently there is a tendency to use units of large capacities to reduce space costs and to handle larger loads. However, the maximum economical benefit of large sets occurs only when these are run continuously at near full load. Running of large sets for long periods at lower than maximum continuous rating increase cost of unit generated

EFFLUENTS FROM POWER PLANTS:

Effluents of thermal power plants contain trace elements and heavy metals, needs remediation before discharging to the environment. Heavy metals tend to bio accumulate in a biological organism such as fish and thus enter the human food chain. Present study has been carried out to assess the contamination of water sources in Yellur and surrounding villages closer to a thermal power plant in Udupi district, Karnataka State, India.

Water samples from 6 Km buffer zone were collected and analyzed for physico chemical parameters and the core zone (within 2km) samples were analyzed for heavy and trace metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn) contamination. This study indicates that the well, stream and pond water within the core zone is contaminated with heavy metals and the levels were higher than the maximum acceptable limits of the stipulated drinking water guidelines. Physico chemical analysis showed DO, Turbidity, TDS, Chlorides, Sodium, Potassium and Hardness of samples of core zone were exceeding the maximum permissible limits of WHO drinking water guidelines.

IMPACT ON ENVIRONMENT:

Due to continuous & long lasting emission of SOx& NOx, which are the principal pollutants coal based plants, surrounding structures, buildings, monuments of historic importance & metallic structures too are affected very badly due to corrosive (Acid rain) reactions. Well known example of this is the victimized Tajmahal of Agra which is being deteriorated due to these toxic gases. It is also worth to note that very high amount of carbon dioxide (CO_2) emission (0.9-0.95 kg/kwh) from thermal power plants contribute to global warming leading to climate change.

Impact on water

The water requirement for a coal-based power plant is about 0.005-0.18 m3/kwh. At STPS, the water requirement has been marginally reduced from about 0.18 m3/kWh to 0.15 m3/kwh after the installation of a treatment facility for the ash pond decant. Still the water requirement of 0.15 m3/kwh = 150 Liters per Unit of electricity is very high compared to the domestic requirement of water of a big city. Ash pond decant contains harmful heavy metals like B, As, Hg which have a tendency to leach out over a period of time.

Due to this the ground water gets polluted and becomes unsuitable for domestic use. At Ramagundam STPS leakage of the ash pond decants was noticed into a small natural channel. This is harmful to the fisheries and other aquatic biota in the water body. Similar findings were noted for Chandrapur. The exposure of employees to high noise levels is very high in the coal based thermal power plant. Moreover, the increased transportation activities due to the operation of the power plant leads to an increase in noise levels in the adjacent localities.

Impact on land

The land requirement per mega watt of installed capacity for coal, gas and hydroelectric power plants is 0.1-4.7 ha, 0.26 ha. and 6.6 ha respectively. In case of coal based power plants the land requirement is generally near the area to the coal mines. While in the case of gas-based it is any suitable land where the pipeline can be taken economically. Land requirement of hydroelectric power plants is generally hilly terrain and valleys. 321 ha., 2616 ha. and 74 ha. of land were used to dispose fly ash from the coal based plants at Ramagundam, Chandrapur and Gandhinagar respectively. Thus large area of land is required for coal based thermal power plant. Due to this, natural soil properties changes. It becomes more alkaline due to the alkaline nature of fly ash.

Biological & thermal impact

The effect on biological environment can be divided into two parts, viz. the effect on flora and the effect on fauna. Effect on flora is due to two main reasons, land acquisition and due to flue gas emissions. Land acquisition leads to loss of habitat of many species. The waste-water being at higher temperature (by 4-5oC) when discharged can harm the local aquatic biota. The primary effects of thermal pollution are direct thermal shocks, changes in dissolved oxygen, and the redistribution of organisms in the local community. Because water can absorb thermal energy with only small changes in temperature, most aquatic organisms have developed enzyme systems that operate in only narrow ranges of temperature. These stenothermic organisms can be killed by sudden temperature changes that are beyond the tolerance limits of their metabolic systems. Periodic heat treatments used to keep the cooling system clear of fouling organisms that clog the intake pipes can cause fish mortality.

Socio-economic impact

The effect of power plants on the socio-economic environment is based on three parameters, viz. Resettlement and Rehabilitation (R & R), effect on local civic amenities and work related hazards to employees of the power plants. The development of civic amenities due to the setting up of any power project is directly proportional to the size of the project. The same has been observed to be the highest for the coal based plants followed by the natural gas based plant and lastly the hydroelectric plant. The coal based plant has the highest number of accidents due to hazardous working conditions. A similar study was undertaken by Agrawal & Agrawal3 (1989) in order to assess the impact of air pollutants on vegetation around Obra thermal power plant (1550 MW) in the Mirzapur district of Uttar Pradesh. 5 study sites were selected northeast (prevailing wind) of the thermal power plant. Responses of plants to pollutants in terms of presence of foliar injury symptoms and changes in chlorophyll, ascorbic acid and S content were noted. These changes were correlated with ambient Sox and suspended particulate matter (SPM) concentrations and the amount of dust settled on leaf surfaces. The Sox and SPM concentrations were quite high in the immediate vicinity of the power plant. There also exists a direct relationship between the concentrations of SPM in air and amount of dust deposited on leaf surfaces. In a lichen diversity assessment carried out around a coal-based thermal power plant by Bajpai et al.4, (2010) indicated the increase in lichen abundance. Distributions of heavy metals from power plant were observed in all directions. Manohar et al.5, (1989) have carried out the study on effects of thermal power plant emissions on atmospheric electrical parameters, as emissions from industrial stacks may not only cause environmental and health problems but also cause substantial deviation in the fair weather atmospheric electric parameters. Observations of the surface atmospheric electric field, point discharge current and wind in the vicinity of a thermal power plant were found to be affected. Warhate6(2009) has studied the impact of coal mining on Air, Water & Soil on the surrounding area of coal mining at Wani dist. Yavatmal. Environmental segments namely air; water & soil in this area are affected within 10-15 Kms from the source. Human beings, animal kingdom, plants & soil are extensively affected within 5 Kms of the source.

Thermal Power Plant affects environmental segments of the surrounding region very badly. Large amount of SOx, NOx & SPM are generated which damage the environment and are highly responsible for deterioration of health of human beings, animal kingdom as well as plants. Emission of SPM & RSPM disperse over 25 Kms radius land and cause respiratory and related ailments to human beings and animal kingdom. SPM gets deposited on the plants which affect photosynthesis. Due to penetration of pollutants inside the plants through leaves & branches, imbalance of minerals, micro and major nutrients in the plants take place which affect the plant growth severely. Spreading & deposition of SPM on soil disturb the soil strata thereby the fertile and forest land becomes less productive. Because of continuous & long lasting emission of SOx& NOx, which are the principal pollutants emitted from a coal based power plant, structures & buildings get affected due to corrosive reactions.

POLLUTANTS AND POLLUTION STANDARDS:

Thermal pollution is the degradation of water quality by any process that changes ambient water temperature. A common cause of thermal pollution is the use of water as a coolant by power plants and industrial manufacturers. When water used as a coolant is returned to the natural environment at a higher temperature, the change in temperature decreases oxygen supply and affects ecosystem composition. Fish and other organisms adapted to particular temperature range can be killed by an abrupt change in water temperature (either a rapid increase or decrease) known as "thermal shock."

Burning Coal in a power plant produces a number of pollutants. Some of these pollutants are specific to the type of fuel or is part of the combustion process or related to the design and configuration of the plant. This article highlights the major pollutants discharged from the power plant.

- **Carbon Dioxide (CO2)**

CO_2 was thought of as a product of combustion and not as a pollutant. Kyoto protocol, effects of Green House gases and global warming issues have changed the way we look at CO_2. CO_2 has turned to be the major greenhouse gas. A fossil fuel power plant is the major contributor of CO_2. One MJ of heat input produces 0.1 kg of CO_2. The only way to eliminate CO_2 is to capture it before leaving to atmosphere. After capturing it has to be stored permanently or sequestered.

Commercially viable capture and sequestration systems are yet to be in place. Till such time the only way is to

- Improve the power plant efficiency so that the reduced coal consumption reduces CO_2 per kwhr.
- Switch over from Fossil based energy sources to renewable sources like wind, solar or hydro power.
- Reduce Deforestation and increase Afforestation to absorb the excess CO_2 produced.

- **Sulphur Dioxide (SO_2)**

This is a product of Combustion and depends on the amount of Sulfur in Coal.This is also referred to as SOx. Sulphur in Coal ranges for 0.1 % to 3.5% depending on type and rank. During combustion Sulfur combines with Oxygen to form SO_2.

Power plants are the largest emitters of SO_2. In the presence of other gases SO_2 forms Sulphuric acid and can precipitate down as acid rain leading to destruction of eco systems. Use of low Sulfur coals is the best ways to reduce the SO_2 emissions. Desulphurization plants downstream of the boilers also reduce emissions. Fluidized bed combustion of coal is another effective method to reduce SO_2 emissions.

- **Ash**

Ash is the residue after the combustion. A 500 MW coal fired power plant burning Coal with around 20 % Ash, collects ash to the tune of Two Million Tons in Five years. Cement plants may utilize a small portion of the ash. Disposing bulk of it on a long term basis can raise major environmental issues.

- Ash contains toxic elements that can percolate into the drinking water system.
- The wind, breach of dykes or ash spills can carry away the ash particles to surrounding areas causing harm to humans and vegetation.

Considering the life of a power plant is 20 years, great foresight , planning and commitment is required to dispose the ash in an eco friendly way.

- **Particulate Matter**

Power plants have elaborate arrangements to collect the ash. A small quantity still goes out through the stack and is categorized as Particulate Matter emission.
The very tall stacks in power plants disperse this ash over a very wide area reducing the concentration levels to human acceptable levels at ground levels.
The particles of size less than 2.5 microns called PM 2.5 is of great concern since these are responsible for respiratory illness in humans.

- **Nitrogen Oxides (NOx)**

Nitrogen in fuel and in the air reacts with Oxygen at high temperatures to form various oxides of Nitrogen collectively called NO_X. Fossil fuel power plants are the second largest emitter of NO_X. This is a hazardous pollutant creating visual and respiratory problems. Also NO_X combines with water to form acid rain, smog, and ground ozone.
Design changes in combustion technology have helped in reducing the NO_X emissions. Methods like Selective Catalytic Reactors are used in power plants to meet the emission regulations.

Pollutants	Emissions (in tones/day)
CO_2	424650
Particulate Matter	4374
SO_2	3311
NO_x	4966

The **Pollutant Standards Index**, or **PSI**, is a type of air quality index, which is a number used to indicate the level of pollutants in air.

PSI	DESCRIPTOR	GENERAL HEALTH ISSUES
0-50	Good	None
51-100	Moderate	Few or none for the general population
100-200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects. To stay indoors
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.
300+	Hazardous	Health alert: everyone may experience more serious health effects

Initially PSI was based on five air pollutants, but since 1 April 2014 it has also included fine particulate matter ($PM_{2.5}$).In addition to the PSI derived by averaging data collected for the past 24 hours, Singapore also publishes a 3h-PSI based on $PM_{2.5}$ concentrations for the past 3 hours. 1-hr $PM_{2.5}$ concentrations are also published every hour. Besides Singapore, some other countries also use air quality indices. However, the calculations used to derive their air quality indices may differ. Different countries also use different names for their indices such as Air Quality Health Index, Air Pollution Index and Pollutant Standards Index.

METHODS OF POLLUTION CONTROL:

The following methods for developing the power generating capacity without pollution to the atmosphere.

1. F.P. Rogers has suggested that it would be safer to set the nuclear power plants underground. This definitely preserves the environment. There would be lot of difficulties in excavation, concreting, roof lining, structural supporting, lowering the reactor equipments and many others. But even then it is suggested that locating the power plant underground would be profitable in the long run.

2. The tidal power must be developed in the coining years that is free from pollution.
3. The thermal discharges to the environment are common from fossil and nuclear-fueled power stations. Significant quantities of particulates and gases from fossil-fueled system, small quantities of radioactive gases from nuclear, have an impact upon an environment. Offshore sitting of power plants mitigates these problems of pollution. Offshore sitting of power stations also isolates the plants from earthquakes and provides the thermal enhancement of the water to increase recreational and commercial values. No doubt, offshore location requires new design consideration and floating platforms in the sea increasing the capital cost of the plant.

4. It was proposed that the thermal pollution of the atmosphere and the generation cost of the plant could be reduced by using the low-grade energy exhausted by the steam. The ideal use for enormous quantity of residual energy from steam power plants requires large demand with unity power factor.

5. Particularly in U.S.A., many uses of energy are available in winter, but not in summer therefore finding large-scale valuable uses of thermal energy is the key for developing beneficial uses.It is estimated that the total energy used in U.S.A. for air-conditioning is equivalent to the total energy used for heating the offices and residences. The low-grade energy exhaust by the thermal plants is not readily usable for air-conditioning purposes. It is possible to use this energy by stopping the expansion of steam at a temperature of 95°C to 100°C and use of this energy can be made to drive an absorption refrigeration system such as lithium bromide water system. This will be a definite positive answer to reduce the thermal pollution of environment otherwise caused by burning extra fuel to run the absorption refrigeration system in summer or to run the heating systems in winter. As for open field irrigation, soil heating with warm water and better cultivation of the fishes in slightly warm water. In short, a combination of uses could consume all heat from a large thermal power station, making conventional cooling unnecessary and reduce the generating cost with minimum thermal pollution of the atmosphere.

6. Use the sun energy for the production of power that is absolutely free from air-pollution.