Steam turbine

A steam turbine is a prime mover in which rotary motion is obtained by the gradual change of momentum of the steam. It is primarily used to run alternator or generator in thermal power plant.

Main parts of steam turbine

(1) Nozzles - In steam turbine normally convergent divergent type nozzle used, there is pressure drop which is converted to velocity or kinetic energy.

(2) Rotor - The rotor or runner consist of a circular disc fixed to horizontal shaft.

(3) Blades - On the periphery of rotor large number of blades are fixed. The steam jet from the nozzle impings on the surface of the blade due to which blade of rotor rotates. The surface of the blade is made of smooth to reduce frictional losses.

(4) Casing - It is a steam tight steel casing which enclose the rotor, blades etc. In multistage turbine the casing also accommods the fixed blade. The casing help the flow of steam and also protect the inner parts of any accident.

classification of turbine

① Impulse
② Reaction

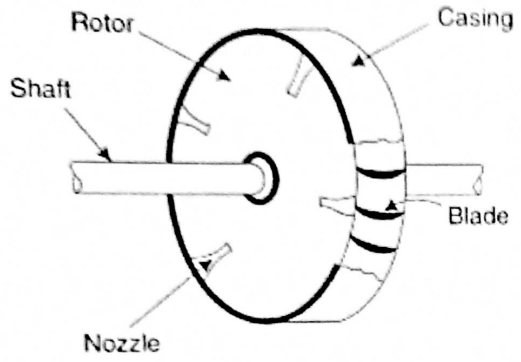
Impulse is the force imparted on the object when a lot of jet of fluid strike the objects with great velocity.
Reaction is the force imparted on the object when a fluid leaves the object with high velocity (relative)

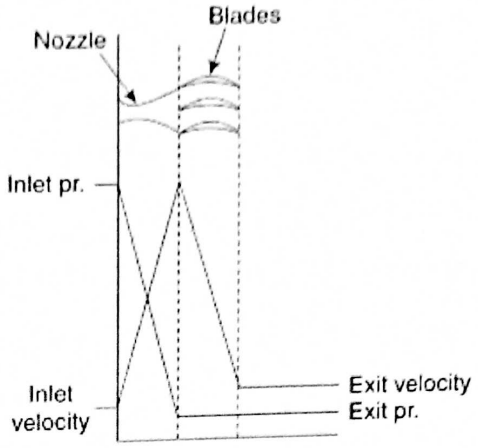
Single stage Impulse Turbine (De-laval Turbine)

first the pressure energy is converted into kinetic energy by expansion of steam through a set of nozzle. Normally in steam turbine use convergent divergent nozzle. The kinetic energy is converted into mechanical energy with the help of moving blade fixed on rotor. The rotor is connected to the output shaft. all the parts are in casing.

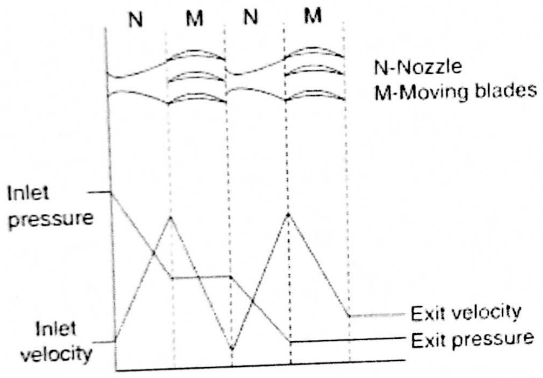
A simple or single stage impulse turbine is only suitable for low pressure steam. In case the steam pressure is high when it expands in one set of nozzle the output velocity of steam from the end of the nozzle will be too high. Due to this the rotor will rotate with high speed. such a high speed is not suitable for practical purpose so in practice we of multistage impulse turbines or compound impulse turbine

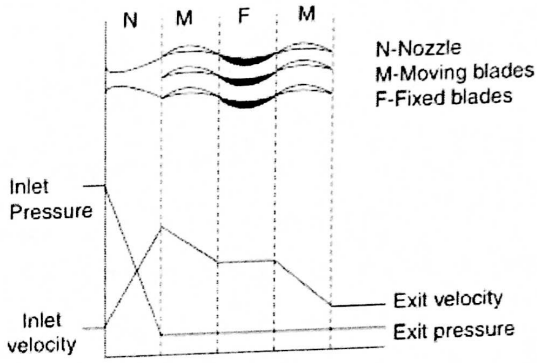
DeLaval Turbine



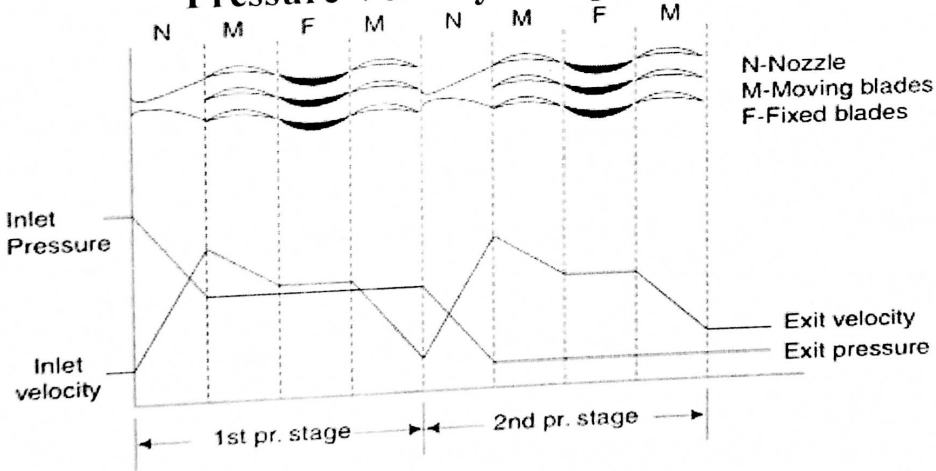


Pressure Compound Velocity compounding





Pressure Velocity Compounding



Compounding of Impulse Steam Turbine

There are three type of compounding

(1) Pressure compounding

The pressure drop or expansion of steam is done in more than one set of nozzle and each set of nozzle is followed by a set of moving blade. The turbine is known as pressure compounding impulse turbine. A two stage pressure compounding.

(2) Velocity compounding

The entire expansion of steam occurs in one set of nozzle resulting in a very high velocity at the outlet. The steam is then passed through several set of moving blades followed by a fixed blade. Moving blade are fitted on the rotor while the fixed blade are fixed on the casting. The function of the fixed blade is to change the direction of steam and guide the steam in the proper angle to the next set of moving blades. A two stage velocity compounding is shown.

(3) Pressure ~~compo~~ velocity compounding

In power plant pressure velocity compounding is more common. In this arrangement for each pressure stage there is a velocity staging. A two stage pressure velocity compounding is shown. In this there are more than 20 stage in a power station.

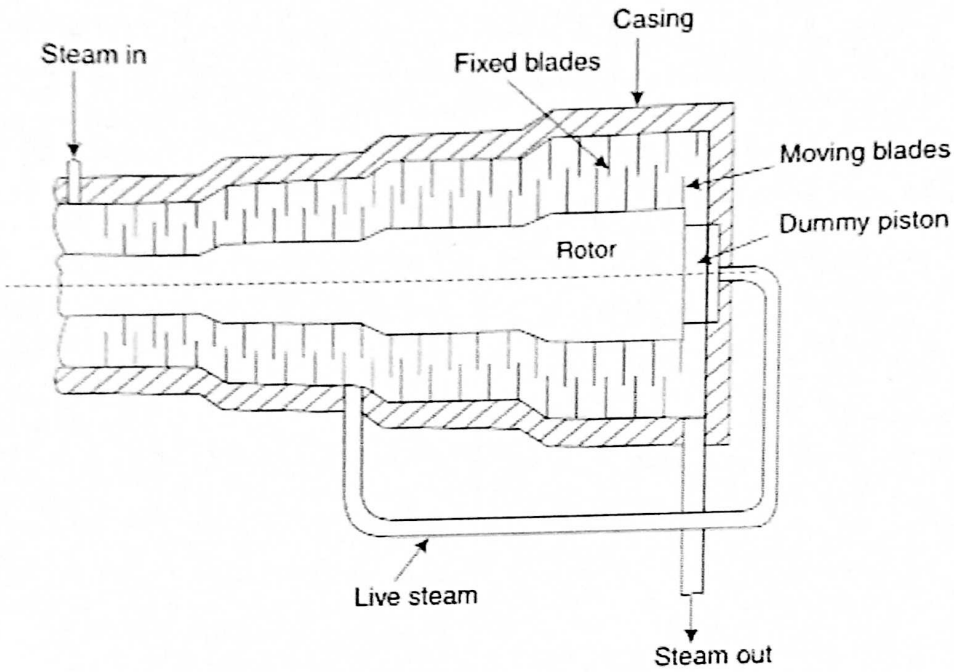
Working of Parson's Reaction turbine

In this turbine the power is obtained mainly by an impulsive force of incoming steam and small reactive force of outgoing steam. This turbine consist of a rotor of a varying diameter. Moving blades are fixed on the rotor. The diameter of the casing also varies. Fixed blades are attached to the casing. steam is admitted to the first set of moving blade through nozzle. The blade receive the impulsive force on incoming steam. then it goes to fixed blades which act as nozzle Thus steam flow alternatively through moving and fixed Blades.

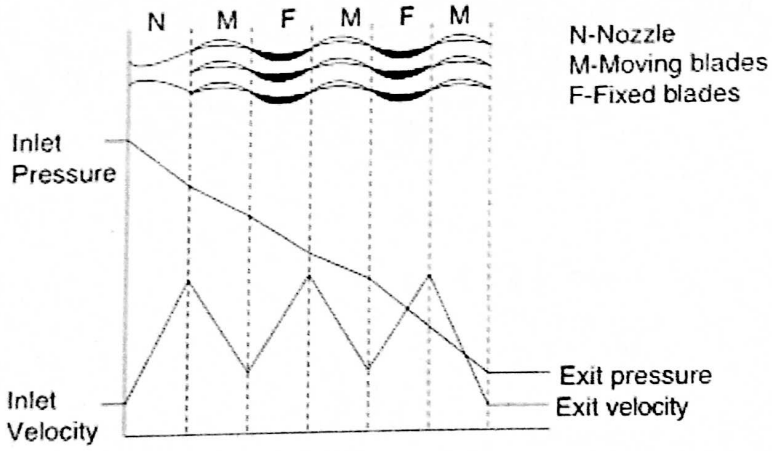
The shape of moving blade is so designed to also have reactive force when a Jet of steam is leaving the blades. for this the area of outlet between the two moving blade will be less than the area at Inlet In addition there will be also some pressure drop even in moving blade. Thus we have a condition of continuous pressure drop in fixed as well as in moving blade.

The diameter of the rotor and casing gradually increase to accommodate the increase volume of steam at reduced pressure. The size of blade also increases in the direction of flow. A dummy piston is used to balance the axial thrust of the rotor by allowing live steam to act on one side of dummy piston. opposite to the direction of steam flow. In case the axial thrust is not balanced properly. there will be undue and uneven wear of the turbine shaft.

Person Reaction Turbine



Pressure drop in reaction Turbine



Difference between Impulse and Reaction turbine

S.NO.	Impulse Turbine	Reaction Turbine
(1)	Power is obtained only due to the impulsive force of the incoming steam	(1) Power is due to both of impulsive force of the incoming steam and due to the reactive force of the outgoing steam.
(2)	Pressure drop is only in the nozzle or in the fixed blade which act on nozzle there is no pressure drop in (incoming moving blade	(2) pressure drop is in fixed and also in the moving blade
(3)	The relative velocity of steam at inlet and outlet of the moving blade are equal	(3) The relative velocity of steam at outlet is higher to get the reactive force.
(4)	Blades are symmetrical	(4) Blade are not symmetrical
(5)	Inlet area of moving blade are equal to the outlet area	(5) Outlet area of the moving blades is smaller than the Inlet area.

Power plants

Power plants are used to generation of electric power. To improve the standered of living, rapid industrialisation for which adequate electric power is essential.

Classification of Powerplants

(1) Steam power plants
(2) Nuclear power plant
(3) Gas turbine power plant
(4) Diesel power plant
(5) Hydroelectric Power plant
(6) power from alternate source of energy.

Steam Power plants

Steam from the boiler is taken to the turbine through a steam pipe fitted with an expansion joint. The joint provides a flexible connection to prevent any crack in the steam pipe which is subjected to expansion and contraction due to variation in temperature. from turbines the steam enters a condenser (details) In the condenser the exhaust steam from turbine is condensed due to which a high vacuum is produced. Due to vacuum the power out

put and thermal efficiency of the turbine are considered increased. Also the condensed water can be recirculated in the system. In condenser cooling water is circulated by a pump through the water tube to condense the exhaust steam. The cooling water at the outlet become hot and it is taken to a cooling pond or cooling tower to cool and to recirculate the same water. If power plant is not located on the bank of a river or a lake.

The condensate from the condenser before entering the boiler is subjected to the following treatment:-

(1) Removal of air and oxygen.

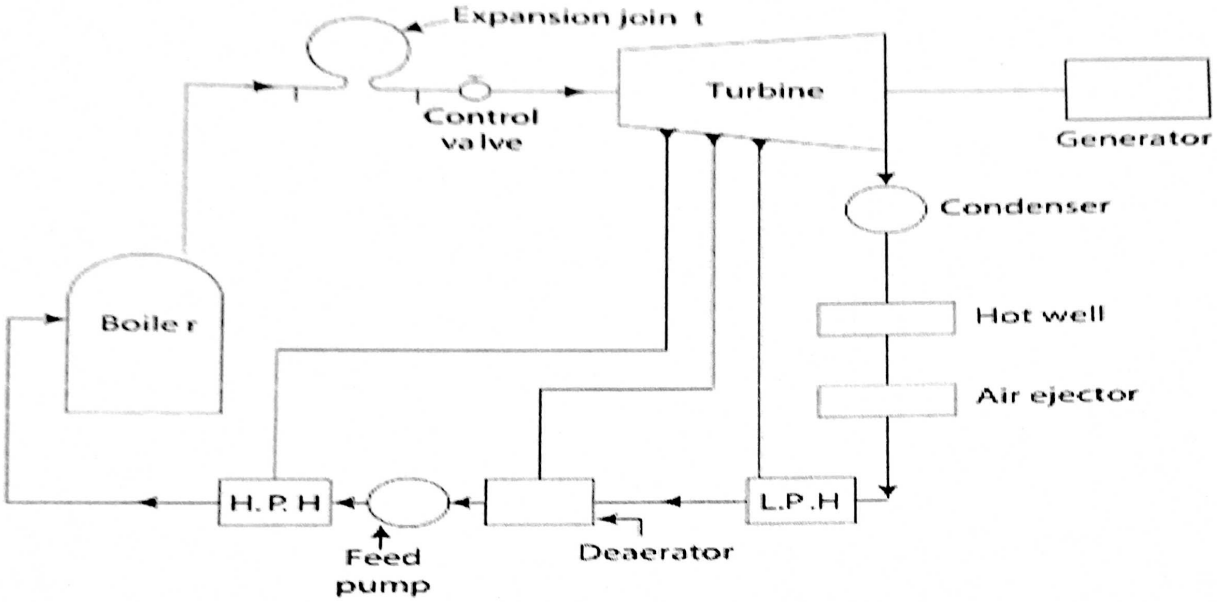
(2) Preheated the feed water in different stages using a low pressure heater (LPH), a deaerator and a high pressure heater (HPH)

Air and oxygen are removed at the air ejector and deaerator. In case air and oxygen are not removed from the feed water the vacuum cannot be maintained in the condenser resulting in loss of power and thermal efficiency.

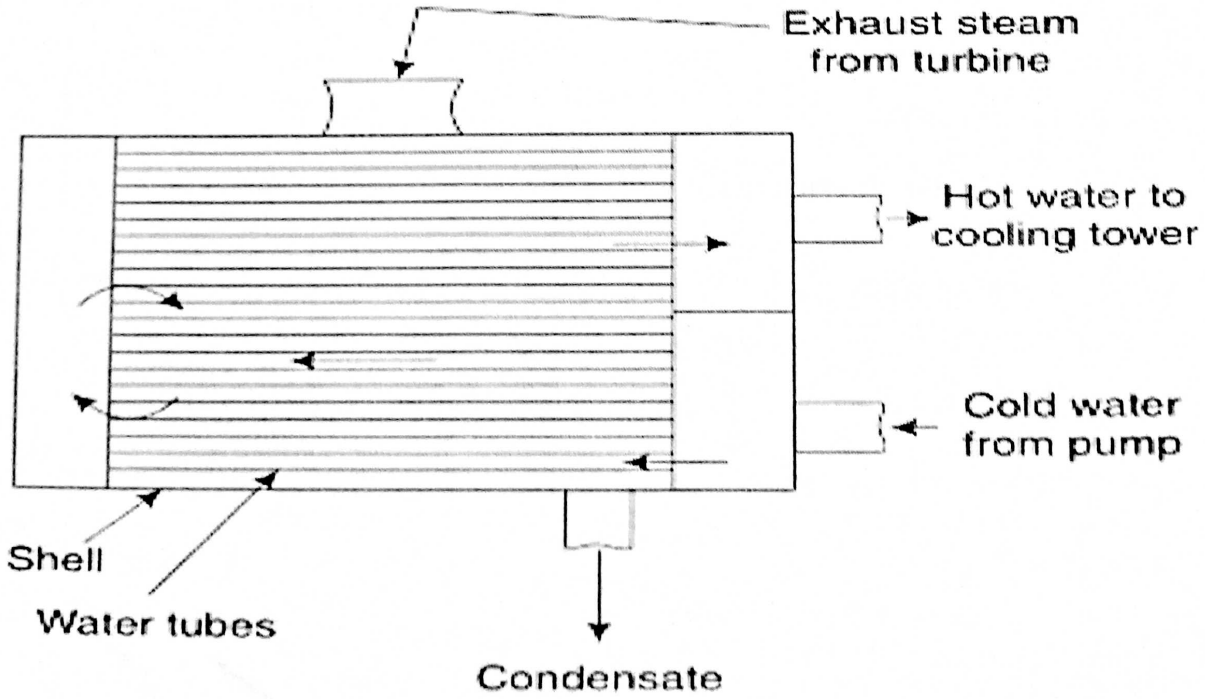
Factor considered in selection of Steam Power plant (site)

(1) The location should be minimum distance from consumer.
(2) Availability of water.
(3) The soil should be satisfactory for strong foundation.
(4) The site should be away from populated area to reduce the effect of pollution
(5) Adequate transport facility is desirable
(6) Space should be available to store coal and ash.

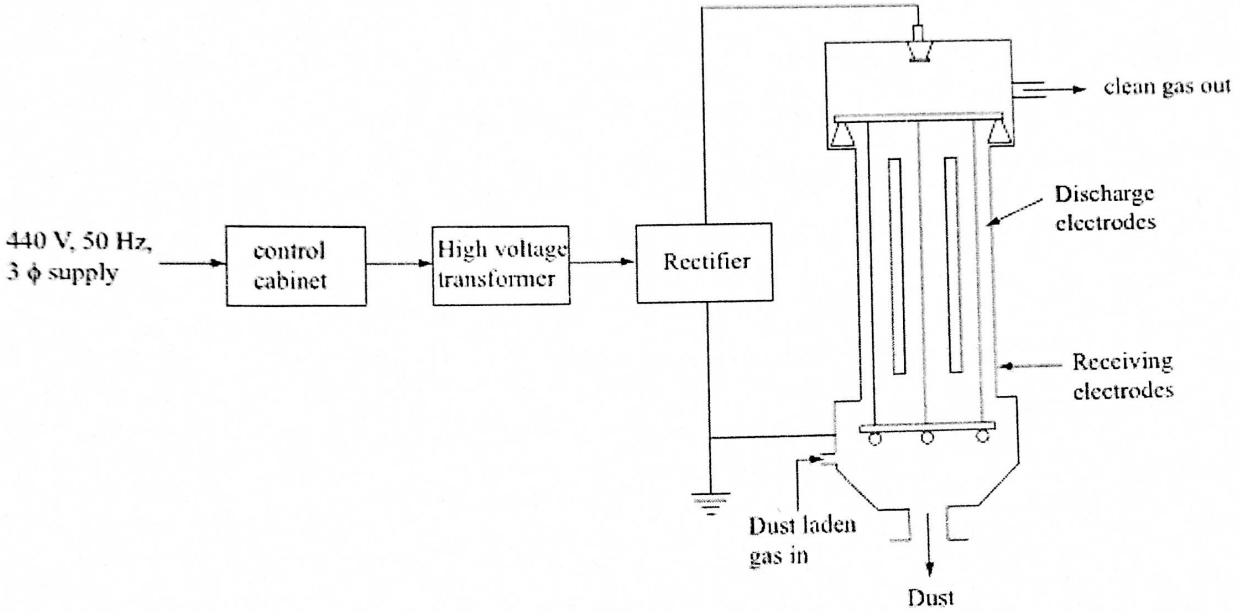
Steam power plant



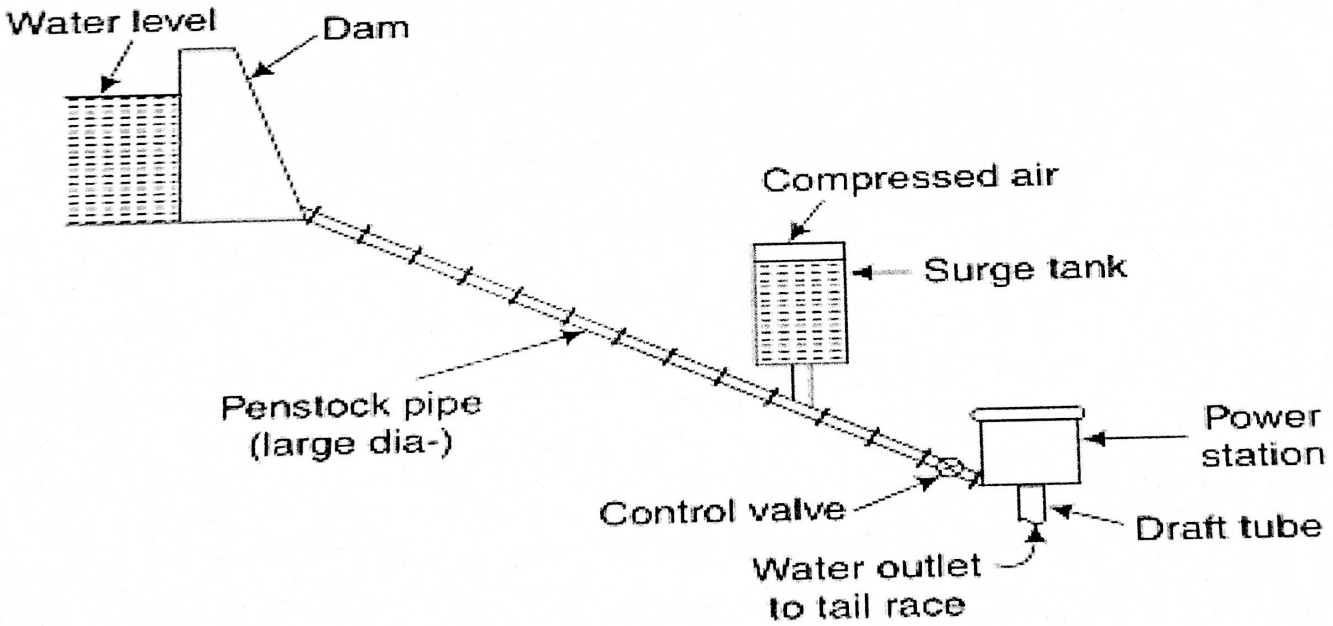
2Pass Steam Condensor



Electrostatic Precipitator



Hydroelectric power plant



Electrostatic Precipitator

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It is used to remove dust and fly ash from chimney gases in a power plant using solid-fuel.

The waste gas with dust and ash is passed between oppositely charged wired and it become ionized as the voltage applied between the wires is quite high in the range of 40,000 to 50,000 volts. The ionized gas is also passed through vertical metal plates alternate plate are positively charged and earthed. As the alternate plate are grounded high intensity electrostatic field exert a force on positive charged dust particle and drive them towards the grounded plate. The deposited dust particles are removed from the plates by giving shaking motion to the plate with the help of cams. As d.c. is not available in power station it become necessary to convert 400 volt AC to high D.C voltage of a about 50,000V this increase the capital cost.

(2) Hydroelectric Power Plant

In this plant the potential energy of water stored in a dam is made of douse running a water turbine coupled to the electrical generator. About 23% of the total electric power in world comes from hydropower. In Tamil Nadu 1950 MW and in all India level it amount about 18000 MW.

In this power plant the water from a dam is brought to water turbine by a large diameter penstock pipe.

The penstock pipe is made of steel or reinforced concrete. It is desirable to eliminate sharp bends in penstock to avoid loss of head and special anchoring.

Depending upon the load on the turbine the water needed is controlled automatically by a valve operated by a centrifugal governor. In case the amount of water is suddenly reduced or stopped by a governor mechanism water coming down with a high velocity with produce turbulance resulting water hammer in the pipe The penstock pipe may be damaged due to water hammer. To prevent this a surge tank is provided from the turbine water is allowed to pass through a draft tube to the tail race. The tail race is water path leading the discharge water from the turbine to river or canal.

Types of water turbine

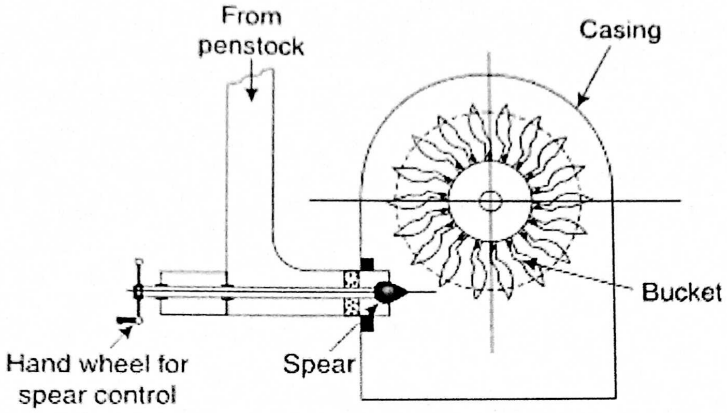
(1) Pelton Wheel.

It is Impulse turbine used for high \$ head. The turbine is named after "Lester A Pelton" an American engineer who develope in 1880.

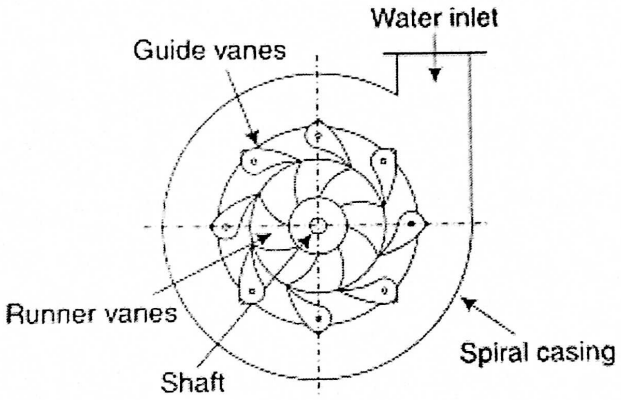
In this pelton wheel runner consist of circular disc with large number of buckets or blades fixed on periphery. the bucket have a shape of double semi elliptical cup. These bucket are made of cast steel, bronze or stainless steel. water can be controlled by rotating the hand wheel by moving the speare in the case of small unit. In bigger unit it control automatically by a governor. The casing is made by cast iron or fabricated steel plates.

It is used at Pykara power house (head 900m)

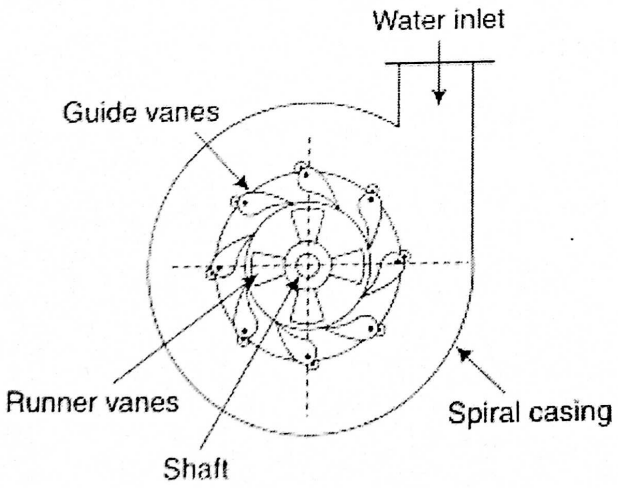
Pelton Wheel

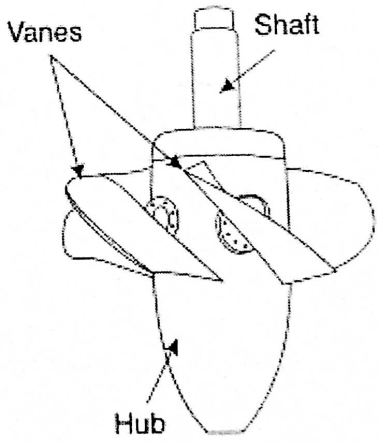


Francis Turbine



Kaplan Turbine





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Francis Turbine

It is mixed flow type Reaction turbine. It is used for medium head ranging from 50 - 400 m. It is used at Periyar Hydro electric project where head 374 m.

The main component are spiral casing, guide blades and a runner. This turbine developed by American Engineer J B Francis in 1849.

water from penstock pipe enter the casing and flow radially towards the center of runner. The casing is made of steel. The water is guided to the runner by guide vanes. Guide Vans are made of Steel or stainless steel. The runner consists of a series of curved vanes numbering 16 to 24. The vanes are so shaped that water enters the runner radially and leave it axially. It is made of mild steel or stainless steel.

Kaplan Turbine

It is axial flow reaction turbine. The German engineer V kaplan developed in 1916. This is suitable for low head ranging from 1.5 m. It is similar to the franiss turbine in construction except the runner. The Runner has only 3, 4 or 6 blades The four blade are common. The blades are adjustable only in kaplan turbine.

Comparison of Thermal and Hydroelectric Power

Sr No	Thermal Power	Hydroelectric Power.
(1)	Not effected by seasons	(1) Affected by seasons.
(2)	Can be installed at any place	(2) only near dam.
(3)	Operating cost is high	(3) Negligible there is no fuel cost.
(4)	Transmission of power is comparatively easier	(4) Not so economical as transmission tower should be erected in hill area.
(5)	capital cost is less	(5) cost including dam is much higher.
(6)	Fuel may be exhaust in due course of time	(6) water will not be exhausted.
(7)	There is problem of all pollution of environment	(7) free from pollution

Environmental Constraint of power generation

(1) Particulate matter :- solid or liquid particle present in the air

(2) Acid Rain, Acid Snow, Acid fog and Dry Acidic Deposition
Increased concentration of SO_2 and NO_x

(3) Greenhouse effect :- A greenhouse has transparent glass panes which allow sunlight to enter and prevent exit of heat, CO_2 and moisture. The climate inside the greenhouse is warm due to high concentration of CO_2 and moisture.

(4) Global warming :- The warming up of earth due to greenhouse effect is called global warming. In this process CO_2 in the air allow the entry of radiation heat of sunlight which contain short wavelength waves and visible patter portion of spectrum. The heat is then absorbed by the earth and atmosphere.

Solar Power plant

Solar Heater :- By using solar radiation water or any fluid can be heated by using a flat plate collector or a parabolic collector. Solar water heating system having many application such as provide hot water to different application or Boiler feed and also in the hosted, hotel and canteens.

Flate plate collector

The absorber plate normally is metallic. It is usually coated Black to absorb more thermal energy, Tube, passage or channel integral with the collector carry water, air or working fluids. Insulation should be provided at the back and at the sides to minimise the heat losses. Usually glass wool is used as insulating material.

A transparent cover (glass) should be provided at the top This cover will permit to radiation from the sun to the metal plate since it is at a shorter wave length. when the radiation strike the part a part of energy is reflected back to cover. As the radiation is higher wavelength it will not go out to the atmosphere. Instead the cover will reflect the energy back to the absorber plate and thereby increase the heat transfer. If there is no transprent cover the reflected energy would have been lost. If the circulating fluid is water the hot water can be collected in a tank and recirculated. A small water circulating pump at inlet side of the collector attached.

Parabolic Reflector :- High polished metallic surface are used

as reflector. It will be normally have a parabolic shape. so. that the sun rays striking the profile will be reflected on its focal length point. If a tube carring a fluid is kept alongs the focal line the fluid will be heated to avery high temperature.

Solar power plant using Butane Boiler

water in flat plate collector is heated to 70 to 80°c due to solar radiation. The hot water heats the butane liquid in the butane boiler. As butane vaporizes at 50°c water at 70° to 80°c is able to vaporize butane. Hot water after transfering the heat to butane is pumped by a circulating (the) pump to the flat plate collector where it is again heated.

Butane vapour from the boiler is taken to the butane turbine which is connected to an electric generator, Exhaust vapour from turbine is condensed in a condenser and the liquid butane is pumped by a feed pump. to the boiler (butane) The cycle will be repeated.

Advantages of solar power plant

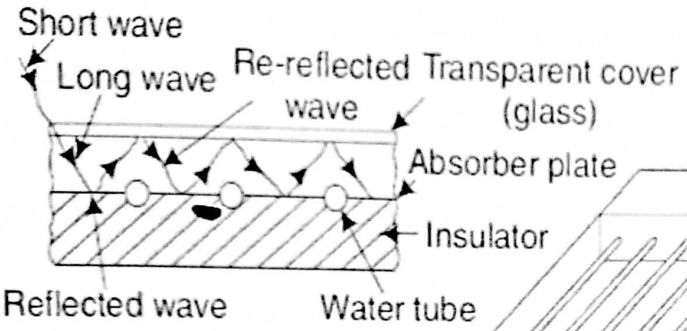
(1) No pollution
(2) No transport and storage problem of any fuel.
(3) Easy to construct and erect.
(4) Heat energy from sun is freely available.

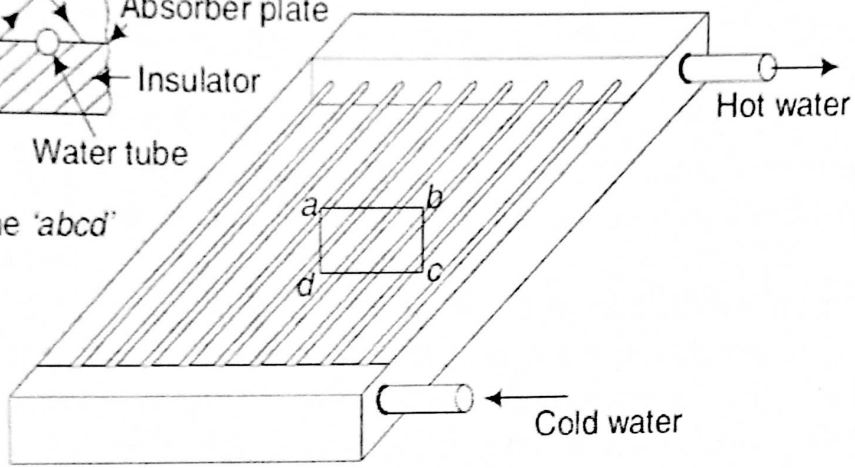
Disadvantage of solar power plant

(1) Solar energy is not available during night.

(2) Power Produced is rather small.

Solar Flat-Plate Collector





Parabolic Reflector

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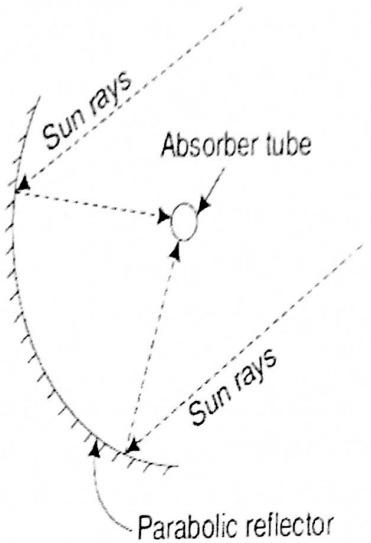
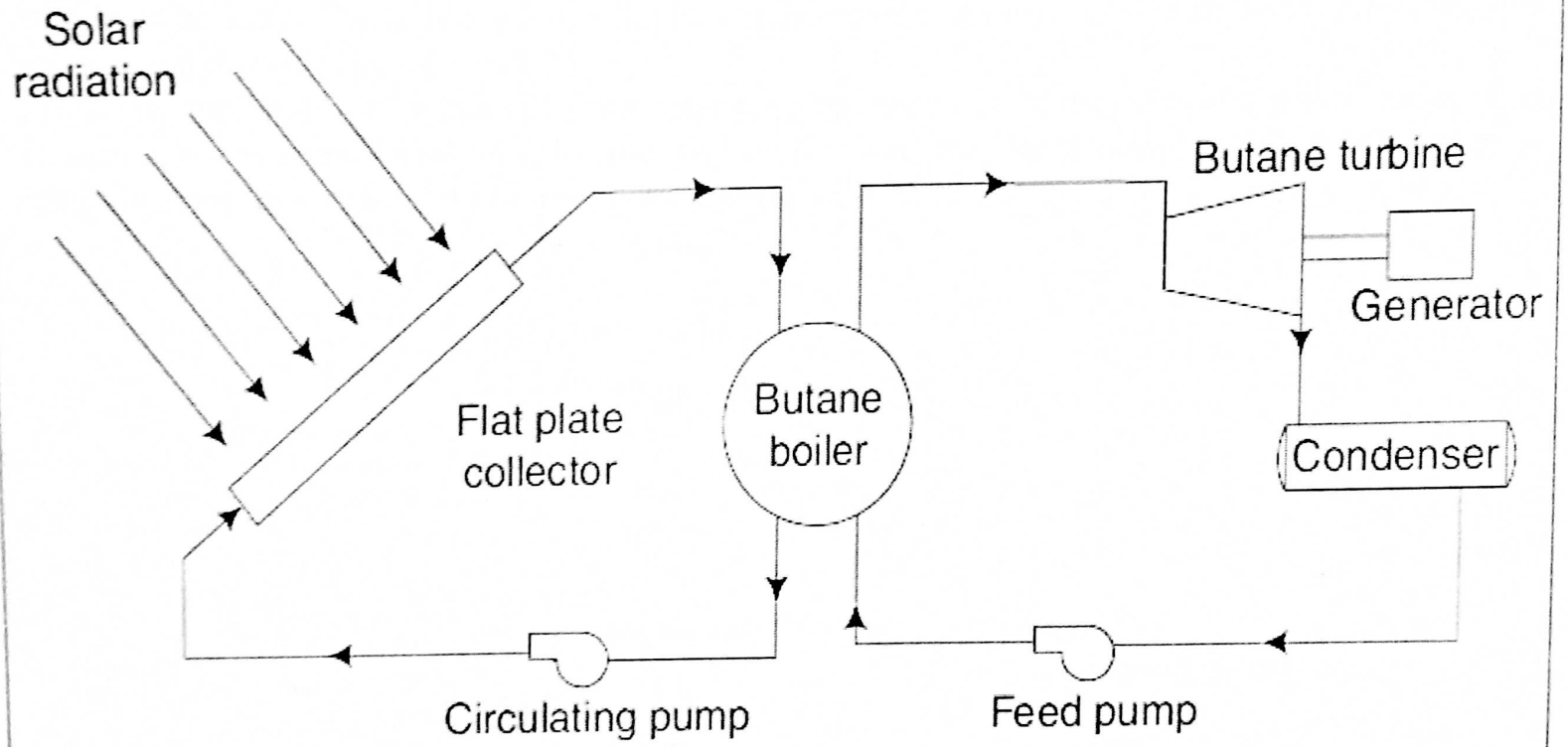


Solar power plant using butane boiler



Wind Energy

The following types of windmills are available.

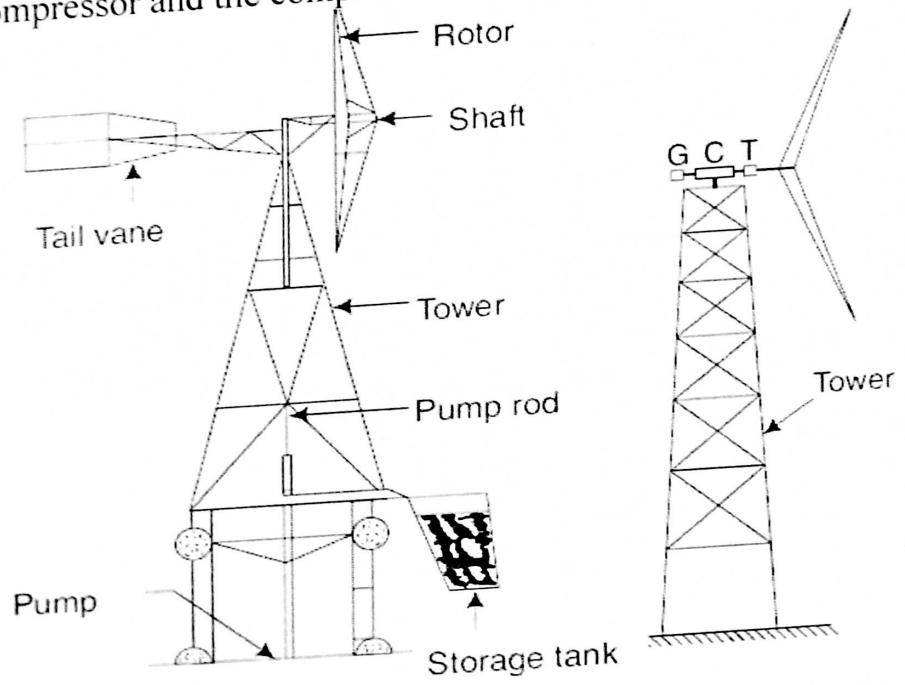
1. High-speed two-blade windmill
2. Medium-speed three-blade windmill
3. Savonius rotor windmill
4. Darrieus rotor windmill
5. Propeller windmill

Utilisation of wind energy

It consists of a tower-mounted, two-bladed or multi-bladed rotor facing the wind, rotating around a horizontal axis and turning an electrical generator.The power in the wind increases with the cube of the wind speed. Such windmills are manufactured with a capacity from a few kW to several MW

The side view of a horizontal axis, multi-bladed windmill for pumping water from wells for domestic use or for minor irrigation. The head against which water is pumped ranges from 3 m to 15 m with a seasonal variation of the order of 5 m. Considering the low speed of windmills, it is most convenient to couple it with positive displacement pumps which can operate efficiently at these speeds. The rotor speed has to be stepped up when it is connected with rotor dynamic pumps. The excess water pumped can be stored in overhead tanks and can be used in nonwindy periods. The tailvane helps the blades to change in the direction of wind. Anemometer can indicate the velocity of wind.

A modern application of windmill water-pumping operation involves pumping water under high pressure to irrigation sprinklers. In another application, the waterpumping windmill drives a small air compressor and the compressed air pumps the water.



Pressurised water reactor (pwr)

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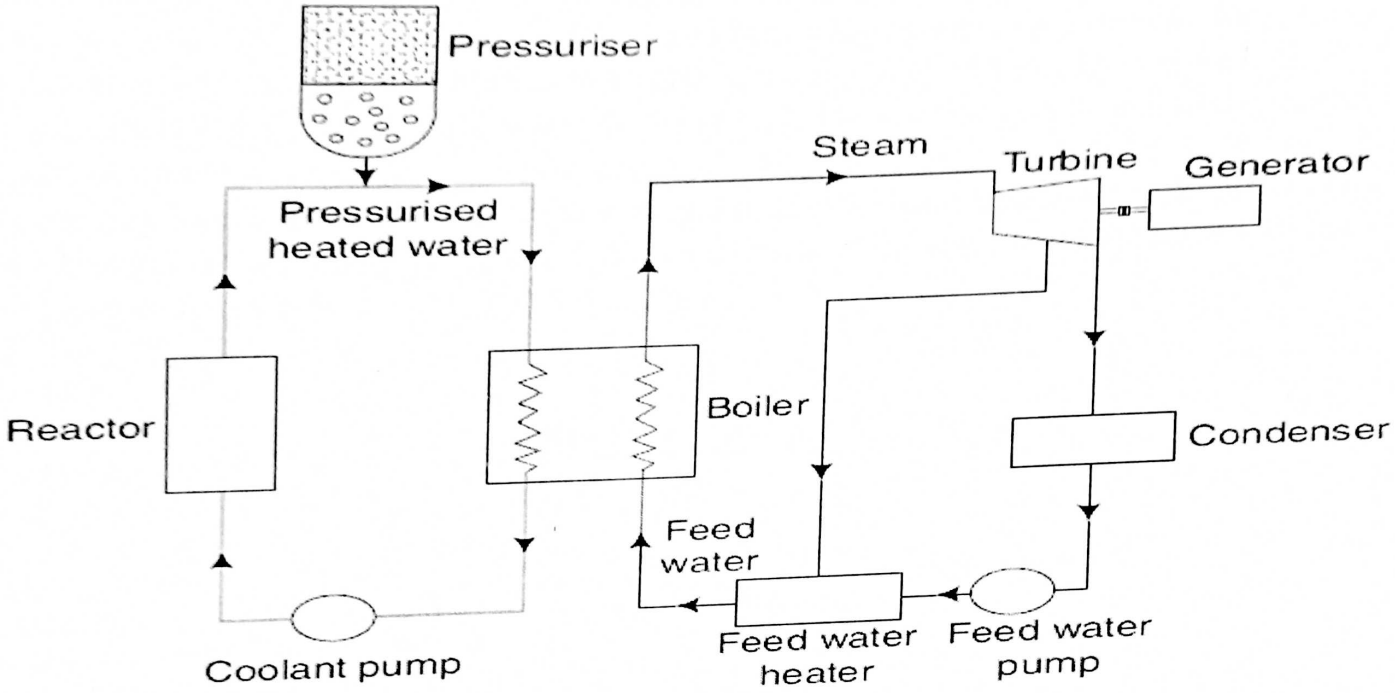
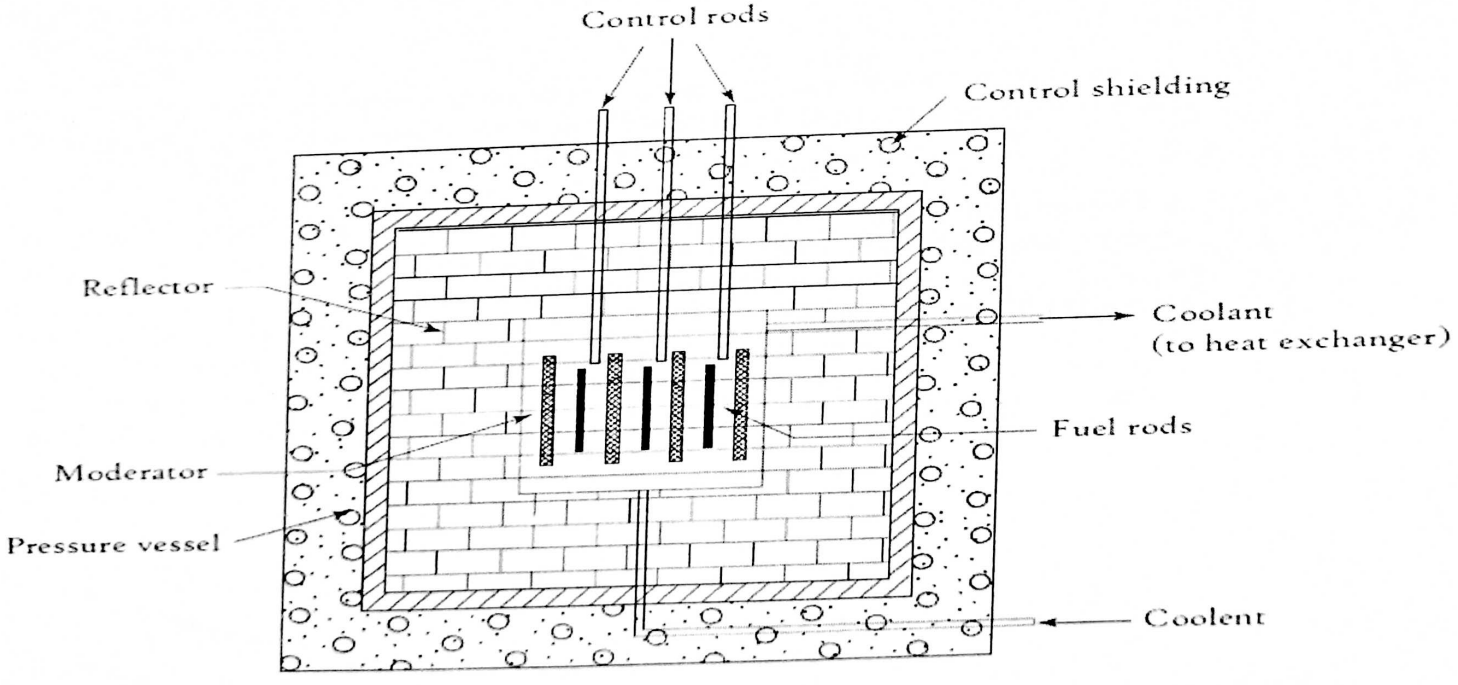


Nuclear Reactor



Pressurised water reactor (pwr)

The schematic diagram of a pressurised water reactor is shown in Fig. 2.2(a). It is also a water-cooled reactor. The system has primary and secondary loops. In the primary loop, the pressuriser maintains a high pressure in the water in the range of 150 bar. Due to the high pressure of water in the reactor, the water does not boil. The coolant gets heated in the reactor and the hot water goes to the boiler and transfers the heat to the feed water in the boiler in the secondary loop. The feed water evaporates and becomes steam and runs a turbogenerator from which power is obtained. Functions of various parts of the reactor are the same as those of a boiling water reactor

Nuclear Reactor

I. Fuel

1. Natural Uranium U_{235}
2. Enriched Uranium
3. Plutonium Pu_{239}
4. Plutonium Pu_{233} (Man Made)

II. Control Rods

Control rods absorb neutrons and control the rate of chain reaction. Materials like boron, cadmium act as control rods. To initiate the operation of the reactor, the control rods can be lifted up.

III. Moderator

In any chain reaction, the neutrons produced are fast moving. They are less effective in causing fission of U_{235}. So, speed of these neutrons should be reduced. This is done by making these neutrons collide with lighter nuclei of materials like graphite.

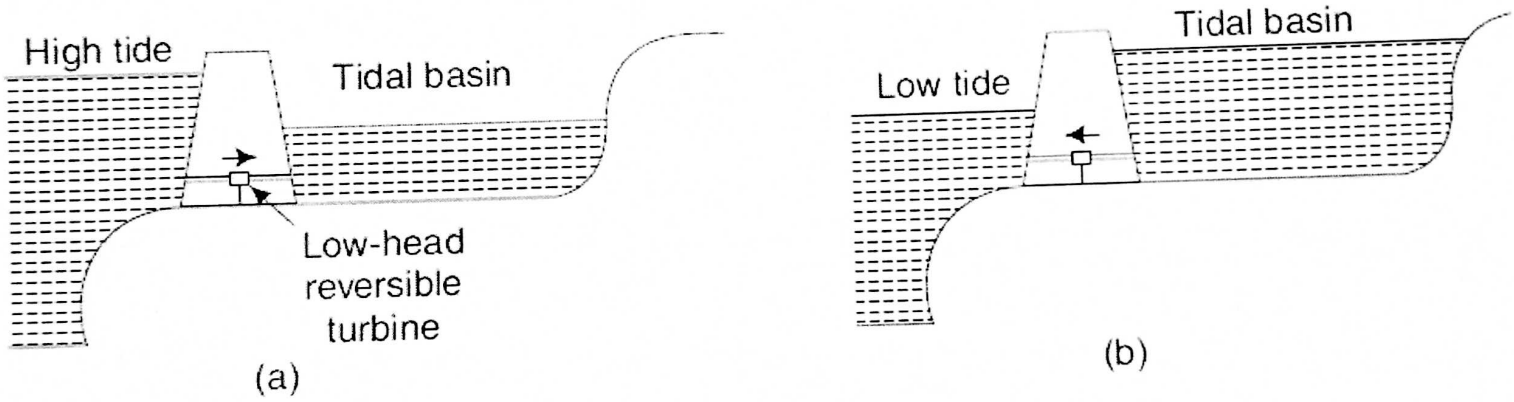
Reflector Some of the neutrons produced during fission will try to escape from the reactor and will be lost. Such losses are minimized by surrounding the reactor with a material called reflector which will reflect the neutrons back to the core. Beryllium acts as a reflector.
Shielding During nuclear fission, Alpha, Beta and Gamma particles are produced. They are very harmful to human life. So, it becomes necessary to shield the reactor with thick layer of concrete. The minimum thickness of concrete should be one meter The shell thickness of KAMINI fast breader reactor at Indira Gandhi Center for Atomic Research (IGCAR) is 1.85m.

Tidal power plant

A tidal power plant mainly consists of the following:
1. A barrage with gates and sluices
2. One or more basins
3. A powerhouse

A barrage is a barrier constructed across the tidal reach to create a basin for storing water. The barrage has to withstand the pressure exerted by the water head and should also resist the shock of the waves. So the side slope of the barrage should not be steep.

A basin is the area where water is retained by the barrage. A tidal power scheme can have a single basin or multiple basins. Low-head reversible water turbines are installed in the barrage separating the sea from the basin. The electric generator and a number of turbine components are enclosed in a water-tight compartment with the whole hydroelectric unit submerged in water

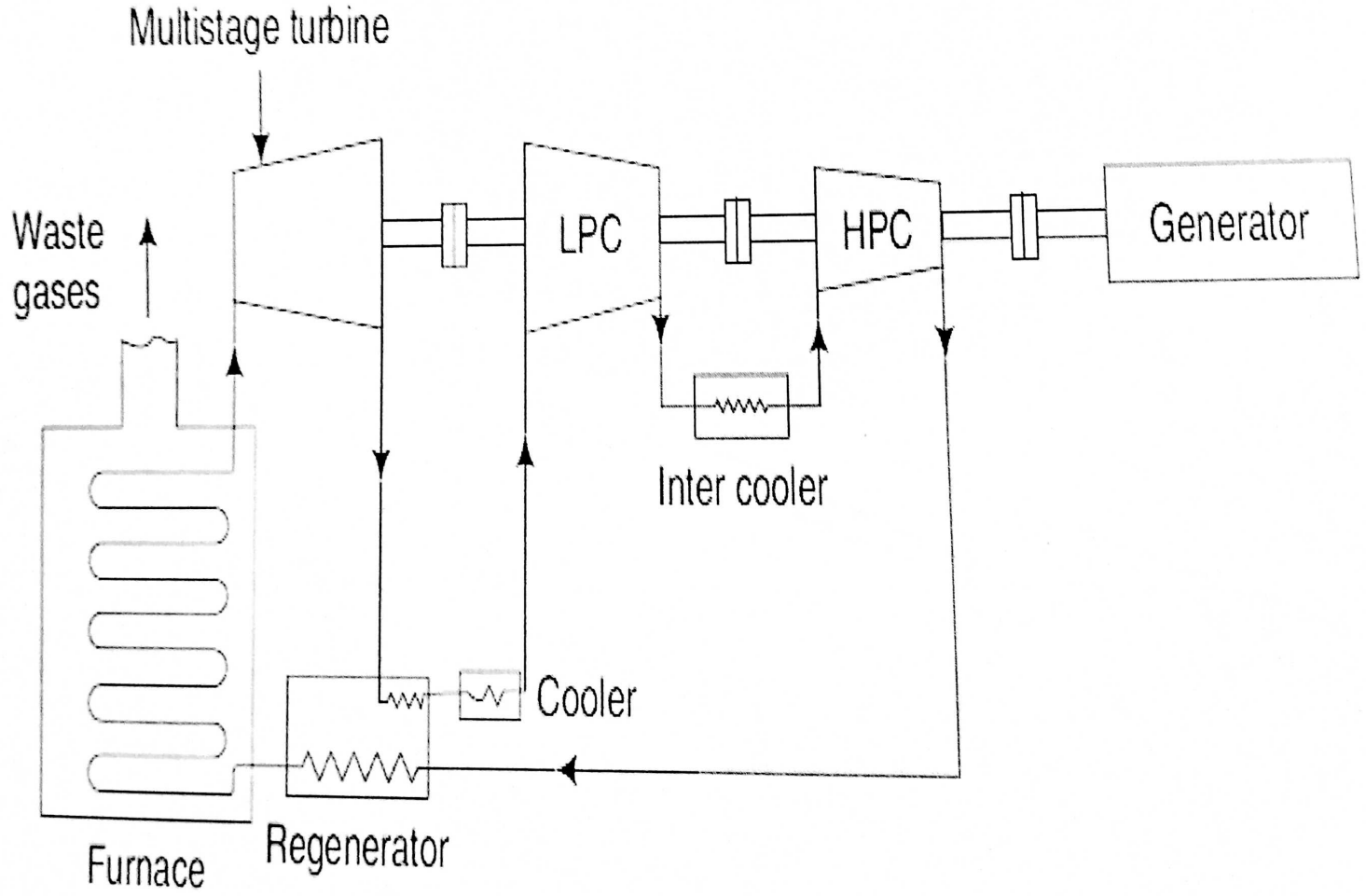


Advantages of a Tidal Power Plant
1. It is an inexhaustive source of energy.
2. There is no problem of pollution.
3. After the capital cost, the cost of power generation is quite low.
4. A high output can be obtained compared to solar or wind energy.

Disadvantages of a Tidal Power Plant
1. Capital cost is very high compared to a thermal or a hydroelectric power plant.
2. As the head is not constant, variable output is obtained.
3. As the head is only low, a large amount of water is necessary for the turbine.
4. The operation of the turbine will have to be stopped when the available head is less than 0.5 m.

Closed-Cycle Gas turbine (air, Carbon dioxide, nitrogen, helium)

The closed-cycle plant can use some stable gas with a higher specific heat as the working medium.Instead of burning the fuel directly in the air stream, an externally fired combustion chamberor furnace is used and heat is transferred to the working medium through a heat exchanger Thus, the working medium is uncontaminated by the products of combustion and is constantlyrecirculated. A cooler is provided for the recirculated working medium before it entersthe low-pressure compressor in order to minimise the compressor work. Similarly, an intercooleris also provided to improve the overall efficiency of compression. As a multistage turbine isused, the temperature of exhaust gases leaving the turbine is considerably reduced resulting in ahigher thermal efficiency. The regenerator preheats the gas before entering the furnace. By theseprovisions, the thermal efficiency is further increased to about 30 per cent



Diesel power plant