ST. ANNE'SCOLLEGE OF ENGINEERING AND TECHNOLOGY
(Approved by AICTE, New Delhi. Affiliated to Anna University, Chennai)
Accredited by NAAC
ANGUCHETTYPALAYAM, PANRUTI – 607 106

COURSE NAME: **CME 384 POWER PLANT ENGINEERING**

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CME384	**POWER PLANT ENGINEERING**	**L**	**T**	**P**	**C**
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COURSE OBJECTIVES

1 To study the coal based thermal power plants.
2 To study the diesel, gas turbine and combined cycle power plants.
3 To learn the basic of nuclear engineering and power plants.
4 To learn the power from renewable energy
5 To study energy, economic and environmental issues of power plants

UNIT – I COAL BASED THERMAL POWER PLANTS 9

Rankine cycle - improvisations, Layout of modern coal power plant, Super Critical Boilers, FBC Boilers,Turbines, Condensers, Steam & Heat rate, Subsystems of thermal power plants – Fuel and ash handling, Draught system, Feed water treatment. Binary Cycles and Cogeneration systems.

UNIT – II D I E S E L , GAS TURBINE AND COMBINED CYCLE POWER PLANTS 9

Otto, Diesel, Dual & Brayton Cycle - Analysis & Optimisation. Components of Diesel and Gas Turbine power plants. Combined Cycle Power Plants. Integrated Gasifier based Combined Cycle systems.

UNIT – III NUCLEAR POWER PLANTS 9

Basics of Nuclear Engineering, Layout and subsystems of Nuclear Power Plants, Working of Nuclear Reactors: Boiling Water Reactor (BWR), Pressurized Water Reactor (PWR), CANada Deuterium-Uranium reactor (CANDU), Breeder, Gas Cooled and Liquid Metal Cooled Reactors. Safety measures for Nuclear Power plants.

UNIT – IV POWER FROM RENEWABLE ENERGY 9

Hydro Electric Power Plants – Classification, Typical Layout and associated components including Turbines. Principle, Construction and working of Wind, Tidal, Solar P h o t o Voltaic (SPV), Solar Thermal, Geo Thermal, Biogas and Fuel Cell power systems.

UNIT – V ENERGY, ECONOMIC AND ENVIRONMENTAL ISSUES OF POWER PLANTS 9

Power tariff types, Load distribution parameters, load curve, Comparison of site selection criteria, relative merits & demerits, Capital & Operating Cost of different power plants. Pollution control technologies including Waste Disposal Options for Coal and Nuclear Power Plants.

TOTAL:45 PERIODS.

TEXT BOOKS:

1. Nag. P.K., "Power Plant Engineering", Third Edition, Tata McGraw – Hill Publishing Company Ltd.,2008.
2. A Textbook of Power Plant Engineering by R.K. Rajput | 1 January 2016

REFERENCES:

1. El-Wakil. M.M., "Power Plant Technology", Tata McGraw – Hill Publishing Company Ltd., 2010.
2. Godfrey Boyle, "Renewable energy", Open University, Oxford University Press in association with the Open University, 2004.
3. Thomas C. Elliott, Kao Chen and Robert C. Swanekamp, "Power Plant Engineering", SecondEdition, Standard Handbook of McGraw – Hill, 1998.
4. Power Plant Engineering by B. Vijaya Ramnath C. Elanchezhian, L. Saravanakumar | 1 November 2019
5. Power Plant Engineering, As per AICTE: Theory and Practice by Dipak Kumar Mandal, Somnath Chakrabarti, et al. | 1 January 2019

UNIT -I
COAL BASED THERMAL POWER PLANTS

PART - A

1. Write about classification of draught?

Draught is classified as 1. Natural draught 2. Artificial draught .The artificial draught is further classified as (a) Steam jet draught (b) Mechanical draught (c)Induced draught (d) Forced draught

2. What are the advantages and disadvantages of forced draught system?

Advantages:

- Since the fan handles cold air, the fan size and the power required are less.
- No need of water cooled bearings because the air being handled is cold air,
- Pressure throughout the system is above atmospheric pressure so the air leakage into the furnace is reduced.

Disadvantages:

- Recirculation due to high air-entry and low air-exit velocities

3. What is the difference between stocker firing and pulverized fuel firing?

The stocker firing method is used for firing solid coal whereas pulverized firing method is used for firing pulverized coal.

4. What is supercritical boiler? Give two advantages. (Nov/Dec 2015)

A supercritical boiler is a type of boiler that operates above the critical pressure of 22 MPa.

Advantages:

- Higher unit cycle efficiency (40 - 42%)
- Lower heat rate and electricity generation cost is lower
- Lower water losses because no continuous blow down
- Reduced auxiliary power consumption

5. Describe the steps to be followed in plant coal handling.

(i) Coal delivery (*ii*) Unloading (*iii*) Preparation (*iv*) Transfer (*v*) Temporary storage (*vi*) Covered storage (*vii*) In plant handling (*viii*) Weighing (*ix*) Feeding the coal into furnace.

6. Define Binary cycle.

A binary vapour cycle is a combination of two cycles, one in a high temperature region and the other in a lower temperature region.

7. Write about fluidized bed boilers?

When the high velocity gas is passed through a packed bed of finely divided solid particles, the particles become suspended in the gas stream and the packed bed becomes a fluidized bed. Burning of a fuel in such a state is known as Fluidized Bed Combustion. The boiler plant using this fluidized bed combustion is known as fluidized bed boilers.

8. How the ash handling system is classified?

1. Mechanical handling system
2. Hydraulic system
3. Pneumatic system
4. Steam jet system

9. What is pulverize and why it is used? (Nov/Dec 2015)

In a pulverize, the coal is reduced to fine powder and then supplied into the combustion chamber with the help of hot air current.

The pulverized fuel systems are nowadays universally used for large capacity plants and using low cost (low grade) fuel as it gives high thermal efficiency and better control as per the load demand.

10. What is the function of a draught system? (May/ Jun 2016)

- To supply required quantity of air to the furnace for combustion of fuel.
- To draw the combustion products through the system.
- To remove burnt products from the system

11. Give the example for once through boiler. (May/ Jun 2016)

- Benson boilers
- Once through forced circulation boiler

12. What is meant by cogeneration system?

Cogeneration is the combinations of heat and power (CHP). The power plant generates electricity and useful heat at the same time.

13. What is steam and heat rate? (Nov/Dec 2016)

Steam Rate is the rate at which a boiler produces steam, normally expressed in terms of kg/hr.

The heat rate is the amount of heat energy used by a power plant to generate one kilo watt hour (kWhr) of electricity.

14. What are the methods of improving efficiency of Rankine cycle?

- Reheating
- Regeneration
- Combined reheating and regeneration

15. Name the different circuits of steam power plant.

- Coal and Ash circuit
- Water and Steam circuit
- Air and Flue gas circuit
- Cooling water circuit

16. What do you understand by the term boiler draught? (Nov/Dec 2016)

Boiler draught may be defined as the small difference between the pressure of outside air and that of gases within a furnace or chimney at the grate level, which causes flow of air/hot flue gases to take place through boiler.

17. Define compounding of steam turbines (April/May 2017)

Compounding of steam turbines is the method in which energy from the steam is extracted in a number of stages rather than a single stage in a turbine

18. What is stoker? Classify it. (April/May 2017)

A mechanical device for feeding coal to a furnace

- Class 1 Stokers - *10 to 100 lbs (4.5 to 45 kg)* coal per hour
- Class 2 Stokers - *100 to 300 lbs (4.5 to 135 kg)* per hour
- Class 3 Stokers - *300 to 1200 lbs (135 to 540 kg)* per hour
- Class 4 Stokers - *more than 1200 lbs (more than 540 kg)* per hour

PART B

1. Draw the general layout of thermal power plant and explain the working of different circuits. (Nov/Dec 2015 & Nov/Dec 2016)

1. Coal and Ash circuit:

This includes coal delivery, preparation, coal handling, boiler furnace, ash handling and ash storage. The coal from coal mines is delivered by ships, rail or by trucks to the power station. This coal is sized by crushers, breakers etc. The sized coal is then stored in coal storage (stock yard). From the stock yard, the coal is transferred to the boiler furnace by means of conveyors, elevators etc.

The coal is burnt in the boiler furnace and ash is formed by burning of coal, Ash coming out of the furnace will be too hot, dusty and accompanied by some poisonous gases. The ash is transferred to ash storage. Usually, the ash is quenched to reduced temperature.

There are different methods employed for the disposal of ash. They are hydraulic system, water jetting, ash sluice ways, pneumatic system etc. In large power plants hydraulic system is used. In this system, ash falls from furnace grate into high velocity water stream. It is then carried to the slumps.

2. Water and Steam circuit

It consists of feed pump, economizer, boiler drum, super heater, turbine condenser etc. Feed water is pumped to the economizer from the hot well. This water is preheated by the flue gases in the economizer. This preheated water is then supplied to the boiler drum. Heat is transferred to the water by the burning of coal. Due to this, water is converted into steam.

The steam raised in boiler is passed through a super heater. It is superheated by the flue gases. The superheated steam is then expanded in a turbine to do work. The turbine drives a generator to produce electric power. The expanded (exhaust) steam is then passed through the condenser. In the condenser, the steam is condensed into water and re-circulated.

3. Air and Flue gas circuit

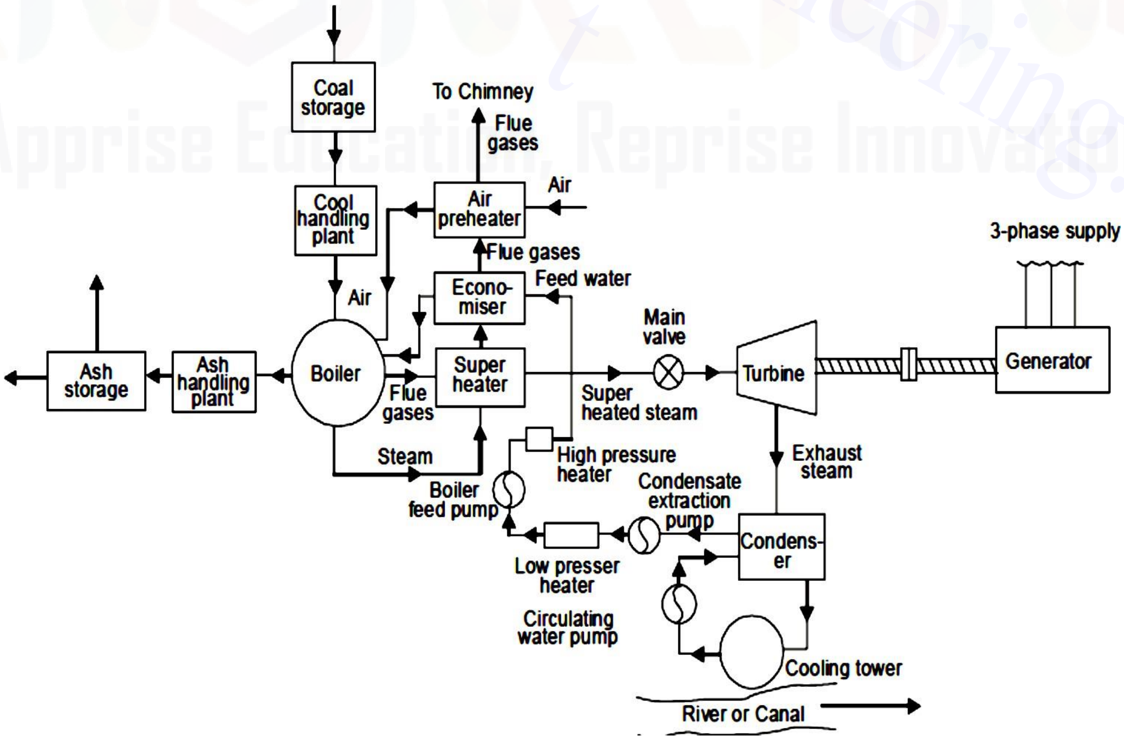
It consists of forced draught fan, air pre heater, boiler furnace, super heater, economizer, dust collector, induced draught fan, chimney etc.

Air is taken from the atmosphere by the action of a forced draught fan. It is passed through an air pre-heater. The air is pre-heated by the flue gases in the pre- heater. This pre-heated air is supplied to the furnace to aid the combustion of fuel. Dueto combustion of fuel, hot gases (flue gases) are formed.

The flue gases from the furnace pass over boiler tubes and super heater tubes. (In boiler, wet steam is generated and in super heater the wet steam is super heated by the flue gases.) Then the flue gases pass through economizer to heat the feed water. After that, it passes through the air pre-heater to pre-heat the incoming air. It is then passed through a dust catching device (dust collector). Finally, it is exhausted to the atmosphere through chimney.

4. Cooling water circuit:

The circuit includes a pump, condenser, cooling tower etc. the exhaust steam from the turbine is condensed in condenser. In the condenser, cold water is circulated to condense the steam into water. The steam is condensed by losing its latent heat tothe circulating cold water.



Thus the circulating water is heated. This hot water is then taken to a cooling tower, In cooling tower, the water is sprayed in the form of droplets through nozzles. The atmospheric air enters the cooling tower from the openings provided at the bottom of the tower. This air removes heat from water. Cooled water is collected in a pond (known as cooling pond). This cold water is again circulated through the pump, condenser and cooling tower. Thus the cycle is repeated again and again. Someamount of water may be lost during the circulation due to vaporization etc. Hence, make up water is added to the pond by means of a pump. This water is obtained from ariver or lake.

2. Explain in detail about different types of Fluidized Bed Combustion (FBC) boiler. (May/June 2016)

Principles of Fluidized Bed Combustion Operation:

A fluidized bed is composed of fuel (coal, coke, biomass, etc.,) and bed material (ash, sand, and/or sorbent) contained within an atmospheric or pressurized vessel. The bed becomes fluidized when air or other gas flows upward at a velocity sufficient to expand the bed.

Classification of Fluidized Bed Combustion:

1. Atmospheric fluidized Bed Combustion (AFBC)
   a. Bubbling fluidized bed combustors
   b. Circulating fluidized
2. Pressurized Fluidized Bed Combustion (PFBC)

As the fluidizing velocity is increased, smaller particles are entrained in the gas stream and transported out of the bed. The bed surface, well-defined for a BFB combustor becomes more diffuse and solids densities are reduced in the bed. A fluidized bed that is operated at velocities in the range of 4 to 7 m/s is referred to as a circulated fluidized bed, or CFB.

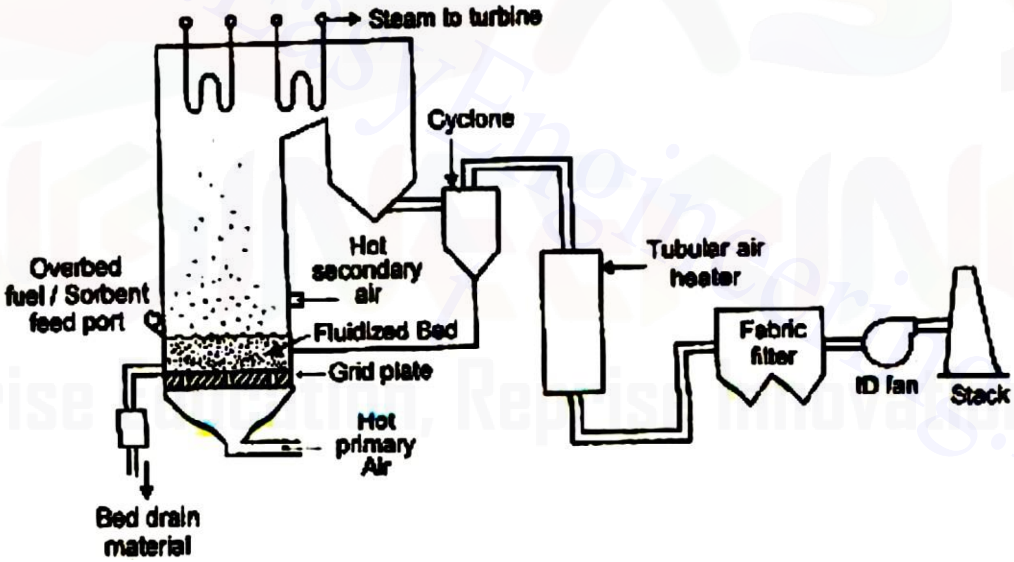
Bubbling fluidized bed combustor

At low fluidizing velocities (0.9 to 3 m/s) relatively high solids densities are maintained in the bed and only a small fraction of the solids are entrained from the bed. A fluidized bed that is operated in this velocity range is referred to as a bubbling fluidized bed (BFB).

A typical BFB arrangement is illustrated schematically in figure. Fuel and sorbent are introduced either above or below the fluidized bed. (Overbed feed is illustrated.) The bed consisting of about 97% limestone or inert material and 3% burning fuel, is suspended by hot primary air entering the bottom of the combustion chamber. The bed temperature is controlled by heat transfer tubes immersed in the bed and by varying the quantity of coal in the bed. As the coal particle size decreases, as a result of combustion or attrition, the particles are elutriated from the bed and carried out the combustor. A portion of the particles elutriated from the bed are collected by a cyclone collector down-stream of the convection pass and returned to the bed toimprove combustion efficiency.

Secondary air can be added above the bed to improve combustion efficiency and to achieve staged combustion, thus lowering NOx emissions.

Most of the early BFBs used tubular air heaters to minimize air leakage that could occur as a result of relatively high primary air pressures required to suspend the bed.

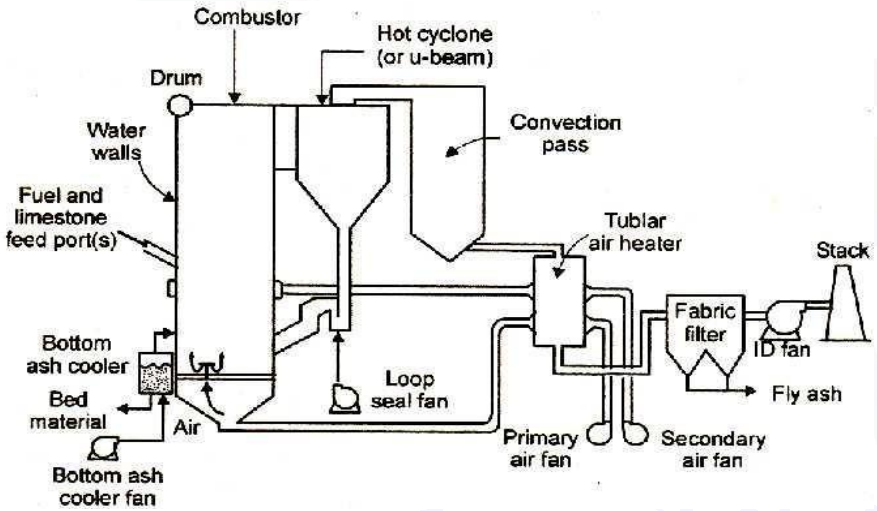


Circulating fluidized bed combustor

As the fluidizing velocity is increased, smaller particles are entrained in the gas stream and transported out of the bed. The bed surface, well-defined for a BFB combustor becomes more diffuse and solids densities are reduced in the bed. A fluidized bed that is operated at velocities in the range of 4 to 7 m/s is referred to as a circulated fluidized bed, or CFB.

Typical CFB arrangement is illustrated schematically in figure. In a CFB,primary air is introduced into the lower portion of the combustor, where the heavy bed material is fluidized and retained. The upper portion of the combustor contains the lessdense material that is entrained from the bed. Secondary air typically is introduced at higher levels in the combustor to ensure complete combustion and to reduce NOx emissions.

The combustion gas generated in the combustor flows upward with a considerable portion of the solids inventory entrained. These entrained solids are separated from the combustion gas in hot cyclone-type dust collectors or in mechanical particle separators, and are continuously returned to the combustion chamber by a recycle loop.



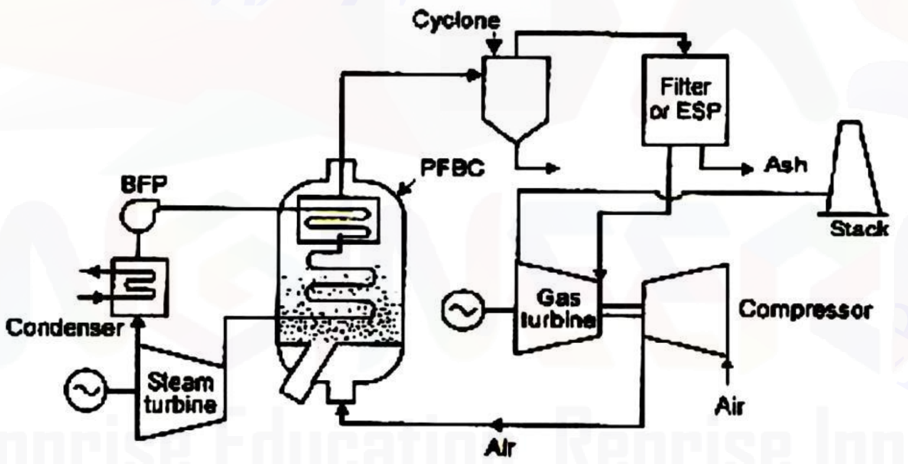
The combustion chamber of a CFB unit for utility applications generally consists of membrane-type welded water walls to provide most of the evaporative boiler surface. The lower third of the combustor is refractory lined to protect the water walls from erosion in the high velocity dense bed region. Several CFB design offer external heat exchangers, which are unfired dense BFB units that extract heat from the solids collected by the dust collectors before it is returned to the combustor. The external heat exchangers are used to provide additional evaporative heat transfersurface as well as superheat and reheat surface, depending on the manufacturer’s design.

The flue gas, after removal of more than 99% of the entrained solids in the cyclone or particle separator, exists the cyclone or separator to a convection pass. The convection pass designs are similar to those used with unconventional coal-fueled units, and contain economizer, superheat, and reheat surface as required by the application.

Pressurized Fluidized Bed Combustion

The PFBC unit is classified as either turbocharged or combined cycle units. In turbocharged arrangements (figure) combustion gas from the PEBC boiler is cooled to approximately 394° C and is used to drive a gas turbine. The gas turbine drives an air compressor, and there is little, if any, net gas turbine output. Electricity is produced by a turbine generator driven by steam generated in the PFBC boiler.

In the combined cycle arrangement, 815^0C to 871^0C combustion gas from the PFBC boiler is used to drive the gas turbine. About 20% of the net plant electrical output is provided by the gas turbine. With this arrangement, thermal efficiency 2 to 3 percentage points higher than with the turbocharged cycle are feasible



Advantages of fluidized bed combustion

1. SO_2 can be removed in the combustion process by adding limestone to the fluidized bed, eliminating the need for an external desulfurization process.

2. Fluidized bed boilers are inherently fuel flexible and, with proper design provision, can burn a variety of fuels.

3. Combustion FBC units take place at temperatures below the ash fusion temperature of most fuels. Consequently, tendencies for slagging and fouling are reduced with FBC.

4. Because of the reduced combustion temperature, NOx emissions are inherently low.

3. Explain the various processes involved in coal and ash handling with neat sketch. (**Nov/Dec 2015,April/May 2017)**

(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 buckets and coal accelerators. Rotary car dumpers although costly are quite efficient for unloading closed wagons.

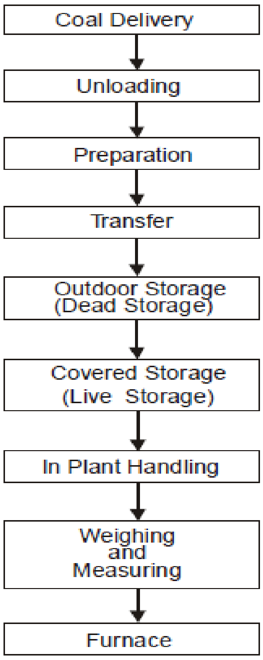
(iii) **Preparation.** When the coal delivered is in the form of big lumps and it is not of proper size, the preparation (sizing) of coal can be achieved by crushers, breakers, sizers driers and magnetic separators at the power station. In case the coal is brought by railway wagons, ships or boats, the unloading may be done by car shakes, rotary car dumpers, cranes, and grab.

(*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.

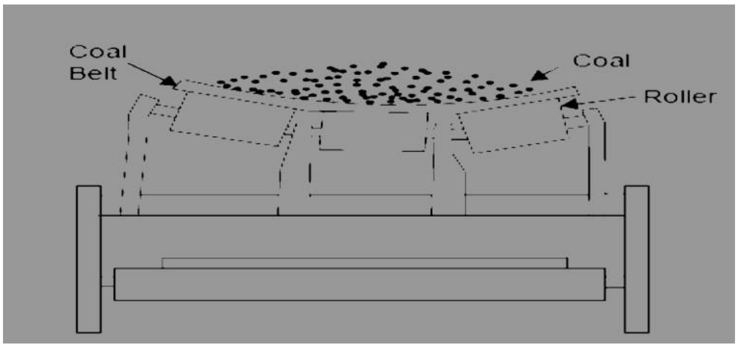
Figure shows a belt conveyor. It consists of an endless belt, which is moving over a pair of end drums (rollers). At some distance a supporting roller is provided at the center. The belt is made, up of rubber or canvas. Belt conveyor is suitable for the transfer of coal over long distances. It is used 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 about20.Average speed of belt conveyors varies between 200-300 r.p.m. This conveyor is preferred than other types.



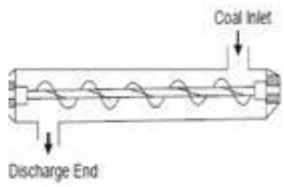
Advantages of belt conveyor

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.

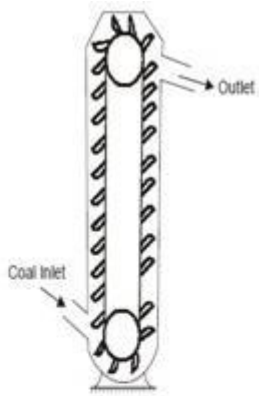
2. Screw conveyor. It consists of an endless helicoid screw fitted to a shaft The screw while rotating in a trough transfers the coal from feeding end to the discharge end. This system is suitable, where coal is to be transferred over shorter distance and space limitations exist. The initial cost of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



Belt conveyor



Screw Conveyor



Bucket Elevator

(*v*) **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.

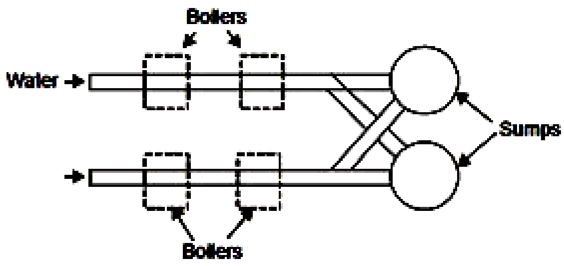
(vi) In Plant Handling. From the dead storage the coal is brought to covered storage (Live storage) (bins or bunkers). A cylindrical bunker shown in Fig. In plant handling may include the equipment such as belt conveyors, screw conveyors, bucket elevators etc. to transfer the coal. Weigh lorries hoppers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

(vii) 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 weightier 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.

Ash handling.

The commonly used ash handling systems are as follows

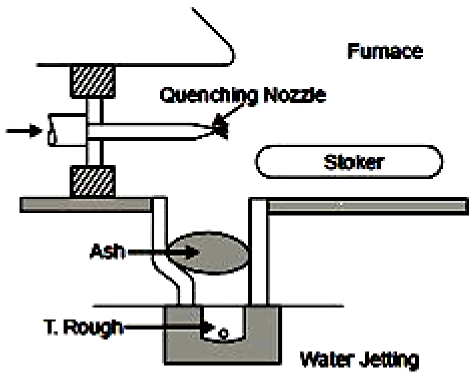
(i) **Hydraulic System.** In this system, ash from the furnace grate falls into a system of water possessing high velocity and is carried to the sumps. In this method water at sufficient pressure is used to take away the ash to sump. Where water and ash are separated. The ash is then transferred to the 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.



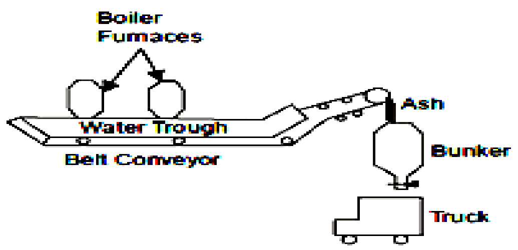
Hydraulic System.

(ii) **Water Jetting.** In this method a low pressure jet of water coming out of the quenching nozzle is used to cool the ash. The ash falls into a trough and is then removed.
(iii) **Ash Sump System.** This system used high pressure (H.P.) pump to supply high pressure (H.P.) water-jets which carry ash from the furnace bottom through ash sluices (channels) constructed in basement floor to ash sump fitted with screen. The screen divides the ash sump into compartments for coarse and fine ash. The fine ash passes through the screen and moves into the dust sump (D.S.). Dust slurry pump (D.S. pump) carries the dust through dust pump (D.P), suction pipe and dust delivery (D.D.) pipe to the disposal site. Overhead crane having grab bucket is used to remove coarse ash.
(*iv*) **Pneumatic system.** In this system 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.
v) **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.



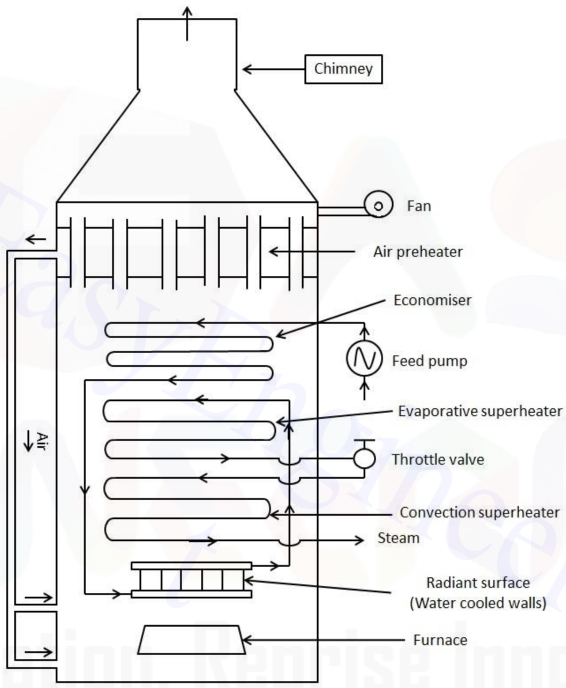
Water Jetting of Ash.



Mechanical Ash Handling.

4. Construction and working of Benson Boiler(Nov/Dec 2160

The main parts of Benson boil



Benson Boiler

1. Air Preheater

It preheats the air before entering into the furnace. The preheated air increases the burning efficiency of the fuel.

2. Economiser

It heats the water to a certain temperature.

3. Radiant Superheater

It is super heater which heats the water with radiation produced by the burnt fuel. It raises the temperature to supercritical temperature.

4. Convection Evaporator

It evaporates the superheated water and converts them into steam. It does so by the convection mode of heat transfer to the water from the hot flue gases.

5. Convection Superheater

It superheats the steam to the desired temperature (nearly 650 degree Celsius).

6. Furnace

It is the place where the fuel is burnt.

7. Feed Pump

It is used to supply the water inside the boiler at supercritical pressure of 225 bars.

Working Principle

It works on the principle that the pressure of the water is increased to the supercritical pressure (i.e. above critical pressure of 225 bar). When the pressure of water is increased to the super critical level, the latent heat of water becomes Zero and due to this, it directly changes into steam without boiling. And this prevents the formation of bubbles at tube surface.

Working

In Benson Boiler, the feed pump increases the pressure of the water to the supercritical pressure and then it enters into the economiser. From economiser, the water the water passes to the radiant heater. Here the water receives the heat through radiation and partly gets converted into steam. The temperature raises almost to the supercritical temperature. After that mixture of steam and water enters into convective evaporator where it is completely converted into steam and may superheated to some degree. Finally it is passed through the superheater to obtained the desired superheated steam. This superheated steam is then used by turbines or engine to produce the electricity.

Advantages

The various advantages of the boiler are

It is a drum less boiler and hence the weight of this type of boiler is 20 % less as compared with other types of boiler.

It is light in weight.

Occupy smaller floor area for its erection.

Explosion hazard is almost negligible because of use of smaller diameter tubes.

It can be started very easily within 15 minutes.

It avoids bubble formation due to the super critical pressure of water.

Transportation is easy.

This boiler may achieve thermal efficiency upto 90 %.

Application

This supercritical boiler is used in different industries to generate steam for the production of electricity or mechanical power. The average operating pressure, temperature and capacity of benson boiler is 650 degree Celsius, 250 bar and 135 tonnes/h.

5. Explain in detail about various types of condenser used in thermal power plant. (May/June 2016)

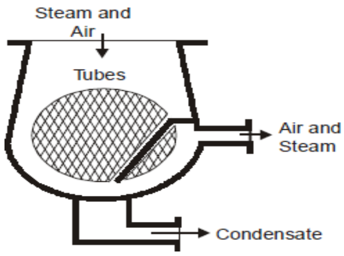
A condenser is a device in which the steam is condensed by cooling it with water. The condensed steam is known as condensate. The following are the advantages of installing a condenser in a steam power plant.

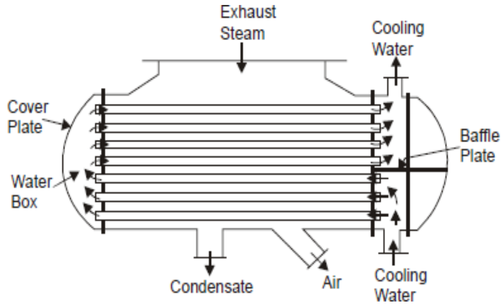
1. More work is done by the given amount of steam than could be obtained without a condenser. Thus, the efficiency of the power plant is increased.
2. Steam consumption is reduced for the given output.
3. The condensate is recovered for the boiler feed water.

Surface condensers

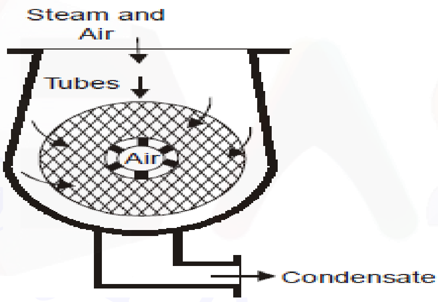
In surface condensers there is no direct contact between the steam and cooling water and the condensate can be re-used in the boiler: In such condenser even impure water can be used for cooling purpose whereas the cooling water must be pure in jet condensers. Although the capital cost and the space needed is more in surface condensers but it is justified by the saving in running cost and increase in efficiency of plant achieved by using this condenser. Depending upon the position of condensate extraction pump, flow of condensate and arrangement of tubes the surface condensers may be classified as follows:

(i) **Down flow type.** Fig shows a sectional view of dawn flow condenser. Steam enters at the top and flows downward. The water flowing through the tubes in one direction lower half comes out the opposite direction in the upper half

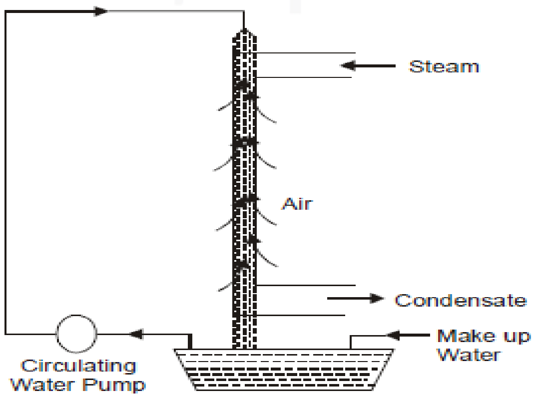




Central flow condenser. Fig shows a central flow condenser. In this condenser the steam passages are all around the periphery of the shell. Air is pumped away from the centre of the condenser. The condensate moves radially towards the centre of tube nest. Some of the exhaust moving towards the centre meets the under cooled condensate and pre-heats it thus reducing under cooling.



(*iii*) **Evaporation condenser.** In this condenser (Fig.) steam to be condensed is passed through a series of tubes and the cooling waterfalls over these tubes in the form of spray. A steam of air flows over the tubes to increase evaporation of cooling water, which further increases the condensation of steam.



The various advantages of a surface condenser are as follows:

1. The condensate can be used as boiler feed water.

2. Cooling water of even poor quality can be used because the cooling water does not come in direct contact with steam.

3. High vacuum (about 73.5 cm of Hg) can be obtained in the surface condenser. This increases the thermal efficiency of the plant.

The various disadvantages of' the surface condenser is as follows:

1. The capital cost is more.

2. The maintenance cost and running cost of this condenser is high.

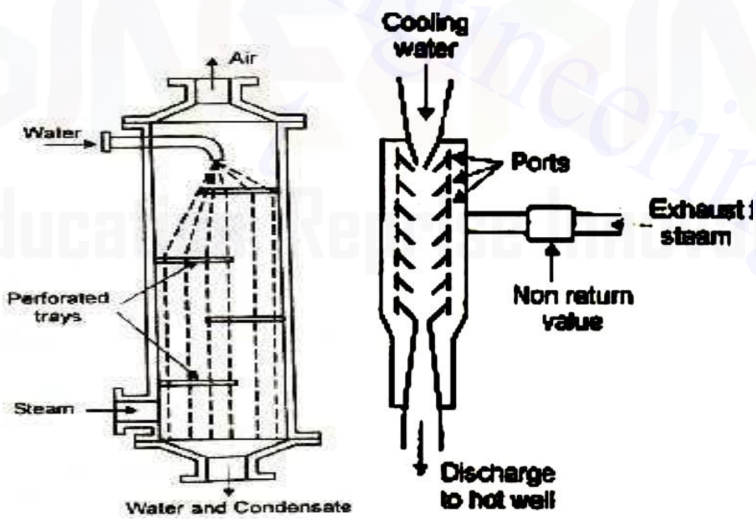
3. It is bulky and requires more space.

Jet condenser

In a jet condenser, the steam to be condensed and the cooling water come in direct contact and the temperature of the condensate is the same as that of the cooling water leaving the condenser. For jet condensers the recovery of the condensate for reuse as boiler feed water is not possible.

Low level jet condenser

In this condenser, the cooling water enters at the top and sprayed through jets. The steam enters at the bottom and mixes with the fine spray of cooling water. The condensate is removed by a separate pump. The air is removed by an air pump separately from the top.



High level jet condenser

This is similar to a low level condenser, except that the condenser shell is placed at a height of 10.36 m [barometric height] above the hot well. The column of water in the tail pipe forces the condensate into the hot well by gravity. Hencecondensate extraction pump is not required.

Ejector condenser

In this condenser cooling water under a head of 5 to 6 m enters at the top of the condenser**.** It is passed through a series of convergent nozzles. There is a pressure drop at the throat of the nozzle. The reduction is pressure draws exhaust steam into the nozzle through a non-return valve. Steam is mixed with water and condensed. In the converging cones, pressure energy is partly converted into kinetic energy. In divergingcones, the kinetic energy is partly converted into pressure energy. The pressure obtained is higher than atmospheric pressure and this forces the condensate to the hot well.

6. Explain the different types of draught systems. (Nov/Dec 2015,April/may 2017)

Draught is defined as the difference between absolute gas pressure at any point in a gas flow passage and the ambient (same elevation) atmospheric pressure. Draught is plus if Patm < Pgas and it is minus Patm > Pgas. Draught is achieved by small pressure difference which causes the flow of air or gas to take place. It is measured in milimetre (mm) or water.

The purpose of draught is as follows:

- To supply required amount of air to the furnace for the combustion of fuel. The amount of fuel that can be burnt per square root of grate area depends upon the quantity of air circulated through fuel bed.
- To remove the gaseous products of combustion.

Classification of draught:

1. Natural draught 2. Artificial draught

The artificial draught is further classified as

(a) Steam jet draught

(b) Mechanical draught

The Mechanical draught is further classified as

(i) Induced draught

(ii) Balanced draught

(iii) Forced draught

1. Natural draught:

If only chimney is used to produce the draught, it is called natural draught.

2. Artificial draught:

If the draught is produced by steam jet or fan it is known as artificial draught

Steam jet Draught:

It employs steam to produce the draught

Mechanical draught

It employs fan or blowers to produce the draught.

Induced draught

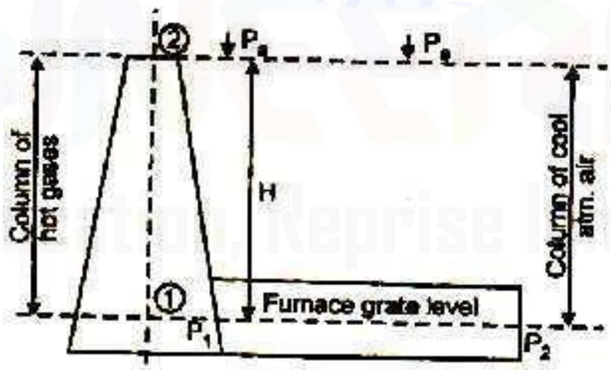
The flue is drawn (sucked) through the system by a fan or steam jet

Forced draught

The air is forced into system by a blower or steam jet.

Natural Draught:

Natural draught system employs a tall chimney as shown in figure. The chimney is a vertical tubular masonry structure or reinforced concrete. It is constructed for enclosing a column of exhaust gases to produce the draught. It discharges the gaseshigh enough to prevent air pollution. The draught is produced by this tall chimney due to temperature difference of hot gases in the chimney and cold external air outside the chimney.



Where H- Height of the Chimney (m)

p_a – Atmospheric pressure (N/m2)

p_1 – Pressure acting on the grate from chimney side (N/m2)

p_2 – Pressure acting on the grate from atmospheric (N/m2)

Due to this pressure difference (p), the atmospheric air flows through the furnace grate and the flue gases flow through the chimney. The pressure difference can be increased by increasing the height of the chimney or reducing the density of hot gases.

Artificial Draught:

It has been seen that the draught produced by chimney is affected by the atmospheric conditions. It has no flexibility, poor efficiency and tall chimney is required. In most of the modern power plants, the draught used must be independence of atmospheric condition, and it must have greater flexibility (control) to take the fluctuating loads on the plant. Today's large steam power plants requiring 20 thousand tons of steam per hour would be impossible to run without the aid of draft fans. A chimney of an reasonable height would be incapable of developing enough draft to remove the tremendous volume of air and gases (400 × 103 m3 to 800 × 103 m3 per minutes). The further advantage of fans is to reduce the height of the chimney needed. The draught required in actual power plant is sufficiently high (300 mm of water) and to meet high draught requirements, some other system must be used, known as artificial draught. The artificial draught is produced by a fan and it is known as fan (mechanical) draught. Mechanical draught is preferred for central power stations.

Forced Draught:

In a forced draught system, a blower is installed near the base of the boiler and air is forced to pass through the furnace, flues, economizer, air-pre heater and to the stack. This draught system is known as positive draught system or forced draught system because the pressure and air is forced to flow through the system. The arrangement of the system is shown in figure. A stack or chimney is also in this system as shown in figure but its function is to discharge gases high in the atmosphere to prevent the contamination. It is not much significant for producing draught therefore height of the chimney may not be very much.

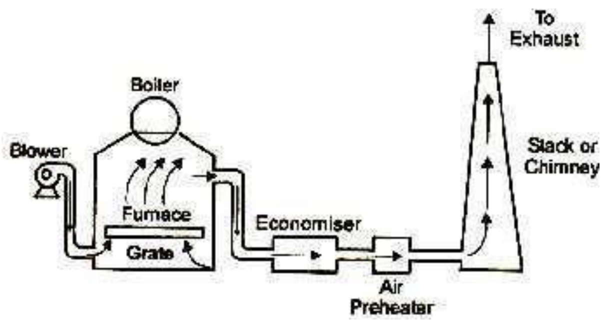


Figure: Forced draught

Induced Draught:

In this system, the blower is located near the base of the chimney instead of near the grate. The air is sucked in the system by reducing the pressure through the system below atmosphere. The induced draught fan sucks the burned gases from the furnace and the pressure inside the furnace is reduced below atmosphere and induces the atmospheric air to flow through the furnace.

The action of the induced draught is similar to the action of the chimney. The draught produced is independent of the temperature of the hot gases therefore the gases may be discharged as cold as possible after recovering as much heat as possible in air-pre heater and economizer.

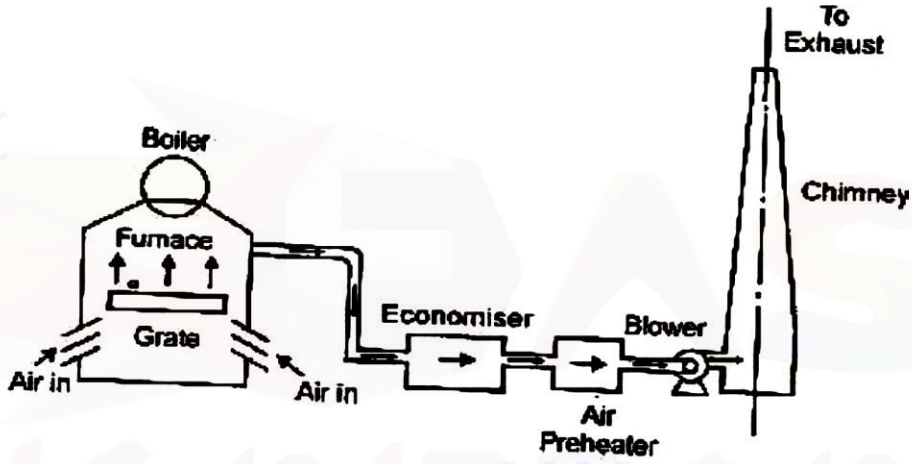


Figure: Induced draught

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

Balanced Draught:

It is always preferable to use a combination of forced draught and induced draught instead of forced or induced draught alone. If the forced draught is used alone, then the furnace cannot be opened either for firing or inspection because the high pressure air inside the furnace will try to blow out suddenly and there is every chance of blowing out the fire completely and furnace stops. If the induced draught is used alone, then also furnace cannot be opened either for firing or inspection because the cold air will try to rush into the furnace as the pressure inside the furnace is below atmospheric pressure. This reduces the effective draught and dilutes the combustion.

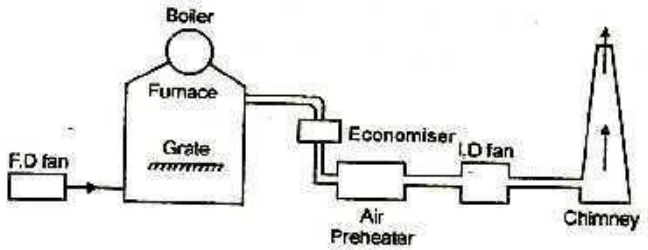


Figure: Balanced draught

To overcome both the difficulties mentioned above either using forced draught or induced draught alone, a balanced draught is always preferred. The balanced draught is a combination of forced and induced draught. The forced draught overcomes the resistance of the fuel bed therefore sufficient air is supplied to the fuel bed for proper and complete combustion.

The induced draught fan removes the gases from the furnace maintaining the pressure in the furnace just below atmosphere. This helps to prevent the blow – off of flames when the doors are opened as the leakage of air is inwards. The arrangement of the balanced draught is shown in figure.

Also the pressure inside the furnace is near atmospheric therefore there is no danger of blowout or there is no danger of inrushing the air into the furnace when the doors are opened for inspection.

7. Discuss the functions of air pre heater and its types (May/June 2016)

An air pre heater (APH) is a general term used to describe any device designed to heat air before another process (for example, combustion in a boiler) with the primary objective of increasing the thermal efficiency of the process. They may be used alone or to replace a recuperative heat system or to replace a steam coil.

In particular, this article describes the combustion air pre heaters used in large boilers found in thermal power stations producing electric power from e.g. fossil fuels, biomass or waste.

The purpose of the air pre heater is to recover the heat from the boiler flue gas which increases the thermal efficiency of the boiler by reducing the useful heat lost in the flue gas. As a consequence, the flue gases are also conveyed to the flue gas stack (or chimney) at a lower temperature, allowing simplified design of the conveyance system and the flue gas stack. It also allows control over the temperature of gases leaving the stack.

Types

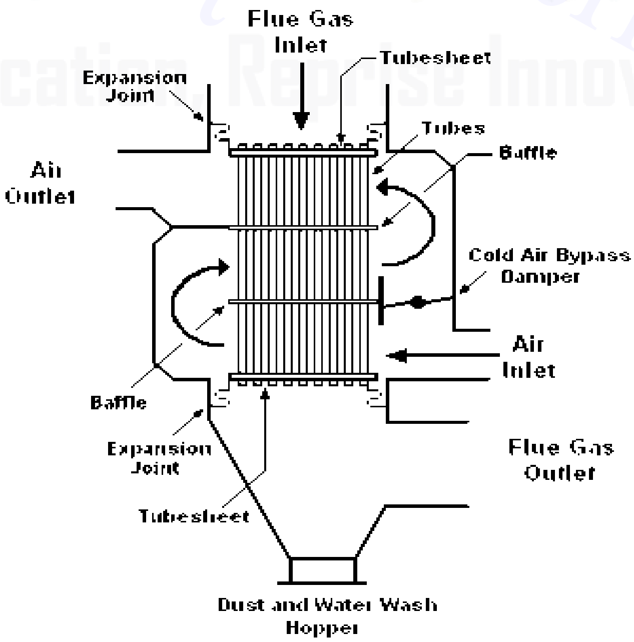
There are two types of air pre heaters for use in steam generators in thermal power stations:

- One is a tubular type built into the boiler flue gas ducting,
- And the other is are regenerative air pre heater. These may be arranged so the gas flows horizontally or vertically across the axis of rotation.

Tubular type:

Construction features:

Tubular pre heaters consist of straight tube bundles which pass through the outlet ducting of the boiler and open at each end outside of the ducting. Inside the ducting, the hot furnace gases pass around the pre heater tubes, transferring heat from the exhaust gas to the air inside the pre heater. Ambient air is forced by a fan through ducting at one end of the pre heater tubes and at other end the heated air from inside ofthe tubes emerges into another set of ducting, which carries it to the boiler furnace for combustion.



Regenerative air pre- heaters

There are two types of regenerative air pre-heaters:

- The rotating-plate regenerative air pre-heaters (RAPH) and
- The stationary-plate regenerative air pre-heaters.

Rotating-plate regenerative air pre- heater

The rotating-plate design (RAPH) consists of a central rotating-plate element installed within a casing that is divided into two (bi-sector type), three (tri-sector type) or four (quad-sector type) sectors containing seals around the element. The seals allow the element to rotate through all the sectors, but keep gas leakage between sectors to a minimum while providing separate gas air and flue gas paths through each sector.

Tri-sector types are the most common in modern power generation facilities. In the tri-sector design, the largest sector (usually spanning about half the cross-section of the casing) is connected to the boiler hot gas outlet. The hot exhaust gas flows over the central element, transferring some of its heat to the element, and is then ducted away for further treatment in dust collectors and other equipment before being expelled fromthe flue gas stack. The second, smaller sector is fed with ambient air by a fan, which passes over the heated element as it rotates into the sector, and is heated before being carried to the boiler furnace for combustion. The third sector is the smallest one and it heats air which is routed into the pulverizers and used to carry the coal-air mixture to coal boiler burners. Thus, the total air heated in the RAPH provides: heating air to remove the moisture from the pulverized coal dust, carrier air for transporting the pulverized coal to the boiler burners and the primary air for combustion.

The rotor itself is the medium of heat transfer in this system, and is usually composed of some form of steel and/or ceramic structure. It rotates quite slowly(around 3-5 RPM) to allow optimum heat transfer first from the hot exhaust gases to the element, then as it rotates, from the element to the cooler air in the other sectors.

In this design the whole air pre heater casing is supported on the boiler supporting structure itself with necessary expansion joints in the ducting.

The vertical rotor is supported on thrust bearings at the lower end and has an oil bath lubrication, cooled by water circulating in coils inside the oil bath. This arrangement is for cooling the lower end of the shaft, as this end of the vertical rotor is on the hot end of the ducting. The top end of the rotor has a simple roller bearing to hold the shaft in a vertical position.

The rotor is built up on the vertical shaft with radial supports and cages for holding the baskets in position. Radial and circumferential seal plates are also provided to avoid leakages of gases or air between the sectors or between the duct and the casing while in rotation.

For on line cleaning of the deposits from the baskets steam jets are provided such that the blown out dust and ash are collected at the bottom ash hopper of the air pre heater. This dust hopper is connected for emptying along with the main dust hoppers of the dust collectors.

The rotor is turned by an air driven motor and gearing, and is required to be started before starting the boiler and also to be kept in rotation for some time after the boiler is stopped, to avoid uneven expansion and contraction resulting in warping or cracking of the rotor. The station air is generally totally dry (dry air is required for the instrumentation), so the air used to drive the rotor is injected with oil to lubricate the air motor.

Safety protected inspection windows are provided for viewing the pre heater's internal operation under all operating conditions.

The baskets are in the sector housings provided on the rotor and are renewable. The life of the baskets depends on the ash abrasiveness and corrosiveness of the boiler outlet gases.

Stationary-plate regenerative air pre heater:

The heating plate elements in this type of regenerative air pre heater are also installed in a casing, but the heating plate elements are stationary rather than rotating. Instead the air ducts in the pre heater are rotated so as to alternatively expose sections of the heating plate elements to the up flowing cool air.

As indicated in the adjacent drawing, there are rotating inlet air ducts at the bottom of the stationary plates similar to the rotating outlet air ducts at the top of the stationary plates.

Stationary-plate regenerative air pre heaters are also known as Rothemuhle pre heaters, manufactured for over 25 years by Balke-Dürr GmbH of Ratingen, Germany.

8. Explain the working of a mercury- water binary cycle (may/June 2016)

Binary Vapour Cycle

Generally water is used a working fluid in vapour power cycle as it is found to be better than any other fluid, but it is far from being the ideal one. The binary cycle is an attempt to overcome some of the shortcomings of water and to approach the ideal working fluid by using two fluids. The most important desirable characteristics of the working fluid suitable for vapour cycles are:

a .A high critical temperature and a safe maximum pressure.

b. Low- triple point temperature

c. Condenser pressure is not too low.

d. high enthalpy of vaporization

e. High thermal conductivity f. It must be readily available, inexpensive, inert and non-toxic.

Therefore it can be concluded that no single working fluids may have desirable requirements of working fluid. Different working fluids may have different attractive feature in them, but not all. In such cases two vapour cycles operating on two different working fluids are put together, one is high temperature region and the other in low temperature region and the arrangement is called binary vapour cycle. The layout of mercury-steam binary vapour cycle is shown in figure.

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In condenser, the water is used for extracting heat from the mercury so as to condensate it. The amount water entering mercury condenser. The mercury condenser also act as steam boiler for super heating of heat liberated during condensation of mercury is too large to evaporate the water entering of seam an auxiliary boiler may be employed or superheating may be realized in the mercury boiler itself.

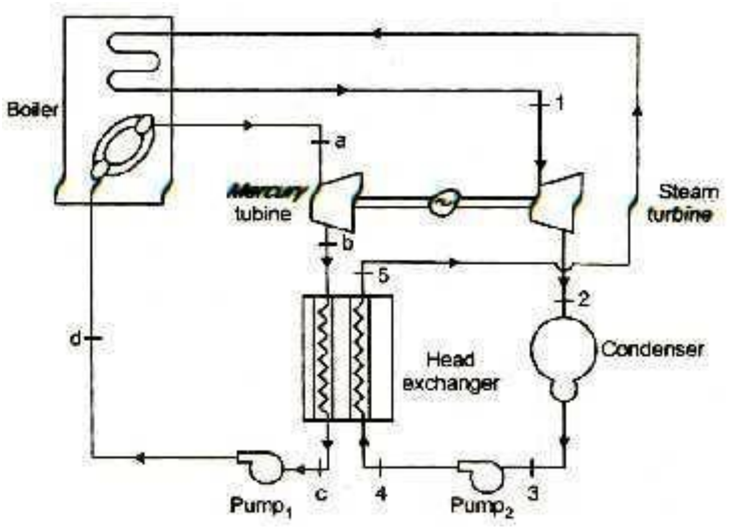

Figure: Mercury-steam binary vapour cycle

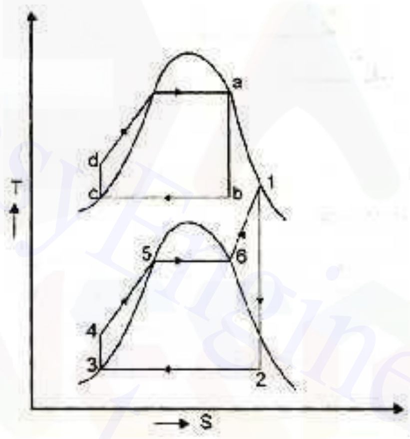

Figure: T-S diagram for Hg-steam binary vapour cycle.

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9. Ideal reheat regeneration cycle operates with steam as the working fluid. Steam enters at 50 bar and 500°C where it expands till its saturated vapour. It isreheated at constant pressure to 400°C and then it expands in the intermediate turbine to appropriate minimum pressure such that a part of the steam bled at this pressure heats feed water to a temperature of 200°C. The remainder expandsto a pressure of 0.1 bar in L.P. turbine. Determine the minimum pressure at

which the bleeding id necessary and the quality of steam bled per Kg of flow at the turbine inlet. Also compute the thermal efficiency of the plant.

Given data:

P_1 = 50 bar

T_1 = 500°C

P_2 = 3 bar

T_3 = 400°C

T_4 = 200°C

P_5 = 0.1 bar

To find :

P_4, m_1 and η

Solution :

From superheated steam table

At 50 bar and 500°C

h_1 = 3443.7 KJ/Kg

s_1= 6.977 KJ/Kg K

At 200°C

P_{sat} = 15.549 bar

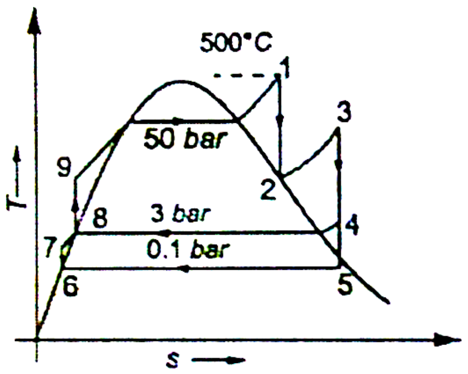
At 0.1 bar

h_f = 191.8 KJ/Kg

h_{fg}=2392.9 KJ/Kg

s_f = 0.649 KJ/Kg

s_{fg} = 7.502 KJ/Kg



1-2 Isentropic expansion process

s_1=s_2=6.977 KJ/Kg K

At s_2=6.977 KJ/Kg K

P_2 = 3.2 bar

At P_2 = 3.2 bar Properties of steam

h_2 = 2727.6 KJ/Kg

s_3 = 8.034 KJ/Kg K

From Steam table select a pressure in such a way that

s_3 = 8.034 KJ/Kg K and T_4 = 200°C

P_4 = 0.74 bar

At 0.74 bar and 200°C

h_4 = 2870 KJ/Kg K

$h_8=h_7$(at 0.74 bar) = 383 KJ/Kg

3-5 Isentropic expansion process

$s_3= s_5$ = 8.034 KJ/Kg K

$s_5=s_{f5} + x_5 \times s_{fg5}$

$8.034 = 0.649 + x_5 \times 7.502$

$x_5 = 0.984$

$h_5= h_{f5} + x_5 \times h_{fg5}$

= 191.8 + 0.984 x 2392.9 = 2546.41 KJ/Kg

At 0.1 bar

h_{f5} = 191.8 KJ/Kg

h_6 = 191.8 KJ/Kg

Pump work 1

$W_p = v_{f5} \times (P_5-P_1)$

$= 0.001010 \times (0.74-0.1) \times 10^5 = 0.06464$ KJ/Kg

$h_7=h_6 - W_p =$ 191.8 – 0.06464 = 191.735 KJ/Kg

Pump work 2

$W_p = v_{f8} \times (P_8-P_9)$

$= 0.001037 \times (50-0.74) \times 10^5 = 5.108$ KJ/Kg

$h_9=h_8 - W_p =$ 383 – 5.108 = 377.89 KJ/Kg

Energy balance in feed water heater

$1 \times h_8 = m_1 \times h_4 + (1-m_1) \times h_7$

$1 \times 383 = m_1 \times 2870 + (1- m_1) \times 191.735$

m_1 = 0.2146 Kg

Efficiency of the cycle

$$\eta = \frac{(h_1 - h_2) + (h_3 - h_4) + (1 - m_1)(h_4 - h_5)}{(h_1 - h_9) + (h_3 - h_2)}$$

$$\eta = \frac{(3443.7 - 2727.6) + (3275.2 - 2870) + (1 - 0.2146)(2870 - 2546.41)}{(3443.7 - 377.89) + (3275.2 - 2727.6)}$$

$$\boxed{\eta = 38.07\%}$$

$= 38.07\ \%$

UNIT –II

DIESEL, GAS TURBINE AND COMBINED CYCLE POWER PLANTS

1. What do you mean by regeneration in gas turbine power plant?

The hot exhaust gases from the turbine are used to pre heat the air entering the combustion chamber. This reduces the amount of fuel needed to reach the desired temperature. This is known as regeneration in gas turbine power plant.

2. How solid injection is classified?

- Common Rail System
- Unit Injection System
- Individual Pump and Nozzle System
- Distributor System

3. List the reason why the cooling system is necessary for a diesel engine.

- To avoid damages and overheating of piston.
- To avoid uneven expansion which results in cracking in the piston and cylinder.
- To avoid pre-ignition and detonation or knocking.
- To avoid reduction in volumetric efficiency and power output of the engine.

4. What type of cycle is used in gas turbine power plant? Write the processes involved.

Brayton cycle is used in gas turbine. It has four thermodynamic processes namely isentropic compression, isobaric heat addition, isentropic expansion and isobaric heat rejection.

5. What is the purpose of intercooler in gas turbine power plant?

Intercooler is used in air compressor of the gas turbine power plant. The air leaving the L.P. compressor is cooled by intercooler and then passed to the H.P compressor. It reduces the work required to operate the compressor.

6. What is the main objective of the supercharging?

Supercharging is a process which is used to increase the pressure of the engine at inlet manifold to increase power output.

7. Why the gas turbine power generation is more attractive than other power generation? (Nov/Dec 2015)

1. Low capital cost 2. High reliability 3. Flexibility in operation
4. Capability to quick start
5. High efficiency

8. List any four applications of diesel power plant. (Nov/Dec2012)

1. Used as peak load plants 2. Suitable for mobile plants
3. Used as standby units 4. Used as emergency plant

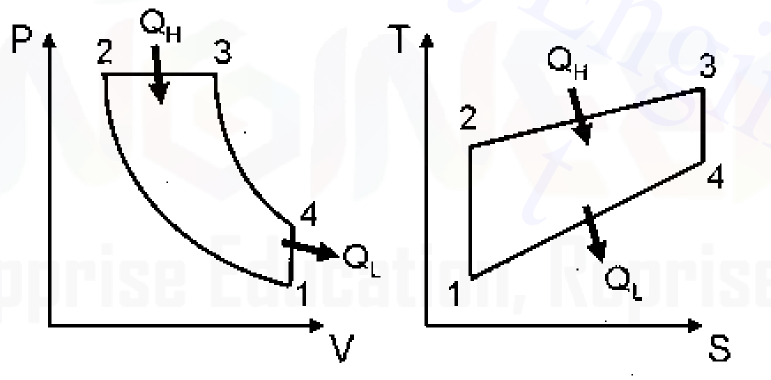
9. What is gasifier?

Gasifier is a device, used to convert solid fuel into gaseous fuel. This is achieved by heating the material at high temperatures (>700 °C), without combustion, with a controlled amount of oxygen and/or steam.

10. Give the examples of combined power cycle.

- Combined cycle of gas turbine and steam power plant.
- Integrated based gasifier based combined cycle.

11. Draw the PV and TS diagram of diesel cycle.



P-V and T-S diagrams of Ideal Diesel Cycle

12. Mention the major differences between Otto and Diesel cycle.(Nov/Dec 2015)

Otto cycle	Diesel cycle
It consists of two adiabatic and two constant volume processes.	It consists of two adiabatic and two constant pressure processes.
Compression ratio is equal to expansion ratio.	Compression ratio is not equal to expansion ratio.
Efficiency is more than diesel	Efficiency is less than otto cycle

cycle for same compression ratio.	for same compression ratio.

13. Name the essential components of diesel electric power plant. (May/June 2016)

The major components in diesel electric power plants are:

- Fuel Supply System
- Air Intake and Exhaust System
- Starting System
- Cooling System
- Lubricating System

14. What is reheating and regenerating of gas turbine? .(Nov/Dec 2016)

Reheating

When a **gas turbine plant** has a high pressure and low pressure **turbine** a reheater can be applied successfully. **Reheating** can improve the efficiency up to 3 % . A reheater is generally is a combustor which**reheat** the flow between the high and low pressure**turbines**. In jet engines an afterburner is used to**reheat**

Regenerating

One of the more common ways to improve the efficiency of a steam **cycle** is to use**regeneration**, a process where heat is taken from steam between turbine stages and used to heat water as it goes through pump stages

15. Name the various "Gas power cycles" .(Nov/Dec 2016)

Gas power cycles are thermodynamic **cycles**, which use air, as the working fluid. A **gas power cycle** may consist of heat transfer, work transfer, pressure variations, temperature variations, volume variations and entropy variations

16. What are the application of Diesel engine power plants (April/May 2017)

The can used as peak load plants in combination with thermal power plant

They can be used as stand –by plants to hydro electric power plant and steam power plant in emergency service

17. List down the various processes of the Brayton cycle (April/May 2017)

1. adiabatic process – compression
2. isobaric process – heat addition
3. adiabatic process – expansion
4. isobaric process – heat rejection

PART- B

1.Explain the working principle of diesel engine power plant.

(May/June 2016 & April/May 2017)

Diesel engine consists various components and processes.

1. Fuel Supply System

It consists of fuel tank for the storage of fuel, fuel filters and pumps to transfer and inject the fuel. The fuel oil may be supplied at the plant site by trucks, rail, road, tank, cars, etc.

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.

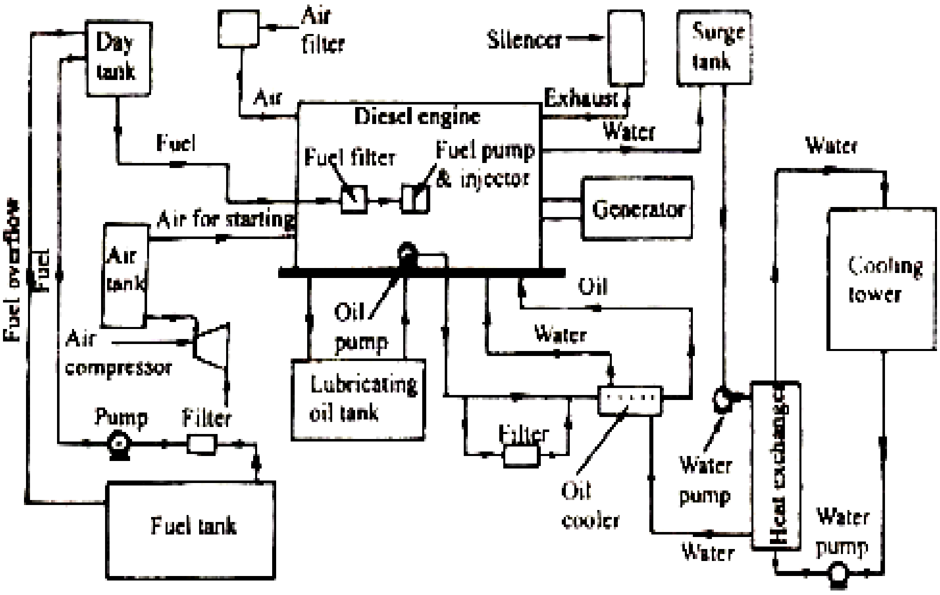
5.To spray fuel into the cylinder in atomized form for thorough mixing and burning.

The above functions can be achieved in a variety of ways.

1.Common Rail.

2.Individual Pump Injection.

3. Distributor.



2. Air Intake and Exhaust System

It consists of pipe for the supply of air and exhaust of the gases. Filters are provided to remove dust etc. from the incoming air. In the exhaust system silencer is provided to reduce the noise.

Filters may be of dry type (made up of cloth, felt, glass, wool etc.) or oil bath type. In oil bath type of filters the air is swept over or through a bath of oil in order that the particles of dust get coated. The duties of the air intake systems are as follows:

i) To clean the air intake supply.

ii) To silence the intake air.iii) To supply air for super charging

The intake system must cause a minimum pressure loss to avoid reducing engine capacity and raising the specific fuel consumption. Filters must be cleaned periodically to prevent pressure losses from clogging. Silencers must be used on some systems to reduce high velocity air noises.

Strainer : This oil then pump to dry tank, by means of transfer pump.

During transferring from main tank to smaller dry tank, the oil passes through strainer to remove solid impurities. From dry tank to main tank, there is another pipe connection. This is over flow pipe. This pipe connection is used to return the oil from dry tank to main tank in the event of over flowing.

From dry tank the oil is injected in the diesel engine by means of fuel injection pump.

3. Starting System

For the initial starting of engine the various devices used is compressed air, battery, electric motor or self-starter.

- **Cooling System**

The heat produced due to internal combustion, drives the engine. But some parts of this heat raise the temperature of different parts of the engine. High temperature may cause permanent damage to the machine. Hence, it is essential to maintain the overall temperature of the engine to a tolerable level.

During combustion process the peak gas temperature in the cylinder of aninternal 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

1. The valves may be kept cool to avoid knock and pre-ignition problems which result from overheated exhaust valves (true for S.I. engines).
2. 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

(i) Open cooling system

(ii) Natural circulation (Thermo-system)

(iii) Forced circulation system

(iv) Evaporation cooling system.

(i).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 isdischarged.

(ii). 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. 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 inthe radiator with the help of air passing over the radiator either by ram effect or by fan or jointly tends to sink.

(iii). forced circulation cooling system:

The system consists of pump, water jacket in the cylinder, radiator, fan and a thermostat. 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.

5. Lubricating System

This system minimises the water of rubbing surface of the engine. Here lubricating oil is stored in main lubricating oil tank. This lubricating oil is drawn from the tank by means of oil pump. Then the oil is passed through the oil filter for removing impurities. From the filtering point, this clean lubricating oil is delivered to the different points of the machine where lubrication is required the oil cooler is provided in the system to keep the temperature of the lubricating oil as low as possible.

(i).Liquid lubricants or wet sump lubrication system

These systems employ a large capacity oil sump at the base of crank chamber, from which the oil is drawn by a low-pressure oil pump and delivered to various parts. Oil then gradually returns back to the sump after serving the purpose.

(ii).Solid lubricants or dry sump lubrication system

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.

(iii).Mist lubrication system

This system is used for two stroke cycle engines. Most of these engines are crank charged, *i.e.*, they employ crank case compression and thus, are not suitable for crank case lubrication. These engines are lubricated by adding 2 to 3 per cent lubricating oil in the fuel tank. The oil and fuel mixture is induced through the carburettor. The gasoline is vaporized; and the oil in the form of mist, goes viacrankcase into the cylinder

5.Starting System

For starting a diesel engine, initial rotation of the engine shaft is required. Until the firing start and the unit runs with its own power. For small DG set, the initial rotation of the shaft is provided by handles but for large diesel power station.

Compressed air is made for starting.

Advantage of Diesel Power Plant

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.

Disadvantage of Diesel Power Plant

1. High Maintenance and operating cost.
2. Fuel cost is more, since in India diesel is costly.
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 power plant.

Application:

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.

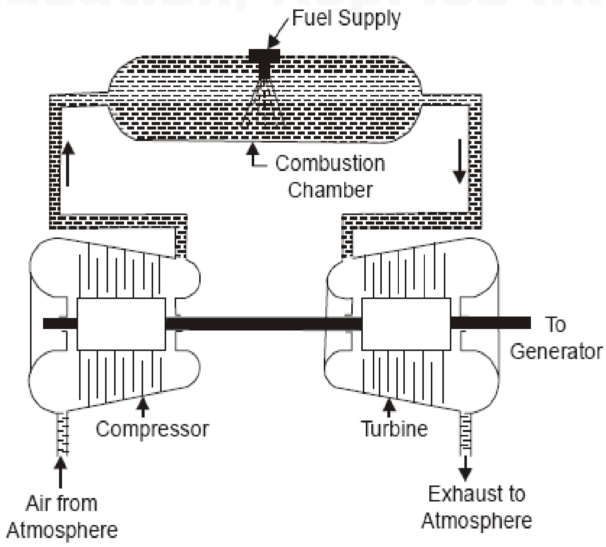
2. Explain different components and operation of gas turbine power plant (Nov/Dec 2015, May/June 2016& April/May 2017)

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.

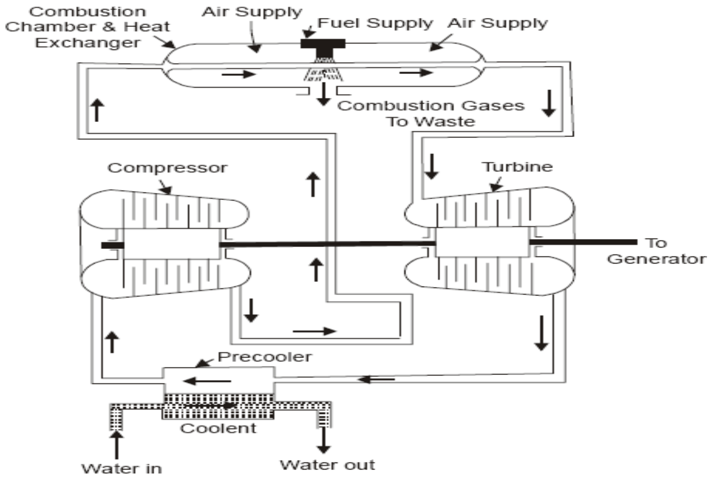
Open cycle gas turbine power plant:

A simple open cycle gas turbine consists of a compressor, combustion chamber and a turbine as shown in Fig. 1. 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.

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 bereplaced 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.



Closed cycle gas turbine power plant:



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 Figure.

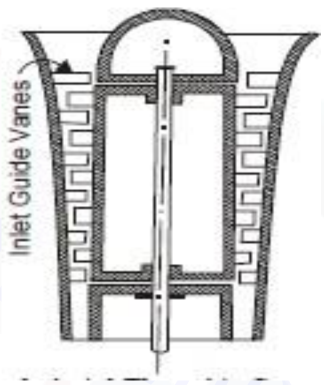
Different components of gas turbine plant

Compressor:

The high flow rates of turbines and relatively moderate pressure ratios necessitate the use of rotary compressors. The types of compressors, which are commonly used, are of two types, centrifugal and axial flow types. The centrifugal compressor consists of an impeller (rotating component) and a diffuser (stationary component). The impeller imparts the high kinetic energy to the air and diffuserconverts the kinetic energy into the pressure energy. The pressure ratio of 2 to 3 is possible with single stage compressor and it can be increased upto 20 with three-stage compressor. The compressors may have single or double inlet. The single inlet compressors are designed to handle the air in the range of 15 to 300 m3/min and double inlets are preferred above 300 m3/min capacity.

The efficiency of centrifugal compressor lies between 80 to 90%. The efficiency of multistage compressor is lower than a single stage due to the losses. The axial flow compressor consists of a series of rotor and stator stages with decreasing diameters along the flow of air. The blades are fixed on the rotor and rotors are fixed on the shaft. The stator blades are fixed on the stator casing. The stator blades guidethe air flow to the next rotor stage coming from the previous rotor stage. The air flows along the axis of the rotor. The kinetic energy is given to the air as it passes throughthe rotor and part of it is converted into pressure. The axial flow compressor is shown in Fig.

rapidly.



The number of stages required for pressure ratio of 5 is as large as sixteen or more. A satisfactory air filter is absolutely necessary for cleaning the air before it enters the compressor because it is essential to maintain the designed profile of the aerofoil blades. The deposition of dust particles on the blade surfaces reduces the efficiency

The advantages of axial flow compressor over centrifugal compressor are high isentropic efficiency (90-95%), high flow rate and small weight for the same flow quantity. The axial flow compressors are very sensitive to the changes in airflow and speed, which result in rapid drop in efficiency. In both types of compressors, it has been found that lowering of the inlet air temperature by 15 to 20°C gives almost 25% greater output with an increase of 5% efficiency.

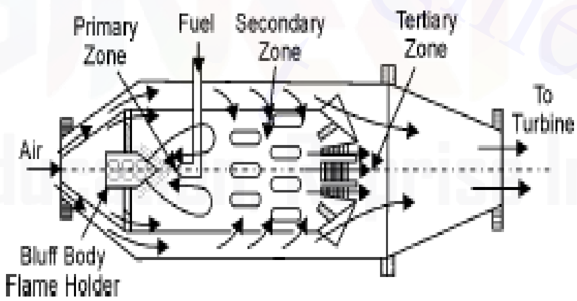
Intercooler:

The intercooler is generally used in gas turbine plant when the pressure ratio used is sufficiently large and the compression is completed with two or more stages.

The cooling of compressed air is generally done with the use of cooling water. A cross-flow type intercooler is generally preferred for effective heat transfer. The regenerators, which are commonly used in gas turbine plant, are of two types, recuperator and regenerator. In a recuperative type of heat exchanger, the air and hot gases are made to flow in counter direction as the effect of counter flow gives high average temperature difference causing the higher heat flow. A number of baffles inthe path of air flow are used to make the air to flow in contact for longer time with heat transfer surface. The regenerator type heat exchanger consists of a heat- conducting member that is exposed alternately to the hot exhaust gases and the cooler compressed air. It absorbs the heat from hot gases and gives it up when exposed to the air. The heat, capacity member is made of a metallic mesh or matrix, which is rotated
slowly (40-60 r.p.m.) and continuously exposed to hot and cold air.

Combustion Chambers:

The gas turbine is a continuous flow system; therefore, the combustion in the gas turbine differs from the combustion in diesel engines. High rate of mass flow results in high velocities at various points throughout the cycle (300 m/sec). One of the vital problems associated with the design of gas turbine combustion system is to secure a steady and stable flame inside the combustion chamber.



The gas turbine combustion system has to function under certain different operating conditions which are not usually met with the combustion systems of diesel engines. A few of them are listed below:

1. Combustion in the gas turbine takes place in a continuous flow system and, therefore, the advantage of high pressure and restricted volume available in diesel engine is lost. The chemical reaction takes place relatively slowly thus requiring large residence time in the combustion chamber in order to achieve complete combustion.

2. The gas turbine requires about 100:1 air-fuel ratio by weight for the reasons mentioned earlier. But the air-fuel ratio required for the combustion in diesel engine is

approximately 15:1. Therefore, it is impossible to ignite and maintain a continuous combustion with such weak mixture. It is necessary to provide rich mixture fm ignition and continuous combustion, and therefore, it is necessary to allow required air in the combustion zone and the remaining air must be added after complete combustion to reduce the gas temperature before passing into the turbine.

3. A pilot or recirculated zone should be created in the main flow to establish a stable flame that helps to ignite the combustible mixture continuously.

4. A stable continuous flame can be maintained inside the combustion chamber when the stream velocity and fuel burning velocity are equal. Unfortunately most of the fuels have low burning velocities of the order of a few meters per second; therefore, flame stabilization is not possible unless some technique is employed to anchor the flame in the combustion chamber.

Gas Turbines:

The common types of turbines, which are in use, are axial flow type. The basic requirements of the turbines are lightweight, high efficiency; reliability in operation and long working life. Large work output can be obtained per stage with high blade speeds when the blades are designed to sustain higher stresses. More stages of the turbine are always preferred in gas turbine power plant because it helps to reduce the stresses in the blades and increases the overall life of the turbine. More stages are further preferred with stationary power plants because weight is not the major consideration in the design which is essential in aircraft turbine-plant. The cooling of the gas turbine blades is essential for long life as it is continuously subjected to high temperature gases. There are different methods of cooling the blades. The common method used is the air-cooling. The air is passed through the holes provided through the blade.

3. Explain in detail about integrated gasifier based combined cycle systems. (Nov/Dec 2015, May/June 2016 &April/May 2017)

An **integrated gasification combined cycle** (**IGCC**) is a technology that uses a gasifier to turn coal and other carbon based fuels into gas—synthesis gas (syngas). It then removes impurities from the syngas before it is combusted. Some of these pollutants, such as sulfur, can be turned into re-usable by products. This results in lower emissions of sulfur dioxide, particulates, and mercury. With additional process equipment, the carbon in the syngas can be shifted to hydrogen via the water-gas shift reaction, resulting in nearly carbon free fuel. The resulting carbon dioxide from the shift reaction can be compressed and stored. Excess heat from the primary combustion and syngas fired generation is then passed to a steam cycle, similar to a combined cycle gas turbine. This result in improved efficiency compared to conventional pulverized coal.

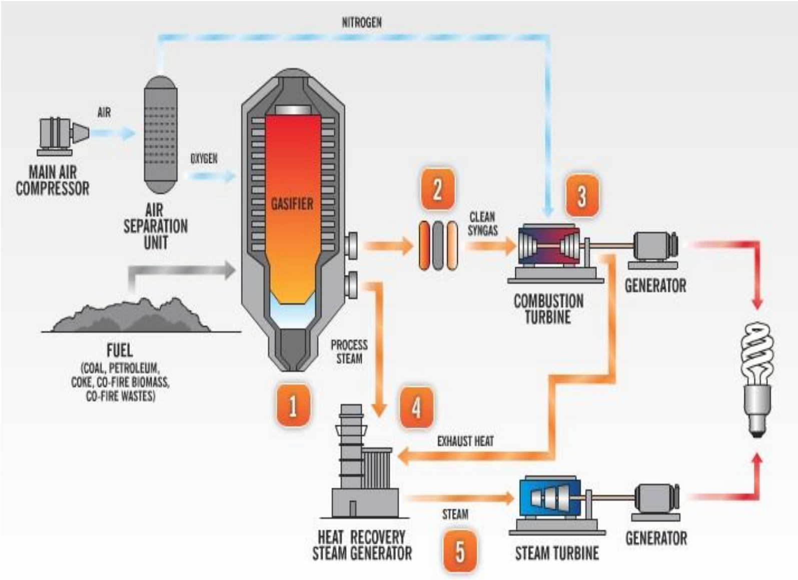
The water-gas shift reaction (WGSR) describes the reaction of carbon monoxide and water vapour to form carbon dioxide and hydrogen (the mixture of carbon monoxide and hydrogen is known as water gas)

$$CO + H_2O \rightleftharpoons CO_2 + H_2$$

Gasification plant including preparation of the feedstock. Raw-gas cooling via water quench or heat recovery systems. Optional water-gas shift reactor. Gas purification system with sulphur removal/recovery and optional CO_2 removal. Air separation unit. Combined cycle unit with gas turbo set, heat recovery steam generator and steam turbo set.

The gasifier feedstock is converted to synthesis gas (syngas) with the addition of steam and oxygen. Entrained-flow gasifiers for coal are fundamentally well suited to integration in the combined cycle, as are entrained-flow systems for refinery residues. The selection of a specific gasifier type to achieve the best cost, efficiency and emissions levels depends on the type of fuel and the particular application, and must be investigated on a case–by-case basis.

The present Siemens Fuel Gasification (SFG) technology applies the entrained-flow principle, followed by a direct water quench to cool the produced hot raw gas. This technique often used in residue gasification is also suitable for a variety of fuels, in particular coal and petroleum coke. In a further development step, it is possible to capture the sensible heat of the hot raw gas in a syngas cooler to generate high- pressure steam for the steam turbine. Both processes cool the gas sufficiently so that it can be sent directly to the gas treatment system.



Syngas coolers are advantageous when targeting high efficiencies with IGCC plants without CO_2 capture (e.g. Buggenum and Puertollano IGCC plants) For IGCC applications with CCS the direct water quench has advantages as the water/steam needed for the shift reaction is already in the raw syngas.

First the particulates soot and heavy metals are eliminated from the initial raw gas purification downstream of the quench system or syngas cooler. Subsequently chemical pollutants such as H_2S, CO, HCl, HF, NH_3 and HCN are separated and removed. The separated H_2S-rich gas stream is processed to recover saleable sulfur, for example in pure elemental form. Downstream of the gas purification system, the clean gas is mixed with nitrogen (for flow control, flame stabilization and NO_x reduction) and/or diluted with water before it is supplied to the gas turbine combustion chamber. In this way, low-level heat can be used efficiently and gas turbine mass flow and output are increased.

In oxygen-blown gasification, the air separation unit (ASU) generates the enriched oxygen supply necessary for the gasification process. The inevitably co-produced nitrogen from the ASU is used primarily in the gas turbine cycle, and, in the case of coal or petroleum coke, smaller amounts are used to transport the solid fuels to the gasifier and for inverting purposes. In addition to air for combustion, the compressor of the gas turbine-generator may also supply all or part of the air for the ASU. Interdependencies between IGCC and ASU are described as air-integrated,nitrogen-integrated or non-integrated respectively.

The steam turbine is supplied with steam from the gas turbine heat recovery steam generator (HRSG). The heat from the raw gas may also be used to generate steam for the steam turbine when gasifiers with high gas outlet temperatures are implemented.

The combined cycle power plant is also well suited to operate on syngas from other non-Siemens gasification processes.

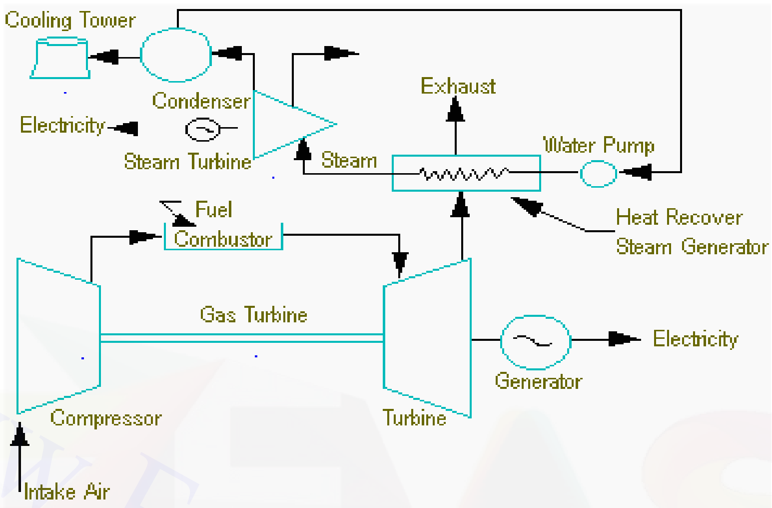
4. Explain in detail about combined cycle power plant. State the advantages and disadvantages of open cycle and closed cycle gas turbine power plant. (May/June 2016 & April/may 2017)

A combined cycle power plant is more efficient than a conventional power plant because it uses a higher proportion of the energy that the fuel produces when it burns.

In a combined cycle power plant (CCPP), or combined cycle gas turbine(CCGT) plant, a gas turbine generates electricity and the waste heat is used to make steam to generate additional electricity via a steam turbine; this last step enhances the efficiency of electricity generation

The gas turbine drives an electrical generator. The gas turbine exhaust is then used to produce steam in a heat exchanger (steam generator) to supply a steam turbine whose output provides the means to generate more electricity. However the Steam Turbine is not necessarily, in that case the plant produce electricity and industrial steam which can be used for heating or industrial purpose. 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. 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.

Open cycle gas turbine power plant

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.

(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.

Closed cycle gas turbine power plant

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. The maintenance cost is low and reliability is high due to longer useful life.

5. 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.

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.

5. Explain about the lubrication system and cooling system of Diesel power plant.

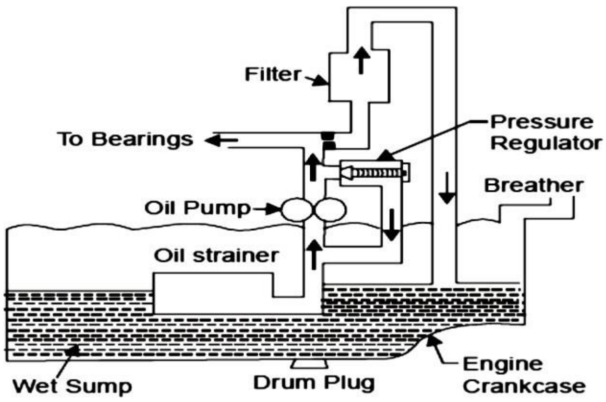
1. Liquid lubricants or wet sump lubrication system

These systems employ a large capacity oil sump at the base of crank chamber, from which the oil is drawn by a low-pressure oil pump and delivered to various parts. Oil then gradually returns back to the sump after serving the purpose.

(a) **Splash system.** This system is used on some small four strokes, stationary engines. In this case the caps on the big ends bearings of connecting rods are provided with scoops which, When the connecting rod is in the lowest position, just dip into oil troughs and thus directs the oil through holes in the caps to the big end bearings. Dueto splash of oil it reaches the lower portion of the cylinder walls, crankshaft and other parts requiring lubrication. Surplus oil eventually flows back to the oil sump. Oil level in the troughs is maintained by means of an oil pump which takes oil from sump, through a filter.

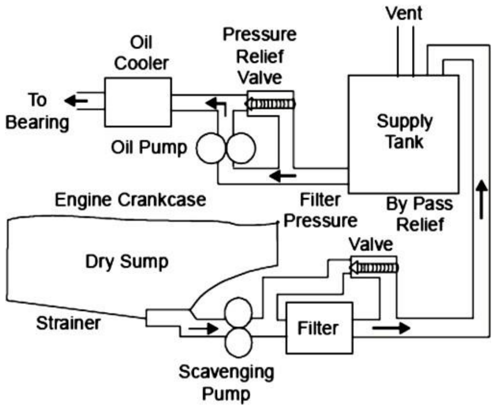
(b) **Semi-pressure system.** This method is a combination of splash and pressure systems. It incorporates the advantages of both. In this case main supply of oil is located in the base of crank chamber. Oil is drawn from the lower portion of the sump through a filter and is delivered by means of a gear pump at pressure of about 1 bar to the main bearings. The big end bearings are lubricated by means of a spray through nozzles. Thus oil also lubricates the cams, crankshaft bearings, cylinder walls and timing gears.

(*c*) **Full pressure system.** The oil is drawn from the sump through filter and pumped by means of a gear pump. The pressure pump at pressure ranging delivers oil from 1.5 to 4 bar. The oil under pressure is supplied to main bearings of crankshaft and camshaft. Holes drilled through the main crankshafts bearing journals, communicateoil to the big end bearings and also small end bearings through holes drilled in connecting rods. A pressure gauge is provided to confirm the circulation of oil to the various parts. A pressure-regulating valve is also provided on the delivery side of this pump to prevent excessive pressure.



2. Solid lubricants or dry sump lubrication system:

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/cm^2. Dry sump lubrication system is generally adopted for high capacity engines.



3. Mist lubrication system:

This system is used for two stroke cycle engines. Most of these engines are crank charged, *i.e.*, they employ crank case compression and thus, are not suitable for crank case lubrication. These engines are lubricated by adding 2 to 3 per cent lubricating oil in the fuel tank. The oil and fuel mixture is induced through the carburettor. The gasoline is vaporized; and the oil in the form of mist, goes via crankcase into the cylinder. The oil that impinges on the crank case walls lubricates the main and connecting rod bearings, and rest of the oil that passes on the cylinder during charging and scavenging periods, lubricates the piston, piston rings and the cylinder.

Cooling system of a diesel power plant:

During combustion process the peak gas temperature in the cylinder of aninternal 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

1. The valves may be kept cool to avoid knock and pre-ignition problems which result from overheated exhaust valves (true for S.I. engines).
2. 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 is 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

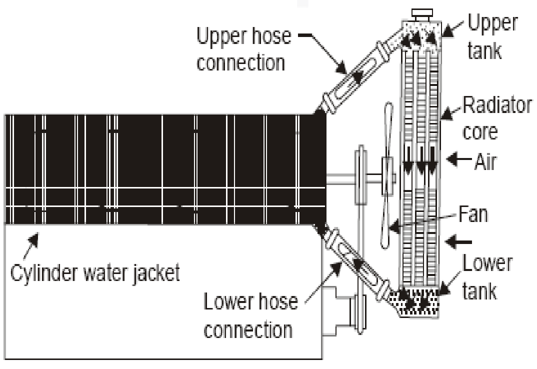
(4) Evaporation cooling system.

1. Open cooling system:

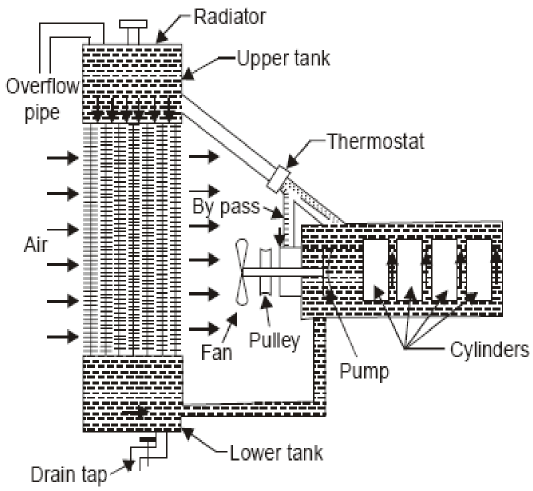
This system is applicable only where plenty of water is available. The water from the storage tank is directly supplied through an inlet valve to the engine cooling water jacket. The hot water coming out of the engine is not cooled for reuse but it is discharged.

2. 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. 8.14 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.



3. Forced circulation cooling system:



The system consists of pump, water jacket in the cylinder, radiator, fan and a thermostat. 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.

6. A dual combustion air standard cycle has a compression ratio of 10. The constant pressure part of combustion takes place at 40 bar. The highest and lowest temperatures of the cycle are 1727°C and 27°C respectively. The pressure at the beginning of compression in 1 bar. Calculate
the following

1. **The pressure and temperature at key points of the cycle.**
2. **The heat supplied at constant volume**
3. **The heat supplied at constant pressure**
4. **The heat rejected**
5. **The work output**
6. **The efficiency**
7. **Mean effective pressure.**

Given data:

r = 10

$P_3 = P_4 = 40$ bar

$T_4 = 1727 + 273 = 2000$ K

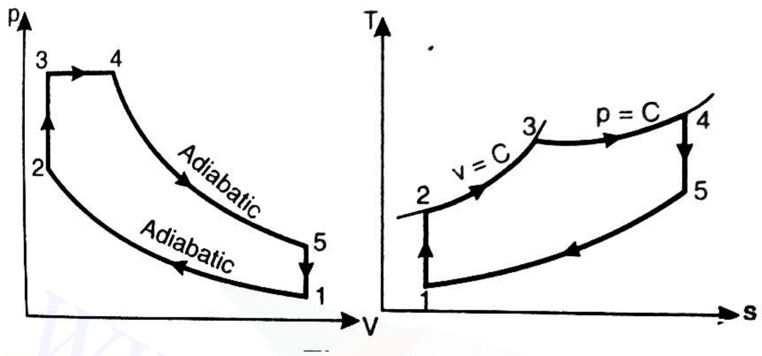
$T_1 = 27 + 273 = 300$ k

$P_1 = 1$ bar

To find

1. P_2, P_5 & T_2 , T_3, T_5
2. Qs_V, Qs_p, Qr,W, η, P_{mi}

Solution



Specific volume,

$P_1V_1 = mRT_1$

$V_1 = mRT_1/ P_1$

$V_1 = 0.861\ m^3$

$V_1/ V_2 = r = 8$

$V_2 = V_1/ r = 0.0861\ m^3 = V_3$

Expansion ratio,

$V_5/ V_4 = r/\rho = 6.02$

We know that

$T_5 = T_1\ K\ \rho^{\gamma}$

$T_5 = 969.77$ K

Process 5-1 – constant volume heat rejection process

$P_5/ T_5 = P_1/ T_1$

$P_5 = 3.23$ bar

Heat supplied at constant volume,

$Q_{sv} = m\ C_v\ (T_3 - T_2)$ ($C_v = 0.717$ KJ/Kg K; $C_p = 1.005$ KJ/Kg K)

$Q_{sv} = 321.39$ KJ

Heat supplied at constant Pressure,

$Q_{sp} = m\ C_p\ (T_4 - T_3)$

$Q_{sp} = 804.05$ KJ

Heat Rejected

$Q_r = m\, C_v\, (T_5 - T_1)$

$Q_r = 482.23$ KJ

Work output,

$W = Q_{sv} + Q_{sp} - Q_r$

$W = 643.21$ KJ

Efficiency,

$$\eta_{\text{dual}} = \frac{Qsv + Qsp - Qr}{Qs}$$

$= 57\%$

Mean effective pressure,

$P_{mi} = W / (V_1 - V_2)$

$P_{mi} = 830.05$ bar

7. Consider a stationary power plant operating on an ideal brayton cycle. The pressure ratio of the cycle is 8, and the gas temperature at the compressor inlet and the turbine inlet are 27º C and 1027˚C respectively. Determine the following.

(i) gas temperatures at the compressor and turbine exit

(ii) Back work ratio

(iii) Thermal efficiency

Assume $P_{r1} = 1.386$ and $P_{r3} = 330.9$

Where P_r is the relative pressure.

Given data:

$r_p = 8 = P_2 / P_1$

$T_1 = 27^\circ C + 273 = 300K$

$T_3 = 1027^\circ C + 273 = 1300K$

$P_{r1} = 1.386$ bar and $P_{r3} = 330.9$ bar

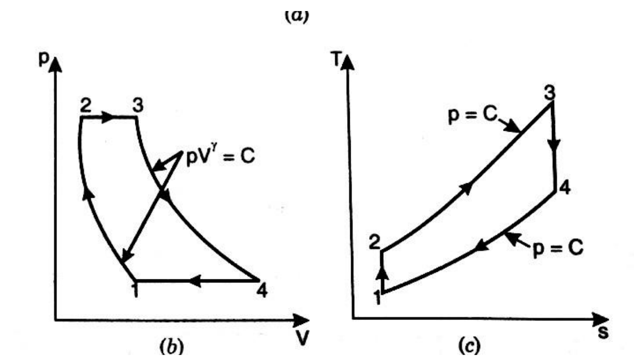
To find;

(i) T_2 & T_4

(ii) Back work ratio

(iii) η_{thermal}

Solution



Process (1-2) : (asiabatic compression)

$P_2/ P_1 = (V_1/ V_2)^{\gamma}$

$V_1/ V_2 = (P_2/ P_1)^{1/\gamma}$

$V_1/ V_2 = 4.416$

$T_2/ T_1 = (V_1/ V_2)^{\gamma-1}$

$T_2 = (4.416)^{(1.4 - 1)} \times 300$

$T_2 = 543.43K$

Process (3 – 4) : (Adiabatic expansion)

$P_4/ P_3 = (V_3/ V_4)^{\gamma}$

$V_3/ V_4 = (P_4/ P_3)^{1/\gamma}$

$V_3/ V_4 = (P_1/ P_2)^{1/\gamma}$ ($P_4 = P_1$; $P_2 = P_3$)

$V_3/ V_4 = 0.2264$

$T_4/ T_3 = (V_3/ V_4)^{\gamma-1}$

$T_4 = (0.2264)^{1.4 - 1} \times 1300$

$T_4 = 717.682K$

Back work ration = W_C / W_T

$W_C = m\ C_p (T_2 – T_1)$ here (C_v = 0.717 KJ/Kg K; C_p = 1.005 KJ/Kg K)

W_C = 244.65 KJ

$W_T = m\ C_p (T_2 – T_1)$

W_T = 585.23 KJ

Back work ratio = 244.65/585.23

= 0.418

$\eta_{thermal} = 1 - \frac{1}{r_p^{\frac{\gamma-1}{\gamma}}}$

= 44.8 %

$\eta_{thermal}$ = 44.8 %

8. Drive Air standard efficiency for otto Cycle.

It consist of the following process

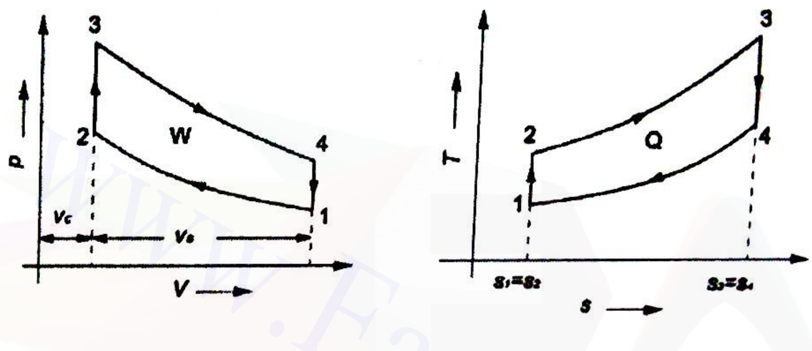
1-2 Isentropic Compression ($PV^{\gamma} = C$)

During the process the air is compressed form P_1V_1 to P_2V_2 and compression ration (r) $= V_1/ V_2$

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$ ---------- (1)

$P_1/ P_2 = V_2^{\gamma}/ V_1^{\gamma}$

$P_1/ P_2 = 1/r^{\gamma}$



p-V diagram *T-s diagram*

$PV = mRT$

$P_1V_1 = mRT_1$; $P_1 = mRT_1 / V_1$

$P_2V_2 = mRT_2$; ; $P_2 = mRT_2 / V_2$

Substitute the P_1 and P_2 value in equation no. 1

$(mRT_1 / V_1) V_1^{\gamma} = (mRT_2 / V_2) V_2^{\gamma}$

mR is same value in both side so that mR will be cancelled

$T_1 V_1^{\gamma -1} = T_2V_2^{\gamma -1}$

$T_1/ T_2 = V_2^{\gamma -1}/ V_1^{\gamma -1}$

$T_1/ T_2 = 1/r^{\gamma - 1}$

$T_2 = T_1 r^{\gamma - 1}$

2-3 Constant volume heat addition V = C

In this process the heat is added at constant volume

$P_2V_2 = mRT_2$; ; $V_2 = mRT_2 / P_2$

$P_3V_3 = mRT_3$; $V_3 = mRT_3 / P_3$

$V_2 = V_3$ (constant volume process)

$mRT_2 / P_2 = mRT_3 / P_3$

mR is same value in both side so that mR will be cancelled

$T_2 / P_2 = T_3 / P_3$

$Q_s = m\,C_v\,(T_3 – T_2)$

3 – 4 – isentropic expansion $PV^\gamma = C$

$P_3V_3^\gamma = P_4V_4^\gamma$ ---------- (2)

$P_3/ P_4 = V_4^\gamma / V_3^\gamma$

$P_3/ P_4 = 1/r^\gamma$

PV = mRT

$P_3V_3 = mRT_3$; $P_3 = mRT_3 / V_3$

$P_4V_4 = mRT_4$; $P_4 = mRT_4 / V_4$

Substitute the P_3 and P_4 value in equation no. 2

$(mRT_3 / V_3)\,V_3^\gamma = (mRT_4 / V_4)\,V_4^\gamma$

mR is same value in both side so that mR will be cancelled

$T_3\,V_3^{\gamma-1} = T_4V_4^{\gamma-1}$

$T_3/ T_4 = V_4^{\gamma-1}/ V_3^{\gamma-1}$

$T_3/ T_4 = r^{\gamma-1}$

$T_3 = r^{\gamma-1}\,T_4$

4-1 Constant volume heat rejection

In this process the heat is added at constant volume

$P_4V_4 = mRT_4$; ; $V_4 = mRT_4 / P_4$

$P_1V_1 = mRT_1$; $V_1 = mRT_1 / P_1$

$V_4 = V_1$ (consatant volume process)

$mRT_4 / P_4 = mRT_1 / P_1$

mR is same value in both side so that mR will be cancelled

$T_4 / P_4 = T_1 / P_1$

$Q_r = m\,C_v\,(T_4 – T_1)$

$Q_s = m\,C_v\,(T_3 – T_2)$

$\eta = \frac{Work\ done}{Heat\ supplied}$

$\eta = \frac{Qs - Qr}{Qs} = 1 - \frac{Qr}{Qs} = 1 - \frac{m\,Cv\,(T4 - T1)}{m\,Cv\,(T3 - T2)}$

Here substitute the value of T3 & T2

$\eta = 1- \frac{1}{r^{\gamma-1}}$

$\eta = 1- \frac{1}{r^{\gamma-1}}$

UNIT III

NUCLEAR POWER PLANTS

PART-A

1. Explain the term nuclear fission?

When an unstable heavy nucleus is bombarded with high-energy neutrons, it splits up roughly into two equal fragments and about 2.5 neutrons are released and a large amount of heat energy is produced. This process is called nuclear fission.

2. What is breeding in nuclear reactor?

The process of producing fissionable material from a fertile material in a nuclear reactor is called as breeding.

3. State some advantages of Pressurized Water reactor?

- The pressurized water reactor is compact
- In this type, water is used as coolant, moderator and reflector. Water is cheap and available in plenty.
- It requires less number of control rods.

4. What is the purpose of control rods? (Nov/Dec 2015)

The control rods are used to start the chain reaction, maintain the chain reaction at required level and to shut down the reactor during emergency.

5. What is the use of moderator?

The moderator is used to reduce speed of the neutron in chain reaction. This is done by making the neutrons collide with lighter nuclei of other materials, which does not absorb these neutrons but simply scatter them. Each collision causes loss of energy and thus the speed of neutrons is reduced. Such a material is called a 'Moderator'. The neutrons thus slowed down are easily captured by the fuel element at the chainreaction proceeds.

6. What are the advantages of gas cooled reactor nuclear power plant?

1. Fuel processing is simple, 2. The use of Co_2 as coolant completely eliminates the possibility of explosion in reactor. 3. No corrosion problem.

7. What are the requirements to sustain fission process?

- The bombarded neutrons must have sufficient energy to cause fission
- The number of neutrons produced must be able to create the rate of fission

8. What are the demerits of breeder reactor?

- Highly enriched fuel is required
- Control is difficult and expensive
- Safety must be provided against melt down
- Handling of sodium is a major problem

9. What is LMFBR? Why liquid metal preferred in fast breeder reactor?

Liquid Metal Fast Breeder Reactor is called as LMFBR. The metal coolants have much higher density than the water they remove much heat more rapidly. This makes the reactor small in size and weight.

10. List some important nuclear reactor? (May/June2016)

Some important reactors are: (i) Pressurized water reactor (PWR) (ii) Boiling water reactor (BWR) (iii) Gas-cooled reactor (iv) Liquid metal-cooled reactor (v) Breeder reactor

11. What is a CANDU type Reactor? (May/June2016)

In CANadian Deuterium Uranium (CANDU) reactors, the natural uranium (0.7% U235) is used as fuel and heavy water as moderator. This type of reactor was first designed and developed in Canada.

12. Mention the drawbacks of BWR.

- The boiling water reactor cannot meet a sudden increase in power demand because as the power output of the turbine increases, the pressure in the reactor falls and the specific volume increases.
- The steam bubbles within the reactor would expand, expel the moderator and tend to shut down the reactor.

13. How do you carry out safety measures for Nuclear power plant?

(Nov/Dec 2015)

- Shut down operating reactors
- Cool down reactors so as to remove heat from nuclear fuel
- To contain radioactive materials

14. What is critical mass of nuclear fuel? (Nov/Dec 2016)
A critical mass is the smallest amount of fissile material needed for a sustained nuclear chain reaction. The critical mass of a fissionable material depends upon its nuclear properties (specifically, the nuclear fission cross-section), its density, its shape, its enrichment, its purity, its temperature, and its surroundings.

15. Why shielding is necessary in nuclear power plants? (Nov/Dec 2016)
function in nuclear reactor. An operating reactor is a powerful source of radiation, since fission and subsequent radioactive decay produce neutrons and gamma rays, both of which are highly penetrating radiations.

16. What is the function of control rods in nuclear reactor?(April/May 2017)
Control rods are used in nuclear reactors to control the fission rate of uranium and plutonium. They are composed of chemical elements such as boron, silver, indium and cadmium that are capable of absorbing many neutrons without themselves fissioning.

17.. What is function of pressurizer in PWR? (April/May 2017)
A Pressurizer is a component of a pressurized water reactor. ... To pressurize the coolant system to a higher pressure than the boiling point of the coolant at operating temperatures, a separate pressurizing system is required. That is the function of the pressurizer.

PART-B

1. Draw and explain block diagram of Nuclear power plant and write few advantages and disadvantages?(Nov/Dec2015,May/June2016 &Novc/Dec 2016)

Nuclear Power plants has various components,

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

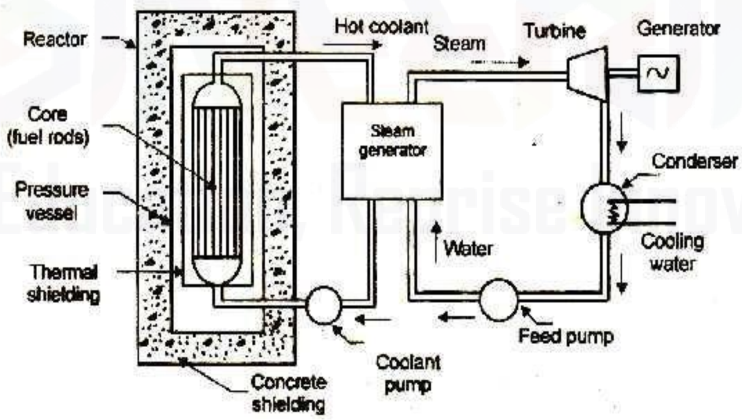
Out of these U235 is most unstable and is capable of sustaining chain reaction and has been given the name as primary fuel. U233 arid Pu239 are artificially produced from Th232 and U238 respectively and are called secondary fuel.

i) Moderators

In any chain reaction, the neutrons produced are fast moving neutrons. These are less effective in causing fission of U235 and they try to escape from the reactor. It is thus implicit that speed of these neutrons must be reduced if their effectiveness is carrying out fission is to be increased. This is done by making these neutrons collide with lighter nuclei of other materials, which does not absorb these neutrons but simply scatter them. Each collision causes loss of energy and thus the speed of neutrons is reduced. Such a material is called a 'Moderator'. The neutrons thus slowed down are easily captured by the fuel element at the chain reaction proceeds
slowly.

A moderator should process the following properties :

1. It should have high thermal conductivity.
2. It should be available in large quantities in pure form.
3. It should have high melting point in case of solid moderators and low melting point in case of liquid moderators.
4. It should provide good resistance to corrosion.
5. It should be stable under heat and radiation.
6. It should be able to slow down neutrons



ii) Reflectors

Some of the neutrons produced during fission will be partly absorbed by the fuel elements, moderator, coolant and other materials. The remaining neutrons will try to escape from the reactor and will be lost. Such losses are minimized by surrounding (lining) the reactor core with a material called a reflector which will reflect theneutrons back to the core. They improve the neutron economy. Economy: Graphite, Beryllium.

iii) Shielding

During Nuclear fission alpha, beta, comma particles and neutrons are also produced. They are harmful to human life. Therefore it is necessary to shield the reactor with thick layers of lead, or concrete to protect both the operating personnel as well as environment from radiation hazards.

iv) Cladding

In order to prevent the contamination of the coolant by fission products, the fuel element is covered with a protective coating. This is known as cladding.

Control rods are used to control the reaction to prevent it from becoming violent. They control the reaction by absorbing neutrons. These rods are made of boron or cadmium. Whenever the reaction needs to be stopped, the rods are fully inserted and placed against their seats and when the reaction is to be started the rods are pulled out.

v) Coolant

The main purpose of the coolant in the reactor is to transfer the heat produced inside the reactor. The same heat carried by the coolant is used in the heat exchanger for further utilization in the power generation.

Some of the desirable properties of good coolant are listed below

1. It must not absorb the neutrons.
2. It must have high chemical and radiation stability
3. It must be non-corrosive.
4. It must have high boiling point (if liquid) and low melting point (if solid)
5. It must be non-oxidizing and non-toxic.

The above-mentioned properties are essential to keep the reactor core in safe condition as well as for the better functioning of the content.

6. It must also have high density, low viscosity, high conductivity and high specific heat. These properties are essential for better heat transfer and low pumping power.

The water, heavy water, gas (He, CO_2), a metal in liquid form (Na) and an organic liquid are used as coolants. The coolant not only carries large amounts of heat from the core but also keeps the fuel assemblies at a safe temperature to avoid their melting and destruction.

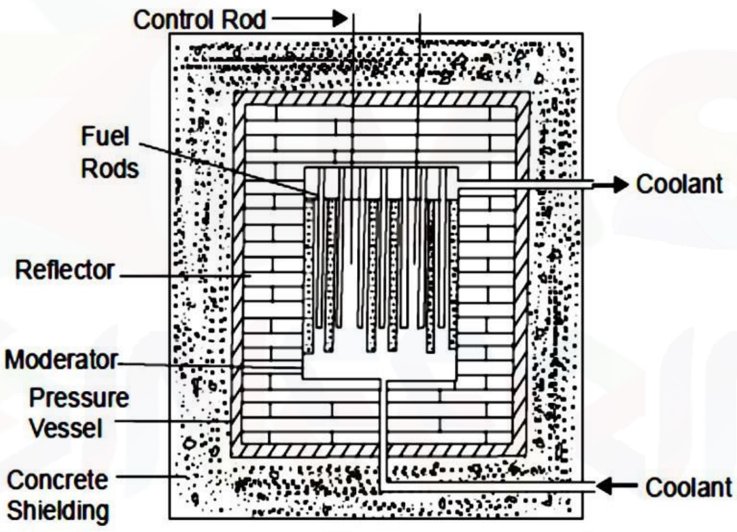
vi) Nuclear reactor:

A nuclear reactor may be regarded as a substitute for the boiler fire box of a steam power plant. Heat is produced in the reactor due to nuclear fission of the fuel

U235. The heat liberated in the reactor is taken up by the coolant circulating through the core. Hot coolant leaves the reactor at top and flows into the steam generator (boiler).

Radiation hazards and Shielding:

The reactor is a source of intense radioactivity. These radiations are very harmful to human life. It requires strong control to ensure that this radioactivity is not released into the atmosphere to avoid atmospheric pollution. A thick concrete shielding and a pressure vessel are provided to prevent the escape of these radiations toatmosphere. Fig. shows a schematic diagram of nuclear reactor.



vii) Steam generator

The steam generator is fed with feed water which is converted into steam by the heat of the hot coolant. The purpose of the coolant is to transfer the heat generated in the reactor core and use it for steam generation. Ordinary water or heavy water is a common coolant.

viii) Turbine

The steam produced in the steam generator is passed to the turbine and work is done by the expansion of steam in the turbine.

ix) Coolant pump and Feed pump

The steam from the turbine flows to the condenser where cooling water is circulated.Coolant pump and feed pump are provided to maintain the flow of coolant and feed water respectively.

Advantages of nuclear power plant

1. It can be easily adopted where water and coal resources are not available.
2. The nuclear power plant requires very small quantity of fuel. Hence fuel transportation cost is less.
3. Space requirement is less compared to other power plants of equal capacity.
4. It is not affected by adverse weather conditions.
5. Fuel storage facilities are not needed as in the case of the thermal power plant.

Disadvantages

1. Radioactive wastes, if not disposed of carefully, have adverse effect on the health of workmen and the population surrounding the plant.
2. It is not suitable for varying load condition.
3. It requires well-trained personnel.
4. It requires high initial cost compared to hydro or thermal power plants.

2. **Write about principle of nuclear energy and chain reaction .Draw and explain the construction and working principle of Pressurized Water Reactor (PWR)? (Nov/Dec 2015,April/May 2017)**

A nuclear power plant is similar to a conventional steam power plant except how that energy is evolved. The heat is produced in the nuclear power plant by fission, whereas in steam and gas turbine plants, the heat is produced by combustion in the furnace. The nuclear reactor acts as a furnace where nuclear energy is evolved by splitting or fissioning of the nucleus of fissionable material like Uranium U-235. It is claimed that 1 kg U-235 can produce as much heat energy that can be produced by burning 4500 tones of high grade coal or 1700 tons of oil.

Heat energy evolved by the fission reaction of one kg of U235 can produce as much energy as can be produced by burning 4500 tons of high grade coal.

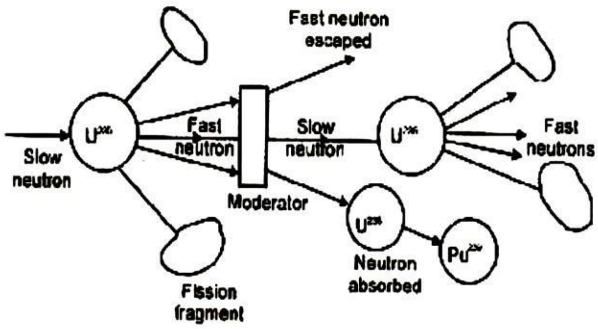
Uranium exists in the isotopic form of U235 which is unstable.

When a neutron enters the nucleus of U235, the nucleus splits into two equal fragments and also releases 2.5 fast moving neutrons with a velocity of 1.5 × 107 metres / sec producing a large amount of energy, nearly 200 millions electron-volts. This is called “nuclear fission”.

Chain reaction

The neutrons released during the fission can be made to fission other nuclei of U235 causing a "chain reaction. A chain reaction produces enormous amount of heat, which is used to produce steam".

The chain reaction under uncontrolled conditions can release extremely large amounts of energy causing "atomic explosion



Energy liberated in chain reaction, according to Einstein Law, is $E = mc^2$,

Where E = energy liberated,

m = mass in grams,

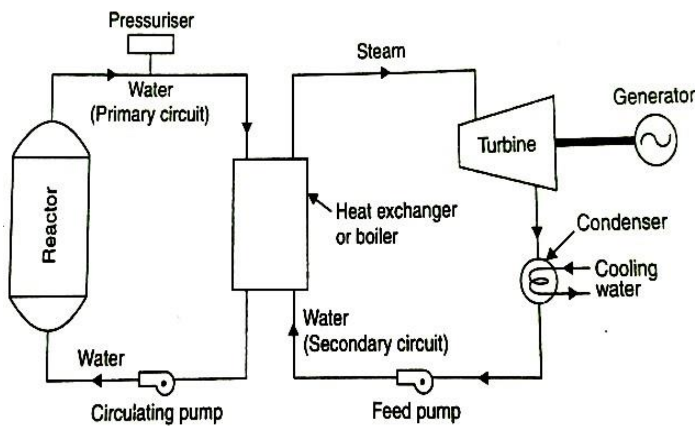
c = speed of light = 3 □ 1010 cm/sec.

If thorium is used in the reactor core, it gets converted to fissionable material U-233.

Thorium 232 + Neutron □ U-233

Pu-239 and U-233 so produced are fissionable materials are called secondary fuels. They can be used as nuclear fuels. U-238 and Th-232 are called fertile materials

Out of 2.5 neutrons released in fission of each nuclei of U235, one neutron is used to sustain the chain reaction, 0.9 neutron is converted into fissionable material Pu239 and 0.6 neutron is absorbed by control rod and coolant moderator.



In the more common PWR, the water that cools the nuclear fuel is at a higher pressure and does not turn into steam. However, because of the higher pressure, this primary water can reach higher temperatures and is used to convert a secondary water supply into steam and from there to the steam turbine.

In a typical design concept of a commercial PWR, the following process occurs:

1. The core inside the reactor vessel creates heat.
2. Pressurized water in the primary coolant loop carries the heat to the steam generator.
3. Inside the steam generator, heat from the primary coolant loop vaporizes the water in a secondary loop, producing steam.
4. The steam line directs the steam to the main turbine, causing it to turn the turbine generator, which produces electricity.

The unused steam is exhausted to the condenser, where it is condensed into water. The resulting water is pumped out of the condenser with a series of pumps, reheated, and pumped back to the steam generator.

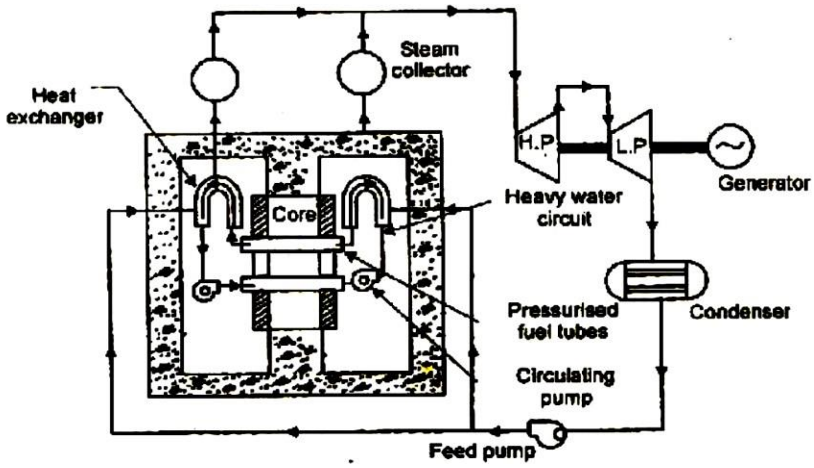
The reactor's core contains fuel assemblies that are cooled by water circulated using electrically powered pumps. These pumps and other operating systems in the plant receive their power from the electrical grid. If offsite power is lost, emergency cooling water is supplied by other pumps, which can be powered by onsite diesel generators. Other safety systems, such as the containment cooling system, also need electric power. PWRs contain between 150-200 fuel assemblies

Function of the moderator is to reduce the energy of neutrons evolved during fission in order to maintain the chain reaction. The moderators which are commonly used are ordinary water and heavy water.

3. Draw and explain construction and working principle of CANDU Type Reactor. (Nov/Dec 2015, NOV/DEC 2016)

These reactors are more economically to those nations which do not produce enriched uranium as the enrichment of uranium is very costly. In this type of reactors, the natural uranium (0.7% U235) is used as fuel and heavy water as moderator.

This type of reactor was first designed and developed in Canada. The first heavy water reactor in Canada using heavy water as coolant and moderator of 200 MW capacity with 29.1% thermal efficiency was established at Douglas (Ontario known as Douglas power station. The arrangement of the different components of CANDU type reactor isshown in figure.



The coolant heavy water is passed through the fuel pressure tubes and heat-exchanger. The heavy water is circulated in the primary circuit in the same way as with a PWR and the steam is raised in the secondary circuit transferring the heat in the heat exchanger to the ordinary water.

The control of the reactor is achieved by varying the moderator level in the reactor and, therefore, control rods are not required. For rapid shutdown purpose, the moderator can be dumped through a very large area into a tank provided below the reactor.

Advantages

1. The major advantage of this reactor is that the fuel need not be enriched.

2. The reactor vessel may be built to withstand low pressure, therefore, the cost of the vessel is less.

3. No control rods are required; therefore, control is much easier than other types.

4. The moderator can be kept at low temperature which increases its effectiveness in slowing down neutrons.

Disadvantages

1. The cost of heavy water is extremely high (Rs. 300/kg).

2. The leakage is a major problem as there are two mechanically sealed closures per fuel channel. Canadian designs generally are based or recovering high proportion of heavy water leakages as absolute leak-tightness cannot be assured.

3. Very high standard of design, manufacture inspection and maintenance are required.

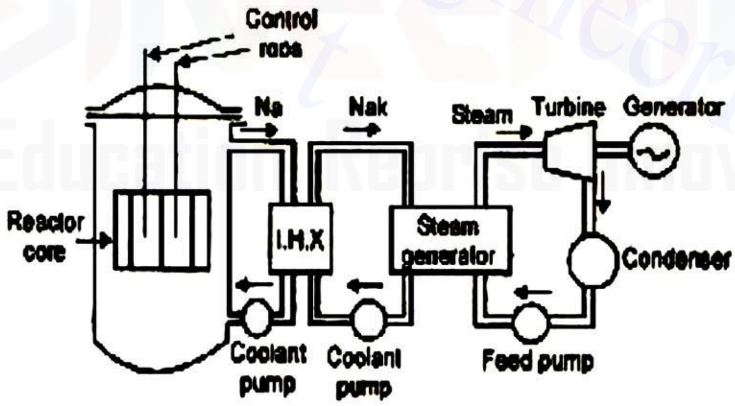
4. The power density is considerably low (9.7 kW/liter) compared with PWR and BWR, therefore, the reactor size is extremely large.

4. Draw and explain the Liquid metal cooled nuclear reactor? What are the safety Measures carried out in Nuclear Power Plant?

The reactor shown in figure uses two liquid metal coolants. Liquid sodium (Na) serves as the primary coolant and an alloy of sodium potassium (NaK) as the secondary coolant.

Sodium melts at 208°C and boils at 885°C. This enables to achieve high outlet coolant temperature in the reactor at moderate pressure nearly atmospheric which can beutilized in producing steam of high temperature, thereby increasing the efficiency of the plant. Steam at temperature as high as 540°C has been obtained by this system. This shows that by using liquid sodium as coolant more electrical power can be generated for a given quantity of the fuel burn up.

Secondly low pressure in the primary and secondary coolant circuits permits the use of less expensive pressure vessel and pipes etc. Further sodium can transfer its heat very easily. The only disadvantage in this system is that sodium becomes radioactive while passing through the core and reacts chemically with water. So it is not used directly to transfer its heat to the feed water, but a secondary coolant is used. Primary coolant while passing through the tubes of intermediate heat exchanges (I.H.X) transfers its heat to the secondary coolant. The secondary coolant then flows through the tubes of steam generator and passes on its heat to the feed water.



Graphite is used as heat transfer media have certain advantages of using liquids used for heat transfer purposes. The various advantages of using liquid metals as heat transfer media are that they have relatively low melting points and combine high densities with low vapor pressure at high temperatures as well as with large thermal conductivities.

Safety measures carried out in Nuclear Power Plant

Safety for nuclear power plants: Nuclear power plants should be located far away from the populated area to avoid the quanta whichγ particles, neutrons and β and αradioactive hazard. A nuclear reactor produces can disturb the normal functioning of living organisms. Nuclear power plants involve radiation leaks, health hazard to workers and community, and negative effect on surrounding forests. At nuclear power plants there are three main sources of radioactive contamination of air.

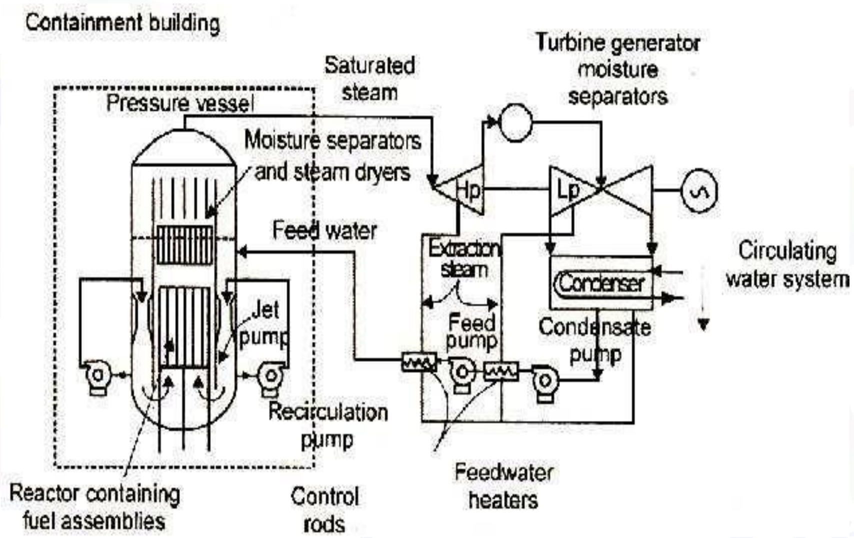
1. Fission of nuclei of nuclear fuels.
2. The second source is due to the effect of neutron fluxes on the heat carrier in the primary cooling system and on the ambient air.
3. Third source of air contamination is damage of shells of fuel elements.

This calls for special safety measures for a nuclear power plant. Some of the safety measures are as follows.

1. Nuclear power plant should be located away from human habitation.
2. Quality of construction should be of required standards.
3. Waste water from nuclear power plant should be purified. The water purification plants must have efficiency of water purification and satisfy rigid requirements as regards the volume of radioactive wastes disposed to burial.
4. An atomic power plant should have an extensive ventilation system. The main purpose of this ventilation system is to maintain the concentration of all radioactive impurities in the air below the permissible concentrations.
5. An exclusion zone of 1.6 km radius around the plant should be provided where no public habitation is permitted.
6. The safety system of the plant should be such as to enable safe shut down of the reactor whenever required. Nuclear Power plants generate large quantities of highly radioactive material. This is due to the left over isotopes (atoms) from the splitting of the atom and the creation of heavier atoms, like plutonium, which the Nuclear Power plant does not utilize. It is called nuclear waste. The actual quantity of waste output is some 100,000 times less than a Fossil Fuel plant but it is much more radioactive.

5. **Draw and explain construction and working principle of Boiling Water Reactor (BWR)? (May/June2016)**

Figure shows a simplified BWR. Light water, which acts as the coolant and moderator, passes through the core where boiling takes place in the upper part of the core. The wet steam then passes through a bank of moisture separators and steam dryers in the upper part of the pressure vessel. The water that is not vaporized to steam is re-circulated through the core with the entering feed water using two recirculation pumps coupled to jet pumps (usually 10 to 12 per recirculation pump). The steam leaving the top of the pressure vessel is at saturated conditions of 7.2 mPa and 278 deg C.



The steam then expands through a turbine coupled to an electrical generator. After condensing to liquid in the condenser, the liquid is returned to the reactors as feed water. Prior to entering the reactor, the feed water is preheated in several stages of feed water heaters. The balance of plant systems (Example: Turbine generator, feed water heaters) are similar for both PWR and BWRs.

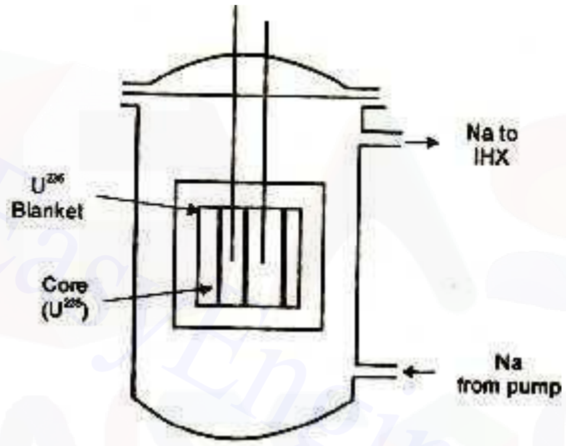
The BWR reactor core, like that in a PWR, consists of a large number of fuel rods housed in fuel assemblies in a nearly cylindrical arrangement. Each fuel assembly contains an 8×8 or 9×9 square array of 64 or 81 fuel rods (typically two of the fuel rods contain water rather than fuel) surrounded by a square Zircaloy channel box to ensure no coolant cross flow in the core. The fuel rods are similar to the PWR rods, although larger in diameter. Each fuel rod is a zirconium alloy clad tube containing pellets of slightly enriched uranium dioxide (2% to 5% U-235) stacked end-to end.

The reactor is controlled by control rods housed in a cross-shaped, or cruciform, arrangement called a control element. The control elements enter from the bottom of the reactor and move in spaces between the fuel assemblies. The BWR reactor core is housed in a pressure vessel that is larger than that of a PWR. A typical BWR pressure vessel, which also houses the reactor core, moisture separators, and steam dryers, has a diameter of 6.4 m, with a height of 22 m. Since a BWR operators at a nominal pressure of 6.9 MPa, its pressure vessel is thinner that of a PWR.

6. Explain the working principle of Fast Breeder Reactor and Gas-cooled reactor.

Fast Breeder Reactor

Figure shows a fast breeder reactor system.



In this reactor the core containing U235 in surrounded by a blanket (a layer of fertile material placed outside the core) of fertile material U238. In this reactor no moderator is used. The fast moving neutrons liberated due to fission of U235 are absorbed by U238 which gets converted into fissionable material Pu239 which is capable of sustaining chain reaction.

Thus this reactor is important because it breeds fissionable material from fertile material U238 available in large quantities. Like sodium graphite nuclear reactor this reactor also uses two liquid metal coolant circuits. Liquid sodium is used as primary coolant when circulated through the tubes of intermediate heat exchange transfers its heat to secondary coolant sodium potassium alloy. The secondary coolant while flowing through the tubes of steam generator transfers its heat to feed water.

Fast breeder reactors are better than conventional reactors both from the point of view of safety and thermal efficiency. For India which already is fast advancing towards self reliance in the field of nuclear power technology, the fast breeder reactor becomes inescapable in view of the massive reserves of thorium and the finite limits of its uranium resources. The research and development efforts in the fast breeder reactor technology will have to be stepped up considerably if nuclear power generation is to make any impact on the country's total energy needs in the not too distant future.

The commonly used coolants for fast breeder reactors are as follows:

i) Liquid metal (Na or NaK).

ii) Helium (He)

iii) Carbon dioxide.

Sodium has the following advantages:

i) It has very low absorption cross-sectional area.

ii) It possesses good heat transfer properties at high temperature and low pressure.

iii) It does not react on any of the structural materials used in primary circuits.

Gas-cooled reactor

A gas-cooled reactor (GCR) is a nuclear reactor that uses graphite as a neutron moderator and carbon dioxide (helium can also be used) as coolant. Although there are many other types of reactor cooled by gas, the terms GCR and to a lesser extent gas cooled reactor are particularly used to refer to this type of reactor.

The GCR was able to use natural uranium as fuel, enabling the countries that developed them to fabricate their own fuel without relying on other countries for supplies of enriched uranium, which was at the time of their development only available from the United States or Soviet Union.

There were two main types of generation I GCR:

- The Magnox reactors developed by the United Kingdom.
- The UNGG reactors developed by France.

The main difference between these two types is in the fuel cladding material. Both types were mainly constructed in their countries of origin, with a few

Export sales: Magnox plants to Italy and Japan, and a UNGG to Spain. Both types used fuel cladding materials that were unsuitable for medium term storage under water, making reprocessing an essential part of the nuclear fuel cycle.

Both types were, in their countries of origin, also designed and used to produce weapons-grade plutonium, but at the cost of major interruption to their use forpower generation despite the provision of online refuelling.

In the UK, the Magnox was replaced by the advanced gas-cooled reactor (AGR), an improved Generation II gas cooled reactors. In France, the UNGG was replaced by the pressurized water reactor (PWR). More recently, GCRs based on the declassified drawings of the early Magnox reactors have been constructed by North Korea at the Yongbyon Nuclear Scientific Research Center.

UNIT IV

POWER FROM RENEWABLE ENERGY

PART-A

1. What do you understand by water hammer?

A water hammer commonly occurs when a valve closes suddenly at an end of a pipeline system, increases the pressure and produces a hammering sound in the pipe. It is also called hydraulic shock.

2. Why is a surge tank important in a hydro electric power plant? (May/June 2016)

The surge tank is used to provide better regulation of water pressure in the system. The surge tank controls the water when the load on the turbine decreases and supplies water when the load on the turbine increases. Thus, surge tank controls the pressure variations resulting from the rapid changes in water flow in penstock and hence prevents water hammer.

3. List the various types of solar energy collectors.

1. Stationary collectors (or) Non- concentrating

(a) Flat plate collectors

(b) Compound parabolic collectors

(c) Evacuated tube collectors

2. Sun tracking concentrating collector

(a) Single axis tracking

(b) Two-axis tracking

4. What is fuel cell?

A fuel cell is an energy conversion device that provides the reaction of fuel and oxygen to produce electricity. The most common fuel is hydrogen, produces electricity, water, and heat by the combination of hydrogen and oxygen.

5. What is the source of geothermal energy?

Geothermal energy is clean and renewable source of energy that refers to heat found in Earth's core. The geothermal energy is basically a form of thermal energy that has its origin in radioactive decay of various minerals inside the Earth's core.

6. What are sources of Biogas?

Biogas can be produced by anaerobic digestion of organic matter. Potential raw materials available on a large scale are cow dung, municipal waste and plants specially grown for this purpose like water hyacinths, algae, certain types of grasses.

7. Write the advantages of fuel cell?

- Water is the only discharge
- High efficiency
- Low weight and volume
- Portable
- No hazardous emissions

8. Mention the various advantages of wind power. (Nov/Dec 2015)

1. Inexhaustible fuel source 2.No pollution 3. Excellent supplement to other renewable source 4. Energy source free

9. List four advantages of hydro electric power plant.

- It is a clean and safe source of energy
- They are self sustaining
- They create habitat for more types of fish
- They can act as a flood controller
- They are the most efficient energy source running from 90-95% efficiency

10. What is Biological fuel cell?

Biological fuel cell converts the chemical energy of carbohydrates, such as sugars and alcohol directly into electrical energy.

11. What are limitations of tidal power plant? (Nov/Dec 2015)

- Due to variation in tidal range the output is not uniform.
- Since the turbines have to work on a wide range of head variation (due to variable tidal range) the plant efficiency is affected.
- There is a fear of machinery being corroded due to corrosive sea water.
- It is difficult to carry out construction in sea.
- As compared to other sources of energy, the tidal power plant is costly.
- The power transmission cost is high because the tidal power plants are located away from load centres.

12. Why is a tall tower essential for mounting a horizontal axis wind turbine? (May/Jun 2016)

The wind speed increases with height. So, taller towers enable turbines tocapture more energy and generate more electricity. Generally output power of the wind system increase with increase in height and also reduces the turbulence in wind.

13. List out the various components of hydro electric power plant.

Some of the major components in hydroelectric power plants are: Reservoirs, Dam, Trash Rack, Forebay, Surge Tank, Penstock, Spillway, Prime Mover and Generator, Draft Tube.

14. What is the principle of SPV?

Solar Photo Voltaic (SPV) is a best known method of generating electric power by using solar cells. The photovoltaic effect refers to photons of light excitingelectrons into a higher state of energy, allowing them into act as charge carries for an electric current.

15. What is biogas? Give the advantages. (Nov/Dec 2016)

Biogas typically refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen

It's a renewable energy source
It's eco-friendly
Reliable

16.List the difference between Francis and kaplan turbine(Nov/Dec 2016)

Efficiency of Kaplan turbine is higher than Francis turbine. ... In Kaplan turbine, the water flows axially in and axially out while in Francis turbine it is radially in and axially out. The runner blades in the Kaplan turbine are less in number as the blades are twisted and covers a larger circumference.

17. What is fuel cell? State the advantages.(April/May 2017)

A fuel cell is an electrochemical cell that converts the chemical energy from a fuel into electricity through an electrochemical reaction of hydrogen-containing fuel with oxygen or another oxidizing agent

1. Most abundant element
2. Hydrogen is non-polluting:

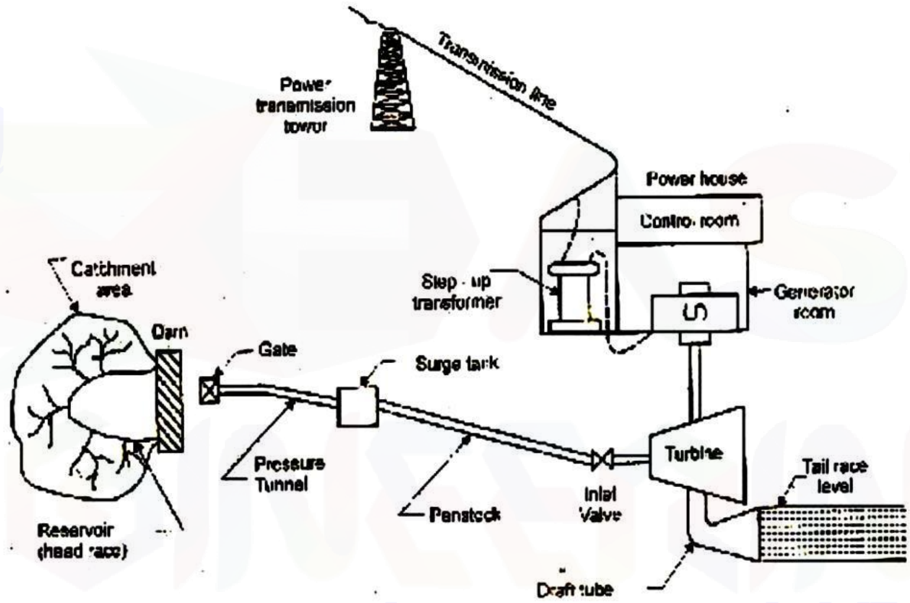
18. What is spillway? (April/May 2017)

A spillway is a structure used to provide the controlled release of flows from a dam or levee into a downstream area, typically the riverbed of the dammed river itself. In the UK they may be known as overflow channels. Spillways ensure that the water does not overflow and damage or destroy the dam

PART-B

1. Draw the Layout diagram of Hydro electric Power Plant and also explain the components and working of Hydro electric power plant?
[Nov/Dec 2016,April/May 2017]

Hydro-electric power plant utilizes the potential energy of water stored in a dam built. Across the river the potential energy of water is used to run water turbine to which the electric generator is coupled. The mechanical energy available at the shaft ofthe turbine is converted into electrical energy means of the generator.



i) Water reservoir

Continuous availability of water is the basic necessity for a hydro-electric plant. Water collected from catchment area during rainy season is stored in the reservoir. Water surfaces in the storage reservoir us known as head race.

ii) Dam

The function of a dam is to increase the height of water level behind it which ultimately increases the reservoir capacity. The dam also helps to increase the working heat of the power plant.

ii) Spillway

Water after a certain level in the reservoir overflows through spillway without allowing the increase in water level in the reservoir during rainy season

iv) Pressure tunnel

It carries water from the reservoir to surge tank.

v) Penstock

Water from surge tank is taken to the turbine by means of penstocks, made up of reinforced concrete pipes or steel.

vi) Surge tank

There is sudden increase of pressure in the penstock due to sudden backflow of water, as load on the turbine is reduced. The sudden rise of pressure in the penstock is known as water hammer. The surge tank is introduced between the dam and the power house to keep in reducing the sudden rise of pressure in the penstock. Otherwise penstock will be damaged by the water hammer.

vii) Water turbine

Water through the penstock enters into the turbine through and inlet valve. Prime movers which are in common use are Pelton turbine, Francis turbine and Kaplanturbine. The potential energy of water entering the turbine is converted into mechanical energy. The mechanical energy available at the turbine shaft is used to run the electric generator. The water is then discharged through the draft tube.

viii) Draft tube

It is connected to the outlet of the turbine. It allows the turbine to be placedover tail race level.

ix) Tail race

Tail race is a water way to lead the water discharged from the turbine to the river. The water held in the tail race is called tail race water level.

x) Step-up transformer

Its function is to raise the voltage generated at the generator terminating before transmitting the power to consumers.

xi) Power house

The power house accommodates the turbine, generator, transformer and control room.

Advantages:

1. Water is renewable source of energy. Water which is the operating fluid, is neither consumed nor converted into something else.

2. Water is the cheapest source of energy because it exists as a free gift of nature. The fuels
needed for the thermal, diesel and nuclear plants are exhaustible and expensive.

3. There is no ash disposal problem as in the case of thermal power plant.

4. Hydro-plant does not pose the problem of air pollution as in the case of thermal plant orradiation hazards as in the case of nuclear plant.

5. Variable loads do not affect the efficiency in the case of a hydro-plant.

Disadvantages:

1. Hydro-plants are generally situated away from the load centres. Hence long transmission lines are required for delivery of power. This increases the cost of transmission lines and also transmission losses. But a thermal plant can be located near the load centre, thereby the transmission cost and transmission losses are considerably reduced.

2. The power produced by hydro-plant depends upon the quantity of water which in turn is dependent upon the rainfall. The dry year affects the hydro-power generation considerably.

3. Initial cost of the plant is high.

4. Erection of hydro-plant (construction of dam etc.) usually takes long period of time.

2. Explain the principle of wind electric system. State the basic Components and their working in wind electric system. (Nov/Dec 2016)

Converts kinetic energy in moving air (wind) into electrical energy.If mechanical energy is directly used it is called a wind mill. Winds are essentiallycaused by the solar heating of the atmosphere. They carry enormous quantity of energy. Wind as a source of power is very attractive because it is plentiful, inexhaustible, renewable and non-polluting. There is no depletion of scarce resources further, it does not impose extra burden on the environment.

The Figure illustrates the two types of turbines and typical subsystems for an electricity generation application. The subsystems include a blade or rotor, which converts the energy in the wind to rotational shaft energy; a drive train, usually including a gearbox and a generator, a tower that supports the rotor and drive train, and other equipment, including controls, electrical cables, ground support equipment, and interconnection equipment.

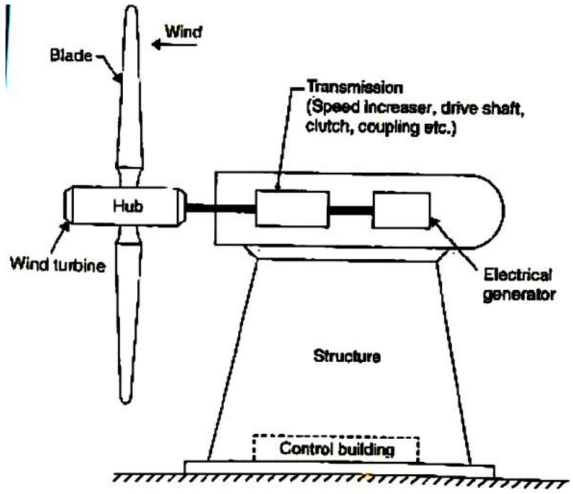


Figure shows the various parts of a wind-electric generating power plant. These are:

1. Wind turbine or rotor.
2. Wind mill head – it houses speed increaser, drive shaft, clutch, coupling etc
3. Electric generator.
4. Supporting structure.

The most important component is the **rotor**. For an effective utilization, all components should be properly designed and matched with the rest of the components.The wind mill head performs the following functions:

(i) It supports the rotor housing and the rotor bearings.

(ii) It also houses any control mechanism incorporated like changing the pitch of the blades for safety devices and tail vane to orient the rotor to face the wind, the latter is facilitated by mounting it on the top of the supporting structure on suitable bearings.

The wind turbine may be located either unwind or downwind of the power. In the unwind location the wind encounters the turbine before reaching the tower. Downwind rotors are generally preferred especially for the large aero generators.

The supporting structure is designed to withstand the wind load during gusts. Its type and height is related to cost and transmission system incorporated. Horizontal axis wind turbines are mounted on towers so as to be above the level of turbulence andother ground related effects.

Types of Wind Machines

Wind machines (aero generators) are generally classified as follows:

1. Horizontal axis wind machines.

2. Vertical axis wind machines.

Horizontal axis wind machines.

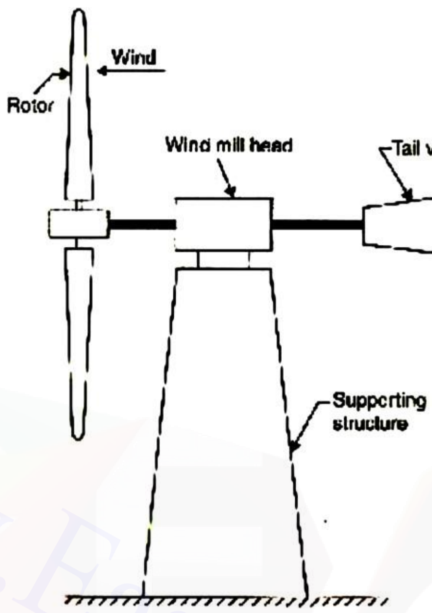


Figure shows a schematic arrangement of horizontal axis machine. Although the common wind turbine with horizontal axis is simple in principle yet the design of a complete system, especially a large one that would produce electric powereconomically, is complex. It is of paramount importance's that the components like rotor, transmission, generator and tower should not only be as efficient as possible but they must also function effectively in combination.

Wind electric generators (WEG)

Wind electric generator converts kinetic energy available in wind to electrical energy by using rotor, gear box and generator. The wind speed is the most important factor influencing the amount of energy a wind turbine can produce. Increasing wind velocity increases the amount of air passing the rotor, which increases the output of the wind system.

In order for a wind system to be effective, a relatively consistent wind flow is required. Obstructions such as trees or hills can interfere with the wind supply to the rotors. To avoid this, rotors are placed on top of towers to take advantage of the strong winds available high above the ground. The towers are generally placed 100 metres away from the nearest obstacle. The middle of the rotor is placed 10 metres above any obstacle that is within 100 metres.

Vertical axis wind machines.

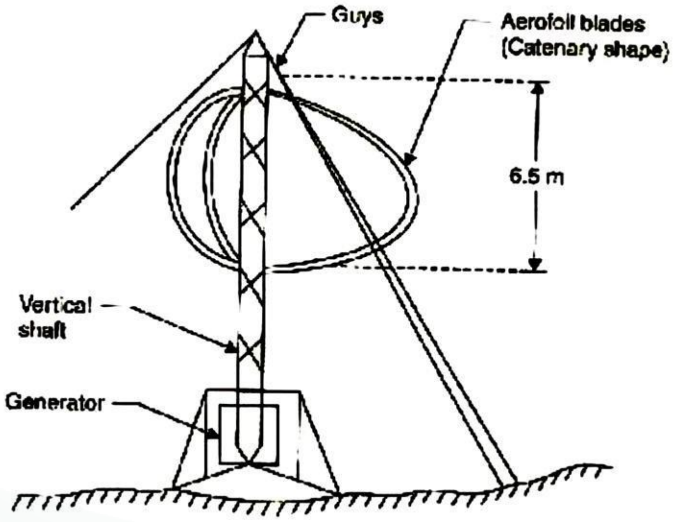
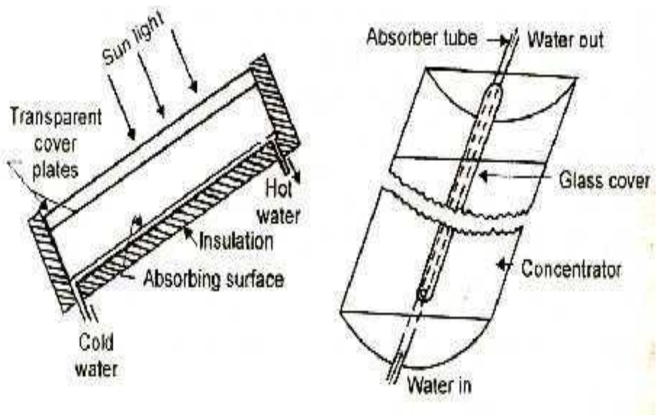


Figure shows vertical axis type wind machine. One of the main advantages of vertical axis rotors is that they do not have to be turned into the wind stream as the wind direction changes. Because their operation is independent of wind direction, vertical axis machine are called panemones.

3. Explain the construction and working principle of solar thermal power plant (Nov/Dec 2015, May/June 2016)

a)Flat plate collector

In a flat plate collector (figure), the radiation energy of the sun falls on a flat surface coated with black paint having high absorbing capacity. It is placed facing the general direction of the sun. The materials used for the plate may be copper, steel aluminium. The thickness of the plate is 1 to 2 mm. Tubing of copper is provided in thermal contact with the plate.



Heat is transferred from the absorbed plate to water which is circulated in the copper tubes through the flat plate collection. Thermal insulation is provided behind the absorber plate to prevent heat losses from the rear surface. Insulating material is generally fibre glass or mineral wool. The front cover is made up of glass and it is transparent to the incoming solar radiations.

b) Cylindrical parabolic concentrator collector

Concentrator collectors (figure) are of reflecting type utilizing mirrors. The reflecting surface may be parabolic mirror. The solar energy falling on the collector surface is reflected and focused along a line where the absorber tube is located. As large quantity of energy falling on the collector surface is collected over a small surface, the temperature of the absorber fluid is very much higher than in flat plate collector. While flat place collectors may be used to heat water upto 80□C (low temperature), the concentrating type of collectors are designed to heat water to medium and high temperature ranges.

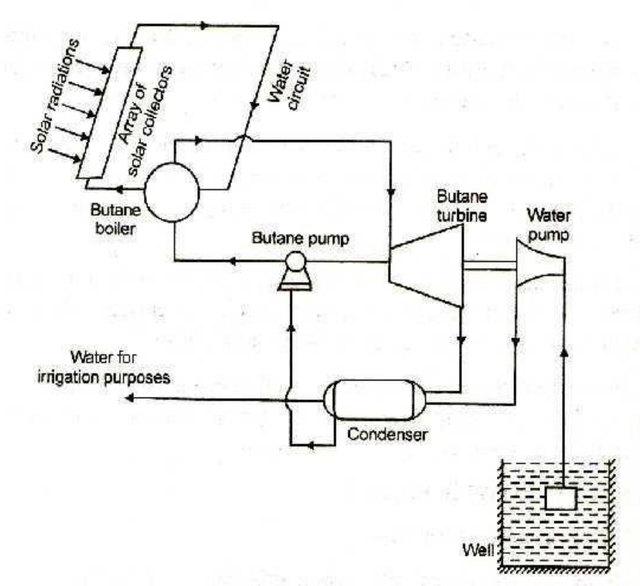
Figure shows a solar power plant with a low temperature solar engine using heated water from flat plate solar collector and Butane as the working fluid. This was developed to lift water for irrigation purposes.

c) Butane boiler

The water heated in flat plate solar collector to 80° is used for boiling butane at high pressure in the butane boiler. Boiling point of butane is about 50°

d) Turbine

The butane vapour generated at high pressure in the boiler is used to run the vapour turbine which drives the electrical generator. The vapour coming out of the turbine at low pressure is condensed in a condenser using water. The condensed liquid Butane is fed back to the butane boiler using feed pump.



Tower concept for power generation

The tower concept consists of an array of plane mirrors or heliostats which are individually controlled to reflect radiations from the sun into a boiler mounted on a 500 meters high tower. Steam in generated in the boiler, which may attain a temperature upto 2000K. Electricity is generated by passing steam through the turbine coupled to a generator.

Advantages

1. Sun is essentially an infinite source of energy. Therefore solar energy is a very large inexhaustible and renewable source of energy

2. It is environmentally very clean and is hence pollution-free.

3. It is a dependable energy source without new requirements of a highly technical.

4. It is the best alternative for the rapid depletion of fossil fuels

Disadvantages

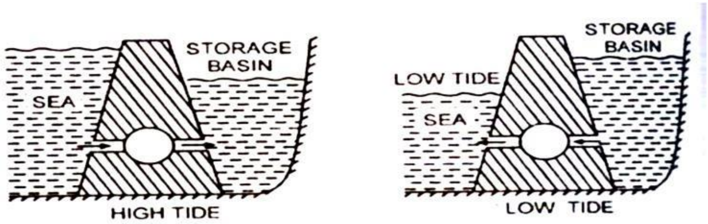
1. Very large collecting areas are required.

2. Capital cost is more for the solar plant.

3. Solar energy is not available at night or during cloudy or rainy days.

4. Explain how electrical energy can be generated in single basin two way cycle of tidal power generation.

The tidal power plants are generally classified on the basis of the number of basins used for the power generation. They are further subdivided as one-way or two-way system as per the cycle of operation for power generation



(a) (b)

A dam is constructed to create basin to store the water. Hence power is generated during both flood & ebb tide. By using reversible water turbine the turbine can run continuously both during high tide and low tide. The principle of operation is illustrated in above figure. This arrangement is costlier but provides greater flexibility and continuous power output.

A Tidal power plant mainly consists of the following:

1. A barrage with gates and sluices
2. One or more basins
3. A power house

A barrage is a barrier constructed across the sea to create a basin for storing water. The barrage has to withstand the pressure exerted by the water head and also should resist the shock of the waves.A basin is the area where water is retained by the barrage. Low head reversible water turbines are installed in the barrage separating the sea from the basin.

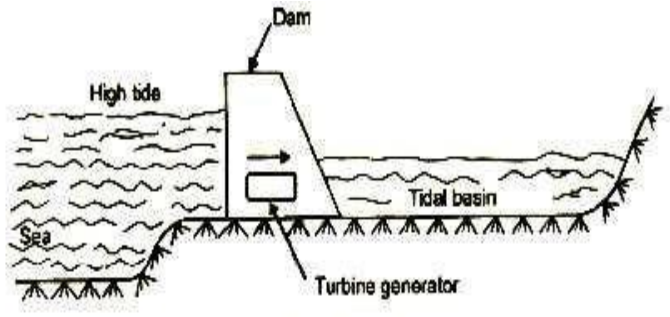
Principle

Tide or wave is periodic rise and fall of water level of the sea. Tides occur due to the attraction of sea water by the moon. Tides contain large amount of potential energy which is used for power generation. When the water is above the mean sea level, it is called flood tide. When the water level is below the mean level it is called ebb tide.

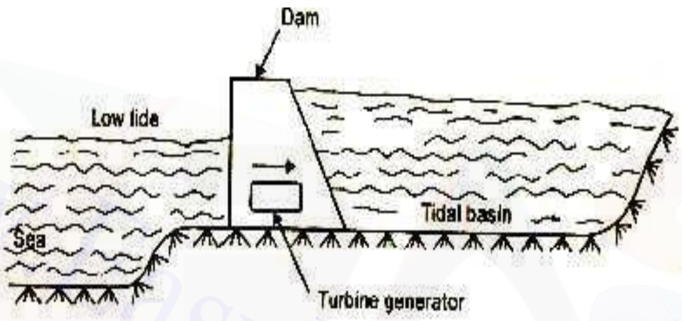
Working

The arrangement of this system is shown in figure. The ocean tides rise and fall and water can be stored during the rise period and it can be discharged during fall. A dam is constructed separating the tidal basin from the sea and a difference in water level is obtained between the basin and sea.

During high tide period, water flows from the sea into the tidal basin through the water turbine. The height of tide is above that of tidal basin. Hence the turbine unit operates and generates power, as it is directly coupled to a generator.



(a) High tide



(b) Low tide

During low tide period, water flows from tidal basin to sea, as the water level in the basin is more than that of the tide in the sea. During this period also, the flowing water rotates the turbine and generator power.

The generation of power stops only when the sea level and the tidal basin level are equal. For the generation of power economically using this source of energy requires some minimum tide height and suitable site

Working of different tidal power plants

Single basin-one-way cycle

This is the simplest form of tidal power plant. In this system a basin is allowed to get filled during flood tide and during the ebb tide, the water flows from the basin to the sea passing through the turbine and generates power. The power is available for a short duration ebb tide

Single-basin two-way cycle

In this arrangement, power is generated both during flood tide as well as ebb tide also. The power generation is also intermittent but generation period is increased compared with one-way cycle. However, the peak obtained is less than the one-way cycle.

Single – basin two-way cycle with pump storage

In this system, power is generated both during flood and ebb tides. Complex machines capable of generating power and pumping the water in either direction are used. A part of the energy produced is used for introducing the difference in the water levels between the basin and sea at any time of the tide and this is done by pumping water into the basin up or down.

Double basin type

In this arrangement, the turbine is set up between the basins as shown in figure. One basin is intermittently filled tide and other is intermittently drained by the ebb tide. Therefore, a small capacity but continuous power is made available with this system as shown in figure. The main disadvantages of this system are that 50% of the potential energy is sacrificed in introducing the variation in the water levels of the two basins

Double basin with pumping

In this case, off peak power from the base load plant in a interconnected transmission system is used either to pump the water up the high basin. Net energy gain is possible with such a system if the pumping head is lower than the basin-to- basin turbine generating head.

Advantages of tidal power plants.

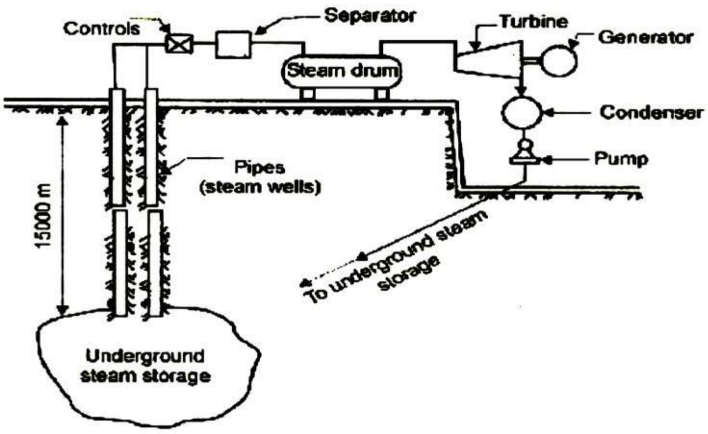
1. It is free from pollution as it does not use any fuel.
2. It is superior to hydro-power plant as it is totally independent of rain.

Disadvantages

1. Tidal power plants can be developed only if natural sites are available on the bay.
2. As the sites are available on the bays which are always far away from load centres, the power generated has to be transmitted to long distances. This increases the transmission cost and transmission losses.

5. Explain with a neat sketch the working principle of Geothermal Power plant. What are the advantages and disadvantages of Geothermal energy.

Geothermal wells are drilled at suitable locations. Water vaporized into steam comes out of the earth's surface in a dry condition at around 200°C and 8 bar. The moisture is removed by a centrifugal separator and this steam will run the turbine coupled with a generator. Steam is condensed in a condenser and re injected back into the ground by a rejection well.



Types of Geothermal Sources

Hydrothermal systems

Hydrothermal systems are those in which water is heated by contact with the hot rock. Hydrothermal systems are in turn subdivided into

1) Vapor-dominated and

2) Liquid-dominated systems.

Vapor-dominated systems

In these systems the water is vaporized into steam that reaches the surface in relatively dry Condition at about 205^0C and rarely above 8 bar. This steam is the most suitable for use in turboelectric power plants with the least cost

Liquid-dominated systems

In these systems the hot water circulating and trapped underground is at a temperature range of 174 to 315^0C. When tapped by wells drilled in the right places and to the right depths the water flows either naturally to the surface or is pumped up to it.

Steam well

Pipes are embedded at places of fresh volcanic action called steam wells, where the molten internal mass of earth vents to the atmospheric with very high temperatures. By sending water through embedded pipes, steam is raised from the underground steam storage wells to the ground level.

Separator

The steam is then passed through the separator where most of the dirt and sand carried by the steam are removed.

Turbine

The steam from the separator is passed through steam drum and is used to run the turbine which in turn drives the generator. The exhaust steam from the turbine is condensed. The condensate is pumped into the earth to absorb the ground heat again and to get converted into steam.

Location of the plant, installation of equipment like control unit etc., within the source of heat and the cost of drilling deep wells as deep as 15,000 meters are some of the difficulties commonly encountered.

Working

Bore (hole) are drilled into the earth until it reaches wet steam geothermal reservoirs. This wet steam is brought up with very high pressure with the help of pump, So steam remains in liquid state.

When the water comes to the surface of the earth then it is filtered to remove abrasive (solid crushed stone particles. Then it is passed through flash chamber where pressure of high temperature water decreases suddenly.

As pressure drops water is converted into steam in flash tank. This steam is used to run the steam turbine which gives mechanical power. Alternator is coupled with steam turbine which mechanical energy into electrical energy.

ADVANTAGES

1. Geothermal energy is cheaper
2. Used as space heating for buildings
3. Used as industrial process heat
4. Geothermal energy is inexhaustible

DISADVANTAGES

Low overall power production efficiency (about 15%)

Large areas are needed foe exploitation of geothermal energy

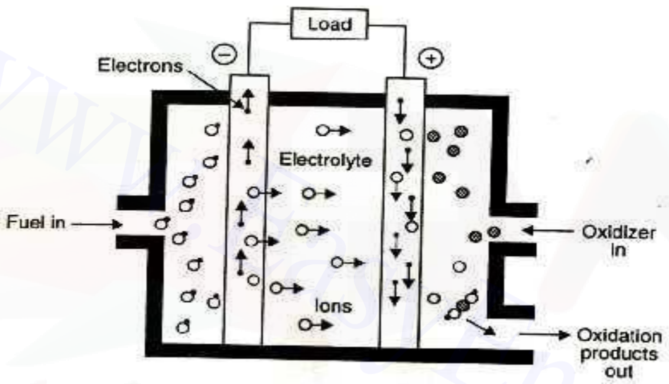
6. Explain the working principle of fuel cell. (Nov/Dec 2016)

Fuel cell:

Fuel cells are a means of converting a fuel to electrical energy using an electrochemical membrane. The most popular to date has been the proton exchange hydrogen fuel cell. It takes two molecules of hydrogen and one molecule of oxygen and produces two molecules of water leaving behind four spare electrons to generate an electric current.

In terms of the energy value of the hydrogen, the conversion process is around 75% to 80% efficient. Some fuel cells use other chemical fuels as a source of hydrogen such as methanol, which is processed into hydrogen for the use by the fuel cell.

Although this means that the system doesn't have to store large quantities of highly explosive hydrogen, it does reduce the efficiency of the electricity generation process to 30% or 40%. This is still more efficient than burning the methanol directly combustion engines are only around 20% efficient in terms of the energy of the fuel that is actually transferred into motion on the ground.



Working of Fuel Cell

The problem with hydrogen fuel cells is generating the hydrogen to fuel them. To get those 4 electrons out by combining two hydrogen molecules with an oxygen molecule, you have to put them in at the point you manufacture of the hydrogen

The principle of operation is similar to electrolysis of water but in the reverse manner. Due to chemical action at anode hydrogen atom split into an electron and proton, which take different route to reach the cathode. The proton from hydrogen migrates through electrolyte to cathode. The electron creates a separate current that reaches the cathode faster. This chemical transformation result in the generation of electric power.

The fuel gas diffuses through the anode and is oxidized, thus releasing electrons to the external circuit; the oxidizer diffuses through the cathode and is reduced by the electrons that have come from the anode by way of the external circuit.

The fuel cell is a device that keeps the fuel molecules from mixing with the oxidizer molecules, permitting, however, the transfer of electrons by a metallic path that may contain a load of the available fuels, hydrogen has so far given the most promising results, although cells consuming coal, oil or natural gas would be economically much more useful for large scale applications.

Advantages of fuel cell

i) It is a static piece, So no mechanical losses.

ii) It is noiseless in operation.

iii) There is no air pollution. No heat losses, so no cooling water is required.

UNIT V

ENERGY, ECONOMIC AND ENVIRONMENTAL ISSUES OF POWER PLANTS

1. Define demand factor?

Demand factor is defined as the ratio of maximum demand to connected load. Connected load is the sum of ratings in kW of equipment installed in the consumer's premises. Maximum demand is the maximum load, which a consumer uses at any time.

2. What are the elements of fixed and operating costs?(May/June2016)

Fixed cost includes the following cost.

1. Cost of land, 2. Cost of building, 3. Cost of equipment, 4. Cost of installation,
5. Interest, 6. Depreciation cost,7. Insurance and 8. Management cost

Operating cost includes the following cost.

1. Cost of fuel, 2. Cost of operating labour, 3. Cost of maintenance labours and materials. 4. Cost of supplier like Water for feeding boilers, for condenser and for general use. Lubrication oil, grease, water treatment chemicals etc.

3. What is the significance of load curve? (Nov/Dec 2015)

Load curve is a graphical representation between load in kW and time in hours. It. shows variation of load at the power station. The area under the load curve -represents the energy generated in a particular period.

4. What is the need of depreciation cost?

Depreciation cost is the amount to be set aside per year from the income of the plant to meet the depreciation caused by the age of service, wear and tear of the machinery and equipments. Depreciation amount collected every year helps in replacing and repairing the equipment.

5. Write nuclear waste disposal methods.

(a) Utilizing underground facility (b) Injecting into deep aquifers (c) Deep bore holes (d) Rock melting

6. Fly ash Disposal in Ash Ponds

Primarily, the fly ash is disposed off using either dry or wet disposal scheme. In dry disposal, the fly ash is transported by truck, chute or conveyor at the site and disposed off by constructing a dry silo. In wet disposal, the fly ash is transported as slurry through pipe and disposed off in impoundment called "ash pond". Most of the power plants in India use wet disposal system

7. What is the purpose of electrostatic precipitator?

An electrostatic precipitator (ESP) is a filtration device that removes fine particles, like dust and smoke, from a flowing gas using the force of aninduced electrostatic charge.

8. Define load factor and capacity factor. (May/Jun 2016)

Load factor is defined as the ratio of average load to the peak load (or) maximum demand.

Capacity factor is defined as the ratio of actual energy produced to the maximum possible energy that could have been produced during the same period.

9. What are the equipments used to control the particulates? (Nov/Dec 2015)

- Electrostatic precipitators
- Scrubbers
- Cyclonic collectors
- Fabric filters and combinations of these equipments.

10. Mention the different types of tariff.

- Flat Demand Tariff
- Simple Tariff
- Flat Rate Tariff
- Step Rate Tariff
- Hopkinson Demand Rate or Two Part Tariff
- Maximum Demand Tariff
- KVA Maximum Demand Tariff
- Doherty Rate or Three Part Tariff
- Off Peak Tariff

11. What is main objective of tariff? (Nov/Dec 2016)

A tariff is a tax imposed on the import or export of goods. In general parlance, however, it refers to "import duties" charged at the time goods are imported. Tariffs have three primary functions: to serve as a source of revenue, to protect domestic industries, and to remedy trade distortions

12. Define plant use factor. (Nov/Dec 2016)

It is the ratio of the average power load of a plant to its rated capacity.

13. What is fixed and operating cost? (April/May 2017)

A business's operating costs are comprised of two components, fixed costs and variable costs, which differ in important ways. A fixed cost is one that does not changewith an increase or decrease in sales or productivity and must be paid regardless of the company's activity or performance.

14. List down the nuclear waste disposal methods (April/May 2017)

There are four main types of nuclear waste:

High-level waste

Intermediate-level waste

Low-level waste

Mill Tailings wast

PART-B

1. What are the objectives of tariff? Discuss the different types of tariff.(April/May 2017)

Tariff:

Tariff means the schedule of rates framed for supply of electrical energy to the various categories of consumers. All types of tariffs must cover the recovery of costs of

(i) Capital investment in generating, transmitting and distributing equipment

(ii) Operation, supplies and maintenance of equipment and

(ii) Metering equipment, billing, collection and miscall anions services

(iv)A satisfactory return on the total capital investment.

(i) Flat Demand Tariff:

This is one of the earliest forms of tariffs used for charging the consumers for electrical energy consumption. This tariff is expressed as energy charges,

y = Rs a kW where a is the rate per lamp or kW of connected load and x is the number of lamps or load connected in kW. In these types of tariff the metering equipment, meter reading, billing, and accounting costs are eliminated. Now-a-days such a tariff is restricted to use such as in street lighting, signal systems, sign lightings etc.

(ii) Simple Tariff:

This is the simplest type of tariff according to which the cost o energy is charged on the basis of units consumed and can be expressed in the form y = Rs ax where a is charges in rupees per unit and x is the total electrical energy consumed in units or kWhr.

(ii)Flat Rate Tariff:

This types of tariff differs from the former one in the sense that the different types of consumers are charged at different rates i.e. the flat rate for light and fan loads is slightly higher than that for power load. The rate for each category of consumers is arrived at by taking into accounts its load factor and diversity factor.

(iv)Step Rate Tariff:

The step rate tariff is a group of flat rate tariffs of decreasing unit charges for higher range of consumption.

(**vi)Hopkinson Demand Rate or Two Part Tariff**:

The total energy charge to be made to the consumer is split into two components namely fixed charge and running charge. This type of tariff is expressed as

Y = Rs a kW + b kWhr

Where Rs a is the charge per kW of maximum demand assessed and Rs b is the charge per kWhr of energy consumed. This tariff is mostly applicable to medium industrial consumers.

(vi)Maximum Demand Tariff:

This tariff is similar to that of two part tariff except that in this case maximum demand is actual y measured by a maximum demand indicator instead of merely assessing it on the basis of rate able value.

(**vii) KVA Maximum Demand Tariff:**

It is a modified form of two part tariff. In this case maximum demand is measured in kW instead of in kW. This type of tariff encourages the consumers to operate their machines/equipment at improved power factor because low power factor will cause more demand charges.

(ix) Doherty Rate or Three Part Tariff:

In this tariff total energy charge is split into three elements namely fixed charge, semi-fixed charge and variable charge. Such a tariff is expressed as

y = Rs a + b kW + c kWhr.

Where a is a constant charge,

B is unit charge in Rs per kW of maximum demand in kW during biling period (in some case it is also charged in Rs per kVA instead of Rs per kW) and

C is the unit charge for energy in Rs per kWhr of energy consumed.

This type of tariff is usual y applicable to bulk supplies.

(x) Off Peak Tariff:

The load on the power station usual y has pronounced peak loads in the morning and early evening and a very low load during the night (from 10 P.M. to 6 A.M.). During the night, therefore, and other off-peak period which may occur, a largeproportion of the generating and distribution equipment will be lying idle.

In case the consumers are encouraged to use electricity during off peak hours by giving a special discount, the energy can be supplied without incurring an additional capital cost and should therefore prove very profitable. This type of tariff is very advantageous for certain processes such as water heating by thermal storage, pumping, refrigeration

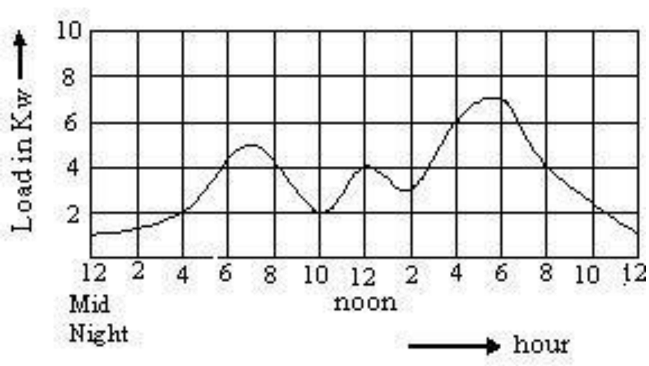
2. Explain the importance of load curve and Load duration curve in detail .

Load curve: (Apirl/May 2017)

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

Definition:

The curve showing the variation of load on the power station with respect to time.



The variation of load on the power station during different hours of the day.

The area under the curve gives the number of units generated in the day.

The maximum and minimum values of the daily load.The highest point on the load curve represents the maximum demand on the station on that day.

The load curve helps in selecting the size and number of generating units.

Information whether the installation is working efficiently or not.

It helps in preparing the operation schedule of the station.

The area under the load curve divided by the total numbers of hours (24 hours) gives the average load on the station.

Average Load = Area under daily load current/.24 hours

Types of Load Curve:

Daily load curve–Load variations during the whole day

Monthly load curve–Load curve obtained from the daily load curve Yearly load curve-Load curve obtained from the monthly load curve

Daily load curve

The curve drawn between the variations of load with reference to various time period of day is known as daily load curve.

Monthly load curve

It is obtained from daily load curve.

Average value of the power at a month for a different time periods are calculated and plotted in the graph which is known as monthly load curve

Yearly load curve

It is obtained from monthly load curve which is used to find annual load factor.

Base Load:

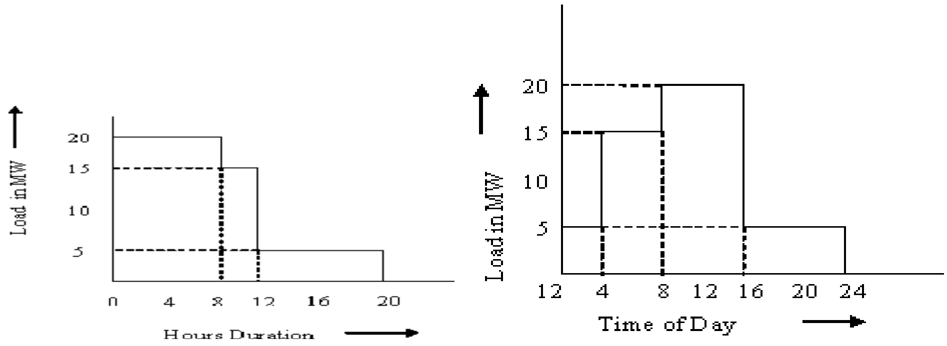
The unvarying load which occurs almost the whole day on the station

Peak Load:

The various peak demands so load of the station

Load duration curve:

Load duration curve is the plot of load in kilowatts versus time duration for which it occurs. When the elements of a load curve are arranged in the order of descending magnitudes



The load duration curve gives the data in a more presentable form. The area under the load duration curve is equal to that of the corresponding load curve. The load duration curve can be extended to include any period of time

3. Discuss in detail about economic aspects of power generation

Cost of electrical energy:

Electric Energy is the source of energy for electrical appliances. Electric Energy is measured in kWhr (kilowatt-hour) or mWhr (megawatt-hour). Power is equal to work done in respect to time, so work equals power multiplied by time. Since work equals energy, electric energy would be measured by a kilowatt-hour.

$P = W/t$

$W = E = Pt$

$(1000W)(1h) = 1kWh$

Economics of power generation.

1) Fixed Charges 2) Semi fixed Charges 3) Running Charges

These are all important parameters pertaining to the Economics of power generation and are considered in details below.

Fixed Charges of Power Generation

Fixed charges, as the name suggest does not vary either with the capacity of the plant or with plant operation. These costs remain fixed under all circumstances. These mainly include the salaries of higher officials of the central organization and the rent of the land reserved for future expansion.

Semi Fixed Charges of Power Generation

These charges mainly depend on the installed capacity of the plant and are independent of the electrical energy output of the plant. These charges include the following:

1) Interest and depreciation on the capital cost of the generating plant, transmission and distribution network, buildings and other civil engineering works etc. Capital cost of the plant also includes the interest paid during the construction of the plant, salaries of engineers and other employees, development and construction of the power station. It also includes cost incurred on account of transportation, labor etc. to bring the equipment on site and installing the same, all of which are involved for the overall economics of power generation.

It is particularly note worthy, that in nuclear stations the capital cost of the station also includes the cost of initial charges of the nuclear fuel minus the salvage value paid at the end of its useful life.

2) It also includes all types of taxes, insurance premiums pain on policies to cover the risk of accidental breakdown.

3) Rent paid for the land being actually used for the construction purpose.

The cost due to starting and shutting down of plants are also included in this category, when the power plant operates on one or two shift basis.

Running Charges of Power Generation

The running charges or running cost of a power plant is probably one of the most important parameters while considering the economics of power generation as it depends upon the number of hours the plant is operated or upon the number of units of electrical energy generated. It essentially comprises of the following costs incurred mentioned below.

1) Cost of the fuel delivered coupled with the fuel handling cost in the plant. Coal is the fuel used in a thermal power plant, and diesel oil in case of a diesel station. In case of a hydro-electric plant there is no fuel cost as water is the free gift of nature. But a hydro-plant requires higher installation cost and their mega Watt output of power generation is also lower compared to the thermal power plants.

2) Wastage of the operational and maintenance stuff and salaries of supervisor staffs engaged in running the plant.

3) In case of a thermal power plant, power generation economics includes the cost of feed water for the boiler, like the cost of water treatment and conditioning.

4) As the amount of wear and tear of the equipment depends on the extent to which the plant is being used, so the lubricating oil cost and repair and maintenance charges of the equipment are also included in the running charges.

So, we can conclude saying, that the total annual charges incurred in the power generation, and the overall power generation economics can be represented by the equation,

E = a + b KW + c kWhr

1. Where 'a' represents the total fixed cost of the plant, and has no relation with the total output of the plant or the number of hours for which the plant is running.
2. 'b' represents the semi-fixed cost, which mainly depends on the total output of the plant and not on the number of hours for which the plant is being operated. The unit for 'b' is thus ideally chosen to be in k-Watt.
3. 'c' essentially represents the running cost of the plant, and depends on the number of hours for which the plant is running to generate a certain mega watt of power. Its unit is given in K-Watt-Hr.

4. Explain different methods of nuclear waste disposal

Waste Disposal:

Waste disposal problem is common in every industry. Wastes from atomic energy Installations are radioactive, create radioactive hazard and require strong control to ensure that radioactivity is not released into the atmosphere to avoid atmospheric pollution. The wastes produced in a nuclear power plant may be in the form of liquid, gas or solid and each is treated in a different manner:

1. Liquid Waste

The disposal of liquid wastes is done in two ways:

i) Dilution

The liquid wastes are diluted with large quantities of water and then released into the

ground. This method suffers from the drawback that there is a chance of contamination of underground water if the dilution factor is not adequate

ii) Concentration to small volumes and storage

When the dilution of radioactive liquid wastes is not desirable due to amount or nature of isotopes, the liquid wastes are concentrated to small volumes and stored in underground tanks. The tanks should be of assured long term strength and leakage of liquid from the tanks should not take place otherwise leakage or contents, from the tanks may lead to significant underground water contamination.

2. Gaseous Waste

Gaseous wastes can most easily result in atmospheric pollution. Gaseous wastes are generally diluted with air, passed through filters and then released to atmosphere through large stacks (chimneys).

3. Solid Waste

Solid wastes consist of scrap material or discarded objects contaminated with radioactive matter. These wastes if combustible are burnt and the radioactive matter. These wastes if concrete are drummed and shipped for burial. Non-combustible solid wastes are always buried deep in the ground.

Most used fuel from nuclear power plants is stored in steel-lined concrete pools filled with water, or in airtight steel or concrete-and-steel containers.

Safely Managing Used Fuel

By law, the U.S. Department of Energy is responsible for developing a disposal facility for the long-term management of used uranium fuel from America's nuclear power plants. The federal government, however, does not have a viable program for the management of used nuclear fuel from commercial nuclear energy facilities and high-level radioactive waste from the government's defense and research activities.

Integrated Used Fuel Management

Until the federal government puts in place a program to dispose of these materials, nearly all commercial used fuel is stored safely and securely at the reactor sites in steel-lined concrete pools filled with water, or in airtight steel or concrete-and-steel containers. This temporary storage is but one component of an integrated used fuel management system. Other facets include recycling, transportation and final geologic disposal.

The federal government has defaulted on its legal obligation to take used nuclear fuel from commercial reactors beginning in 1998. The nuclear energy industry is committed to working with Congress, the administration and state leaders on proposedlegislation to create a sustainable, integrated program.

Used Nuclear Fuel Storage

Used nuclear fuel consists of small uranium pellets stacked inside alloy fuel rods. All the used nuclear fuel produced by the nuclear energy industry in nearly 50 years—if stacked end to end—would cover an area the size of a football field to a depth of less than 10 yards.

NEI supports the development of a consolidated facility for temporary storage of used nuclear fuel in a willing host community and state, while substantial progress is made toward developing the Yucca Mountain site or another geologic repository.

Disposal

Whether nuclear fuel is used only once or recycled for subsequent use, disposal of high-level radioactive byproducts in a permanent geologic repository is necessary. Underground disposal in a specially designed facility is an essential element of a sustainable, integrated used nuclear fuel management program. The industry supports the completion of the Nuclear Regulatory Commission's review of the DOE license application to build a repository at Yucca Mountain, Nevada.

Recycling Used Nuclear Fuel

The industry supports research, development and demonstration of improved or advanced fuel cycle technologies such as recycling, thereby potentially reducing the volume, heat and toxicity of by products placed in the repository. A geologic repository will be required for all fuel cycles. Low-level waste is a by product of the beneficial uses of a wide range of radioactive materials. These include electricity generation, medical diagnosis and treatment, and various other medical processes

5. Explain site Selection of site for Nuclear, hydro and thermal Power Station. (Nov/Dec 2016)

Site Selection of Nuclear Power Station

1. **Availability of water:** Although very large quantity of water is not regulated as hydro-electric power plant, but still sufficient supply of neutral water is obvious for cooling purposes in nuclear power station. That is why it is always preferable to locate this plant near a river or sea side.
2. **Disposal of Water:** The byproducts or wastes of nuclear power station are radioactive and may cause severe health hazards. Because of this, special care to be taken during disposal of wastes of nuclear power plant. The wastes must be buried in sufficient deep from earth level or these must be disposed off in sea quite away from the sea share. Hence, during selecting the location of nuclear plant, this factor must be taken into consideration.
3. **Distance from Populated Area:** As there is always a probability of radioactivity, it is always preferable to locate a nuclear station sufficiently away from populated area.
4. **Transportation Facilities:** During commissioning period, heavy equipments to be erected, which to be transported from manufacturer site. So good railways and road ways availabilities are required. For availability of skilled manpower good public transport should also be present at the site.

Selection of site for thermal power plant

Transportation network: Easy and enough access to transportation network is required in both power plant construction and operation periods.

Power transmission network: To transfer the generated electricity to the consumers, the plant should be connected to electrical transmission system. Therefore the nearness to the electric network can play a roll.

Geology and soil type: The power plant should be built in an area with soil and rock layers that could stand the weight and vibrations of the power plant.

Earthquake and geological faults: Even weak and small earthquakes can damage many parts of a power plant intensively. Therefore the site should be away enough from the faults and previous earthquake areas.

Topography: It is proved that high elevation has a negative effect on production efficiency of gas turbines. In addition, changing of a sloping area into a flat site for the construction of the power plant needs extra budget. Therefore, the parameters of elevation and slope should be considered.

Rivers and floodways: obviously, the power plant should have a reasonable distance from permanent and seasonal rivers and floodways.

Water resources: For the construction and operating of power plant different volumes of water are required. This could be supplied from either rivers or underground water resources. Therefore having enough water supplies in defined vicinity can be a factor in the selection of the site.

Environmental resources: Operation of a power plant has important impacts on environment. Therefore, priority will be given to the locations that are far enough from national parks, wildlife, protected areas, etc.

Population centers: For the same reasons as above, the site should have an enough distance from population centers.

Need for power: In general, the site should be near the areas that there is more need for generation capacity, to decrease the amount of power loss and transmission expenses.

Land cover: Some land cover types such as forests, orchard, agricultural land, pasture are sensitive to the pollutions caused by a power plant. The effect of the power plant on such land cover types surrounding it should be counted for.

Area size: Before any other consideration, the minimum area size required for the construction of power plant should be defined.

Distance from airports: Usually, a power plant has high towers and chimneys and large volumes of gas. Consequently for security reasons, they should be away from airports.

Archeological and historical sites: Usually historical buildings are fragile and at same time very valuable. Therefore the vibration caused by power plant can damage them, and a defined distance should be considered.

Site Selection for Hydropower Plants

- Availability of Water: Run-off data for many years available
- Water Storage: for water availability throughout the year

• Head of Water: most economic head, possibility of constructing a dam to get required head

• Geological Investigations: strong foundation, earthquake frequency is less

• Water Pollution: excessive corrosion and damage to metallic structures

• Sedimentation: capacity reduces due to gradual deposition of silt

• Social and Environmental Effects: submergence of areas, effect on biodiversity (e.g. western ghat), cultural and historic aspects

• Access to Site: for transportation of construction material and heavy machinery new railway lines or roads may be needed

• Multipurpose: power generation, irrigation, flood control, navigation, recreation; because initial cost of power plant is high because of civil engineering construction work

6. The peak load on a power station is 30 MW. The loads having maximum demands of 15MW, 10MW, 5M and 7MW are connected to the power station. The capacity of the power station is 40MW and annual load factor is 50%. Find

a) Average load on the power station

b) Energy supplied per year

c) Demand factor

d) Diversity factor

Given:

The peak load on a power station = 30 MW

Connected loads = 15,10,5 and 7MW

The capacity of the power station = 40MW

Annual load factor = 50%

To find:

a) Average load on the power station

b) Energy supplied per year

c) Demand factor

d) Diversity factor

Solution:

a) We know that,

Load factor = Average load/ Max. Load

Average load = Load factor x Max. Load

= 30 x 0.5

Average load = 15 mW

b) Energy supplied per year E = Average load x 365 x 24

$= 15 \times 10^3 \times 8760$

$E = 131.4 \times 10^3$ kW- hr

c) Demand factor = Max. Load/ Connected loads

= 30/(15+10+5+7)

D.F = 0.81

d) Diversity factor = Connected loads / Max.demand

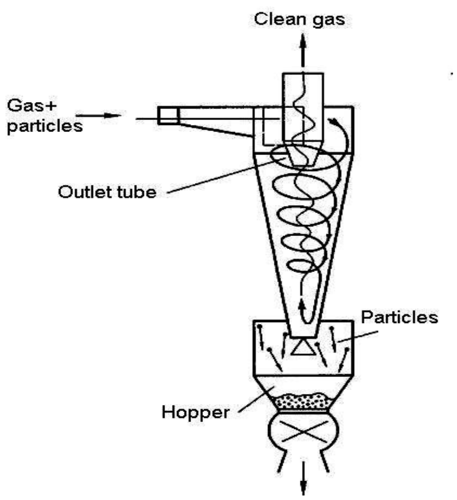
= 37/30

Div.F = 1.23

7. Explain the pollution control method of cyclone separator and electrostatic precipitator in thermal power plants.

Cyclone separator:

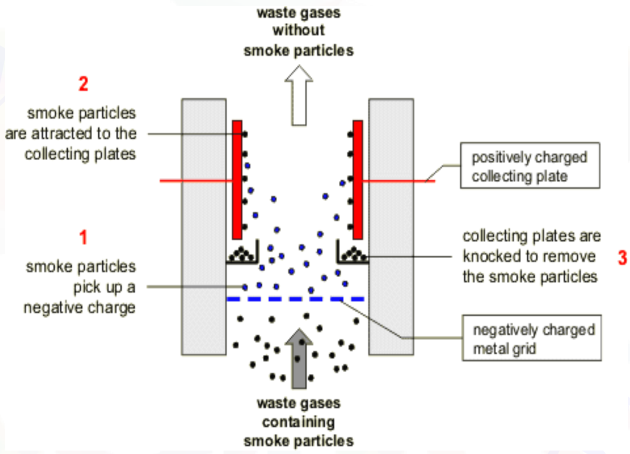
Cyclone separators operate by incorporating centrifugal, gravitational, and inertial forces to remove fine particles suspended in air or gas. These types of separators use cyclonic action to separate particulates from a gas stream. Typically,PM enters the cyclone separator at an angle (perpendicular to the flow stream, tangentially, or from the side), and is then spun rapidly.



A centrifugal force is created by the circular airflow that throws the particulate towards the wall of the cyclone. Once the PM hits the wall, it falls into a hopper below. "Clean" exhaust is then either blown through or recirculated to be filteredagain.

Electro static precipitators:

Electrostatic smoke precipitators work by forcing dirty flue gas (the gas escaping from a smokestack) past two electrodes (electrical terminals), which take the form of metal wires, bars, or plates inside a pipe or smokestack. The first electrode is charged to a very high negative voltage. As the dirt particles move past it, they pick upa negative charge. Higher up the pipe (or further along, if it's a horizontal pipe), there'sa second electrode consisting of metal plates charged to a high positive voltage.



Since unlike charges attract, the negatively charged soot particles are attracted to the positively charged plates and stick there. From time to time, the collecting plates have to be shaken to empty away the soot; that can be done either manually (by someone brushing them clean) or automatically (by some kind of automated shakingor brushing mechanism in a process called rapping). Illustration: Electrostatic smoke precipitators use static electricity to remove the soot from smoke. Dirty air moves past negatively charged wires (shown as −ve) so the soot particles pick up a negative charge. The negatively charged particles of soot then stick to positively charged plates (shown as +ve) further along the pipe.

Industrial/Practical connectivity of the subject:

1. Tuticorin thermal power corporation
2. Nuclear power plant (Kudankulam)
3. Hydro electric power plant (papanasam)

4. Bio gas power plant (CET)
5. Wind power plant (Nagercoil)
6. Solar power plant (kayathar)
7. Fuel cell (DSRT FXEC)

8. Explain the methods to control pollution in thermal and nuclear power plants. (Nov/Dec 2016,April/May 2017)

Control of Thermal Pollution:

Control of thermal pollution is necessary as its detrimental effects on aquatic ecosystem may be detrimental in the future. Viable solutions to chronic ther•mal discharge into water bodies are as follows:

(1) Cooling Ponds:

Cooling ponds or reservoirs constitute the simplest method of controlling ther•mal discharges. Heated effluents on the surface of water in cooling ponds maximize dissipation of heat to the atmosphere and minimize the water area and volume. This is the simplest and cheapest method which cools the water to a considerable low tem•perature. However, the technique alone is less desirable and inefficient in terms of air-water contact.

(2) Cooling Towers:

Using water from water sources for cooling purposes, with subsequent return to the water body after passing through the condenser is termed as cooling process. In order to make the cooling process more effective, cooling towers are designed to control the temperature of water. In-fact, cooling towers are used to dissipate the recovered waste heat so as to eliminate the problems of thermal pollution.

(3) Artificial Lake:

Artificial lakes are man-made bodies of water which offer possible alternative to once through cooling. The heated effluents may be discharged into the lake at one end and the water for cooling purposes may be withdrawn from the other end. The heat is eventually dissipated through evaporation.

Control Measures for nuclear power plants.

a. Laboratory generated nuclear wastes should be disposed off safely and scientifically.

b. Nuclear power plants should be located in areas after careful study of the geology of the area, tectonic activity and meeting other established conditions.

c. Appropriate protection against occupational exposure.

d. Leakage of radioactive elements from nuclear reactors, careless use of radioactive elements as fuel and careless handling of radioactive isotopes must be prevented.

e. Safety measure against accidental release of radioactive elements must be ensured in nuclear plants.

f. Unless absolutely necessary, one should not frequently go for diagnosis by x-rays.

g. Regular monitoring of the presence of radioactive substance in high risk area should be ensured.