DIGITAL NOTES

POWER PLANT ENGINEERING
R15A0334

B.Tech –Year – Semester

DEPARTMENT OF MECHANICAL ENGINEERING

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(An Autonomous Institution – UGC, Govt.of India)

Recognizes under 2(f) and 12(B) of UGC ACT 1956

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MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

COURSE OBJECTIVES:

- To create awareness about working and availability of product/system as and when required and
- Working to its fullest capacity & efficiency to the satisfaction of the end user.
- Able to learn about different power plants.

UNIT – I:

Introduction to the Sources of Energy: Resources and Development of Power in India. **Steam Power Plant:** Plant Layout, Working of different Circuits, Fuel and handling equipments, types of coals, coal handling, choice of handling equipment, coal storage and Ash handling systems.

Combustion Process: Properties of coal – overfeed and underfeed fuel beds, traveling grate stokers, spreader stokers, retort stokers, pulverized fuel burning system and its components, combustion needs and draught system, cyclone furnace, design and construction, Dust collectors, cooling towers and heat rejection. Corrosion and feed water treatment.

UNIT – II:

Internal Combustion Engine Plant: DIESEL POWER PLANT: Introduction – IC Engines, types, construction– Plant layout with auxiliaries – fuel supply system, air starting equipment, lubrication and cooling system – super charging.

Gas Turbine Plant: Introduction – classification - construction – Layout with auxiliaries – Principles of working of closed and open cycle gas turbines. Combined Cycle Power Plants and comparison.

UNIT – III:

Hydro Electric Power Plant: Water power – Hydrological cycle / flow measurement – drainage area characteristics – Hydrographs – storage and Pondage – classification of dams and spill ways.

Hydro Projects and Plant: Classification – Typical layouts – plant auxiliaries – plant operation pumped storage plants.

Power From Non-Conventional Sources: Utilization of Solar- Collectors- Principle of Working, Wind Energy – types – HAWT, VAWT -Tidal Energy**.**

Direct Energy Conversion: Solar energy, Fuel cells, Thermo electric and Thermo ionic, MHD generation.

UNIT-IV:

Nuclear Power Station: Nuclear fuel – breeding and fertile materials – Nuclear reactor – reactor operation.

Types of Reactors: Pressurized water reactor, Boiling water reactor, sodium-graphite reactor, fast Breeder Reactor, Homogeneous Reactor, Gas cooled Reactor, Radiation hazards and shielding – radioactive waste disposal.

UNIT – V:

Power Plant Economics and Environmental Considerations: Capital cost, investment of fixed charges, operating costs, general arrangement of power distribution, Load curves, load duration curve. Definitions of connected load, Maximum demand, demand factor, average load, load factor, diversity factor – related exercises. Effluents from power plants and Impact on environment – pollutants and pollution standards – Methods of Pollution control.

COURSE OUTCOMES:

- Students learn about the failures, maintainability and availability of the intended products/systems and services
- Students get the exposure of different pollution standards.
- Students get the exposure of different power distribution techniques.

TEXT BOOKS:

1. A Course in Power Plant Engineering: / Arora and S. Domkundwar/ Dhanpat Rai Publisher
2. Power Plant Engineering / P.C.Sharma / S.K.Kataria Publisher
3. A Text Book of Power Plant Engineering / R.K.Rajput / Laxmi Publications

REFERENCES:

1. Power Plant Engineering/ P.K.Nag II Edition /TMH Publishers
2. An Introduction to Power Plant Technology / G.D. Rai/Khanna Publishers
3. Power plant Engg /Elanchezhian/I.K. International Publishers

Course Coverage:

Unit-1> A Text Book of Power Plant Engineering , Rajput. R.K., 4/e, Laxmi Publ, 2007 (78-261)
Power Plant Engineering, P.C.Sharma , S.K.Kataria Publ.(200-420)

Unit-2> A Text Book of Power Plant Engineering , Rajput. R.K., 4/e, Laxmi Publ, 2007(140-200, 266-361)
Power Plant Engineering, P.C.Sharma , S.K.Kataria Publ.(502-635)

Unit-3> Power Plant Engineering, P.C.Sharma , S.K.Kataria Publ.(333-382)
Power Plant Engineering, P.K.Nag, 2/e, TMH.(222-297)

Unit-4> Power Plant Engineering, P.C.Sharma , S.K.Kataria Publ.(812-832)
Power Plant Engineering, P.K.Nag, 2/e, TMH.(535-549)

Unit-5> Power Plant Engineering, P.C.Sharma , S.K.Kataria Publ.(925-932)
Power Plant Engineering, P.K.Nag, 2/e, TMH.(645-654)

CONTENTS

UNIT-I

1. Energy and different forms of energy:

Energy:Energy is the ability to accomplish mechanical work or produce movement of a body against resistance. It is a vital requirement for economic development of every nation.

Different forms of energy:

➢ Energy exists in various forms.
➢ One form of energy can be converted into other forms by the use of suitable arrangements.
➢ Energy from the sun also gives rise to the winds in the atmosphere, which can operates the windmills.
➢ Also, the sun's heat produces rains. The rain water flows in rivers, there by driving water wheels.
➢ Energy utilised by mankind exists in the forms given below

1. Potential energy
2. Kinetic energy
3. Magnetic energy
4. Electric energy
5. Chemical energy
6. Nuclear energy
7. Heat energy
8. Light energy
9. Sound energy, etc..,

➢ Out of all these forms of energy, electrical energy is most preferred.

2. Resources and development of power in India

➢ In our country energy is obtained from both non-commercial and commercial sources.
➢ Fuels which come under non-commercial form are firewood, agricultural waste and animal dung, which provides more than 40% of the total energy that, is being consumed.
➢ The % contribution of firewood, agricultural waste and animal dung in the total non commercial energy consumption is about 65%, 15% and 20% respectively. Energy sources can be broadly classified into 2 types. They are:

a) Renewable energy sources
i) Wind energy
ii) Geothermal energy
iii) Ocean thermal energy
iv) Solar energy etc..,
b) Non renewable energy sources
i) Coal
ii) Oil
iii) Nuclear power, etc…,

Renewable and non renewable energy sources:

➢ Non renewable energy is generally derived from fossil fuels (coal, wood and oil).

➢ The fossil fuel deposits can be regarded to be available in fixed quantity

➢ The time taken for the development of energy, which is obtained by combustion of fossil fuel, is approximately 600 million years.

➢ At the present consumption rate, it is probable to consume earth's entire supply of fossil fuel in less than hundred years.

➢ Renewable energy can be derived from different sources, such as sun's heat (solar energy), earth's heat (geothermal energy), energy in waves (tidal power) and wind (wind power).

➢ The problem associated with renewable energy sources is that, the energy will not be available at all times and in sufficient quantity.

➢ The sun does not shine always; hence it is not possible to obtain energy during winter and rainy days.

➢ The speed of waves required to operate a wave conversion machine is not constant.

➢ The wind does not always blow with sufficient velocity, required to operate the wind mill.

➢ Thus, the above aspects necessitate the use of some form of energy storage device.

<u>2.2 Renewable energy resources:</u>

1)<u>Wind energy:</u>

➢ In India, greater wind speeds are obtained in coastal areas of saurashtra, some parts of central India and Western Rajasthan. In these areas, there would be a possibility of using medium and large size air mills for the generation of electricity.

➢ In India, the interest in the wind mills was seen in the late 50's and early 60's.

➢ The wind energy generated annually on earth is about $1.67x10^5$ KWh. This is through natural phenomena and 10 times the obtained value gives over the entire global region.

➢ Many projects on the wind mill systems for water pumping and for production of electrical power (small amounts) are taken up by many organizers in our country.

Some of the developments are given below:

i) WP-2 water pumping wind mill by NAL Banglore.

ii) CAZRI wind mill at Jodhpur (Rajasthan)

iii) WP 2 500 wind mill at NAL Banglore.

iv) MP-1 soil wind mill at NAL Banglore

v) Madhuri wind mill at Maduri(TamilNadu).

2)<u>Geothermal energy:</u>

➢ Remarkable developments in the use of geothermal energy are expected in several countries including India in the years to come. This will be merit both from the point of view of pollution control in the atmosphere and conserving fossil.

➢ The geothermal power is roughly estimated for a depth of 3km to $8x10^{21}$joules of total energy stored while for a depth of 10 km, the total energy stored is found to be $4x10^{22}$jouled approximately.

➢ In India, Himachal Pradesh is reported to have geothermal energy in exploitable amount.

➢ Under the sponsorship of DNES (Department of Non-Conventional Energy Source), a 7.5 Tonne capacity cold storage pilot plant based on geothermal energy is installed at Manikarnika, Himachal Pradesh .

3) Ocean thermal energy:

➢ In India, the department of non conventional energy sources, also known as (DNCS) has proposed to install at 1MW OTEC plant in Lakshadweep Island at Minicoy and Kavaralti.

➢ Preliminary oceanographic studies on the eastern side of Lakshadweep Island indicates the possibility
of the established at shore based OTEC plant at the island.

➢ Both the islands possess large lagoons on western side.

➢ The OTEC plant will bring up the water from 1000m depth which has large nutrient value.

4) Non- renewable energy sources:

Coal: Since the emergence of industrialization coal has become the most common source of energy. The commissioning of an additional 500MW unit at Kobra thermal power station, the power station has become the largest power station of India. The project is the second in the series of super thermal power stations set up by the NTPC. The huge complex has been set up in 2 stages.
In the first stage 3 units of 200 Megawatt were setup.
In the second stage 3 units of 500 Megawatt were setup.
With the commissioning of last 500 Megawatt units the plant has attained its ultimate capacity of 2,100 Megawatts. The 500 Megawatt generators were provided by BHEL. States like Madhyapradesh, Gujarat, Maharashtra and Goa were benefitted from the project.

Oil: Nearly 40% of energy needs of the world are fed by oil. In the last 3 decades, the world has changed over from coal to oil as a major source of energy because it is cleaner and simpler to obtain useful energy from oil. India is not specifically rich in petroleum reserves.
The potential oil bearing areas are situated in Tripura, Assam, West Bengal, Manipur, Punjab, Kutch, Ganga Valley, Himachal Pradesh and Eastern and western coastal areas such as Andhra Pradesh, Tamil Nadu and Kerala. Also Lakshadweep, Andaman and Nicobar islands and in the continental shelves adjoining these areas.

Nuclear power: The uranium reserves in the world presently are small. A country like India has uranium sufficient enough only to produce $6x10^6$ KW, only 1% of its current energy requirements. India has abundant resources of nuclear fuel which will help development of nuclear power in the country. The reserves of uranium are at 2 locations namely Jaduguda and Narwapahar and Bhattin (Bihar) and total about 33000 Tonnes. There are other important deposits in Singhbhum (Bihar) and other minor deposits in H.P, M.P, Rajasthan, U.P. in India, plentiful Thorium deposits are available for monazite sand in the west coast. Hence, India's interests lie in Thorium breeder reactors.
The following are the nuclear power plants in India:

➢ 400 MW (2x200MW) Tharapore (Maharashtra) nuclear power stations.
➢ Plant at Rana Pratap Sagar, Kota (Rajasthan) with capacity of 400MW (2x200MW).
➢ Station at Kalpakkam (TamilNadu) has the capacity of 440MW (2x200 MW).
➢ Station at Narora has the capacity has the capacity of 470 MW (2x235 MW).
➢ Station at Kakrapar (Gujarat) has the capacity of 940 MW (4x235 MW).

Thermal power development, importance, development during last 6 plan periods:

The ministry of irrigation and power has reviewed the power generation programme and concluded that, it is essential to augment the installed generating capacity in the country to about 35 million KW by 1990 to ensure power supply with an acceptable degree of reliability and quality. However, a plan for increasing the installed capacity to 38000MW has been drawn up at the end of 5th plan taking into account the availability of financial and other resources.

The important aspect for the development of thermal power in the country is that, the electricity must be supplied to every house and to every development activity to make it clear to the people that, they are living in a true welfare state.

Thermal power plants use coal due to which exploitation of coal resources in India is extremely important. Our coal reserves are plentiful and those will be sufficient even for 100 years. But 65 % of the total coal exists in the eastern sector.

Due to uneven distribution of energy resources, it was impossible to plan power development in all states of the country. To overcome this problem, government of India has divided the country into 5 regions. The power development programmes are planned by the government of India and

the plan wise increase in power capacity in the country is attained. In last 10 years, the development of power in the country is seen due to the setup of 5 super thermal pit head stations of nearly 2000MW capacity.

During the 6th plan, department of power and central electricity authority approached a compressive programme to restore and modernise old units placed in various states. The performance of 200 MW or 210 MW units also convinced to stabilize. In this plan, the total capacity is estimated at 196.66 lakh KW, which can be obtained by adding the power developed at each plant (i.e., hydro plant 47.68 lakh KW, thermal plant 142.08 lakh KW and nuclear plant 6.90 lakh KW). Therefore, 72.3 % of the estimated power is achieved successfully.

Why the development of nuclear power is slow in India:

The development of nuclear power is slow in India for the following reasons. The major cause of slow growth is not signing the non-proliferation treaty, due to the nuclear arm race with neighbouring country. Non- proliferation treaty contains terms and conditions regarding the nuclear energy utilization. So as to control the development of nuclear weapons and to support nations who prefer to use nuclear energy for civil purpose.

It is worldwide treaties that bans all countries from having nuclear weapons except five countries and stop the signed countries to have any trade of nuclear plant or material with the countries that are outside the treaty. So India was not allowed to have trade of nuclear plant and material from other countries, which resulted in slow growth. India has two signed the treaty in year 2009.

The other factors for slow growth are

➢ Lack of experience and technical personnel.

➢ Import of nuclear power plant's main components is required since the technologies not sufficient to manufacture them in India, but lack of foreign exchange, restricts on the purchase of components.

➢ Initial cost is very high.

➢ Lack of available land, as the country is densely populated. Plants are required to be constructed away from residential areas for safety considerations.

➢ **STEAM POWER PLANT:**

The steam power plant converts the chemical energy of the fossil fuels (coal, oil, gas) into mechanical, electrical energy. This is achieved by raising the steam in the boilers, expanding it through the turbines and coupling the turbines to the generators which converts mechanical energy to electrical energy.

Principles of site selection of a steam power station:

Site selection for thermal power station:

The following factors must be considered while selecting the site for the thermal power station.

1) Availability of raw material (coal, oil, gas):

Oil and gas resources in India are limited. Coal is the major source of fuel for thermal power plants. Roughly 1000MW station operating at 50% load factor requires 2000 tons of coal per month. Hence, a plant that needs a huge quantity of coal should be located near to the coal mines, but transmission distance of power will be larger, which can be compensated with minimum coal transport charges. If it is not possible to locate the plant near the coal fields, it must be located near the railway station, so that the coal can be directly unloaded at the site of the plant.

2) Ash disposal facilities:

The coal used for power generation contains 20% to 40% of ash. Therefore, large quantities of ash are produced, which pollutes the atmosphere and causes injury to the human health. Hence, large area must be provided for ash disposal. In recent years, the ash from the power plants is used in many industries like brick making.

3) Space requirements:

The average land requirement is 3 to 5 acres per MW capacity, which includes space for cold storage and

ash disposal area. Approximately, the total area can be divided as 10% for buildings, 33% for coal storage, 27%

for cooling towers (if any), 7% for switch control and remaining 23% is utilized for other jobs. Therefore, the cost of the land must be economical.

4) Nature of land:

The soil must possess good bearing capacity so that it can absorb the machine vibrations and the dead load of the plant buildings. The land should posses a minimum bearing capacity of $1MN/m^3$.

5) Availability of water:

Large quantities of water are required for the steam power plant, mainly for raising the steam and for condensing the steam. If the river water is not available, same water is used by employing cooling tower or spray pond. However, some water lose will be there that can be taken care by makeup water. 6 to 10 tonnes of makeup water per hour is required for a 60 MW power plant. In addition, water is required for disposal of ash and for drinking purpose for staff and workers. Therefore, the plant must be located where enough water resources are available.

3. COMPONENTS USED IN STEAM POWER PLANT:

- **Alternator** is an electrical generator that converts mechanical energy into electrical energy in the form alternating current.
- **Generator** is a machine that converts one burn of energy into another specially mechanical energy into electrical energy as a dynamo.
- **Feed water** is the water that is to be supplied to the boiler from a tank or condenser for conversion into steam.
- **Flue gas** is the mixture of gases produced by the burning of fuel or other materials in power stations and industrial plants and extracted via ducts.
- **Make up water** is supplied (as to a steam boiler or cooling tower) to compensate for losses by evaporating and lekage.

- **ESSENTIALS OF STEAM POWER PLANT EQUIPMENT A STEAM POWER PLANT MUST HAVE FOLLOWING EQUIPMENT :**

(a) A furnace to burn the fuel.

(b) Steam generator or boiler containing water. Heat generated in the furnace is utilized to convert water into steam.

(c) Main power unit such as an engine or turbine to use the heat energy of steam and perform work.
(d) Piping system to convey steam and water. In addition to the above equipment the plant requires various auxiliaries and accessories depending upon the availability of water, fuel and the service for which the plant is intended.

The flow sheet of a thermal power plant consists of the following four main circuits :

(a) Feed water and steam flow circuit.

(b) Coal and ash circuit.

(c) Air and gas circuit.

(d) Cooling water circuit.

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

5.1 COMPONENTS OF STEAM POWER PLANT

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

(a) High pressure boiler

(b) Prime mover

(c) Condensers and cooling towers

(d) Coal handling system

(e) Ash and dust handling system

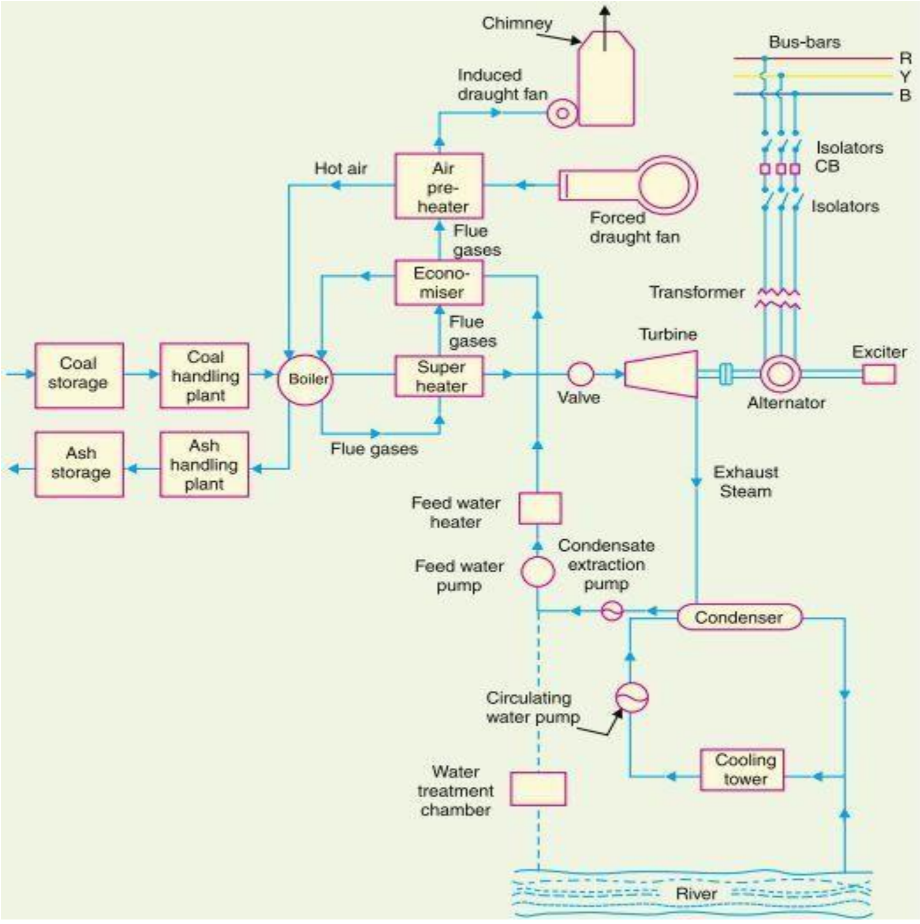
(f) Draught system

(g) Feed water purification plant

(h) Pumping system

(i) Air preheater, economizer, super heater, feed heaters.

. Coal received in coal storage yard of power station is transferred in the furnace by coal handling unit. Heat produced due to burning of coal is utilized in converting water contained in boiler drum into steam at suitable pressure and temperature. The steam generated is passed through the superheater. Superheated steam then flows through the turbine. After doing work in the turbine the pressure of steam is reduced. Steam leaving the turbine passes through the condenser which is maintained the low pressure of steam at the exhaust of turbine. Steam pressure in the condenser depends upon flow rate and temperature of cooling water and on effectiveness of air removal equipment. Water circulating through the condenser may be taken from the various sources such as river, lake or sea. If sufficient quantity of water is not available the hot water coming out of the condenser may be cooled in cooling towers and circulated again through the condenser. Bled steam taken from the turbine at suitable extraction points is sent to low pressure.



Air taken from the atmosphere is first passed through the air pre-heater, where it is heated by flue gases. The hot air then passes through the furnace. The flue gases after passing over boiler and superheater tubes, flow through the dust collector and then through economiser, air pre-heater and finally they are exhausted to the atmosphere through the chimney.

Steam condensing system consists of the following :

(a) Condenser

(b) Cooling water

(c) Cooling tower

(d) Hot well

(e) Condenser cooling water pump

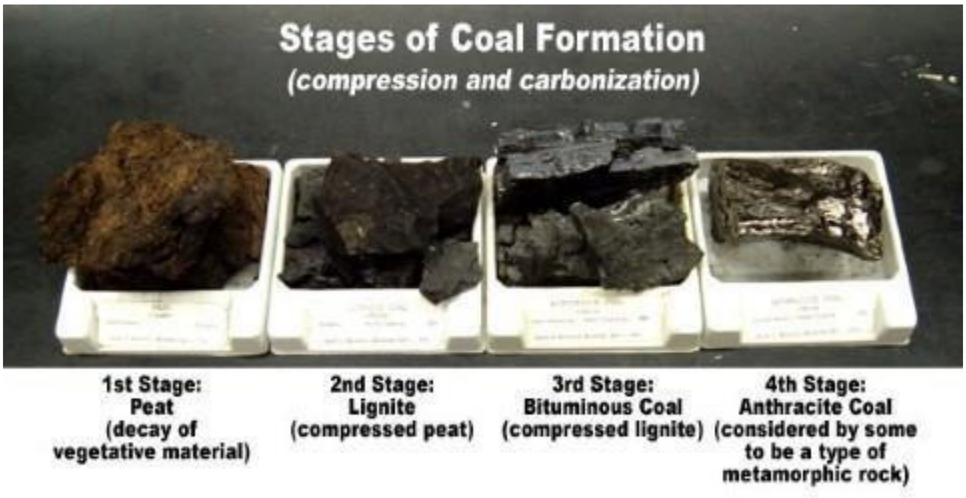
(f) Condensate air extraction pump

(g) Air extraction pump

(h) Boiler feed pump

(i) Make up water pump

TYPES OF COAL



i)Peat:

- Contains **less than 40 to 55 per cent carbon == more impurities.**
- Contains sufficient volatile matter and **lot of moisture** [more smoke and more pollution].
- Left to itself, it burns like **wood**, gives less heat, emits more smoke and leaves a **lot of ash.**

- Lignite

- Brown coal.
- Lower grade coal.
- 40 to 55 per cent carbon.
- Intermediate stage.
- Dark to black brown.
- Moisture content is high (over 35 per cent).
- It undergoes SPONTANEOUS COMBUSTION [Bad. Creates fire accidents in mines]

ii) Bituminous coal

- Soft coal; most widely available and used coal.
- Derives its name after a liquid called bitumen.
- 40 to 80 per cent carbon.
- Moisture and volatile content (15 to 40 per cent)
- Dense, compact, and is usually of black colour.
- Does not have traces of original vegetable material.
- Calorific value is very high due to high proportion of carbon and low moisture.
- Used in production of coke and gas.

Anthracite coal

- Best quality; hard coal.
- 80 to 95 per cent carbon.
- Very little volatile matter.
- Negligibly small proportion of moisture.
- Semi-metallic lustre.
- Ignites slowly == less loss of heat == highly efficient.
- Ignites slowly and burns with a nice short blue flame. [Complete combustion == Flame is BLUE == little or no pollutants. Example: LPG]
- In India, it is found only in Jammu and Kashmir and that too in small quantity.

STEPS INVOLVED IN COAL HANDLING

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

1. Coal delivery.
2. Unloading
3. Preparation
4. Transfer
5. Outdoor storage
6. Covered storage
7. Inplant handling
8. Weighing and measuring
9. Feeding the coal into furnace.

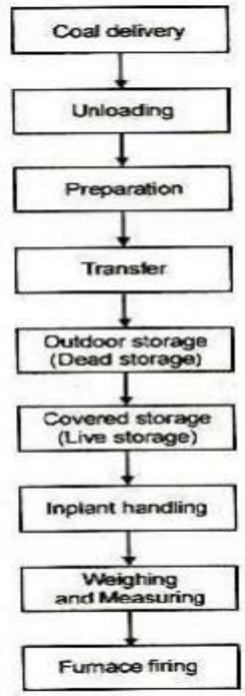


Figure: Steps involved in fuel handling system

i) Coal delivery

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

ii) Unloading

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

(iii) Preparation

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

1. **Transfer**

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

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

a) Belt Conveyor

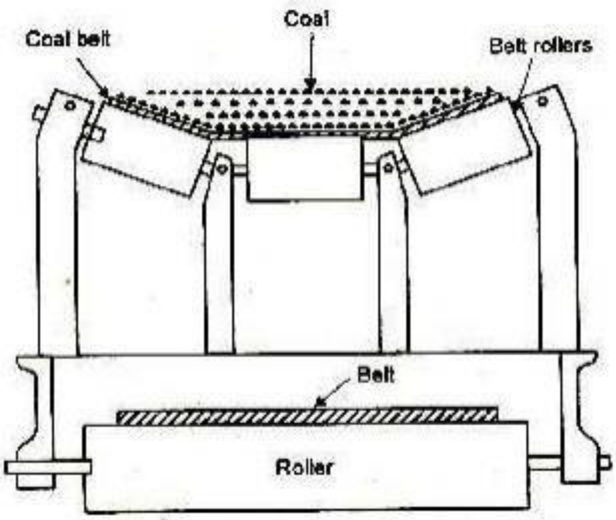


Figure: Belt Conveyor

It consists of an endless belt moving over a pair of end drums (rollers). At some distance a supporting roller is provided at the centre. 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 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 preferred than other types.

Advantages of belt conveyor

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

5. **Screw Conveyor**

It consists of an endless helicoid screw fitted to a shaft (figure). The screw while rotating in a trough transfers the coal from feeding end to the discharge end.

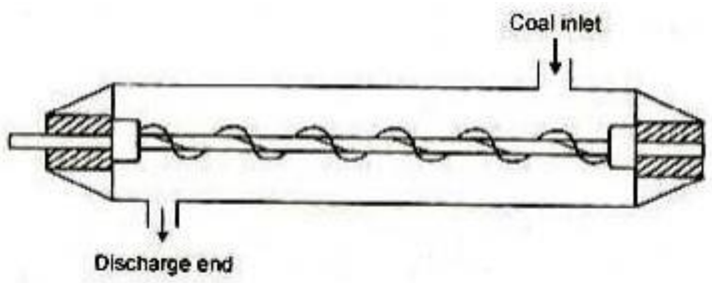


Figure: Screw conveyor

This system is suitable, where coal is to be transferred over shorter distance and space limitations exist. The initial cost of the consumption is high and there is considerable wear o screw. Rotation of screw varies between 75-125 r.p.m

6. **Bucket elevator**

It consists of buckets fixed to a chain (figure). The chain moves over two wheels. The coal is carried by the bucket from bottom and discharged at the top.

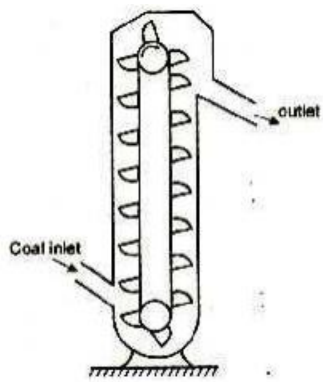


Figure: Bucket elevator

7. **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 figure . Although the initial cost of this system is high but operating cost is less.

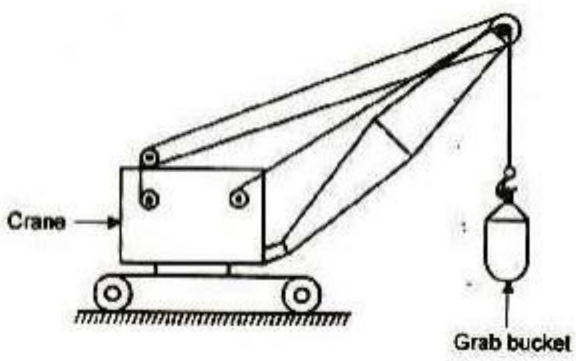


Figure: Grab bucket elevator.

8. 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 strike 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 are 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.

Boilers burning pulverized coal (PC) have bottom furnaces. The large ash particles are collected under the furnace in a water-filled ash hopper, Fly ash is collected in dust collectors with either an electrostatic precipitator or a baghouse

7) Layout of Ash handling system a)Ash Handling System:

Boilers burning pulverized coal (PC) have bottom furnaces. The large ash particles are collected under the furnace in a water-filled ash hopper, Fly ash is collected in dust collectors with either an electrostatic precipitator or a baghouse. A PC boiler generates approximately 80% fly ash and 20% bottom ash. Ash must be collected and transported from various points of the plants as shown in figure. Pyrites, which are the rejects from the pulverizers, are disposed of with the bottom ash system. Three major factors should be considered for ash disposal systems.

1. Plant site
1. Fuel source
2. Environmental regulation

Needs for water and land are important considerations for many ash handling systems. Ash quantities to be disposed of depend on the king of fuel source. Ash storage and disposal sites are guided by environmental regulations.

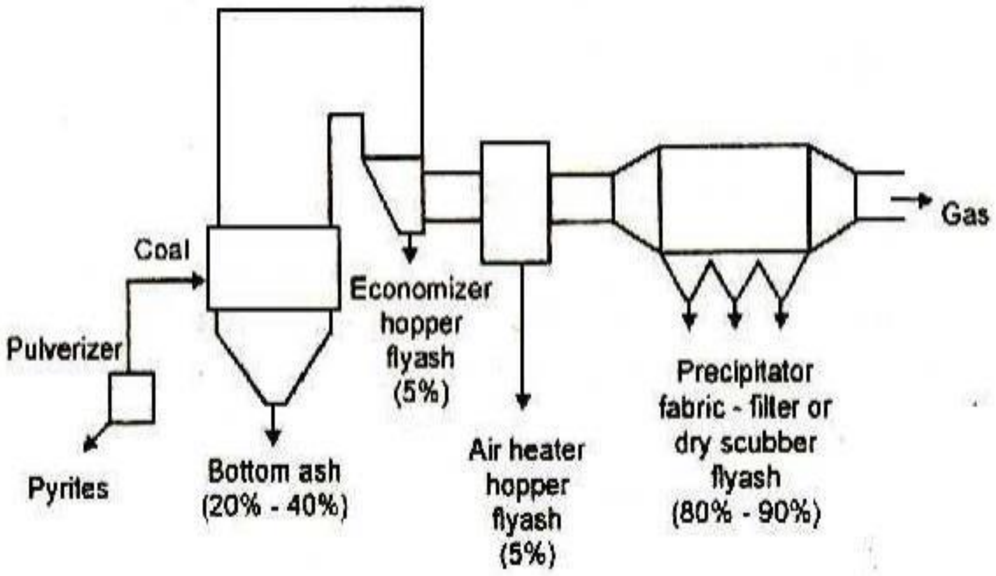


Figure: Layout of ash collection and transportation

The sluice conveyor system is the most widely used for bottom ash handling, while the hydraulic vaccum conveyor (figure) is the most frequently used for fly systems.

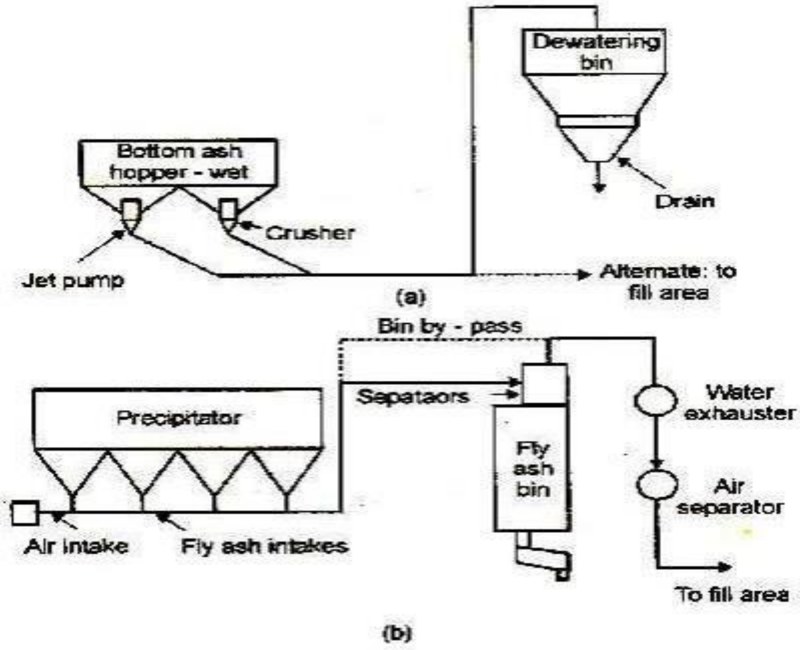


Figure: Layout of ash handling system.

Bottom and slag may be used as filling material for road construction. Fly ash can partly replace cement for making concrete. Bricks can be made with fly ash. These are durable and strong.

b) Ash Handling Equipment:

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

1. Capital investment, operating and maintenance charges of the equipment should be low.
2. It should be able to handle large quantities of ash.
3. Clinkers, shoot, dust etc. create troubles. The equipment should be able to handle them smoothly.

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

4. The equipment should be corrosion and wear resistant.

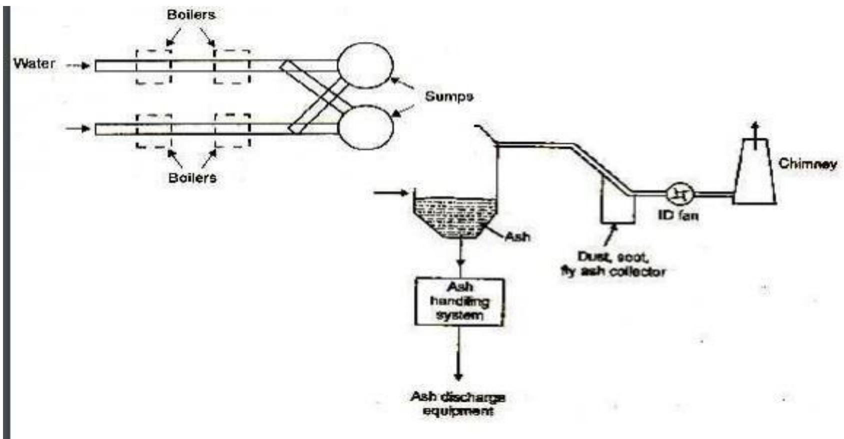


Figure: Ash handling equipment

c) **Pulverized coal storage in Bunker**

Periodically a power plant may encounter the situation where coal must be stored for sometimes in a bunker, for instance during a plant shut down. The bunker, fires can occur in dormant pulverized coal from spontaneous heating within 6 day of loading. This time can be extended to 13 days when a blanket of CO2 is piped into the top of the bunker. The perfect sealing of the bunker from air leakage can extend the storage time as two months or more. The coal in the bunker can be stored as long as six months by expelling air from above the coal with the use of CO2 and then blanketing of all sources of air. A control system used for storing the pulverized fuel in bunker is shown in figure.

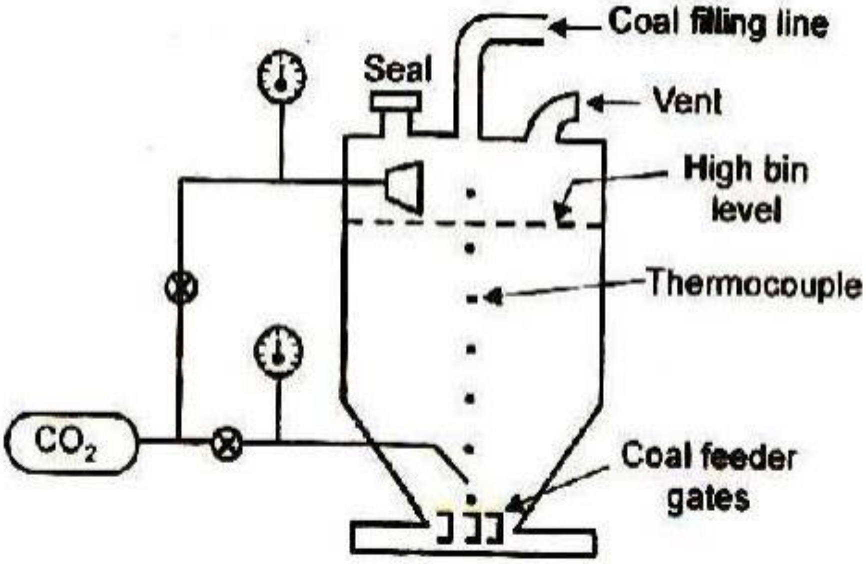


Figure : Control system used for storing the pulverized coal with the use of CO.

8) PULVERIZED COAL HANDING SYSTEM AND

PULVERIZED FUEL HANDLING SYSTEM:

Two methods are in general use to feed the pulverized fuel to the combustion chamber of the power plant. First is ‘Unit System’ secoand is ‘Centralor Bin System ‘.

In unit system, each burner of the plant is fired by one or more pulverizers connected to the burners, while in the central system, the fuel is pulverized in the central plant and then disturbed to each furnace with the help of high pressure air current. Each type of fuel handling system consists of crushers, magnetic separators, driers, pulverizing mills, storage bins, conveyors and feeders.

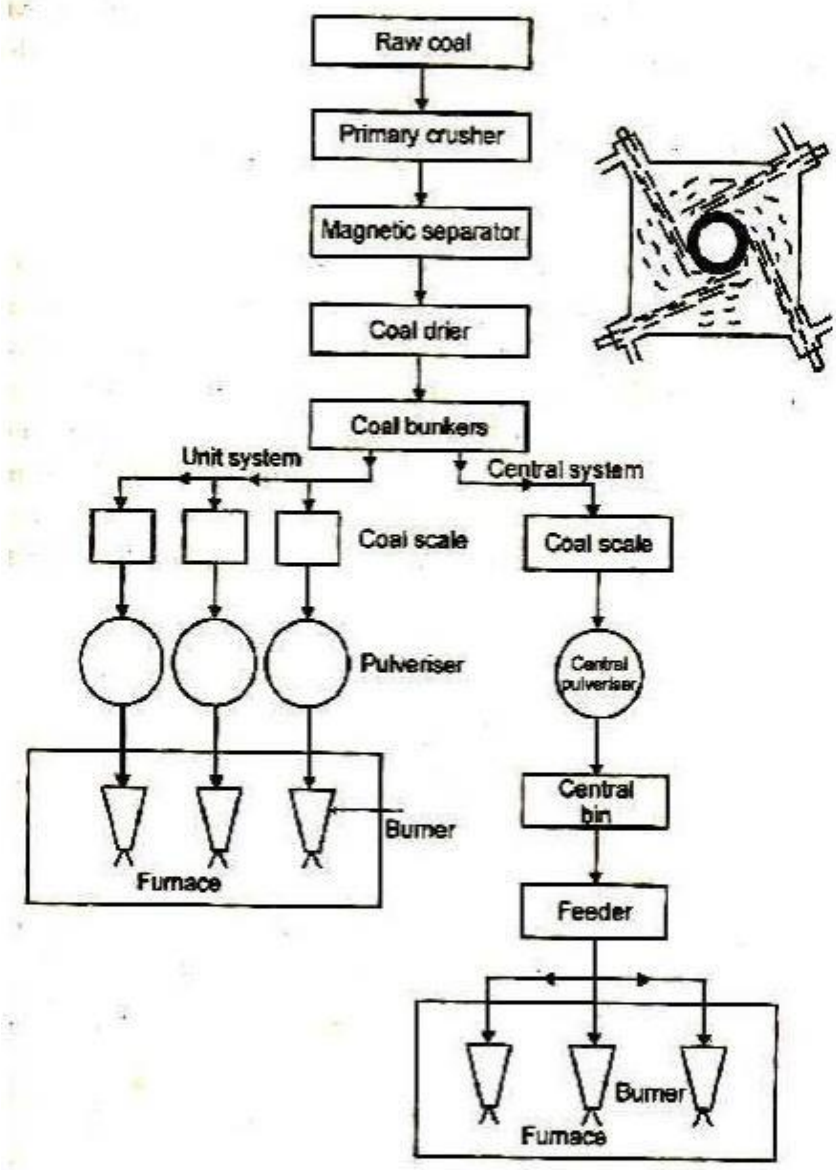


Figure: Pulverized coal handling plant showing all required equipment for unit and central system.

The arrangement of different equipment required in both systems is shown in figure. With the help of a block diagram.

The coal received by the plant from the mine may vary widely in sizes. It is necessary to make the coal of uniform size before passing the pulverizer for efficient grinding. The coal received from the mine is passed through a preliminary crusher to reduce the size to allowable limit (30 mm). The crushed coal is

further passed over magnetic separator which removes pyrites and tramp iron. The further equipment through which coal is passed before passing to pulverizer are already shown in figure.

a) Ball mill pulverizing Ball and Race mill pulverizing
b) Ball Mill

A line diagram of ball mill using two classifiers is shown in figure. It consists of a slowly rotating drum which is partly filled with steel balls. Raw coal from feeders is supplied to the classifiers from where it moves to the drum by means of a screw conveyor. As the drum rotates the coal get pulverized due to the combine impact between coal and steel balls. Hot air is introduced into the drum. The powdered coal is picked up by the air and the coal air mixture enters the classifiers, where sharp changes in the direction of the mixture throw out the oversized coal particles. The over-sized particles are returned to the drum. The coal air mixture from the classifier moves to the exhauster fan and then it is supplied to the burners.

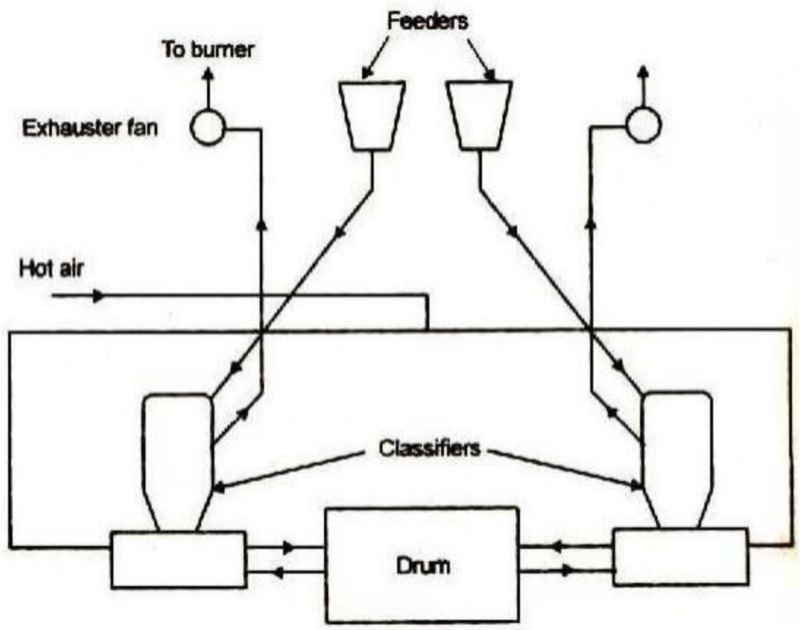


Figure: Ball mill

9. Ball and Race Mills

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

8.1 Classification of Fluidized Bed Combustion:

1. Atmospheric fluidized Bed Combustion (AFBC)
   a. Bubbling fluidized bed combustors

b. Circulating fluidized

c. Pressurized Fluidized Bed Combustin (PFBC)

1.Atmospheric Fluidized Bed Combustion (AFBC) a)Bubbling fluidized bed combustor

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

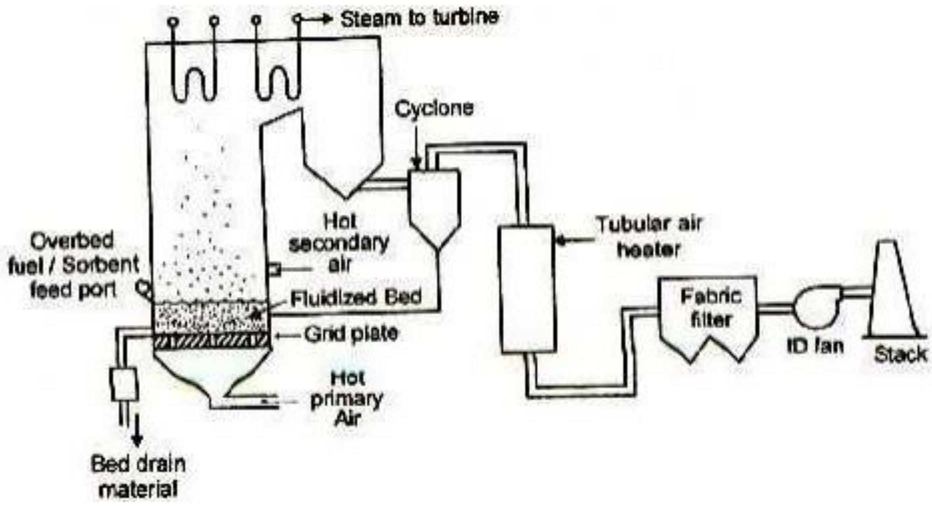


Figure: BFB Arrangement

Secondary air can be added above the bed to improve combustion efficiency and to achieve staged combustion , thus lowering NOx emissions. Most of the early BFBs used tubular air heaters to minimize air leakage that could occur as a result of relatively high primary air pressures required to suspend the bed. Recent designs have included regenerative type air heaters.

b) Circulating fluidized bed combustor

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

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

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

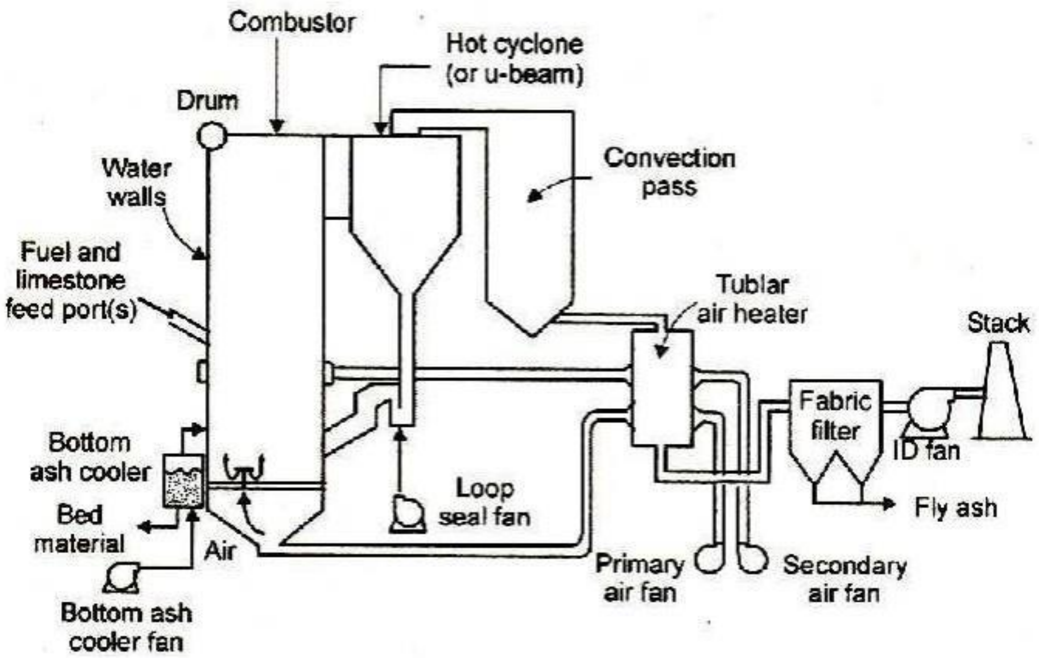


Figure: Atmospheric circulating bed combustor.

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

2)Pressurized Fluidized Bed Combustion:

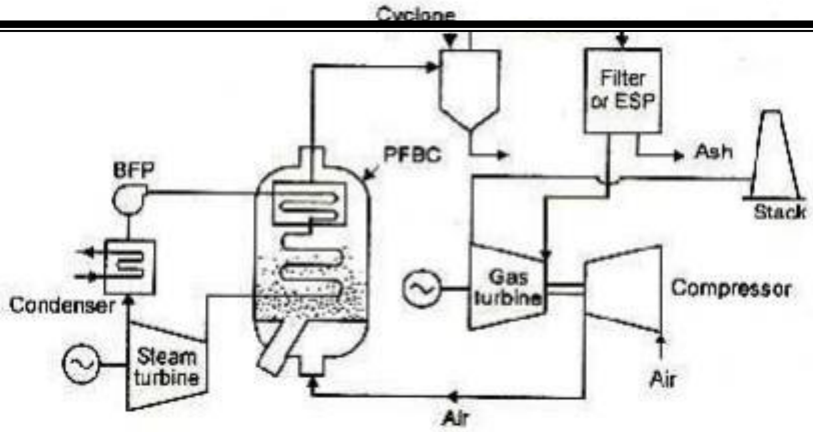


Figure: PFBC turbocharged arrangement

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

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

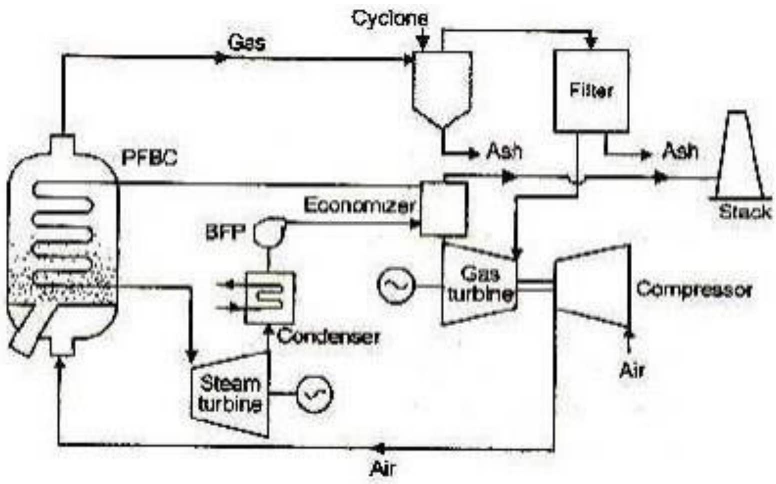


Figure: PFBC combined cycle rearrangement

9) Draught and Wright the types of Draught

Draught:

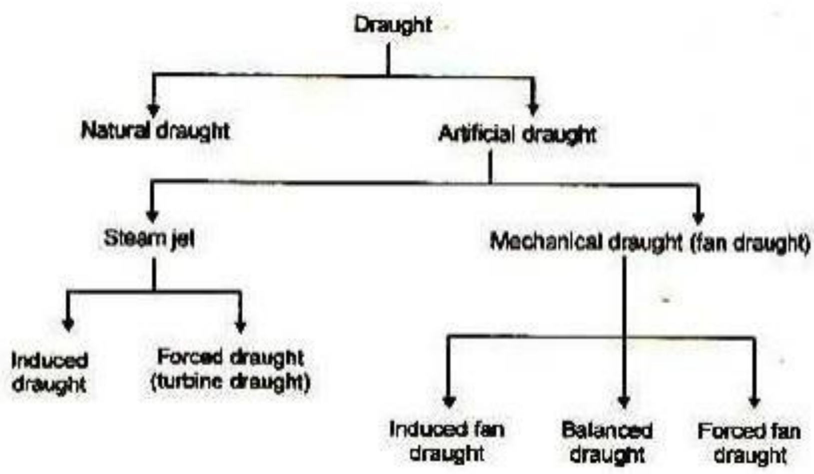
Draught is defined as the difference between absolute gas pressure at any point in a gas flow passage and the ambient (same elevation) atmospheric pressure. Draught is plus if Patm < Pgas and it is minus Patm> Pgas. Draught is achieved by small pressure difference which causes the flow of air or gas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

take place. It is measured in milimetre (mm) or water.

The purpose of draught is as follows:

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

1. Classification of DRAUGHT:



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

a) Artificial Draught

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

b) Steam jet Draught:

It employs steam to produce the draught

c) Mechanical draught

It employs fan or blowers to produce the draught.

d) Induced draught

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

e) Forced draught

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

2. **Natural Draught with advantages and disadvantages applications in Natural Draught:**

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

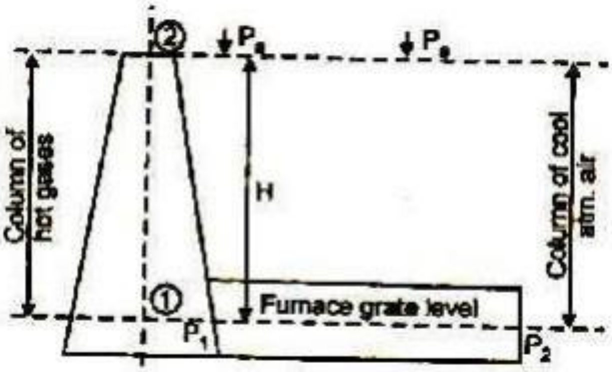


Figure: Natural draught

Where H- Height of the Chimney (m)

pa –Atmospheric pressure (N/m^2)
p1 –Pressure acting on the grate from chimney side (N/m^2) p2 –Pressure acting on the grate from atmospheric (N/m^2)

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

3. **Merits of Natural Draught**

4. No external power is required for creating the draught.
5. Air pollution is prevented since the flue gases are discharged at a higher level
6. Maintenance cost is practically nil since there are no mechanical parts.
7. t has longer life.
8. Capital cost is less than that of an artificial draught

9. **Demerits of natural draught**

10. Maximum pressure available for producing draught by the chimney is less.
11. Flue gases have to be discharged at high temperature since draught increases with the increase in temperature of flue gases.

12. Heat cannot be extracted from the flue gases for economizer, superheater, air pre-heater, etc. since

13. the effective draught will be reduced if the temperature of the flue gases is decreased.

14. Overall efficiency of the plant is decreased since the fluid gases are discharged at higher temperatures.

15. Poor combustion and specific fuel consumption is increased since the low velocity of air affects thorough mixing of air and fuel.

16. Not flexible under peak loads since the draught available for a particular height of a chimney is constant.

17. A considerable amount of heat released by the fuel (about 20%) is lost due to flue gases.

18. Applications

Natural draught system is used only in small capacity boilers and it is not used in high capacity thermal plants.

a) **Forced Draught**
b) **Induced Draught**
c) **Balanced Draught Artificial Draught**

It has been seen that the draught produced by chimney is affected by the atmospheric conditions. It has no flexibility, poor efficiency and tall chimney is required. In most of the modern power plants, the draught used must be independence of atmospheric condition, and it must have greater flexibility (control) to take the fluctuating loads on the plant.

Today'srgelasteam power plants requiring 20 thousand tons of steam per hour would be impossible to run without the aid of draft fans. A chimney of an reasonable height would be incapable of developing enough draft to remove the tremendous volume of air and gases (400×10^3 m^3 to 800×10^3 m^3 per minutes). The further advantage of fans is to reduce the height of the chimney needed.

The draught required in actual power plant is sufficiently high (300 mm of water) and to meet high draught requirements, some other system must be used, known as artificial draught. The artificial draught is produced by a fan and it is known as fan (mechanical) draught. Mechanical draught is preferred for central power stations.

a) **Forced Draught**

In a forced draught system, a blower is installed near the base of the boiler and air is forced to pass through the furnace, flues, economizer, air-preheater and to the stack. This draught system is known as positive draught system or forced draught system because the pressure and air is forced to flow through the system.

The arrangement of the system is shown in figure. A stack or chimney is also in this system as shown in figure but its function is to discharge gases high in the atmosphere to prevent the contamination. It is not

much significant for producing draught therefore height of the chimney may not be very much.

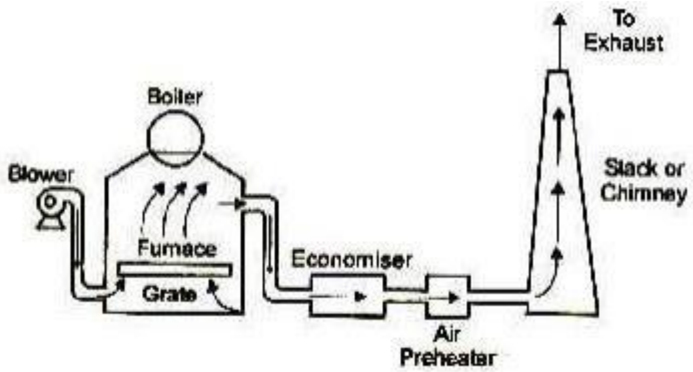


Figure: Forced draught

Induced Draught:

In this system, the blower is located near the base of the chimney instead of near the grate. The air is sucked in the system by reducing the pressure through the system below atmosphere. The induced draught fan sucks the burned gases from the furnace and the pressure inside the furnace is reduced below atmosphere and induces the atmospheric air to flow through the furnace. The action of the induced draught is similar to the action of the chimney. The draught produced is independent of the temperature of the hot gases therefore the gases may be much heat as possible in air-preheater and an izer and air-preheater are incorporated in the hat the temperature of the gas handled by the em and its function is similar as mentioned in forced draught but total draught produced in induced draught system is the sum of the draughts produced by the fan and chimney. The arrangement of the system is shown in figure.

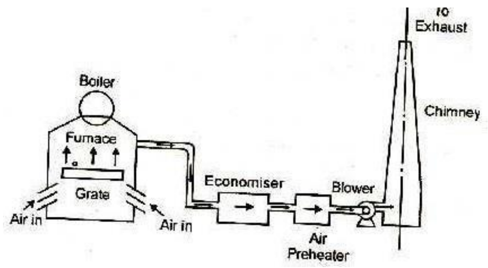


Figure: Induced draught

b) **Balanced Draught:**

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

If the forced draught is used alone, then the furnace cannot be opened either for firing or inspection

because the high pressure air inside the furnace will try to blow out suddenly and there is every chance of blowing out the fire completely and furnace stops.

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

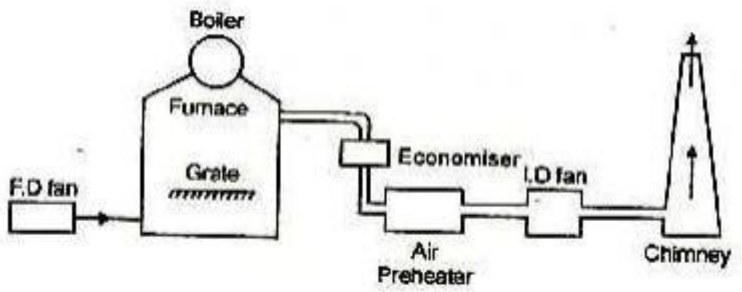


Figure: Balanced draught

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

The arrangement of the balanced draught is shown in figure. Also the pressure inside the furnace is near atmospheric therefore there is no danger of blowout or there is no danger of inrushing the air into the furnace when the doors are opened for inspection.

10. PULVERIZED COAL STORAGE

Periodically a power plant may encounter the situation where coal must be stored for sometimes in a bunker, for instance during a plant shut down. The bunker, fires can occur in dormant pulverized coal from spontaneous heating within 6 day of loading. This time can be extended to 13 days when a blanket of CO_2 is piped into the top of the bunker. The perfect sealing of the bunker from air leakage can extend the storage time as two months or more. The coal in the bunker can be stored as long as six months by expelling air from above the coal with the use of CO_2 and then blanketing of all sources of air.

UNIT 2

INTERNAL COMBUSTION ENGINE PLANT

1. DISEL POWER PLANTS Introduction:

Diesel Engine Power Plants are installed were supply of coal and water is not available in sufficient quantity or were power is to be generated in small quantity are were stand by sets are required for continuity of supply such as in hospitals, telephone exchanges, radio stations and cinemas. These plans in the range of 2 to 5 MW capacity are used as central stations for supply authorities and works and they are universally adopted to supplement hydro electric or thermal stations were standby generating plants are essential for starting coal and under emergency conditions.

In several countries, the demand for diesel power plants is increased for electrical power generation because of difficulties experienced in construction of new hydraulic plants and enlargement of old hydro plants. A long term planning is required for the development of thermo and hydro plants which cannot keep the pace with many times the increased demand by the people and industries.

The diesel units used for electrical generation are more reliable and long lived piece of equipment compared with other types of plants.

Advantages and disadvantages of diesel power plants:

Advantages:

1. Design and installation are very simple
2. Can respond to varying loads without any difficulty
3. The standby losses are less
4. Occupy less space
5. Can be started and put on load quickly
6. Require less quantity of water for cooling purpose
7. Overall capital cost is less than that for steam plants.
8. Require less operating and supervising staff as compared to that for steam plant.
9. The efficiency of such plants at part loads does mot fall so much as that of a steam plant.
10. The cost of working and civil engineering works is low.
11. Can burn fairly wide range of fuels.
12. These plants can be located very near to the load centres many times in the heart of the town.
13. No problem of ash handling.
14. The lubrication system is more economical as compared with that of a steam power plant.

The diesel power plants are more efficient than steam power plants in the range of 150 MW capacity.

Disadvantages:

1. High operating cost
2. High maintenance and lubrication cost
3. Diesel units capacity is limited. These cannot be constructed in large sizes
4. In a diesel power plant noise is a serious problem
5. Diesel plants cannot supply overload continuously, whereas steam power plants can work under 25% overload continuously
6. The diesel power plants are not economical where fuel has to be imported
7. The life of a diesel power plant is limited (2 to 5 years or less) as compared to that of steam power plant (25 to 30 years)

The different fields were the use of diesel power plant is essential

a) Application of diesel power plant:

1. The peak load plant
2. Emergency plant
3. Mobile plant

4. Starting stations
5. Standby units
6. Nursery stations
7. Central stations
8. Small Scale Industries
9. Commercial purposes such as cinema halls and hospitals
10. Public utilities such as multiplexes

b) Site Selection:

The following factors should be considered while selecting the site for a diesel power plant:

1. Foundation of sub-soil conditions

The conditions of sub-soil should be such that a foundation of a reasonable depth should be capable of providing a strong support to the engine

2. Accession to the site:

The site should be so selected that it is accessible to rail and road.

3. Distance from the load centre:

The location of the plant should be near the load centre.

c) Classification of IC Engines:

Internal combustion engines may be classified as given below:

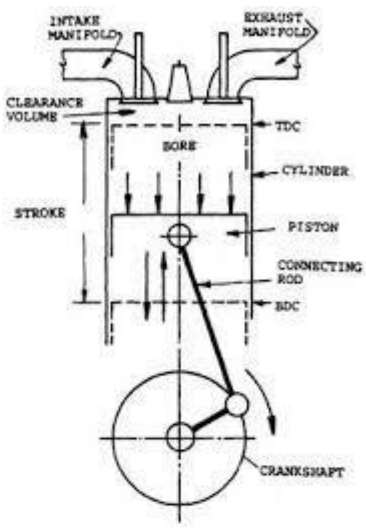
1. According to the cycle of operation
   a. Two stroke cycle engines
   b. Four stroke cycle engines
2. According to cycle of combustion
   a. Otto cycle engine (combustion at constant volume)
   b. Diesel cycle engine (combustion at constant pressure)
   c. Duel combustion or semi-diesel cycle engine (combustion partly at constant volume and partly constant pressure)
3. According to arrangement of cylinders
   a. Horizontal engine
   b. Vertical engine
   c. V - type engine
   d. Radial engine etc.
4. According to their uses
   a. Stationary engine
   b. Portable engine
   c. Marine engine
   d. Automobile engine
   e. Aero engine etc.
5. According to the fuel employed and method of fuel supply to the engine
   a. Oil engine
   b. Petrol engine
   c. Gas engine
   d. Kerosene engine etc
   e. Carburettor, hard bulb, solid injection and air injection engine
6. According to the speed of the engine
   a. Low speed engine
   b. Medium speed engine
   c. High speed engine
7. According to the method of ignition
   a. Spark ignition engine

b. Compression ignition engine

8. According to the method of cooling
a. Air cooled engine
b. Water cooled engine
9. According to the method of governing
a. Hit and miss engine governed engine
b. Quality governed engine
c. Quantity governed engine
10. According to valve arrangement
a. Overhead valve engine
b. L-head type engine
c. T-head type engine
d. F-head type engine
11. According to number of cylinders
a. Single cylinder engine
b. Multi cylinder engine

2. Construction details of an IC Engine:

i) Cylinder:



Cylinder is considered as the heart of an engine in which the combustion of fuel takes place. The inside diameter of the cylinder is called as bore. In order to protect to cylinder from wear, liners or sleeves or sometimes inserted in the cylinder. The material of the cylinder should be such that it should withstand high pressure and the temperature of the combustion of fuel.

ii) Piston:

Piston is a close fitted cylindrical plunger, which moves to and fro inside an engine cylinder. The main functions of Piston is to transmit the force exerted due to combustion of fuel to the connecting rod which in turn transmit it to the crank shaft to produce mechanical power.

iii) Piston Rings:
The Piston Rings are the metallic rings inserted into the circumferential grooves provided at the top end of the piston. These rings maintain a gas tight joint between the piston and cylinder while the piston is reciprocating in cylinder. They also helps in conducting the heat from the piston on to the cylinder walls.
iv) Connecting rod:
It is the link that connects the piston and the crank shaft by means of pin joints. It converts the reciprocating movement of piston into circular motion (or rotary motion) of crank shaft as it is subjected to alternatively tensile and compressive stresses as well as bending stresses. Therefore, it should be designed and manufactured carefully.
v) Crank and crank shaft:
A crank is a leaver that is connected to the end of the connecting rod by a pin joint with its other end connected rigidly to a shaft called crank shaft. It rotates about the axis of the crank shaft and causes the connecting rod to oscillate. The main function of crank shaft is to convert the reciprocating motion of the piston into rotary motion with the help of connecting rod.
vi) Valves:
The valves are the devices, which control the flow of the intake charge and the exhaust gases to release from the engine cylinder respectively. They are also called poppet valves. These valves are separated by means of cams driven by the crank shaft through a timing gears or chain.
vii)Fly wheel:
It is a heavy wheel mounted on the crankshaft of the engine to maintain uniform rotation of the crank shaft.
viii) Crank case:
It is the lower part of an engine serving as an enclosure for the crank shaft and also as a reservoir for the lubricating oil.
ix) TDC (Top Dead Centre):
Top Dead Centre position is defined as the position of the piston when it is at its top most position or when the volume in the cylinder is lowest.
x) BDC (Bottom Dead Centre):
It is the position of the piston when the volume in the cylinder is maximum or when piston is at its lowest position.
Swept Volume:
It is the volume swept by the piston when moving from BDC to TDC or TDC to BDC. It is denoted by V_s .
xi) Clearance Volume:
It is the volume in the cylinder when the piston is at TDC position. It is denoted by V_c.
Total volume inside the cylinder = Swept Volume + Clearance Volume.
$V = V_s + V_c$
xii)Stroke:
It is the distance travelled by the piston when moving from BDC to TDC position or TDC to BDC position.
xiii) Compression Ratio:
It is defined as the total volume to clearance volume. Compression ratio = $V_S + V_C / V_C$

3) Four stroke cycle diesel engines:

This type of engine comprises of the following four strokes:

1. Suction stroke:

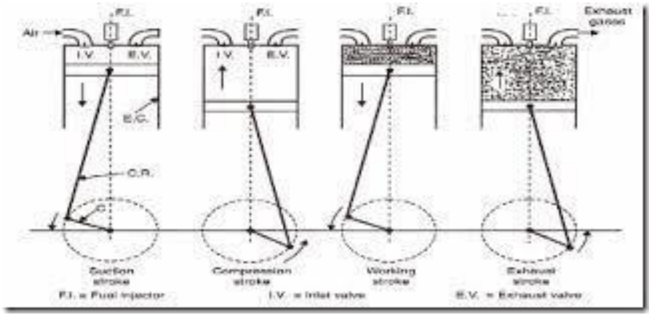
With the movement of the piston from TDC to BDC during this stroke, the inlet valve opens and the air at atmospheric pressure is drawn inside the engine cylinder:, the exhaust valve however remains closed. This operation is represented by the line 5-1.

2. Compression stroke:

The drawn air at atmospheric pressure during the suction stroke is compressed to high pressure and temperature (to the valve of 35 bar and 600^0 C) as the piston moves from BDC to TDC. This operation is represented by 1-2. Both the inlet and exhaust valve do not open during any part of the stroke.

3. Expansion or working stroke:

As the piston starts moving from TDC a metered quantity of fuel is injected into the hot compressed air in time sprays by the fuel injector and it (fuel) starts burning at constant pressure by the 2-3. At the point 3 fuel supply is cut off. The fuel is injected at the end of compression stroke but in actual practice the ignition of the fuel starts before the end of the compression stroke. The hot gases of the cylinder expand adiabatically to point 4 thus doing work on the piston. The expansion is shown by



4. Exhaust stroke:

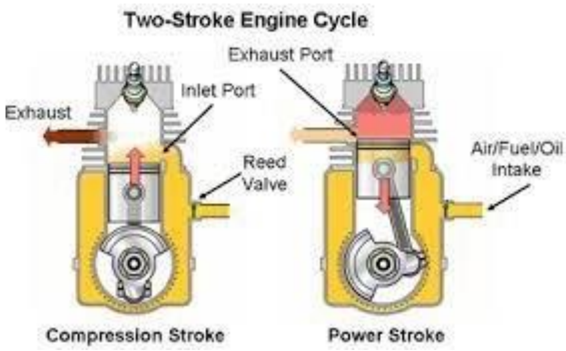
The piston moves from BDC to TDC and the exhaust gases escape to the atmosphere through the exhaust valve. When the piston reaches the TDC the exhaust valve closes and the cycle is completed. The stroke is represented by the line 4-5.

The actual p-v diagram of 4 stroke diesel engine. It may be noted that the line 5-1 is below the atmospheric pressure line. This is due to the fact that owing to the restricted area of the inlet passages the entering air cannot cope with the speed of the piston. The exhaust line 4-5 is slightly above the atmospheric line. This is because of the restricted exhaust passages which do not allow the exhaust gases to leave the engine cylinder quickly.

The loop of area 4-5-1 is called negative loop. It gives the pumping loss due to admission of air and removal of exhaust gases. The area 1234 is the total or gross work obtained from the piston and network can be obtained by the subtracting area 451 from area 1234.

5. Two Stroke Cycle Diesel Engine:

The cylinder ‘L’ is connected to the closed crank chamber ‘CC’. During the upward stroke of the piston ‘M’ the gases in ‘L’ are compressed and at the same time fresh air enters the crank chamber through the valve ‘V’. When the piston moves downwards, ‘V’ closes and air in the crank chamber is compressed.



The piston is moving upwards and is compressing the air which has previously been supplied to ‘L’ and before it (piston) reaches the TDC the fuel injector supplies fuel to the engine cylinder.

Ignition of fuel takes place due to high temperature of air and gases are produced. These gases expand and the piston then travels downwards and near the end of this stroke the piston uncovers exhaust port (EP) and the burnt exhaust gases escape through this port (iii).

The transfer port (TP), then is uncovered immediately and compressed air from the crank chamber flows into the cylinder and is deflected upwards by the hump provided on the head of the piston.

It may noted that the incoming air helps the removal of gases from the engines cylinder. The piston then again starts moving from BDC to TDC and the air gets compressed when exhaust port (EP) and transfer port (PT) are covered by the piston, thus the cycle is repeated.

6. Comparison between Petrol and Diesel engine:

Petrol Engine	**Diesel Engine**
1. Air petrol mixture is sucked in the engine cylinder during suction stroke	Only air is sucked during suction stroke
2. Spark plug is used	Employees an injector
3. Power is produced by spark ignition	Power is produced by compressed ignition
4. Thermal efficiency is upto 25%	Thermal efficiency is upt 40%
5. Occupies less space	Occupy more space
6. More running cost	Less running cost
7. Light in weight	Heavy in weight
8. Fuel (petrol) costlier	Fuel (diesel) cheaper
9. Petrol being is volatile is dangerous	Diesel is not dangerous as it is non-volatile
10. Pre-ignition is possible	Pre-ignition is not possible
11. Works on otto cycle	Works on diesel cycle
12. Less dependable	More dependable
13. Used in cars and motor cycles	Used in heavy duty vehicles like trucks and heavy machinery

7. Comparison of four stroke and two stroke cycle engines:

Four Stroke Cycle Engine	**Two Stroke Cycle Engine**
1. The cycle is completed in four strokes of the piston or in two revolutions of crank shaft. Thus one power stroke is obtained in every two revolutions of the crank shaft.	The cycle is completed in two strokes of the piston or in one revolution of the crank shaft. Thus one power is obtained in each revolution of the crank shaft.
2. Because of the above turning movement is not no uniform and hence heavier fly wheel is needed.	More uniform turning movement and hence lighter fly wheel is needed.

3. Again because of one power stroke for two revolutions power produced for same size of engine is small or for the same power the engine is heavy and bulky	Because of one power stroke for one revolution power produced for same size of engine is more or for same power the engine is light and compact.
4. Because of one power stroke in two revolutions lesser cooling and lubrication is required. Low rate of wear and tear.	Because of one power stroke in one revolution greater cooling and lubrication requirement. Great rate of wear and tear.
5. The four stroke engine contains valve and valve mechanism.	Two stroke engine has no valves but only ports.
6. Because of the heavy weight and complication of valve mechanism higher is the initial cost.	Because of light weight and simplicity due to absence of valve mechanism cheaper is the initial cost.
7. Volumetric efficiency is more due to more time of injection.	Volumetric efficiency is less due to less time for injection.
8. Thermal efficiency is higher, part load efficiency better than two stroke cycle engine.	Thermal efficiency is lower, part load efficiency lesser than four stroke cycle engine.
9. Used where efficiency is important in cars, buses, trucks, tractors, industrial engines, aeroplanes, power generators etc.	In two stroke petrol engine some fuel is exhausted during scavenging. Used where (a) low cost, (b) compactness and light weight is important. Two stroke (air cooled) petrol engine used in very small sized only, lawn movers, scooters, motor cycles (lubricating oil mixed with petrol) Two stroke diesel engines used in very large sizes more than 60 cm bore, for ship propulsion because of low weight and compactness.

4) Essential components of a Diesel Power Plant

1. Engine
2. Air Intake System
3. Exhaust System
4. Fuel System
5. Cooling System
6. Lubrication System
7. Engine Starting System
8. Governing System

i) Engine

This is the main component of the plant which develops required power. It is generally directly coupled to the generator.

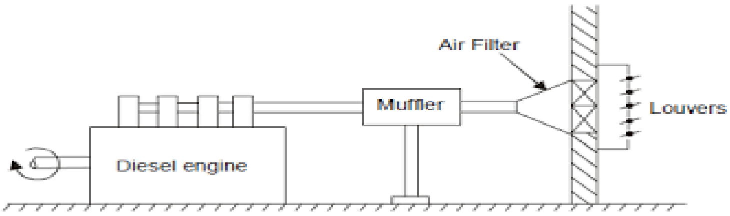
ii) Air Intake System

Air filters, ducts and super chargers are together known as air supply system or air suction system. Generally air system begins with an intake located outside of the building provided with a filter to catch dirt which would otherwise cause excessive wear in the engine. For large diesel plants around 4 to 8 m^3 /KV of air would be needed per hour.

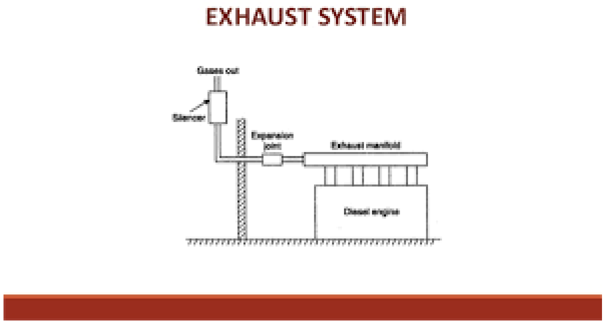
Filters are of two types:

a. Dry type
b. Oil Bath type:

In dry type filters, filters are made up of cloth, glasses, wool etc. But in the case of oil bath type filters, the air is swept over a path of oil so that the dust particles get eliminated. The filters should be cleaned periodically. If super chargers are used then they increase the pressure of air supply to the engine.



iii) Exhaust System:



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

The silencer and connecting ducts are the main constituents of the exhaust system. A muffler will be provided to the exhaust pipe to reduce the pressure in the exhaust line. Since the exhaust gases have a very high temperatures, these gases can be used to pre-heat the oil and air supply to the engine.

iv) Exhaust Manifolds:

In automobiles an exhaust manifold collects the exhaust gases from multiple cylinders into one pipe. However, special combustion arrangements such as pre-combustion chambers, air cells ect., are necessary to secure good mixing. Engines driving electrical generators have lower speeds and simple combustion chambers.

5) Functions of a Fuel Injection System:

1. Filter the fuel
2. Meter or measure the correct quantity of fuel to be injected
3. Time the fuel injection
4. Control the rate of fuel injection
5. Atomise or break-up the fuel to fine particles
6. Properly distribute the fuel in the combustion chamber

The injection systems are manufactured with great accuracy, especially the parts that actually meter and inject the fuel. Some of the tolerances between the moving parts are very small of the order of one micron. Such closely fitting parts require special attention during manufacturing and hence the injection systems are costly.

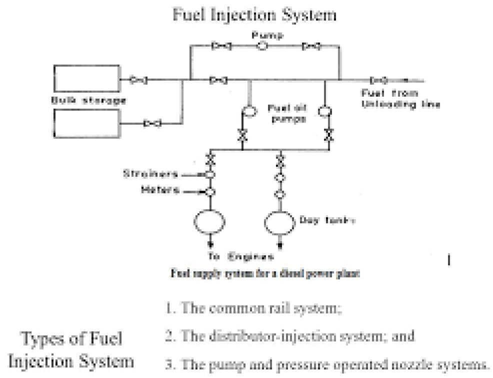
Types of Fuel Injection System:

The following injection system are commonly used in diesel power station:

1. Common rail injection system
2. Individual pump injection system
3. Distributor

Atomisation of fuel oil has been secured by a. air blast b. pressure spray. Early diesel engines used air fuel injection at about 70/. This is sufficient not to inject oil but also to atomise it.

4. Fuel systems are fuel storage and supply system.



The fuel storage tank, fuel pump, strainers and heater are together known as fuel system. To transfer fuel from delivery point to storage tanks, fuel transfer pumps are used. Fuel can be cleaned by using strainers (filters). During winter heaters are used to avoid oil condensation.

After the fuel is transferred to the daily consumption tank located above the engine level, it flows into the injection pump by using transfer pump. Adequate quantity of fuel is injected into the cylinder.

The mechanical heart of the diesel engine is the fuel injection system. The engine can perform no better than its fuel injection system. A very small quantity of fuel must be measured out, injected, atomised and mixed with combustion air. The mixing problem becomes more difficult. The larger the cylinder and faster the rotative speed. Fortunately the high speed engines are the small bore auto-types.

Rapid and through combustion:

The expense of providing an air compressor and tank led to the development of solid injection. Using a liquid pressure of between 100 and 200 bar which is sufficiently high to atomise the oil it forces through the spray nozzles. Great advantages have been made in the field of solid injection of the fuel through research and progress in fuel pump, spray nozzles and combustion chamber design.

1. Common rail injection system

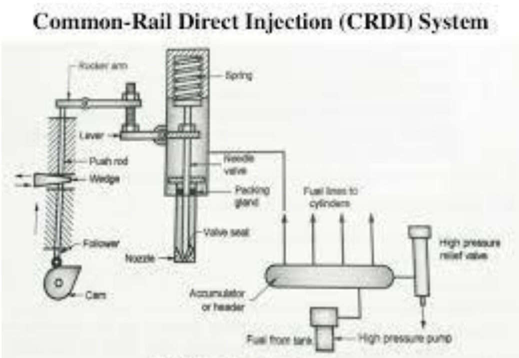
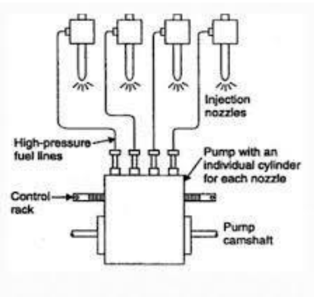


Fig. 4.31.1 : Common rail system

A single pump supplied high pressure fuel to header, a relief valve holds pressure constant. The control wedge adjusts the lift of mechanical operated valve to set amount of	Controlled pressure system has pump which maintains set head pressure. Pressure relief and timing valves regulate injection time and amount. Spring loaded spray walls act as a
time and injection.	check.

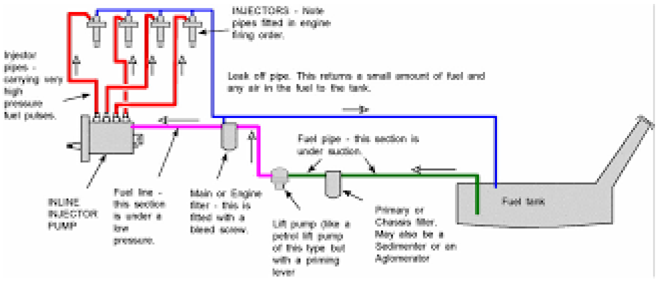
2. Individual pump injection system



In this system an individual pump or pump cylinder connects directly to each fuel nozzles. Pump meters change and control injection timing. Nozzles contain a delivery valve actuated by the fuel oil pressure.

3. Distributor system:

The fuel is metered at a central point. A pump pressurises 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 the nozzles.



Fuel Pump:

Various types of fuel injection pumps are used in CI engines.

1. Variable spill and stroke types
2. Single cylinder and multi cylinder types
3. Jerk pump type and distributor type
4. Cam-operated in-line plunger type and rotary distributor type

Jerk pump type:

Jerk diesel pump has a cylinder and plunger assembly with a scroll for each cylinder. The main parts of the pump are:

1. Delivery valve: Delivery valve has a specialized construction. This construction has provisions of longitudinal and annular grooves, stem of the this valve is in longitudinal directions. This valve is located at upper most region of pump.

2. Plunger: Plunger serves the purpose controlling the quantity of fuel to be injected. It contains helix at its upper end and has a provision of vertical slot. Plunger is located at the centre in the pump and revolve by means of control rack.
3. Toothed control sleeve: This serves the purpose of controlling the angular position of the plunger so that correct quantity of fuel is injected. It encloses a plunger barrel and it tightly fits over it. A toothed pinion is made integrally on it. This pinion measures with control rack.
4. Control Rack: It causes to and motion to control sleeve, which again causes rotational movement to plunger through desired angle. For this function to be performed, rack is imparted by reciprocating motion by accelerated pedal through linkages.
5. Lug: Lug is in lower region of jerk diesel pump. It is on the plunger and fitted into slot cut at the bottom of toothed sleeve. So that toothed sleeve is in contact with teeth on control rack.

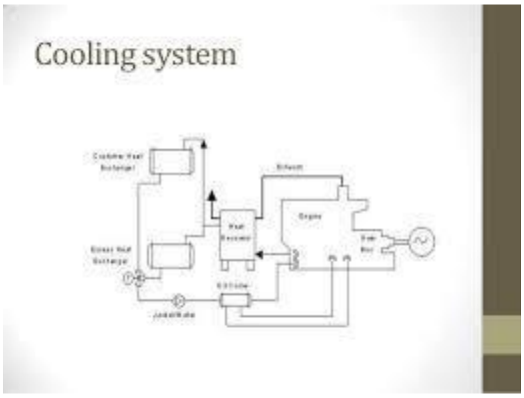
Fuel atomizer or Injector:

It consists of a nozzle valve fitted in the nozzle body. The nozzle valve is held on its seat by a spring which exerts pressure through this spindle. Adjusting screws by which the nozzle valve lift can be adjusted. Usually, the nozzle valve is set to lift at 135 to 170 bar. Feeling pin which indicated whether valve is working properly or not. The fuel under pressure from the fuel pump enters the injector through the passages B and C and lifts the nozzle valve.

The fuel travels down nozzle ‘V’ and injected into the engine cylinder in the form of fine spray. Then the pressure of the oil falls, the nozzle valve occupies its seat under the spring force and fuel supply is cut-off. Any leakage of fuel accumulated above the valve is led to the fuel tank through the passage ‘A’. the leakage occurs when the nozzle valve is worn out.

Cooling system

Part of heat released by fuel burning in the engine cylinder passes through the cylinder walls, piston, rings, etc. and may cause damage to the system. To keep the temperature of engine parts within safe operating limits, cooling is provided. The cooling system consists of a water source, pump and cooling towers. The pump circulates water through cylinder and head jacket. The water takes away heat form engine and it becomes hot. The hot water is cooled by cooling towers and is recirculated for cooling.



7. Lubrication System for Diesel Engines

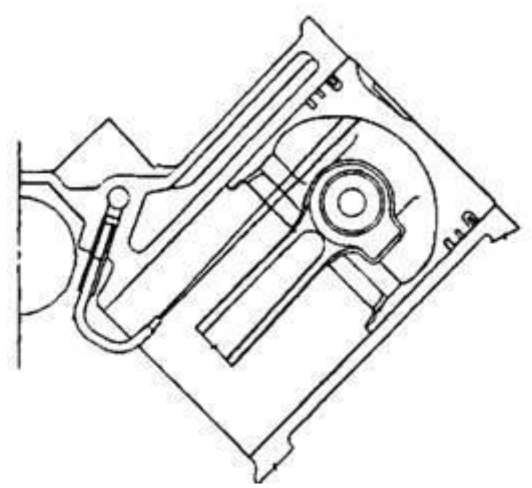
The lubrication system in a diesel engine is very similar to the systems in gasoline engines. However, there are some significant differences between the two systems. An oil cooler is connected in series with the oil filter on some diesel engines. Engine coolant is circulated around the oil passages in the cooler to dissipate heat from the oil.

Oil is supplied from passages in the engine block to curved discharge tubes at the bottom of each cylinder. The oil is sprayed from an orifice in the discharge tubes against the under crown of the piston to provide additional piston cooling and more uniform piston temperature.

This extra piston cooling allows close clearances between the piston rings and ring grooves and reduces the possibility of the rings sticking in their grooves.

Also high combustion temperature and elements such as sulphur in the diesel fuel make the CI engines more prone to deposits of carbon, formation of gums around the piston rings, and lacquer deposits on the side of the pistons.

These conditions are minimised by using heavy-duty detergent oil. Detergent additives hold the carbon and soot in suspension in the oil so that the foreign particles harmlessly pass around the system until the oil is next drained.

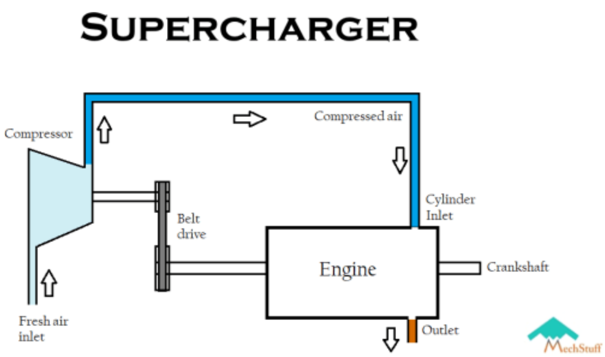


Oil-cooled pistons.

i)Superchargers :-

In simple words, Superchargers are pressure boosting devices(compressors) which increase the pressure of the air before letting it get into cylinder of the internal combustionengine . And the process of increasing the pressure or forcing more air to get into engine is called as supercharging.

Working of Superchargers :-

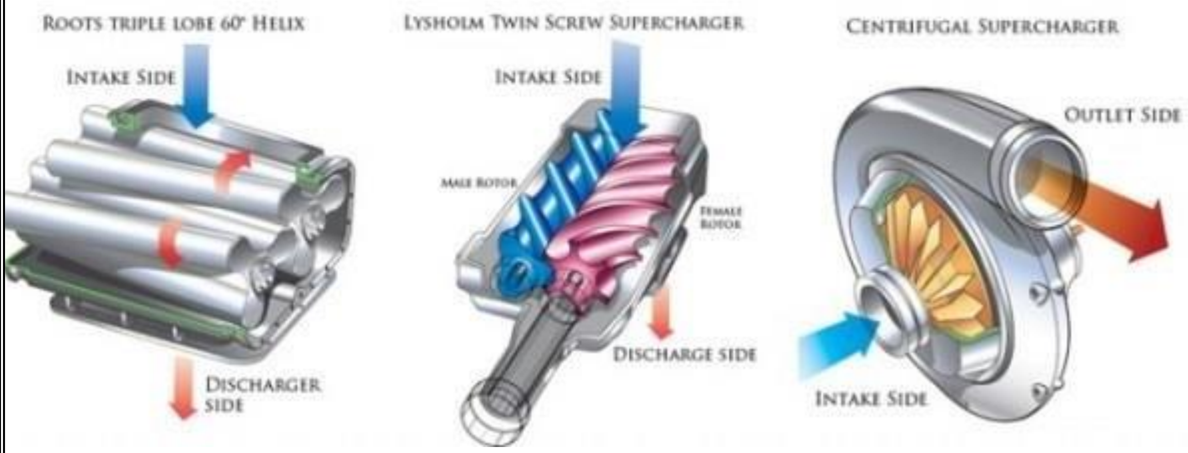


Superchargers are basically compressors/blowers which takes air at normal ambient pressure &

compresses it and forcefully pushes it into engine ! Power to the compressor/blower is transmitted f rom engine via the belt drive. The addition of extra amount of air-fuel mixture into the cylinder increases

the mean effective pressure of the engine. An increment in MEP makes the engine produce more power. In this way, adding a compressor to the engine makes it more efficient.

9.3) Types of superchargers : -



Centrifugal superchargers –

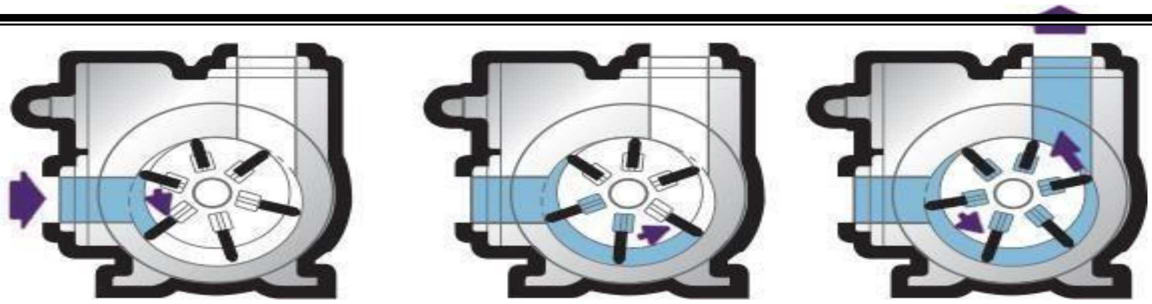
These are commonly used in the vehicles & are powered by the engine via a belt -pulley system. The air- fuel mixture enters the impeller at the centre. The air is then passed through diffuser, which increases the pressure. Finally the air makes it way through the volute casing to the engine.

Root’s type supercharger –

Root’s type contain two rotors of epicycloid shape. The rotors are of equal size inter-meshed & are mounted and keyed on 2 different shafts. Any one shaft is powered by the engine via a V -belt or gear train(depending on the distance). Each rotor can have 2 or more than 2 lobes depending upon the requirement. The air enters through the inlet & gets trapped on its way to outlet. As a result, pressure at outlet would be greater than the inlet.

Vane type supercharger –

A number of vanes are mounted on the drum of the supercharger. These vanes are pushed outwards via pre-compressed springs. This arrangement helps the vane to stay in contact with the inner surface of the body.
Now due to eccentric rotation, the space between two vanes is more at the inlet & less at the oulet. In this way, the quantity of air which enters at the inlet decreases it’s volume on its way to oulet. A decrease in volume results in increment of pressure of air. Thus the mixture obtained at the outlet is at higher pressure than at the inlet.



Advantages of supercharging :-

- Higher power output. This was whole point of studying & installing superchargers.
- Reduced smoke from exhaust gases. The extra air pushed into cylinder, helps the air to complete combust leading to lesser smoke generation.
- Quicker acceleration of vehicle. Supercharger starts working as soon as the engine starts running. This way the engine gets a boost even at the beginning leading to quicker acceleration.
- Cheaper than turbocharger.

Limitations :-

- Draws power from engine. Though the overall mechanical efficiency is increased but it consumes power from the engine. The same job is done by a turbocharger without consuming extra power !
- Increased heat generation. The engine should have proper heat dissipation systems as well as it should be able to withstand thermal stresses !
- Induces stress. The engine must hold up against the high pressure & bigger explosions generated in the cylinder. If the engine is not designed considering these stresses, it may damage the piston head.

10. GAS TURBINE POWER PLANT

Introduction

Gas turbine is a rotary type internal combustion thermal prime mover. The gas turbine plant work on a gas power cycle. Of the various means of producing mechanical power, the gas turbine is in many respects the most satisfactory one. Its outstanding advantages are: - exceptional reliability, - freedom from vibration, - ability to utilize grades of fuel not suitable for high performance spark-ignition engines, and - ability to produce large bulk of power from units of comparatively small size and weight. The gas turbine obtains its power by utilizing the energy of a jet of burnt gases and air, the velocity of jet being absorbed as it flows over several rings of moving, blades, which are fixed on a rotor mounted on a common shaft. It thus, resembles a steam turbine, but it is a step forward in eliminating water-to steam step (the process of converting water into steam in a boiler) and using hot gases directly to drive the turbine.

Classification Gas turbine plants can be classified according to the following factors:

a. Combustion : Continuous-combustion or constant pressure gas turbine and explosive type combustion or constant volume gas turbine.

b.Thermodynamic (Gas Power) Cycle : Brayton or Joule cycle (for constant volume gas turbines), Atkinson cycle (for constant volume gas turbines) and Ericsson cycle (for constant pressure gas turbine with large number of intercooling and reheating.)

c. Cycle of Operation : Open cycle, closed cycle, or semi-closed cycle gas turbine. Continuous-combustion (constant pressure) gas turbine may work with open or closed cycle. Constant volume gas turbine works with open cycle. Closed cycle gas turbine is an external combustion engine while open cycle gas turbine is an internal combustion engine.

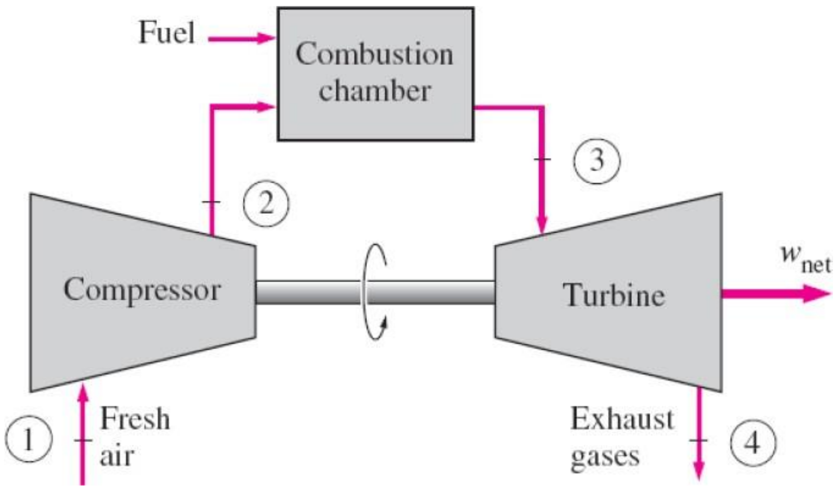
d) Arrangement of shafts. : Single shaft gas turbines (compressor is run by power turbine) and Multi-shaft gas turbines (separate compressor turbine and power turbine), Series flow gas turbines and Parallel flow gas turbines, etc.

e) Fuel: Liquid fuel, gaseous fuel or solid fuel gas turbine.

f) Application : Stationary, automotive, locomotive, marine and air-craft gas turbine

PRINCIPLE OF WORKING OF OPEN CYCLE GAS TURBINE

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



The heated gases coming out of the combustion chamber are then passed to the turbine where it expands doing mechanical work. Some part of the power developed by the turbine is utilized in driving the compressor and other accessories and remaining is used for power generation. Fresh air enters into the compressor and gases coming out of the turbine are exhausted into the atmosphere, the working medium need to 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.

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 occupies less space compared to close cycle plants.
5. The stipulation of a quick start and take-up of load frequently are the points in favor of open cycle plant when the plant is used as peak load plant.
6. Component or auxiliary refinements can usually be varied in open cycle gas turbine plant to improve the thermal efficiency and can 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 need cooling water.

8. Therefore, the plant is independent of cooling medium and becomes self-contained.

Disadvantages:

1. The part load efficiency of the open cycle gas turbine plant decreases rapidly as the considerable percentage of power developed by the turbine is used for driving the compressor.
2. The system is sensitive to the component efficiency; particularly that of compressor. The open cycle gas turbine plant is sensitive to changes in the atmospheric air temperature, pressure and humidity.
3. The open cycle plant has high air rate compared to the closed cycle plants, therefore, it results in increased loss of heat in the exhaust gases and large diameter duct work is needed.
4. It is essential that the dust should be prevented from entering into the compressor to decrease erosion and depositions on the blades and passages of the compressor and turbine. So damages their profile. The deposition of the carbon and ash content on the turbine blades is not at all desirable as it reduces the overall efficiency of the open cycle gas turbine plant.

CLOSED CYCLE GAS TURBINE:

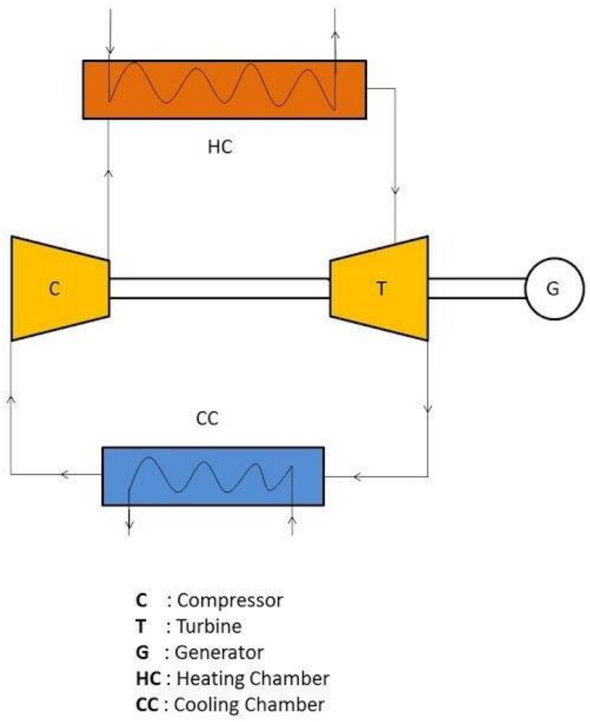
A closed cycle gas turbine is a turbine in which the air is circulated continuously within the turbine. The components of this turbine are compressor, heating chamber, gas turbine which drives the generator and compressor, and a cooling chamber.

Closed Cycle Gas Turbine

The main components of a simplest form of a closed cycle gas turbine are:

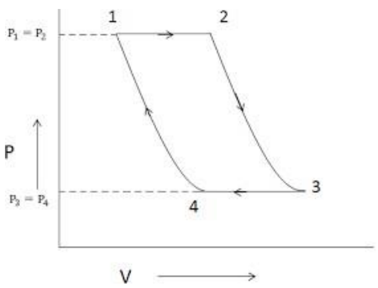
1. **Compressor:** It is used to compress the gas.
2. **Heating chamber:** The heating of the compressed gas is takes place in the heating chamber.
3. **Gas turbine:** it is used to produce the useful work which is used by the generator to generate electricity.
4. **Generator:** It generates the electricity with the help of the gas turbine.
5. **Cooling chamber:** Cooling of the gas after passing from the turbine takes place in the cooling chamber.

Schematic diagram of a closed cycle gas turbine

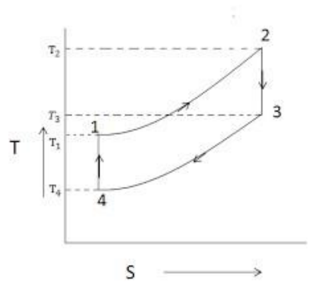


- Working
  - The closed cycle gas turbine works on the principle of Joule's or Brayton's cycle
  - In this turbine, the gas is compressed isentropically and then passed into the heating chamber. The compressor generally used is of rotary type.
  - The compressed air is heated with the help of some external source and then made to flow over the turbine

- blades. The turbine used here is of reaction type.
- The gas while flowing over the blades of the turbine, gets expanded. From the turbine the gas is passed to the cooling chamber. Here the gas is cooled at constant pressure with the help of circulating water to its original temperature.
- Now the gas is again made to flow through the compressor to repeat the process.
- Here the same gas is circulated again and again in the working of a closed cycle gas turbine. P-V and T-S diagram



P-V Diagram



T-S Diagram

The various processes used in this turbine are:

1. Process 1-2: It denotes the heating of gas in heating chamber at constant pressure.

2. Process 2-3: In this process the expansion of gas takes place isentropically.

3. Process 3-4: This process shows the cooling of gas at constant pressure in cooling chamber.

4. Process 4-1: Isentropic compression of gas takes place in the compressor.

Explanation of the P-V and T-S diagram

- **Process 1-2:**The heating of the gas is done at constant pressure. Here as the pressure is constant, so P1 = P2 and the temperature increases from T1 to T2, the entropy of the gas increases during this process.
- **Process 2-3:** isentropic expansion of the gas takes place in the turbine. Here the pressure drops from P2 to P3 and volume increases from V2 to V3. In T-S diagram the entropy remains constant but the temperature drops from T3 to T4.
- **Process 3-4:** Cooling of gas is happen at constant pressure during this process. In P-V diagram the pressure remain constant i.e. P3= P4 and the volume decreases from V3 to V4.
- **Process 4-1:** Isentropic compression takes place in the compressor. In P-V diagram the pressure increases from P4 to P1 and volume decreases from V4 to V1 (i.e. gas returns to its initial volume). In T-S diagram the entropy remains constant (i.e. S4= S1) and the temperature increases from T4 to T1(T1 is the initial temperature of the gas, it means the gas attainsits initial temperature).

Net work available
= work done by the turbine per Kg of air
− work required by the compressor per Kg of air

$$W = c_p(W_T - W_C)$$

Where,

$$W_T = c_p(T_2 - T_3)$$

$$W_C = c_p(T_1 - T_4)$$

W_T = Work done by the turbine per Kg of air.

W_C = Work done by the compressor per Kg of air.

12)DIRECT ENERGY CONVERSIONS:

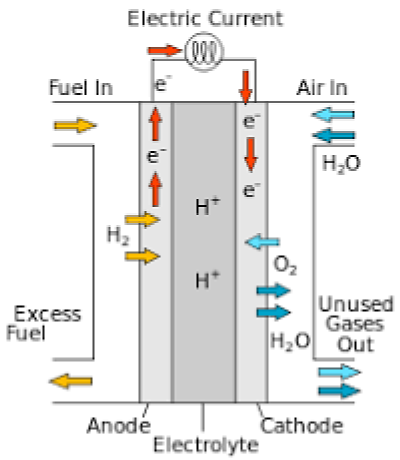
Direct energy conversion (DEC) or simply **direct conversion** converts a charged particle's kinetic**energy** into a voltage. It is a scheme for power extraction from nuclear fusion.

FUEL CELL:

It is an electro mechanical energy is generated by chemical reaction. The basic difference between storage or primary cell and fuel cell is that the electrode and the electrolyte are invariant. When cell operates fuel is oxidized and chemical reaction provides the energy which can be converted into electricity. One of the major advantage of this type of fuel cell it can be carried isothermally I.e the carnot limitations on efficiency is not applicable

WORKING

Fuel cell is supplied with anode where it oxidized thereby freeing electrons, which flow in the circuit and the hydrogen ions which pass though the electrolyte to the cathode combine with oxygen and electrons to form water. Electrodes for this type of cell are usually porous impingement with catalyst. In catalyst electrolyte, a delicate balance is achieved in which surface tension and density of the liquid must be considered.



DIRECT ENERGY CONVERSION SYSTEMS

The energy conversions systems that are used for a long time are those that accept energy as heat and produces mechanical work which is transformed into electric power distribution at large.

The following methods are used for converting solar energy which is obtained from thermal energy into electrical energy

1. Thermo electric process
2. Thermoionic process
3. Ferroelectric process
4. Magneto hydrodynamic process
5. Electro gas dynamic process

THERMO ELECTRIC GENERATOR:

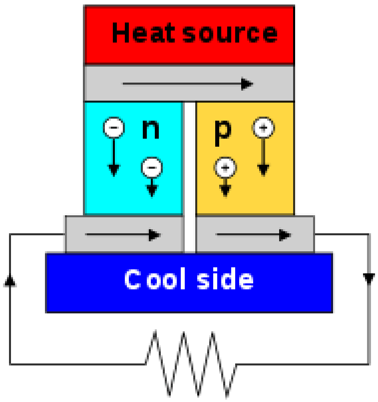
A **thermoelectric generator** (TEG), also called a Seebeck **generator**, is a solid state device that converts heat flux (temperature differences) directly into electrical energy through a phenomenon called the Seebeck effect (a form of **thermoelectric**effect).

12.5 SEEBECK EFFECT

The Seebeck Effect produces an electric current when dissimilar metals are exposed to a variance in temperature. Seebeck effect applications are the foundation of thermoelectric generators (TEGs) or Seebeck generators which convert heat into energy. The voltage produced by TEGs or Seebeck generators is proportional to the temperature distance across between the two metal junctions.

12.6 ENERGY GENERATION

When a p-type element electrically connects to the n-type element, the mobile holes in the p-type element "see" the mobile electrons in the n-type element and migrate. When one electrically connects a p-type element to the n-type element, the mobile holes in the p-type element "see" the mobile electrons in the n-type element and migrate just to the other side of the junction. For every hole that migrates into the n-type element, an electron from the n-type element migrates into the p- type element. Soon, each hole and electron that "switch sides" will be in equilibrium and act like a barrier, preventing more electrons or holes from migrating. This is called the depletion zone.



13. THERMOIONIC GENERATOR

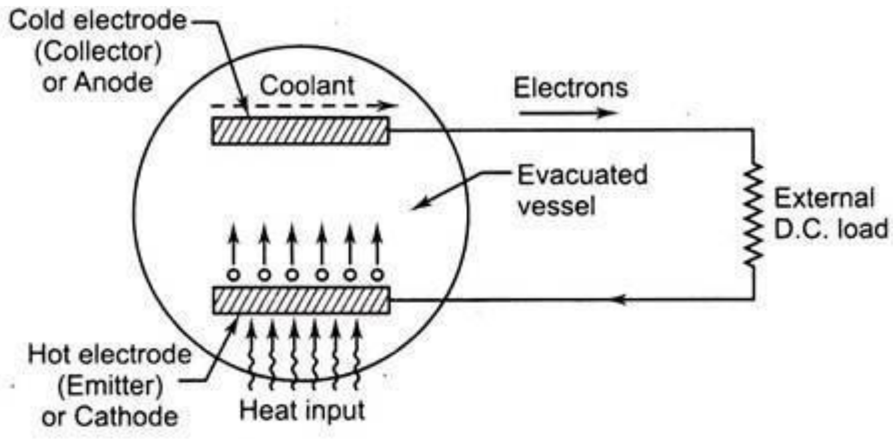


Fig. 9.7. Thermionic generator.

i. A thermionic converter/generator comprises a heated cathode (electron emitter) and an anode

ii. (electron collector) separated by 'vacuum', the electrical output circuit being connected between the two

iii. The heat which is supplied to the cathode raises the energy of its electrons to such a level that it enables than, to escape from the surface and flow to anode. At the ‘anode’ the energy of electrons appears partially as heat, removed by cooling and partially as electrical energy delivered to the circuit.

iv. Although the distance between anode and cathode is only about 1mm. The negative space charge with such an arrangement hinders the passage of the electrons and must be reduced, this can be achieved by introducing positive ions into the inter electrode space, ‘cesium vapour’ being valuable source of such ions.

V.In order to materialise a substantial electron emission rate (per unit area of emitter), and hence a significant current output as well as a high efficiency, the emitter temperature in a thermionic converter containing cesium should be at least 1000°C, the efficiency is then 10 per cent.

vi.Efficiency as high as 40 per cent can be obtained by operating at still higher temperatures. Although temperature has little effect on the voltage generated, the increase in current (per unit emitter area) associated with a temperature increase results in increase in power. Electric power (P) is the product of voltage (E) and current (I) i.e. , P = EI.

vii. Anode materials should have a low work function e.g. barium and strontium oxides while that of the cathode should be considerably higher, tungsten impregnated with a barium compound being a suitable material.

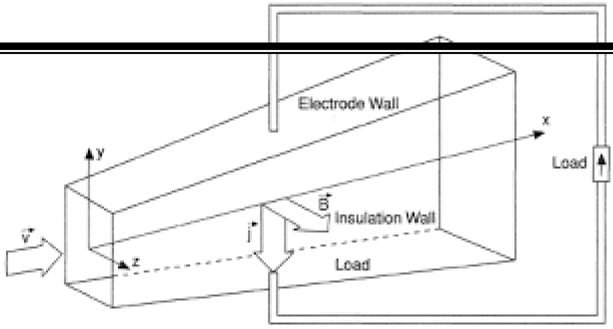
viii. Even with these materials temperatures upto 2000°C will be required to secure for the generator itself, efficiencies of 30-35 per cent. Electrical outputs of about 6 W/cm^2 of anode surface are envisaged with about 13 W/cm^2 removed by coolant.

ix. A thermionic generator, in principle, can make use of any fuel (may be fossil fuel, a nuclear fuel or solar energy) subject to the condition that sufficiently high temperatures are obtainable. The thermionic conversion can be utilized in several different situations—remote locations on the earth and in space.

14. MAGNETO HYDRO DYNAMIC GENERATOR:

PRINCIPLE

It is based on faradays law of electromagnetic induction. It states that, when electric conductor passes through a magnetic field a voltage is developed in the conductor. The MHD generator consists of a gaseous conductor i.e an ionized gas or conducting fluid which generates current when passes through a magnetic with high velocity. The electrodes are laced in the path of current to extract it. The power developed by MHD generator is DC and it is converted into AC by an invertor.



Consider an electric conductor that is moving through the magnetic field. Then the emf and current are produced and also the conductor is subjected to retarding force and stated by faradys law of electro magnetic induction

The emf induced

E= velocity of conducting medium x magnetic field

intensity E = u x B

The current density

J = electrical conductivity x emf

induced J = ʊ x E

Retarding force = J x B

HYDRO ELECTRIC POWER PLANT:

1. HYDROPOWER:

Hydropower is the power obtained by utilizing the energy of water by making it to move through the turbines anf finally generating electricity. It is the conventional, renewable source for the generation of power wich means, obtaining the electricity is free from any kind of pollution and has good overfall effect on the environment. Hydro power forms a major share when it comes to the total power required by a country like india.

Advantages

1. It is a renewable source of energy, non polluting and does not pose any threat to the environment.
2. It does not need any fuel to propel the turbines as in the case of power generation from the other means such as thermal,nuclear.
3. It is highly reliable and has very low maintenance and operating charges.
4. These plants also used for irrigation and food control purposes.
5. These are built in hilly areas away from the cities and towns as such the cost of the land does not pose a major problem
6. Initial cost is high and running cost is low.

2. HYDROLOGY

Hydrology may be defined as the science which deals with the depletion and replenishment of water resources. It deals with the surface water as well as the ground water. It is also concerned with the transportation of water from one place to another, and from one form to other. It helps us in determining the occuerence ans availability of water.

It aims to answer some of the questions:

1. How is the water going to precipitate?
2. How is water going to behave?
3. What will happen to water after precipitation?

The basic knowledge of this science is a must for every civil engineer, particularly the one who is engaged in the design, planning or construction of irrigation structures, bridges and highways, flood control works etc.

3. HYDRLOGICAL CYCLE:

Most of the earths water sources, such as river, lakes, oceans and underground sources, etc. get their supplies from rains, while the rain water itself is the evaporation from tese sources. Water is lost to the atmosphere as vapour from earth, which is then precipated back in the form of rain, snow,hail, dew, sleet or frost. This evaporation and precipatation continues for ever, and thereby, a balance is maintained between the two. This process is known as Hydrological Cycle.

Hydrlogic equation is expressed as $P = R + E$

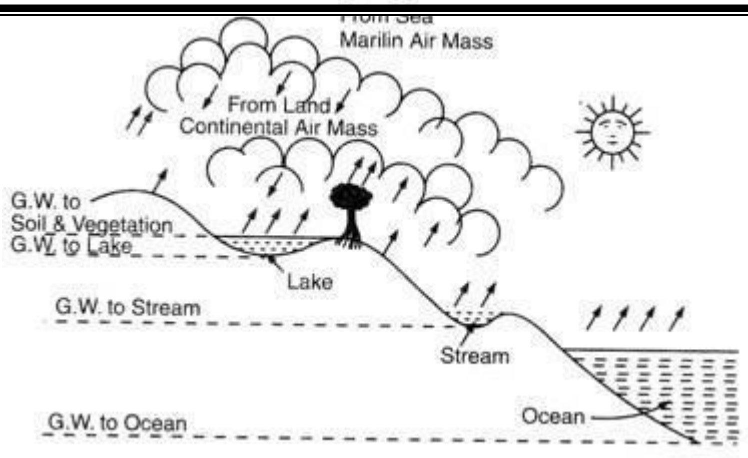


Fig. 1.1. Hydrologic cycle

Precipitation: it includes all the water that falls from atmosphere to earth surface. Precipitation is of two types:

1. Liquid precipitation(rain fall)
2. Solid precipitation(snow fall)

Run off and surface run off: Run off includes all the water flowing in the stream channel at any given section. While the surface water run off includes only the water reaches the stream channel without first precolating down to the water table.

Run off can be named as Discharge or Stream flow. Rainfall duration, its intensity and a real distribution influence the rate and volume of run off

Evaporation: Transfer of water from liquid to vapour state is called evaporation.

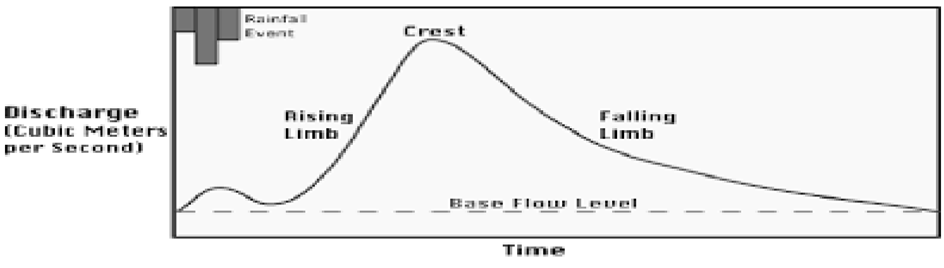
Transpiration: The process by which water is released to the atmosphere by the plants is called transpiration .

4.HYDROGRAPH:

It is defined as a graph showing discharge of flowing water with respect to time for a specified time. Discharge graph are known as flood or run off graphs. Eacg hydrograph has a reference to a particular river site. The time period for discharge hydrograph may be hour, day, week or month.

Hydrograph of stream of river will depend on the characteristics of the catchment area and precipitation over the catchment. Hydrograph will access the flood of rivers hence it is essential that anticipated hydrograph could be drawn for river for a given strom.

It indicates the power available from the stream at different times of day, week or year.



5. UNIT HYDROGRAPH:

It may be defined as a hydrograph which represents unit run off resulted from a intense rainfall of unit duration and specific areal distribution.

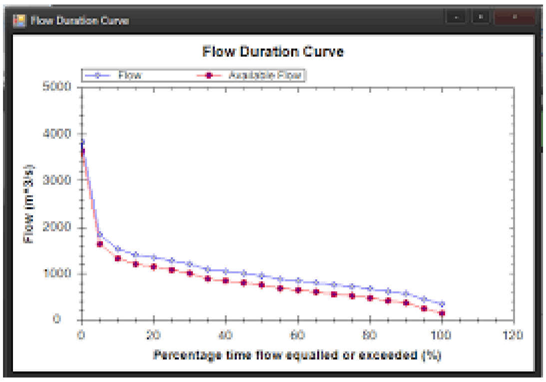
The following steps are used for the construction of unit hydrograph:

1. Choose an isolated intense rainfall of unit duration duration from past records
2. Plot the discharge hydrograph for outlet from the rain fall records
3. Deduct the base flow from discharge hydrograph to get hydrograph of surface run off
4. Find out the volume of surface run off and convert this volume into cm of run off over the catchment area
5. Measure the ordinates of surface run off hydrograph
6. Divide the ordinates by obtained run off in cm to get ordinates of unit hydrograph

6. FLOW DURATION CURVE:

Flow duration curve is another useful form to represent the run off for the given time. This curve is plotted between flow available during a period verses the fraction of time. If the magnitude on the ordinate is the potential power contained in the stream flow, then the curve is known as power duration curve. This curve is a very useful tool in the analysis for the development of water power.

The area under flow duration curve gives the total quantity of run off durning that period as the flow duration curve is representation of graph with its flows arranged in order of descending magnitude.



If the head of discharge is known, the possible power developed from water in KW can be determined from the following equation:

Power (KW) $=\{wQH/1000\} \times \eta_o$

Q= Discharge

H= Head available

w= Weight density of water η_o= Overall efficiency

Uses of flow duration curve:

1. A flow duration curve allows the evaluation of low level flows.

2. It is highly useful in the planning and design of water resources projects. In particular, for hydropower studies, the flow duration curve serves to determine the potential for firm power generation. In the case of a run-of-the-river plant, with no storage facilities, the firm power is usually computed on the basis of flow available 90 to 97 percent of the time. The firm power is also known as the: primary power. Secondary power is the power generated at the plant utilizing water other than that used forthe generation of firm power.

3. If sediment rating curve is available for the given stream, the flow duration curve can be converted into cumulative sediment transport curve by multiplying each flow rate by its rate of sediment transport. The area under this curve represents the total amount of sediment transported.

4. The flow duration curve also finds use in the design of drainage systems and in flood control studies.

5. A flow duration curve plotted on a log-log paper provides a qualitative description of the run-off variability in the stream.Thisistypical of the conditionswhere theflow is mainlyfrom surface run- off. A flat slope indicates small variability which is a characteristic of the streams receiving both surface run-off and ground water run-off.A flat portion at the lower end of the curve indicates substantial contribution from ground water run-off, while the flat portion at the upper end of the CUl'Ve is characteristic of streams with large flood plain storage,such as lakes and swaps,or where thehigh flows aremainly derived from snowmelt.

6. The shape of the flow duration curve may change with the length of record. This aspect of the flow duration curve can be utilised for extrapolation of shortrecords.

CLASSIFICATION OF HYDRO ELECTRIC POWER PLANTS

Hydro electric power plants may be classified as

A. According to availability of head

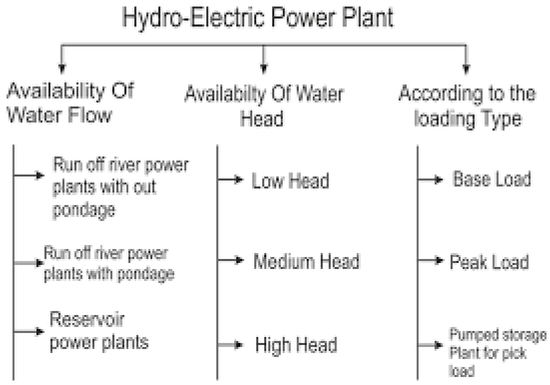
1. High head power plants
2. Medium head power plants
3. Low head power plants

B. According to nature of load

1. Base load plants
2. Peak load plants

C. According to the quantity of water available

1. Run off river water without pondage
2. Run off river water with pondage
3. Storage type plants
4. Pump storage pants
5. Mini and micro hydel plants



7(A).Classification According to the Extent of Water Flow Regulation Available:

According to the extent of water flow regulation available the hydroelectric power plants may be classified into:

(a) Run-off river power plants without pondage.

(b) Run-off river power plants with pondage.

(c) Reservoir power plants.

(a) Run-Off Power Plants without Pondage:

Some hydro power plants are so located that the water is taken from the river directly, and no pondage or storage is possible. Such plants are called the run-off river power plants without pondage. Such plants can use water only as and when available; these cannot be used at any time at will or fit any desired portion of the load curve. In such plants there is no control on flow of water.

During high flow and low load periods, water is wasted and during the lean flow periods the plant capacity is very low. As such these plants have a very little firm capacity. At such places, the water is mainly used for irrigation or navigation and power generation is only incidental. Such plants can be built at a considerably low cost but the head available and the amount of power generated are usually very low.

During floods, the tail water level may become excessive rendering the plant inoperative. The main objective of such plants is to use whatever flow is available for generation of energy and thus save coal that otherwise be necessary for the steam plants. During the high flow periods such plants can be employed to supply a substantial portion of base load.

(b). Run-Off River Power Plants with Pondage:

The usefulness of run-off river power plants is increased by pondage. Pondage refers to storage at the plant which makes it possible to cope, hour to hour, with fluctuations of load throughout a week or some longer period depending on the size of pondage. With enough pondage, the firm capacity of the power plant is increased.

Such type of power plants can be used on parts of the load curve as required, within certain limitations and

is more useful than a plant without pondage. Such power plants are comparatively more reliable and its

generating capacity is less dependent on available rate of flow of water. Such power plants can serve as base load or peak load power plants depending on the flow of stream.

During high flow periods these plants may be used as base load and during lean flow periods these plants may be used to supply peak loads only. When providing pondage, tailrace condition should be such that floods do not raise the tailrace water level, thus reducing the head on the plant and impairing its effective- ness. Such plants offer maximum conservation of coal when operated in conjunction with steam power plants.

(c). Reservoir Power Plants:

When water is stored in a big reservoir behind a dam, it is possible to control the flow of water and use it most effectively. Storage increases the firm capacity of the plant and it can be used efficiently throughout the year. Such a plant can be used as a base load or as a peak load plant as per requirement. It can also be used on any portion of the load curve in a grid system. Most of the hydroelectric power plants everywhere in the world are of this type.

7(B). Classification According to Availability of Water Head:

According to availability of water head the hydroelectric power plants may be classified into:

(a) Low Head

(b) Medium Head and

(c) High Head Power Plants.

Though there is no definite line of demarcation for low, medium and high heads but the head below 30 metres is considered low head, the head above 30 metres and below 300 metres is considered as medium head and above 300 metres is considered as high head.

(a) Low Head Hydroelectric Power Plants:

A typical low head installation on a river consists essentially of a dam across the stream to back up the river and create a fall, the water flowing through the turbines and remerging the river below the dam. A dam or barrage constructed across the river creates the necessary head. The power plant is located near the dam and therefore, no surge tank is required. Either one half of the barrage has regulating gates for discharge of surplus water while the plant is in front of second half or the plant is constructed by the side of the river.

In low head power plants Francis, propeller or Kaplan turbines are employed. Since for given output, large quantity of water is required, head being low, therefore pipes of large diameter and short length are required in low head plants. Structure of such plants is extensive and expensive. Generators employed in such plants are of low speed and large diameter.

(b) Medium Head Hydroelectric Power Plants:

In these power plants, the river water is usually tapped off to a forebay on one bank of the river as in case of a low head plant. From the forebay the water is led to the turbines through penstocks. The forebay provided at the beginning of penstock serves as a water reservoir for such power plants.

In these plants, water is usually carried in open channel from main reservoir to the forebay and then to the turbines through the penstock. The forebay itself serves as the surge tank in this case. In these plants horizontal shaft Francis, propeller or Kaplan turbines are used. The arrangement is shown in Fig. 2.14.

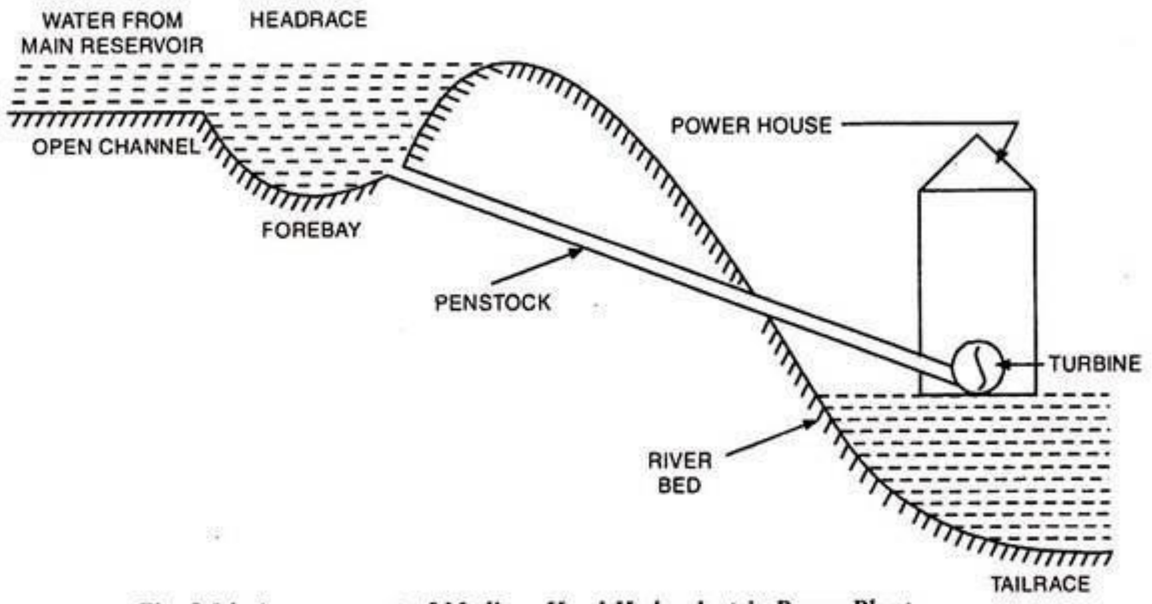


Fig. 2.14. ***Arrangement of Medium Head Hydroelectric Power Plant***

(c) High Head Hydroelectric Power Plants:

If high head is available, a site may be chosen, where a stream descending a steep lateral valley can be dammed and a reservoir for storage of water is formed. A pressure tunnel is constructed between reservoirs to valve house at the start of penstock to carry water from reservoir to valve house.

Surge tank (a tank open from the top) is built just before the valve house so that the severity of water hammer effect on penstock can be reduced in case of sudden closing of fixed gates of the water turbine. Surge tank also serves as a ready reservoir from which the turbine can draw water temporarily when there is sudden increase in demand.

The valve house consists of main sluice valves and automatic isolating valves, which operate on bursting of penstock and cut off further supply of water to penstock. Penstocks are pipes and carry the water from the valve house to the turbines.

For heads above 500 m Pelton wheels are used while for lower heads Francis turbines are employed. The generators used are of high speed and small diameter. Penstocks are of large length and comparatively smaller cross section.

7(C). Classification According to Type of Load Supplied:

According to the load supplied hydroelectric power stations may be classified into:

(a) Base Load,
(b) Peak Load, and
(c) Pumped Storage Plants for the Peak Load.

(a) Base Load Plants:

The plants, which can take up load on the base portion of the load curve of the power system, are called the base load power plants. Such plants are usually of large capacity. Since such plants are kept running practically on block load (i.e., the load that is practically constant), load factor of such plants is therefore high. Run-off river plants without pondage and reservoir plants are used as base load plants.

Plants having large storage can best be used as base load plants and particularly in rainy seasons, when the water level of the reservoir will be raised by rain water. For a plant to be used as base load plant, the unit cost of energy generated by the plant should be low.

(b) Peak Load Plants:

Plants used to supply the peak load of the system corresponding to the load at the top portion of the load curve are called the peak load plants. Runoff river plants with pondage can be employed as peak load plants. If the pondage is enough, a large portion of the load can be supplied by such a plant if and when required. Reservoir plants can of course be used as peak load plants also. Peak load plants have large seasonal storage. They store water during off-peak periods and are operated during peak load periods. Load factor of such plants is low.

(c) Pumped Storage Plants for the Peak Load:

This is a unique design of peak load plant.

7 Classification of Hydroelectric Power Plants Based on Installed Capacity:

Apart from above classification, hydroelectric power plants can be classified, on the basis of installed capacity, as large, medium, small, mini, and micro hydro power plants. Generally the mini, micro, and pico hydro come under the subcategory of small hydro plants.

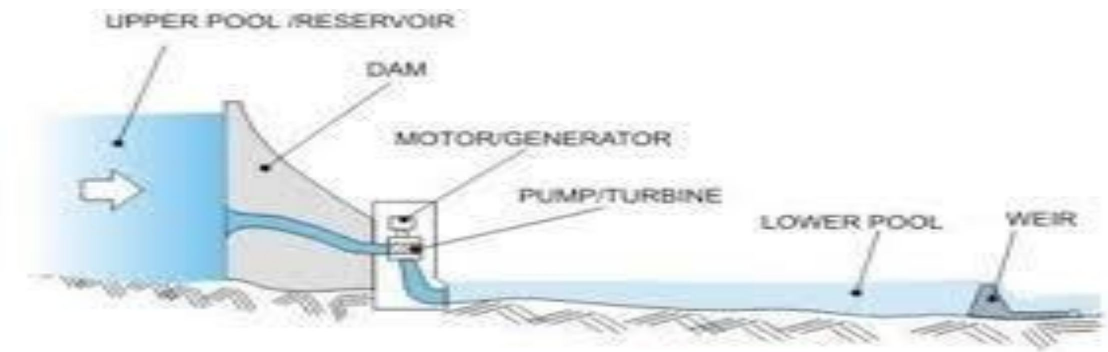
These are briefly described as below:

Large hydro	Exceeding 100 MW and usually feeding into a large grid.
Medium hydro	15-100 MW—usually feeding into a grid
Small hydro	1-15 MW—usually feeding into a grid
Mini hydro	100 kW-1 MW—either isolated or feeding into a grid
Micro hydro	5 kW-100 kW—usually provides power for a small community or rural industry in remote areas away from the grid.
Pico hydro	From few hundred watts up to 5 kW.

Apart from the above said classification, there is also a class of very large hydro power plants coming up

with capacity ranging from more than 5,000 MW up to 10,000 MW due to the large scale investment and better technology available. However, as far as small hydro is concerned the upper and lower limit varies from country to country while defining the small hydro. There is a general tendency all over the world to define small hydro by power output. Different countries are following different norms keeping the upper limit ranging from 5 to 50 MW.

1. STORAGE TYPE PLANTS:



Pumped storage plants are employed at the places where the quantity of water available for power generation is inadequate. Here the water passing through the turbines is stored in 'tail race pond '. During low load periods this water is pumped back to the head reservoir using the extra energy available. This water cim be again used for generating power during peak load periods. Pumping ofwater maybedon.e seasonally ordailydepending upon theconditions oftheBite and the nature of the load on the plant.

Such plants are usually interconnected with steam or diesel engine plants so that off peak capacity of interconnecting stations isused in pumping water and the same isused during pelik.foad periods.Of course, the energy available from the quantity of water pumped by the plant is less than the energy input during pumped operation.Again while usingpumped water thepower available reducedonaccount oflossesoccuringinprimemovers.

Advantages.The pump storage plants entail the following advantages :

1. There is substantial increase in peak load capacity ofthe plant at comparatively low capital cost.

2. Due to load comparable to rated load on the plant, the operating efficiency of the plantis high.
3. There is an improvement in the load factor of the plant.
4. The energy available during peak load periods is higher than that of duriQg off peak periodssothatinspiteoflossesincurred inpumpingthereisover-allgain .
5. Load on the hydro-electric plant remains uniform.
6. The hydro-electric plant becomespartly independent of the stream flow conditions.

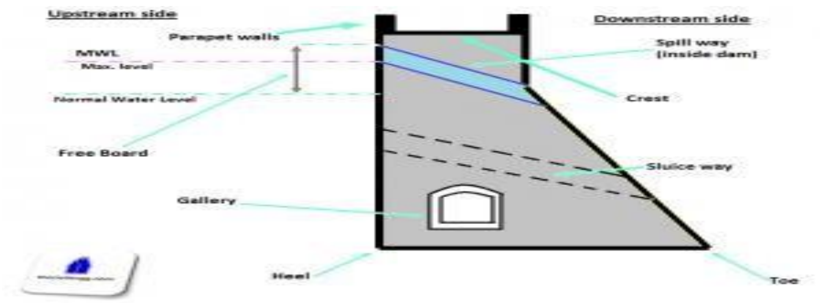
Under pump storage projects almost 70 percent power used in pumping the water can be recovered. In this field the use of"R euersible Turbine Pump• units is also worth noting.These units can be used as turbine while generating power and as pump while pumping water to storage.The generator in this case works as motor during reverse operation.Th efficiency in such caseis.high and almost the same inboth theoperations.With the use of reversible turbine pump sets,additional capital investment on pump and its motor can be saved and the scheme can be worked more

economically.

CLASSIFICATION OF DAMS:

A dam is a hydraulic structure of fairly impervious material built across a river to create a reservoir on its upstream side for impounding water for various purposes. These purposes may be Irrigation, Hydropower, Water-supply, Flood Control, Navigation, Fishing and Recreation. Dams may be built to meet the one of the above purposes or they may be constructed fulfilling more than one. As such, Dam can be classified as: Single-purpose and Multipurpose Dam.

Different parts & terminologies of Dams:



Dam illustration

Crest: The top of the Dam. These may in some cases be used for providing a roadway or walkway over the dam.

- Parapet walls: Low Protective walls on either side of the roadway or walkway on the crest.
- Heel: Portion of Dam in contact with ground or river-bed at upstream side.
- Toe: Portion of dam in contact with ground or river-bed at downstream side.
- Spillway: It is the arrangement made (kind of passage) near the top of dam for the passage of surplus/ excessive water from the reservoir.
- Abutments: The valley slopes on either side of the dam wall to which the left & right end of dam are fixed to.
- Gallery: Level or gently sloping tunnel like passage (small room like space) at transverse or longitudinal within the dam with drain on floor for seepage water. These are generally provided for having space for drilling grout holes and drainage holes. These may also be used to accommodate the instrumentation for studying the performance of dam.
  - Sluice way: Opening in the dam near the base, provided to clear the silt accumulation in the

reservoir.

- Free board: The space between the highest level of water in the reservoir and the top of the dam.
- Dead Storage level: Level of permanent storage below which the water will not be withdrawn.
- Diversion Tunnel: Tunnel constructed to divert or change the direction of water to bypass the dam construction site. The dam is built while the river flows through the diversion tunnel.

Various types of dams

Dams can be classified in number of ways. But most usual ways of classification of dams are mentioned below:

Based on the functions of dam, it can be classified as follows:

(a) Storage dams: They are constructed to store water during the rainy season when there is a large flow in the river. Many small dams impound the spring runoff for later use in dry summers. Storage dams may also

provide a water supply, or improved habitat for fish and wildlife. They may store water for hydroelectric

power generation, irrigation or for a flood control project. Storage dams are the most common type of dams and in general the dam means a storage dam unless qualified otherwise.

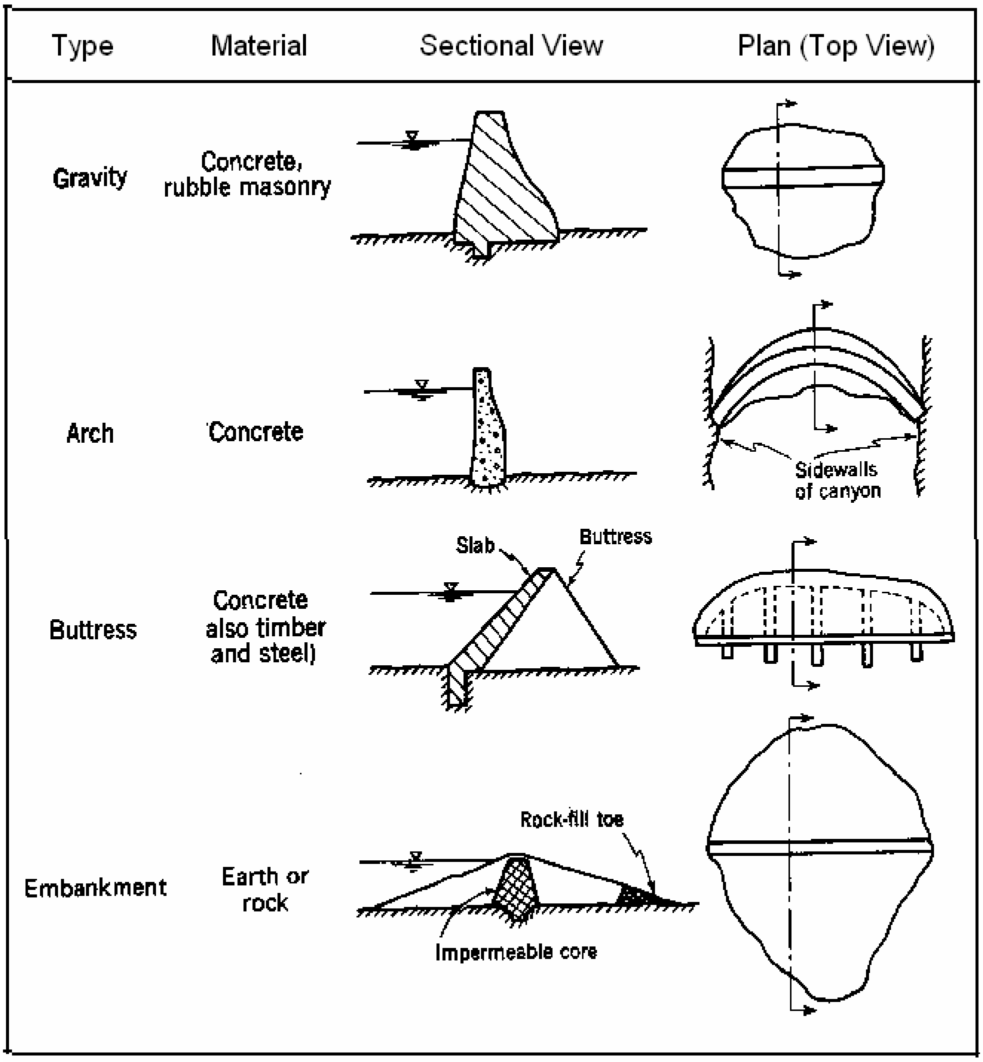
(b) Diversion dams: A diversion dam is constructed for the purpose of diverting water of the river into an off-taking canal (or a conduit). They provide sufficient pressure for pushing water into ditches, canals, or other conveyance systems. Such shorter dams are used for irrigation, and for diversion from a stream to a distant storage reservoir. A diversion dam is usually of low height and has a small storage reservoir on its upstream. The diversion dam is a sort of storage weir which also diverts water and has a small storage. Sometimes, the terms weirs and diversion dams are used synonymously.

(c) Detention dams: Detention dams are constructed for flood control. A detention dam retards the flow in the river on its downstream during floods by storing some flood water. Thus the effect of sudden floods is reduced to some extent. The water retained in the reservoir is later released gradually at a controlled rate according to the carrying capacity of the channel downstream of the detention dam. Thus the area downstream of the dam is protected against flood.

(d) Debris dams: A debris dam is constructed to retain debris such as sand, gravel, and drift wood flowing in the river with water. The water after passing over a debris dam is relatively clear.

(e) Coffer dams: It is an enclosure constructed around the construction site to exclude water so that the construction can be done in dry. A **cofferdam** is thus a temporary dam constructed for facilitating construction. A coffer dam is usually constructed on the upstream of the main dam to divert water into a diversion tunnel (or channel) during the construction of the dam. When the flow in the river during construction of the dam is not much, the site is usually enclosed by the coffer dam and pumped dry. Sometimes a coffer dam on the downstream of the dam is also required.

Based on structure and design, dams can be classified as follows:



Gravity Dams: A gravity dam is a massive sized dam fabricated from concrete or stone masonry. They are designed to hold back large volumes of water. By using concrete, the weight of the dam is actually able to resist the horizontal thrust of water pushing against it. This is why it is called a gravity dam. Gravity essentially holds the dam down to the ground, stopping water from toppling it over.

Gravity dams are well suited for blocking rivers in wide valleys or narrow gorge ways. Since gravity dams must rely on their own weight to hold back water, it is necessary that they are built on a solid foundation of bedrock.

Examples of Gravity dam: Grand Coulee Dam (USA), (Nagarjuna Sagar Dam (India) and Itaipu Dam (Between Brazil and Paraguay).

(f) Earth Dams: An earth dam is made of earth (or soil) built up by compacting successive layers of earth, using the most impervious materials to form a core and placing more permeable substances on the upstream and downstream sides. A facing of crushed stone prevents erosion by wind or rain, and an ample spillway, usually of concrete, protects against catastrophic washout should the water overtop the dam. Earth dam resists the forces exerted upon it mainly due to shear strength of the soil. Although the weight of the earth dam also helps in resisting the forces, the structural behavior of an earth dam is entirely different from that of a gravity dam. The earth dams are usually built in wide valleys having flat slopes at flanks (abutments).The foundation requirements are less stringent than those of gravity dams, and hence they can be built at the sites where the foundations are less strong. They can be built on all types of foundations. However, the height of the dam will depend upon the strength of the foundation material.

Examples of earthfill dam: Rongunsky dam (Russia) and New Cornelia Dam (USA).

(g) Rockfill Dams: A rockfill dam is built of rock fragments and boulders of large size. An impervious membrane is placed on the rockfill on the upstream side to reduce the seepage through the dam. The membrane is usually made of cement concrete or asphaltic concrete. In early rockfill dams, steel and timber membrane were also used, but now they are obsolete.

Mohale dam, Lesoto Africa

A dry rubble cushion is placed between the rockfill and the membrane for the distribution of water load and for providing a support to the membrane. Sometimes, the rockfill dams have an impervious earth core in the middle to check the seepage instead of an impervious upstream membrane. The earth core is placed against a dumped rockfill. It is necessary to provide adequate filters between the earth core and the rockfill on the upstream and downstream sides of the core so that the soil particles are not carried by water and

piping does not occur. The side slopes of rockfill are usually kept equal to the angle of repose of rock, which is usually taken as 1.4:1 (or 1.3:1). Rockfill dams require foundation stronger than those for earth dams.

Examples of rockfill dam: Mica Dam (Canada) and Chicoasen Dam (Mexico)

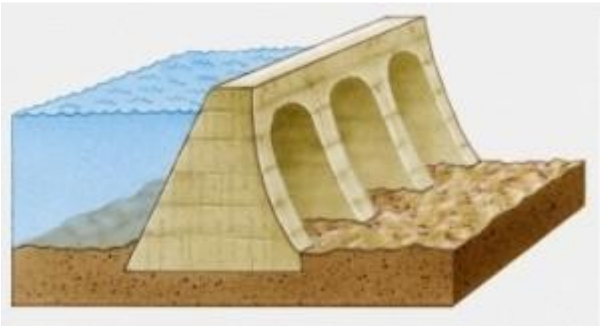
(h) Arch Dams: An arch dam is curved in plan, with its convexity towards the upstream side. An arch dam transfers the water pressure and other forces mainly to the abutments by arch action. An arch dam is quite suitable for narrow canyons with strong flanks which are capable of resisting the thrust produced by the arch action.

Hoover Dam, USA

The section of an arch dam is approximately triangular like a gravity dam but the section is comparatively thinner. The arch dam may have a single curvature or double curvature in the vertical plane. Generally, the arch dams of double curvature are more economical and are used in practice.

Examples of Arch dam: Hoover Dam (USA) and Idukki Dam (India)

(i) Buttress Dams: Buttress dams are of three types : (i) Deck type, (ii) Multiple-arch type, and (iii) Massive-head type. A deck type buttress dam consists of a sloping deck supported by buttresses. Buttresses are triangular concrete walls which transmit the water pressure from the deck slab to the foundation. Buttresses are compression members. Buttresses are typically spaced across the dam site every 6 to 30 metre, depending upon the size and design of the dam. Buttress dams are sometimes called hollow dams because the buttresses do not form a solid wall stretching across a river valley.The deck is usually a reinforced concrete slab supported between the buttresses, which are usually equally spaced.



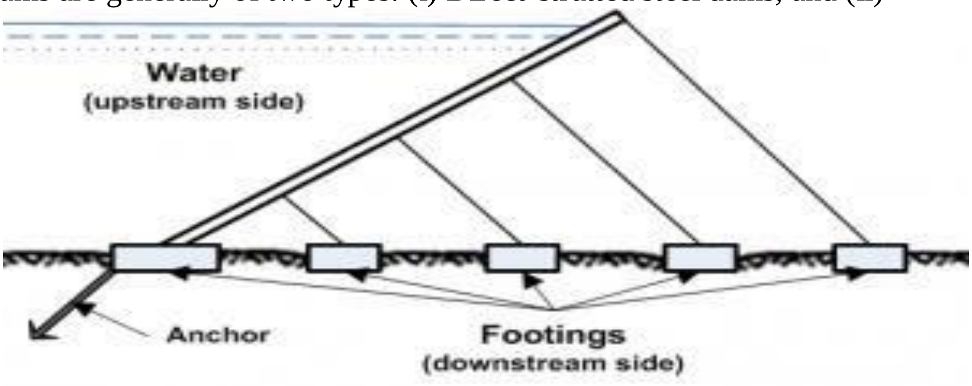
Buttress Dam

In a multiple-arch type buttress dam the deck slab is replaced by horizontal arches supported by buttresses.

The arches are usually of small span and made of concrete. In a massive-head type buttress dam, there is no deck slab. Instead of the deck, the upstream edges of the buttresses are flared to form massive heads which span the distance between the buttresses. The buttress dams require less concrete than gravity dams. But they are not necessarily cheaper than the gravity dams because of extra cost of form work, reinforcement and more skilled labor. The foundation requirements of a buttress dam are usually less stringent than those in a gravity dam.

Examples of Buttress Dam: Bartlett dam (USA) and The Daniel-Johnson Dam (Canada)

(j) Steel Dams: A steel dam consists of a steel framework, with a steel skin plate on its upstream face. Steel dams are generally of two types: (i) Direct-strutted steel dams, and (ii)



Steel Dam

Cantilever type steel dams. In a direct strutted steel dam, the water pressure is transmitted directly to the foundation through inclined struts. In a cantilever type steel dam, there is a bent supporting the upper part of the deck, which is formed into a cantilever truss. This arrangement introduces a tensile force in the deck girder which can be taken care of by anchoring it into the foundation at the upstream toe. Hovey suggested that tension at the upstream toe may be reduced by flattening the slopes of the lower struts in the bent.

However, it would require heavier sections for struts. Another alternative to reduce tension is to frame together the entire bent rigidly so that the moment due to the weight of the water on the lower part of the deck is utilised to offset the moment induced in the cantilever. This arrangement would, however, require bracing and this will increase the cost. These are quite costly and are subjected to corrosion. These dams are almost obsolete. Steel dams are sometimes used as temporary coffer dams during the construction of the permanent dams. Steel coffer dams are supplemented with timber or earthfill on the inner side to make them water tight. The area between the coffer dams is dewatered so that the construction may be done in dry for the permanent dam.

Examples of Steel Dam: Redridge Steel Dam (USA) and Ashfork-Bainbridge Steel Dam (USA)

(k) Timber Dams: Main load-carrying structural elements of timber dam are made of wood, primarily coniferous varieties such as pine and fir. Timber dams are made for small heads (2-4 m or, rarely, 4-8 m) and usually have sluices; according to the design of the apron they are divided into pile, crib, pile-crib, and
buttressed dams.

Timber Dam

The openings of timber dams are restricted by abutments; where the sluice is very long it is divided into several openings by intermediate supports: piers, buttresses, and posts. The openings are covered by wooden

shields, usually several in a row one above the other. Simple hoists—permanent or mobile winches—are used to raise and lower the shields.

1. CLASSIFICATION OF SPILLWAYS:

Definition:

Spillways are structures constructed to provide safe release of flood waters from a dam to a downstream are, normally the river on which the dam has been constructed. Every reservoir has a certain capacity to store water. If the reservoir is full and flood waters enter the same, the reservoir level will go up and may eventually result in over-topping of the dam. To avoid this situation, the flood has to be passed to the downstream and this is done by providing a spillway which draws water from the top of the reservoir. A spillway can be a part of the dam or separate from it.

Types of Spillways - Classification of Spillways

There are different types of spillways that can be provided depending on the suitability of site and other parameters. Generally a spillway consists of a control structure, a conveyance channel and a terminal structure, but the former two may be combined in the same for certain types. The more common types are briefly described below:

1. Drop Spillway
2. Ogee Spillway
3. Siphon Spillway
4. Chute or Trough Spillway
5. Shaft Spillway
6. Side Channel Spillway

Drop Spillway

In drop spillway, the over flowing water falls freely and almost vertically on the downstream side of the hydraulic structure. This type of spillway is suitable for weirs or low dams. The crest of the spillway is provided with nose so that the water jet may not strike the downstream base of the structure. To protect the structure from the effect of scouring horizontal impervious apron should be provided on the downstream side. Sometimes a basin is constructed on the downstream side to form a small artificial pool which is known as water cushion. This cushion serves the purpose of energy

\
dissipater.

Ogee Spillway

The Ogee spillway is generally provided in rigid dams and forms a part of the main dam itself if sufficient length is available. The crest of the spillway is shaped to conform to the lower nappe of a water sheet flowing over an aerated sharp crested weir.
It is a modified form of drop spillway. Here, the downstream profile of the spillway is made to coincide with the shape of the lower nappe of the free falling waterjet from a sharp crested weir. In this case, the shape of the lower nappe is similar to a projectile and hence downstream surface of the ogee spillway will follow the parabolic path where “0” is the origin of the parabola. The downstream face of the spillway forms a concave curve from a point “T” and meets with the downstream floor. This point “T” is known as point of tangency. Thus the spillway takes the shape of the letter “S” (i.e. elongated form). Hence, this spillway is termed as ogee spillway.

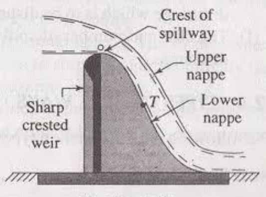


Fig: Ogee Spillway

Chute (Trough) Spillway

In this type of spillway, the water, after flowing over a short crest or other kind of control structure, is carried by an open channel (called the "chute" or "trough") to the downstream side of the river. The control structure is generally normal to the conveyance channel. The channel is constructed in excavation with stable side slopes and invariably lined. The flow through the channel is super-critical. The spillway can be provided close to the dam or at a suitable saddle away from the dam where site conditions permit.

Side Channel Spillway

Side channel spillways are located just upstream and to the side of the dam. The water after flowing over a crest enters a side channel which is nearly parallel to the crest. This is then carried by a chute to the downstream side. Sometimes a tunnel may be used instead of a chute.

Shaft (Morning Glory or Glory hole) Spillway

This type of spillway utilizes a crest circular in plan, the flow over which is carried by a vertical or sloping tunnel on to a horizontal tunnel nearly at the stream bed level and eventually to the downstream side. The diversion tunnels constructed during the dam construction can be used as the horizontal conduit in many cases.

Siphon Spillway

As the name indicates, this spillway works on the principle of a siphon. A hood provided over a conventional spillway forms a conduit. With the rise in reservoir level water starts flowing over the crest as in an "ogee" spillway. The flowing water however, entrains air and once all the air in the crest area is removed, siphon action starts. Under this condition, the discharge takes place at a much larger head. The spillway thus has a larger discharging capacity. The inlet end of the hood is generally kept below the reservoir level to prevent floating debris from entering the conduit. This may cause the reservoir to be drawn down below the normal level before the siphon action breaks and therefore arrangement for de-

priming the siphon at the normal reservoir level is provided.

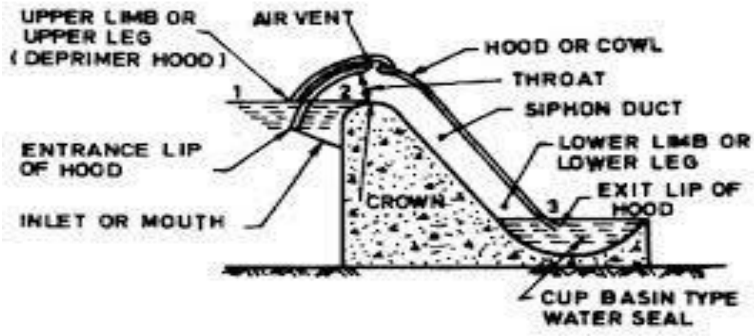


Fig. 11.13 Siphon spillway

1. ESSENTIAL AUXILIARIES USED FOR STARTING THE GENERATING UNIT OF HYDRO ELECTRIC PLANT:

The essential auxiliares are used for starting the generating unit of hydro electric plant are as follows:

1. Exciter : It is an essential component of plant and it is important for the reliability and flexibility of operation. The station can start itself without the help of an external power. An emergency service station requires the stand by auxiliary. Exicter is used as the main generatot which is connected directly to auxiliary water turbine driven or motor genrator type engine driven.
2. Governer oil systems: It is driven by the turbine main shaft through the pressurised oil system and a certain amount of pressure is maintained in the oil tank durning shut down, for the easy starting of turbine. The governing oil system requires high power to open gates in order to start the turbine from off position. For emergency start durning shut down, standby motor driven pump is installed.
3. Lubricating oil pump: The turbine shaft drives the lubricating oil pump. The oil pump starts working as the unit is started. A standby lubricating pump is also installed in the hydroelectric plant

There are some other auxilaries which do not directly require for starting of hydroplants:

a. Coolant pumps
b. Air compressor
c. Cranes
d. Valves
e. Battery charging unit

2. LIST OF VARIOUS NON CONVENTIONAL ENERGY SOURCES:

1. Solar Energy:

The sun provides us enormous amounts of energy in the form of solar radiation — energy that travels in small wave packets called photons, reaching the surface of the Earth from a distance of 150 million kms (93 million miles) in only 8 minutes. Solar energy can be used in production of heat, electricity, bio-energy etc.

There are some simple devices using solar energy like solar cooker, solar water heater, solar desalinator, solar air heaters, solar space conditioner, solar refrigerator, solar steam generators, direct conversion to electricity, photovoltaic technology, solar cells and modules.

2. Bio-Energy:

Includes those processes where biological forms of matter such as plants, vegetables, bacteria, enzymes etc. provide the basis for energy or its conversion from one form to another. The widest use of bio- energy is the traditional way where wood plants and agricultural matters are burnt to provide heat. Bio-mass includes both terrestrial as well as aquatic matter and can be grouped into new plant growth, residues and wastes.

The use of bio-mass as source of energy has tremendous potential. About 40% of total energy consumed in India even today comes from sources like wood-wastes and animal wastes etc. Most dry forms of bio-mass can be burnt directly to produce heat, steam or electricity.

3. Wind Energy:

Is the kinetic energy associated with movement of large masses of air resulting from differential heating of the atmosphere by the sun. Wind energy is renewable and poses no major environmental threats. Small windmills with direct mechanical drive matched to a pump and tank storage are in extensive use in many parts of the world.

Some new all-metal multi-bladed windmill designs have been developed; like the traditional multi-bladed windmills, they have a good starting torque, but lighter in weight, are simpler to fabricate and have slightly better efficiencies.

4. Animal Energy:

Draught Animal Power (DAP) is one of the important renewable energy sources which has served mankind from times immemorial. Animals have served humankind for work, food, skin. In urban areas also draught animals play a significant role in transportation.

5. Ocean Energy:

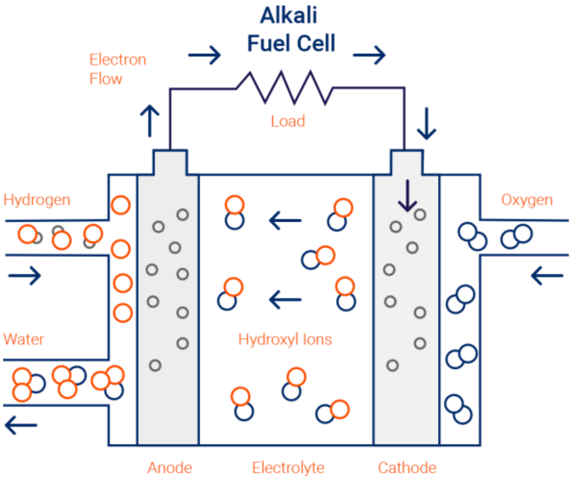
The sea which is constantly receiving solar radiations and acts as the world’s largest natural solar collector
— has potential to provide a means of utilizing renewable energy. It acts not only as a collector but also has an enormous storage capacity. Energy from ocean is available in several forms such as — ocean thermal energy, wave, tidal, Salinity gradient, ocean current, ocean wind and bio-mass.

6. Hydrogen Energy:

Hydrogen is a versatile fuel and can play an important role. Hydrogen has the highest energy content per unit of mass of any chemical fuel. It is a raw material for chemical industry. It can replace coke or coal as a metallurgical reductant. Liquid hydrogen can be used for automobiles, aircraft etc

13. UTILIZATION OF SOLAR COLLECTORS:

Solar energy is the most important form of non conventional sources of energy. The rapid progress in thetechnological advancement has led to the development of photovoltaic cells with higher efficiency and are economically viable.



If free electrons or other substances could travel through the electrolyte, they would disrupt the chemical reaction. Whether they combine at anode or cathode, together hydrogen and oxygen form water, which drains from the cell. As long as a fuel cell is supplied with hydrogen and oxygen, it will generate electricity.

This post provides the description and analysis of different types of solar air heaters used in space heating and drying purposes. The Solar air heaters have the following advantages over other solar heat collectors.

Solar air heater advantages

- The need to transfer heat from working fluids to another fluid is eliminated as air is being used directly as the working substance. The system is compact and less complicated.
- Corrosion is a great problem in solar water heater. And this problem is not experienced in solar air heaters.
- Leakage of air from the duct does not create any problem.
- Freezing of working fluid virtually does not exist.
- The pressure inside the collector does not become very high.
- Thus air heater can be designed using cheaper as well as lesser amount of material and it is simpler to use than the solar water heaters.

Solar Air Heater Disadvantages

- Air heaters have certain disadvantages also the first and foremost is the poor heat transfer properties of air. Special care is required to improve the heat transfer.
- Another disadvantage is the need for handling large volume of air due to its low density.
- Air cannot be used as a storage fluid because of its low thermal capacity.
- In the absence of proper design the cost of solar air heaters can be very high.

Solar Air Heater Classification

A conventional solar air heater is essentially a flat plate collector with absorber plate, a transparent cover system at the top and insulation at the bottom and on the sides. The whole assembly is encased in a sheet metal container. The working fluid is air, though the passage for its flow varies according to the type of air heater.

Material for construction of air heaters are similar to those of liquid flat plate collectors. The transmission of solar radiation through the cover system and its subsequent absorption in the absorber plate can be given by expressions identical to that of liquid flat plate collectors. Selective coating on the absorber plate can be used to improve the collection efficiency but cost effectiveness

criterion should be kept in mind.

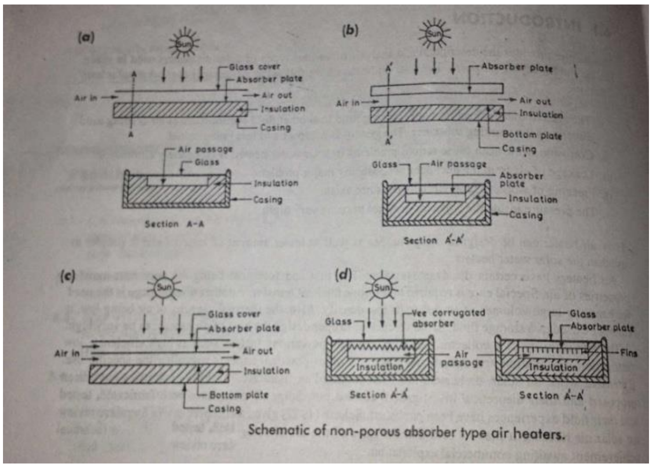
14. NON POROUS TYPE SOLAR AIR HEATER

In non-porous type, air stream does not flow through below the absorber plate but air may flow above and/or behind the plate. In first type, no separate passage is required and the air can flows between the transparent cover system and the absorber plate. (see the figure). In this heater as the hot air flows above the absorber, the cover receives much of the heat and in turn, loses it to the ambient. Thus a substantial amount of heat is lost to the ambient and hence this air heater is not recommended.

The non-porous type with air passage below the absorber is most commonly used. A plate parallel to the absorber plate is provided in between the absorber and the insulation, thus forming a passage of high aspect ratio.

In another variety of non-porous type air heater, the absorber plate is cooled by air stream flowing on both sides of the plate.

Depending on the type of the absorber plate, the air heater can be non-porous and porous. Figure below shows the non-porous absorber type air heaters.



Schematic of non-porous absorber type air heaters.

It may be noted that the heat transfer between the absorber plate and the flowing air being low, the efficiency of air heaters is less. The performance, however, can be improved by roughening the absorber surface or by using a vee-corrugated plate as the absorber plate. Turbulence induced to the air flow helps increase the convective heat transfer.

The radiative loss from the absorber plate are significant, unless selective coatings are used, decreasing the collector efficiency. Also, the uses of fin may result in a prohibitive pressure drop, thus limiting the applicability of non-porous type.

Advantages of porous solar air heater

- Solar radiation penetrates to a great depth and is absorbed along its path. Thus the radiation loss decreases. Air stream heats up as it passes through the matrix.
- The pressure drop is usually lower than the non-porous type.

15. WIND ENERGY

ENERGY FROM WIND Wind is simple air in motion. It is caused by the uneven heating of the

earth's surface by the sun. Since the earth's surface is made of very different types of land and water, it

absorbs the sun's heat at different rates. During the day, the air above the land heats up more quickly than the air over water.

The warm air over the land expands and rises, and the heavier, cooler air rushes in to take its place, creating winds. At night, the winds are reversed because the air cools more rapidly over land than over water. In the same way, the large atmospheric winds that circle the earth are created because the land near the earth's equator is heated more by the sun than the land near the North and South Poles. Today, wind energy is mainly used to generate electricity. Wind is called a renewable energy source because the wind will blow as long as the sun shines.

Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and may be pointed into or out of the **wind**. Small**turbines** are pointed by a simple **wind** vane, while large **turbines** generally use a**wind** sensor coupled with a servo motor.

A **vertical-axis wind turbines** (VAWT) is a type of **wind turbine** where the main rotor shaft is set transverse to the **wind** (but not necessarily vertically) while the main components are located at the base of the **turbine**

Vertical Axis Wind Turbines vs Horizontal Axis Wind Turbines

In the wind turbine business there are basically two types of turbines to choose from, vertical axis wind turbines and horizontal axis wind turbines. They both have their advantages and disadvantages and the purpose of this article is to help you choose the right system for your application.

Horizontal axis wind turbine

Horizontal axis wind turbine dominate the majority of the wind industry. Horizontal axis means the rotating axis of the wind turbine is horizontal, or parallel with the ground. In big wind application, horizontal axis wind turbines are almost all you will ever see. However, in small wind and residential wind applications, vertical axis turbines have their place. The advantage of horizontal wind is that it is able to produce more electricity from a given amount of wind. So if you are trying to produce as much wind as possible at all

times, horizontal axis is likely the choice for you. The disadvantage of horizontal axis however is that it is generally heavier and it does not produce well in turbulent winds.

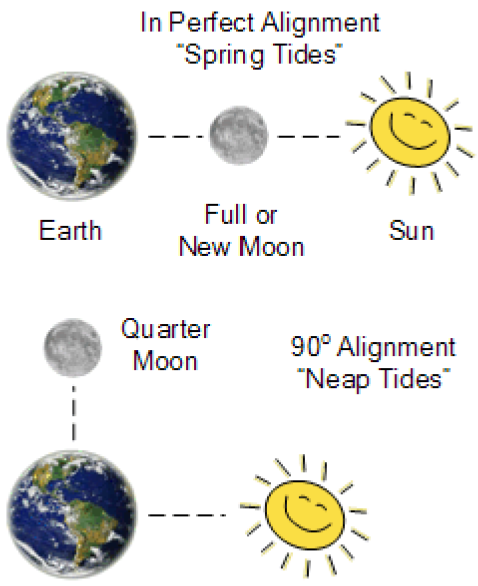
Vertical axis wind turbine

In comes the vertical axis wind turbine. With vertical axis wind turbines the rotational axis of the turbine stands vertical or perpendicular to the ground. As mentioned above, vertical axis turbines are primarily used in small wind projects and residential applications.Vertical-Axis-Wind-Turbine This niche comes from the OEM's claims of a vertical axis turbines ability to produce well in tumultuous wind conditions. Vertical axis turbines are powered by wind coming from all 360 degrees, and even some turbines are powered when the wind blows from top to bottom. Because of this versatility, vertical axis wind turbines are thought to be ideal for installations where wind conditions are not consistent, or due to public ordinances the turbine cannot be placed high enough to benefit from steady wind.

16. TIDAL ENERGY

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 everyday to move vast quantities of water around the oceans and seas producing tides.

As the Earth, its Moon and the Sun rotate around each other in space, the gravitational movement of the moon and the sun with respect to the earth, causes millions of gallons of water to flow around the Earth's oceans creating periodic shifts in these moving bodies of water. These vertical shifts of water are called "tides".



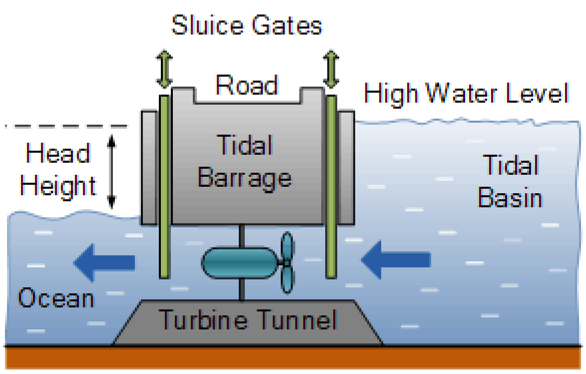
Alignment of the Moon and Sun on Tides

When the earth and the moons gravity lines up with each other, the influences of these two gravitational forces becomes very strong and causes millions of gallons of water to move or flow towards the shore creating a "high tide" condition. Likewise when the earth and the moons gravity are at 90^{o} to each other, the influences of these two gravitational forces is weaker and the water flows away from the shore as the mass of water moves to another location on the earth, creating a "low tide" condition. This ebbing and flowing of the tides happens twice during each period of rotation of the earth with stronger weekly and annual lunar cycles superimposed onto these tides.

When the moon is in perfect alignment with the earth and the sun, the gravitational pull of the moon and sun together becomes much stronger than normal with the high tides becoming very high and the low tides becoming very low during each tidal cycle. Such tides are known as *spring tides*(maximum). These spring tides occur during the full or new moon phase.

The other tidal situation arises during *neap tides* (minimum) when the gravitational pull of the moon and the sun are against each other, thus cancelling their effects. The net result is a smaller pulling action on the sea water creating much smaller differences between the high and low tides thereby producing very weak tides. Neap tides occur during the quarter moon phase. Then spring tides and neap tides produce different amounts of potential energy in the movement of the sea water as their effects differ from the regular high and low sea levels and we can use these tidal changes to produce renewable energy. So we can say that the tides are turning for alternative energy.

Different Types of Tidal Energy Systems



Tidal Barrage – A *Tidal Barrage* is a type of tidal power generation that involves the construction of a fairly low dam wall, known as a “barrage” and hence its name, across the entrance of a tidal inlet or basin creating a tidal reservoir. This dam has a number of underwater tunnels cut into its width allowing sea water to flow through them in a controllable way using “sluice gates”. Fixed within the tunnels are huge water turbine generators that spin as the water rushes past them generating tidal electricity.

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.

The one disadvantage of **Tidal Barrage Generation**, is that it can only generate electricity when the tide is actually flowing either “in” or “out” as during high and low tide times the tidal water is stationary. However, because tides are totally predictable, other power stations can compensate for this stationary period when there is no tidal energy being produced. Another disadvantage of a tidal barrage system, is the environmental and ecological effects that a long concrete dam may have on the estuaries they span.

Tidal Stream – A *Tidal Stream Generation* system reduces some of the environmental effects of tidal barrages by using turbine generators beneath the surface of the water. Major tidal flows and ocean currents, like the Gulf Stream, can be exploited to extract its tidal energy using underwater rotors and turbines.

Tidal stream generation is very similar in principal to wind power generation, except this time water currents flow across a turbines rotor blades which rotates the turbine, much like how wind currents turn the blades for wind power turbines. In fact, tidal stream generation areas on the sea bed can look just like underwater wind farms.

Unlike off-shore wind power which can suffer from storms or heavy sea damage, tidal stream turbines operate just below the sea surface or are fixed to the sea bed. Tidal streams are formed by the horizontal fast flowing volumes of water caused by the ebb and flow of the tide as the profile of the sea bed causes the water to speed up as it approaches the shoreline.

As water is much more denser than air and has a much slower flow rate, tidal stream turbines have much smaller diameters and higher tip speed rates compared to an equivalent wind turbine. Tidal stream turbines generate tidal power on both the ebb and flow of the tide. One of the disadvantages of **Tidal Stream Generation** is that as the turbines are submerged under the surface of the water they can create

hazards to navigation and shipping.

Other forms of tidal energy include tidal fences which use individual vertical-axis turbines that are mounted within a fence structure, known as the caisson, which completely blocks a channel and force water through them. Another alternative way of harnessing tidal power is by using an "oscillating tidal turbine".

This is basically a fixed wing called a Hydroplane positioned on the sea bed. The hydroplane uses the energy of the tidal stream flowing past it to oscillate its giant wing, similar to a whales flipper, up and down with the movement of the tidal currents. This motion is then used to generate electricity. The angle of the hydroplane to the flow of the tide can be varied to increase efficiency.

Tidal energy is another form of low-head hydro power that is completely carbon neutral like wind and hydro energy. Tidal power has many advantages compared to other forms of renewable energy with its main advantage being that it is predictable. However, like many other forms of renewable energy, tidal energy also has its disadvantages such as its inflexible generation times dependant upon the tides and the fact that it operates in the hostile conditions of the oceans and seas. So here are some of the advantages and disadvantages associated with "tidal energy"

Advantages of Tidal Energy

- Tidal energy is a renewable energy resource because the energy it produces is free and clean as no fuel is needed and no waste bi-products are produced.
- Tidal energy has the potential to produce a great deal of free and green energy.
- Tidal energy is not expensive to operate and maintain compared to other forms of renewable energies.
- Low visual impact as the tidal turbines are mainly if not totally submerged beneath the water.
- Low noise pollution as any sound generated is transmitted through the water.
- High predictability as high and low tides can be predicted years in advance, unlike wind.
- Tidal barrages provide protection against flooding and land damage.
- Large tidal reservoirs have multiple uses and can create recreational lakes and areas where before there were none.

Disadvantages of Tidal Energy

- Tidal energy is not always a constant energy source as it depends on the strength and flow of the tides which themselves are effected by the gravitational effects of the moon and the sun.
- Tidal Energy requires a suitable site, where the tides and tidal streams are consistently strong.
- Must be able to withstand forces of nature resulting in high capital, construction and maintenance costs.
- High power distribution costs to send the generated power from the submerged devices to the land using long underwater cables.
- Intermittent power generation, only generates power ten hours a day during the ebb and flow of the tides
- Changes to estuary ecosystem and an increase in coastal erosion where the tides are concentrated.

- Build up of silt, sediments and pollutants within the tidal barrage from rivers and streams flowing into basin as it is unable to flow out into the sea.
- Danger to fish and other sea-life as they get stuck in the barrage or sucked through the tidal turbine blades.

UNIT 4: Nuclear Power Station & Types of Reactors:

Nuclear fuel is material used in nuclear power stations to produce heat to power turbines. Heat is created when nuclear fuel undergoes nuclear fission.

Most nuclear fuels contain heavy fissile actinide elements that are capable of undergoing and sustaining nuclear fission. The three most relevant fissile isotopes are Uranium-233, Uranium-235 and Plutonium-239. When the unstable nuclei of these atoms are hit by a slow-moving neutron, they split, creating two daughter nuclei and two or three more neutrons. These neutrons then go on to split more nuclei. This creates a self-sustaining chain reaction that is controlled in a nuclear reactor, or uncontrolled in a nuclear weapon.

The processes involved in mining, refining, purifying, using, and disposing of nuclear fuel are collectively known as the nuclear fuel cycle.

Not all types of nuclear fuels create power from nuclear fission; plutonium-238 and some other elements are used to produce small amounts of nuclear power by radioactive decay in radioisotope thermoelectric generatorsand other types of atomic batteries.

Nuclear fuel has the highest energy density of all practical fuel sources.

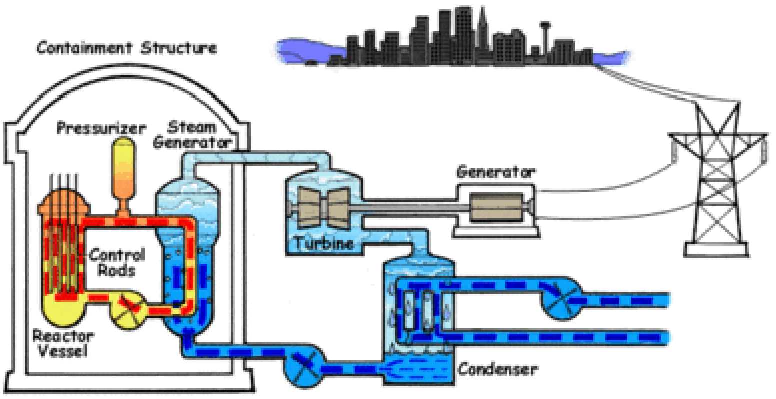
Breeding & Fertile Material

In nuclear engineering, **fertile material** (nuclide) is material that can be **converted to fissile material** by neutron transmutation and subsequent nuclear decay. The process of the transmutation of fertile materials to fissile materials is referred to as **fuel breeding**. Fertile materials are not capable of undergoing fission reaction after absorbing thermal (slow or low energy) neutrons and these materials are not capable of sustaining a nuclear fission chain reaction. There are two basic fertile materials: **^{238}Uand ^{232}Th.**
^{239}Pu and ^{241}Pu are products of the transmutation of the fertile isotope **^{238}U**, while **^{233}U** is product of the transmutation of the fertile isotope **^{232}Th**. These two transmutation and decay chains are shown below:

Pressurized water reactor:

Pressurized water reactors (PWRs) constitute the large majority of the world's nuclear power plants (notable exceptions being Japan and Canada) and are one of three types of light water reactor (LWR), the other types being boiling water reactors(BWRs) and supercritical water reactors (SCWRs). In a PWR, the primary coolant (water) is pumped under high pressure to the reactor core where it is heated by the energy released by the fission of atoms. The heated water then flows to a steam generator where it transfers its thermal energy to a secondary system where steam is generated and flows to turbines which, in turn, spin an electric generator. In contrast to a boiling water reactor, pressure in the primary coolant loop prevents the water from boiling within the reactor. All LWRs use ordinary water as both coolant and neutron moderator.

PWRs were originally designed to serve as nuclear marine propulsion for nuclear submarines and were used in the original design of the second commercial power plant at Shippingport Atomic Power Station.

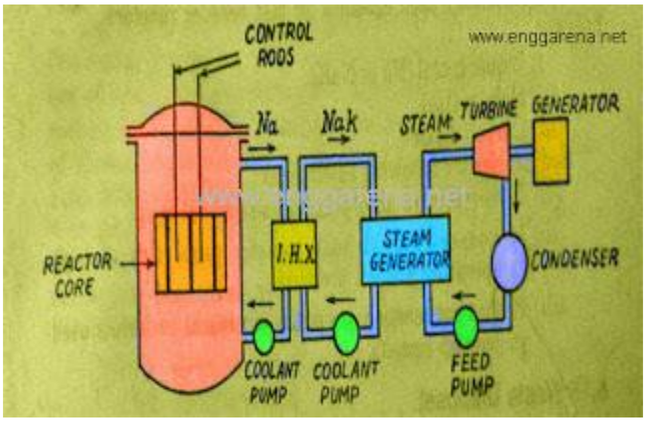


Boiling water reactor:

A boiling water reactor (BWR) is a type of light water nuclear reactor used for the generation of electrical power. It is the second most common type of electricity-generating nuclear reactor after the pressurized water reactor (PWR), which is also a type of light water nuclear reactor. The main difference between a BWR and PWR is that in a BWR, the reactor core heats water, which turns to steam and then drives a steam turbine. In a PWR, the reactor core heats water, which does not boil. This hot water then exchanges heat with a lower pressure water system, which turns to steam and drives the turbine. The BWR was developed by the Argonne National Laboratory and General Electric (GE) in the mid-1950s. The main present manufacturer is GE Hitachi Nuclear Energy, which specializes in the design and construction of this type of reactor.

Sodium-graphite reactor:

It uses graphite as a moderator and liquid sodium as coolant which reach a temperature of about 850 degree Celsius at a low pressure of only 7 bar.
In the primary circuit, the heat is absorbed by liquid sodium in the reactor. The sodium becomes radioactive while it passes through the core and reacts chemically with water. Therefore, the heat absorbed by sodium is transferred to secondary coolant *sodium potassium (NaK)* in the primary heat exchanger which in turn transfers the heat in the secondary heat exchanger called Steam generator.
Water leaving the generator is converted into super-heated steam up to a temperature of 540 degree Celsius. This steam is used for power generation in the steam plant circuit in the usual manner. The reactor vessel, primary circuit and the primary heat exchanger have to be shielded from radiations. The liquid metal is required to be handled under the cover of an inert gas like helium to prevent the contact with air while charging or draining in the primary and secondary heat exchangers.



Fast Breeder Reactor:

A breeder reactor is a nuclear reactor that generates more fissile material than it consumes.[1] Breeder reactors achieve this because their neutron economy is high enough to create more fissile fuel than they use, by irradiation of a fertile material, such as uranium-238 or thorium-232 that is loaded into the reactor along with fissile fuel. Breeders were at first found attractive because they made more complete use of uranium fuel than light water reactors, but interest declined after the 1960s as more uranium reserves were found,[2] and new methods of uranium enrichment reduced fuel costs.

Homogeneous Reactor:

Aqueous homogeneous reactors (AHR) are a type of nuclear reactor in which soluble nuclear salts (usually uranium sulfate or uranium nitrate) are dissolved in water. The fuel is mixed with the coolant and the moderator, thus the name "homogeneous" ("of the same physical state") The water can be either heavy water or ordinary (light) water, both of which need to be very pure.

Their self-controlling features and ability to handle very large increases in reactivity make them unique among reactors, and possibly safest. At Santa Susana, California, Atomics International performed a series of tests titled The Kinetic Energy Experiments. In the late 1940s, control rods were loaded on springs and then flung out of the reactor in milliseconds. Reactor power shot up from ~100 watts to over ~1,000,000 watts with no problems observed.

Aqueous homogeneous reactors were sometimes called "water boilers" (not to be confused with boiling water reactors), as the water inside appears to boil, though the bubbling is actually due to the production of hydrogen and oxygen as radiation and fission particles dissociate the water into its constituent gases, a process called radiolysis. AHRs were widely used as research reactors as they are self-controlling, have very high neutron fluxes, and were easy to manage. As of April 2006, only five AHRs were operating according to the Research Reactor database.[1]

Radiation hazards and shielding:

Radiation protection, also known as radiological protection, is defined by the International Atomic Energy Agency (IAEA) as "The protection of people from harmful effects of exposure to ionizing radiation, and the means for achieving this". The IAEA also states "The accepted understanding of the term radiation protection is restricted to protection of people. Suggestions to extend the definition to include the protection of non-human species or the protection of the environment are controversial".[1] Exposure can be from a radiation source external to the human body or due to the bodily intake of a radioactive material.

Ionizing radiation is widely used in industry and medicine, and can present a significant health hazard by causing microscopic damage to living tissue. This can result in skin burns and radiation sickness at high exposures, known as "tissue" or "deterministic" effects (conventionally indicated by the gray), and statistically elevated risks of cancer at low exposures, known as "stochastic effects" (conventionally measured by the sievert).

Fundamental to radiation protection is the reduction of expected dose and the measurement of dose uptake. For radiation protection and dosimetry assessment the International Committee on Radiation Protection (ICRP) and International Commission on Radiation Units and Measurements (ICRU) publish recommendations and data which is used to calculate the biological effects on the human body of certain levels of radiation, and thereby advise acceptable dose uptake limits. Supporting these are preventive dose reduction techniques such as radiation shielding, exposure planning and avoidance of ingestion of radioactive substances. Radiation protection instruments are used to indicate radiation hazards, and personal dosimeters and bioassay techniques are used to measure personal dose uptake.

Radioactive waste disposal:

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

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

A summary of the amounts of radioactive waste and management approaches for most developed countries are presented and reviewed periodically as part of the International Atomic Energy Agency (IAEA) Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.[1]

UNIT 5 Plant Economics And Environmental Considerations

Structure

- Introduction

Objectives

- Terms and Definitions
- Fixed Cost
- Methods of Depreciation
  - Straight-line Depreciation
  - Sinking Fund Method
  - Declining Balance/Reducing Balance
  - Activity Depreciation
- Operational Cost
  - Cost of Fuels
  - Labour Cost
  - Cost of Maintenance and Repairs
  - Cost of Stores
  - Supervision
  - Taxes
- Economics in Plant Selection
- Factors Affecting Economics of Generation and Distribution of Power
- Summary
- Key Words
- Answers to SAQs

INTRODUCTION

In all fields of industry economics plays an important role. In power plant engineering economics of power system use certain well established techniques for choosing the most suitable system. The power plant design must be made on the basis of most economical condition and not on the most efficient condition as the profit is the main basis in the design of the plant and its effectiveness is measured financially. *The main purpose of design and operation of the plant is to bring the cost of energy produced to minimum*. Among many factors, the efficiency of the plant is one of the factors that determines the energy cost. In majority of cases, unfortunately, the most thermally efficient plant is not economic one.

Objectives

After the studying of this unit, you should be able to

- know the costs associated with power generation,
- describe the fixed and operational costs,
- explain the economics of plant selection, and
- explain the economics of plant operation.

TERMS AND DEFINITIONS

Connected Load

The connected load on any system, or part of a system, *is the combined continuous rating of all the receiving apparatus on consumers' premises, which is connected to the system, or part of the system, under consideration*.

Demand

The demand of an installation or system *is the load that is drawn from the source of supply at the receiving terminals averaged over a suitable and specified interval of time*. Demand is expressed in kilowatts (kW), kilovolt-amperes (kVA), amperes (A), or other suitable units.

Maximum Demand or Peak Load

The maximum demand of an installation or system *is the greatest of all the demands that have occurred during a given period*. It is determined by measurement, according to specifications, over a prescribed interval of time.

Demand Factor

The demand factor of any system, or part of a system, is *the ratio of maximum demand of the system, a part of the system, to the total connected load of the system, or of the part of the system, under consideration*. Expressing the definition mathematically,

$$\text{Demand factor} = \frac{\text{Maximum demand}}{\text{Connected load}} \quad \ldots (7.1)$$

Land Factor

The load factor is *the ratio of the average power to the maximum demand*. In each case, the interval of maximum load and the period over which the average is taken should be definitely specified, such as a "half-hour monthly" load factor. The proper interval and period are usually *dependent upon local conditions and upon the purpose for which the load factor is to be used*. Expressing the definition mathematically,

$$\text{Load factor} = \frac{\text{Average load}}{\text{Maximumdemand}} \quad \ldots (7.2)$$

Diversity Factor

The diversity factor of any system, or part of a system, *is the ratio of the maximum power demands of the subdivisions of the system, or part of a system, to the maximum demand of the whole system, or part of the system, under consideration, measured at the point of supply*. Expressing the definition mathematically,

$$\text{Diversity factor} = \frac{\text{Sum of individual maximum demands}}{\text{Maximum demand of entire group}} \quad \ldots (7.3)$$

Utilisation Factor

The utilisation factor is defined as *the ratio of the maximum generator demand to the generator capacity.*

Plant Capacity Factor

It is defined as the *ratio of actual energy produced in kilowatt hours* (*kWh*) *to the maximum possible energy that could have been produced during the same period*. Expressing the definition mathematically,

$$\text{Plant capacity factor} = \frac{E}{C \times t} \quad \ldots (7.4)$$

where, E = Energy produced (kWh) in a given period,

C = Capacity of the plant in kW, and

t = Total number of hours in the given period.

Plant Use Factor

It is defined as *the ratio of energy produced in a given time to the maximum possible energy that could have been produced during the actual number of hours the plant was in operation*. Expressing the definition mathematically,

$$\text{Plant use factor} = \frac{E}{C \times t'} \qquad \ldots (7.5)$$

where, t' = Actual number of hours the plant has been in operation.

Types of Loads

Residential Load

This type of load includes domestic lights, power needed for domestic appliances such as radios, television, water heaters, refrigerators, electric cookers and small motors for pumping water.

Commercial Load

It includes lighting for shops, advertisements and electrical appliances used in shops and restaurants, etc.

Industrial Load

It consists of load demand of various industries.

Municipal Load

It consists of street lighting, power required for water supply and drainage purposes.

Irrigation Load

This type of load includes electrical power needed for pumps driven by electric motors to supply water to fields.

Traction Load

It includes terms, cars, trolley, buses and railways.

Load Curve

A load curve (or load graph) *is a graphic record showing the power demands for every instant during a certain time interval*. Such a record may cover 1 hour, in which case it would be *an hourly load graph*; 24 hours, in which case it would be a *daily load graph*; a month in which case it would be a *monthly load graph*; or a year (7860 hours), in which case it would be a *yearly load graph*. The following points are worth noting:

(i) The area under the load curve represents the energy generated in the period considered.

(ii) The area under the curve divided by the total number of hours gives the average load on the power station.

(iii) The peak load indicated by the load curve/graph represents the maximum demand of the power station.

Significance of Load Curves

- Load curves give full information about the incoming and help to decide the installed capacity of the power station and to decide the economical sizes of various generating units.

- These curves also help to estimate the generating cost and to decide the operating schedule of the power station, i.e. the sequence in which different units should be run.

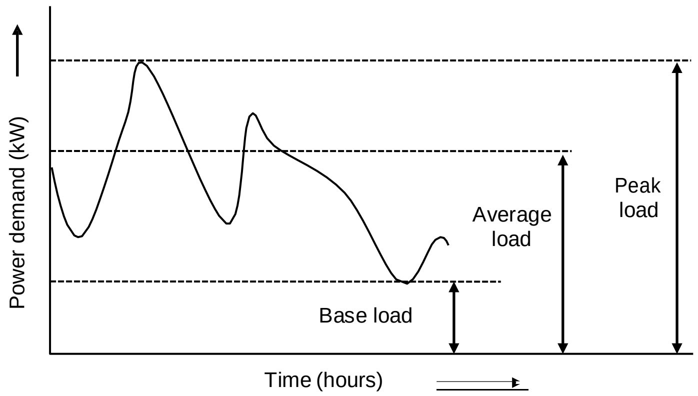


Figure 7.1: Load Curve

Load Duration Curve

A load duration curve represents re-arrangements of all the load elements of chronological load curve in order of descending magnitude. This curve is derived from the chronological load curve.

Figure 7.2 shows a typical daily load curve for a power station. It may be observed that the maximum load on power station is 35 kW from 8 AM to 2 PM. This is plotted in Figure 7.3. Similarly, other loads of the load curve are plotted in *descending order* in the same figure. This is called *load duration curve* (Figure 7.3).

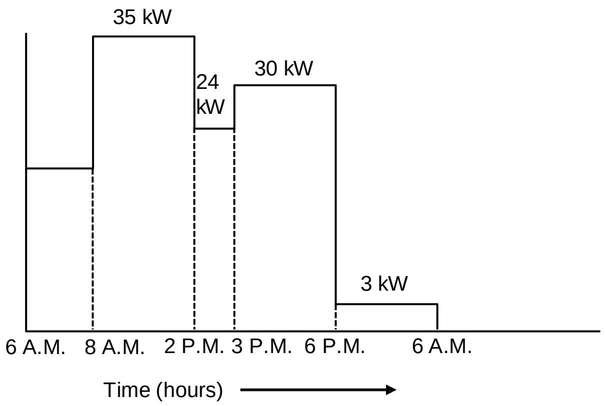


Figure 7.2: Typical Daily Load Curve

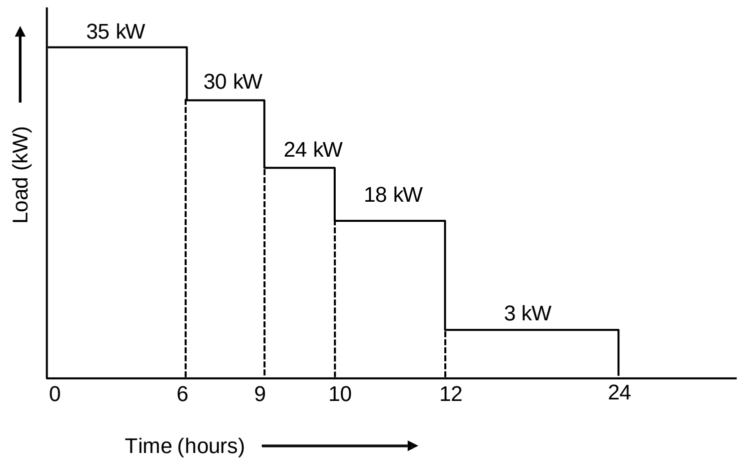


Figure 7.3: Load Duration Curve

The following points are worth noting:

(a) The area under the load duration curve and the corresponding chronological load curve is equal and represents total energy delivered by the generating station.

(b) Load duration curve gives a clear analysis of generating power economically. Proper selection of base load power plants and peak load power plants becomes easier.

Dump Power

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

Firm Power

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

Prime Power

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

Cold Reserve

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

Hot Reserve

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

Spinning Reserve

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

FIXED COST

Initial Cost of the Plant

Initial cost of the plant, which includes:

(a) Land cost

(b) Building cost

(c) Equipment cost

(d) Installation cost

(e) Overhead charges

Rate of Interest

It is the difference between the money obtained and the money returned and may be charged as simple interest or compound interest.

Depreciation Cost

It takes into account the deterioration of the component over a period of time.

METHODS OF DEPRECIATION

There are several methods for calculating depreciation, generally based on either the passage of time or the level of activity (or use) of the asset.

Straight-line Depreciation

Straight-line depreciation is the simplest and most-often-used technique, in which the company estimates the salvage value of the asset at the end of the period during which it will be used to generate revenues (useful life) and will expense a portion of original cost in equal increments over that period. The salvage value is an estimate of the value of the asset at the time it will be sold or disposed of; it may be zero or even negative. Salvage value is also known as scrap value or residual value.

$$\text{Annual Depreciation Expense} = \frac{\text{Cost of Fixed Assed} - \text{Residual Value}}{\text{Useful Life of Asset (Years)}}$$

Sinking Fund Method

The sinking fund technique of calculating depreciation sets the depreciation expense as a particular amount of an annuity**.** The depreciation is calculated so that at the end of the useful life of the annuity, the amount of the annuity equals the acquisition cost. The sinking fund method calculates more depreciation closer to the end of the useful life of the asset, and isn't used very often.

Declining Balance/Reducing Balance

This way of calculating depreciation falls under the accelerated depreciation category. This means that it sets depreciation expenses as higher earlier on, more realistically reflecting the current resale value of an asset.

The way that declining-balance depreciation is calculated is by taking the net book value from the previous year, and multiplying it by a factor (usually 2) which has been divided by the useful life of the asset.

Activity Depreciation

This way of calculating depreciation bases the depreciation expense on the activity of an asset, like a machine. Multiplying the rate by the actual activity level of the asset will give depreciation expense for the year.

Sum of Years Digits

This way of calculating depreciation is given by the following formula:

$$\text{Sum} = \frac{N\,(N+1)}{2}$$

$$D\,(t) = \frac{(N - t + 1) \times (B = S)}{\text{Sum}}$$

where, N = Depreciable life,

B = Cost basis,

S = Salvage value, and

$D\,(t)$ = Depreciation charge for year t.

Taxes and Insurance.

OPERATIONAL COST

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

(a) Cost of fuels.

(b) Labour cost.

(c) Cost of maintenance and repairs.

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

(e) Supervision.

(f) Taxes.

Cost of Fuels

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

The cost of fuel varies with the following:

(a) Unit price of the fuel.

(b) Amount of energy produced.

(c) Efficiency of the plant.

Labour Cost

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

Cost of Maintenance and Repairs

In order to avoid plant breakdowns *maintenance* is necessary. *Maintenance* includes *periodic cleaning, greasing, adjustments and overhauling of equipment*. The material used for maintenance is also charged under this head. Sometimes an arbitrary percentage is assumed as maintenance cost. A good plan of maintenance would keep the sets in dependable condition and avoid the necessity of too many stand-by plants.

Repairs are necessitated when the plant breaks down or stops due to faults developing in the mechanism. The repairs may be minor, major or periodic overhauls and are charged to the depreciation fund of the equipment. This item of cost is higher for thermal plants than for hydro-plants due to complex nature of principal equipment and auxiliaries in the former.

Cost of Stores (Other Than Fuel)

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

Supervisions

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

Taxes

The taxes under operating head includes the following:

(a) Income tax

(b) Sales tax

(c) Social security and employee's security, etc.

ECONOMICS IN PLANT SELECTION

After selection of type of drive (such as steam, gas diesel or water power) which depends on availability of cheap fuels or water resources, further selection of the design and size of the equipment is primarily based upon economic consideration and a *plant that gives the lowest unit cost of production is usually chosen*. In case of all types of equipment the working *efficiency is generally higher with larger sizes of plants and with high load factor operation. Also, the capital cost per unit installation reduces as the plant is increased in size*. However, *a bigger size of plant would require greater investment and possibilities of lower than optimum, load factor usually increase with larger size of the plant*.

Steam Power Plants

In case of steam power plants the choice of *steam conditions* such as throttle pressure and temperature, is an important factor affecting operating costs and is, therefore, very carefully made. *As throttle pressure and temperature are raised the capital cost increases but the cycle efficiency is increased*. The advantages of higher pressures and temperatures is generally not apparent below capacity of 10,000 kW unless fuel cost is very high.

Heat rates may be improved further through *reheating* and *regeneration*, but again the capital cost of additional equipment has to be *balanced against gain in operating cost*.

The use of heat reclaiming devices, such as air pre-heaters and economisers, has to be considered from the point of economy in the consumption of fuel.

Internal Combustion Engine Plants

In this case also the selection of I.C. engines also depends on thermodynamic considerations. *The efficiency of the engine improves with compression ratio but high pressures necessitate heavier construction of equipment which increases cost*.

The choice may also have to be made between *four-stroke* and *two-stroke* engines, the *former having higher thermal efficiency* and the *latter lower weight* and *cost*.

The cost of the *supercharger* may be justified if there *is a substantial gain in engine power which may balance the additional supercharger cost*.

Gas Turbine Power Plant

The cost of the gas turbine power plant increases as the simple plant is modified by inclusion of other equipment such as *intercooler, regenerator, re-heater,* etc. but the gain in thermal efficiency and thereby a reduction in operating cost may justify this additional expense in first cost.

Hydro-electric Power Plant

As compared with thermal stations an hydro-electric power plant has little operating cost and if sufficient water is available to cater to peak loads and special conditions for application of these plants justify, *power can be produced at a small cost*.

The *capital cost* per unit installed is *higher if the quantity of water is small*. Also, the unit cost of conveying water to the power house is greater if the quantity of water is small. The cost of storage per unit is also lower if the quantity of water stored is large.

An existing plant capacity may be *increased by storing additional water* through increasing the height of dam or by diverting water from other streams into the head reservoir. However, again it would be an economic study whether this additional cost of civil works would guarantee sufficient returns.

Some hydro-power plants may be made *automatic* or *remote controlled* to reduce the operating cost further, but the cost of automation has to be *balanced against the saving effected in the unit cost of generation*.

Interconnected Hydro-steam System

In such a system where *peak loads are taken up by steam units*, the capacity of water turbine may be kept somewhat higher than the water flow capacity at peak loads, and lesser than or equal to maximum flow of river. This would make it possible for the water turbine to generate adequate energy at low cost during sufficient water flow.

Some of the principal characteristics of hydro-electric, steam and diesel power plants are listed below:

Sl. No.	Characteristics	Hydro-plant	Steam Plant	Diesel Plant
1.	Planning and construction	Difficult and takes long time	Easier than hydro-plant	Easiest
2.	Civil works cost	Highest	Lower than hydro-plant	Lowest
3.	Running and maintenance cost (as a fraction of total generation cost)	$\frac{1}{10}$	$\frac{1}{7}$	$\frac{1}{6}$
4.	Overall generation cost	Lowest	Lower than for diesel plant	Highest
5.	Reliability	Good	Good	Excellent

Advantages of Interconnection

Major advantages of interconnecting various power stations are:

(a) Increased reliability of supply.

(b) Reduction in total installed capacity.

(c) Economic operation.

(d) Operating savings.

(e) Low capital and maintenance costs.

(f) Peak loads of combined system can be carried at a *much lower cost* than what is possible with small individual system.

FACTORS AFFECTING ECONOMICS OF GENERATION AND DISTRIBUTION OF POWER

The economics of power plant operation is greatly influenced by:

(a) Load factor

(b) Demand factor

(c) Utilisation factor

Load Factor

In a *hydro-electric power station* with water available and a fixed staff for maximum output, the cost per unit generated at 100% *load factor* would be *half* the cost per unit at 50% load factor. In a *steam power station* the difference would not be so pronounced since fuel cost constitutes the major item in operating costs and does not vary in the same proportion as load factor. The cost at 100% load factor in case of this station may, therefore, be about 2/3rd of the cost 50% load factor. For a *diesel station* the cost per unit generated at 100% load factor may be about 3/4th of the same cost at 50% load factor. From the above discussion it follows that:

(a) Hydro-electric power station should be run at its maximum load continuously on all units.

(b) Steam power station should be run in such a way that all its running units are economically loaded.

(c) Diesel power station should be worked for fluctuating loads or as a stand by.

Demand Factor and Utilisation Factor

A higher efficient station, if worked at low utilisation factor, may produce power at high unit cost.

The time of maximum demand occurring in a system is also important. In an interconnected system, a study of the curves of all stations is necessary to plan most economical operations.

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

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

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

SAQ

(a) Describe the various costs associated with power plants.

(b) Explain the economics in plant selection.

(c) Describe the factors affecting economics of generation and distribution of power.

FURTHER READING

R. K. Rajput (2009), *A Text Book of Power Plant Engineering*, Laxmi Publications (P) Ltd.

R. K. Rajput (2009), *A Text Book of Internal Combustion Engines*, Laxmi Publications (P) Ltd.

R. K. Rajput (2009), *A Text Book of Thermal Engineering*, Laxmi Publications (P) Ltd.

Question Bank:

Unit -1

1. Draw a general layout of thermal power plant and explain the working of different circuits?
2. What factors are considered in selecting a site for big thermal power plants?
3. What is the necessity of coal desulphurization? Explain Meyers's process of desulphurization?
4. Give a brief classification of types of coals and how they effect on furnace design?
5. Write a short note on ash handling techniques?
6. What is meant by overfeed and underfeed principle of coal firing? Which is preferred for high volatile coal?
7. Describe different types of overfeed stokers and discuss its advantages and disadvantages?
8. Write a short note on dust collectors?
9. Explain a) De aeration process for feed water treatment
   b) Ion exchange process for feed water treatment
10. What is cooling tower? How are they classified? Explain any one with neat sketch.

Unit-2

1. Draw a neat line diagram of a diesel power plant showing all the systems?
2. What are the different methods of fuel injection used in diesel power plant?
3. Why is supercharging necessary in diesel power plants? What methods are used for supercharging the diesel engines?
4. Draw a neat diagram of lubrication system used for diesel power plants?
5. Draw a neat diagram of cooling system for diesel power plant showing all essential components?
6. State the advantages and disadvantages of gas turbine power plant over diesel and thermal power plant
7. Define the following terms
   a)Air ratio b)Pressure ratio c) Work ration d)compressor efficiency e)engine efficiency f)mechanical efficiency g)combustion efficiency h)thermal efficiency
8. How are gas turbine power plants classified? Explain any one classification?
9. What do you mean by combination gas turbine cycles? Explain briefly combined gas turbine and steam power plant?
10. write a short notes on a)Gas turbine fuels b)Applications of gas turbine c)factors selection for gas turbine power plant

Unit-3

1. Draw a neat diagram of storage type hydro electric power plant and describe the function of each component used in the plant?
2. Define hydrograph and explain its importance in the design of stage type hydro electric power project?
3. What different methods are used to measure the rainfall?
4. Mention the advantages and disadvantages of hydroelectric power plants compared with thermal power plant?
5. What do you understand by "pump storage plant "what are advantaged and limitations of this power plant?
6. Describe the working of solar power plant?
7. Explain the basic principle of thermoelectric power generation?
8. Explain with a real diagram of a wind electric generating power plant?
9. What do you understand by MHD? Explain the working principle of MHD with neat sketch?
10. Explain the difference between open and close cycle MHD system?

Unit-4

1. Draw a neat diagram of nuclear reactor and explain the functions of different components?
2. Draw a neat diagram and explain the principle and working of Pressurized water reactor?
3. Draw a neat diagram and explain the principle and working of boiling water reactor
4. Draw a neat diagram and explain the principle and working of Sodium graphite reactor?
5. Draw a neat diagram and explain the principle and working of CANDU type reactor?
6. Briefly explain the boiling water reactor
7. Briefly explain the sodium graphite reactor
8. Briefly explain the fast breed reactor.
9. Write short note on radioactive waste disposal
10. Write short note on radiation hazards & shieldings

UNIT -5

1. Define connected load, maximum demand, demand factor and load .Explain the importance of each in a power plant operation
2. What different load curves are considered in designing a power plant? What is the effect of its nature on the way of power plant?
3. Define the Diversity factor and state the advantages and disadvantages of load in a power supply system
4. Explain briefly the following
A) Capital cost b) Fixed cost c) operating cost?
5 write short notes on methods of pollution control?
6. Write short note on pollutants & pollution standards.
7. Define terms demand factor, load factor, diversity factor, maximum demand
8. Write short note on methods of pollution control .
9. Write short note on operating costs.
10. Write short note on Load curve & load duration curve.

Short Answer Questions:

Unit-1

Unit-1

1. Name the four major circuits in steam power plant.

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

2 . What consists of air and flue gas circuit?

Air and flue gas circuit consists of forced draught fan, air-pre-heater, boiler, furnace, super heater, economiser, dust collector, induced draught fan and chimney.

3. What consists of feed water and steam flow circuit in steam power?

The feed water and steam flow circuit consists of feed pump, economiser boiler drum super heater, turbine and condenser.

4. What consists of cooling water circuit and coal & ash circuit in steam power plant?

The cooling water circuit consists of a pump, condenser and cooling tower. The coal and ash circuit consists of coal delivery, preparation of coal, handling of coal to the boiler furnace, ash handling and ash storage.

5. State the uses of high pressure boilers?

The high-pressure boilers are used to increase the efficiency of the plant and to reduce the cost of electricity production.

6. State important advantages of high-pressure boilers?

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

7. Name important high pressure boilers?

1. La Mont boiler 2.Benson boiler
3. Loeffler boiler 4. Velox boiler.

8. Write about La Mont boiler? What is the major disadvantage of La Mont boiler?

Mont boiler is a forced circulation high pressure water tube boiler. The major disadvantage is the formation of bubbles, salt and sediment on the inner surfaces of the heating surfaces. This reduces the heat flow and steam generation.

9. Write about fluidized bed boilers?

When the high velocity gas is passed through a packed bed of finely divided solid particles, the particles become suspended in the gas stream and the packed bed becomes a fluidised bed. When the gas velocity is very high, the fluidised bed become turbulent and rapid mixing of particles occurs. Ultimately, the, behaviour of mixture solid particles and -gas become a fluid. Burning of a fuel in such a state is known as Fluidised Bed Combustion. The boiler plant using this fluidised bed combustion is known as fluidised bed boilers.

10. State some advantages of fluidised bed boilers?

1. Any type of fuel - solid, liquid (or) gaseous fuel (or) domestic and industrial waste can be used in FBC system. Any type- of combustible matter can be burned by adjusting the factors as size, air velocity and rate of feed.

2. High heat transfer rate is possible to the surfaces immersed in the bed, because solid mixing is extremely possible.

3. High combustion efficiency.

4. The solid fuel need not be pulverised in fluidised bed boilers.

Unit-2

1. **What are the uses of air filter and superchargers in diesel engine power plant?**

The purpose of air filter is to filter the air from dust and other suspended particles. The purpose of super charger is to increase the pressure of the engine to increase power of the engine.

2. **What is the use 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.

3. **What is the function-of cooling system in Diesel power plant?**

The function of cooling system is to remove heat from the engine cylinder to keep the temperature of the cylinder in low range and extend engine life.

4. **What consists of lubrication system in diesel engine power plant?**

The lubrication system consists of oil pumps, oil tanks, filters, coolers and connecting pipes. The purpose of the lubrication is to reduce the friction of moving parts and also pipes to reduce the wear and tear of moving parts.

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

Since the power required to compress the air is less in isothermal process it is required to maintain the, temperature of air constant as far as possible. Hence the air leaving the L.P. compressor is cooled by intercooler and then passed to the H.P compressor.

6. **Name two combined power cycles?**

   1. Combined cycle of gas turbine and steam power plant.
   2. Combined cycle of gas turbine and diesel power plant.

7. **Define turbo charging in combined gas turbine and diesel cycles?**

In the combined cycle, the exhaust gas from the diesel engine is expanded in the turbine, which is coupled with compressor which supplies pressurized air to the diesel engine. This increases diesel engine output. This arrangement is known as turbo charging.

8. **What are the important advantages of Re-heating?**

- Due to reheating, network done increases
- Heat supply increases
- Thermal efficiency increases
- Due to reheating, the turbine exit dryness fraction increases so moisture decreases - so blade erosion becomes minimum - so life of the turbine will be increased.

9. **Name different methods of reheating?**

(a) Gas Reheating(b) Live - steam reheating (c)Combined gas live steam reheater.

10.Define bleeding in steam power plant?

Assume I kg of steam is expanded in the turbine. Before complete amount of steam -is expanded, some amount of steam (m kg) is -extracted ' Extracting the steam in the turbine before exhaust is called bleeding. This bled steam is used to heat the feed water.

Unit-3

1. What is the main purpose of the reservoir?

The main purpose of reservoir is to store water received from catchments areas during the rainy seasons and supply the same during the dry season.

2. What is the main purpose of the dam?

The main purpose of the dam is to increase the height of water level and also to increase the working head of the hydraulic power plant.

3. Why trash rack is used?

The trash rack is used to prevent the entry of debris, which might damage the turbine runners and chock up the nozzle of impulse turbine.

4. What is the use of 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.

5. What is the function of Fore bay?

Fore bay is considered as naturally provided surge tank. It is temporary water storage when the load on the plant is reduced and provides water for initial increment on increasing load.

6. Explain about penstock?

The pipe between surge tank and prime mover is known as penstock. It is designed to withstand high pressure. It is made up of reinforced concrete. In very cold areas, the penstock is buried to prevent ice formation and to reduce the expansion joints.

7. What is the use of spill Ways?

Spillway is like a safety valve of the dam. It discharges major flood without damaging the dam. It keeps the reservoir level below the maximum level allowed.

8. Write about prime movers?

Prime mover converts the kinetic energy of water into mechanical energy to produce electrical energy. Pelton wheel, turbine, Francis turbine, Kaplan turbine and Propeller turbine are prime movers used in hydraulic power plants.

9. List the advantages of solar Energy.

1. Solar energy is free from pollution
2. They collect solar energy optically and transfer it to a single receiver, thus minimizing Thermal-energy transport requirements
3. They typically achieve concentration ratios of 300 to 1500 and so are highly Efficient both in collecting energy and converting it to electricity.
4. The plant requires little maintenance or help after setup It is economical

10. List any four disadvantages of solar energy.

1. Avilable in day time only
2. Need storage facilities
3. It needs a backup power plant
4. Keeping back up plants hot includes an energy cost which includes coal burning

Unit-4

1. 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.

2. Write about isotopes of an element?

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. Such type of elements which ' have the same atomic number – same number of protons - the - same chemical properties but different mass numbers due to different number of neutrons, are known as I the isotopes of an element.

3. What are the requirements to sustain fission process?

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

4. Define multiplication factor of a fission process.

A criticality factor or effective multiplication factor (k) is defined to denote the relative number of neutrons produced in successive fission events. In effect, 'k' is the ratio of number of neutrons produced by fission in one generation to the number of neutrons produced by fission in the preceding generation.

5. Define fertile materials and breeding in reactors

There are materials like U235 and Th232 which are not fissile but can be converted into fissile materials by the bombardment of neutrons. Such materials are known as fertile materials.

The process of converting more fertile material into fissile material in a reaction is known as breeding.

6. What are the desirable properties of a good moderator?

- It must be as light as possibleIt 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

7. 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

8. Name few types of reactors.

Fast reactors, Thermal reactors, natural fuel reactors, Enriched Uranium reactors, water moderated reactors, heavy water moderated reactor, graphite moderated reactor, gas cooled reactors and Sodium cooled reactors.

9. What are the advantages using CO2 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

10. 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
- The operation of the reactor is not limited by Xe poisoning

Unit-5

1. What are the waste materials, which can be used for fuel for power generation?

1. Municipal waste 2. Industrial waste 3.Paper waste 4.Rubber waste.

2. Define the term waste heat recovery?

Waste heat is the heat which is not at all used and exhausted out as a waste product. Waste heat is normally available from the industry in the form of process steam and water at high temperature. Also, the waste heat is discharged with the exhaust gases in so many industries. This heat can be recovered for useful purpose. This process is known-as waste heat recovery.

3. 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.

4. What includes fixed cost?

Fixed cost includes the following cost.

1. Cost of land 2. Cost of building 3. Cost of equipment
4. Cost of installati6n 5. Interest 6. Depreciation cost
7. Insurance 8. Management cost

5. What includes operating cost?

Operating cost includes the following cost.

1. Cost of fuel 2. Cost of operating labour,
3. Cost of maintenance labours and materials. 4. Cost of supplier like

Water for feeding boilers, for condenser and for general use.
Lubrication oil and, grease.
Water treatment chemicals.

6. What is meant by 'Desulphurisation' and name the methods adopted for desulphurisation?

Desulphurisation of fuel is the process of reducing the sulphur content in the fuel. The f ollowing methods are adopted for desulphurisation.

1.Chemical treatment 2.Forth flotation 3.Magnetic separation

7. What are the methods adopted to remove' S02 flue gases?

1. Wet scrubbing 2. Solid absorbent 3. Catalytic oxidation

8. Write about C02 recorders?

In thermal power plants, it is necessary to keep the concentration Of C02 as low is necessary as possible. To achieve this, a constant recording of concentration Of C02 These recorders are based on the three different principles, as given below.

1. Thermal conductivity cell
2. Chemical absorption cell
3. Density balance 92. 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.

9. Name some of the automatic controlling methods for feed water?

1. Single element pilot operated system
2. Single element self operated system
3. Two element pilot operated system
4. Three element pilot operated system

10.What is the purpose of automatic, combustion control?

The main purpose of -automatic combustion' control system is to maintain load against demand, to prevent smoke, to increase boiler house efficiency, to carry out routine adjustments and to provide interlocking safe guards.

Course Coverage:

Unit-1> A Text Book of Power Plant Engineering , Rajput. R.K., 4/e, Laxmi Publ, 2007 (78-261)

Power Plant Engineering, P.C.Sharma , S.K.Kataria Publ.(200-420)

Unit-2> A Text Book of Power Plant Engineering , Rajput. R.K., 4/e, Laxmi Publ, 2007(140-200, 266-361)

Power Plant Engineering, P.C.Sharma , S.K.Kataria Publ.(502-635)

Unit-3> Power Plant Engineering, P.C.Sharma , S.K.Kataria Publ.(333-382)

Power Plant Engineering, P.K.Nag, 2/e, TMH.(222-297)

Unit-4> Power Plant Engineering, P.C.Sharma , S.K.Kataria Publ.(812-832)

Power Plant Engineering, P.K.Nag, 2/e, TMH.(535-549)

Unit-5> Power Plant Engineering, P.C.Sharma , S.K.Kataria Publ.(925-932)

Power Plant Engineering, P.K.Nag, 2/e, TMH.(645-654)

Group Projects: Power Plant Engineering

1. Fabrication of coal handling systems(prototype)
2. Heat recovery system for internal combustion engine.
3. Air driven Engine
4. Vacuum braking system
5. Design of solar powered vapour absorption system
6. Solar cooler