UNIT-I - COAL BASED THERMAL POWER PLANTS
PART-A

1. Why thermal power plants are not suitable for supplying fluctuating loads?

Thermal power plants are not suitable for supplying fluctuating loads because any change in load demand requires the corresponding change in the output energy. In thermal plants, the input energy is produced by burning the coal. So, there is always a large time lapse between the change in energy output & input which is not desirable. Therefore, such power stations are used only as base load stations & it supplies the constant power.

2. Define the overall efficiency of steam power plant?

Overall efficiency is defined as the combined efficiency of boiler, steam turbine, condenser & pump.

$\eta_{Overall} = \eta_{boiler} \times \eta_{turbine} \times \eta_{condenser} \times \eta_{pump}$

3. Enumerate the energy losses in steam turbines.

1. Losses in regulating valves 2. Losses due to steam friction 3. Losses due to mechanical friction 4. Losses due to leakage 5. Residual velocity losses 6. Carry over losses 7. Losses due to wetness of steam 8. Losses due to radiation

4. What is the fundamental difference between the operation of impulse and reaction turbines?

S.No	**Impulse turbine**	**Reaction turbine**
1	It consist of nozzles & moving blades	It consist of fixed blades & moving blades
2	Pressure occurs only in nozzles but not in moving blades	Pressure occurs in fixed as well as moving blades
3	Steam strikes the blade with kinetic energy	Steam passes over the moving blades with pressure & kinetic energy
4	It has constant blade channel area	It has varying blade channel area
5	Due to more pressure drop per blade , the number stages required is less	The number stages required is more

5. What is purpose of condenser?

- The condenser condenses the steam in to water.
- It maintains the low back pressure on the exhaust side of the steam turbine.
- It supplies the feed water as the condensed steam to the boiler.

6. Define draught, what is the use of draught in thermal power plants?

Draught is defined as a small pressure difference required between the fuel bed (furnace) and outside air is to maintain constant flow of air and to discharge the gases through chimney to the atmosphere. The uses are 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.

7. What are the requirements of a modern surface condenser?

i) The steam should be evenly distributed over the whole cooling surface of the condenser with minimum pressure loss.

ii) The deposition of dirt on the outer surface of the tubes should be prevented. it is achieved by passing the cooling water through tubes & allowing the steam to flow over tubes.

iii) There should be no under cooling of condensate

iv) There should be no air leakage in to the condenser because it destroys the vacuum in condenser.

8. What are the types of Fluidized bed boilers?

(i) Atmospheric Fluidized bed boilers, (ii) Pressurized Fluidized bed boilers.

9. Write about artificial draught?

In modem power plants, the draught should be flexible to meet the fluctuating loads and it should be independent of atmospheric conditions. To achieve this, the aid of draft fans becomes must and by employing the draft fans, the height of the chimney would be reduced.

10. Write about forced draught system? (Nov/Dec 2014)

In this system, the blower (forced draft fan) is located at the base of the boiler near the grate. Air is forced to the furnace by forced fan and the flue gases are forced to chimney through economiser and air pre-heater.

11. What are the advantages and disadvantages of forced draught system (Nov/Dec 2014)

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

12. How the induced draught is working?

In an induced draught system, a blower (induced draft fan) is placed near (or) at the base of the chimney. The fan sucks the flue gas from the furnace creating a partial vacuum inside the furnace. Thus atmospheric air is induced to flow through the furnace to aid the combustion of fuel. The flue gases drawn by the fan passes through chimney, to the atmosphere.

13. Why the balanced draught system is preferred than other system?

In the induced draught system, when the furnace is opened for firing, the cold air enters the furnace and dilate the combustion. In the forced draught system, when the furnace is opened for firing, the high pressure air will try to blow out suddenly and furnace may stop. Hence the furnace cannot be opened for firing (q) inspection in both, systems. Balanced draught, which is a combination of induced and forced draught, is used to overcome the above stated difficulties.

14. Define Steam rate and Heat rate.

Steam rate: It is defined as the rate of steam flow required for producing unit shaft output.

Heat rate: It is defined as heat input needed to produce one unit of power output. It indicates the amount of fuel required to generate one unit of electricity

15. What is function of economizer?

The economizer is used to preheat the feed water before it goes to the boiler using the waste hot gases before going to the chimney.

16. List out the four important circuits of steam power plant?

(a) Coal & ash circuit, (b) Air & flue gas circuit, (c)Feed water & steam circuit (d)Cooling water circuit

17. What are advantages of pulverised fuel coal? (Nov/Dec 2012)

1. The layout is simple and economical, 2. It gives direct control of combustion, 3.Coal transportation system is simple , 4. Maintenance cost is less

18. How the ash handling system is classified?

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

19. What are the methods by which the efficiency of Rankine cycle can be increased?

(i)Reheating, (ii) Regeneration, (iii) Combined Reheating & Regeneration

20. State important advantages of high-pressure boilers? (Nov/Dec 2012)

- The amount of scale formation is less, since the velocity of water through pipes are more.
- All parts of the system are heated uniformly, so there is no danger of overheating.

21. What is the function of hot primary air? (May/June2013)

Coal contains moisture. Hot air form the Primary Air Fans dry the coal in the pulverisers. This makes the burning easy and efficient. This air also carries the dry coal powder from the pulverisers to the burners in the boiler furnace. In the burners the coal powder is mixed with the required amount of Combustion air and burned in the furnace.

22. What is supercritical boiler? Give two advantages. (May/June 2013, Nov/Dec 2015)

A supercritical steam generator is a type of boiler that operates at supercritical pressure, frequently used in the production of electric power. In contrast to a subcritical boiler, a supercritical steam generator operates at pressures above the critical pressure 22 MPa in which bubbles can form. Instead, liquid water immediately becomes steam. Water passes below the critical point as it does work in a high pressure turbine and enters the generator's condenser, resulting in slightly less fuel use and therefore less greenhouse gas production.

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

23. Describe the steps to be followed in in-plant coal handling of coal. (May/June 2014)

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

24. Write short notes on cogeneration.

Cogeneration or combined heat and power (CHP) is the use of a heat engine or power station to generate electricity and useful heat at the same time. Cogeneration is a thermodynamically efficient use of fuel. In separate production of electricity, some energy must be discarded as waste heat, but in cogeneration this thermal energy is put to use.

25. Define Binary cycle.

A binary vapor cycle is defined in thermodynamics as a power cycle that is a combination of two cycles, one in a high temperature region and the other in a lower temperature region.

26. What is pulveriser and why it is used? (Nov/Dec 2015)

The pulveriser is used to pulverise the coal in order to increase the surface exposure. Pulverised coal enables rapid combustion. The different types of pulverising mills are 1. Ball mill 2. Hammer mill 3. Ball and race mill.

PART B

1.Explain in detail about Rankine cycle.

Rankine cycle is the idealized cycle for steam power plants. This cycle is shown on p-v, T-v, h-s, diagram in the above figures. It consists of following processes:

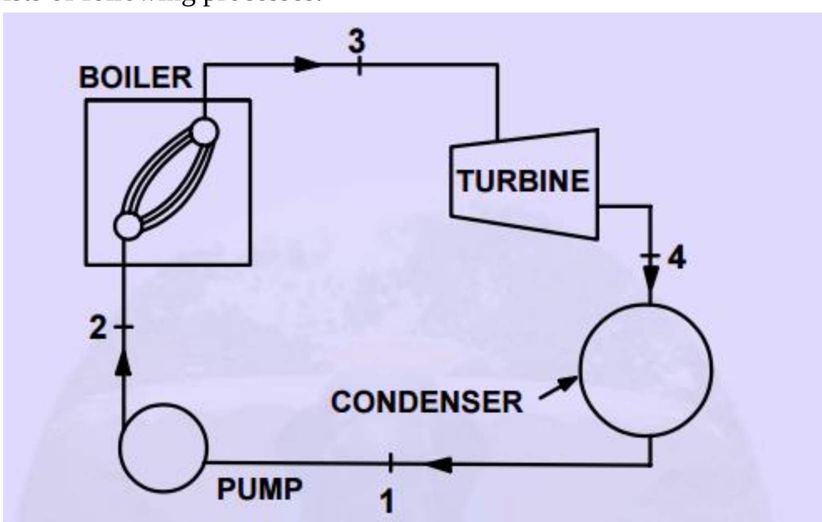


Fig. Rankine cycle

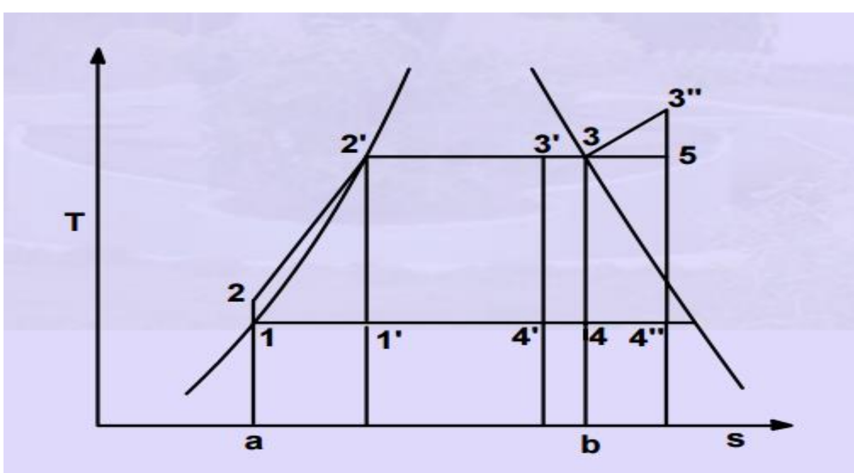


Fig. T-S Diagram of rankine cycle

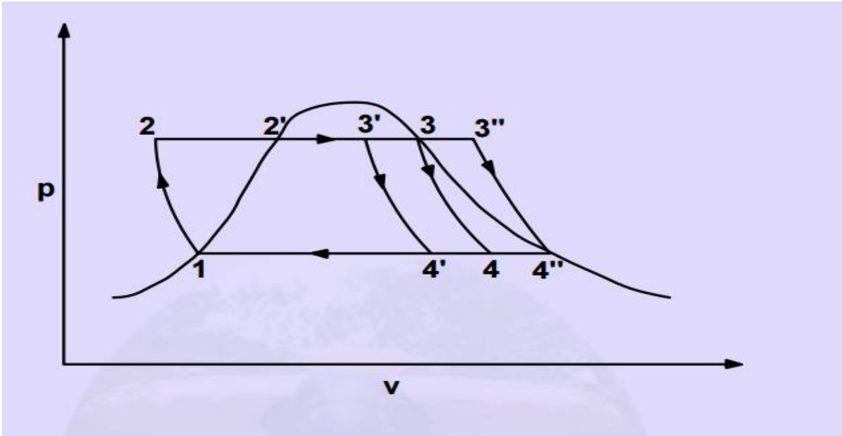


Fig. P-V Diagram of rankine cycle

Process 1-2: Water from the condenser at low pressure is pumped into the boiler at high pressure. This process is reversible adiabatic.

Process 2-3: Water is converted into steam at constant pressure by the addition of heat in the boiler. Process 3-4: Reversible adiabatic expansion of steam in the steam turbine.

Process 4-1: Constant pressure heat rejection in the condenser to convert condensate into water. The steam leaving the boiler may be dry and saturated, wet or superheated.

The corresponding T-s diagrams are 1-2-3-4-1; 1-2-3'-4'-1 or 1-2-3"-4"-1.

Thermal Efficiency of Rankine Cycle:

Consider one kg of working fluid, and applying first law to flow system to various processes with the assumption of neglecting changes in potential and kinetic energy, we can write,

$$\delta q - \delta w = dh$$

For process 2-3, $\delta w = 0$ (heat addition process), we can write,

$$(\delta q)_{boiler} = (dh)_{boiler} = (h_3 - h_2)$$

For process 3-4; $\delta q = 0$ (adiabatic process)

$$(\delta w)_{turbine} = -(dh)_{turbine} = (h_3 - h_4)$$

Similarly,

$$(\delta q)_{cond} = (h_1 - h_4)$$
$$(\delta w)_{pump} = (h_1 - h_2)$$

$$(\delta w)_{net} = (\delta w)_{turbine} + (\delta w)_{pump} = (h_3 - h_4) + (h_1 - h_2) = (h_3 - h_4) - (h_2 - h_1)$$

Now, Thermal efficiency = $\eta_{th} = \frac{\text{Net work}}{\text{heat supplied}} = \frac{(\delta w)_{net}}{(\delta q)_{boiler}}$

$$\eta_{rankine} = \eta_{th} = \frac{(h_3 - h_4) - (h_2 - h_1)}{(h_3 - h_2)} = \frac{\text{area } 122'341}{\text{area } a22'3ba}$$

The pump work $(\delta w)_{pump}$ is negligible, because specific volume of water is very small.

Therefore,

$$\eta_{rankine} = \frac{h_3 - h_4}{h_3 - h_2} = \frac{\text{area } 12'341}{\text{area } a12'3ba} \text{ (Neglecting pump work)}$$

Note that the rankine cycle has a lower efficiency compared to corresponding Carnot cycle 2'-3-4-1' with the same maximum and minimum temperatures. The reason is that the average temperature at which heat is added in the rankine cycle lies between T_2 and $T^1{}_2$ and is thus less than the constant temperature $T^1{}_2$ at which heat is added to the Carnot cycle.

2.Explain the layout of steam power plant.

The layout of steam power plant has the following circuits:

1. Fuel (Coal) and ash circuit
2. Air and flue gas circuit
3. Feed water and steam flow circuit
4. Cooling water flow circuit.

Fuel (Coal) and ash circuit

- Coal from mines is delivered by ships, rails or trucks to the power station.
- Coal received at coal yard.
- Coal is sized by crushers, breakers etc.,
- The sized coal is stored in coal storage.
- From stock yard, the coal is transferred to the boiler furnace by means of conveyors, elevators etc.,
- The coal is burnt in the boiler and ash is formed.
- Ash coming out of the furnace will be too hot, dusty and accompanied by poisonous gases.
- The ash is transferred to the ash storage.
- Generally the ash will be quenched to reduce the temperature and the dust content.

Water and Steam Circuit:

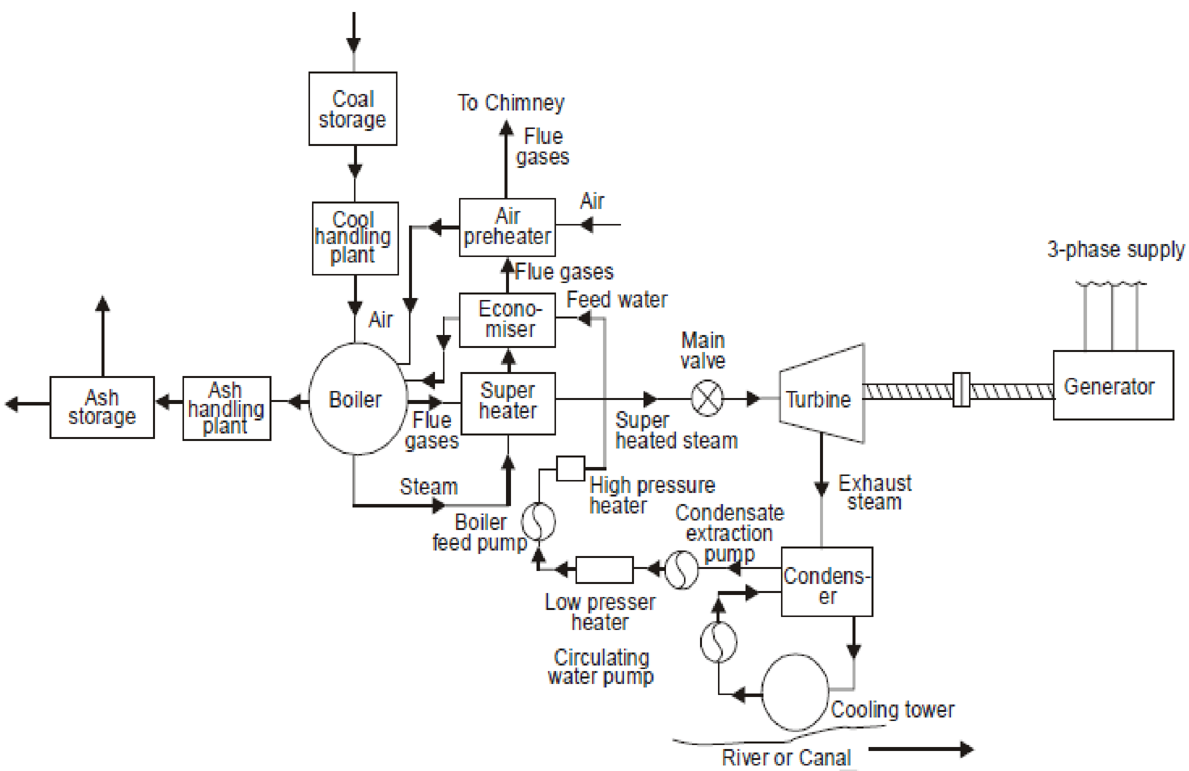
- The water is preheated by the flue gases in the economiser.
- This preheated water is then supplied to the boiler drum.
- Heat is transferred to the water by the burning of the coal.
- Due to this, water is converted into the steam.
- The steam raised in boiler is passed through a super heater.
- It is superheated by the flue gases.
- The turbine drives generator to produce electric power.
- The expanded steam is then passed through the condenser.
- In the condenser, steam is condensed into water the re circulated.

Air and Flue Gas Circuit

- Air is taken from the atmosphere by the action of FD fan.
- It is passed through an air pre heater
- The air is preheated by the flue gases in the pre heater.
- This preheated air is supplied to the furnace to aid the combustion of fuel.
- Due to the combustion of fuel the flue gases are formed.
- The flue gases from the furnace pass over the boiler tubes and superheater tubes.
- Then the flue gases pass through economiser to heat the feed water.
- After that it passes through a dust collector.
- It is then exhausted to atmosphere through chimney.

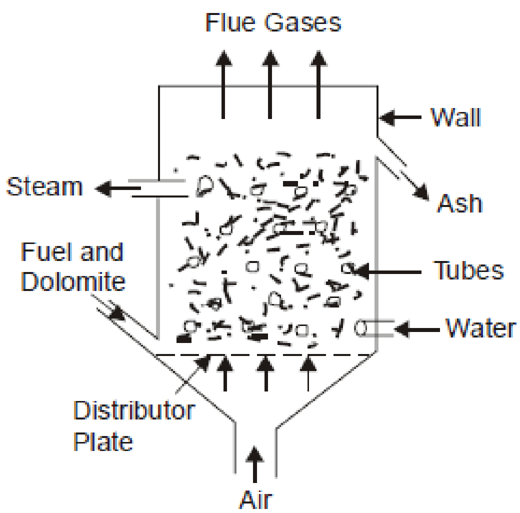
Cooling Water Circuit

- The exhaust steam from the turbine is condensed in the condenser.
- In the condenser, the cold water is circulated to condense the steam into water.
- The steam is condensed by loosing its latent heat to the circulating the cold water.
- Hence the cold water gets 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 cold water is again circulated through the pump, condenser and the cooling
- Some amount of water may be lost during circulation.
- Hence make up water is added to the pond by means of a pump



3.what is meant by Fluidized Bed Combustion(FBC)? Explain in detail about various FBC systems?

Burning of pulverised coal has some problems such as particle size of coal used in pulverized firing is limited to 70-100 microns, the pulverised fuel fired furnances designed to burn a particular can not be used other type of coal with same efficiency, the generation of high temp. about (1650 C) in the furnace creates number of problems like slag formation on super heater, evaporation of alkali metals in ash and its deposition on heat transfer surfaces, formation of SO2 and NOX in large amount. Fluidised Bed combustion system can burn any fuel including low grade coals (even containing 70% ash), oil, gas or municipal waste. Improved desulphurisation and low NOX emission are its main characteristics. Fig. 4.41 shows basic principle of Fluidised bed combustion (FBC) system. The fuel and inert material dolomite are fed on a distribution plate and air is supplied from the bottom of distribution plate. The air is supplied at high velocity so that solid feed material remains in suspension condition during burning. The heat produced is used to heat water flowing through the tube and convert water into steam: During burning SO2 formed is absorbed by the dolomite and thus prevents its escape with the exhaust gases. The molten slag is tapped from the top surface of the bed. The bed temperature is nearly 800-900’C which is ideal for sulphur retention addition of limestone or dolomite to the bed brings down SO2 emission level to about 15% of that in conventional firing methods.



The amount of NOX is produced is also reduced because of low temperature of bed and low excess air as compared to pulverized fuel firing. The inert material should be resistant to heat and disintegration and should have similar density as that of coal. Limestone, or dolomite, fused alumina, sintered ash are commonly used as inert materials.

Various advantages of FBC system are as follows:

(*i*) FBC system can use any type of low grade fuel including municipal wastes and therefore is a cheaper method of power generation.

(*ii*) It is easier to control the amount of SO2 and NOX, formed during burning. Low emission of SO2 and NOX.will help in controlling the undesirable effects of SO2 and NOX. during combustion.

SO2 emission is nearly 15% of that in conventional firing methods.

(*iii*) There is a saving of about 10% in operating cost and 15% in the capital cost of the power plant.

(*iv*) The size of coal used has pronounced effect on the operation and performance of FBC system. The particle size preferred is 6 to 13 mm but even 50 mm size coal can also be used in this system.

TYPES OF FBC SYSTEMS

FBC systems are of following types

(*i*)Atmospheric FBC system

(*a*) Over feed system

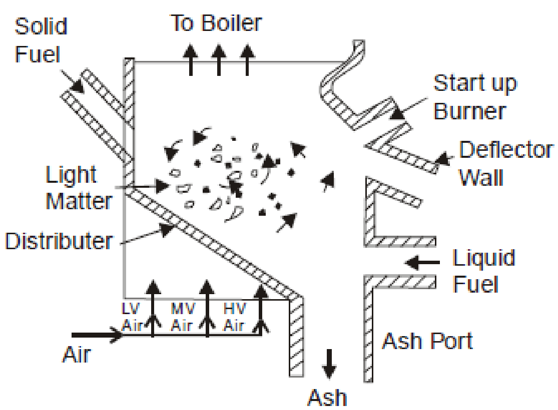
(*b*) Under feed system.

In this system the pressure inside the bed is atmospheric.

Fig. shows commercial circulation FBC system. The solid fuel is made to enter the furnace from the side of walls. The Low Velocity (LV), Medium Velocity (MV) and High Velocity (HV) air is supplied at different points along the sloping surface of the distribution ash is collected from the ash
port. The burning is efficient because of high lateral turbulence.

(*ii*) **Pressurised FBC system.** In this system pressurized air is used for fluidisation and combustion.

This system the following advantages: (*a*) High burning rates. (*b*) Improved desulphurisation
and low NO, emission. (*c*) Considerable reduction in cost.



4.List out the steps to be followed in coal handling systems.

Coal delivery equipment is one of the major components of plant cost. The various steps involved in coal handling are as follows : (Fig)

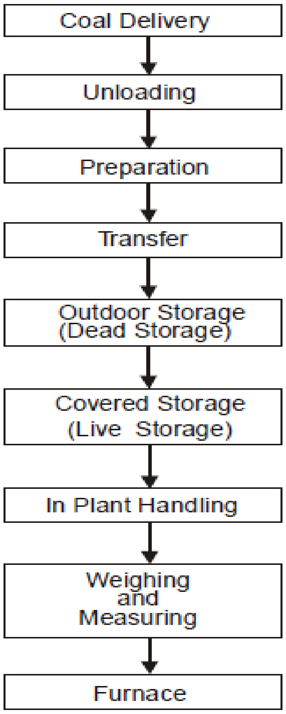
(*i*) Coal delivery (*ii*) Unloading

(*iii*) Preparation (*iv*) Transfer

(*v*) Outdoor storage (*vi*) Covered storage

(*vii*) In plant handling (*viii*) Weighing and measuring

(*ix*) Feeding the coal into furnace



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

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

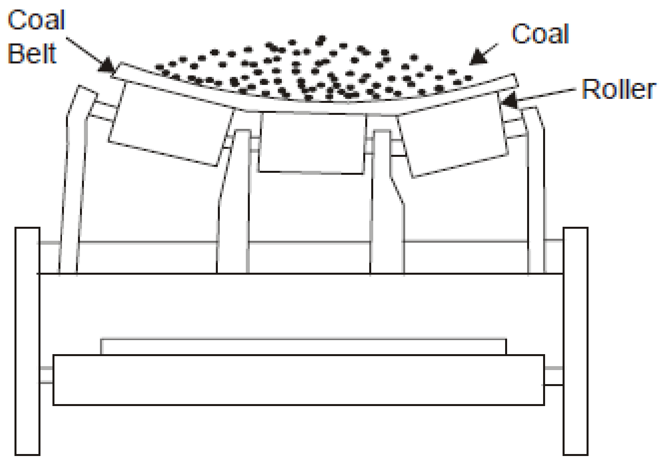
(*iii*) **Preparation.** When the coal delivered is in the form of big lumps and it is not of proper size, the preparation (sizing) of coal can be achieved by crushers, breakers, sizers driers and magnetic separators.

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

1. Belt conveyors. 2. Screw conveyors.

3. Bucket elevators. 4. Grab bucket elevators.

5. Skip hoists. 6. Flight conveyor.



1. Belt conveyor. Fig. 4.3 shows a belt conveyor. It consists of an endless belt. moving over apair of end drums (rollers). At some distance a supporting roller is provided at the center. The belt is made, up of rubber or canvas. Belt conveyor is suitable for the transfer of coal over long distances. It is used in medium and large power plants. The initial cost of the system is not high and power consumption is also low. The inclination at which coal can be successfully elevated by belt conveyor is about 20.Average speed of belt conveyors varies between 200-300 r.p.m. This conveyor is preferred than other types.

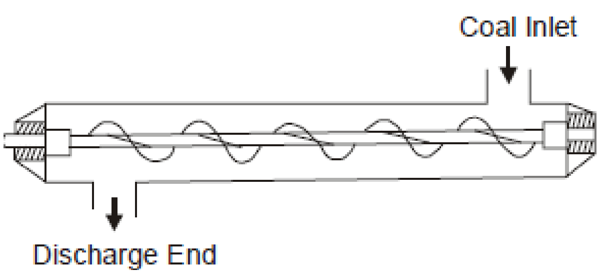


Fig. 4.4. Screw Conveyor.

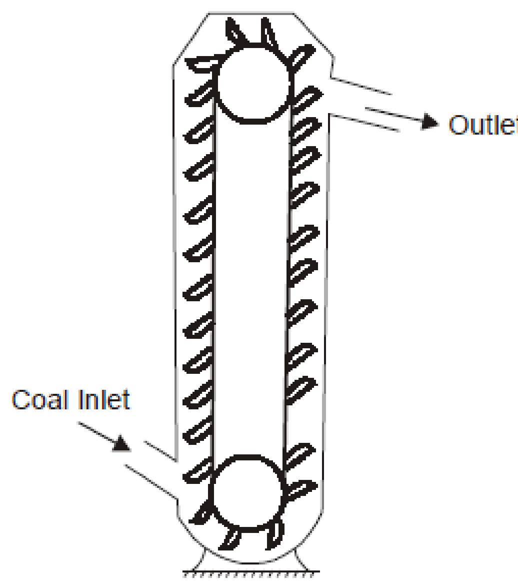


Fig. 4.5. Bucket Elevator.

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.

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

4. Grab bucket elevator. It lifts and transfers coal on a single rail or track from one point to the other. The coal lifted by grab buckets is transferred to overhead bunker or storage. This system requires less power for operation and requires minimum maintenance.

The grab bucket conveyor can be used with crane or tower as shown in Fig. 4.6. Although the initial cost of this system is high but operating cost is less.

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

6. Flight conveyor. It consists of one or two strands of chain to which steel scraper or flights are attached'. which scrap the coal through a trough having identical shape. This coal is discharged in the bottom of trough. It is low in first cost but has large energy consumption. There is considerable wear. Skip hoist and bucket elevators lift the coal vertically while Belts and flight conveyors move the coal horizontally or on inclines.

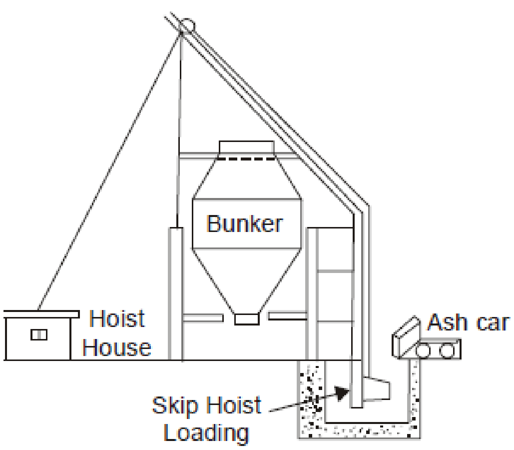


Fig. 4.7. Skip Hoist.

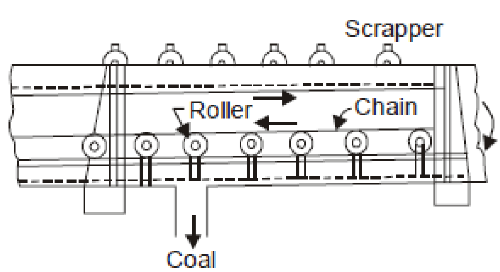


Fig. 4.8. Flight Conveyor.

Fig. shows a flight conveyor. Flight conveyors possess the following **advantages.**

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

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

(*iii*) They have a rugged construction.

(*iv*) They need little operational care.

Disadvantages. Various disadvantages of flight conveyors are as follows :

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

(*ii*) Power consumption is more.

(*iii*) Maintenance cost is high.

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

(*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. Also when the prices are low, the coal can be purchased and stored for future use. The amount of coal to be stored depends on the availability of space for storage, transportation facilities, the amount of coal that will whether away and nearness to coal mines of the power station.

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

The coal received at the power station is stored in dead storage in the form of piles laid directly on the ground.

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

The coal is stored by the following methods :

(*i*) *Stocking the coal in heats.* The coal is piled on the ground up to 10-12 m height. The pile top should be given a slope in the direction in which the rain may be drained off.

The sealing of stored pile is desirable in order to avoid the oxidation of coal after packing an air tight layer of coal. Asphalt, fine coal dust and bituminous coating are the materials commonly used for this purpose.

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

(*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 weighters use a pneumatic transmitter weight head and the corresponding air pressure determined by the load applied. The electronic weighing machines make use of load cells that produce voltage signals proportional to the load applied. The important factor considered in selecting fuel handling systems are as follows:

(*i*) Plant flue rate

(*ii*) Plant location in respect to fuel shipping

(*iii*) Storage area available.

5.Describe the different types of overfeed stockers and discuss merits and demerits of each other.

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

The various advantages of stoker firing are as follows :

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

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

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

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

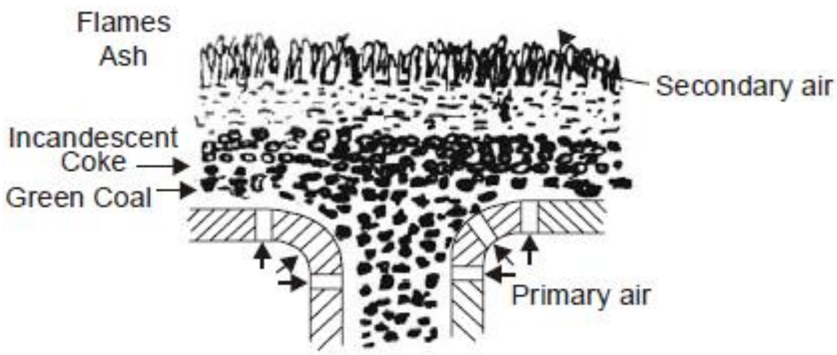
(*v*) Stokers save coal and increase the efficiency of coal firing. The main disadvantages of stokers are their more costs of operation and repairing resulting from high furnace temperatures.

Principles of Stokers. The working of various types of stokers is based on the following two

1. Overfeed Principle. According to this principle (Fig. 4.13) the primary air enters the grate from the bottom. The air while moving through the grate openings gets heated up and air while moving through the grate openings gets heated up and the grate is cooled.

The hot air that moves through a layer of ash and picks up additional energy. The air then passes through a layer of incandescent coke where oxygen reacts with coke to form-C02 and water vapours accompanying the air react with incandescent coke to form CO_2, CO and free H_2. The gases leaving the surface of fuel bed contain volatile matter of raw fuel and gases like CO_2, CO, H_2, N_2 and H_2O. Then additional air known as secondary air is supplied to burn the combustible gases. The combustion gases entering the boiler consist of N_2, CO_2, O_2 and H_2O and also CO if the combustion is not complete.

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



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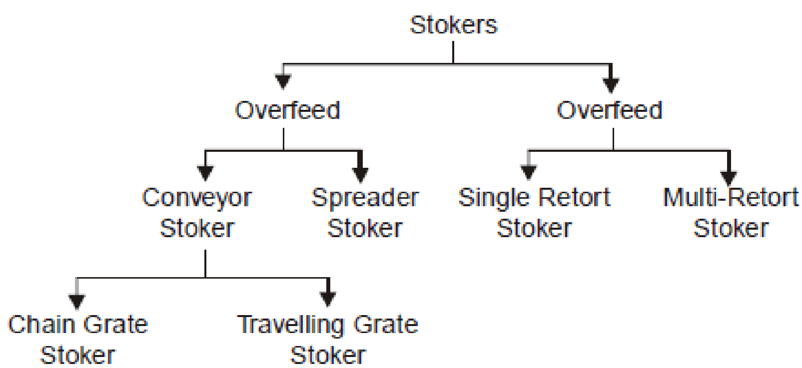
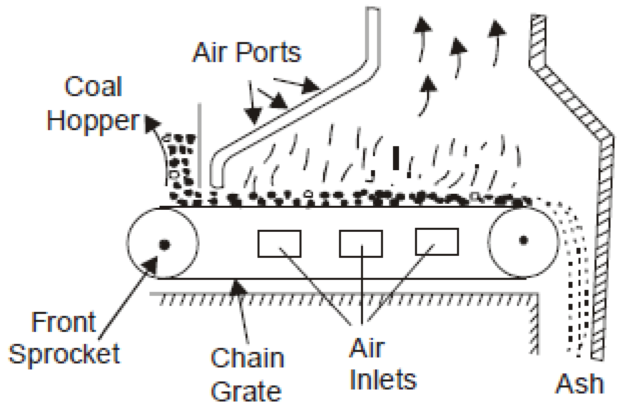
Then it passes through the incandescent coke where reactions similar to overfeed system take place. The gases produced then pass through a layer of ash. The secondary air is supplied to burn the combustible gases. Underfeed principle is suitable for burning the semi-bituminous and bituminous coals.

Types of Stokers. The various types of stokers are as follows:

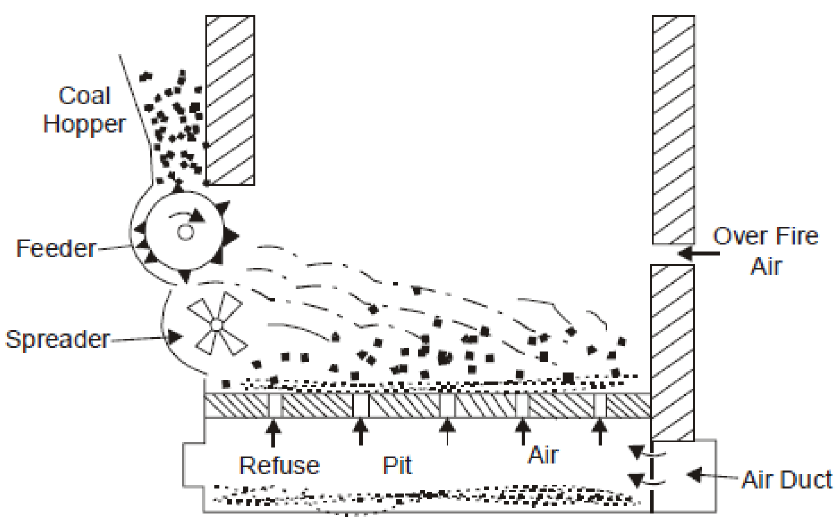


The chain travels over two sprocket wheels, one at the front and one at the rear of furnace. The traveling chain receives coal at its front end through a hopper and carries it into the furnace. The ash is tipped from the rear end of chain. The speed of grate (chain) can be adjusted to suit the firing condition. The air required for combustion enters through the air inlets situated below the grate. Stokers are used for burning non-coking free burning high volatile high ash coals. Although initial cost of this stoker ishigh but operation and maintenance cost is low



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

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



(*ii*) **Spreader Stoker.** A spreader stoker is shown in Fig. 4.17. In this stoker the coal from the hopper is fed on to a feeder which measures the coal in accordance to the requirements. Feeder is a rotating drum fitted with blades. Feeders can be reciprocating rams, endless belts, spiral worms etc. From the feeder the coal drops on to spreader distributor which spread the coal over the furnace. The spreader system should distribute the coal evenly over the entire grate area. The spreader speed depends on the size of coal.

Advantages

The various advantages of spreader stoker are as follows :

1. Its operation cost is low.

2. A wide variety of coal can be burnt easily by this stoker.

3. A thin fuel bed on the grate is helpful in meeting the fluctuating loads.

4. Ash under the fire is cooled by the incoming air and this minimizes clinkering.

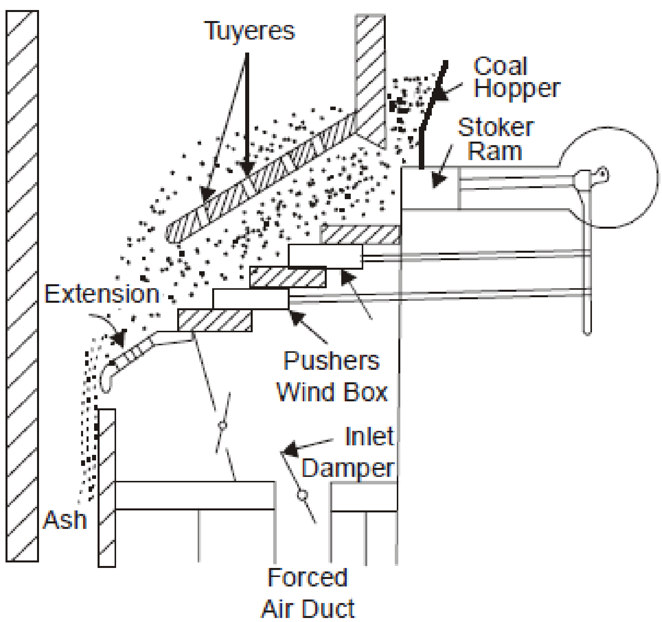
5. The fuel burns rapidly and there is little coking with coking fuels.

Disadvantages

1. The spreader does not work satisfactorily with varying size of coal.

2. In this stoker the coal burns in suspension and due to this fly ash is discharged with flue gases which requires an efficient dust collecting equipment.

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



6.Discuss about ash handling equipments and types of dust collectors.

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

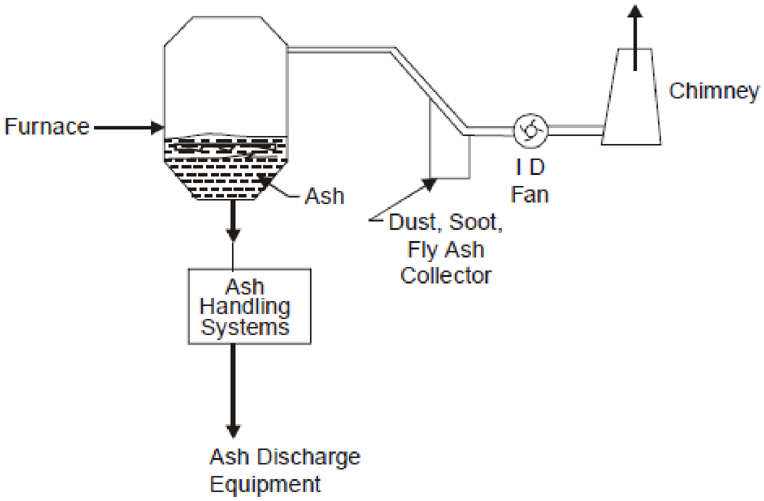


Fig. 4.33. Ash Handling and Dust Collections System.

(1) Capital investment, operating and maintenance charges of the equipment should be low.

(2) It should be able to handle large quantities of ash.

(3) Clinkers, soot, dust etc. create troubles, the equipment should be able to handle them smoothly.

(4) The equipment used should remove the ash from the furnace, load it to the conveying system to deliver the ash to a dumping site or storage and finally it should have means to dispose of the stored ash.

(5) The equipment should be corrosion and wear resistant. Fig. shows a general layout of ash handling and dust collection system. 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. It is generally used in large power plants. Hydraulic system is of two types namely low pressure hydraulic system used for continuous removal of ash and high pressure system which is used for intermittent ash disposal. Fig. shows hydraulic system.

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

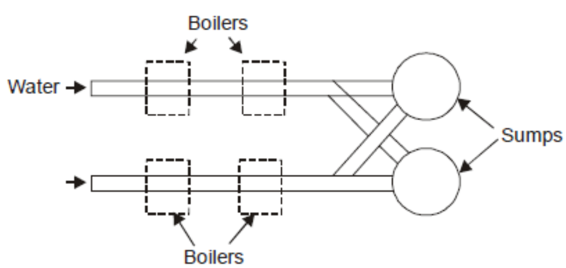


Fig. 4.34. Hydraulic System.

(*ii*) **Water Jetting.** Water jetting of ash is shown in Fig. 4.35. 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 Sluice Ways and Ash Sump System.** This system shown diagrammatically in Fig.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. A.F.N represents ash feeding nozzle and S.B.N. represents sub way booster nozzle and D.A. means draining apron.

(*iv*) **Pneumatic system.** In this system (Fig. 4.37) 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.

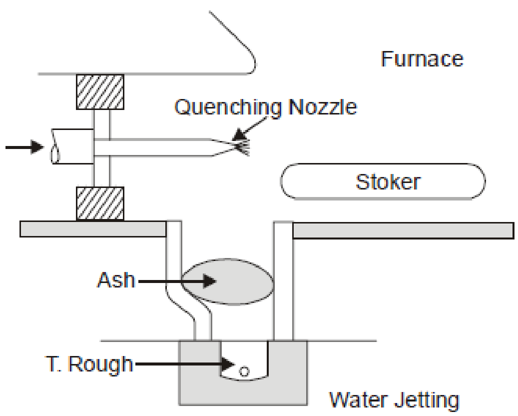


Fig. 4.35. Water Jetting of Ash.

POWER PLANI

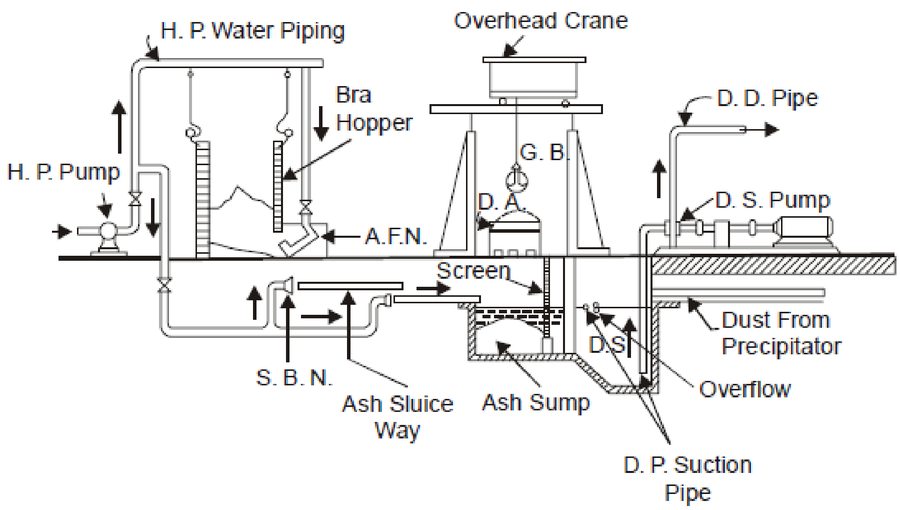


Fig. 4.36. Ash Sump System.

v) **Mechanical ash handling system.** Fig. 4.38 shows a mechanical ash handling system. In this system ash cooled by water seal falls on the belt conveyor and is carried out continuously to the bunker. The ash is then removed to the dumping site from the ash bunker with the help of trucks.

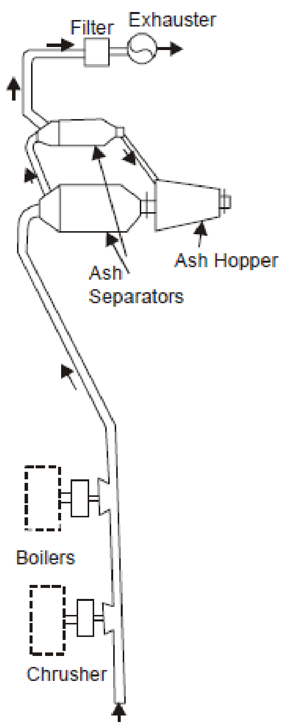


Fig. 4.37. Pneumatic System.

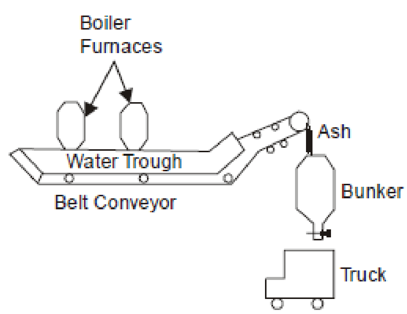


Fig. 4.38. Mechanical Ash Handling.

The various types of dust collectors are as follows :

1. Mechanical dust collectors.
2. Electrical dust collectors.

Mechanical dust collectors. Mechanical dust collectors are sub-divided into wet and dry types. In wet type collectors also known as scrubbers water sprays are used to wash dust from the air. The basic principles of mechanical dust collectors are shown in Fig. 4.38. As shown in Fig.by increasing the cross-sectional area of duct through which dust laden gases are passing, the velocity of gases is reduced and causes heavier dust particles to fall down. Changing the direction of flow of flue gases causes the heavier particles of settle out. Sometime baffles are provided as shown in Fig to separate the heavier particles. Mechanical dust collectors may be wet type or dry type. Wet type dust collectors called scrubbers make use of water sprays to wash the dust from flue gases It has two sets of electrodes, insulated from each other that maintain an electrostatic field between them at high voltage. The flue gases are made to pass between these two sets of electrodes. The electric field ionises the dust particle; that pass through it attracting them to the electrode of opposite charge. The other electrode is maintained at a negative potential of 30,000 to 60,000 volts. The dust particles are removed from the collecting electrode by rapping the electrode periodically.

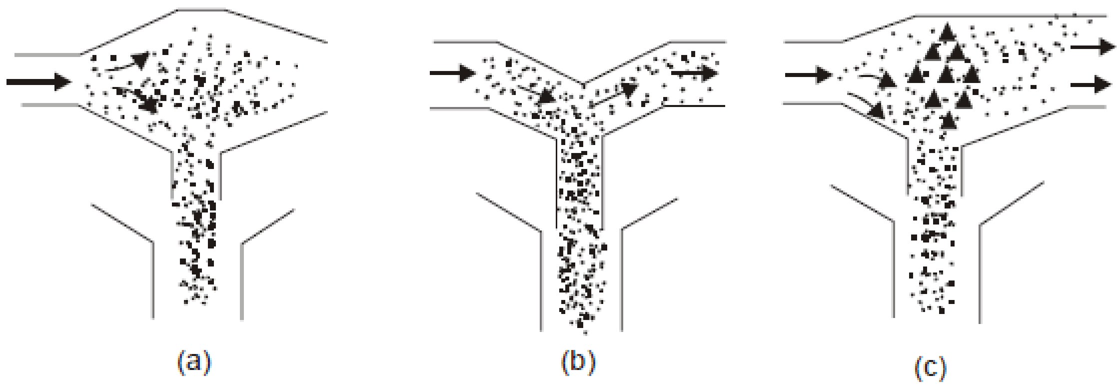


Fig. 4.39. Mechanical Dust Collector.

ELECTROSTATIC PRECIPITATOR

The electrostatic precipitator is costly but has low maintenance cost and is frequently employed with pulverised coal fired power stations for its effectiveness on very fine ash particles and is superior to that of any other type.Depending on the type of fuel and the power of bailer the ash collection in industrial boilers and thermal power stations can be effected by mechanical ash collectors, fly ash scrubbers and electrostatic precipitators.

For fly ash scrubbers of large importance is the content of free lime (CaO) in the ash. With a high concentration of CaO the ash can be cemented and impair the operation of a scrubber. The efficiency of operation of gas cleaning devices depends largely on the physico-chemical properties of the collected ash and of the entering waste gases.

Following are the principal characteristics of the fly ash:

(*i*) Density

(*ii*) Dispersity (Particle size)

(*iii*) Electric resistance (For electrostatic precipitators)

(*iv*) Coalescence of ash particles.

Due to increasing boiler size and low sulphur high ash content coal the problem of collecting fly ash is becoming increasingly complex. Fly ash can range from very fine to very coarse size depending on the source. Particles colour varies from light tan to grey to black. Tan colour indicates presence of ion oxide while dark shades indicate presence of unburnt carbon. Fly ash particles size varies between 1. micron (l μ) to 300 μ. Fly ash concentration in flue gases depends upon mainly the following factors :

(*i*) Coal composition.

(*ii*) Boiler design and capacity.

Percentage of ash in coal directly contributes to fly ash emission while boiler design and operation determine the percentage retained in the furnace as bottom ash and fly ash carried away by flue gas. Fly ash concentration widely varies around 20-90 g/mm3 depending on coal and boiler design. Fly ash particle size distribution depends primarily on the type of boiler such as pulverised coal fired boiler typically produces coarser particles then cyclone type boilers. Electrostatic precipitator (ESP) is quite commonly used for removal of fly ash from flue gases..

7.Explain the various types of boilers. And give their advantages

This boiler consists of a cylindrical shell with its crown having a spherical shape. The furnace is also hemispherical in shape. The grate is also placed at the bottom of the furnace and the ash-pit is located below the grate. The coal is fed into the grate through the fire door and ash formed is collected in the ash-pit located just below the grate and it is removed manually. The furnace and the combustion chamber are connected through a pipe. The back of the combustion chamber is lined with firebricks. The hot gases from the combustion chamber flow through the nest of horizontal fire tubes (generally 6.25 cm in external diameter and 165 to 170 in number). The passing through the fire tubes transfers a large portion of the heat to the water by convection. The flue gases coming out of fire tubes are finally discharged to the atmosphere through chimney

The spherical top and spherical shape of firebox are the special features of this boiler. These shapes require least material for the volume. The hemi spherical crown of the boiler shell gives maximum strength to withstand the pressure of the steam inside the boiler. The hemi-spherical crown of the fire box is advantageous for resisting intense heat. This shape is also advantageous for the absorption of the radiant heat from the furnace. Coal or oil can be used as fuel in this boiler. If oil is used as fuel, no grate is provided but the bottom of the furnace is lined with firebricks. Oil burners are fitted at a suitable location below the fire door. A manhole near the top of the crown of shell is provided for cleaning. In addition to this, a number of hand-holes are provided around the outer shell for cleaning purposes. The smoke box is provided with doors for cleaning of the interior of the fire tubes. The airflow through the grate is caused by means of the draught produced by the chimney. A damper is placed inside the chimney (not shown) to control the discharge of hot gases from the chimney and thereby the supply of air to the grate is controlled. The chimney may also be provided with a steam nozzle (not shown; to discharge the flue gases faster through the chimney. The steam to the nozzle is supplied from the boiler. The outstanding features of this boiler are listed below:

1. It is very compact and requires minimum floor area.
2. Any type of fuel can be used with this boiler.
3. It is well suited for small capacity requirements.
4. It gives about 70% thermal efficiency with coal firing and about 75% with oil firing.
5. The ratio of grate area to the heating surface area varies from 10: 1 to 25: 1.

It is provided with all required mountings. The function of each is briefly described below:

1. Pressure Gauge. This indicates the pressure of the steam in the boiler.

2. Water Level Indicator. This indicates the water level in the boiler The water level in the boiler should not fall below a particular level otherwise the boiler will be overheated and the tubes may burn out.

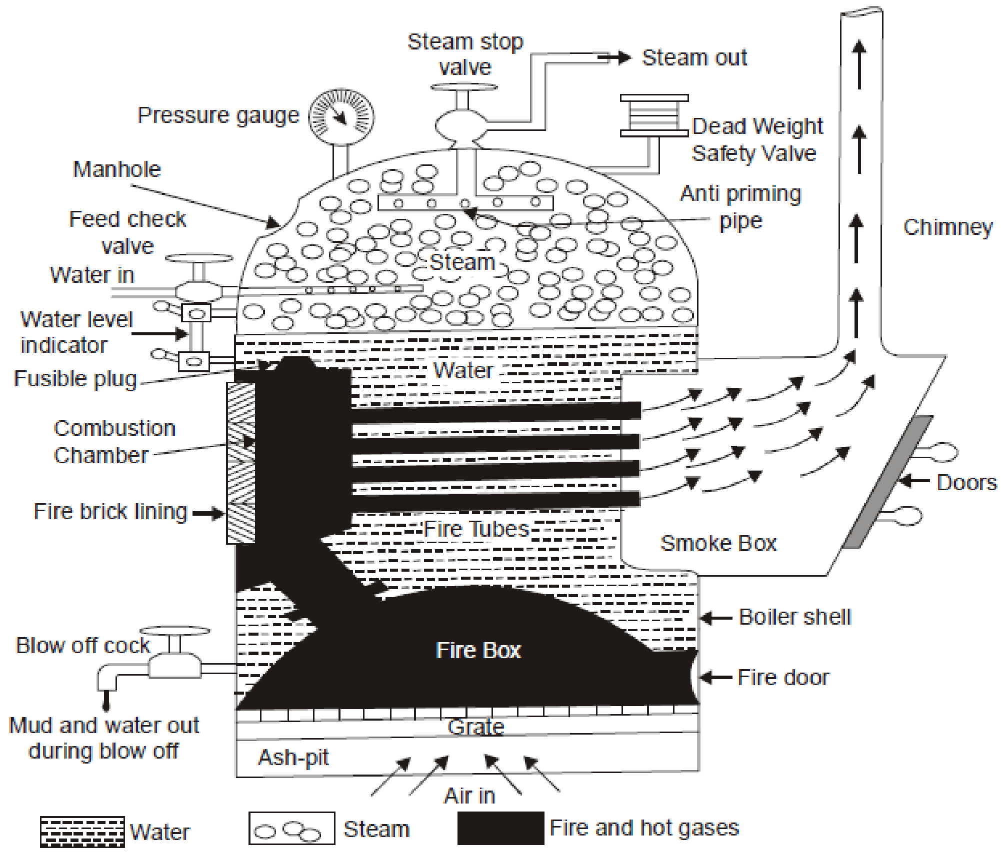
3. Safety Valve. The function of the safety valve is to prevent the increase of steam pressure in the holler above its design pressure. When the pressure increases above design pressure, the valve opens and discharges the steam to the atmosphere. When this pressure falls just below design pressure, the valve closes automatically. Usually the valve is spring controlled.

4. Fusible Plug. If the water level in the boiler falls below a predetermined level, the boiler shell and tubes will be overheated. And if it is continued, the tubes may burn, as the water cover will be removed. It can he prevented by stopping the burning of fuel on the grate. When the temperature of the shell increases above a particular level, the fusible plug, which is mounted over the grate as shown in the Fig, melts and forms an opening. The high-pressure steam pushes the remaining water through this hole on the grate and the fire is *extinguished.*

5. Blow-off Cock. The water supplied to the boiler always contains impurities like mud, sand and, salt Due to heating, these are deposited at the bottom of the boiler, and if they are not removed, they are accumulated at the bottom of the boiler and reduces its capacity and heat transfer rates. Also the salt content will goes on increasing due to evaporation of water. These deposited salts are removed with the help of blow off cock. The blow-off cock is located at the bottom of the boiler as shown in the figure and is operated only when the boiler is running. When the blow-off cock is opened during the running of the boiler, the high-pressure steam pushes the water and the collected material at the bottom is blown out. Blowing some water out also reduces the concentration of the salt. The blow-off cock is operated after every 5 to 6 hours of working for few minutes. This keeps the boiler clean.

6. Steam Stop Valve. It regulates the flow of steam supply outside. The steam from the boiler first enters into an ant-priming pipe where most of the water particles associated with steam are removed.

7. Feed Check Valve. The high pressure feed water is supplied to the boiler through this valve. This valve opens towards the boiler only and feeds the water to the boiler. If the feed water pressure is less than the boiler steam pressure then this valve remains closed and prevents the back flow of steam through the valve.



lancashire boiler.

It is stationary fire tube, internally fired, horizontal, natural circulation boiler. This is a widely used boiler because of its good steaming quality and its ability to burn coal of inferior quality. These boilers have a cylindrical shell 2 m in diameters and its length varies from 8 m to 10 m. It has two large internal flue tubes having diameter between 80 cm to 100 cm in which the grate is situated. This boiler is set in brickwork forming external flue so that the external part of the shell forms part of the heating surface.The main features of the Lancashire boiler with its brickwork shelling are shown in figure. The boiler consists of a cylindrical shell and two big furnace tubes pass right through this. The brick setting forms one bottom flue and two side flues. Both the flue tubes, which carry hot gases, lay below the waterlevel as shown in the Fig. The grates are provided at the front end of the main flue tubes of the boiler and the coal is fed to the grates through the fire doors. A low firebrick bridge is provided at the end of the grate, as shown in the Fig.to prevent the flow of coal and ash particles into the interior of the furnace tubes. Otherwise, the ash and coal particles carried with gases form deposits on the interior of the tubes and prevent the heat transfer to the water. The firebrick bridge also helps in deflecting the hot gases upward to provide better heat transfer.The hot gases leaving the grate pass up to the back end of the tubes and then in the downward direction. They move through the bottom flue to the front of the boiler where they are divided into two and pass to the side flues as shown in the figure. Then they move along the two-side flues and come to the chimney as shown in the figure.

With the help of this arrangement of the flow passages of the gases, the bottom of the shell is first heated and then its sides. The heat is transferred to the water through surfaces of the two flue tubes (which remain in water) and bottom part and sides of the main shell. This arrangement increases the heating surface to a large extent. Dampers in the form of sliding doors are placed at the end of side flues to control the flow of gases. This regulates the combustion rate as well as steam generation rate. These dampers are operated by chains passing over a pulley at the front of the boiler. This boiler is fitted with usual mountings. The pressure gauge and water level indicator are provided at the front whereas steam stop valve, safety valve, low water and high steam safety valve and manhole are provided on the top of the shell. The blow-off cock is situated beneath the front portion of the boiler shell for the removal of sediments and mud. It is also used to empty the water in the boiler whenever required for inspection. The fusible plugs are mounted on the top of the main flues just over the grates as shown in the figure to prevent the overheating of boiler tubes by extinguishing the fire when the water level falls below a particular level. A low water level alarm is usually mounted in the boiler to give a warning in case the water level going below the precast value.A feed check valve with a feed pipe is fitted on the front end plate. The feed pipe projecting into the boiler is perforated so that the water is uniformly distributed into the shell.

The outstanding features of this boiler are listed below:

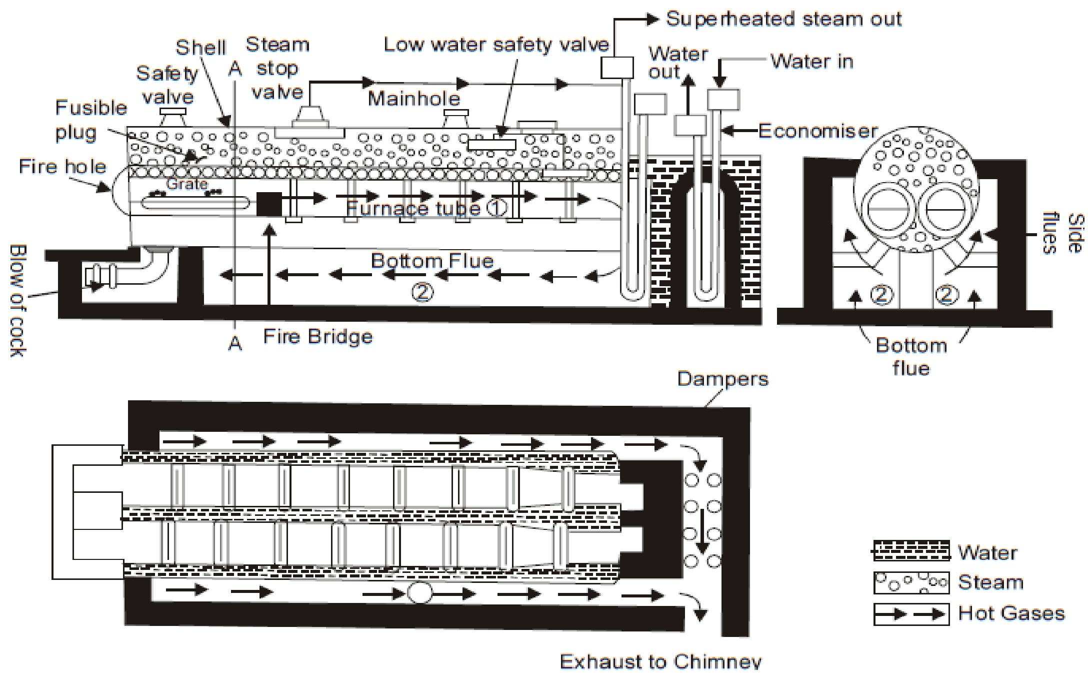
1. Its heating surface area per unit volume at the boiler is considerably large.
2. Its maintenance is easy.
3. It is suitable where a large reserve of hot water is needed. This boiler due to the large reserve capacity can easily meet load fluctuations.
4. Super-heater and economizer can be easily incorporated into the system, therefore; overall efficiency of the boiler can be considerably increased (80-85%).

The super-heater is placed at the end of the main flue tubes. The hot gases before entering the bottom flue are passed over the super-heater tubes as shown in the figure and the steam drawn through the steam stop-valve are passed through the super-heater. The steam passing through the super-heater absorbs heat from hot gases and becomes superheated.

The economizer is placed at the end of side flues before exhausting the hot gases to the chimney.

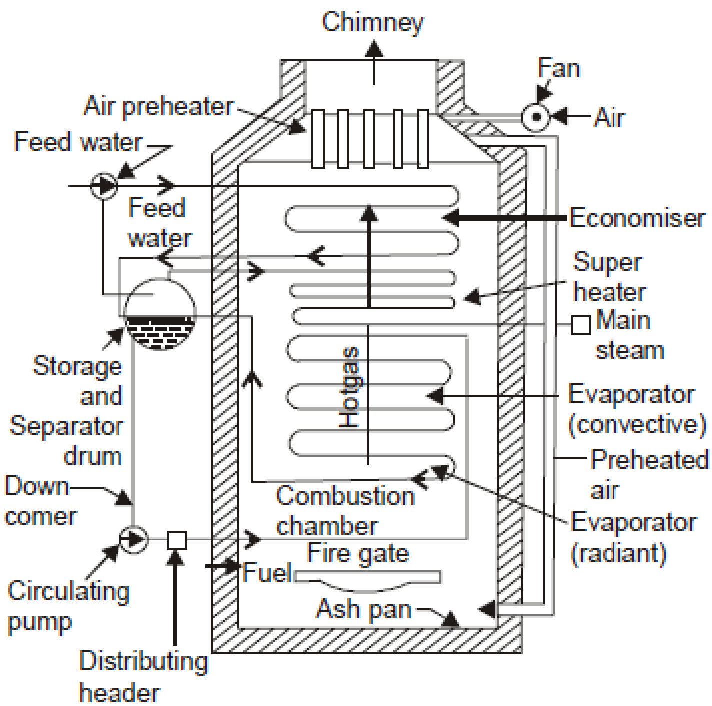
The water before being fed into the boiler through the feed check valve is passed through the economizer.

The feed water is heated by absorbing the heat from the exhaust gases, thus leading to better boiler efficiency. Generally, a chimney is used to provide the draught.



LA MONT BOILER

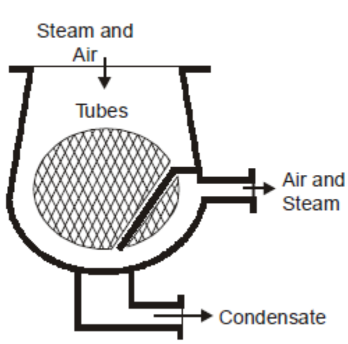
A forced circulation boiler was first introduced in 1925 by La Mont. The arrangement of water circulation and different components are shown in Fig. The feed water from hot well is supplied to a storage and separating drum (boiler) through the economizer. Most of the sensible heat is supplied to the feed water passing through the economizer. A pump circulates the water at a rate 8 to 10 times the mass of steam evaporated. This water is circulated through the evaporator tubes and the part of the vapour is separated in the separator drum. The large quantity of water circulated (10 times that of evaporation) prevents the tubes from being overheated. The centrifugal pump delivers the water to the headers at a pressure of 2.5 bar above the drum pressure. The distribution headers distribute the water through the nozzle into the evaporator. The steam separated in the boiler is further passed through the super-heater. Secure a uniform flow of feed water through each of the parallel boiler circuits a choke is fitted entrance to each circuit These boilers have been built to generate 45 to 50 tonnes of superheated steam at a pressure of 120 bar and temperature of 500°C.

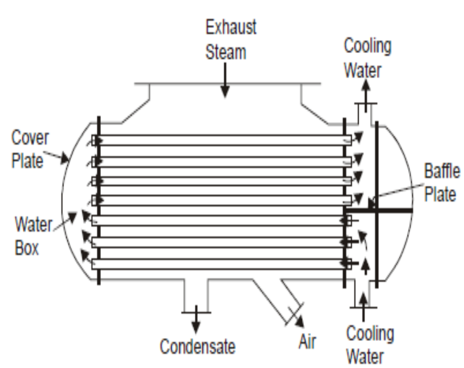


8.explain the condenser and cooling system of thermal power plant

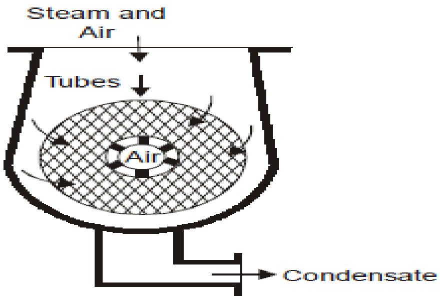
In surface condensers there is no direct contact between the steam and cooling water and the condensate can be re-used in the boiler: In such condenser even impure water can be used for cooling purpose whereas the cooling water must be pure in jet condensers. Although the capital cost and the space needed 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

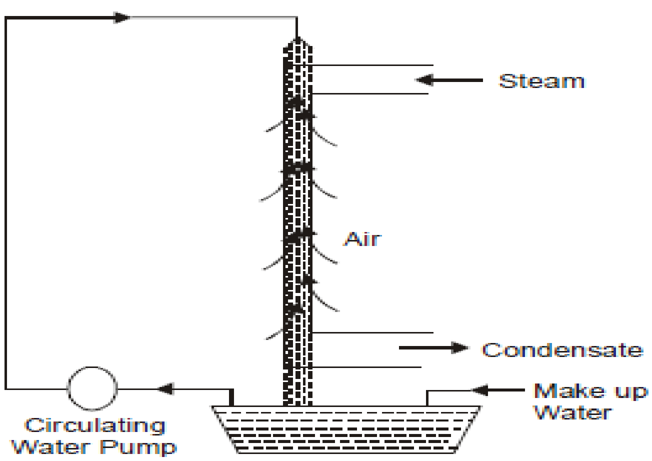




Central flow condenser. Fig. 1.11 shows a central flow condenser. In this condenser thesteam passages are all around the periphery of the shell. Air is pumped away from the centre of thecondenser. The condensate moves radially towards the centre of tube nest. Some of the exhaust steamswhile moving towards the centre meets the undercooled condensate and pre-heats it thus reducingundercooling.



(*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.



ADVANTAGES AND DISADVANTAGES OF A SURFACE CONDENSER

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 are 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.

REQUIREMENTS OF A MODERN SURFACE CONDENSER

The requirements of ideal surface condenser used for power plants are as follows:

1. The steam entering the condenser should be evenly distributed over the whole cooling surface of the condenser vessel with minimum pressure loss.

2. The amount of cooling water being circulated in the condenser should be so regulated that the temperature of cooling water leaving the condenser is equivalent to saturation temperature of steam corresponding to steam pressure in the condenser.

This will help in preventing under cooling of condensate.

3. The deposition of dirt on the outer surface of tubes should be prevented.

Passing the cooling water through the tubes and allowing the steam to flow over the tubes achieve

4. There should be no air leakage into the condenser because presence of air destroys the vacuum in the condenser and thus reduces the work obtained per kg of steam. If there is leakage of air into the condenser air extraction pump should be used to remove air as rapidly as possible.

9. (a) Write pulverized coal firing?

To burn pulverized coal successfully in a furnace, two requirements must be met: (1) the existence of large quantities of very fine particles of coal, usually those that would pass a 200-mesh screen, to ensure ready ignition because of their large surface- to-volume ratios and (2) the existence of a minimum quantity of coarser particles to ensure high combustion efficiency. These larger coarse particles should contain a very small amount larger than a given size, usually that which would be retained on a 50 mesh screen, because they cause slagging and loss of combustion efficiency. Line A in Fig represents a typical range for pulverized coal. It shows about 80 percent of the coal passing a 200 mesh screen that corresponds to a 0.074 mm opening and about 99.99 percent passing a 50 mesh screen that corresponds to a 0.297 mm opening, *i.e.* only 0.1 percent larger than 0.297 mm. The size of bituminous coal that is shipped as it comes from the mine, called *run of mine coal*, is about 8 in. Oversized lumps are broken up but the coal is not screened. Other sizes are given names like *lump*, which is used in hand firing and domestic applications, *egg*, *nut*, *stoker*, and *slack*. [Anthracite coal has similar designations

Crushers. Although there are several types of commercially available coal crushers, a few stand Duty for particular uses. To prepare coal for pulverization, the *ring crusher, or granulator* Fig. and the hammer mill Fig are preferred. The coal is fed at the top and is crushed by the action of rings that pivot off center on a rotor or by swinging hammers attached to it. Adjustable screen bars determine the maximum size of the discharged coal. Wood and other foreign material is also crushed, but a trap is usually provided to collect tramp iron (metal and other hard-to-crush matter.) Ring crushers and hammer mills are used off or on plant site.

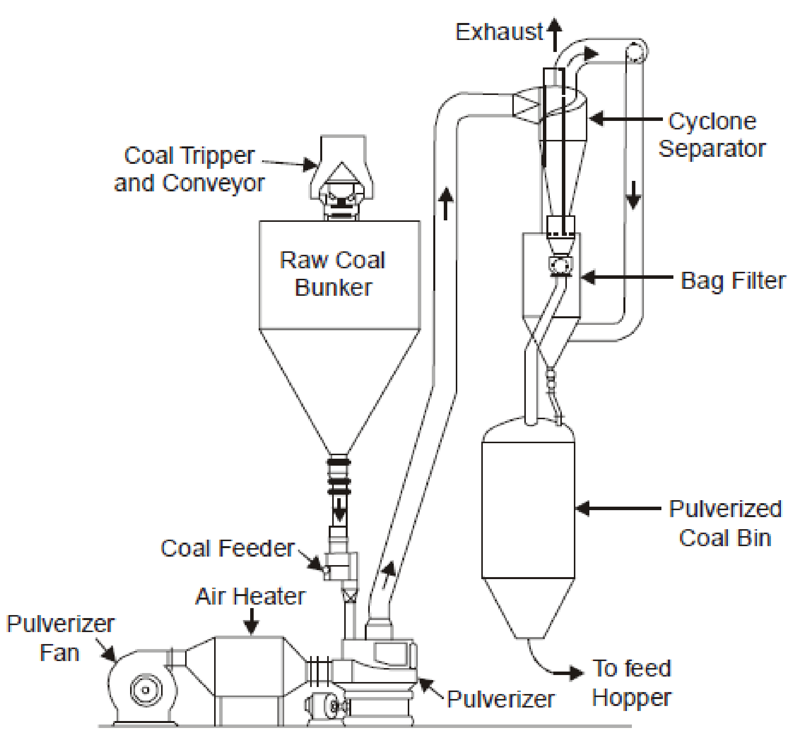
Pulverizers. The pulverizing process is composed of several stages. The first is the *feeding* system, which must automatically control the fuel-feed rate according to the boiler demand and the airrates required for drying (below) and transporting pulverized fuel to the burner (primary air). The nextstage is *drying*. One important property of coal being prepared for pulverization! is that it be dry anddusty. Because coals have varying quantities of moisture and in order that lower-rank coals can be used, *dryers* are an integral part of pulverizing equipment. Part of the air from the steam-generator air preheater,the primary air, is forced into the pulverizer at 650°F or more by the primary air fan. There it is mixedwith the coal as it is being circulated and ground.

Bin System

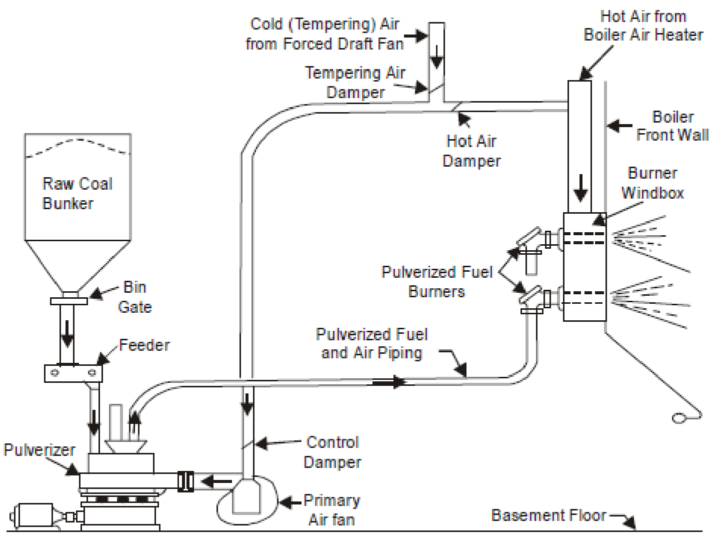
The *bin* system is essentially a batch system by which the pulverized coal is prepared away from the furnace and the resulting pulverized-coal-primary-air mixture goes to a cyclone separator and fabric bag filter that separate and exhaust the moisture laden air to the atmosphere and discharge the pulverized coal to storage bins (Fig. 7.7). From there, the coal is pneumatically conveyed through pipelines to utilization bins near the furnace for use as required. The bin system was widely used before pulverizing equipment became reliable enough for continuous steady operation. Because of the many stages of drying, storing, transporting, etc., the bin system is subject to fire hazards. Nevertheless, it is still in usein many older plants. It has, however, given way to the direct-firing system, which is used exclusively in modern plants.

Direct-firing system

It has greater simplicity and hence greater safety, lower space requirements, lower capital and operating costs, and greater plant cleanliness. As its name implies, it continuously processes the coal from the storage receiving bunker through a feeder, pulverizer, and primary-air fan, to the furnace burners (Fig. 7.7(*a*)). (Another version of this system, less used, places the fan on the outlet side of the pulverizer. Fuel flow is suited to load demand by a combination of controls on the feeder and on the primary-air fan in order to give air-fuel ratios suitable for the various steam-generator loads. The control operating range on any one direct firing pulverizer system is only about 3 to 1. Large steam generators are provided with more than one pulverizer system, each



feeding a number of burners, so that a wide control range is possible by varying the number of pulverizers and the load on each Burners A pulverized-coal *burner* is not too dissimilar to an oil burner. The latter must atomize the liquid fuel to give a large surface-to-volume ratio of fuel for proper interaction with the combustion air. A pulverized-coal burner already receives dried pulverized coal in suspension in the primary air and mixes it with the main combustion air from the steam-generator air preheater. The surface-to-volume ratio

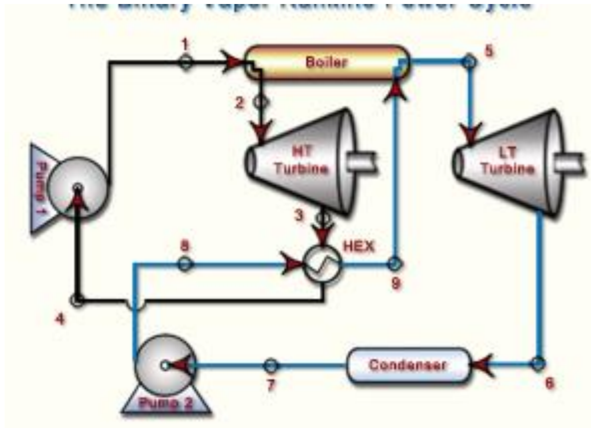


10.**Write briefly about the following topics with suitable illustration**

(a)Binary cycle

A binary cycle power plant is a type of geothermal power plant that allows cooler geothermal reservoirs to be used than with dry steamand flash steam plants. As of 2010, flash steam plants are the most common type of geothermal power generation plants in operation today, which use water at temperatures greater than 182 °C (455 K; 360 °F) that is pumped under high pressure to the generation equipment at the surface.[1] With binary cycle geothermal power plants, pumps are used to pump hot water from a geothermal well, through a heat exchanger, and the cooled water is returned to the underground reservoir. A second "working" or "binary" fluid with a lowboiling point, typically a butane or pentane hydrocarbon, is pumped at fairly high pressure (500 psi (3.4 MPa)) through the heat exchanger, where it is vaporized and then directed through a turbine. The vapor exiting the turbine is then condensed by cold air radiators or cold water and cycled back through the heat exchanger.

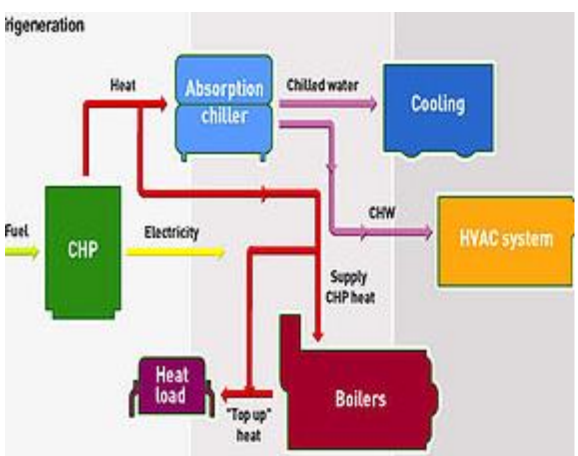
A binary vapor cycle is defined in thermodynamics as a power cycle that is a combination of two cycles, one in a high temperature region and the other in a lower temperature region.



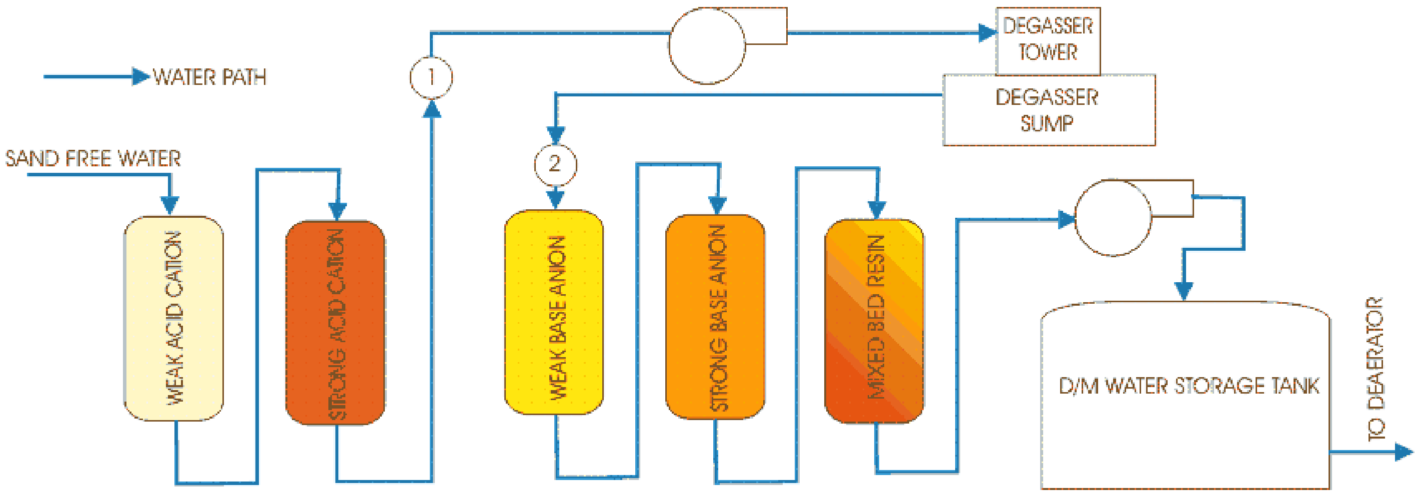
(b)Cogeneration system

Cogeneration or **combined heat and power** (**CHP**) is the use of a heat engine or power station to generate electricity and useful heat at the same time. **Trigeneration** or **combined cooling, heat and power** (**CCHP**) refers to the simultaneous generation of electricity and useful heating and cooling from the combustion of a fuel or a solar heat collector.

Cogeneration is a thermodynamically efficient use of fuel. In separate production of electricity, some energy must be discarded as waste heat, but in cogeneration this thermal energy is put to use. All thermal power plants emit heat during electricity generation, which can be released into the natural environment through cooling towers, flue gas, or by other means. In contrast, CHP captures some or all of the by-product for heating, either very close to the plant, or—especially in Scandinavia and Eastern Europe—as hot water for district heating with temperatures ranging from approximately 80 to 130 °C. This is also called **combined heat and power district heating** (**CHPDH**). Small CHP plants are an example of decentralized energy. By-product heat at moderate temperatures (100–180 °C, 212–356 °F) can also be used inabsorption refrigerators for cooling.



(c)Feed water treatment



Raw water coming from different sources contains dissolved salts and un-dissolved or suspended impurities. It is necessary to remove harmful salts dissolved into the water before feeding it to the boiler. Because-

(1) The deposition of dissolved salts and suspended impurities will form a scale on the inside wall of different heat-exchangers and thus there will create excessive pressure and thermal stress (due to uneven heat exchange across the wall of heat-exchanger) inside the heat-exchangers, which may lead to the explosion and serious hazards for boilers.

(2) The harmful dissolved salts may react with various parts of boiler through which it flows, thereby corrode the surfaces.

(3) Corrosion damage may occur to turbine blades.

Hence, **boiler feed water treatment** is very much required to remove such dissolved and suspended impurities from water before feeding it to boiler.

Arrangements for Boiler Feed Water Treatment

For continuous supply of feed water to boiler, after removing impurities, there are two types of plant generally incorporated. These are:

(1) **Demineralization plant** (**D M plant**) (2) **Reverse Osmosis plant** (**R O plant**)

UNIT II – DIESEL, GAS TURBINE AND COMBINED CYCLE POWER PLANTS

PART A

1. **Define compression ratio and cut off ratio.**
   Compression ratio: It is the ratio of volume when the piston is at BDC to the volume when the piston is at TDC.
   Cut off ratio: It is the ratio of volume after heat addition to the volume before heat addition.
2. **State the fuels used in the gas turbine power plants.**
   Natural gas, gasoline & kerosene are commonly used. Residual liquid fuels, the residue left after the profitable light fractions have been extracted from the crude have been used to some extent.
3. **What are the main units in a gas turbine power plant?**
   (a) Compressor
   (b) Combustion chamber

(c) Turbine

4. State the merits and demerits of closed cycle gas turbine over open cycle gas turbine power plant.

Merits:

(i) Efficiency is same throughout the cycle

(ii)The turbine blades do not wear away since the combustion is external

(iii)Starting of the plant is easy

(iv) Low quality fuel can be used since the combustion is external

Demerits:

(i)A separate pre cooler arrangement is necessary

(ii)The size & weight are more

(iii)Initial cost & maintenance cost are more

(iv)Combustion efficiency is less

5. What are the applications of gas turbine power plant?

a) Peak load plants: gas turbine power plants are used to supply peak loads in steam or hydro plants

b) Standby plants: They are used as Standby plants for hydro – electric plants

c) They are used in industries for driving compressors & electric generators

d) They are used in Jet planes, aircrafts & ships.

6. What is meant by combined cycle power plant?

The maximum steam temperature in a power cycle exceeds 600^0C but the pulverized coal furnace temperature is about 1300^0C. So there is a lot of energy wasted in the power plant. To increase the efficiency & to reduce the fuel consumption, the combined power cycles are introduced by superposing a high temperature power plant as a topping unit & low temperature power plant as a bottoming unit.

7. What is meant by IGCC?

IGCC is a combined cycle process fuelled by coal which is gasified by heating it in a gasifier in the presence of steam & oxygen. The resulting fuel gas is made up mainly of hydrogen & carbon monoxide & when it is cleaned of impurities & burnt in a gas turbine to produce electricity, carbon dioxide & water vapour.

8. How gas turbine power plants are classified?

i) According to the cycle of operation: Open & Closed cycle

ii) According to the process: Constant pressure & Constant volume

iii) According to the load: Peak load, Standby & Base load

iv) According to the application: Aircraft, Marine & locomotive

v) According to the fuel: Solid, liquid & gas

9. What are the applications of diesel engine power plants?

(a)It is quite suitable for mobile power generation

(b) It is used as peak load plants in combined with thermal or hydro plants

(c)) It is used as stand by plants for emergency service

10. What are the functions of lubrication system?

(a)It reduces engine friction & hence wear & tear of moving parts

(b) It removes the heat generated due to friction & keeps the engine parts cool

(c) It keeps the engine parts clean by carrying away dirt & other foreign matters

(d) It form a good seal between piston rings & cylinder walls

(e) It reduces noise of the engine

11. Mention the advantages of diesel engine power plant.

(a) diesel engine power plants are cheaper

(b) Plant layout is simple

(c) Location of the plant is near the load centre
(d) It is quick starting & easy pick up of loads
(e) It requires less quantity of water for cooling purposes
(f) Fuel handling is easier & no problem of ash disposal
(g) diesel plants operates at high overall efficiency than steam power plant
(h) skilled man power is not required
(i) It has no stand by losses

12. What are the methods used for starting a diesel engine?

(a) Starting by an auxiliary engine
(b) Use of electric motors or self starters
(c) Compressed air system

13. List out the inherent advantages of the combined power cycle.

(a) It produces low environmental effect
(b) It needs less amount of water
(c) Investment cost is low
(d) The efficiency of combined cycle plant is more that the open cycle power plant
(e) When compared with ordinary steam plants, these plants produce less smoke
(f) It is simple in operation

14. Mention a few characteristics of Diesel Power Plant.

- Diesel power plants are mainly used where high-torque is required.
- Hybrid possibilities are to combine with other power producing devices.
- Fuel & fluid characteristics mean that Diesel Power Plant could be operated with variety of different fuels depending on configuration.

15. What is Reheating and Regeneration of gas turbine? (May/June 2013)

If the dryness fraction of steam leaving the turbine is less than 0.88, then, corrosion and erosion of turbine blades occur. To avoid this situation, reheat is used. In the simple open cycle system the heat of the turbine exhaust gases goes as waste. To make use of this heat a regenerator is provided. In the regenerator the heat of the hot exhaust gases from the turbine is used to preheat the air entering the combustion chamber.

16. List the components of diesel power plant.

1. Diesel engine 2. Air intake system 3. Exhaust system 4. Fuel system
5. Cooling system 6. Lubricating system

17. What are the advantages of IGCC?

i) Higher efficiencies & lower emissions will be produced.
ii) IGCC plants use less coal than conventional power plant.
iii) Product flexibility is ensured.

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

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

19. List the various functions of fuel injection system.

1. It filters the fuel
2. Monitor the correct quantity of fuel to be injected
3. Timing of the injection process
4. Regulates the fuel supply
5. Fine atomization of fuel oil
6. Distributes the fuel evenly to all cylinders in case of multi cylinder engine

20. List the various types of diesel plants.

Based on number of strokes:

(a) Two stroke diesel engine (b) Four stroke diesel engine

Based on orientation:

(a) Horizontal diesel engine (b) Vertical diesel engine

Based on number of cylinders:
(a) single cylinder (b) Multi cylinder
Based on aspiration:
(a) naturally aspirated (b)supercharging or turbo charging.

21. List the classification of oil injection system.
(a) Common rail injection system (b) Individual pump injection system (c) Distributor system

22. What are the methods of cooling system used?
1. Air cooling 2. Liquid cooling (water is commonly used liquid)

23. List the methods adopted for circulating the water in a cooling system.
1. Thermosiphon cooling 2. Forced cooling by pump 3. Thermostat cooling 4. Pressurised water cooling 5. Evaporative cooling

24. List the various types of lubricating system used in diesel engine.
1. Mist lubricating system 2. Wet sump lubrication system 3. Dry sump lubrication system

25. List any four disadvantages of diesel power plant.
1. High operating cost 2. High maintenance and lubrication cost 3. Capacity is restricted 4. Noise pollution

26. List the advantages and disadvantages of gas turbine power plant.
Advantages: 1. Low capital cost 2. High reliability 3. Flexibility in operation 4. Capability to quick start 5. High efficiency
Disadvantages: 1. No load and Partial load efficiency is low 2. High sensitive to component efficiency
3. The efficiency depends on ambient pressure and ambient temperature 4. High air rate is required to limit the maximum inlet air temperature. Hence exhaust losses are high 5. Air and gas filter is required to prevent dust into the combustion chambers.

27. List the factors which affect the performance of gas turbine power plants.
1. Part load efficiency 2. Fuel consumption 3. Air mass flow rate 4. Thermal efficiency 5. Regeneration

28. How solid injection is classified? (May/June 2013)
Solid Injection Classification:
(i) Common Rail System, (ii) Unit Injection System (iii) Individual Pump and Nozzle System
(iv) Distributor System

29. What type of cycle is used in gas turbine? (Nov/Dec 2013)
In an ideal gas turbine, gases undergo three thermodynamic processes: an isentropic compression, an isobaric (constant pressure) combustion and an isentropic expansion. Together, these make up the Brayton cycle.

30. Mention the major difference between Otto cycle and diesel cycle. (Nov/Dec 2015)

S.No	Otto cycle	Diesel Cycle
1	Otto cycle consists of two isentropic and two constant volume processes.	Diesel cycle consists of two isentropic and one constant volume and one constant pressure process.
2	Heat addition takes place at constant volume	Heat addition takes place at constant pressure
3	Compression ratio is equal to expansion ratio	Compression ratio is greater than expansion ratio

31. Why gas turbine power plant is more attractive than any other plants? (Nov/Dec 2015)
Gas turbine power plant is attractive because of their ability to quickly ramp up power production.

PART-B

1.Enlist the advantages and disadvantages of diesel power plant and discuss the essential components of the diesel power plant with neat layout

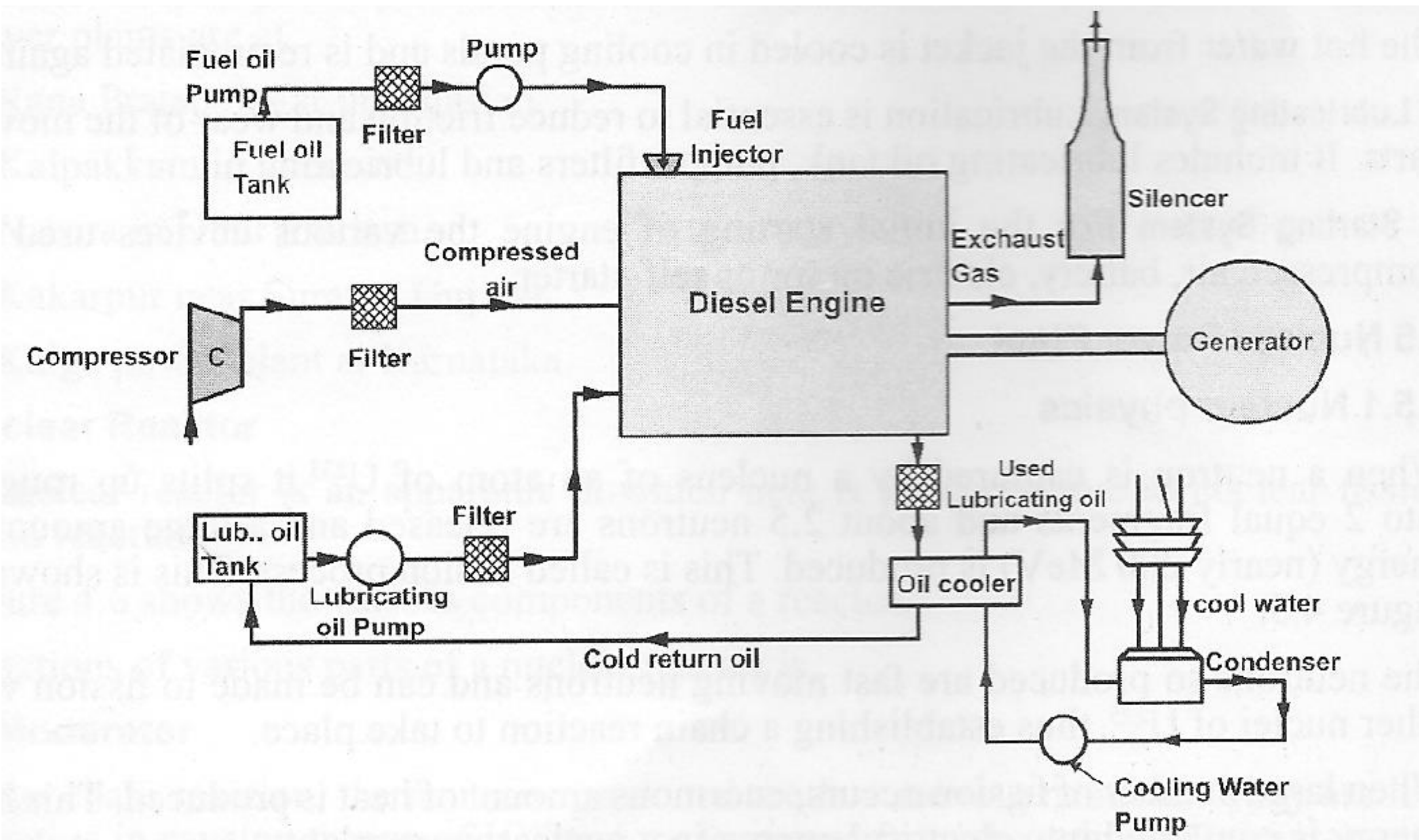
ADVANTAGE OF DIESEL POWER PLANT

The advantages of diesel power plants are listed below.
1. Very simple design also simple installation.
2. Limited cooling water requirement.
3. Standby losses are less as compared to other Power plants.
4. Low fuel cost.
5. Quickly started and put on load.

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

DISADVANTAGE OF DIESEL POWER PLANT

The disadvantages of diesel power plants are listed below.
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.
6. Diesel power plant cannot be constructed for large scale.



1. **Fuel Supply system**

It consists of fuel tank, fuel filter and fuel pump and injector.

2. **Air Intake and Exhaust system**

It consists of compressor, filter and pipes for the supply of air and pipes for exhaust gases. In the exhaust system silencer is provided to reduce the noise.

3. **Cooling system**

Circulates water around the Diesel engines to keep the temp at reasonably low level.

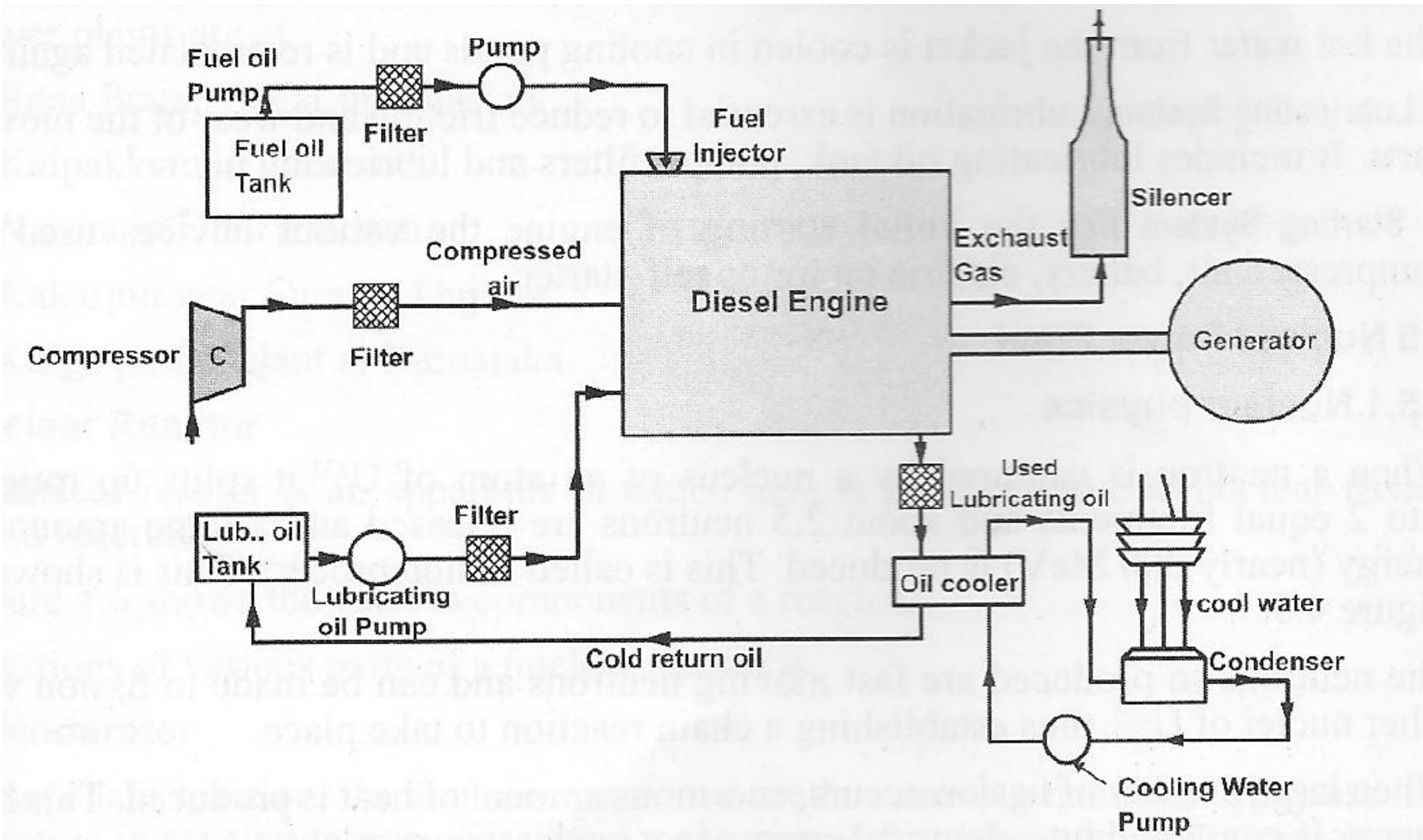
4. **Lubricating system**

It includes lubricating oil tank, pump, filters and lubricating oil.

5. Starting system

For initial starting the devices used are compressed air, battery, electric motor or self-starter.

2.Sketch the layout of a diesel engine power plant and applications of Diesel power plant



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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.

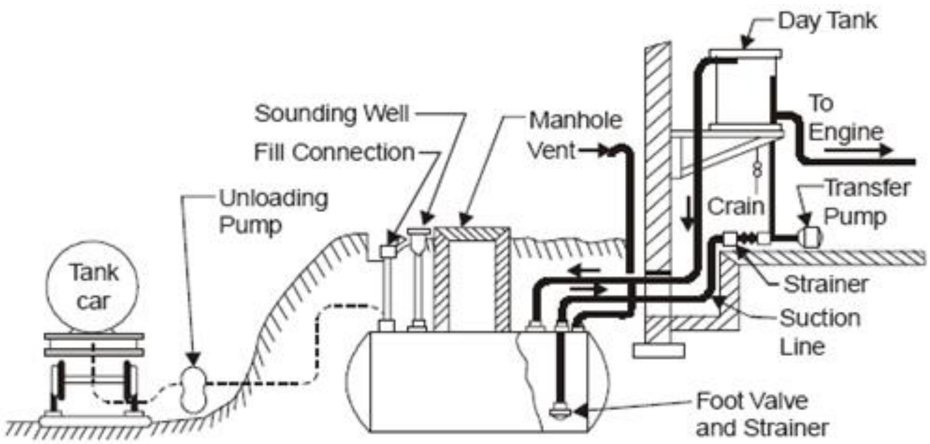
3. They can be used as standby power plants.

4. They can be used as peak load plants for some other types of power plants.

3.What is engine day tank? Explain about fuel injection system of Diesel power plant.

FUEL SYSTEM OF DIESEL POWER PLANT

The fuel is delivered to the plant by railroad tank car, by truck or by barge and tanker and stored in the bulk storage situated outdoors for the sake of safety. From this main fuel tank, the fuel oil is transferred to the daily consumption tank by a transfer pump through a filter. The capacity of the daily consumption should be at least the 8-hour requirement of the plant. This tank is located either above the engine level so that the fuel flows by gravity to the injection pump or below the engine level and the fuel oil is delivered to the injection pump by a transfer pump driven from the engine shaft, Fig.1 Fuel connection is normally used when tank-car siding or truck roadway is above tank level. If it is below tank level, then, an unloading pump is used to transfer fuel form tank car to the storage tank (dotted line).



Fuel System.

The five essential functions of a fuel injection system are:

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

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

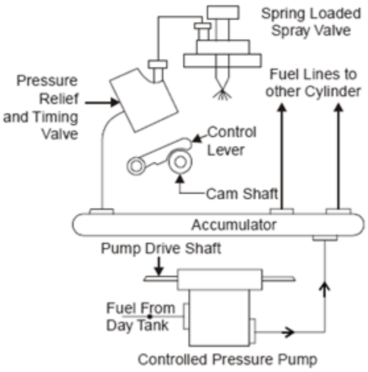
1.Common Rail.
2.Individual Pump Injection.
3. Distributor.

1. COMMON RAIL INJECTION

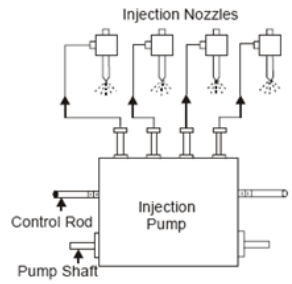
A typical common rail injection system is shown in Fig. 8.4. It incorporates a pump with built in pressure regulation, which adjusts pumping rate to maintain the desired injection pressure. The function of the pressure relief and timing valves is to regulate the injection time and amount. Spring-loaded spray valve acts merely as a check. When injection valve lifts to admit high-pressure fuel to spray valve, its needle rises against the spring. When the pressure is vented to the atmosphere, the spring shuts the valve.

2. INDIVIDUAL PUMP INJECTION

In this system, each fuel nozzle is connected to a separate injection pump, Fig.8.5. The pump itself does the measuring of the fuel charge and control of the injection timing. The delivery valve in the nozzle is actuated by fuel-oil pressure.



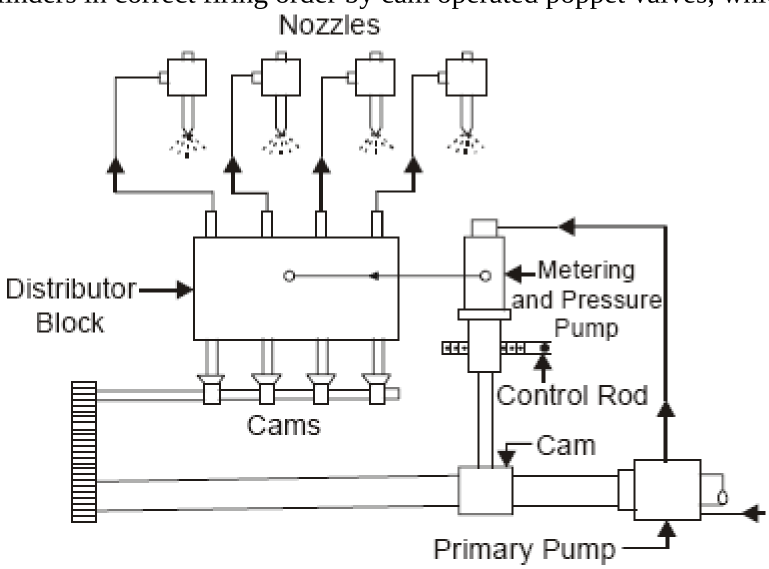
Common Rail Injection.



Individual Pump Injection.

3. DISTRIBUTOR SYSTEM

This system is shown in Fig. 8.6. In this system, the fuel is metered at a central point *i.e.*, the pump that pressurizes, meters the fuel and times the injection. From here, the fuel is distributed to cylinders in correct firing order by cam operated poppet valves, which open to admit fuel to nozzles.



Distribution System.

4.(a)Explain about the lubrication system of Diesel power plant.

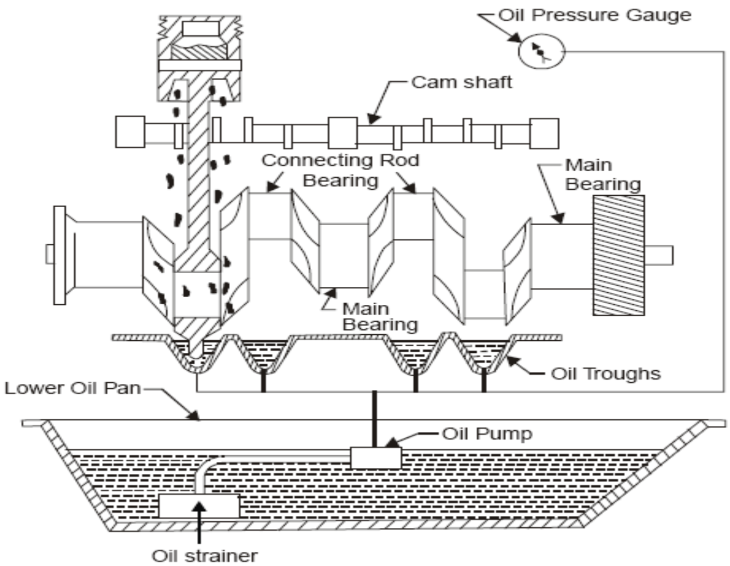
1. Liquid Lubricants or Wet sump lubrication system.
2. Solid Lubricants or Dry sump lubrication system.
3. Semi-solid Lubricants or Mist lubrication system.

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.

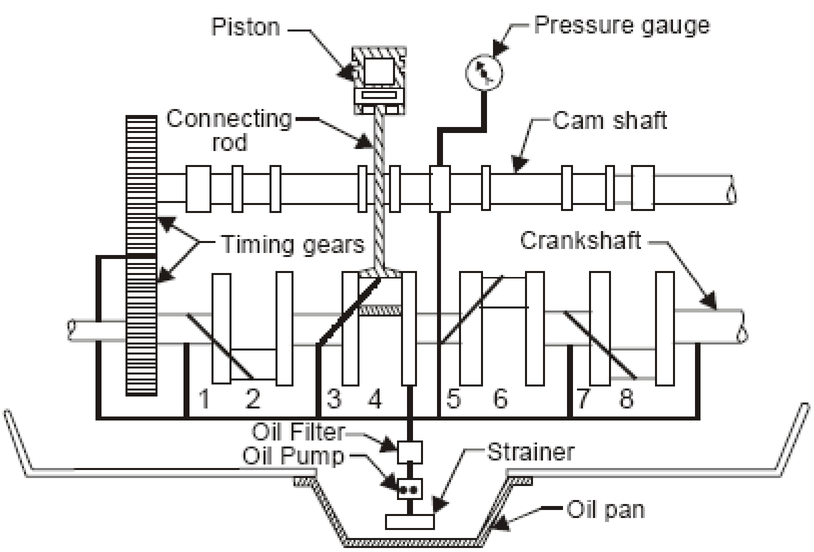
(*a*) **Splash system.** This system is used on some small four strokes, stationary engines. In this case the caps on the big ends bearings of connecting rods are provided with scoops which, when the connecting rod is in the lowest position, just dip into oil troughs and thus directs the oil through holes in the caps to the big end bearings. Due to 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. Splash system is suitable for low and medium speed engines having moderate bearing load pressures. For high performance engines, which normally operate at high bearing pressures and rubbing speeds this system does not serve the purpose.

(*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

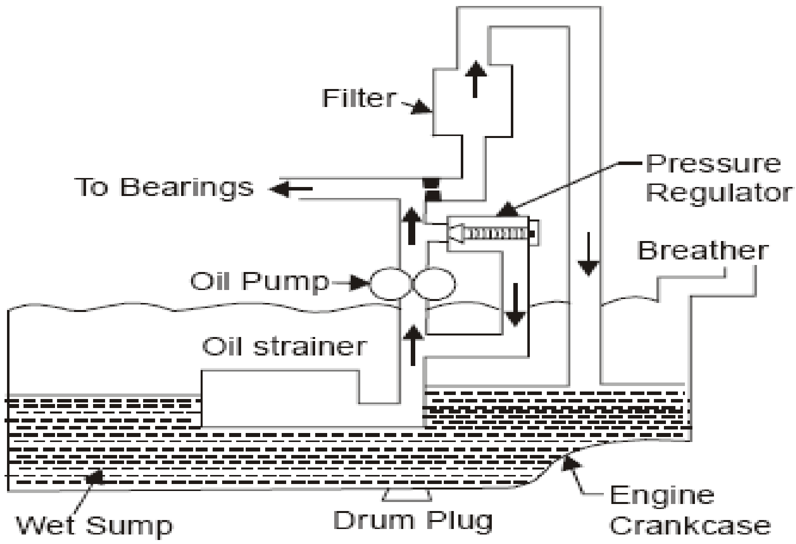


a gear pump at pressure of about 1 bar to the main bearings. The big end bearings are lubricated by means of a spray through nozzles. Thus oil also lubricates the cams, crankshaft bearings, cylinder walls and timing gears. An oil pressure gauge is provided to indicate satisfactory oil supply. The system is less costly to install as compared to pressure system. It enables higher bearing loads and engine speeds to be employed as compared to splash system.

(*c*) **Full pressure system.** In this system, oil from oil sump is pumped under pressure to the various parts requiring lubrication. Refer Fig. 8.8. 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, communicate oil 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.

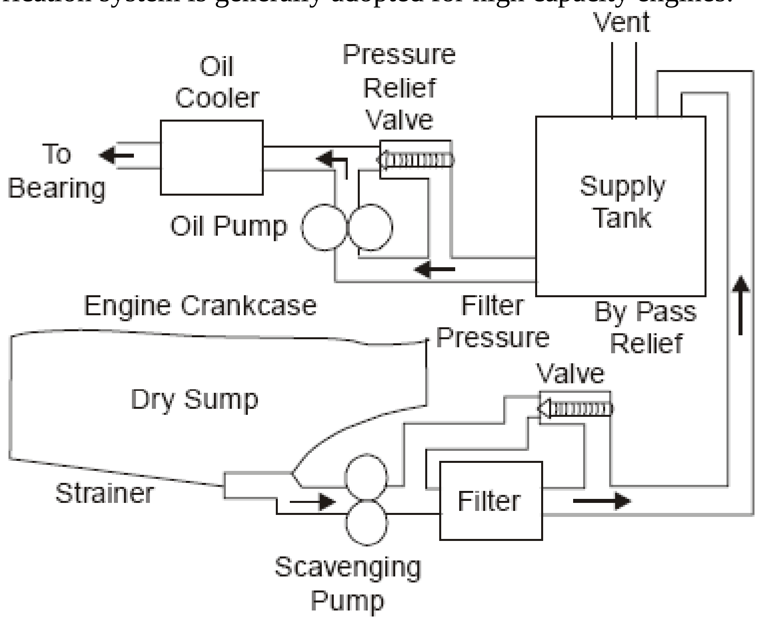


This system finds favour from most of the engine manufacturers as it allows high bearing pressure and rubbing speeds. The general arrangement of wet sump lubrication system is shown in Fig.. In this case oil is always contained in the sump that is drawn by the pump through a strainer.



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/cm2. 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 carburator. 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.

(b)Explain in detail the cooling system of a diesel power plant.

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

1. During combustion period, the heat fluxes to the chamber walls can reach as high as 10 mW/m2.

The flux varies substantially with location. The regions of the chamber that are contacted by rapidly moving high temperature gases generally experience the highest fluxes. In region of high heat flux, thermal stresses must be kept below levels that would cause fatigue cracking.So temperatures must be less than about 400°C for cast iron and 300°C for aluminium alloy for water cooled engines. For air-cooled engines, these values are 270°C and 200°C respectively.

2. The gas side surface temperature of the cylinder wall is limited by the type of lubricating oil used and this temperature ranges from 160°C to 180°C. Beyond these temperature, the properties of lubricating oil deteriorates very rapidly and it might even evaporates and burn, damaging piston and cylinder surfaces. Piston seizure due to overheating resulting from the failure of lubrication is quite common.

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

4. The volumetric and thermal efficiency and power output of the engines decrease with an increase in cylinder and head temperature.

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

(*a*) Air as direct cooling system.

(*b*) Liquid or indirect cooling system

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

(1) Open cooling system

(2) Natural circulation (Thermo-system)

(3) Forced circulation system

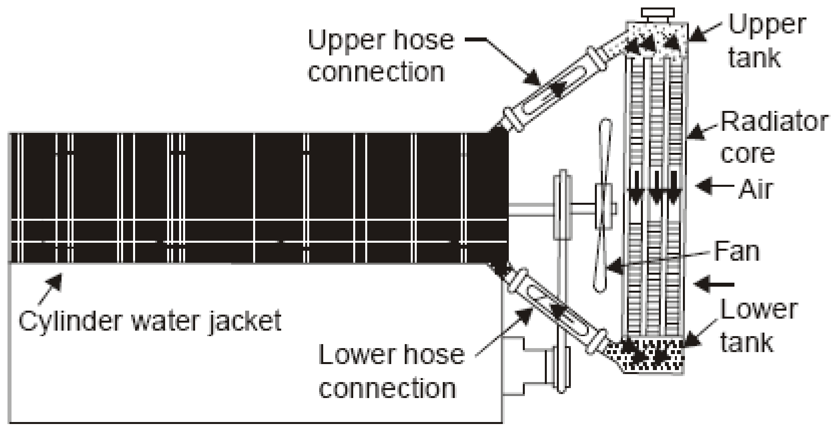
(4) Evaporation cooling system.

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.

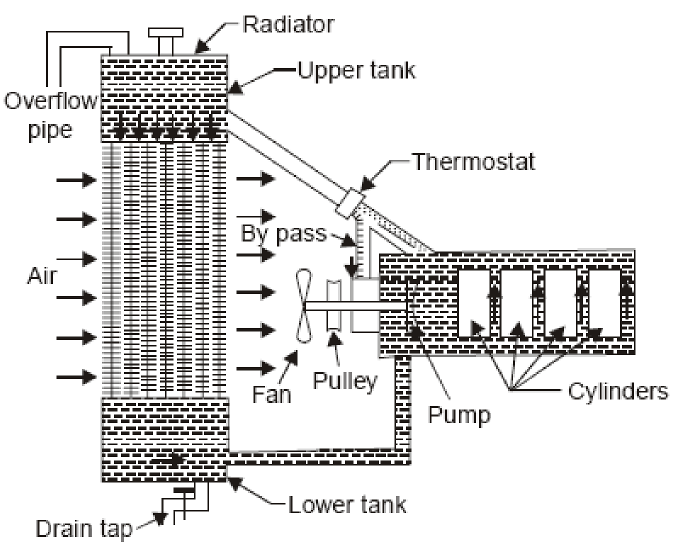
2. NATURAL CIRCULATION SYSTEM

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

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



5.State the advantages and disadvantages of open cycle and closed cycle turbine power plant.

OPEN CYCLE GAS TURBINE POWER PLANT

(A) Advantages

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

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

(B) Disadvantages

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

CLOSED CYCLE GAS TURBINE POWER PLANT

(A) Advantages

1. The inherent disadvantage of open cycle gas turbine is the atmospheric backpressure at the turbine exhaust. With closed cycle gas turbine plants, the backpressure can be increased. Due to the control on backpressure, unit rating can be increased about in proportion to the backpressure. Therefore the machine can be smaller and cheaper than the machine used to develop the same power using open cycle plant.
2. The closed cycle avoids erosion of the turbine blades due to the contaminated gases and fouling of compressor blades due to dust. Therefore, it is practically free from deterioration of efficiency in service. The absence of corrosion and abrasion of the interiors of the compressor and turbine extends the life of the plant and maintains the efficiency of the plant constant throughout its life as they are kept free from the products of combustion.
3. The need for filtration of the incoming air which is a severe problem in open cycle plant is completely eliminated.
4. Load variation is usually obtained by varying the absolute pressure and mass flow of the circulating medium, while the pressure ratio, the temperatures and the air velocities remain almost constant. This result in velocity ratio in the compressor and turbine independent of the load and full load thermal efficiency maintained over the full range of operating loads.
5. The density of the working medium can be maintained high by increasing internal pressure range, therefore, the compressor and turbine are smaller for their rated output. The high density of the working fluid further increases the heat transfer properties in the heat exchanger.
6. As indirect heating is used in closed cycle plant, the inferior oil or solid fuel can be used in the furnace and these fuels can be used more economically because these are available in abundance.
7. Finally the closed cycle opens the new field for the use of working medium (other than air as argon, CO2, helium) having more desirable properties. The ratio □□of the working fluid plays an important role in determining the performance of the gas turbine plant. An increase in □□from 1.4 to 1.67 (for argon) can bring about a large increase in output per kg of fluid circulated and thermal efficiency of the plant. The theoretical thermal efficiencies of the monoatomic gases will be highest for the closed cycle type gas turbine. Further, by using the relatively dense inert gases, such as argon, krypton and xenon, the advantage of smaller isentropic heat fall and smaller cross-sectional flow areas would be realised: Whether CO2 or Helium should be adopted as working medium is matter of controversy at present. Blade material poses a problem to use helium as working fluid. In case of CO2, a new kind of compressor must be designed to compress the fluid. The main advantage of CO2 is that it offers 40% efficiency at 700°C whereas helium would need 850°C or more to achieve the same efficiency. A helium turbine would also need to run faster imposing larger stresses on the rotor.
8. The maintenance cost is low and reliability is high due to longer useful life.
9. The thermal efficiency increases as the pressure ratio (R*p*) decreases. Therefore, appreciable higher thermal efficiencies are obtainable with closed cycle for the same maximum and minimum temperature limits as with the open cycle plant.
10. Starting of plane is simplified by reducing the pressure to atmospheric or even below atmosphere so that the power required for starting purposes is reduced considerably.

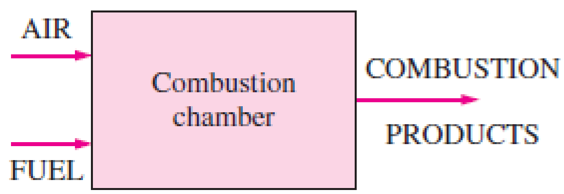
(B) Disadvantages

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

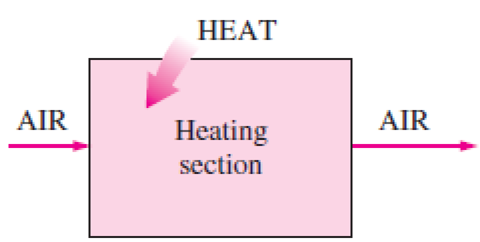
6.Derive the efficiency equation for the following cycles.

The actual gas power cycles are rather complex. To reduce the analysis to a manageable level, we utilize the following approximations, commonly known as the **air-standard assumptions:**

1. The working fluid is air, which continuously circulates in a closed loop and always behaves as an ideal gas.
2. All the processes that make up the cycle are internally reversible.
3. The combustion process is replaced by a heat-addition process from an external source (Fig. 9–9).
4. The exhaust process is replaced by a heat-rejection process that restores the working fluid to its initial state.

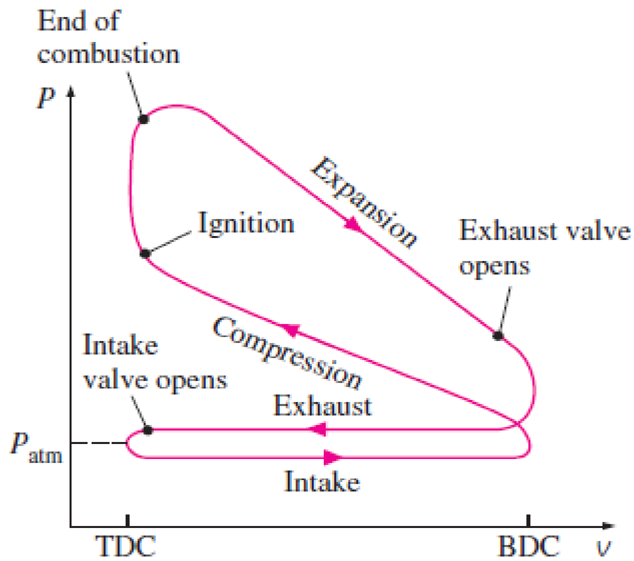


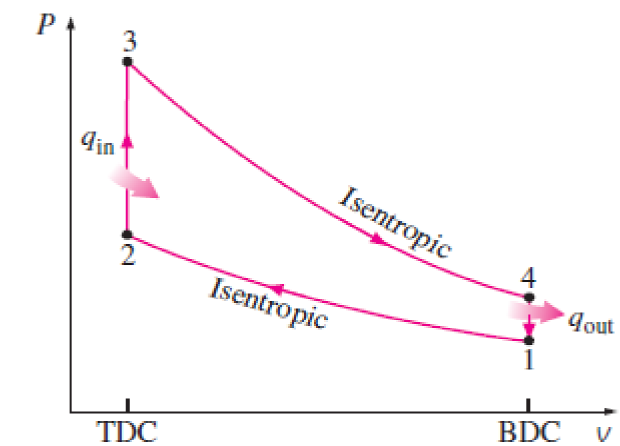
(*a*) Actual



(*b*) Ideal

(a)Otto cycle


End of combustion
P
Expansion
Ignition
Exhaust valve opens
Compression
Intake valve opens
Exhaust
P_{atm}
Intake
TDC
BDC
v


P
3
q_{in}
2
Isentropic
Isentropic
4
q_{out}
1
TDC
BDC
v

The thermodynamic analysis of the actual four-stroke or two-stroke cycles described is not a simple task. However, the analysis can be simplified significantly if the air-standard assumptions are utilized. The resulting cycle, which closely resembles the actual operating conditions, is the ideal **Otto cycle.** It consists of four internally reversible processes:

1-2 Isentropic compression
2-3 Constant-volume heat addition
3-4 Isentropic expansion
4-1 Constant-volume heat rejection

The execution of the Otto cycle in a piston–cylinder device together with a *P-v* diagram is illustrated in Fig. 9–13*b*. The *T-s* diagram of the Otto cycle is given in Fig. 9–16.

The Otto cycle is executed in a closed system, and disregarding the changes in kinetic and potential energies, the energy balance for any of the processes is expressed, on a unit-mass basis, as

$$(q_{in} - q_{out}) + (w_{in} - w_{out}) = \Delta u \qquad (\text{kJ/kg}) \qquad \textbf{(9–5)}$$

No work is involved during the two heat transfer processes since both take place at constant volume. Therefore, heat transfer to and from the working fluid can be expressed as

$$q_{in} = u_3 - u_2 = c_v(T_3 - T_2) \qquad \textbf{(9–6a)}$$

and

$$q_{out} = u_4 - u_1 = c_v(T_4 - T_1) \qquad \textbf{(9–6b)}$$

Then the thermal efficiency of the ideal Otto cycle under the cold air standard assumptions becomes

$$\eta_{th,Otto} = \frac{w_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{T_1(T_4/T_1 - 1)}{T_2(T_3/T_2 - 1)}$$

Processes 1-2 and 3-4 are isentropic, and $v_2 = v_3$ and $v_4 = v_1$. Thus,

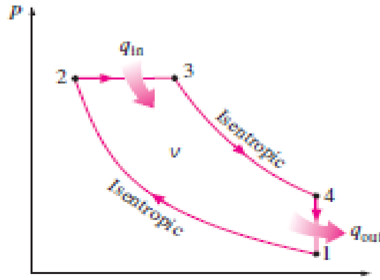
$$\frac{T_1}{T_2} = \left(\frac{v_2}{v_1}\right)^{k-1} = \left(\frac{v_3}{v_4}\right)^{k-1} = \frac{T_4}{T_3} \qquad \textbf{(9–7)}$$

Substituting these equations into the thermal efficiency relation and simplifying give

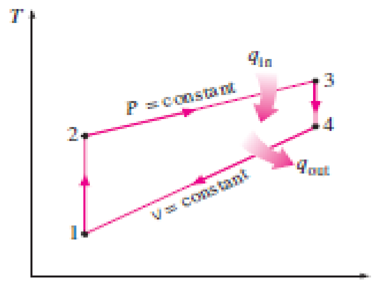
$$\eta_{th,Otto} = 1 - \frac{1}{r^{k-1}} \qquad \textbf{(9–8)}$$

where

(b)Diesel cycle



(a) P- v diagram



(b) T-s diagram

The fuel injection process in diesel engines starts when the piston approaches TDC and continues during the first part of the power stroke. Therefore, the combustion process in these engines takes place over a longer interval. Because of this longer duration, the combustion process in the ideal Diesel cycle is approximated as a constant-pressure heat-addition process. In fact, this is the only process where the Otto and the Diesel cycles differ. The remaining three processes are the same for both ideal cycles. That is, process 1-2 is isentropic compression, 3-4 is isentropic expansion, and 4-1 is constant-volume heat rejection. The similarity between the two cycles is also apparent from the *P*-*v* and *T*-*s* diagrams of the Diesel cycle, shown in Fig. 9–21.

Noting that the Diesel cycle is executed in a piston–cylinder device, which forms a closed system, the amount of heat transferred to the working fluid at constant pressure and rejected from it at constant volume can be expressed as

$$q_{in} - w_{b,out} = u_3 - u_2 \rightarrow q_{in} = P_2(v_3 - v_2) + (u_3 - u_2)$$
$$= h_3 - h_2 = c_p(T_3 - T_2) \qquad \textbf{(9–10a)}$$

and

$$-q_{out} = u_1 - u_4 \rightarrow q_{out} = u_4 - u_1 = c_v(T_4 - T_1) \qquad \textbf{(9–10b)}$$

Then the thermal efficiency of the ideal Diesel cycle under the cold-air-standard assumptions becomes

$$\eta_{th,Diesel} = \frac{w_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{T_4 - T_1}{k(T_3 - T_2)} = 1 - \frac{T_1(T_4/T_1 - 1)}{kT_2(T_3/T_2 - 1)}$$

We now define a new quantity, the **cutoff ratio** r_c, as the ratio of the cylinder volumes after and before the combustion process:

$$r_c = \frac{V_3}{V_2} = \frac{v_3}{v_2} \quad \textbf{(9–11)}$$

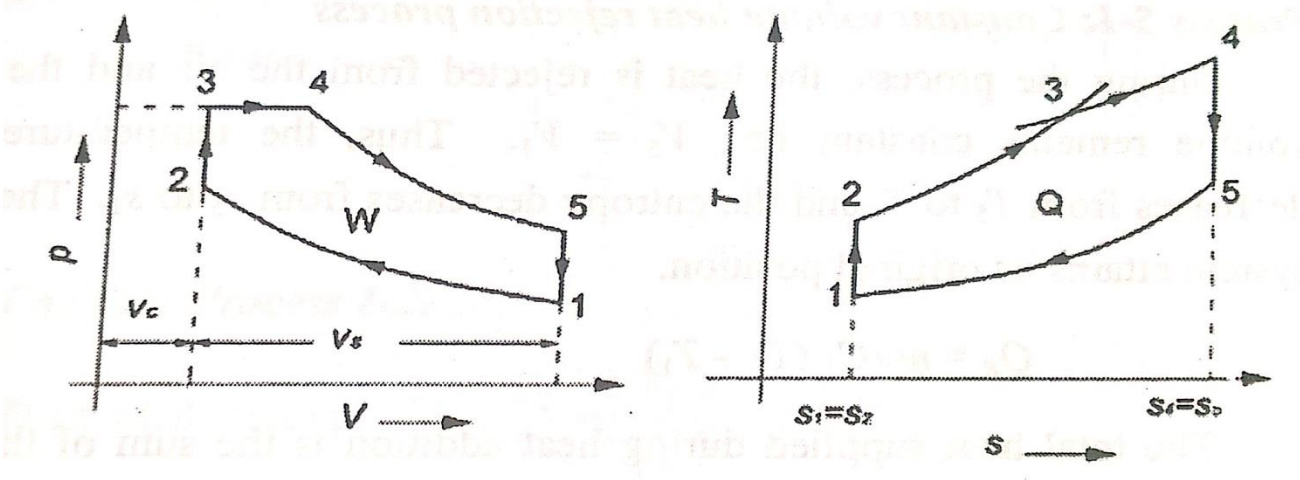
Utilizing this definition and the isentropic ideal-gas relations for processes 1-2 and 3-4, we see that the thermal efficiency relation reduces to

$$\eta_{th,Diesel} = 1 - \frac{1}{r^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right] \quad \textbf{(9–12)}$$

where r is the compression ratio defined by Eq. 9–9. Looking at Eq. 9–12 carefully, one would notice that under the cold-air-standard assumptions, the efficiency of a Diesel cycle differs from the efficiency of an Otto cycle by the quantity in the brackets. This quantity is always greater than 1. Therefore,

$$\eta_{th,Otto} > \eta_{th,Diesel} \quad \textbf{(9–13)}$$

(c)Dual cycle



p-V diagram *T-s diagram*

Air Standard Efficiency

$$\eta = \frac{W}{Q_S} = \frac{Q_S - Q_R}{Q_S}$$

$$= \frac{m\,C_V\left(T_3 - T_2\right) + m\,C_P\left(T_4 - T_3\right) - m\,C_V\left(T_5 - T_1\right)}{m\,C_V\left(T_3 - T_2\right) + m\,C_P\left(T_4 - T_3\right)}$$

$$\eta = 1 - \frac{\left(T_5 - T_1\right)}{\left(T_3 - T_2\right) + \gamma\left(T_4 - T_3\right)} \qquad \left(\because \frac{C_P}{C_V} = \gamma\right)$$

The above efficiency equation is in terms of temperatures only. Hence, the equation is simplified into the function of compression ratio, cut off ratio and pressure ratio.

$$\text{Compression ratio, } r = \frac{V_1}{V_2}$$

$$\text{Pressure ratio } k = \frac{p_3}{p_2}$$

$$\text{Cut-off ratio, } \rho = \frac{V_4}{V_3}$$

$$\text{Expansion ratio, } \frac{V_5}{V_4} = \frac{V_1}{V_4} = \frac{V_1}{V_2} \times \frac{V_2}{V_4} \qquad \left(\begin{matrix}\because V_5 = V_1 \\ V_3 = V_2\end{matrix}\right)$$

$$= \frac{V_1}{V_2} \times \frac{V_3}{V_4} = \frac{r}{\rho}$$

Consider Process 1-2:

$$\text{From adiabatic expression } \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = (r)^{\gamma-1}$$

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

Consider process 2-3:

Constant volume process, $\frac{p_2}{T_2} = \frac{p_3}{T_3}$

$$T_3 = \frac{p_3}{p_2} T_2 = k.\ T_1 (r)^{\gamma-1}$$

Consider process 3-4:

Constant pressure process, $\frac{V_3}{T_3} = \frac{V_4}{T_4}$

$$T_4 = \frac{V_4}{V_3} T_3 = \rho.k.\ T_1 (r)^{\gamma-1}$$

Consider process 4-5:

Isentropic process, $\frac{T_4}{T_5} = \left(\frac{V_5}{V_4}\right)^{\gamma-1} = \left(\frac{r}{\rho}\right)^{\gamma-1}$

$$T_5 = \frac{T_4}{\left(\frac{r}{\rho}\right)^{\gamma-1}} = \frac{T_4\ \rho^{\gamma-1}}{(r)^{\gamma-1}} = \frac{T_1 (r)^{\gamma-1} .k.\rho.\rho^{\gamma-1}}{(r)^{\gamma-1}}$$

$$T_5 = T_1\ k.\rho^{\gamma}$$

Note:

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

$$T_3 = k.\ T_1 (r)^{\gamma-1}$$

$$T_4 = \rho.k.\ T_1 (r)^{\gamma-1}$$

$$T_5 = T_1\ k.\rho^{\gamma}$$

Substituting T_2, T_3, T_4 and T_5 values in η equation,

$$\eta = 1 - \frac{T_1 k\rho^{\gamma} - T_1}{[T_1 (r)^{\gamma-1} k - T_1 (r)^{\gamma-1}] + \gamma[T_1 (r)^{\gamma-1} k\rho - T_1 (r)^{\gamma-1} k]}$$

$$= 1 - \frac{T_1\left[k\rho^{\gamma} - 1\right]}{T_1(r)^{\gamma-1}\left[(k-1) + \gamma k(\rho - 1)\right]}$$

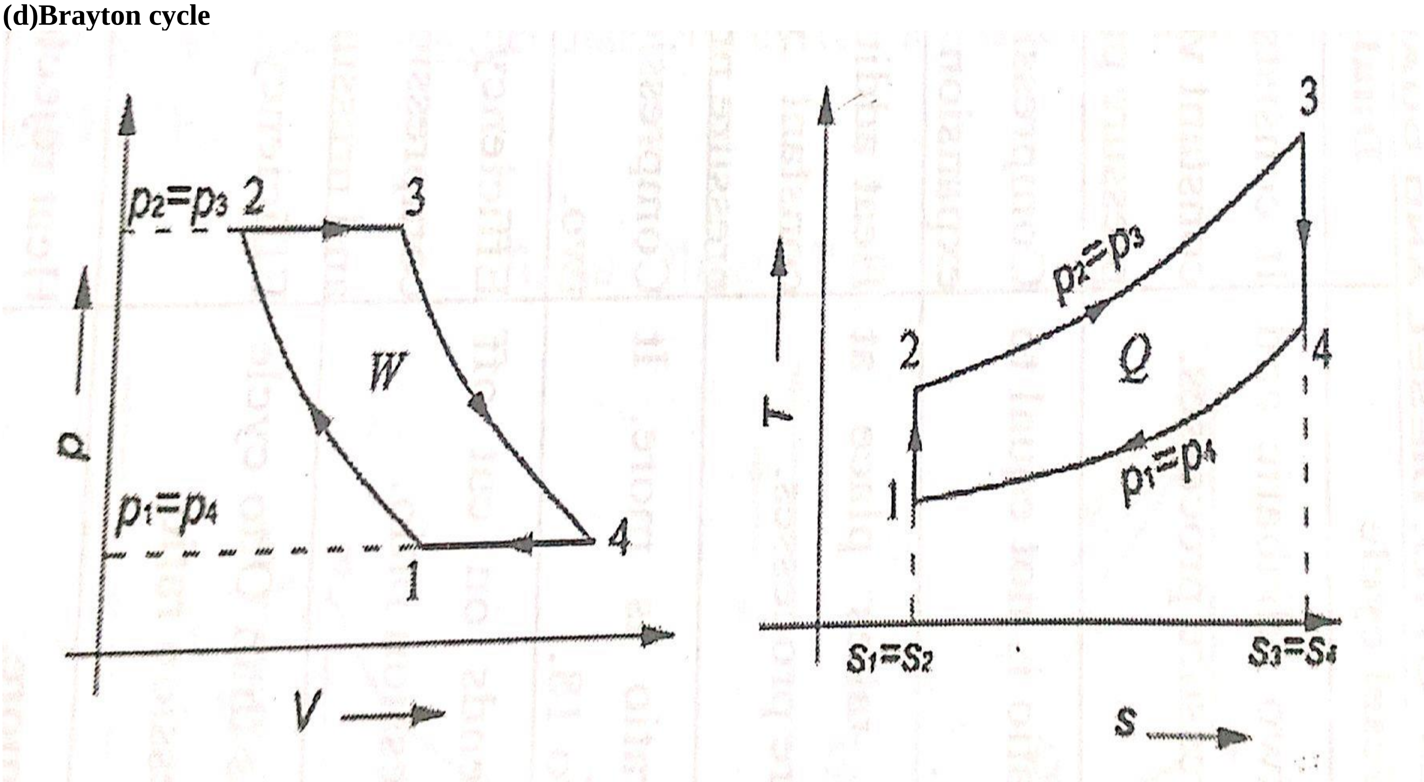
$$\eta_{Dual} = 1 - \frac{1}{(r)^{\gamma-1}}\left[\frac{k\rho^{\gamma} - 1}{(k-1) + \gamma k(\rho - 1)}\right]$$

Note:

When $k = 1$, η_{Dual} equation reduces to η_{Diesel}

When $k = 1$ and $\rho = 1$, η_{Dual} equation reduces to η_{Otto}

(d)Brayton cycle



$$\text{Efficiency } \eta_{Brayton} = \frac{W}{Q_S} = \frac{Q_S - Q_R}{Q_S}$$

$$= \frac{m C_p (T_3 - T_2) - m C_p (T_4 - T_1)}{m C_p (T_3 - T_2)}$$

$$= 1 - \frac{T_4 - T_1}{T_3 - T_2}$$

The efficiency equation can be simplified in terms of compression ratio (r) and pressure ratio (R_P).

$$\text{Compression ratio, } r = \frac{V_1}{V_2} = \frac{V_4}{V_3}$$

$$\text{Pressure ratio, } R_p = \frac{p_2}{p_1} = \frac{p_3}{p_4}$$

Consider process 1–2: isentropic compression

$$\frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} = (r)^{\gamma-1}$$

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

Consider process 3–4: isentropic expansion

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = (r)^{\gamma-1}$$

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

Also,

$$\frac{T_3}{T_4} = \left(\frac{p_3}{p_4}\right)^{\frac{\gamma-1}{\gamma}}$$

$$T_3 = T_4 \left(R_p\right)^{\frac{\gamma-1}{\gamma}}$$

Substituting T_2 and T_3 values in efficiency equation,

$\eta_{Brayton}$ in terms of *pressure ratio,*

$$\eta = 1 - \frac{T_4 - T_1}{T_4\left(R_p\right)^{\frac{\gamma-1}{\gamma}} - T_1\left(R_p\right)^{\frac{\gamma-1}{\gamma}}}$$

$$\eta_{Brayton} = 1 - \frac{1}{\left(R_p\right)^{\frac{\gamma-1}{\gamma}}}$$

$\eta_{Brayton}$ in terms of *compression ratio,*

$$\eta_{Brayton} = 1 - \frac{T_4 - T_1}{T_4 (r)^{\gamma-1} - T_1 (r)^{\gamma-1}}$$

$$= 1 - \frac{T_4 - T_1}{(r)^{\gamma-1}\left(T_4 - T_1\right)}$$

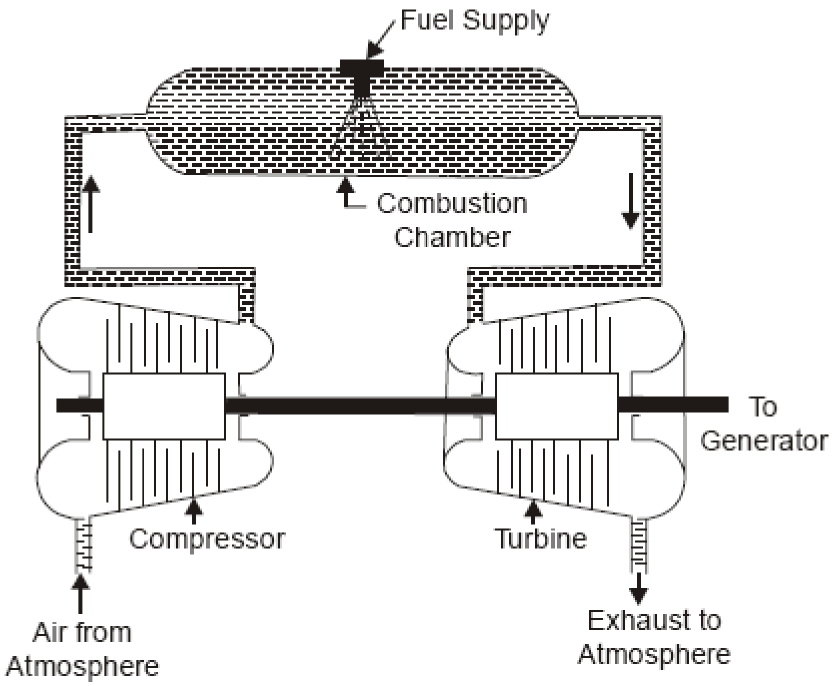
$$\eta_{Brayton} = 1 - \frac{1}{(r)^{\gamma-1}}$$

7.Explain the two types of gas turbine power plant.

The gas turbine power plants which are used in electric power industry are classified into two groups as per the cycle of operation. (*a*) Open cycle gas turbine.(*b*) Closed cycle gas turbine.

OPEN CYCLE GAS TURBINE POWER PLANT

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



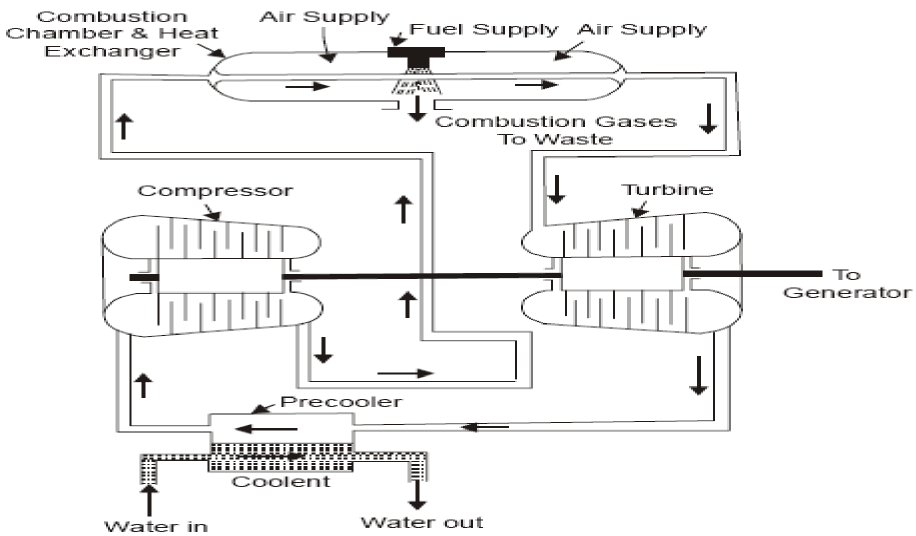
The heated gases coming out of combustion chamber are then passed to the turbine where it expands doing mechanical work. Part of the power developed by the turbine is utilized in driving the compressor and other accessories and remaining is used for power generation. Since ambient air enters into the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

CLOSED CYCLE GAS TURBINE POWER PLANT

Closed cycle gas turbine plant was originated and developed in Switzerland. In the year 1935, J. Ackeret and C. Keller first proposed this type of machine and first plant was completed in Zurich in 1944.

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

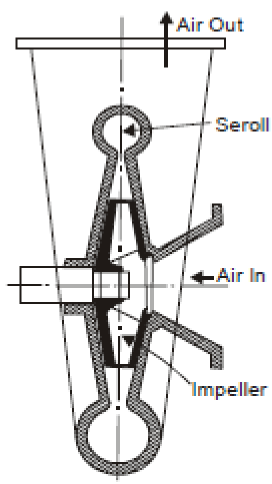
The working fluid is continuously used in the system without its change of phase and the required heat is given to the working fluid in the heat exchanger. The arrangement of the components of the closed cycle gas turbine plant is shown in Fig. 2.



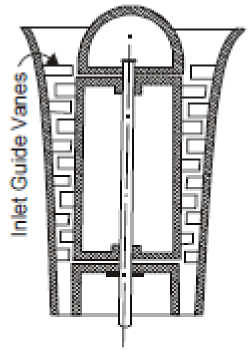
8. (a)Explain different components of gas turbine plant with neat sketch. (MAY/JUN 2013)

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 diffuser converts 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 single inlet centrifugal compressor is shown in Fig.



The efficiency of centrifugal compressor lies between 80 to90%. 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 guide the 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 through the rotor and part of it is converted into pressure. The axial flow compressor is shown in Fig.



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 rapidly.

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.

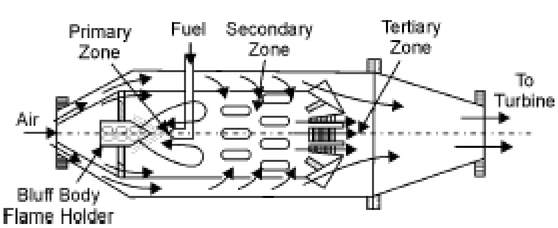
INTERCOOLER

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 counterflow gives high average temperature difference causing the higher heat flow. A number of baffles in the path of airflow 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.

(b)Explain the effect of intercooling, regeneration and reheating in gas turbine (MAY/JUN 2013) (NOV/DEC 2014)

1. Intercooling. A compressor in a gas turbine cycle utilises the major percentage of power developed by the gas turbine. The work required by the compressor can be reduced by compressing the air in two stages and incorporating an intercooler between the two as shown in Fig. 5.5. The corresponding *T-s* diagram for the unit is shown in Fig. 5.6 (*a*). The actual processes take place as follows :

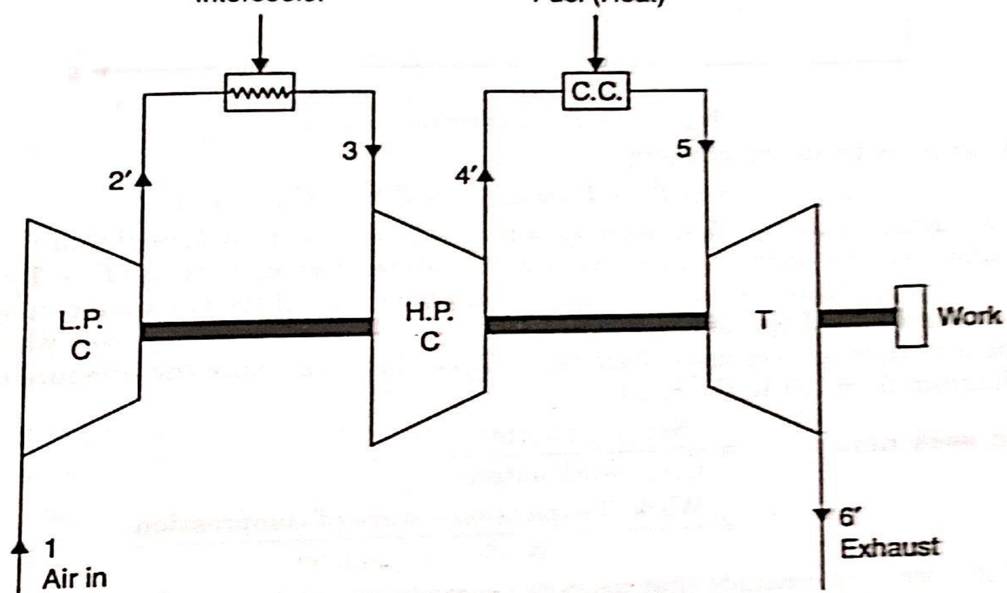


Fig. 5.5. Turbine plant with intercooler.

1-2′ : *L.P. (Low pressure) compression*
2′-3 : *Intercooling*
3-4′ : H.P. (High pressure) compression
4′-5 : C.C. (Combustion chamber)–heating
5-6′ : T (Turbine)–expansion

The ideal cycle for this arrangement is 1-2-3-4-5-6 ; the compression process without intercooling is shown as 1-*L*′ in the actual case, and 1-*L* in the ideal isentropic case.

Now, work input (with intercooling)

$$= c_p(T_2' - T_1) + c_p(T_4' - T_3) \quad \text{...(5.3)}$$

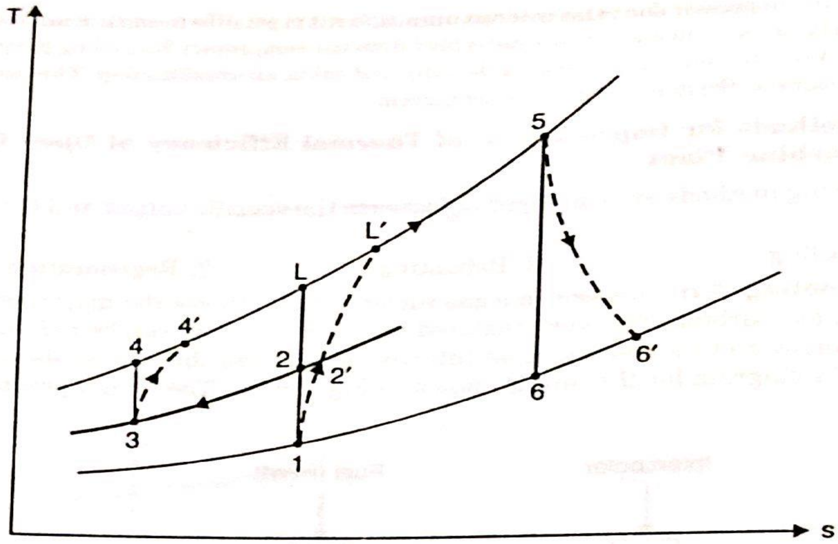


Fig. 5.6. (a) T-s diagram for the unit.

Work input (without intercooling)

$$= c_p(T_L' - T_1) = c_p(T_2' - T_1) + c_p(T_L' - T_2') \quad ...(5.4)$$

By comparing equation (5.4) with equation (5.3) it can be observed that the *work input with intercooling is less than the work input with no intercooling*, when $c_p\ (T_4' - T_3)$ is *less* than $c_p(T_L' - T_2')$. This is so if it is assumed that isentropic efficiencies of the two compressors, operating separately, are each equal to the isentropic efficiency of the single compressor which would be required if no intercooling were used. Then $(T_4' - T_3) < (T_L' - T_2')$ since the pressure lines diverge on the *T-s* diagram from left to the right.

$$\text{Again, work ratio} = \frac{\text{Net work output}}{\text{Gross work output}}$$

$$= \frac{\text{Work of expansion} - \text{work of compression}}{\text{Work of expansion}}$$

From this we may conclude that *when the compressor work input is reduced then the work ratio is increased.*

However the heat supplied in the combustion chamber when intercooling is used in the cycle, is given by,

Heat supplied *with* intercooling $= c_p(T_5 - T_4')$

Also the heat supplied when intercooling is *not* used, with the same maximum cycle temperature T_5, is given by

Heat supplied *without* intercooling $= c_p\ (T_5 - T_L')$

Thus, the *heat supplied when intercooling is used is greater than with no intercooling. Although the net work output is increased by intercooling it is found in general that the increase in heat to be supplied causes the thermal efficiency to decrease.* When intercooling is used a supply of cooling water must be readily available. The additional bulk of the unit may offset the advantage to be gained by increasing the work ratio.

In Fig. 5.6 (*b*) is shown that the intercooling has marked effect on thermal efficiency only at high pressure ratio.

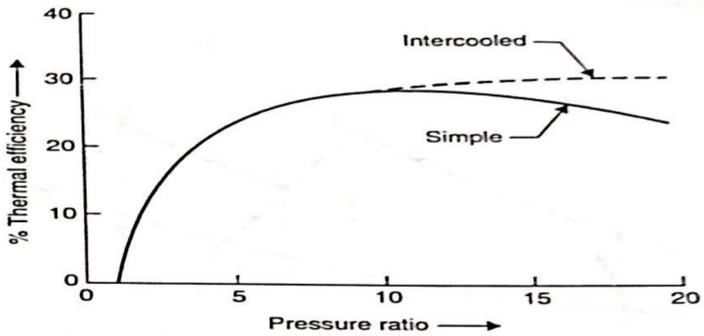


Fig. 5.6 (*b*)

2. Reheating. The output of a gas turbine can be amply improved by expanding the gases in two stages with a reheater between the two as shown in Fig. 5.7. The H.P. turbine drives the compressor and the L.P. turbine provides the useful power output. The corresponding *T-s* diagram is shown in Fig. 5.8 (*a*). The line 4′-*L*′ represents the expansion in the L.P. turbine if reheating is not employed.

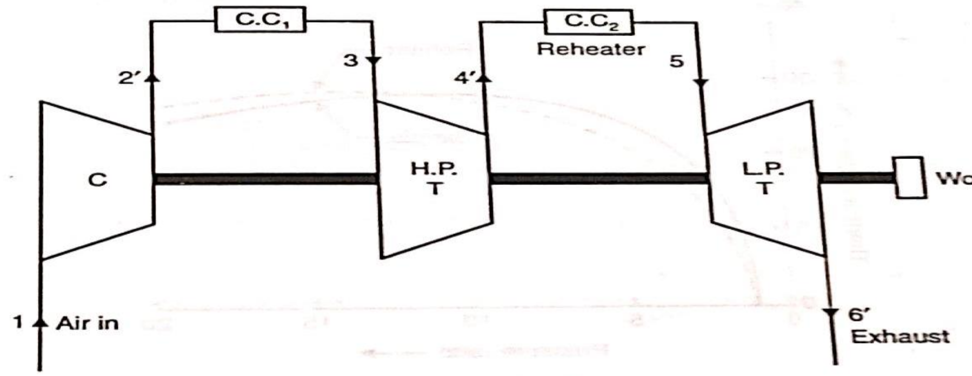


Fig. 5.7. Gas turbine with reheater.

Neglecting mechanical losses the work output of the H.P. turbine must be exactly equal to the work input required for the compressor

i.e.,

$$c_{pa}\,(T_2' - T_1) = c_{pg}\,(T_3 - T_4')$$

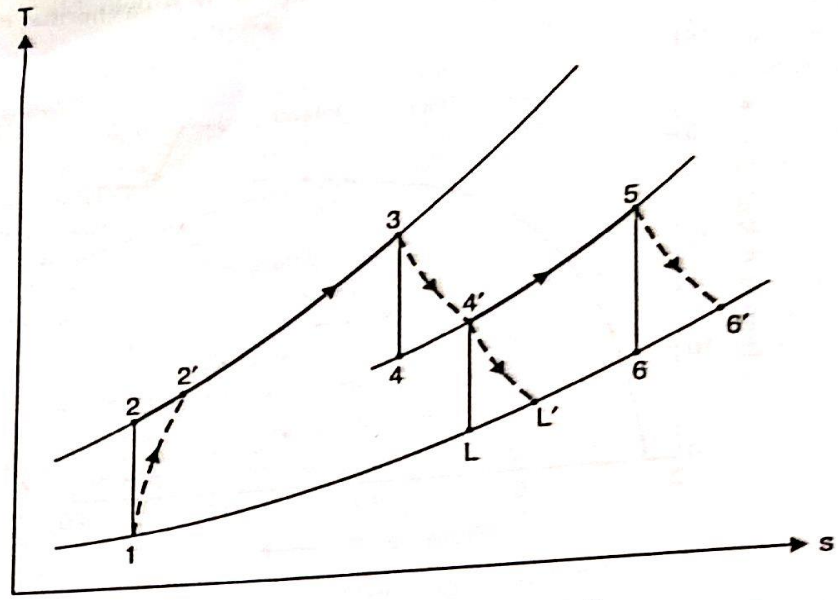


Fig. 5.8. (a) T-s diagram for the unit.

The work output (net output) of L.P. turbine is given by,

Net work output (with reheating) $= c_{pg}\,(T_5 - T_6')$

and Net work output (without reheating) $= c_{pg}\,(T_4' - T_L')$

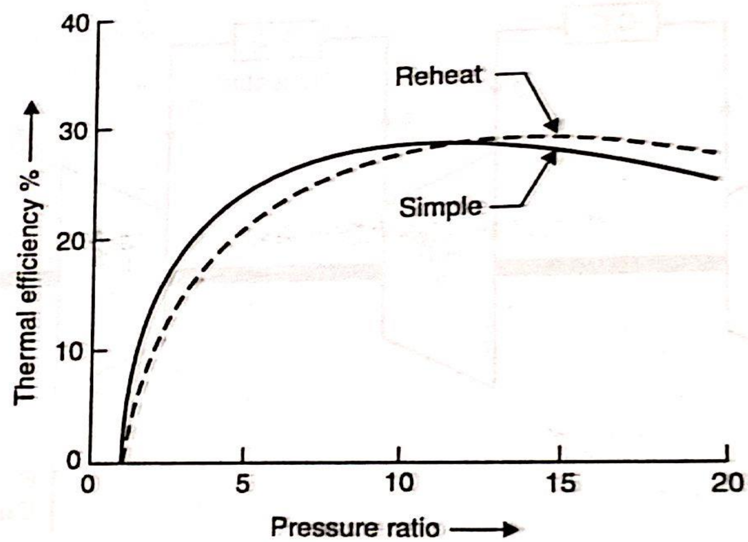


Fig. 5.8 (b)

Since the pressure lines diverge to the right on T-s diagram it can be seen that the temperature difference $(T_5 - T_6')$ is always *greater* than $(T_4' - T_L')$, so that *reheating increases the net work output.*

Although net work is increased by reheating the heat to be supplied is also increased, and the net effect *can be to reduce the thermal efficiency* [Fig. 5.8 (*b*)]

Heat supplied $= c_{pg}(T_3 - T_2') + c_{pg}(T_5 - T_4')$.

Note. c_{pa} and c_{pg} stand for specific heats of air and gas respectively at constant pressure.

3. Regeneration. The exhaust gases from a gas turbine carry a large quantity of heat with them since their temperature is far above the ambient temperature. They can be used to heat the air coming from the compressor thereby reducing the mass of fuel supplied in the combustion chamber. Fig. 5.9 shows a gas turbine plant *with a regenerator*. The corresponding *T-s* diagram is shown in Fig. 5.10. 2′-3 represents the heat flow into the compressed air during its passage through the heat exchanger and 3-4 represents the heat taken in from the combustion of fuel. Point 6 represents the temperature of exhaust gases at discharge from the heat exchanger. The maximum temperature to which the air could be heated in the heat exchanger is ideally that of exhaust gases, but less than this is obtained in practice because a temperature gradient must exist for an unassisted transfer of energy. The effectiveness of the heat exchanger is given by :

$$\text{Effectiveness,} \quad \varepsilon = \frac{\text{Increase in enthalpy per kg of air}}{\text{Available increase in enthalpy per kg of air}}$$

$$= \frac{(T_3 - T_2')}{(T_5' - T_2')} \quad \text{...(5.5)}$$

(assuming c_{pa} and c_{pg} to be equal)

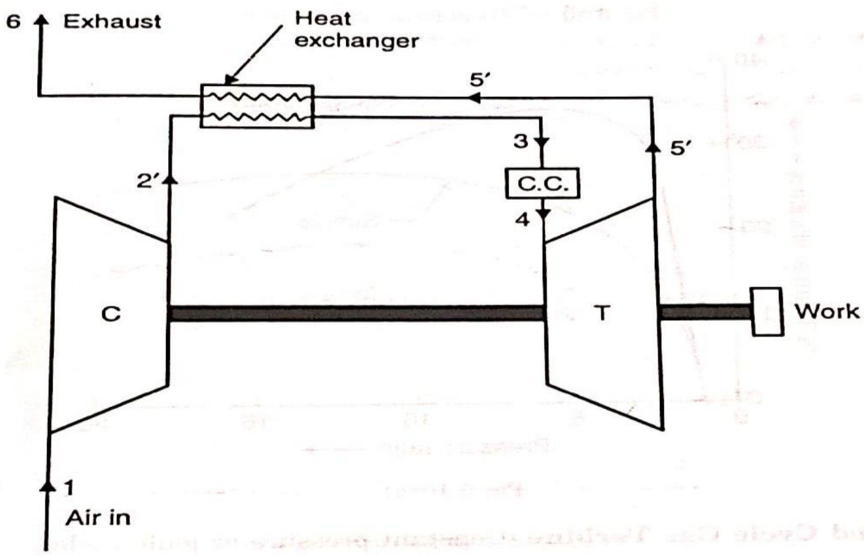


Fig. 5.9. Gas turbine with regenerator.

Fig. 5.10 *(b)* shows that the regenerative cycle has higher efficiency than the simple cycle only at low pressure ratios. At pressure ratios above a certain limit the efficiency of the regenerative cycle drops since in that case the regenerator will cool the compressed air entering the combustion chamber instead of heating it.

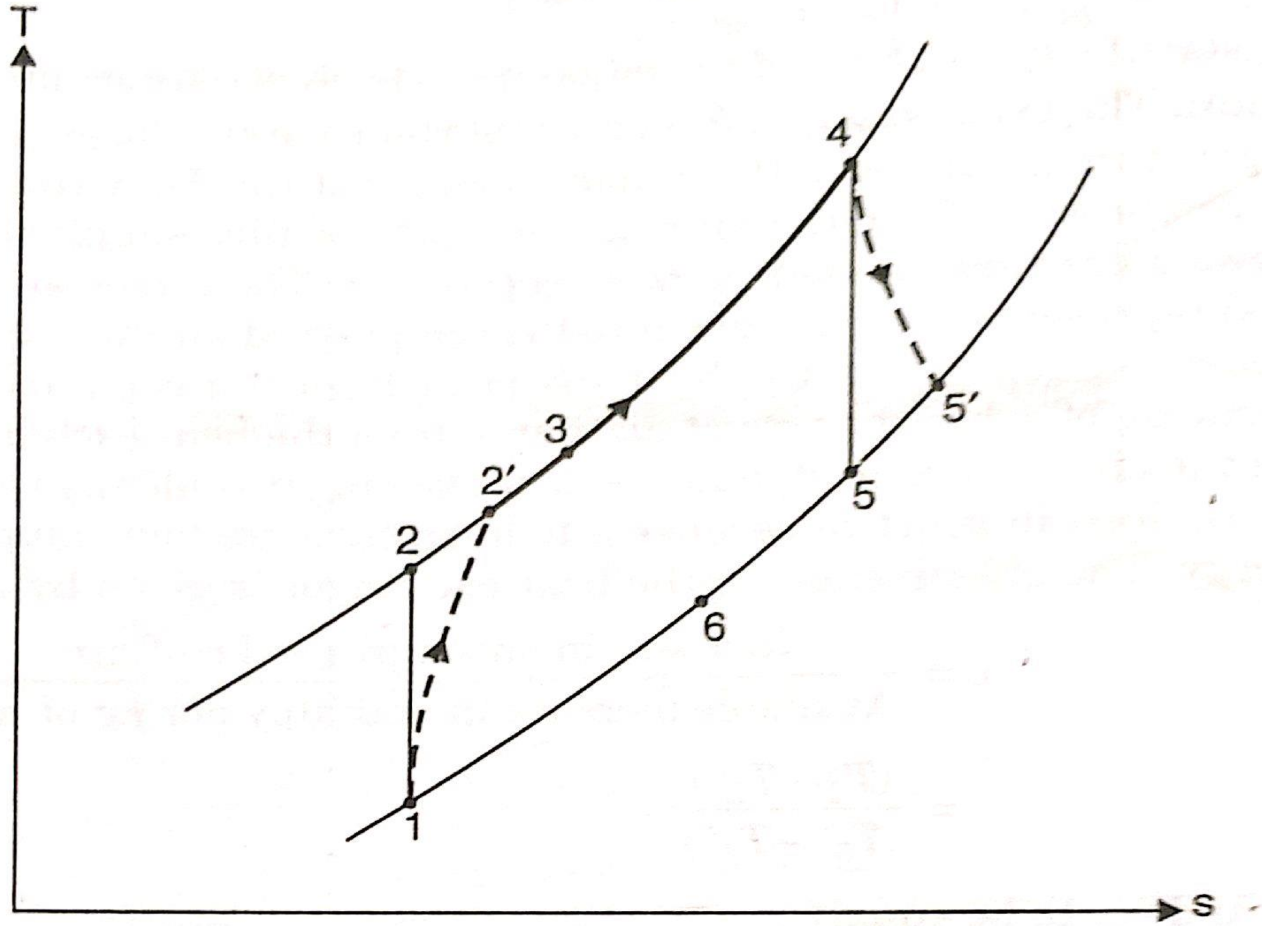
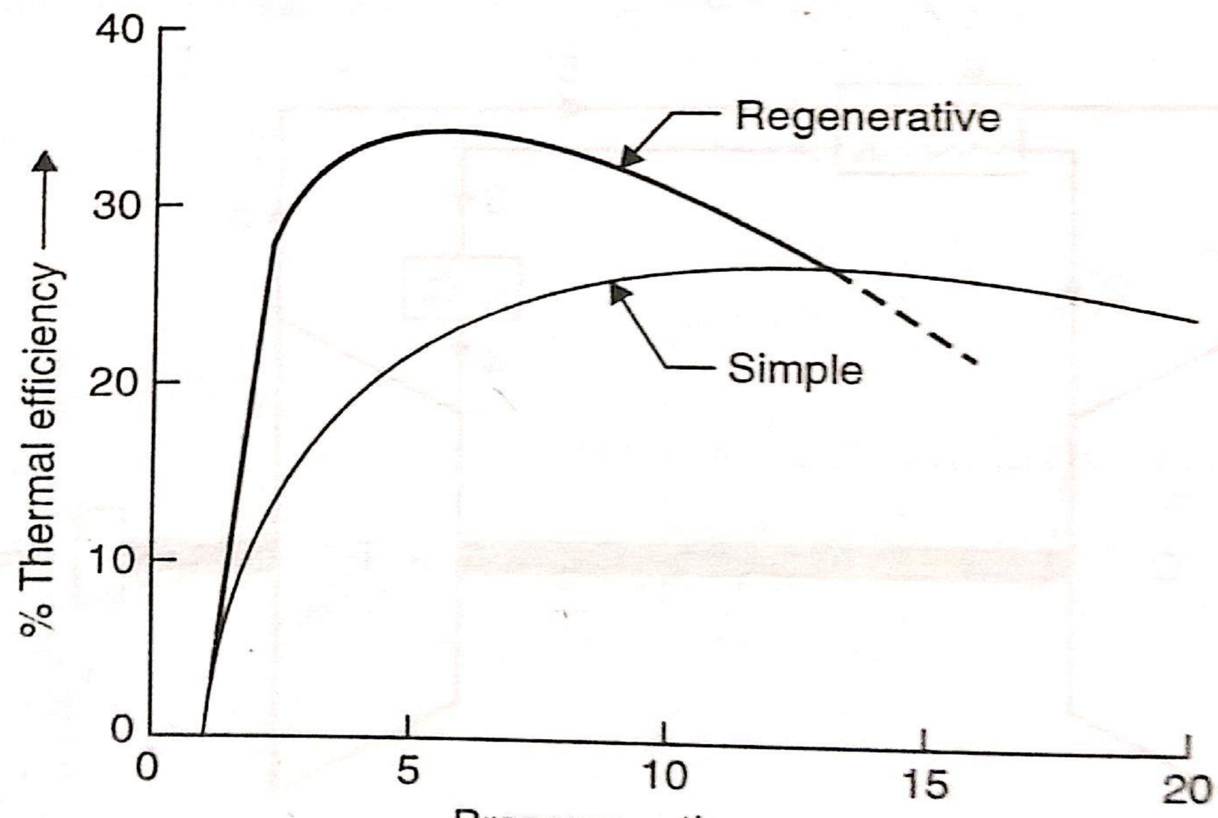


Fig. 5.10. (*a*) *T-s* diagram for the unit.

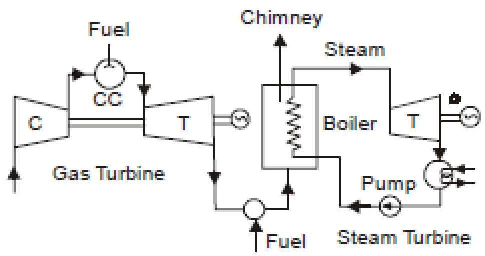


9. Explain in detail about combined cycle power plant.

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.

10. Explain in detail about integrated gasifier based combined cycle systems.

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 byproducts. 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 results in improved efficiency compared to conventional pulverized coal.

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

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

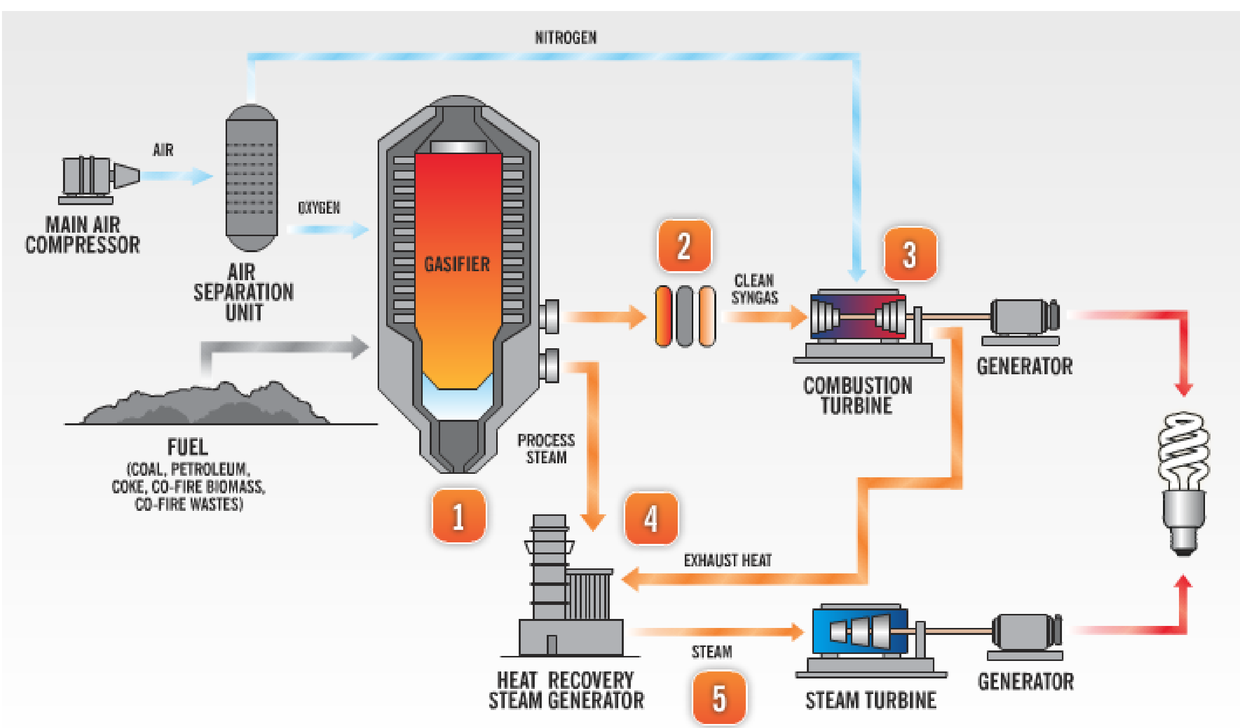
Gasification plant including preparation of the feedstock.Raw-gas cooling via water quench or heat recovery systems.Optional water-gas shift reactor

Gas purification system with sulfur removal/recovery and optional CO_2 removal

Air separation unit.Combined cycle unit with gas turboset, heat recovery steam generator and steam turboset.

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, COS, 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 inerting 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.



UNIT III – NUCLEAR POWER PLANTS
PART A

1. **What are isotopes?**
   Some elements have the same number of protons in the nucleus but different number of neutrons. As a result, these elements have the same atomic number but different mass number. They are known as the isotopes of an element.
2. **Name the different types of fuels used in nuclear reactors**.
   Uranium, Plutonium & Thorium.
3. **What is binding energy?**
   The energy released at the moment of combination of two neutrons to form nucleus of an atom is called binding energy.
4. **Name the three moderators commonly used in nuclear reactor.**
   Heavy water (D_20), water (H_20), Beryllium, Graphite, Helium are commonly used moderators.
5. **Give the requirements of chain reaction.**
   i) The chain reaction will become self – sustaining.
   ii) At least one fission neutron becomes available for causing fission of another nucleus.
   iii) The neutrons emitted in fission must have adequate energy to cause fission of other nuclei
   iv) The fission process must liberate the energy
   v) It must be possible to control the rate of energy liberation
6. **What is moderating ratio?**
   K=Number of neutrons of any one generation/ Number of neutrons of immediately preceding generation.
7. **What is nuclear fission? (Nov/Dec 2013)**
   Nuclear fission is the process of splitting the nucleus in to two almost equal fragments accompanied by the release of heat.
8. **Explain the function of nuclear reactor.**
   A nuclear reactor is similar to the furnace of a steam power plant. In nuclear reactor, heat is produced due to nuclear fission chain reaction.
9. **What are the essential components of nuclear reactor?**
   1.Nuclear fuel 2. Moderator 3. Control rods 4. Reflectors 5. Reactor vessel 6. Biological shielding 7. Coolant
10. **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.
11. **Why is shielding of nuclear reactor necessary?**
    During fission of nuclear fuel, alpha particles, beta particles, deadly gamma rays and neutrons are produced. Shielding is essential to protect the operating men from the harmful effects. A protection must be provided against them. Thick layers of lead or concrete are provided round the reactor for stopping the gamma rays. Thick layers of metals or plastics are sufficient to stop the alpha and beta particles.
12. **Define the term Breeding**.
    The process of producing fissionable material from a fertile material such as uranium 238 (U^{238}) and thorium 232 (Th^{232}) by neutron absorption is known as breeding.
13. **How do you cater for safety of nuclear power plant? (Nov/Dec 2015)**

a. Radiological protection of workers
b. Dose limit
c. Radioactive waste management

14. What is LMFBR? Why is a liquid metal the preferred coolant in a fast breeder reactor? (May/June2013)

LMFBR stands for liquid metal fast breeder reactor. The liquid metal is always preferred as the coolant since it is an excellent heat transfer material.

15. List some of the disadvantages of nuclear power plant.

i) It is not suitable for variable load conditions
ii) It requires high initial cost
iii) It requires well trained personnel.
iv) If the accident occurs large amount of radioactive material could be released in to the environment.

16. What is a gas cooled-nuclear reactor?

A nuclear reactor in which gaseous coolants such as air, hydrogen, helium or carbon di-oxide is used as a coolant is called gas cooled reactors

17. What are the advantages of using CO_2 as coolant?

Gases do not react chemically with the structural materials, Gas can attain any temperature for a particular pressure, they do not absorb neutron, the leakage of gas will not affect the reactivity, the gas coolant provides best neutron economy

18. What are the advantages of breeder reactors?

It gives high power density than any other reactor, High breeding is possible, High burn-up of fuel is achievable, No moderator is required, High efficiency can be obtained.

19. Write about atomic number?

The nucleus contains protons and neutrons. The number of protons in a given atom is an atomic number (Z). The atomic number for H is 1 and He -is 2.

20. What is the difference between the fission and fusion?

Sl.No.	Fission	Fusion
1	It is the process of splitting a heavy nucleus in to 2 fragments with liberation of large amount of energy.	It is the process of combining of 2 nuclei in to single nucleus with liberation of large amount of energy
2	The process results in the emission of radioactive rays.	The process does not emit any kind of radioactive rays.
3	The process gives rise to chain reaction.	The process does not give rise to chain reaction.
4	During fission neutrons are emitted	During fusion protons are emitted.

21. What are the desirable properties of a good moderator? (May/June 2014)

It must be as light as possible It must slowdown the neutron as quick as possible, It must have resistance to corrosion .It must have good machinability, It must have good conductivity and high melting point

22. Define multiplication factor of a fission process.

$$k = \frac{\text{Number of neutrons of any one generation}}{\text{Number of neutrons of immediately preceding generation.}}$$

23. What are the desirable properties of a coolant?

It should not absorb neutron, Have high chemical and radiation stability, Non-corrosive, Have high boiling point Non-toxic.

24. 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.

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

1. Fuel processing is simple, 2. The use of $C0_2$ as coolant completely eliminates the possibility of explosion in reactor. 3. No corrosion problem

26. Name the coolants commonly used for fast breeder reactors?

Liquid metal (Na (or) Na K), Helium (He), Carbon dioxide.

27. What is the necessity of Automatic controls for feed water?

The electrical load on power plant varies in an irregular manner. The automatic control provided at a steam power plant successfully meets over the variable load. The automatic control for feed water is necessary sine the supply of feed water depends upon plant load.

28. What is mass defect? (May/June 2013)

Mass defect refers to the difference in mass between of an atom and the sum of the masses of the protons, neutrons, and electrons of the atom. This mass is typically associated with the binding energy between nucleons.

29. What do you understand by radioactive decay? (Nov/Dec 2014)

Radioactive decay is the spontaneous breakdown of an atomic nucleus resulting in the release of energy and matter from the nucleus. Remember that a radio isotope has an unstable nucleus that does not have enough binding energy to hold the nucleus together.

PART-B

1.Explain in detail about the nuclear radioactivity and its effects.

A radioactive atom is one that spontaneously emits energetic particles or waves (known as radiation). This radiation is emitted when an unstable (i.e. radioactive) nucleus transforms to some other nucleus or energy level. Imagine a big ball made of magnets that's spinning really fast. Sometimes a few pieces of the magnet will shoot out and hit the wall. That's kind of what radiation is like. As it applies to nuclear energy, many materials created during the operation of a reactor are unstable. As they decay over varying lengths of time (from microseconds to hundreds of thousands of years), they emit energetic particles or waves. The energy carried by this radiation is often sufficient to cause damage to biological cells and is therefore a health risk. Thus, radiation is the primary cause of safety concerns related to nuclear energy.

Types of Nuclear Radiation

Alpha Particles

Named alpha because they were the first to be discovered, these particles are made up of 2 protons and 2 neutrons: the helium nucleus. Often, large atoms decay by emitting an energetic alpha particle. These particles are relatively large and positively charged, and therefore do not penetrate through matter very well. A thin piece of paper can stop almost any alpha particle. However, the particles cause extreme damage of materials that they stop in by displacing atoms as they slow. Paper under sustained alpha-irradiation would degrade.

Beta Particles

Beta particles are energetic electrons that are emitted from the nucleus. They are born when a neutron decays to a proton. Since neutrons are neutral particles and protons are positive, conservation of charge requires a negatively charged electron to be emitted. Some isotopes decay by converting a proton to a neutron, thus emitting a positron (an anti-electron). These particles can penetrate matter more than can alpha particles, and it takes a small aluminum plate to stop most beta particles.

Gamma rays

Gamma rays are photons that are emitted from the nucleus. Often an atom in an excited state will de-excite by emitting a gamma ray. Gamma rays are similar to light waves and x-rays, except they are usually much higher frequency and consequently, more energetic. This radiation has no charge, and can penetrate most matter easily, requiring lead bricks for shielding.

Effects of Radiation on Living Matter

Prolonged exposure to radiation often has detrimental effects on living matter. This is due to radiation's ionizing ability, which can damage the internal functioning of cells. Radiation either ionizes or excites atoms or molecules in living cells, leading to the dissociation of molecules within an organism. The most destructive effect radiation has on living matter is ionizing radiation on DNA. Damage to DNA can cause cellular death, mutagenesis (the process by which genetic information is modified by radiation or chemicals), and genetic transformation. Effects from exposure to radiation include leukemia, birth defects, and many forms of cancer.

Most external radiation is absorbed by the environment; for example, most ultraviolet radiation is absorbed by the ozone layer, preventing deadly levels of ultraviolet radiation to come in contact with the surface of the earth. Sunburn is an effect of UV radiation damaging skin cells, and prolonged exposure to UV radiation can cause genetic information in skin cells to mutate, leading to skin cancer.
Alpha, beta, and gamma rays also cause damage to living matter, in varying degrees. Alpha particles have a very small absorption range, and thus are usually not harmful to life, unless ingested, due to its high ionizing power. Beta particles are also damaging to DNA, and therefore are often used in radiation therapy to mutate and kill cancer cells. Gamma rays are often considered the most dangerous type of radiation to living matter. Unlike alpha and beta particles, which are charged particles, gamma rays are instead forms of energy. They have large penetrating range and can diffuse through many cells before dissipating, causing widespread damage such as radiation sickness. Because gamma rays have such high penetrating power and can damage living cells to a great extent, they are often used in irradiation, a process used to kill living organisms.

1. **(a)Explain different types of nuclear reactions and initiations of nuclear reactions. (MAY/JUN 2013)**

A process that occurs as a result of interactions between atomic nuclei when the interacting particles approach each other to within distances of the order of nuclear dimensions (≃10^{-12} cm). While nuclear reactions occur in nature, understanding of them and use of them as tools have taken place primarily in the controlled laboratory environment. In the usual experimental situation, nuclear reactions are initiated by bombarding one of the interacting particles, the stationary target nucleus, with nuclear projectiles of some type, and the reaction products and their behaviors are studied.
Types of nuclear interaction
As a generalized nuclear process, consider a collision in which an incident particle strikes a previously stationary particle, to produce an unspecified number of final products. If the final products are the same as the two initial particles, the process is called scattering. The scattering is said to be elastic or inelastic, depending on whether some of the kinetic energy of the incident particle is used to raise either of the particles to an excited state. If the product particles are different from the initial pair, the process is referred to as a reaction.
The most common type of nuclear reaction, and the one which has been most extensively studied, involves the production of two final products. Such reactions can be observed, for example, when deuterons with a kinetic energy of a few megaelectronvolts are allowed to strike a carbon nucleus of mass 12. Protons, neutrons, deuterons, and alpha particles are observed to be emitted, and reactions.

(1) $2{}^2_1H + {}^{12}_6C \rightarrow {}^2_1H + {}^{12}_6C$

(2) ${}^2_1H + {}^{12}_6C \rightarrow {}^1_1H + {}^{13}_6C$

(3) $2{}^2_1H + {}^{12}_6C \rightarrow {}^2_1H + {}^{12}_6C$

(4) $2{}^2_1H + {}^{12}_6C \rightarrow {}^2_1H + {}^{12}_6C$

are responsible. In these equations the nuclei are indicated by the usual chemical symbols; the subscripts indicate the atomic number (nuclear charge) of the nucleus, and the superscripts the mass number of the particular isotope. These reactions are conventionally written in the compact notation ${}^{12}C(d,d){}^{12}C$, ${}^{12}C(d,p){}^{13}C$, ${}^{12}C(d,n){}^{13}N$, and ${}^{12}C(d,\alpha){}^{10}B$, where d represents deuteron, p proton, n neutron, and α alpha particle. In each of these cases the reaction results in the production of an emitted light particle and a heavy residual nucleus. If the residual nucleus is formed in an excited state, it will subsequently emit this excitation energy in the form of gamma rays or, in special cases, electrons.

(b)Explain different methods of nuclear waste disposal with neat sketch. (MAY/JUN 2013)

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 proposed legislation 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 byproducts placed in the repository. A geologic repository will be required for all fuel cycles.

Low-Level Radioactive Waste

Low-level waste is a byproduct of the beneficial uses of a wide range of radioactive materials. These include electricity generation, medical diagnosis and treatment, and various other medical processes.

2. **Explain the nuclear fission and nuclear fusion**

   Nuclear fusion and nuclear fission are different types of reactions that release energy due to the presence of high-powered atomic bonds between particles found within a nucleus. In fission, an atom is split into two or more smaller, lighter atoms. Fusion, in contrast, occurs when two or more smaller atoms fuse together, creating a larger, heavier atom.

Parameter	Nuclear Fission	Nuclear Fusion
Definition	Fission is the splitting of a large atom into two or more smaller ones.	Fusion is the fusing of two or more lighter atoms into a larger one.
Natural occurrence of the process	Fission reaction does not normally occur in nature.	Fusion occurs in stars, such as the sun.
Byproducts of the reaction	Fission produces many highly radioactive particles.	Few radioactive particles are produced by fusion reaction, but if a fission "trigger" is used, radioactive particles will result from that.

Conditions	Critical mass of the substance and high-speed neutrons are required.	High density, high temperature environment is required.
Energy Requirement	Takes little energy to split two atoms in a fission reaction.	Extremely high energy is required to bring two or more protons close enough that nuclear forces overcome their electrostatic repulsion.
Energy Released	The energy released by fission is a million times greater than that released in chemical reactions, but lower than the energy released by nuclear fusion.	The energy released by fusion is three to four times greater than the energy released by fission.
Energy production	Fission is used in nuclear power plants.	Fusion is an experimental technology for producing power.
Fuel	Uranium is the primary fuel used in power plants.	Hydrogen isotopes (Deuterium and Tritium) are the primary fuel used in experimental fusion power plants.
Reaction	${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{139}_{56}Ba + {}^{94}_{36}Kr + 3\,{}^{1}_{0}n$	$4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{+1}e$

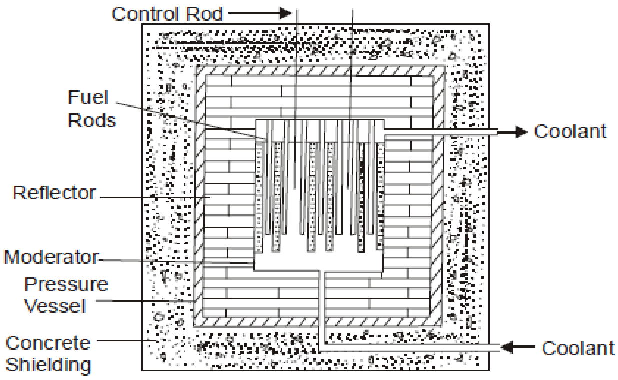
3. List out the various components of nuclear power plant and explain briefly

A nuclear reactor is an apparatus in which heat is produced due to nuclear fission chain reaction.

Fig shows the various parts of reactor, which are as follows :

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

Fig. shows a schematic diagram of nuclear reactor.



Nuclear fuel

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

U233, U235 and Pu239.

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

U238 — 99.3%

U235 — 0.7%

U234 — Trace

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

Moderator

In the chain reaction the neutrons produced are fast moving neutrons. These fast moving neutrons are far less effective in causing the fission of U235 and try to escape from the reactor. To improve the utilization of these neutrons their speed is reduced. It is done by colliding them with the nuclei of other material which is lighter, does not capture the neutrons but scatters them. Each such collision causes loss of energy, and the speed of the fast moving neutrons is reduced. Such material is called Moderator. The slow neutrons (Thermal Neutrons) so produced are easily captured by the nuclear fuel and the chain reaction proceeds smoothly. Graphite, heavy water and beryllium are generally used as moderator.Reactors using enriched uranium do not require moderator. But enriched uranium is costly due to processing needed.

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. Solid moderators should also possess good strength and machinability.

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.

Control Rods.

The Control and operation of a nuclear reactor is quite different frorn a fossil and fuelled (coal or oil fired) furnace. The furnace is fed continuously and the heat energy in the furnace is controlled by regulating the fuel feed, and the combustion air whereas a nuclear reactor contains as much fuel as is sufficient to operate a large power plant for some months. The consumption of this fuel and the power level of the reactor depends upon its neutron flux in the reactor core. The energy produced in the reactor due to fission of nuclear fuel during chain reaction is so much that if it is not controlled properly the entire core and surrounding structure may melt and radioactive fission products may come out of the reactor thus making it uninhabitable. This implies that we should have some means to control the power of reactor. This is done by means of control rods.

Reflector

The neutrons produced during the fission process will be partly absorbed by the fuel rods, moderator, coolant or structural material etc. Neutrons left unabsorbed will try to leave the reactor core never to return to it and will be lost. Such losses should be minimized. It is done by surrounding the reactor core by a material called reflector which will send the neutrons back into the core. The returned neutrons can then cause more fission and improve the neutrons economy of' the reactor. Generally the reflector is made up of graphite and beryllium.

Reactor vessel

It is a. strong walled container housing the cure of the power reactor. It contains moderator, reflector, thermal shielding and control rods.

Biological shielding

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

Coolant

Coolant flows through and around the reactor core. It is used to transfer the large amount of heat produced in the reactor due to fission of the nuclear fuel during chain reaction. The coolant either transfers its heat to another medium or if the coolant used is water it takes up the heat and gets converted into steam in the reactor which is directly sent to the turbine. Coolant used should be stable under thermal condition. It should have a low melting point and high boiling point. It should not corrode the material with which it comes in contact. The coolant should have high heat transfer coefficient. The radioactivity induced in coolant by the neutrons bombardment should be nil. The various fluids used as coolant are water (light water or heavy water), gas (Air, CO_2,Hydrogen, Helium) and liquid metals such as sodium or mixture of sodium and potassium and inorganic and organic fluids.

Reactor core

Reactor core consists of fuel rods, moderator and space through which the coolant flows.

4. **Write about principle of nuclear energy? List the nuclear power stations in India and explain any one in detail. (NOV/DEC 2014)**

Stars were formed by clouds of hydrogen collapsing under their own weight, with the energy released making them hot enough to start combining hydrogen atoms into helium. This process too released energy (whether it can be reproduced usefully on Earth remains to be seen) and still powers the emission of light and heat from the sun. In time it went further, forming higher element though releasing much less energy per step. In fact, to make elements beyond a certain point would require a great input of energy, which could however be supplied by explosions in dying stars. So were formed the heavier elements such as uranium, which were scattered into space and available to be gathered into later generations of stars and planets.

Atomic structure and radioactivity

On the simplest view, atoms comprise three types of particle:

- protons which carry a single positive electrical charge;
- neutrons which are electrically neutral; and
- electrons with a single negative charge.

Protons and neutrons are almost two thousand times heavier than electrons, and are confined to a nucleus of about a ten-thousandth of the atomic diameter; the rest of the space is occupied by a surrounding cloud of electrons equal in number to the protons when the atom is complete. Thus atoms can interact directly only through the electrons, and chemical identity is determined by the number of electrons or protons - the atomic number.

Protons repel each other electrically, so apart from hydrogen with only a single proton, all nuclei need a similar or larger number of neutrons to hold them together. In fact the heavier the atom, the greater the proportion of neutrons needed. Beyond lead, all elements are to some extent unstable, although atoms may last for billions of years before disintegrating.

Because chemical identity depends on the protons, the number of neutrons is not necessarily the same in all atoms of an element, giving rise to isotopes of the element. The number cannot vary very widely without causing instability: too many neutrons and one may convert to a proton, emitting an electron as a beta-particle to balance the charge; too few, and a proton may convert to a neutron by emitting a positron (anti-electron) or absorb an electron from the surrounding cloud. All such changes are to a state of lower energy within the atom, with the excess divided between the remaining nucleus, emitted material particles and electromagnetic radiation - gamma rays.

The heaviest elements have two other possible ways of decaying: they may emit a helium nucleus or alpha-particle, or split into two major parts - fission.

Tarapur Atomic Power Station

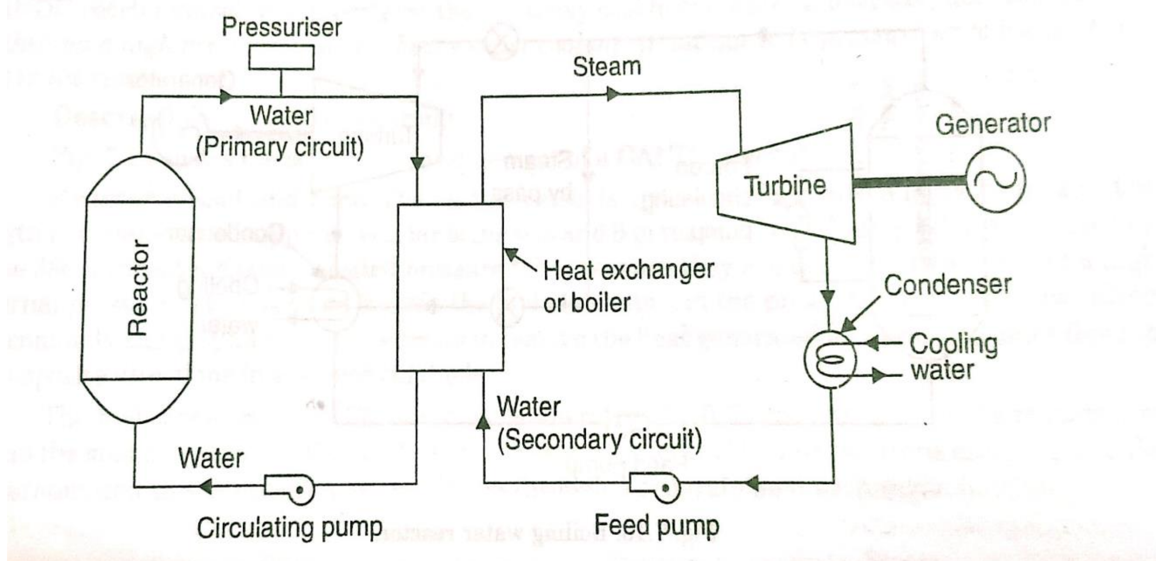
Tarapur Atomic Power Station (T.A.P.S.) is located in Tarapur, Maharashtra town of (India). It was initially constructed with two Boiling water reactor (BWR) units of 210 MWe each initially by Bechtel and GE under the 1963 123 Agreement between India, the United States, and the International Atomic Energy Agency (IAEA). The capacity of units 1 and 2 was reduced to 160 MWe later on due to technical difficulties. Units 1 and 2 were brought online for commercial operation on 28 October 1969. These were the first of their kind in Asia. More recently, an additional two Pressurised heavy water reactor (PHWR) units of 540 MW each were constructed by L & T and Gammon India, seven months ahead of schedule and well within the original cost estimates. Unit 3 was brought online for commercial operation on 18 August 2006, and unit 4 on 12 September 2005.

The Boiling water reactors (BWRs) at Tarapur 1 and 2 units are similar to the reactors involved in the Fukushima Daiichi nuclear disaster. The reactors' age and old design have raised safety concerns and according one local leader, the two reactors have already been in operation for 16 years more than their design lives. The reactors were originally designed for 40 years at full capacity i.e. 210 MWe. But due to technical problems in the reactor that arose later on, the capacity had to be reduced to 160 MWe. Hence according to the experts and officials of the plant, their corrected life for unit 1 and 2 is around 23 and 24 years respectively as of March 2012.

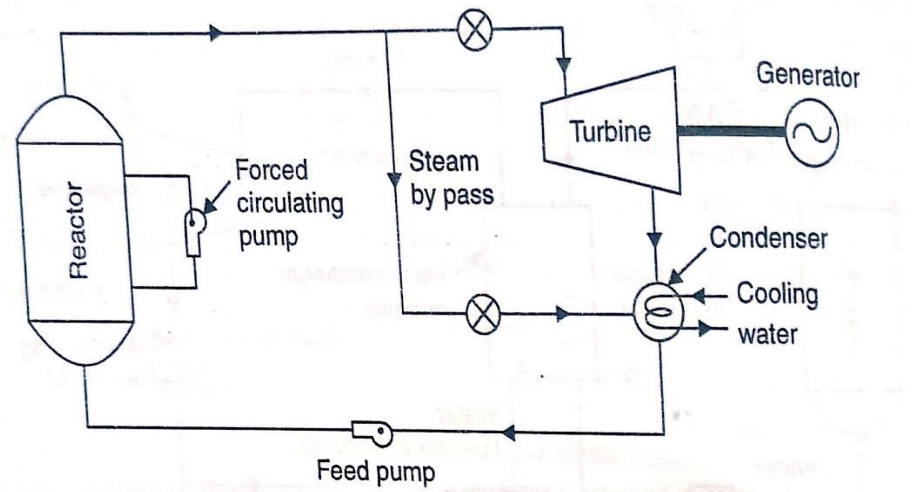
Tarapur nuclear plant has received the highest safety awards given to any electricity producing plants in India.

In 2007, Atomic Energy Regulatory Board (AERB) evaluated seismic safety features at Tarapur 1 and 2 and reported many shortfalls, following which NPCIL installed seismic sensors. In 2011, AERB formed a 10 member committee, consisting of experts from Indian Institutes of Technology (IIT) and India Meteorological Department (IMD), to assess the vulnerability of the Tarapur to earthquakes and tsunamis. A. Gopalakrishnan, former director of AERB, said that Tarapur 1 and 2 reactors are much older than the reactors involved in the Fukushima nuclear accident and argued that they should be immediately decommissioned.

5. **Explain the working of following:**
   1. **Pressurized water reactor (PWR) (MAY/JUN 2013)**

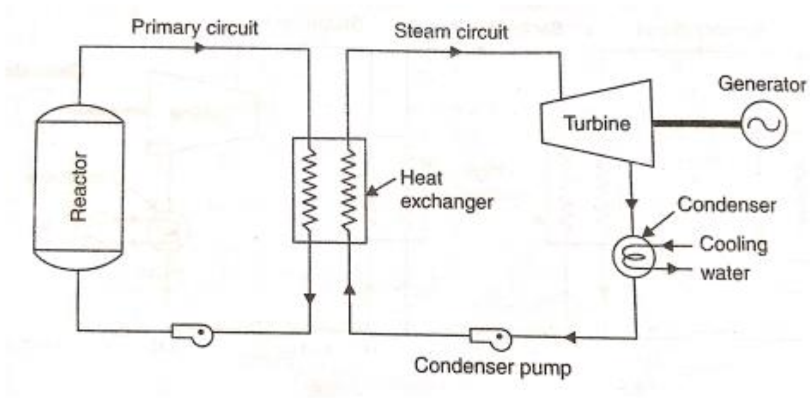


   2. **Boiling water reactor (BWR) (MAY/JUN 2013) (MAY/JUN 2014) (NOV/DEC 2014)**

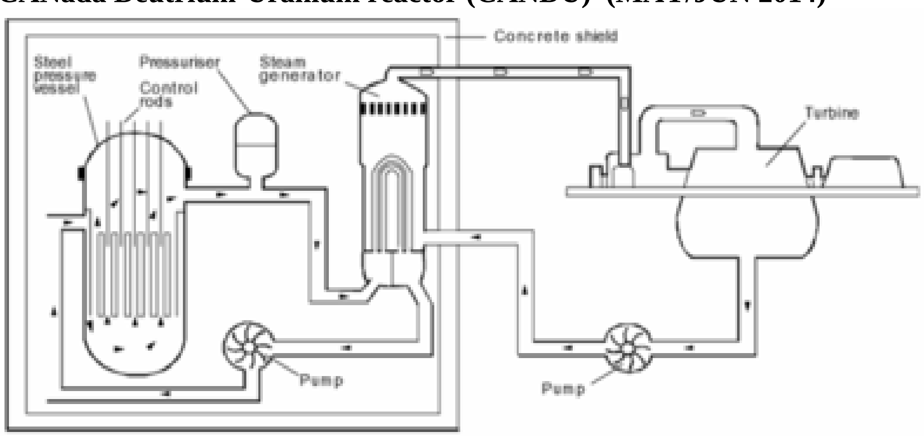


   3. **Gas-cooled and Liquid metal cooled reactors**

Gas Cooled Reactor



4. **CANada Deutrium-Uranium reactor (CANDU) (MAY/JUN 2014)**



6. **Comparison of nuclear power reactors**
   Compare the nuclear fuel, moderator, coolant, control rods used in PWR, BWR,CANDU reactor, FBR, Liquid metal cooled reactor. (tabulated form is preferred)
7. **Explain the nuclear power plant challenges**.

Nuclear Power plants generate large quantities of highly radioactive material. This is due to the left over isoptopes (atoms) from the splitting of the atom and the creation of heavier atoms, like plutonium, which the Nuclear Power plant does not utilise. 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

Accidents at Nuclear Power Plants

Like any large scale industrial activity, there have been numerous accidents and mistakes at Nuclear Power plants and reprocessing facilities. A partial list of these is available from this wikipedia link.

However two large accidents have had the greatest impact on global consciousness regarding Nuclear Power. These are:

- Three Mile Island in 1979.
- Chernobyl in 1986.

Here are additional links that describe the after effects of the Chernobyl accident.

- Health effects of the Chernobyl accident
- Chernobyl Now

The Chernobyl accident resulted from a lack of "safety culture" at the plant, design flaws in the RBMK reactor and a violation of procedure. The lessons learned from Chernobyl and the phasing out of the older reactor design means that an accident of this type is most unlikely to occur again.

Since the contained meltdown at Three Mile Island reactor, many improvements have been made to Nuclear Reactor design. The third generation reactors currently proposed are designed so that a failure leading to a contained core melt-down, (which would destroy the commercial value of the reactor) should occur at the rate of 1 in 2-million reactor-years. If the cost of a new reactor is 2 billion dollars and operates for 60 years, this risk would amount to an extra $80,000 insurance.

After the events on September 11th, 2001, many people were reasonably concerned about the safety of nuclear power plants from terrorist activities. However the containment facilities of nuclear reactors and the structures holding spent fuel rods are very strong and make hard terrorist targets

Radiation

Thus we can see that during our normal daily activities we are continually exposed to ionising radiation both from natural and human-made sources. The passage of ionising radiation through the body may produce adverse biological effects. The effects of concern are primarily, although not solely, due to damage to the genetic material inside the cell; the DNA or `double-helix' molecule that carries genetic information. The current scientific data suggests that there is no safe minimum, or threshold, for adverse radiation effects on the DNA of biological systems and that even small doses can produce consequences for the organism. The low-dose response of biological systems it believed to be linear - that is, smaller doses of radiation produce a proportionately smaller risk of adverse effects like a straight-line graph.

The biological effects fall into the following categories,

- Cell Death or Apoptosis
- Cancer Induction
- Genetic Damage to Future Generations
- Dose-Response Tissue Reactions

Storage and Disposal of High Level Nuclear Reactor Waste

Since the spent nuclear reactor (SNF) fuel is highly radioactive initially it is too dangerous to handle and thus it is very important to shield the radioactivity from humans and the environment. The radioactive material in the SNF generally falls into three categories: (1) un-reacted fuel, usually uranium, (2) fission products, and (3) activation products, most notably plutonium. Because of the nature of radioactivity, on a per-atom or by-weight basis the fission products are by far the most radioactive, and have the shortest half-life. The un-reacted uranium and the plutonium have vastly longer half-lives, but are correspondingly less radioactive. Once the SNF has been removed from the nuclear reactor it is placed in interim storage at the reactor site. Usually this consists of putting the nuclear waste into large pools of water. The water cools the radioactive isotopes and shields the environment from the radiation. Nuclear waste is typically stored in these supervised pools between 20-40 years. As the SNF ages the radioactivity decreases, reaching the point where it does not need to be water cooled and can be placed in dry storage facilities. Throughout this time there is a great reduction in heat and radioactivity and this makes handling of nuclear waste safer and easier.

After this "cooling off" period the high level waste can be handled in different ways. It can be reprocessed then disposed of permanently or directly disposed permanently in a geological repository.

8. List out the advantages and disadvantages of the nuclear power plant.

ADVANTAGES OF NUCLEAR POWER PLANT

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

1. Space requirement of a nuclear power plant is less as compared to other conventional power plants are of equal size.

2. A nuclear power plant consumes very small quantity of fuel. Thus fuel transportation cost is less and large fuel storage facilities are not needed Further the nuclear power plants will conserve the fossil fuels (coal, oil, gas etc.) for other energy need.

3. There is increased reliability of operation.

4. Nuclear power plants are not effected by adverse weather conditions.

5. Nuclear power plants are well suited to meet large power demands. They give better performance at higher load factors (80 to 90%).

6. Materials expenditure on metal structures, piping, storage mechanisms are much lower for a nuclear power plant than a coal burning power plant.

For example for a 100 mW nuclear power plant the weight of machines and mechanisms, weight of metal structures, weight of pipes and fittings and weight of masonry and bricking up required are nearly 700 tonnes, 900 tonnes, 200 tonnes and 500 tonnes respectively whereas for a 100 mW coal burning power plant the corresponding value are 2700 tonnes, 1250 tonnes, 300 tonnes and 1500 tonnes respectively. Further area of construction site required aired for 100 mW nuclear power plant is 5 hectares whereas was for a 100 mW coal burning power plant the area of construction site is nearly 15 hectares.

7. It does not require large quantity of water.

DISADVANTAGES

1. Initial cost of nuclear power plant is higher as compared to hydro or steam power plant.

2. Nuclear power plants are not well suited for varying load conditions.

3. Radioactive wastes if not disposed carefully may have bad effect on the health of workers and other population.

In a nuclear power plant the major problem faced is the disposal of highly radioactive waste in form of liquid, solid and gas without any injury to the atmosphere. The preservation of waste for a long time creates lot of difficulties and requires huge capital.

4. Maintenance cost of the plant is high.

5. It requires trained personnel to handle nuclear power plants.

9. Explain the safety measures required for nuclear power plant.

Safety in nuclear power plants (NPPs) in India is a very important topic and it is necessary to dissipate correct information to all the readers and the public at large. In this article, I have briefly described how the safety in our NPPs is maintained. Safety is accorded overriding priority in all the activities. NPPs in India are not only safe but are also well regulated, have proper radiological protection of workers and the public, regular surveillance, dosimetry, approved standard operating and maintenance procedures, a well-defined waste management methodology, proper well documented and periodically rehearsed emergency preparedness and disaster management plans. The NPPs have occupational health policies covering periodic medical examinations, dosimetry and bioassay and are backed-up by fully equipped Personnel Decontamination Centers manned by doctors qualified in Occupational and Industrial Health. All the operating plants are ISO 14001 and IS 18001 certified plants. The Nuclear Power Corporation of India Limited today has 17 operating plants and five plants under construction, and our scientists and engineers are fully geared to take up many more in order to meet the national requirements.

RADIOLOGICAL PROTECTION OF WORKERS

Radiological protection of the workers is ensured by the following measures:

Design aspects

The design considerations that have a bearing on radiation protection in NPPs include:

1. Proper design, plant layout and adequate shielding:
   Design values are prescribed for the radiation level at a specified distance from the equipment/components as well as for the general radiation fields in different areas of the plant. The plant layout is such that the areas are segregated according to their radiation levels and contamination potential. The design, layout of areas and equipment, maintenance approach and shielding, etc. are made such that the collective dose to the station personnel would be "as low as reasonably achievable" (ALARA) and meet the specified regulation on collective dose.
2. Limits of air contamination levels in different zones of the plant:
   Provision of ventilation is made such that in full-time occupancy areas of the plant, the airborne contamination are maintained below 1/10 Derived Air Concentration.
3. Source control by proper selection of materials/components:
   Materials used in plant systems are selected in such a way that the activation products arising from the base material or the impurity content do not significantly contribute to radiation exposures.
4. Design limit for collective dose:

A limit on the collective dose is specified at the design stage of each NPP so that adequate provisions for radiation protection are made in the design of the plant to keep radiation levels in different areas below design levels.

Dose limits

The AERB has prescribed the following dose limits for exposures to ionizing radiations for occupational workers:

1. Effective dose (whole body)
   1.1 Twenty Milli- Sievert (mSv)/year averaged over five consecutive years, calculated on a sliding scale of 5 years. (The cumulative effective dose in the same 5-year period shall not exceed 100 mSv.)
   1.2 A maximum of 30 mSv in any year.
2. Equivalent dose (individual organs)
   2.1 Eye lens 150 mSv/year.
   2.2 Skin 500 mSv/year.
   2.3 Extremities 500 mSv/year (hands and feet).
3. Pregnant woman
   3.1 Equivalent dose limit to the surface of the woman's lower abdomen (for the remaining period of pregnancy) – 2 mSv.
   3.2 Annual Limit on Intake (ALI) for radionuclides – 0.05 ALI. (For the remaining period of pregnancy.)
4. Apprentices and students (above the age of 16 years)
   Effective dose (whole body): 6 mSv/year.
   Equivalent dose (individual organs)
   4.1 Eye lens 15 mSv/year.
   4.2 Skin 50 mSv/year.

4.3 Extremities 50 mSv/year (hands and feet).

RADIOLOGICAL PROTECTION OF PUBLIC

The following measures ensure the radiological protection of the public due to the operation of a NPP.

Design aspects

1. Dose limits for members of the public
   The sources contributing to generation of radioactive solid, liquid and gaseous wastes and their release to the environment are examined with respect to minimization of waste at the source at the design stage itself. The dose to public resulting from these releases are assessed and, if necessary, appropriate design measures to reduce these releases are introduced.
2. Exposure criteria for accident analysis
   The design analysis should demonstrate that the calculated doses to the members of the public at the site boundary under design basis accident condition should not exceed the reference doses prescribed by the AERB.

Dose limit

The AERB has prescribed the following limits to a member of the public at exclusion distance due to releases of radioactive effluents from nuclear facilities at a site:.

Effective dose (whole body): 1 mSv (1000 μSv)/year.

Equivalent dose (individual organs)

1. Eye lens 15 mSv/year.
2. Skin 50 mSv/year.

UNIT IV– POWER FROM RENEWABLE ENERGY

PART A

1. **Define the term “Hydrology”.**
   Hydrology is the study of science concentrating the properties of the earth’s water & the movement of earth with respect to land.
2. **For which purposes hydro projects are developed?**
   i) To meet the power needs during peak & off peak requirements.
   ii) To run of the river
   iii) To obtain a clean process of power generation
   iv) To avoid suffering from the limitation of inflation on account of fuel consumption in the long run.
3. **What is the purpose of using dams?**
   The dam is used in hydro power plants to increase the height of water level there by increasing the capacity of reservoir.
4. **Define Run-off?**
   Runoff isdefined as the movement of land water to the oceans mainly in the form of rivers, lakes & streams.
5. **List any 4 advantages of hydro power.(May/June2013)**
   i**)** Water is the cheapest & renewable source of energy
   ii) There is no air pollution
   iii) There is no problem of handling the fuel & ash
   iv) Maintenance cost is low
6. **What are the types of water turbines?**
   - According to action of water flow: i) Impulse turbine ii) Reaction turbine
   - According to direction water flow: i) Tangential flow turbine ii) Radial flow turbine iii) axial flow turbine
   - According to head : i) High Head ii) Medium Head iii) Low Head
   - According to Specific speed : i) High Specific speed ii) Medium Specific speed iii) Low Specific speed

7. What is the function of draft tube?

The draft tube is used to regain the kinetic energy of water coming out of reaction turbine. It enables the reaction turbine to be placed over tailrace level.

8. What is a surge tank?

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.

9. What do you understand by zero energy houses?

It is also known as zero net energy building. It refers a building with zero net energy consumption & zero carbon emissions annually.

10. List out the advantages of tidal power plant.

i) It is free from pollution
ii) Large area of land is not required
iii) It is much superior to hydro power plants as it is totally independent of rain
iv) It is inexhaustible

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

i) The tidal ranges are highly variable & therefore, turbines have to work on a wide range of head variation.
ii) Construction in sea is found difficult.
iii) More corrosion will occur due to corrosive sea water.
iv) The power transmission cost is high because the tidal power plants are located away from load centres.

12. What are factors to be considered for suitable site selection of tidal power plant?

i) The location of the plant must be near the ocean
ii) Site selection for the plant should be in such a way that tidal range of ocean is large
iii) The sluice gates of dam should allow water to or from basins
iv) There should also be a nearby demand for electricity, otherwise the energy which is produced has to be stored in some way or transported to where it is needed which increases the cost.

13. What are the applications of solar photovoltaic system?

i) Water pumping sets for micro irrigation & drinking water supply
ii) Weather monitoring
iii) Railway signaling equipment

14. What are classifications of geothermal energy?

i) Hydrothermal convective systems, ii) Geo pressure resources, iii) Petro thermal or Hot dry rocks, iv) Magma resources and v) volcanoes

15. What is fuel cell?

It can be defined as an electrochemical device in which the chemical energy of a fuel is directly converted in to electrical energy.

$$H_2 + 1/2O_2 \longrightarrow H_2O + \text{Electrical Energy} + \text{Heat Energy}$$

16. Mention the various disadvantages of hydro power plants.

1. Initial cost is high
2. Power generation is dependent quantity of water available.
3. It takes longer time for construction
4. Hydro power plants are generally located away from load centre, it leads to more transmission losses.

17. What are the advantages of pumped storage plant?

1. The pumped storage plant can be constructed near the load centre easily than conventional hydro (or) thermal plant

2. Its capacity is not controlled by river flow

3.Since storage is done usually on daily / weekly basis, the size of the reservoir required is small

4. The cost of electricity during high demand period is much more than during off- peak hours. Thus the potential for high cost energy is increased by pumping the water back at the cost of low value energy.

18. What are factors affecting bio digestion or generation of gas?

PH or hydrogen-ion concentration, temperature, total solid content, loading rate, seeding, Diameter to depth ratio.

19. What are the components of wind energy system?

Wind mill, Wind turbine, towers, pump/motor, storage and energy converter

20. **List the advantages of solar Energy.**

- Solar energy is free from pollution
- They collect solar energy optically and transfer it to a single receiver, thusminimizing thermal-energy transport requirements
- They typically achieve concentration ratios of 300 to 1500 and so are highlyEfficient both in collecting energy and converting it to electricity
- The plant requires little maintenance or help after setup
- It is economical

21. 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 hyancith, algae and certain types of grasses

22.What are the components of solar energy?

(j) Collector, (ii) Storage unit

23. What is concentration ratio?

Concentration ratio is defined as the ratio between the aperture area and the receiverabsorber area of the collector.

24. List the various types of solar energy collectors. (Nov/Dec2013)

1.Stationary collectors (or) Non- concentrating

(a) Flate plate collectors

(b) Compound parabolic collectors

(c) Evaculated tube collectors

2.Sun tracking concentrating collector

(a) single axis tracking, (b) Two-axis tracking

25. List any four applications of solar collectors.

(i) Solar water heating, (ii) Solar space heating systems, (iii) Solar refrigeration, (iv)Industrial process heat systems

26.List any four disadvantages of solar energy.

(i) Available in day time only, (ii) Need storage facilities, (iii) It needs a backup power plant

27.Mention the various advantages of wind power. (Nov/Dec2015)

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

28.List the disadvantages of wind power generation.

1.Low energy production 2.Expensive maintenance

29.What are the components of tidal power station?

1.Barrage 2.Turbines 3.Sluices 4.Embankments

30. What is pondage and storage?(May/June2014)

Storage: In a conventional hydropower plant, the water from the reservoir flows through the plant, exits and is carried downstream. A pumped-storage plant has two reservoirs:**Upper reservoir -** Like a conventional hydropower plant, a dam creates a reservoir. The water in this reservoir flows through the hydropower plant to create electricity.**Lower reservoir** - Water exiting the hydropower plant flows into a lower reservoir rather than re-entering the river and flowing downstream.

Pondage: It usually refers to the comparably small water storage behind the weir of a run-of-the-river hydroelectric power plant. Such a power plant has considerably less storage than the reservoirs of large dams and conventional hydroelectric stations which can store water for long periods such as a dry season or year. With pondage, water is usually stored during periods of low electricity demand and days when the power plant is inactive, enabling its use as a peaking power plant in dry seasons and a base load power plant during wet seasons.

31. What is water hammer? ((May/June2014)

Water hammer (fluid hammer) is a pressure surge or wave caused when a fluid in motion is forced to stop or change direction suddenly (momentum change). A water hammer commonly occurs when a valve closes suddenly at an end of a pipeline system, and a pressure wave propagates in the pipe. It is also called hydraulic shock.

32.What is the source of geothermal energy? (Nov/Dec2013)

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.

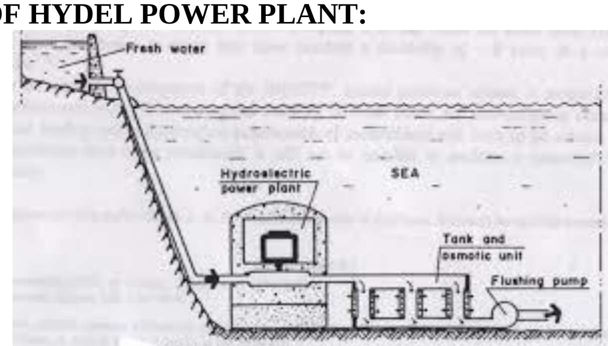
33.Write the advantages of fuel cell?

(i) Water is the only discharge (pure H_2), (ii) High efficiency, (iii) Low weight and volume, (iv) Portable, (v) No hazardous emissions

<u>PART-B</u>

1. With a neat diagram, explain the working principle of the Hydro Electric power plant. (May/June2013, Nov/Dec 2015)

LAYOUT OF HYDEL POWER PLANT:



Simplified schematic diagram of the SHEOPP converter.

Hydroelectric power plants convert the hydraulic potential energy from water into electrical energy. Such plants are suitable were water with suitable head are available. Water stored in the dam is allowed to flow through the penstock to the turbine, where the kinetic energy of water is converted into mechanical energy, later this mechanical energy is converted into electrical energy in the generator which is coupled with the shaft of the turbine. The layout covered in this article is just a simple one and only cover the important parts of hydroelectric plant. The different parts of a hydroelectric power plant are

(1) Dam

Dams are structures built over rivers to stop the water flow and form a reservoir.The reservoir stores the water flowing down the river. This water is diverted to turbines in power stations. The dams collect water during the rainy season and stores it, thus allowing for a steady flow through the turbines throughout the year. Dams are also used for controlling floods and irrigation. The dams should be water-tight and should be able to withstand the pressure exerted by the water on it. There are different types of dams such as arch dams, gravity dams and buttress dams. The height of water in the dam is called head race.

(2) Spillway A spillway as the name suggests could be called as a way for spilling of water from dams. It is used to provide for the release of flood water from a dam. It is used to prevent over toping of the dams which could result in damage or failure of dams. Spillways could be controlled type or uncontrolled type. The uncontrolled types start releasing water upon water rising above a particular level. But in case of the controlled type, regulation of flow is possible.

(3) Penstock and Tunnel

Penstocks are pipes which carry water from the reservoir to the turbines inside power station.They are usually made of steel and are equipped with gate systems.Water under high pressure flows through the penstock. A tunnel serves the same purpose as a penstock. It is used when an obstruction is present between the dam and power station such as a mountain.

(4) Surge Tank

Surge tanks are tanks connected to the water conductor system. It serves the purpose of reducing water hammering in pipes which can cause damage to pipes. The sudden surge of water in penstock is taken by the surge tank, and when the water requirements increase, it supplies the collected water thereby regulating water flow and pressure inside the penstock.

(5) Power Station

Power station contains a turbine coupled to a generator. The water brought to the power station rotates the vanes of the turbine producing torque and rotation of turbine shaft. This rotational torque is transfered to the generator and is converted into electricity. The used water is released through the tail race. The difference between head race and tail race is called gross head and by subtracting the frictional losses we get the net head available to the turbine for generation of electricity

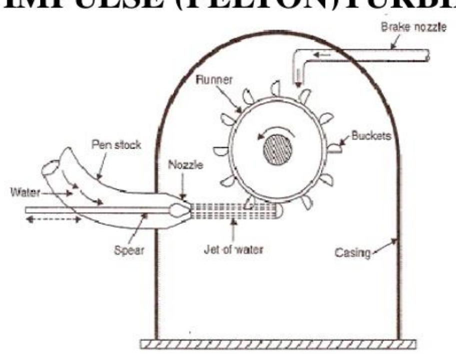
2. Write about selection of water turbine? Explain any one turbine with neat sketch used in hydroelectric power plants. (Nov/Dec2014)

***** Rotational speed of the turbine * Specific speed * Maximum efficiency * Part load efficiency* Head * Type of water * Runway speed * Cavitation * No. of turbine units * Overall cost

Pelton turbine:

This is a special type of axial flow impulse turbine generally mounted on horizontal shaft, as mentioned earlier A number of buckets are mounted round the periphery of the wheel. The water is directed towards the wheel through a nozzle or nozzles. The flow of water through the nozzle is generally controlled by special regulating system. The water jet after impinging on the buckets is deflected through an angle of 160° and flows axially in both directions thus avoiding the axial thrust on the wheel. The hydraulic efficiency of Pelton wheel lies between 85 to 95%. Now-a-days, Pelton wheels are used for very high heads up to 2000 meters. Arrangement of jets. In most of the Pelton wheel plants, single jet with horizontal shaft is used. The number of the jets adopted depends upon the specific speed required. Any impulse turbine achieves its maximum efficiency when the velocity of the bucket at the center line of the jet is slightly under half the jet velocity. Hence, for maximum speed of rotation, the mean diameter of the runner should be as small as possible. There is a limit to the size of the jet which can be applied to any impulse turbine runner without seriously reducing the efficiency

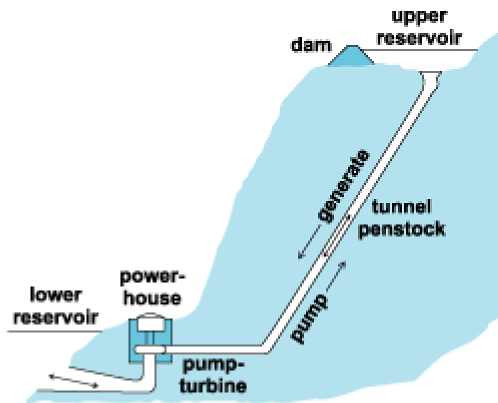
WORKING DIAGRAM OF IMPULSE (PELTON)TURBINE



3. What are factors to be considered for selection of turbine

***** Rotational speed of the turbine * Specific speed * Maximum efficiency * Part load efficiency * Head * Type of water * Runway speed * Cavitation * No. of turbine units * Overall cost

4. Describe pumped storage power plant with neat sketch (May/June2013)



There's another type of hydropower plant, called the **pumped-storage plant**. In a conventional hydropower plant, the water from the reservoir flows through the plant, exits and is carried down stream. A pumped-storage plant has two reservoirs:

Upper reservoir - Like a conventional hydropower plant, a dam creates a reservoir. The water in this reservoir flows through the hydropower plant to create electricity.

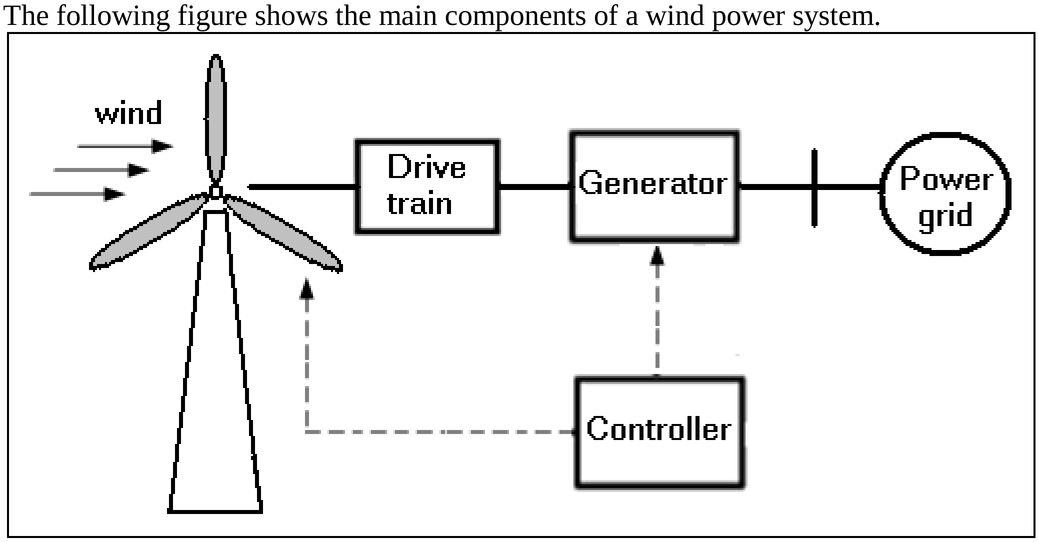
- **Lower reservoir -** Water exiting the hydropower plant flows into a lower reservoir rather than re-entering the river and flowing downstream.

Using a **reversible turbine**, the plant can pump water back to the upper reservoir. This is done in off-peak hours. Essentially, the second reservoir refills the upper reservoir. By pumping water back to the upper reservoir, the plant has more water to generate electricity during periods of peak consumption.

5. Write the principle, construction and working of Wind power system.

Introduction to a Wind Power System

The following figure shows the main components of a wind power system.



The main components of this system are the wind turbine, the mechanical drive train, the generator, the power grid, and the controller. The wind turbine converts the kinetic energy of the wind into mechanical energy. The generator converts the mechanical energy into electrical energy. The controller is the "brain" of the system. It ensures that the whole system works as expected.

The mechanical power P_{mech} is extracted from the wind. The following formula describes P_{mech}:

$P_{mech} = 0.5\ \rho\pi R^2 v^3 C_p(\lambda,\Theta)$

where P_{mech} is the mechanical power

ρ is the air density

R is the turbine's radius

v is the wind speed

C_p is the power coefficient

λ is the tip speed ratio

Θ is the pitch angle

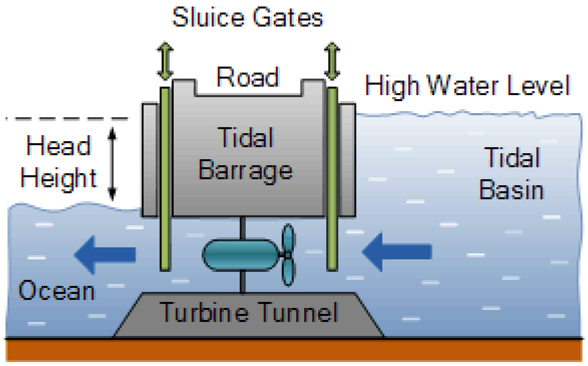
λ is defined as:

$$\lambda = \frac{\omega_m R}{v}$$

where ω_m is the turbine rotation speed
R is the turbine's radius
v is the wind speed

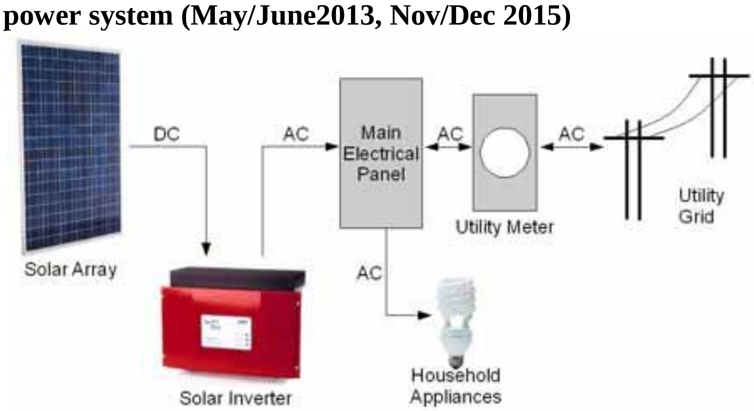
The extracted mechanical power P_{mech} is proportional to the cube of the wind speed v. The power coefficient C_p affect P_{mech}. C_p is a function of the tip speed ratio λ and of the pitch angle Θ. λ describes the ratio between the system rotational speed ω_m and v. Θ is the angle between the wind flow direction and the turbine blade. Increasing Θ moves the blades out of the wind, thereby reducing the effective wind area.

6. Write the principle, construction and working ofTidal power system(May/June2013)



Tidal Energy or **Tidal Power** as it is also called is another form of hydro power that utilises large amounts of energy within the oceans tides to generate electricity. *Tidal Energy* is an "alternative energy" that can also be classed as a "renewable energy source", as the Earth uses the gravitational forces of both the moon and the sun. A *Tidal Barrage* is a type of tidal power generation that involves the construction of a fairly low dam wall, known as a "barrage". Tidal barrages generate electricity using the difference in the vertical height between the incoming high tides and the outgoing low tides. As the tide ebbs and flows, sea water is allowed to flow in or out of the reservoir through a one way underwater tunnel system. This flow of tidal water back and forth causes the water turbine generators located within the tunnels to rotate producing tidal energy with special generators used to produce electricity on both the incoming and the outgoing tides.

7. Write the principle, construction and working of solar power system and Solar Photo Voltaic power system (May/June2013, Nov/Dec 2015)



Photovoltaic systems convert sunlight into electricity by using the mass of a photon (a little piece of sunlight or a sun beam) to dislodge an electron on a solar collector. This causes a difference in Electrical Potential (Voltage). The groups of these dislodged electrons that accumulate over a period of time (a Current), is called an Ampere, or Amp. Together the Current of Electrons (Amps) multiplied by their Potential (Volts), gives a measurable unit of Power. The power in quanties called Watts. (Amps x Volts = Watts).

8. Write the principle, construction and working of Geothermal power system

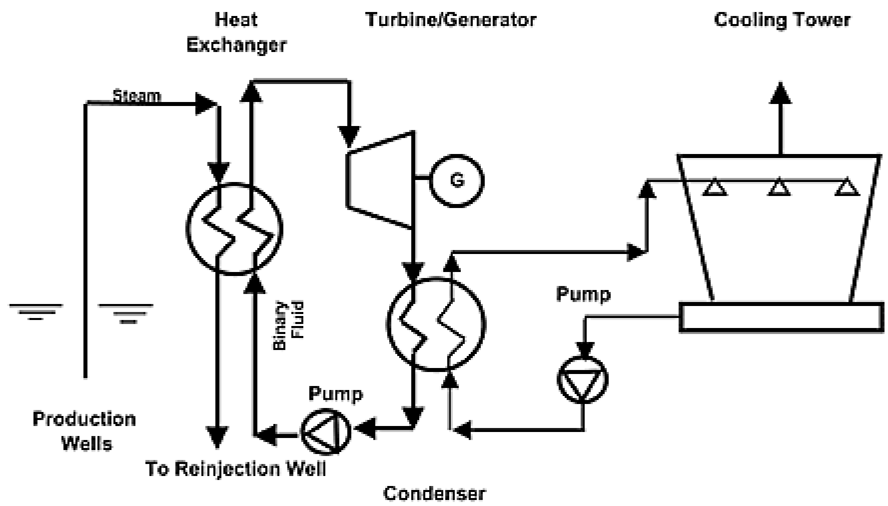
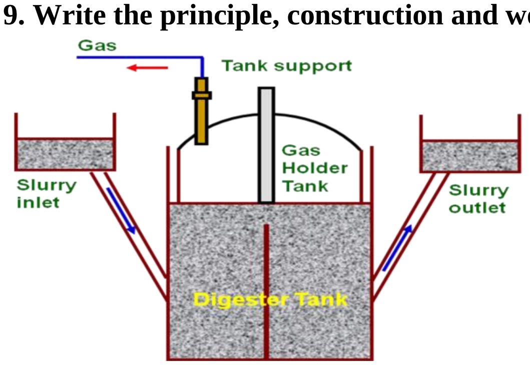


Figure 3
Geothermal Power Plant with Binary Cycle

***** Geothermal energy is the heat from high pressure steam coming from the earth.
* It is a renewable source of energy derived from the rainwater in the earth heated to over180 dry hot rocks.
Geothermal sources

- Hydrothermal convective systems
- Geo pressure resources
- Petro – Thermal or hot dry rocks
- Magma resources
- Volcanoes

9. Write the principle, construction and working of Biogas power system. (Nov/Dec 2015)



The feedstock (mainly dung) is mixed with water and fed into a tank, where feedstock goes through number of reaction producing biogas (mainly methane). The mixture of dung and water is called slurry. After biogas production, the slurry eventually comes out of the tank, which is rich in nutrients and can be used as fertilizer.
The biogas produced in a biogas plant is stored in a gas holder. On the basis of the gas holder, the present biogas plants are classified mainly into two groups; fixed dome type or floating drum type.

Digester:

- This is the fermentation tank and is built partially or fully underground.
- It is generally cylindrical in shape and made up of bricks and cement.
- It holds the slurry within it for the period of digestion for which it is designed

Gas Holder:

- After release of methane from digester, it is collected in tank called gas holder.
- It may be a floating drum (drum floats on slurry in the digester) or a fixed dome.
- The floating dome is made of steel or iron while the fixed dome is made of cement and concrete.
- The gas connection is taken from the top of this gas holder. The gas is then taken through pipes to the burners.

Slurry mixing (inlet):

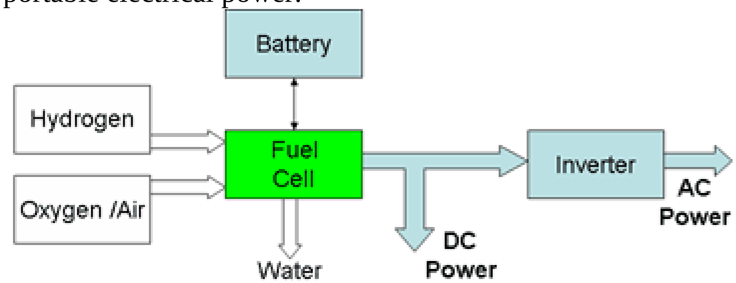
Dung is mixed with water and fed into the digester from inlet.

Slurry pit (outlet):

An outlet from the digester, from where slurry is taken out to the field.

10. What is fuel cell? Explain the principle and working of fuel cell power system?(Nov/Dec2014, Nov/Dec 2015)

Fuel cell takes in Hydrogen and Oxygen from the air and puts out electricity, heat, and water. It doesn't use fossil fuels and it doesn't produce greenhouse gases and so it should be the ideal solution to providing distributed or portable electrical power.



Fuel Cells

Fuel cells don't store energy like batteries. They only provide electrical energy while the active chemicals are supplied to the electrodes.

UNIT V– ENERGY ECONOMIC AND ENVIRONMENTAL ISSUES OF POWERPLANTS

PART-A

1. Define load curve?

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.

2. Define load factor & demand factor?

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

3. **What are fixed cost & operating cost?**

- Fixed costs are the cost required for the installation of complete power plant. 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 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 likeWater for feeding boilers, for condenser and for general use. Lubrication oil and grease.

4.Write down theSite selection criteria for hydroelectric power plant?

1. Availability of water 2. Water storage, 3. Water head 4. Accessibility of site, 5.Distance from the load centre 6. Type of the land of the site

5. Write nuclear waste disposal methods.

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

6. Define Law of conservation of energy.

Energy may be neither created nor destroyed but it can be transferred from one form to another form.

7. List the types of tariffs to calculate energy rate.

1. Flat demand rate, 2. Straight line meter rate, 3. Block- meter rate, 4. Hopkinson demand rate
5. Doherty rate

8. What do you understand by load duration curves?

Load duration curves are Re arrangement of all load elements of load curve in the order of decreasing magnitude.

9. What are the different pollutions in the flue gas?

1. Oxides of nitrogen, 2. Oxides of sulphur, 3. Carbon monoxide, 4. Particulates

10.Write the types of pollution control methods adopted in thermal power plants?

1. Air pollution control
   (a)Electrostatic precipitators (b)Low NOX burners, (c)Flue gas stack (d) Dry ash extraction
2. Water pollution control
   (a)Coal/oil setting pits (b) Ash dykes & disposal systems, (c) Ash water recycling system (d) Effluent treatment plant
3. Thermal pollution control
4. Noise pollution control

11. Define demand for electricity.

It is defined as the electricity requirement during the period of time of high price or more stress.

12. How the tariff for electrical energy is arrived?

$E = Ax + By + C$

Where , E = Total amount of bill for the period considered

A = rate per kW of maximum demand

x = Maximum demand in kW

B = Energy rate per kWh

y = energy consumed in kWh during the period considered.

C = Constant amount charged to the consumer during each bill period.

This charge is independent of demand or total energy.

13. Define flat rate tariff.

The charging of amount depending only on the connected load & fixed number of hours of use per month or year is called flat rate tariff.

14. Define diversity factor.

Diversity factor is defined as the ratio of sum of the individual maximum demand to the actual peak load of the system.

15. What are major factors that decide the economics of power plants?

i) Connected load ii) Demand iii) Maximum demand iv)Load factor, v) Demand factor

vi) Diversity factor viii) Capacity factor ix) Utilization factor x) Plant use factor

16. 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 an induced electrostatic charge minimally impeding the flow of gases through the unit.

17. Site selection criteria for nuclear power plant?

1. Availability of water 2. Disposal of Waste 3. Away from populated area

4. Nearest to the load centre 5. Other Factors – Accessibility to the road and rail are general considerations.

18. 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.

19. Site selection criteria for thermal power plant?

1. Transportation network 2. Geology and soil type

3. Topography 4. Water resources 5.Population centre 6.Area size

20. What are the pollutants come out of the coal fired power plant?

Coal combustion releases nitrogen oxides, sulfur dioxide, particulate matter (PM), mercury, and dozens of other substances known to be hazardous to human health

21.Write advantages and disadvantages of nuclear power plant?

Advantages

- Economic
- Environmental
- Portability & Productivity

Disadvantages

- Waste storage
- Accidents
- National Security
- Ease of peaceful usage to weapons program

22. Flyash Disposal in Ash Ponds

Primarily, the flyash is disposed off using either dry or wet disposal scheme. In dry disposal, the flyash is transported by truck, chute or conveyor at the site and disposed off by constructing a dry embankment (dyke). In wet disposal, the flyash 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.

23.What are the pollutants from nuclear power plants?

Nuclear power plants do not emit carbon dioxide, sulfur dioxide, or nitrogen oxides as part of the power generation process. However, fossil fuel emissions are associated with the uranium mining and uranium enrichment process as well as the transport of the uranium fuel to and from the nuclear plant.

24. What do you mean by spent fuel? How it is disposed?

Every 18 to 24 months, nuclear power plants must shut down to remove and replace the "spent" uranium fuel.This spent fuel has released most of its energy as a result of the fission process and has become radioactive waste. Currently, the spent fuel is stored at the nuclear plants at which it is generated, either in steel-lined, concrete vaults filled with water or in above-ground steel or steel-reinforced concrete containers with steel inner canisters.

25. What are the effects on aquatic life and water by nuclear wastes?

- Heavy metals and salts build up in the water used in all power plant systems, including nuclear ones. These water pollutants, as well as the higher temperature of the water discharged from the power plant, can negatively affect water quality and aquatic life. Nuclear power plants sometimes discharge small amounts of tritium and other radioactive elements as allowed by their individual wastewater permits.
- Waste generated from uranium mining operations and rainwater runoff can contaminate groundwater and surface water resources with heavy metals and traces of radioactive uranium.

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

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

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

(i) Scrubbers (ii) Cyclone separator (iii) Electro static precipitator (iv) Fabric filters

PART-B

1. A steam power station has an installed capacity of 120 MW and a maximum demand of 100 MW. The coal consumption is 0.4 kg per kWh and cost of coal is Rs. 80 per tonne. The annual expenses on salary bill of staff and other overhead charges excluding cost of coal are Rs.50 × 10^5. The power station works at a load factor of 0.5 and the capital cost of the power station is Rs. 4 ×10^5. If the rate of interest and depreciation is 10% determine the cost of generating per kWh

$$\text{Load factor} = \frac{\text{Average load}}{\text{Maximum demand}}$$

Fixed cost = Interest and depreciation on capital cost

Running cost =Cost of fuel oil, salaries and taxation
Total annual cost= Fixed cost + operating cost

2. Merits and demerits gas turbine and diesel power plant.

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.

DISADVANTAGE OF DIESEL POWER PLANT

1. The plant generally used to produce small power requirement.2. Cost of lubricants is high.3. Maintenance is quite complex and costs high.

Advantages of Gas Turbine power plant:

Simplicity: The combustion chamber is inexpensive, light weight and small with a high rate of heat release. It can be designed to burn almost all hydrocarbon fuels ranging from gasoline to heavy diesel oil.

Low weight and size: The property of producing more power output in a small space and low weight is quite useful in the field of aeronautics.

No warm-up period: Open cycle gas turbine can accelerate from a cold start to a full load without a warm-up period.

Low capital cost: Since open cycle gas turbine has only minimum components and has low weigh and size per unit power output ,the capital cost is less compared to other plants.

Disadvantages of Open Cycle Gas Turbine:

Sensitivity: The simple open cycle gas turbine is sensitive to changes in the atmospheric temperature and component efficiencies.

High air rate: Simple open cycle gas turbine has a very high air rate. This high air rate is mostly in the applications like a aviation field but is a prime factor in marine applications.

3. Write the advantages and disadvantages of nuclear power plant.

1. The nuclear power plant is more economical compared with thermal in areas where coal field is far away.
2. There is no problem of fuel transportation, storage and handling and ash handling as in thermal power plants.
3. Man power required for the operation of nuclear power plant is less. Therefore the cost of operation is reduced.
4. Nuclear plant occupies less space than thermal power plants, which reduces the cost of civil construction.

Disadvantages of nuclear power plants.

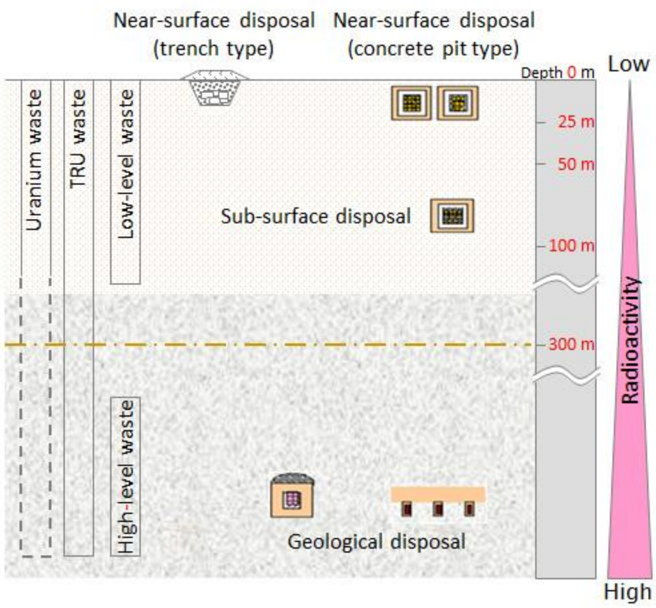
l. Danger of nuclear radiation.
2. Problem of disposing the radioactive waste materials.
3. It has to be operated at full load throughout for a good efficiency. So part load operation becomes inefficient.
4. Capital cost of small size plants is very high.

4. Explain the pollution control technologies for Coal based thermal power plant.

Air pollution by thermal plants is a contributing factor in the cause of various respiratory diseases and lung cancer and causes significant damage to the property in addition to causing annoyance to the public.The thermal power plants burning conventional fuels (coal, oil or gas) contribute to air pollution in a large measure. The combustible elements of the fuels are converted to gaseous products, and noncombustible
elements as ash. The common gaseous products of interest are sulphur dioxide, nitrogen oxide, carbon dioxide and carbon monoxide, and large quantities of particulate materials as fly ash,carbon particles, silica, alumina and iron oxide.

It was proposed that the thermal pollution of the atmosphere and the generation cost of the plant could be reduced by using the low-grade energy exhausted by the steam. The ideal use for enormous quantity of residual energy from steam power plants requires large demand with unity power factor.
The low-grade energy exhaust by the thermal plants is not readily usable for air-conditioning purposes. It is possible to use this energy by stopping the expansion of steam at a temperature of 95°C to 100°C and use of this energy can be made to drive an absorption refrigeration system such as lithium bromide water system. This will be a definite positive answer to reduce the thermal pollution of environment otherwise caused by burning extra fuel to run the absorption refrigeration system in summer or to run the heating systems in winter.
Pollution from Thermal Power Plants. Thermal power plants contribute to 13% of air pollution.The main pollutants are stack emissions; fly ash generation and fugitive emission in coal handling.All three thermal power plants need better use of their emission control devices and the fly ash that they enerate. There is an immediate need to use beneficiated/washed coal, which has a maximum ash content of 30%, which will reduce fly ash generation by about 25%. It has also been recommended to the Thermal Power Stations to examine the possibility of installing Bag House Filters in order to control emission of particles between the size of PPM 2.5 to PPM-10.

5. Explain the pollution control technologies for nuclear power plant



Several types of disposal facilities have been designed according to the radioactivity levels of the wastes.

Near-surface Disposal (Trench Type)

Very low-level radioactive wastes are placed in shallow, unlined trenches and then covered with soil.

Near-surface Disposal (Concrete Pit Type)

After low-level radioactive wastes are placed in concrete pits, mortar is poured into the spaces between the wastes. The pits are enclosed with low water permeability soil in order to prevent groundwater from flowing into the pits.

Sub-surface Disposal

Relatively high-level radioactive wastes are disposed of at a depth of 50–100 meters below the surface of the ground, while maintaining enough distance from general underground use.

Geological Disposal

High-level radioactive wastes are disposed of in concrete constructs at least 300 m below the surface of the ground.

6. Explain the following:

(a) Power tariff types,
(b) Load distribution parameters,
(c) Load curve

(a) There are two tariff systems, one for the consumer which they pay to the DISCOMS and the other one is for the DISCOMS which they pay to the generating stations. Let us first discuss about the **tariff of electricity** for the consumer i.e the cost consumer pay to the DISCOMS. The total cost levied on the consumer is divided into 3 parts usually referred as 3 part tariff system. Total cost of electrical energy = fixed cost +semi fixed cost + variable cost = (a + b*KW +c*KW-h) Rs.

Here, a = fixed cost independent of the maximum demand and actually energy consumed.

b = constant which when multiplied by maximum KW demand gives the semi fixed cost.

c = a constant which when multiplied by by actual energy consumed KW-h gives the running cost.

Thus the total amount paid by the consumer depends on its maximum demand, actual energy consumed plus some constant sum of money. Now electrical energy is generally expressed in terms of unit, and 1 unit = 1 KW-hr (1 kw of power consumed for 1 hr).

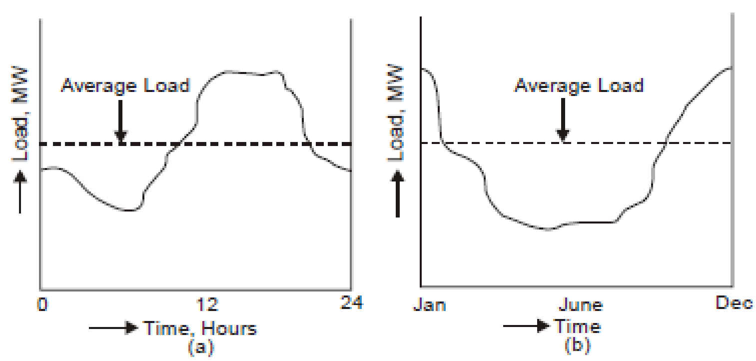
(b) Load distribution parameters:

The characteristics and method of use of power plant equipment is largely influenced by the extent of variable load on the plant. Supposing the load on the plant increases. This will reduce the rotational speed of the turbo-generator. The governor will come into action operating a steam valve and admitting more steam and increasing the turbine speed to its normal value. This increased amount of steam will have to be supplied by the seam generation. The governor response from load to turbine is quite prompt, but after this point, the governing response will be quite slower.

Variable load results in fluctuating steam demand. Due to this it become, very difficult to secure good combustion since efficient combustion requires the co-ordination of so many various services.Efficient combustion is readily attained under steady steaming conditions. In diesel and hydro powerplants, the total governing response is prompt since control is needed only for the prime mover.

(c)Load curve:

The load demand on a power system is governed by the consumers and for a system supplying industrial and domestic consumers, it varies within wide limits. This variation of load can be considered as daily, weekly, monthly or yearly.



7. (i) Explain the analysis of pollution from thermal power plants. (Nov/Dec 2015)

Pollution from Thermal Power Plants. Thermal power plants contribute to 13% of air pollution.The main pollutants are stack emissions; fly ash generation and fugitive emission in coal handling.All three thermal power plants need better use of their emission control devices and the fly ash that they enerate. There is an immediate need to use beneficiated/washed coal, which has a maximum ash content of 30%, which will reduce fly ash generation by about 25%. It has also been recommended to the Thermal Power Stations to examine the possibility of installing Bag House Filters in order to control emission of particles between the size of PPM 2.5 to PPM-10.

(ii)Elucidate the objectives and requirements to tariff and general form of tariff. (Nov/Dec 2015)

OBJECTIVES:

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

REQUIREMENTS OF A TARIFF

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

8.A Central power station has annual factors as follows. Load factor = 60%, capacity factor = 40% and use factor = 45%. Power station has a maximum demand of 15,000 kW. Determine the annual energy production, reserve capacity over and above peak load and hours per year not in service.(Nov/Dec 2015)

Load factor = Average load/Maximum demand

Capacity factor is given as,

$$\frac{\textbf{Energy Estimated}}{\textbf{(Plant Generator Name plate capacity x 24 Hours x 365Days)}}$$

Utilization Factor = The time that a equipment is in use./ The total time that it could be in use.