

LECTURE NOTES
ON
POWER STATION ENGINEERING



6TH SEMESTER

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Steam Power Plant

A Steam Power Plant converts the chemical energy of the fuel (coal, oil, gas) into mechanical or electrical energy. The main purpose of a power plant is

- produce electric power
- produce steam for other work in plants

classification

- (1) Central Station \rightarrow The electrical energy available from the stations is meant for general sale to the public who wish to purchase it. The plants are condensing type where the exhaust steam is discharged into a condenser instead of atmosphere.
- (2) Industrial / Captive Power Station \rightarrow This type of plant is run by a manufacturing company for its own use and its output is not available for sale to general public. These are non-condensing type.

Layout of a modern steam power plant

- (1) coal and ash circuit \rightarrow coal arrives at the storage yard and after necessary handling passes to the furnace through the fuel feeding device. Ash resulting from the combustion of coal collects at the backyard of the boiler.
- (2) Air and gas circuit \rightarrow Air is taken from the atmosphere through forced / induced draft fan and passes to the furnace through air-preheater.

where it has been heated by the application of flue gas which passes to the chimney via air-preheater. Then the air is passed to the economiser.

(3) Feedwater and Steam Flow Circuit →

In the water and steam circuit condensation leaving the condenser is first heated in a closed feed water heater through extracted steam from the lowest pressure extraction point from the turbine. It then passes through deaerators and few more water heaters before going into the boiler through economiser. Wet steam from the boiler drum is further heated up in the superheater before being supplied to the turbine.

(4) cooling water circuit → The cooling water supply to the condenser helps in maintaining a low pressure in it. The water may be taken from the natural source such as river, lake or sea.

Components of a Modern Steam Power Plant

- (1) Boiler (superheater, re-heater, Economiser, Air-preheater)
- (2) Steam Turbine (3) Generator
- (4) Condenser (5) Cooling Towers
- (6) Circulating water pump (7) Boiler feed pump
- (8) Control Room (9) Switch yard (10) coal mill

- (11) Boiler chimney (12) induced draft fan
 (13) crusher house (14) Ash precipitation

Selection of site for steam power station

- (1) Availability of Raw material
- (2) Nature of the land
- (3) cost of the land
- (4) Availability of water
- (5) Transport Facility
- (6) Ash disposal Facility
- (7) Availability of labour
- (8) Size of the plant
- (9) Load centre
- (10) Public Problems
- (11) Future extension

List of Thermal Power Station in odisha

- (1) NTPC (Talcher Super Thermal Power station)
 in the district of Angul having generating capacity of 3000 MW (Jharsuguda)
- (2) IB Thermal Power Plant (Banharpali)
 having capacity of 420 MW (Bhubaneswar)
- (3) TTPS (Talcher Thermal Power station)

Located in Angul in Orissa having

Capacity of 460 MW.

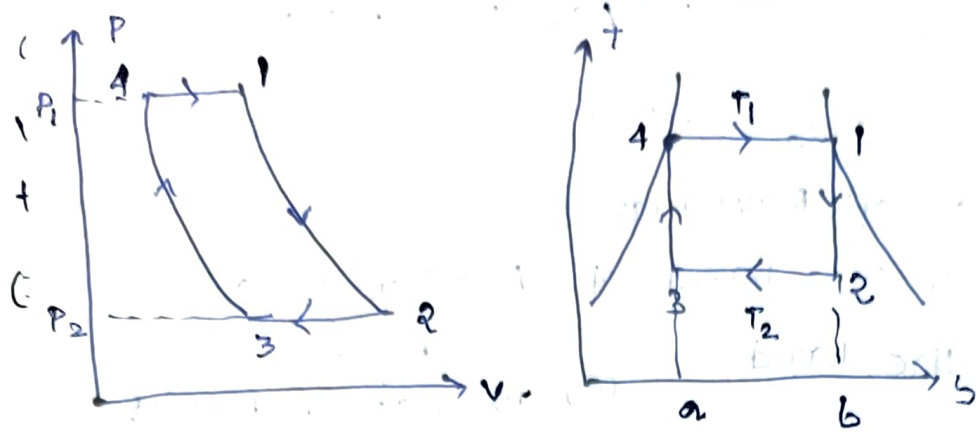
Operation of Boiler

It is also known as Steam Generators

which are used for generating steam which is used for

- (1) Power generation in steam engines
- (2) used in industrial process
- (3) used for heating installation in building

Carnot vapour power cycle



consists of two constant pressure process (4-1) and (2-3)

Two adiabatic process (1-2) and (3-4)

(4-1) \rightarrow 1 kg of boiling water at temperature T_1 is heated to form steam

heat is absorbed ($P=c, T=c$)

(1-2) steam is expanded isentropically to temperature T_2 and P_2

(2-3) heat is rejected at constant pressure P_2 and T_2 . As steam is exhaust (cool).

(3-4) The wet steam is compressed isentropically till the steam regain its original state T_1, P_1

Heat supplied (Q_1) = $T_1 (s_1 - s_4)$ or $T_2 (s_2 - s_3)$

heat rejected (Q_2) = $T_2 (s_2 - s_3)$

work done = $Q_1 - Q_2$

= $(T_1 - T_2) (s_2 - s_3)$

$\eta = \frac{W.D}{Q_{supplied}} = \frac{(T_1 - T_2) (s_2 - s_3)}{T_1 (s_2 - s_3)} = \frac{T_1 - T_2}{T_1}$

Though Carnot cycle is very simple and gives highest efficiency among all but practically it is very difficult.

Rankine Cycle

It is the theoretical cycle on which the steam turbine/engine works.

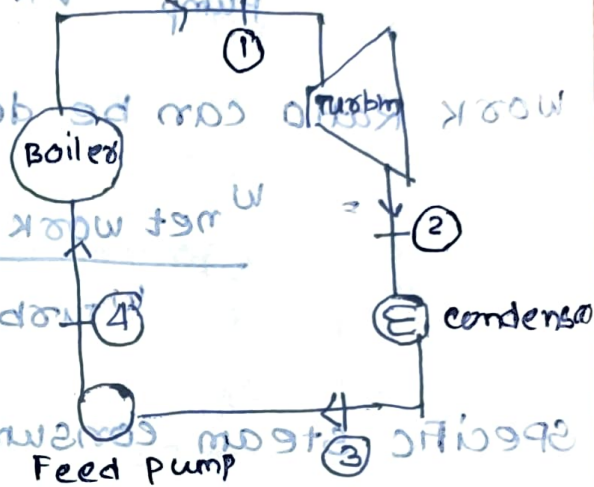
1-2 (Adiabatic expansion

to turbine)

2-3 (constant pressure heat rejection)

3-4 (pumping process Adiabatic)

4-1 (constant pressure heat addition)

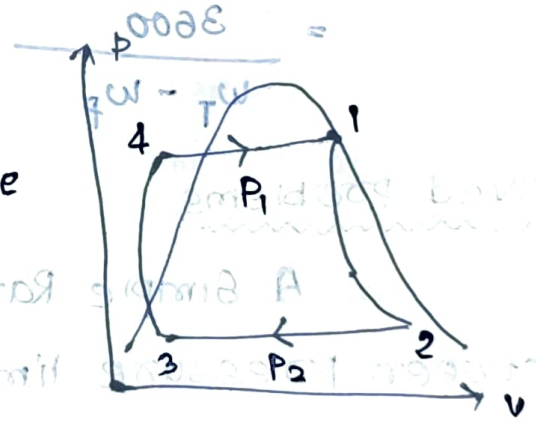


work done on the turbine

$$W_T = h_1 - h_2$$

work done on the pump

$$W_P = h_3 - h_4$$



heat is rejected on the condenser

$$Q_1 = h_2 - h_3$$

heat is supplied to the boiler

$$Q_2 = h_1 - h_4$$

$$\eta_{\text{Rankine}} = \frac{\text{Net W.D}}{Q_{\text{supplied}}} = \frac{W_T - W_P}{Q_2} = \frac{(h_1 - h_2) - (h_3 - h_4)}{(h_1 - h_4)}$$

The feed pump handles liquid water which is in-compressible which means with increase in pressure its density or specific volume changes.

$$h_4 - h_3 = v_3 (P_1 - P_2)$$

$$W_{\text{pump}} = v \times dp$$

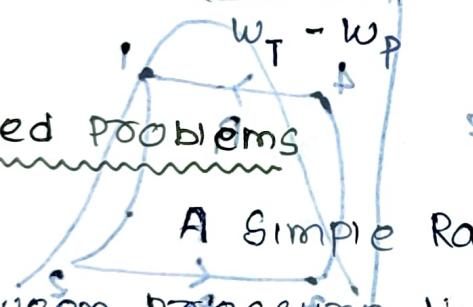
Work Ratio can be defined as the Ratio of

$$W_{\text{net work done}}$$

W_{Turbine}

Specific steam consumption = $\frac{3600}{W_{\text{net}}}$

$$= \frac{3600}{W_{\text{net}}}$$



Solved problems

A Simple Rankine cycle works

between pressure limits of 28 bar and 0.06 bar calculate cycle efficiency, work done work ratio and specific steam consumption

Ans → at 28 bar

at 0.06 bar

$$h_1 = 2802 \text{ kJ/kg}$$

$$h_2 = 1910 \text{ kJ/kg}$$

$$h_4 = 151.93 \text{ kJ/kg}$$

$$\frac{(h_1 - h_2) - (h_4 - h_3)}{(h_1 - h_2)} = \frac{2802 - 1910 - 151.93}{2802 - 1910} = \dots$$

$$W_{net} = W_{Turbine} - W_{pump}$$

$$= (280.2 - 191.8) - (200.93 - 151.93)$$

$$= 88.94 \text{ kJ/kg}$$

Boiler Accessories

Accessories are the auxiliary parts

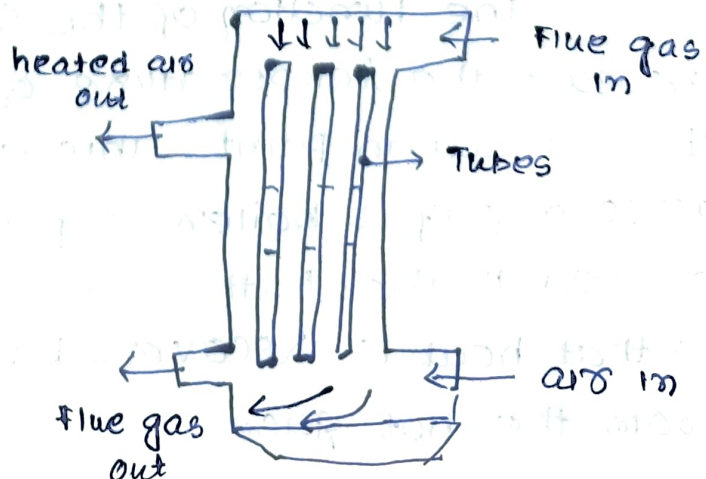
required for steam boiler for their proper operation and increase of their efficiency.

(1) Air Preheater → The function of air preheater is to increase the temp of air before it enters into the Furnace. It is generally placed after the Economiser, so the flue gases pass through the Economiser then air preheater.

It consists of plates or tubes with hot gases on one side and air on other side. It pre-heats the air to be supplied to the Furnace, so that air accelerates the combustion process.

There are three types of air preheater

(1) Tubular type (2) Plate type (3) Storage type



(2) Economiser \rightarrow An economiser is a device in which the waste heat of the flue gas is utilised for heating feed water. It is divided into two types (1) independent type (2) integral type

It is placed at the passage of flue gas from the boiler to chimney.

Vertical tube economiser

which is employed Range

upto 25 bar. It consists

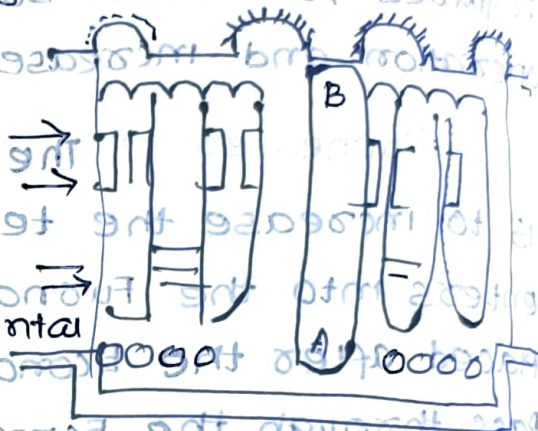
of large numbers of vertical

C-I pipes which are

connected with two horizontal

pipe, one at the top

and one at the bottom.



From pipe A through which feed water is

pumped to the economiser then it passes

to pipe B through vertical pipes. The flue gas

moves around the pipes in a direction

opposite the flow of water so heat transfer

takes place and water gets heated.

Superheater

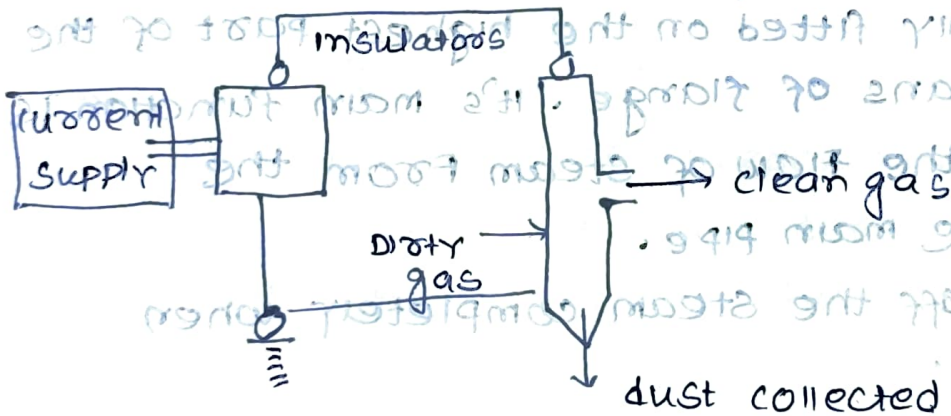
The function of the Superheater is to increase the temperature of the steam above its saturation point. This is the most important accessory of a boiler. Superheaters are located in the path of the furnace gas so that heat is recovered by the superheater from the hot gases.

These are two types of Superheater

- (1) Convective Superheater makes the use of heat from the Flue gas whereas Radiant Superheater is placed in the furnace wall and tubes receive heat from the burning of fuel.

Electrostatic Precipitator

The (ESP) Removes particle from a gas stream by using electrical energy to charge particle either positively or negatively. This works on the principle of attraction of a charged particle for an oppositely charged collector. They have been used for controlling particulate emissions from sources.



Boiler Mountings

These are the fittings which are mounted on the boiler for its safe and proper functioning. Important mountings are →

- (1) Water level Indicator → This indicates the water level inside the boiler to an observer. These are generally two in number. It consists of three cock and a glass tube.

(2) Pressure gauge → The pressure of steam inside the boiler (measure). It is fixed in front of steam boiler. Generally Bourdon tube. Pressure gauges are used for this operation.

(3) Safety valves → The function of the safety valve is to release the excess steam when the pressure of steam inside the boiler exceeds the rated pressure. These are mounted on the top of the shell. Every boiler must be fitted with two safety valves.

- (1) Lever safety valve
 - (2) Deadweight safety valve
 - (3) Spring loaded safety valve
 - (4) High steam and low water safety valve
- Steam stop valve

It is the largest valve in the steam boiler, usually fitted on the highest part of the shell by means of flange. Its main function is to control the flow of steam from the boiler to the main pipe.

To shut off the steam completely when required.

- (5) Blow off cock

The main function of a blow off cock are

- (1) To empty the boiler when required.
- (2) To discharge the mud, sediment which are accumulated at the bottom of the boiler.

It is fitted at the bottom of the boiler drum and consists of a conical plug fitted to the body.

(6) Feed check valve

It's function is to control the supply of water to the boiler and to prevent the escaping of water from the boiler when the pump pressure is less or pump is stopped. It is fitted on the water space of the boiler.

(7) Fusible Plug

It is fitted to the crown plate of the furnace or the fire box. Its objective is to put off the fire in the furnace of the boiler when the level of water in the boiler falls to an unsafe limit, thus avoid the explosion which may occur due to overheating of the furnace plate. It is made from gun metal material.

Draught System

The small pressure difference which causes a flow of gas to take place is termed as draught. The main function of the draught in the boiler is to force air to the fire and to carry away the gaseous product of combustion. In a boiler combustion process occurs properly if sufficient quantity of air is supplied.

(1) Natural draught

Natural draught is obtained with the help of chimney. (1) It produces the draught whereby the air and the gases are forced through the fuel bed, furnace and boiler pass

(11) It carries the product of combustion to such a height before discharging them so that, there will be no harmful effect to the environment.

The draught produced by the chimney is due to the density difference between the hot gas and cold air outside.

Forced Draught

In mechanical draught system, the draught is produced by a fan. A blower or fan is installed near the boiler or at the base of the boiler to force the air through the cool bed and other passage through furnace, flues and air preheater.

Induced Draft

In this system a fan or blower is located at or near the base of the chimney. The pressure at the fuel bed is below that of atmospheric pressure so that a partial vacuum is created and the product of combustion are drawn to the chimney.

Balanced Draught

It is the combination of forced and induced draft. In this system the forced draught fan overcome the resistance of air-preheater while the induced draft fan overcomes the draught losses through economiser, air-preheater etc.

Advantages

- (1) Easy control of combustion & evaporation
- (2) Reduced chimney height
- (3) Prevention of smoke
- (4) Improvement in efficiency of the plant
- (5) Increase in evaporation power of the boiler
- (6) capability of consuming low grade fuel.

(Cooling Towers)

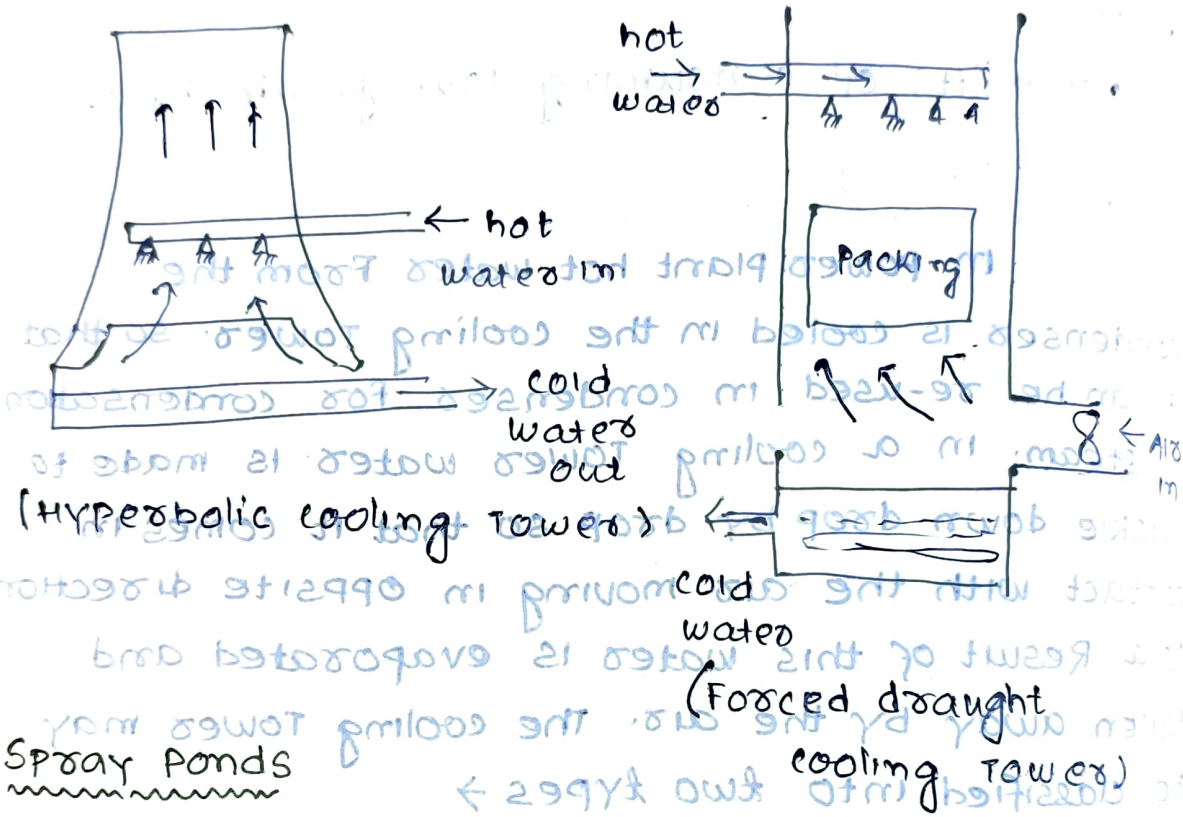
In power plant hot water from the condenser is cooled in the cooling tower so that it can be re-used in condenser for condensation of steam. In a cooling tower water is made to trickle down drop by drop so that it comes in contact with the air moving in opposite direction. As a result of this water is evaporated and taken away by the air. The cooling towers may be classified into two types →

(1) Natural Draught cooling Tower

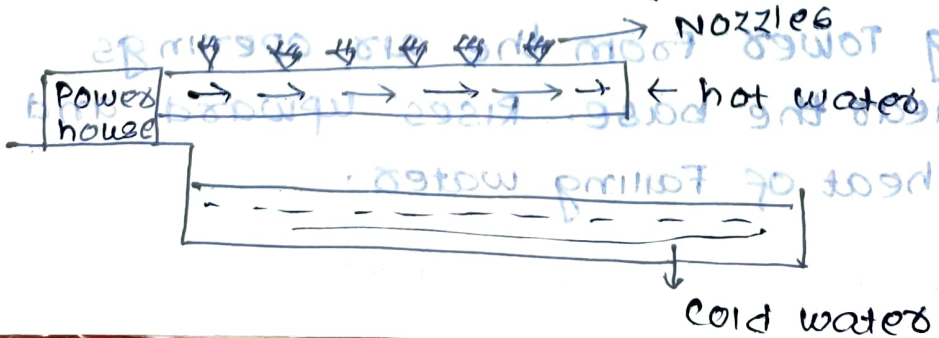
The hot water from the condenser is pumped to the trough and nozzle situated near the bottom. Trough spray the water falls in the form of droplets into a pond situated at the bottom of the tower. The air enters the cooling tower from the air openings provided near the base. Rises upwards and takes up heat of falling water.

(2) Mechanical Draught cooling Tower

In these towers the draught of air for cooling water is produced mechanically by means of propelled fans. The internal structure is same as natural draught tower but the side of the towers are closed and form an air-tight structure and there is opening for the fans only.



Warm water receives from the condenser is sprayed through the nozzle over a pond of large area and cooling effect is mainly due to the evaporation from the surface of water. Sufficient amount of water is lost by evaporation and windage.



The spacing of the nozzle in a spray pond depends upon the design and size of the nozzles. These are mounted in group of five.

Steam Condenser

Steam condenser is a device in which steam condensed and heat released by the steam is absorbed by water. Its main function

(1) maintains low back pressure on the exhaust side of the piston, and due to the expansion of steam there is increase in heat energy.

(2) Supplies pure and hot feed water to the boiler.

Classification of Condenser

Mainly steam condensers are classified into two types →

(1) Jet Condenser → The exhaust steam and water comes in direct contact with each other and temperature of the condensate is same that of cooling water. These condensers are divided into →

(1) Parallel flow type → Both exhaust steam and cooling water find their entry at the top of the condenser and flow downwards.

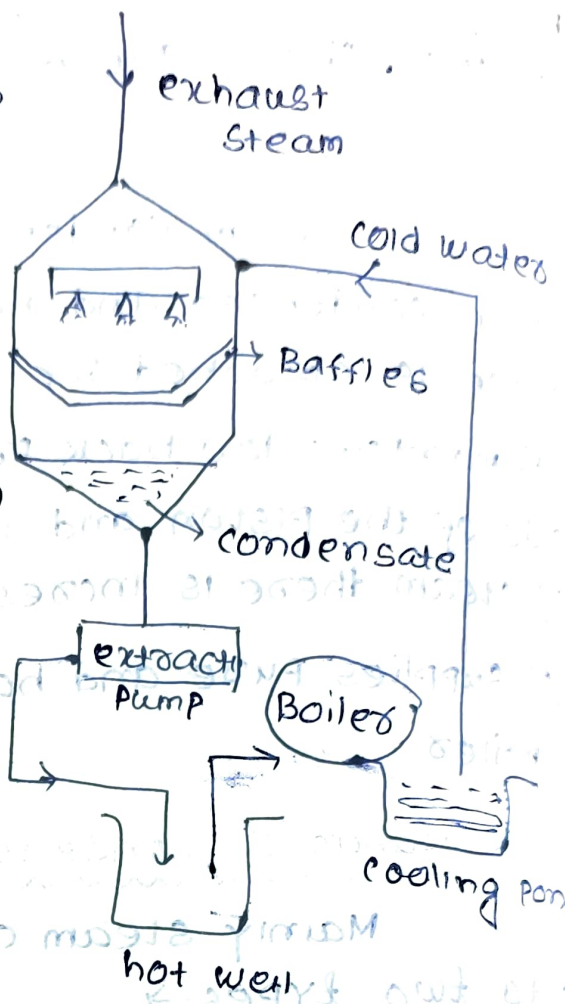
(2) counter flow type → steam and cooling water enters the condenser in opposite direction

Generally exhaust steam flow upwards and meet the cooling water downwards.

(3) Ejector type condenser

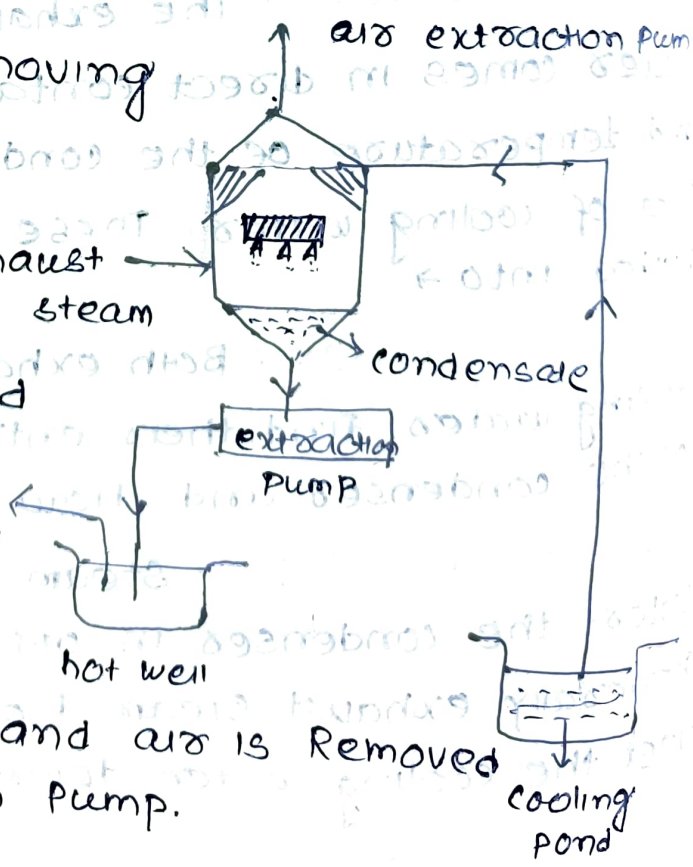
Low Level Jet condensers (Parallel Flow)

Exhaust steam enters from the top and cold water is being sprayed on its way. Baffles plates are provided for uniform mixing. An extraction pump discharge the condensate to the hot well where it may be fed to the boilers.



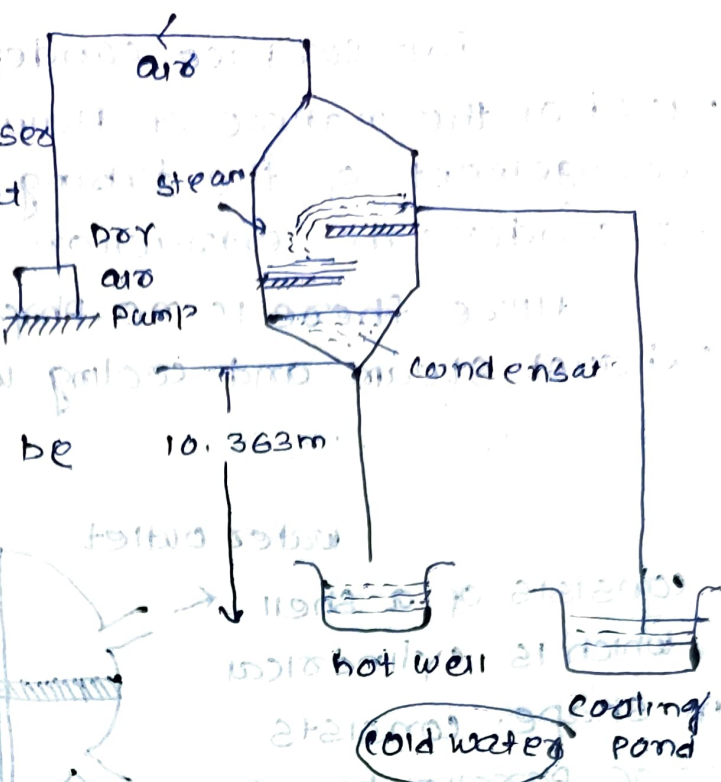
Low Level Jet Condensers (Counter Flow)

The steam moving upward comes in contact with the water and gets condensed. The condensate and water mixture is sent to the hot well by means of an extraction pump and air is removed by an air extraction pump.

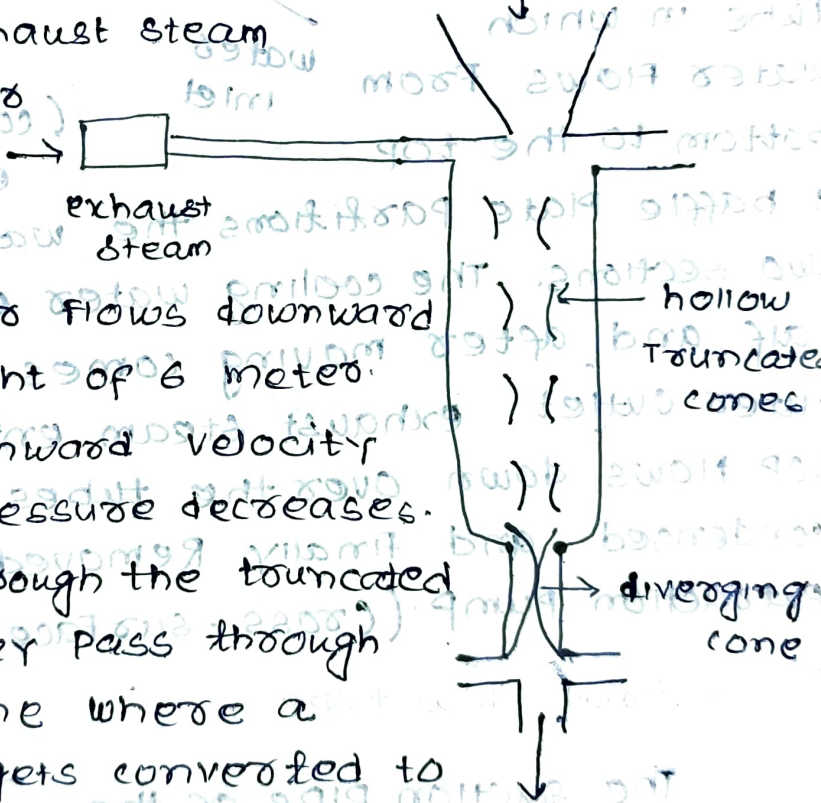


high level Jet Condenser (counter flow)

It is also called as barometric condenser. The shell is placed at a height of 10.363 m above the hot well. The necessity of air extraction pump can be avoided.



here the exhaust steam and cooling water mixed in hollow truncated cones.



The cooling water flows downward. Placed at a height of 6 meters. as it moves downward velocity increases but pressure decreases. after passing through the truncated cones finally they pass through the diverging cone where a portion of K.E gets converted to pressure energy which is more than atmospheric pressure. so the condensate consisting of condensed steam, cooling water and air is discharged into the hot well.

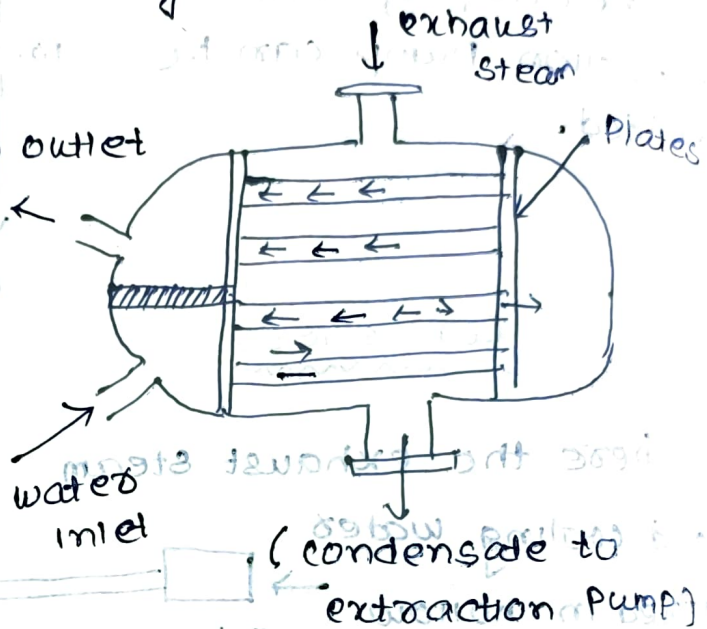
Surface Condensers

The surface condensers are classified based on the nature of flow of condensate, arrangement of the tubing and position of the condensate extraction pump.

Here there is no physical mixing of exhaust steam and cooling water.

(1) Down flow type →

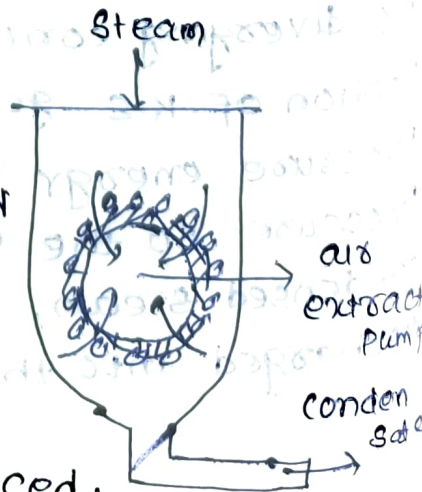
consists of a shell which is cylindrical in shape. consists no. of parallel brass tube in which water flows from bottom to the top.



A baffle plate partitions the water box into two sections. The cooling water enters at lower half and after moving comes out from upper outlet. exhaust steam enters from the top flows down over the tubes and get condensed. and finally removed by air extraction pump. (cross-surface condenser)

(2) central flow type →

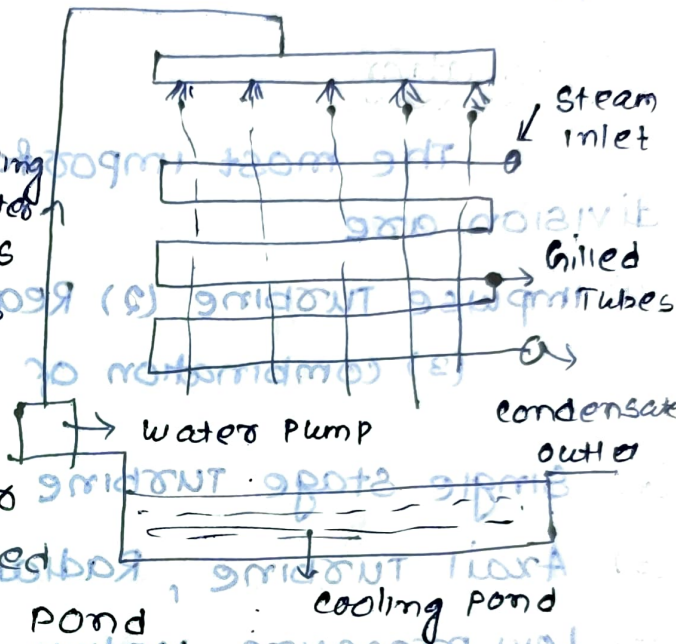
The suction pipe of the air-extraction pump is located in the centre of the tube which results in radial flow of the steam. due to large passage pressure drop is reduced.



(3) Inverted Flow type \rightarrow This type of condenser has the air suction at the top, the steam after entering at the bottom rises up and then again flow down to the bottom of the condenser.

(4) evaporative type \rightarrow

The exhaust steam enters from the top through gilled tubes. The water pump sprays water on the pipes and water condensate the steam. The water which is not evaporated falls into the cooling pond which can be re-used again.



Condenser Auxiliaries

- (1) Hot well \rightarrow It acts as a water Reservoir for the turbine cycle. When the hot well level Reaches at the highest point a dump valve opens to move the condensate From the hot well to storage tanks.
- (2) condensate extraction Pump \rightarrow It extract the condensate water from the condenser and Pumped it through the condensate Polishing system.
- (3) Air extraction Pump \rightarrow It is used to Remove condensate air from the condensed. Basically Air Pump creates a vacuum in the condenser as nearly as possible.

Steam Turbine

The steam turbine is a prime mover in which the potential energy of the steam is transformed to kinetic energy which again transformed into mechanical energy in turbine shaft.

Classification

The most important and common division are

- (1) Impulse turbine (2) Reaction turbine
- (3) combination of both
- (2) Single stage turbine or Multi-stage turbine
- (3) Axial turbine, Radial turbines
- (4) Low pressure, Medium pressure, high pressure
- (5) Nozzle governing, By-pass, Throttle

Advantages of steam turbine

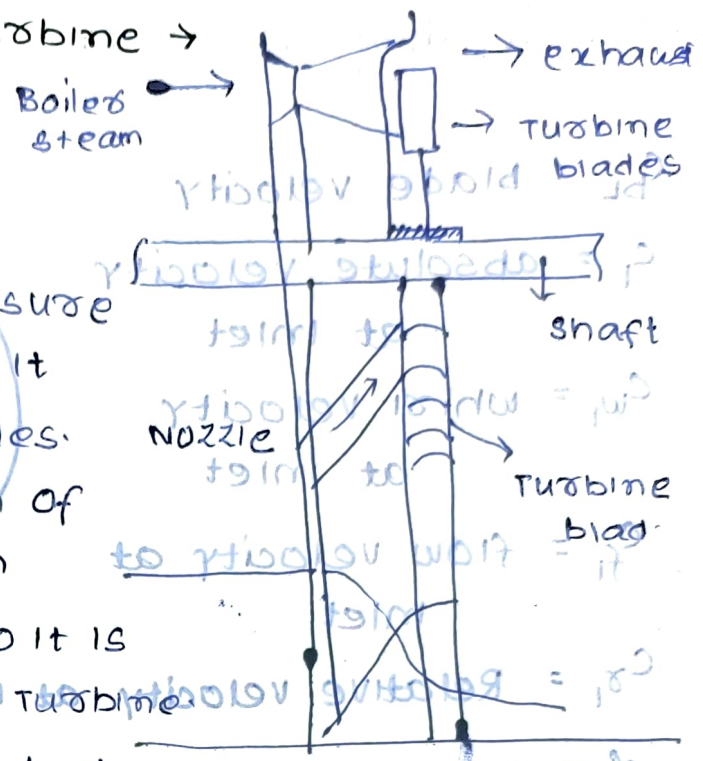
- (1) Thermal efficiency of a steam turbine is much higher than that of a steam engine.
- (2) The power generation rate is uniform.
- (3) Much higher range of speed can be obtained.
- (4) It also provide higher output.
- (5) No internal lubrication required due to the absence of moving parts.
- (6) No loss due to initial condensation of steam.
- (7) With the absence of moving parts, Reciprocating balancing problem is minimised.

Common Types of Turbines

(1) Simple Impulse Turbine →

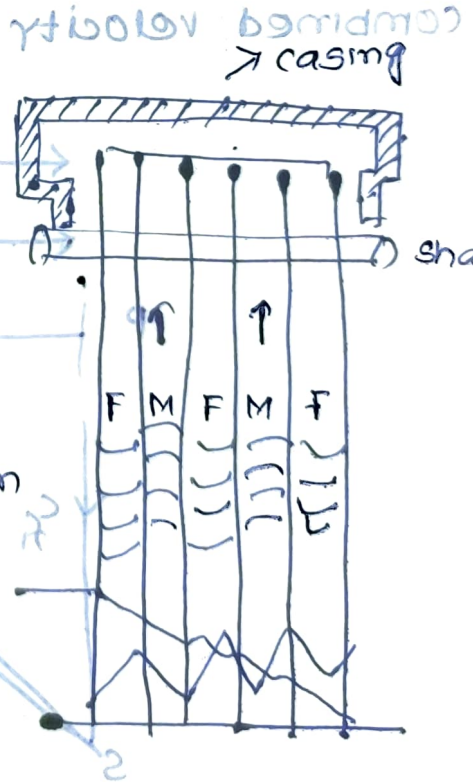
Here the steam is expanded in the nozzle and its pressure does not change as it moves over the blades. Here the expansion of steam takes place in one set of nozzles so it is called simple impulse turbine.

As the steam flows high velocity of steam leaves the moving blade which is a large portion of the kinetic energy.
 example → "De Laval Turbine"



(2) Reaction Turbine →

here there is pressure drop which takes place continuously over the fixed and moving blades. The function of fixed blades is same as nozzle, they alter the direction of steam and as the steam flows through moving blades kinetic energy is absorbed by them.



(Multi-stage Reaction Turbine)

The work done on the blades may be found out from change in momentum equation

$$F = m \times a = m \times \frac{dv}{dt} = m_s \times (C_{w1} - C_{w2})$$

work is done by the blades is done by the tangential component

work done = Force \times velocity

$$= m_s (C_{w1} + C_{w2}) \times C_{bL}$$

$$\text{Power} = \frac{\text{work done}}{1000} = \frac{m_s \times C_w \times C_{bL}}{1000} \text{ kW}$$

Blade or diagram efficiency \rightarrow

$$= \frac{\text{work done on the blades}}{\text{Energy supplied to the blades}}$$

$$= \frac{m_s \times (C_{w1} + C_{w2}) \times C_{bL}}{\frac{1}{2} \times m_s \times C_1^2} = \frac{2 \times C_{bL} \times (C_{w1} + C_{w2})}{C_1^2}$$

Stage efficiency

$$= \frac{\text{work done on the blade per kg of steam}}{\text{Total Energy supplied per kg}}$$

$$= \frac{C_{bL} \times (C_{w1} + C_{w2})}{(h_1 - h_2)}$$

Hydel Power Station

Classification

Depending upon load Area →

- (1) Base Load Power Plant → These plants are required to supply constant power when connected to the grid. They run without stop and are often remote controlled so least staffs are required for such plant.
- (2) Peak load power plant → These plants supply the power during peak load condition. Some plants may also supply during average load but also supply peak load when it is there.

Depending upon water head →

- (1) High head → 100 meters to above
- (2) Medium head → (30 to 100) meters
- (3) Low head → (20 to 80) meters

Elements of a hydro-electric power plant

- (1) Catchment Area → The whole area behind the dam draining into stream or river across which the dam has been built.
- (2) Reservoir → It is used to store water which is further utilised to generate power by running the hydraulic turbine. It is the primary requirement. It may be natural or artificial.
- (3) Dam → A dam is a barrier to confine or raise water storage or diversion to create

hydraulic load. It diverts the flow of water from the river to the turbine and usually increase the head. Dams are built up concrete or stone masonry, earth or rock fill or timber.

Masonry dams may be solid gravity type, buttress type or arch type.

4) spillways → When water enters the reservoir basin, the level of water in the basin rises. The rise is arranged to be temporary in nature because excess amount of water endangers the stability of dam structure. To relieve this excess amount of water a structure is provided in the body of the dam or near the dam.

5) conduits → A head race is a channel which leads water from the reservoir to a turbine where as tail race is a channel which conducts water from wheels.

open conduits → canals and flumes

close conduits → tunnels, pipeline, penstock

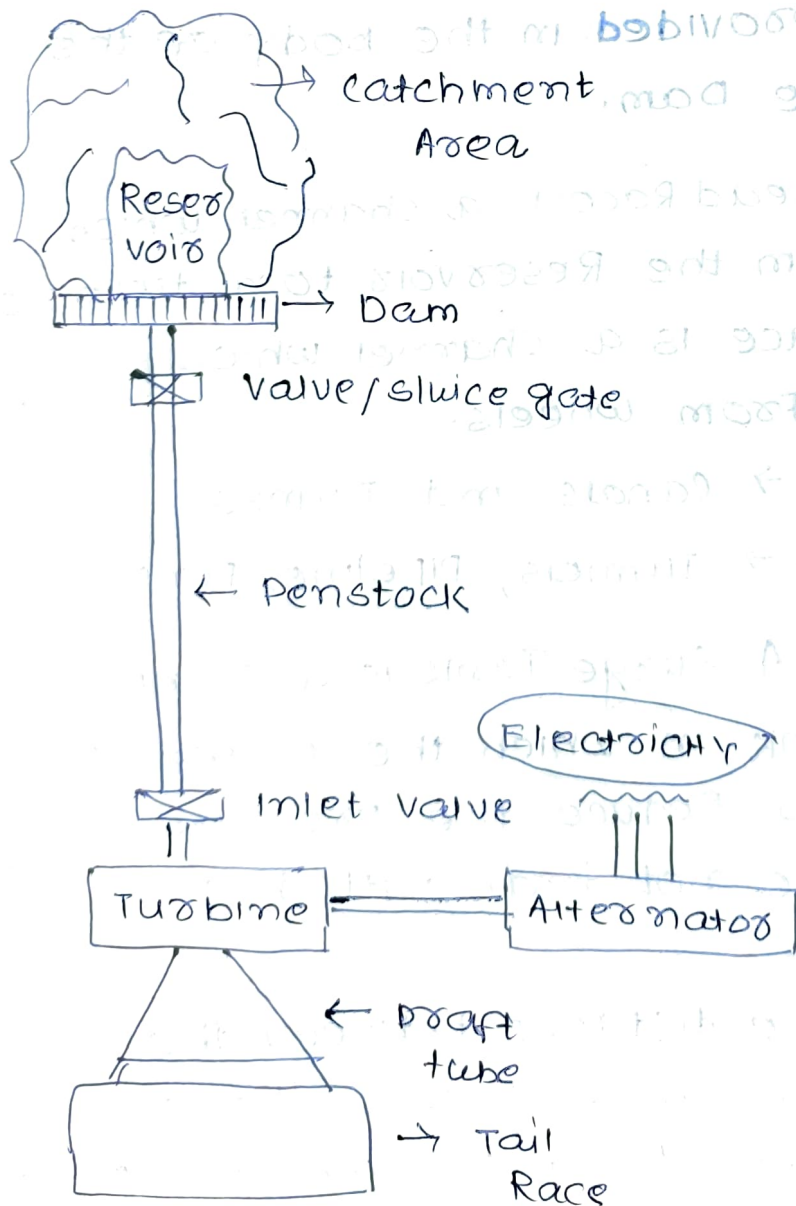
6) surge tank → A surge tank is a small reservoir or tank in which the water level rises or falls to reduce the pressure swings so that they are not transmitted in closed conduit.

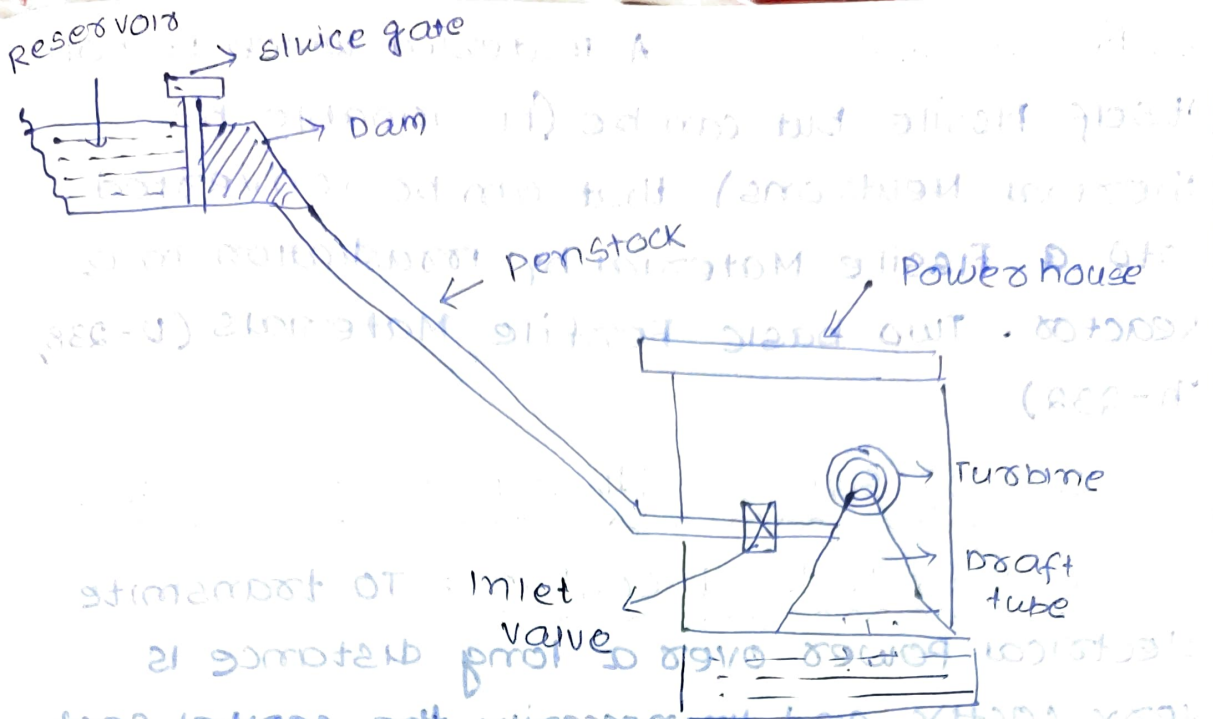
→ It reduces the distance between the free water surface and turbine thereby reducing the water hammer effect on penstock.

→ To serve as a supply tank to the turbine when the water in the pipe is accelerating during increased load condition and as a storage tank when the water is de-accelerating during reduced load condition. Various types of surge tanks are these →

- (1) Simple surge tank
- (2) Inclined surge tank
- (3) Differential surge tank
- (4) Restricted orifice surge tank

Flow sheet of hydro-electric Power plant





(Medium Head Hydro Power Plant)

Nuclear Power Plant

In the near future all Fossil Fuel will be used up and energy will then be derived solely from the remaining sources and the Nuclear Fuels (Fissionable and Fusionable) materials. Nuclear Power Plants across the globe are producing about 16% of the world's electricity.

Nuclear Fuel

Nuclear Fuel is the fuel that is used in a Nuclear Reactor to sustain a Nuclear chain Reaction. These fuels are fissile and radioactive materials. ${}_{92}^{235}\text{U}$ and ${}_{94}^{239}\text{Pu}$ etc are the materials.

- (1) Fissile Material \rightarrow These are the materials that undergoes the Fission Reaction. (U-235) and (Pu-239). It is the key components of Nuclear weapons or other Nuclear products.

(2) Fertile Material \rightarrow A material which is not itself fissile but can be (fissionable by thermal neutrons) that can be converted into a fissile material by irradiation in a reactor. Two basic fertile materials ($U-238$, $Th-232$)

Selection of site for Nuclear Power station

(1) Proximity to load centre \rightarrow To transmit electrical power over a long distance is very costly and unnecessarily the capital cost amount increases. Therefore, the closer power plant site can be located to the load centre. The lower can be the power delivered to the customer.

(2) Population distribution \rightarrow Since the power reactors must be located close to the load centers and due to meteorological condition, disposal of nuclear waste, it is very much important according to the safety of the public. So the plant must be located at a safer distance from the population.

(3) Land use \rightarrow The use to which the land surrounding a nuclear power plant site is being put, it has an effect on suitability of the plant. If the land is used for agriculture or other works, we have to concern about that also.

(4) Meteorology

During the selection of site for a Nuclear Power Plant we have to mainly focus on various meteorological factors. The main concern about the discharge of Nuclear waste and Radioactive materials. Other factors like wind direction, wind velocity, frequency and duration, Frequency and severity of storms which can damage the plant.

(5) Geology

Investigation of the site Geology is necessary to determine the bearing capacity of the soil and types of foundation which must be used for the major portion of the power plant. Test borings are usually made for this purpose, possibility of sudden earth movement which could damage the plant.

(6) Seismology

It is of particular concern in area of high seismic activity because of the possibility of forces which can be produced by earthquakes could be sufficient to damage the plant and reactor system. Therefore careful observation must be given to the seismic history of the area including details about earthquakes. All active faults must be determined and evaluated.

(7) Hydrology

Local hydrology is the major concern while selecting a power plant. Present day Nuclear power plant requires greater quantity of cooling water due to higher turbine heat rate. Sufficient water flow for the discharge of low-level radioactive material.

List of Nuclear Power Station in India

- (1) Tarapur Atomic Power Station - Maharashtra - 1400 MW
- (2) Kakrapar Atomic Power Station - Gujarat - 440 MW
- (3) Kudankulam Nuclear Power plant - Tamil Nadu - 2000 MW
- (4) Kaiga Nuclear Power Plant - Karnataka - 880 MW
- (5) Madras Atomic Power Station - Tamil Nadu - 440 MW
- (6) Rajasthan Atomic Power Station - Rajasthan - 1180 MW
- (7) Narora Atomic Power Station - Uttar Pradesh - 440 MW

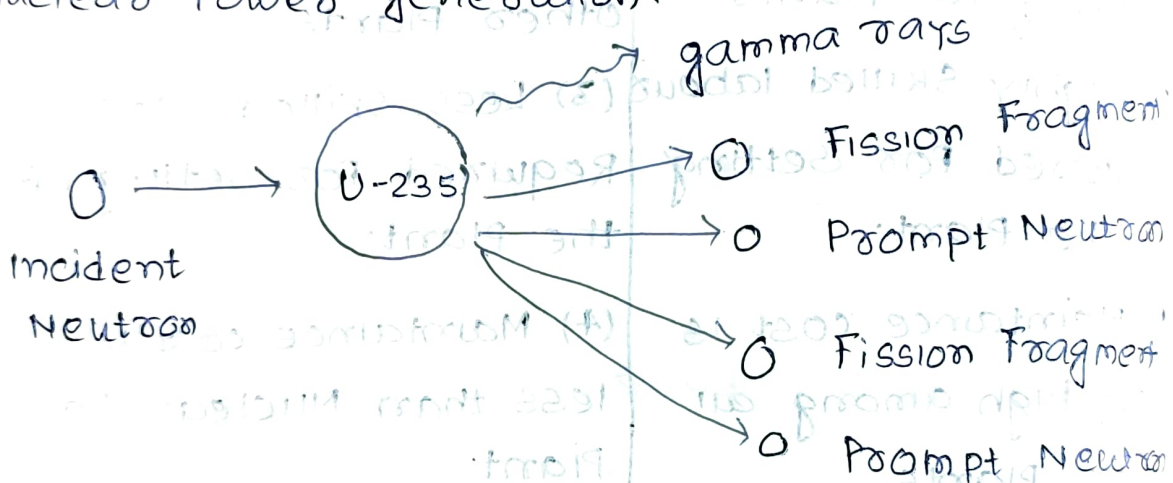
Presently India has 22 Nuclear Power Reactors operating in 7 states with an installed capacity of 6780 Mega watt (electric)

Comparison between (Nuclear vs Thermal) Power Plant

<u>Nuclear</u>	<u>Thermal</u>
(1) use the heat from the combustion of chemical reactions.	(1) use the heat from the combustion of coal.
(2) initial cost is highest among all plants.	(2) initial cost is very low as compared to other plants.
(3) highly skilled labour required for setting up the plant.	(3) Less skilled labour required for setting up the plant.
(4) Maintenance cost is very high among all power plants.	(4) Maintenance cost is less than Nuclear Power Plant.
(5) More Environment friendly than Thermal Power Plant.	(5) Least environment friendly.
(6) Efficiency is more than Thermal Power plants	(6) overall efficiency is 25-30%.
(7) Running cost is low as low fuel is required	(7) Running cost is very high among all the power stations.

Fission of Nuclear Fuel

It is the process that occurs when a neutron collides with the nucleus of certain heavy atom, causing the original nucleus to split into two or more unequal fragments which carry off most of the energy of fission as kinetic energy. This process is accompanied by the emission of neutron and gamma rays. The energy released during the process is the basis of nuclear power generation.



The fission fragments that result from the process are radioactive and decay by emission of beta particle, gamma rays.

Distribution of Energy

Instantaneous Energy Release:	Mev
Kinetic energy of fission fragments	168
Prompt gamma rays	7
Kinetic energy of prompt neutron	5
	<hr/>
	180

The chain Reaction

A chain Reaction is the Process in which the number of neutrons keeps on multiplying rapidly (G.P) during fission, till whole of the fissionable material is disintegrated. This can be understood more clearly from a Multiplication Factor (k) =
$$\frac{\text{No. of neutrons in any particular generation}}{\text{No. of neutron in preceding generation}}$$

If $k > 1$ (chain Reaction continue)

$k < 1$ (chain Reaction stopped)

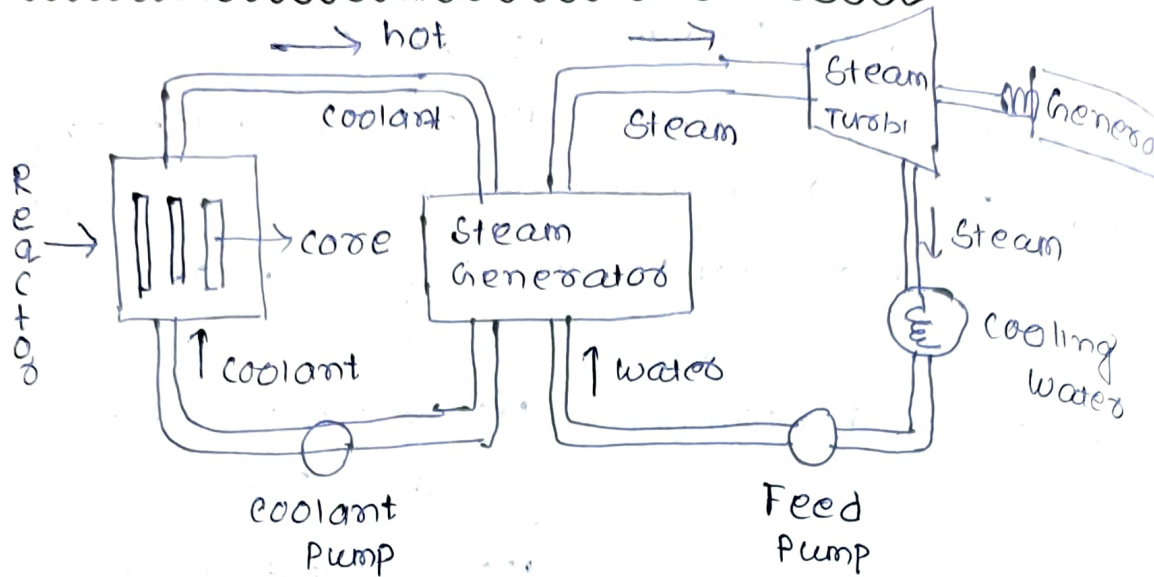
Nuclear Fusion

It is the process of combining or fusing two lighter nuclei into a stable or heavier nuclide. In this case also large amount of energy is released because mass of the product nucleus is less than masses of the two nuclei which are fused.

Fusion Reaction must be occurs in a self sustaining manner and more energy must be released than is consumed in initiating the reaction.

It is thought that the energy liberated in sun and other stars are due to Nuclear Fusion.

Working of a Nuclear Power Plant



The main components of a Nuclear Power Plants are →

- (1) Nuclear Reactor
- (2) Heat exchanger
- (3) Steam Turbine
- (4) Condenser
- (5) Generator

The Reactor performs the same function as that of a furnace of steam power plant. The heat liberated in the reactor as a result of the nuclear fission reaction is taken up by the coolant which is supplied by the reactor core. Hot coolant leaves the reactor from the top and then flows through the tubes of steam generator and passes heat to the feed water. The steam so produced expands in the cycle of steam turbine from which the mechanical power is converted to electrical power with the help of generator. To maintain the flow in the circuit feed pumps are provided.

Nuclear Reactors

A Nuclear Reactor is a apparatus in which nuclear fission is produced in the form of a controlled chain reaction supplying nuclear energy. It burns the fuel like U^{235} , U^{238} , Pu^{239} which produces heat, neutrons and radio-isotope.

Classification

According to the Neutron Energies in Fission →

- (1) Fast Reactor
- (2) Intermediate Reactor
- (3) Slow Reactor

According to Fuel State →

- (1) Solid
- (2) Liquid
- (3) Gas

Fuel-Moderator Assembly →

- (1) Homogeneous
- (2) Heterogeneous

Essential Component of a Nuclear Reactor

(1) Reactor Core → Here the fission chain reaction is made to occur and the fission energy is liberated in the form of heat for operating power conversion equipment. It is the assembly of fuel elements, control rods, coolant and moderator. Reactor core generally have a shape of right circular cylinder with diameter ranging from 0.5 m to 15 m. The fuel elements are made up from plate or rods.

(2) Reflector \rightarrow It's function is to reflect back some of the neutrons that leaks out from the surface of the core.

(3) Control Mechanism \rightarrow

- (1) For starting the Reactor (Normal Range)
- (2) For maintaining at that level (Power at Steady)
- (3) For shutting down the Reactor

It is also necessary to prevent the chain reaction from becoming violent and damaging the Reactor.

(4) Moderator \rightarrow

(1) to slow down the neutrons from high velocities and hence high energy level which slow down the fission process.

(2) slow down the neutrons but not absorb them

H_2O , D_2O , He , B are commonly used as moderators.

(5) Coolant \rightarrow The function of the coolant is to remove the intense heat produced in the reactor and bring out heat for utilised.

commonly used coolants are \rightarrow

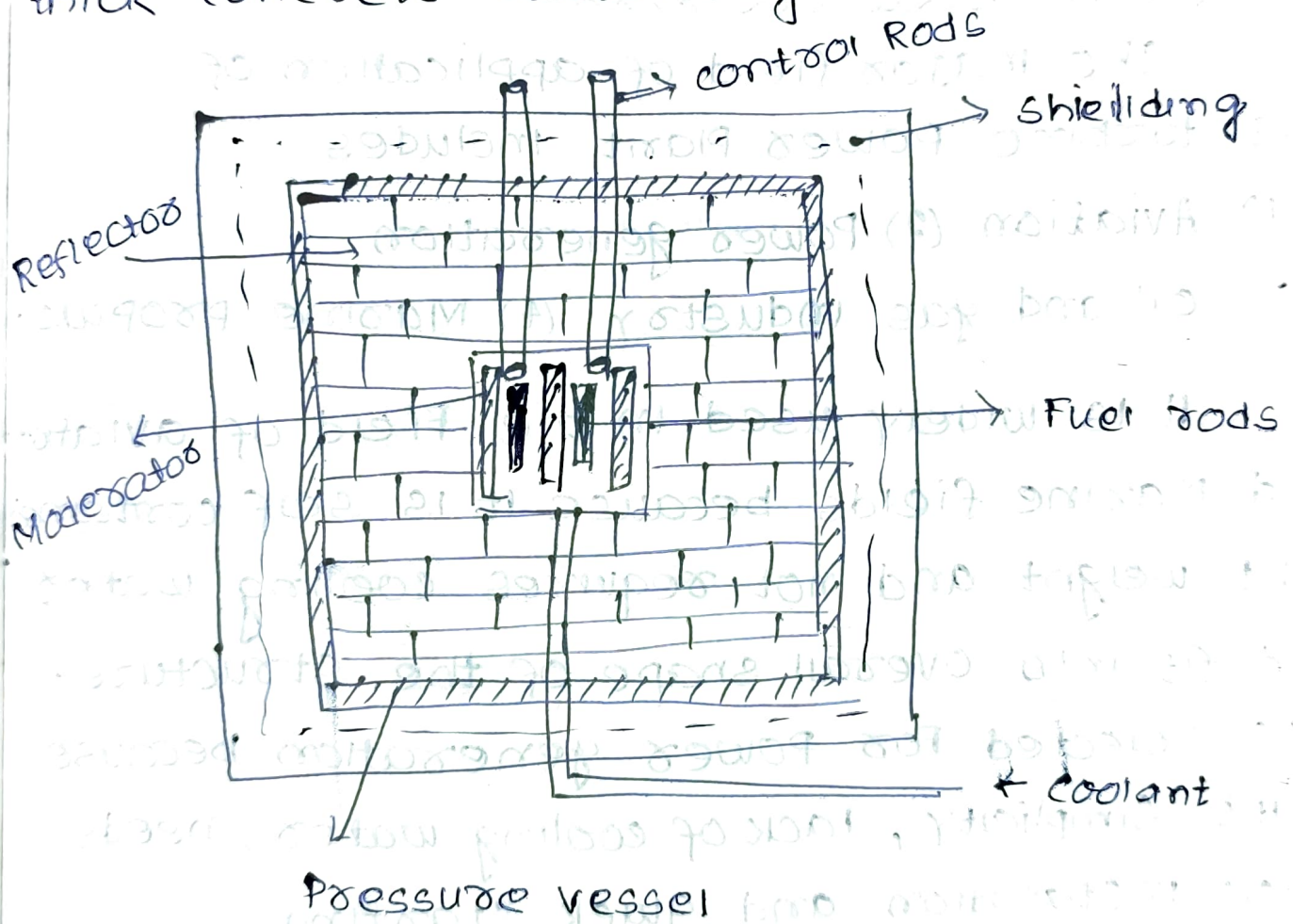
Santi wax R (Hg , He , CO_2)

gaseous coolant $\rightarrow CO_2$

(6) Shielding →

- (1) protect the wall of the Reactor vessel from Radiation damage
- (2) also protect operating personnel from exposure to Radiation.

Thermal shield is provided with steel linings while the other is provided with thick concrete surrounding the Reactor.



(Nuclear Reactor)

— x x x —

Gas Turbine Power Station

The gas turbine represents the most satisfactory way of producing very large quantities of power in a self-contained and compact unit. The thermal efficiency of gas turbine is 20 to 30% which is less than a steam power plant.

Application of Gas Turbine

The major field of application of gas turbine power plant includes

- (1) Aviation
- (2) Power generation
- (3) oil and gas industry
- (4) Marine propulsion

It is widely used in the field of aviation and marine fields because it is self contained, light weight and not requires cooling water and fit into overall shape of the structure. It is selected for power generation because of its simplicity, lack of cooling water, needs quick installation and quick starting.

Limitation of gas Turbine

- (1) They are not self starting.
- (2) Low efficiency at part loads.
- (3) NON-reversibility
- (4) Higher Rotor speed
- (5) Low overall plant efficiency

Advantages over Thermal and diesel Plant

(1) over diesel Plant

- (1) The work developed per kg of air is large compared to diesel plant.
- (2) Less vibration in machine parts.
- (3) Capital cost is less.
- (4) Higher mechanical efficiency.
- (5) Lower installation and maintenance cost.
- (6) Poor quality of fuel can be used.

(2) over Steam power plant

- (1) No ash handling problem.
- (2) Low capital cost (3) Shortage of fuel is smaller.
- (4) Space requirement is very less.
- (5) Fewer auxiliaries required.
- (6) These are more preferable for peak load power plant.

Site selection for gas turbine power plant

- (1) The plant should be located near the load centre to avoid transmission cost.
- (2) The site should be away from business centre due to noisy operations.
- (3) Cheap and good quality fuel should be easily available.
- (4) Availability of labour.
- (5) Availability of transportation facilities.

- (6) The land should be available at cheap price.
- (7) bearing capacity of the land should be high.

Fuels For gas Turbine

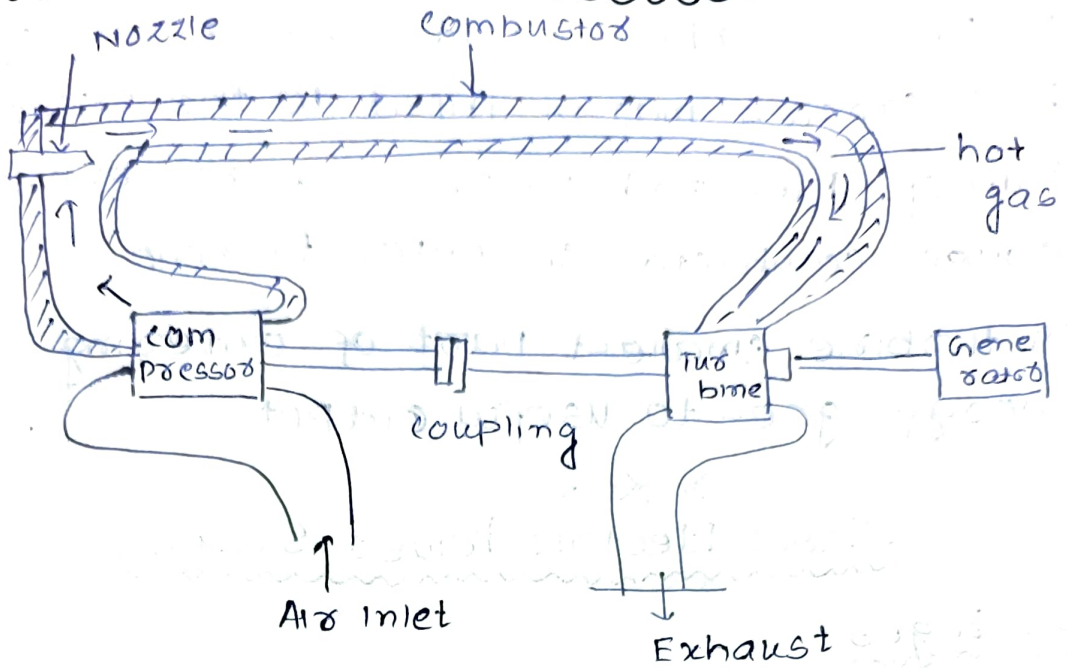
The various fuels used for gas turbine

(1) Gaseous Fuels \rightarrow Natural gas is the ideal fuel for gas turbine but this is not available everywhere. Blast furnace gas and producer gas may also be used.

(2) Liquid Fuels \rightarrow Liquid Fuels of Petroleum origin such as distillate oils or residual oil are most commonly used for gas turbine. The essential qualities includes proper volatility, viscosity, calorific value. At the same time it should be free from any content of moisture and suspended impurities that would clog the passage of nozzles. Minerals like sodium, vanadium are dangerous for turbine blading.

(3) Solid Fuels \rightarrow The use of solid fuel such as coal in pulverised form present several difficulties. The pulverised plant of coal for gas turbine is very small. The introduction of fuel in the combustion chamber is at high pressure. The degree of completeness of combustion in gas turbine should be very high.

Simple Gas Turbine Power Plant



A gas turbine power plant may be defined as one in which the principal prime mover is of turbine type and working medium is permanent gas.

The working fluid is compressed in a compressor which is rotary (multistage) type. Heat energy is added to the compressed fluid in the chamber. This high energy fluid at higher temperature and pressure then expand in the turbine unit there by generating power. A simple gas turbine power plant consists of the following

- (1) turbine
- (2) compressor
- (3) combustor
- (4) auxiliaries such as fuel system, oil system, lubrication system

The complete operation of this type of plant can be explained as

- The air brings in minute amount of energy
- compressor adds considerable amount of energy
- Fuel carries major input to the cycle
- Sum of Fuel and compressed air energy leaves combustion to enter turbine
- In turbine, smallest part of entering energy goes to useful output

~~***~~ Diesel Electric Power Station

Advantages

- (1) Simple Design and Layout
- (2) occupies less space
- (3) can be started quickly
- (4) Requires less water for cooling
- (5) NO ash handling problem
- (6) Thermal efficiency is better than steam Power plant

Dis-advantages

- (1) high running cost due to costly price of diesel
- (2) Generates small amount of power
- (3) cost of lubrication is high
- (4) high maintenance charges
- (5) Noise Problem

Site - selection for Diesel Engine Power plant

- (1) Availability of Fuel
- (2) Distance from populated Area