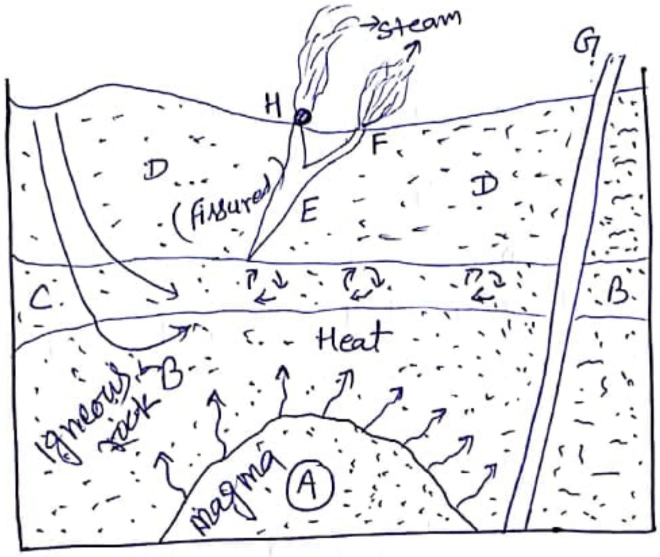
Geothermal Energy

Geothermal energy is the thermal energy present in the interior of the earth. It can be extracted from earths interior in the form of heat, Volcanoes, geysers & hot springs are visible signs of the large amounts of heat lying in earth's interior.

* Igneous rocks found at the surface is called volcanic action or great heat.
* Steam is continuously vented through fissures in the ground, these vents are called fumarols.



C - Porous & permeable reservoir
D - Solid rock
E - fissure
F → geyser fumarols
G - hot spring
H - well tap steam from fissures

Typical Geothermal ~~field~~ field.

Fig. shows a typical geothermal field. The hot magma (molten mass) near the surface (A) solidifies into igneous rock (B). The heat of the magma is conducted upward to this igneous rock. Ground water that finds its way down to this rock through fissures in it, will be heated by the heat of the rock or by mixing with hot gases & steam emanating from the magma. The heated water will then rise convectively upward & into a porous & permeable reservoir (C) above the igneous rock. The reservoir is capped by a layer of impermeable solid rock (D), that traps the hot water in the reservoir. The solid rock, however has fissures (E) that act as vents of the gaint underground boiler. The vents show up at the surface as geysers fumarols (F) or hot spring (G). A well (H) taps steam from the fissures for use in a geothermal power plant. These steams are two types.

i) Steam originating from magma is called magmetic steam.

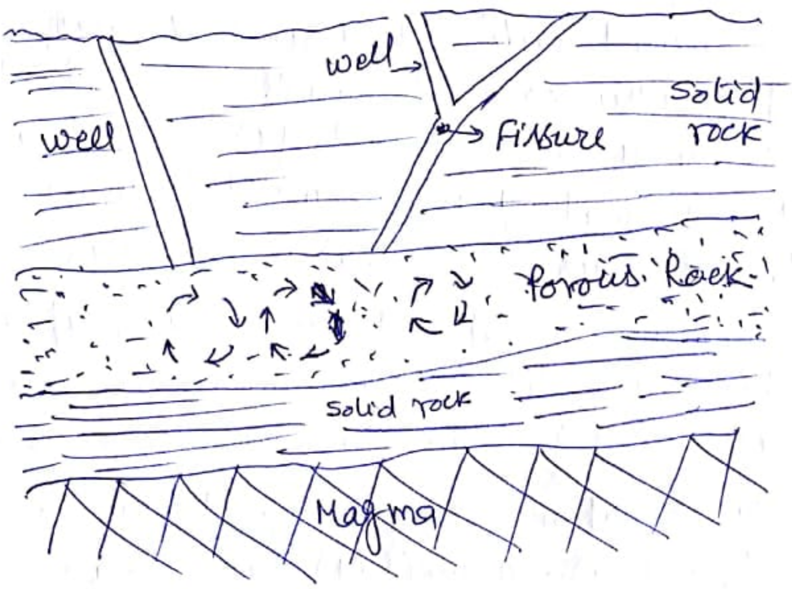
ii) Steam from ground water heated by magma called meteoritic steam.

Estimates of Geothermal powers:— The estimates vary very widely. However the following give a rough estimate. For depth of 3 km, the total stored energy of known fields is approximately $8*10^{21}$ Joules & for depth of 10 km the total stored energy is estimated to be about $4*10^{22}$ Joules. The energy stored in hot springs is about 10% of above quantities.

Geothermal sources: — Five general categories of geothermal resources have been identified.

1) Hydrothermal convective system.
   a) Vapordominated or dry steam fields
   b) Liquid-dominated or wet steam fields
   c) Hot water field.
2) Geopressure resources
3) Petro-thermal or Hot dry rocks (HDR)
4) Magma resources.
5) Volcanoes.

Hydrothermal Convective resources: —



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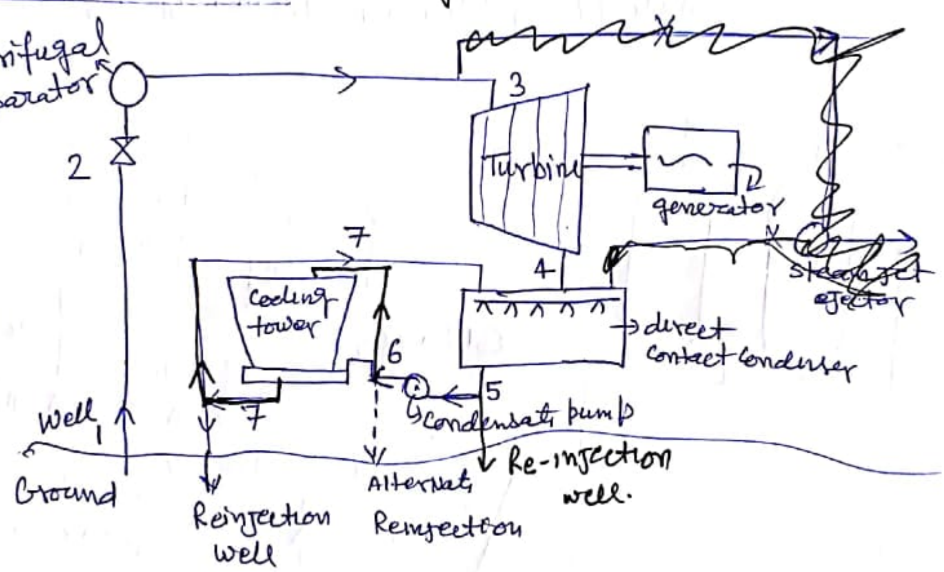
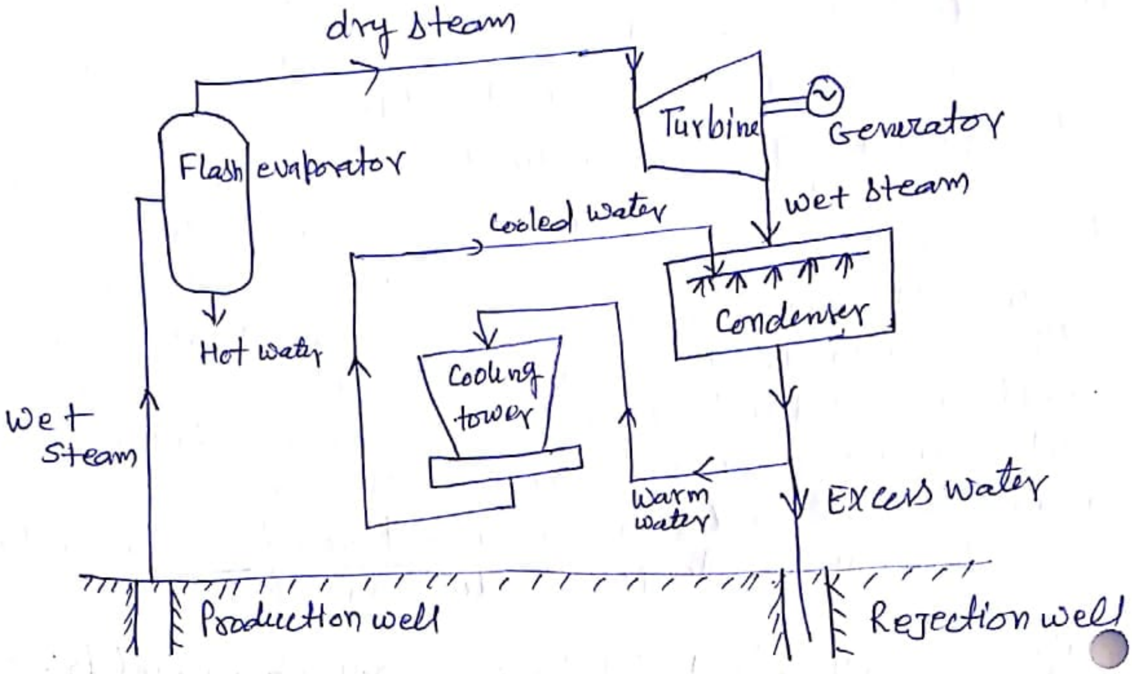
The molten rock (magma), raised by internal earth forces is overlaid by an impervious rock formation, through which heat is conducted upward. Above this is a permeable layer into which water has penitrated, after from a considerable distance. The permeability could result from fractures pores. The heat taken up by the water from the rocks below, is transferred by a convection to a layer of impervious rocks above, Hot water or steam often escapes through fissures in the rock, thus forming hot springs, geysers fumarols etc. In order to utilize the hydrothermal energy wells are drilled either to intercept a fissure or more commonly into the formation containing the water. Most hydrothermal wells range in depth from about 600 to 2100 m, although there are some shallower & deeper production wells.

Vapor Dominated System: or Dry steam fields: —

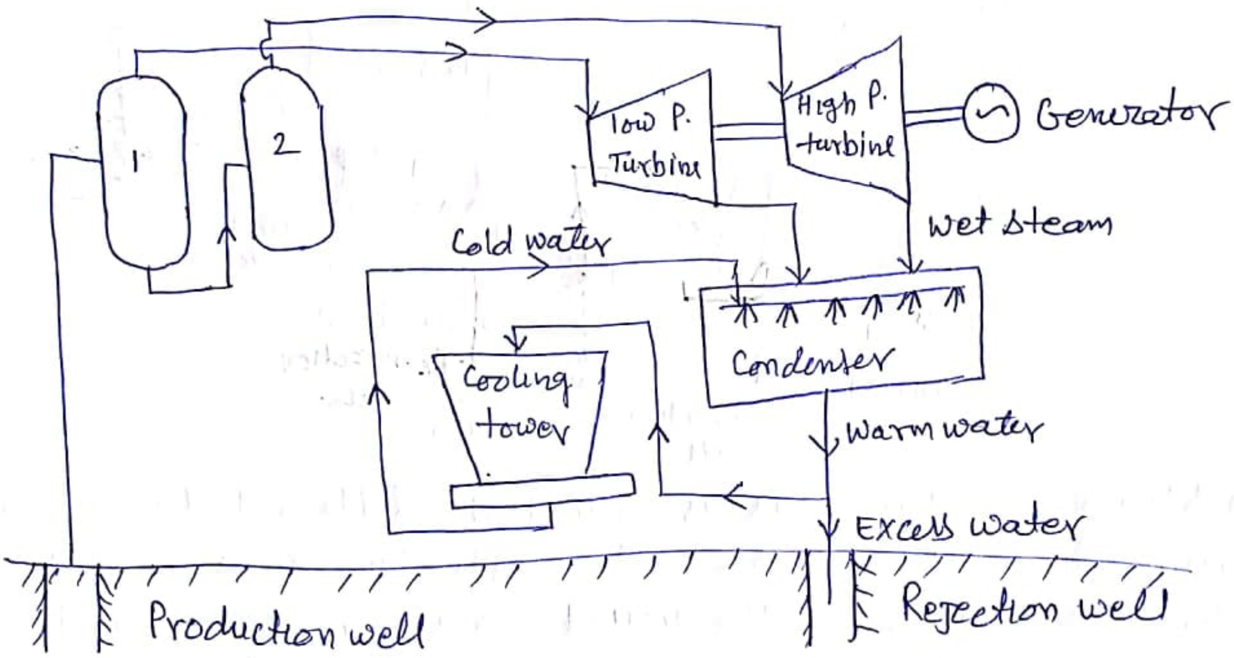


Dry steam from the wells is collected, filtered to remove abrasive particles & passed through turbines, which drive electric generators in the usual manner. The essential difference b/w this system & a conventional steam turbine generator system, using fossil or nuclear fuel, is that geothermal steam is supplied at much lower temp. & pressure. The dry steam from well(1) at perhaps 200°C is used. It is nearly saturated at the bottom of the well & may have a shut-off pressure up to about 35 bar. Pressure drops through the well cause it to slightly super heat at the well head (2) (P=7bar). It then goes through a centrifugal separation & then enters turbine after additional pressure drop. Processes b/w well to turbine are essentially processes with const enthalpy. The steam after expansion in the turbine(3) enters condenser at(4).

Wet steam or liquid dominated! —



Single flash steam in liquid dominated high Temp. plant

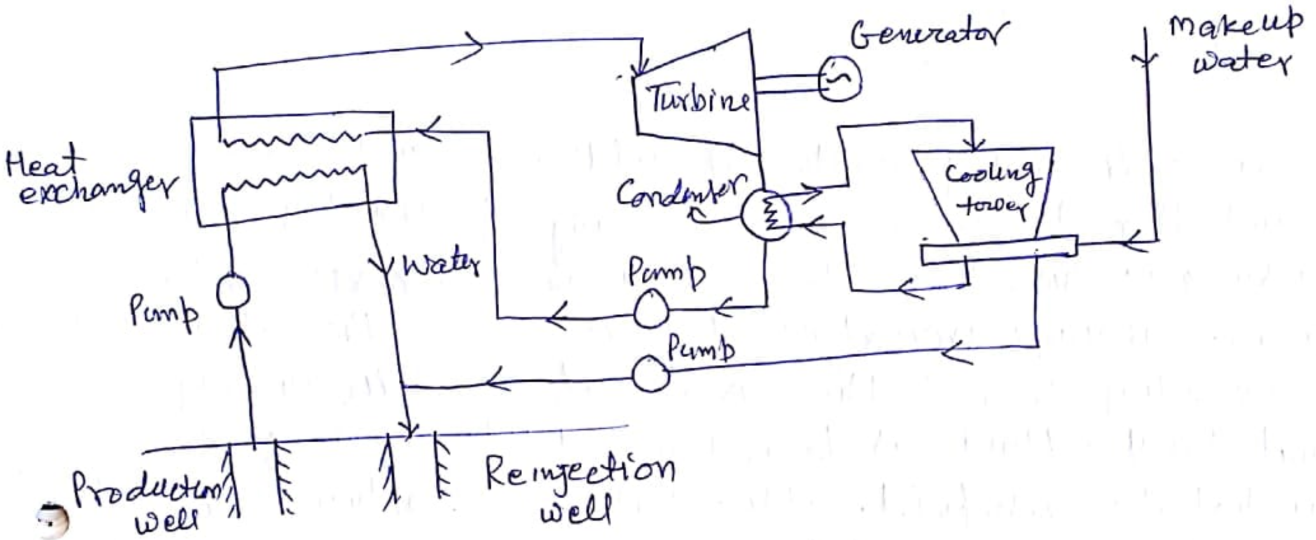


Double flash steam system

The wet or liquid dominated fields or resources can be furthere divided into high temp. (>175°C) enabling the use of flash steam evaporator to produce dry steam & Low temp. (range 95-175°C) where geothermal heat is used to vaporise a violatic refrigerant.

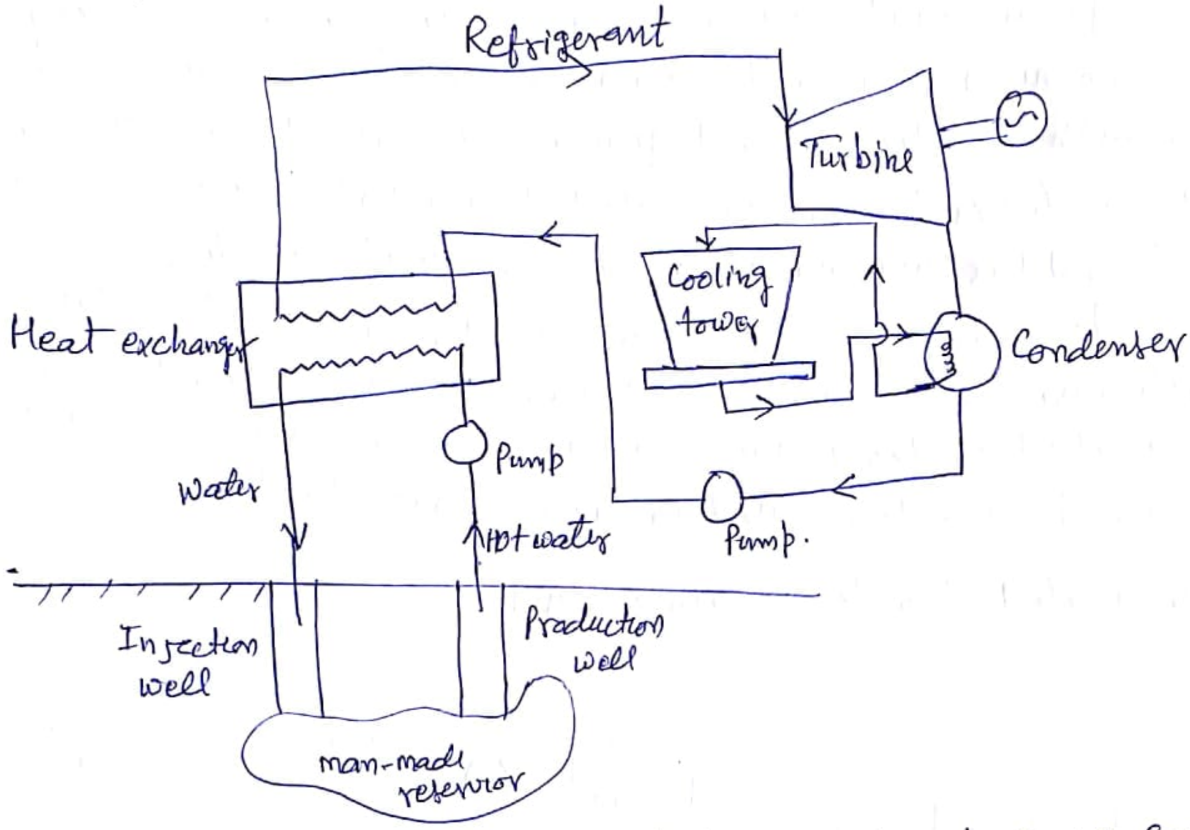
Liquid dominated High-Temperature System: — The type of plant is used where hydrothermal reservior has temp. & Pressure of 230°C & 40atm respectively. The plant consists of flash evaporator to obtain dry steam from high temp wet steam by lowering pressure in it, turbine with directly coupled generator to extract energy from dry steam, condenser to condense used steam into water & cooling tower to cool the warm water. The excess water is disposed of in the ground. In dual flash system, the hot water flashed in to flash evaporators in two stages. Steam obtained in the first stage is used in low pressure turbine & steam is again flashed to obtain high pressure to be used in high pressure turbine.

Liquid dominated Low temperature System: —



The water available from the hydrothermal reservoir is at low temp. range of 90-175°C, which is insufficient to produce steam using flash evaporator. A low boiling point refrigerant is used as a working medium. The plant runs on binary cycle. The refrigerant is evaporated in a heat exchanger using the heat of water obtained from hydrothermal reservior. The refrigerant vapour runs the turbine with a generator coupled to it. The used refrigerant vapor condenses in a condenser. The cooled water for cooling in condenser is obtained from cooling tower.

Hot Dry Rock Resources (HDR): —



HDR resources or dry geothermal fields are much more common than hydrothermal reservoirs. The working of high dry rock binary fluid system. These HDR resources are more accessible compared resources. The underground hot dry rocks to geothermal heating have temp. exceeding 200°C & there is no water in their vicinity. Water as heat transfer fluid has to be injected into a man-made reservior in the hot dry rocks field. After drilling & fracturing of the field, a man-made reservior created. Injection for wells pumping inside & production wells for hot water pumping out are drilled. A series of injection wells & extraction wells can be drilled to tap a sufficient amount of geothermal energy. The hot water extracted from the man made reservior is made to vaporise low boiling point refrigerant which is used to run a turbine coupled with a generator. The refrigerant vapor exiting the turbine is condensed in a condenser which is pumped into the heat exchanger again.

Potential of Geothermal Energy in India : - As a result of studies & surveys out for the assesment of geothermal energy resources in India, about 340 potential hot springs have been identified throughout the country. These hot springs are potential & can continuously provide hydrothermal fluids. The hydrothermal have temperature varying from 37 to 90°C. Majority of these resources have low temp. & these can be utilized for direct thermal application. Few hydrothermal resources are suitable for electric power generation as hydrothermal fluids have sufficient high temp.. The potential of these resources has been estimated to be about 10,000 MW. The pilot plants have been commissioned at Manikaran (H.P), Puga & Chumanthang (J&K)

The Potential sites as identified are:

a) The Himalayas (Puga valleys, Manikaran)
b) Sohana
c) West Coat (Unai)
d) Cambay (Tuwa)
e) Son-Narmada-Tapi (SONATA)
f) Godavari
g) Mahanadi

Ist USA

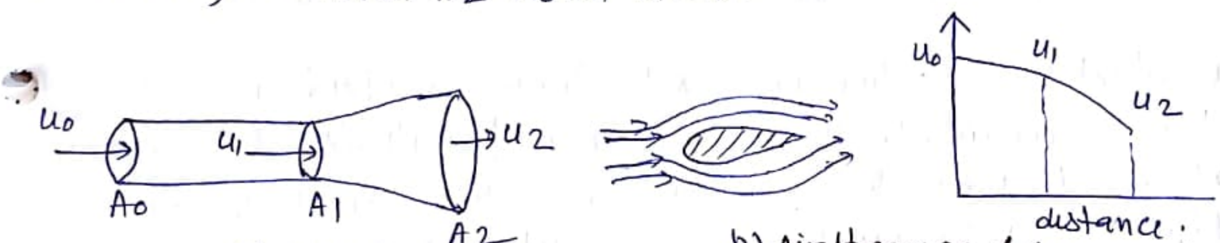
Wind Energy

India → 22500 MW (2014) 5th Position

Wind energy is a form of solar energy. Wind energy (power) describes the process by which wind is used to generate electricity. Wind turbines converts the kinetic energy in the wind into mechanical power. A generator can convert mechanical power into electricity.

* wind turbines convert the kinetic energy in the wind into mechanical Energy.
* operating wind speed → 5-25 m/sec are suitable to wind turbine

Principle of wind energy conversion: —— wind turbine is used to extract useful energy from wind. The energy can be extracted by partially decelerating & expanding the air stream (reduction of pressure) using wind turbine. The rotor of the wind turbine collects wind from the whole area swept by rotor. The area swept can be considered as airstream tube which is continuously expanding as shown in fig. This airstream tube model also called Betz model for expanding air. As air mass flow rate should be the same everywhere within the stream tube according to the law of continuity, the wind speed must decrease as air expands. As shown, airstreams tube has area A_0 at upstream, Area of A_1 while passing through rotor blade (aerofoil) & Area A_2 down stream

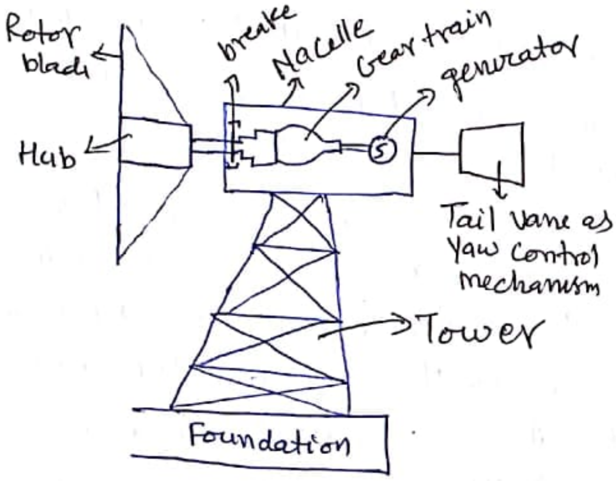


a) Air stream tube b) Air stream aerofoil c) Variation of wind Velocity

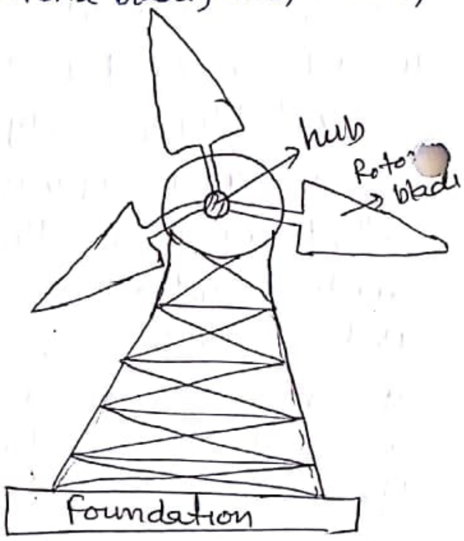
Fig: Extraction of wind energy & Betz model for expanding air.

Types of windmills:— It can be mainly classified as horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT). When the axis of rotation is parallel to the airstream, the turbine is called HAWT & when it is perpendicular to the air stream, it is called VAWT. Horizontal axis windmills are the most commonly used machines & these have rotors similar to aircraft rotors. Vertical axis windmills have eggbeater type rotors.

Horizontal axis wind turbine:— Wind energy conversion sys (WECS):—
The constructional details of three-bladed, horizontal axis wind turbine are shown in fig. The main components are turbine blade, hub, nacelle, yaw control mechanism, generator & tower.



a) Side view of the windturbine



b) front view of the wind turbine.

Turbine blades:— Turbine blades have aerofoil type cross section to extract from wind. These blades are of high density material such as wood, glass fiber & epoxy composites. The blades are twisted from tip to root to maintain pitch angle. Most of wind turbines have 2 or 3 blades similar to the propeller of an old aeroplane, but blades of wind turbines rotates very slowly compared to that of an aeroplane. The two bladed rotors gives much smoother power output compared to three bladed rotors. A three-bladed rotor generates little more power output (25%), but additional blade incorporation adds to substantial addition weight to the wind mills (about 50% extra) — A two-bladed rotor is also simpler to be constructed & erected on the ground.

Hub:—
The central solid portion of a rotor is called hub. It helps in the attachment of all blades & the incorporation of pitch angle control mechanism.

Nacelle: — The rotor is attached to nacelle which is mounted at the top of a tower. It houses gear box, generator, controls & breakes. The purpose of gear box is to regulate the out put rotation from the rotor with the speed of the generator. Electromagnetic breakes are provided for automatic application of breakes if the wind speed exceed the design speed.

Yaw control system: — It is provided to adjust the nacelle around the vertical axis so that rotor blades are always facing the wind stream. In small wind turbine a tail vane is used as passive yaw control.

Tower: — It is provided to support nacelle & rotor. The tower height should be sufficient so that enough wind speed can be intercepted by the rotor. For medium & large sized wind turbines, the tower is slightly taller than the rotor diameter, while in small sized wind turbines, the tower is much larger than the rotor diameter.

Electrical system: — The wind turbines are provided with induction generators to convert mechanical energy to electrical energy. Induction generator has brushless & rugged construction. It is also available at economical cost.

Basic components of WECS: —

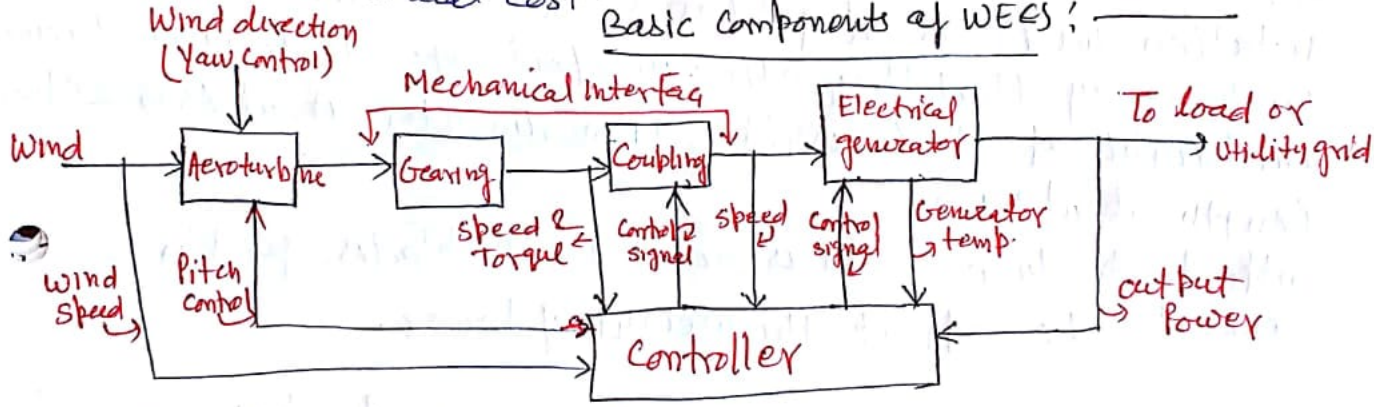
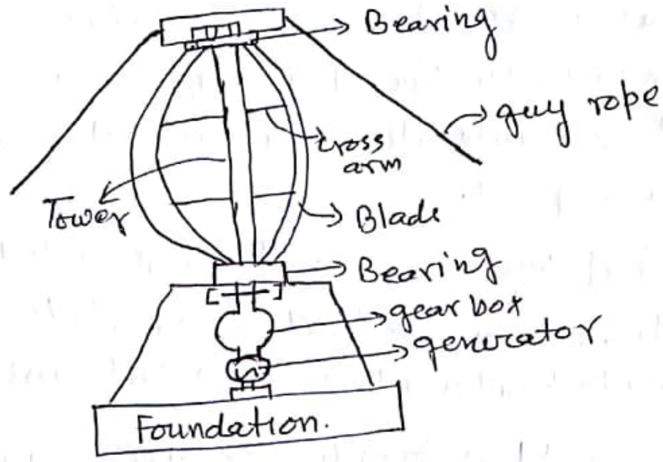


Fig: Basic components of a wind Energy Conversion sys (WECS)

Vertical axis wind Turbine: (VAWT) It has the axis of rotation of its perpendicular to the wind stream. Its advantageous as I) It can accept wind from any direction, thereby eleminating the necessity of any yaw control system & II) It can have its gearbox & generator system (Nacelle) at the ground level, thereby eleminating the necessity of mounting the heavy nacelle at the top of the tower. These features of VAWT also help in the simpler design & installation of the wind turbine, the easier inspection & maintenance of the wind turbine and reducing the overall cost of the wind turbine.

A VAWT (Darrieus) with all its components is shown in fig.
The component systems include ~~tower~~ blades & support structure.



Tower (rotor shaft) :— The tower consists of a hollow vertical axis b/w its bearing at top & bottom. It is provided with a support structure at the bottom & at the upper end, it is supported by guy ropes. The height of the tower is about 100m.

Blades: — The wind turbine has two or three blades which are thin & curved shaped similar to an "eggbeater". The blades are curved in such a way that minimum bending stresses are produced on rotation due to centrifugal forces. The blades are designed in such a way that they offer aerofoil type c/s to wind stream. The height of blade is kept 94 m, diameter about 65 m & chord length about 2.4 m.

Support structure: — It is provided with blades, gearbox & generator to support the weight of tower.

Recent development in the wind energy in India: —— ?

Bioenergy Resources

Indroduction: – Plants grow through photosynthesis process which takes place primarily in their green leaves. Biomass is mainly in the form of wood & it is the source of energy. Biomass is used both in domestic & in idustrial activities by way of the direct combustion. Hence, we use solar energy in the form of biomass for cooking & heating purpose. The dominant use of biomass or fuel wood in the world is made for cooking & heating primarily in rural areas. Biomass accounts for about 15% of the energy used in the world.

Biogas is the gaseous fuel which is obtained from biomass by means of anaerobic fermentation. The raw materials for biogas include animal waste, urban waste from agriculture, waste from forest, rural animal waste, urban waste (left over food & other rubbish) & aqua waste (fishery, algae etc)

Biomass: – It is organic or carbon based material that can either with oxygen for combustion or undergo metabolic process to release heat. Biomass can be used as such in its original form. more often, it is transformed to more convenient & useful form, thereby forming solid, liquid & gaeous fuels.

Biofuels: – It can be fuelwood, charcoal, fuel pellets, Bioethanol, biogas, producer gas & biodiesel.

- biogas → CH_4 – 65–75%, CO_2 – 25–35%
- producer gas → 19% CO, 18% H_2, 1% CH_4, 11% CO_2
- biodiesel → from vegitable oil
- charcoal → Carbonization of wood
- fuel pellets → Pellets from crop residue
- Bioethanol → C_2H_5OH, CH_3OH

Biomass Resources: –

I) Forest → wood, charcoal & producer gas

II) Agriculture residues → straw, rice husk, groundnut shell, coconut shell & sugarcane

III) Energy crops → sugar plants → Bioethanol, starch plants → Bioethanol, oil producing plant (sunflower, palm oil, groundnut & cotton seeds) → Biodiesel.

IV) Urban waste → garbage or municipal solid waste & sewage or liquid waste

V) Aquatic plants → The fast growing water plants include water hyacinth, seaweed, algae & kelp.

Biogas:— It is gaseous fuel which is obtained from biomass by means of an anaerobic digestion or fermentation of wet organic matters. The biogas is a flammable gas. The combustion of biogas includes 50–60% CH_4, 35–40% CO_2, 5% H_2 & small amount of H_2S & other gases.

Aerobic process taking place in the presence of oxygen or air.

Anaerobic process are taking place in the absence of oxygen or air.

Biomass Conversion:—

1) Wet processes →

II) Dry processes →

Simply bioconversion can take many forms :-

1) Direct combustion, such as wood waste & bagasse (sugar cane refuge)

ii) Thermochemical conversion.

III) Biochemical conversion.

Anaerobic digestion:— "Process production of biogas from biomass"

Biogas is produced from biomass slurry having 90-95% water content by the bacterial action of microorganism called anaerobe. The carbon part of biomass is oxidised & the remaining is reduced to produce mainly CH_4 (65-75%) & CO_2 (25-35%). These bacteria are found to live & grow without atmospheric O_2 as they produce themselves the needed O_2 by decomposing the biomass. The digestion or fermentation process of wet biomass by these bacteria is favoured by the factors such as wetness, warmness & darkness conditions.

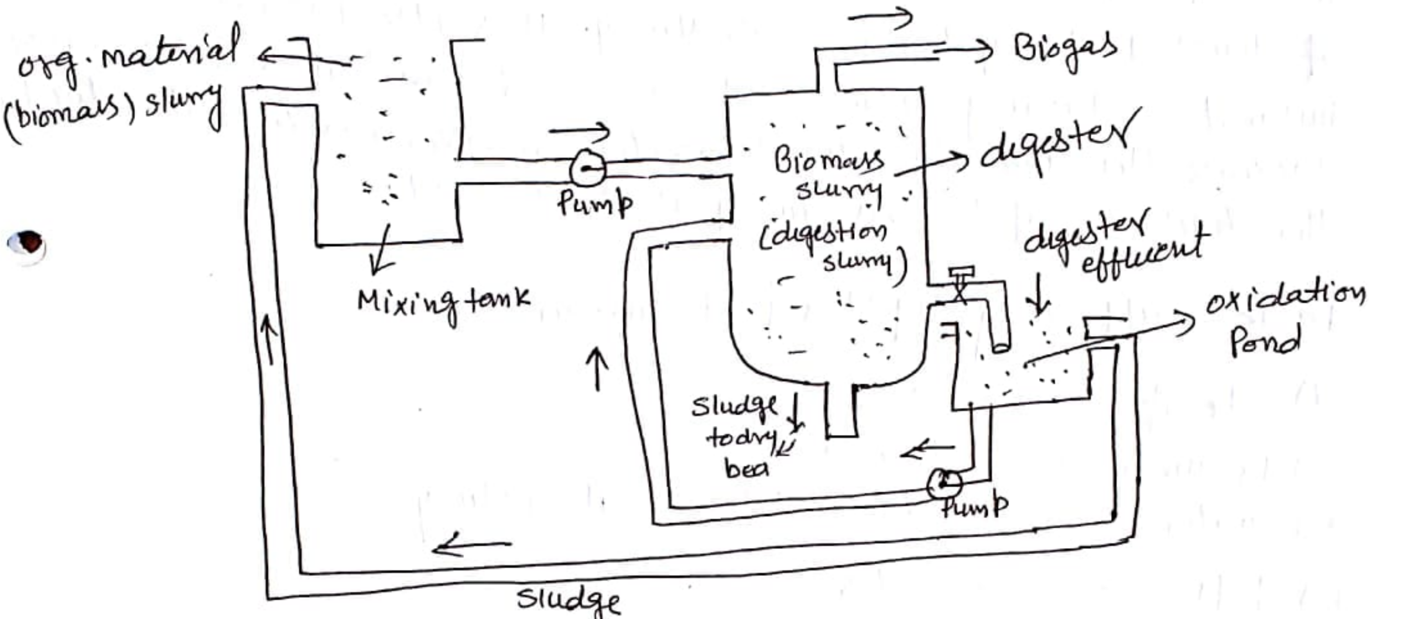
The general equation for anaerobic digestion is as follows.

$$C_x H_y O_z + \left(x - \frac{y}{4} - \frac{z}{2}\right) H_2O \rightarrow \left(\frac{x}{2} - \frac{y}{8} + \frac{z}{4}\right) CO_2 + \left(\frac{x}{2} + \frac{y}{8} - \frac{z}{4}\right) CH_4$$

In case of cellulose, the equation is given by :-

$$(C_6H_{10}O_5)_n + nH_2O \longrightarrow 3nCO_2 + 3mCH_4$$

The airtight equipment used to convert the wet biomass into biogas by digestion or fermentation process is called biogas digester or plant which is properly constructed & controlled to favour biogas or CH_4 production. The conversion process is called biodigestion or anaerobic fermentation & the output is CH_4 or biogas. The residuals or nutrients such as soluble nitrogen compounds remaining in the wet biomass slurry provide or produce excellant natural fertilizers & humus. The biogas can provide 60–75% of the energy of the dry converted biomass during combustion.



"Biogas digester or plant"

The biochemical process of converse in from biomass to biogas takes place in the following three steps.

I) Hydrolysis of organic Matter:— The biomass (complex compounds of carbohydrates, protein & fats) is broken due to the action of water (hydrolysis) into simpler soluble compounds. Similarly, large molecules (Polymers) are reduced to basic molecules (monomers). The process is completed in a day at a temp. of about 25°C.

II) Anaerobic & faculative microorganism:- These bacteria start growing to produce acetic acid & propionic acids. The process is completed in a day at the temp. of 25°C. The output of the process is the production of CO_2.

III) Digestion:— Anaerobic bacteria slowly digest the biomass slurry to produce biogas. The process is completed in 2 weeks at temp. 25°C.

Digester :- The anaerobic digester or plant shown in fig. Feed consist of organic material slurry prepared in mixing tank. Feed supply per day to the digester is called loading rate. Neither overloading nor underloading of the digester is desirable as it reduces bio gas production. The acid forming bacteria growing rapidly, whereas CH_4 forming bacteria (anaerobe) grows slowly. To obtain max. biogas generation rate, seeding of digestion slurry with CH_4 forming bacteria is done. This is achieved by adding certain portion of digested slurry to the fresh slurry. It is also possible to add nutrient containing nitrogen, H_2, O_2, P, S & carbon, which can also increase the anaerobic digestion rate. The recommended pH value for the digestion of biomass slurry is about 7-8.

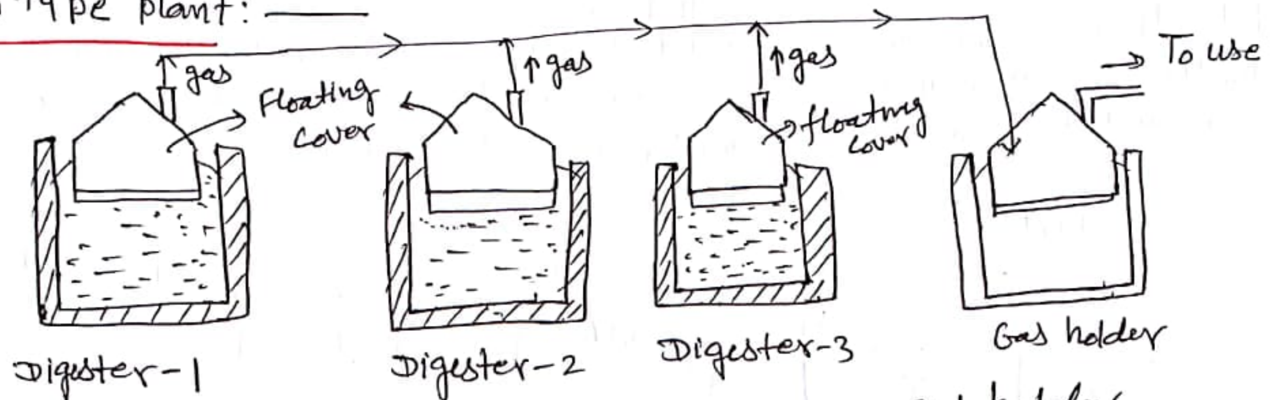
Factors affecting digester performance :-

1) Temp – 20–65°C
2) Pressure – 6–10 atm
3) water → 90–95% water content in slurry
4) pH → 6.5–7.5
5) Feed rate → uniform feed rate
6) Presence of Nutrient → C, N, & others are essential for digestion.
7) Seeding
8) Mixing & stirring
9) Retention time → 30–50 days
10) Type of bio mass → Cow dung, poultry manure, sheep manure, rice husk, algae & water hyacinth.

Scanned by CamScanner

Classification of biogas plants: – Biogas plants can be classified as batch type & continuous type. The continuous type biogas plants can be further classified as i) floating drum or const. Pressure type plant & ii) fixed dome or constant volume type plant.

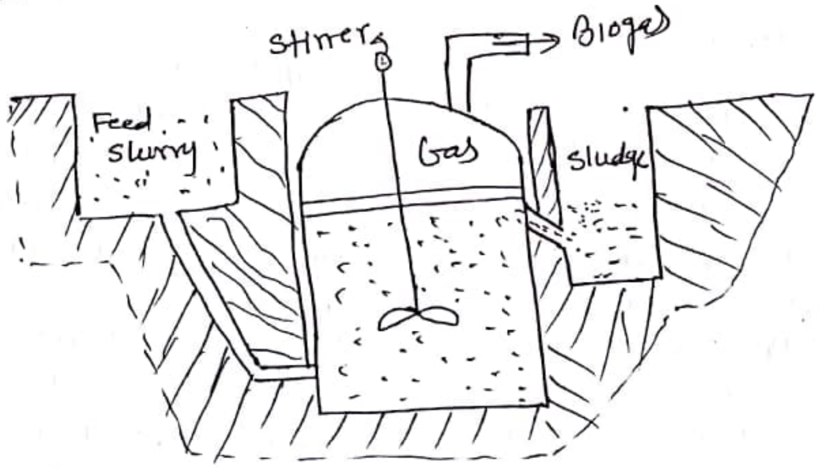
Batch type plant: —



Biogas batch type plant with 3 digester & a gas holder

A batch type plant consists of a number of digesters which are charged, used & emptied one by one in a synchronous manner to maintain regular supply to gas holder or storage tank. Each digester is charged with fresh biomass & it starts supply biogas after 8–10 days. The digester is now capable of supply biogas for about 40–50 days till its biomass is completely digested. Afterwards, this digester is emptied & recharged with fresh biomass. Hence, each digester should be charged in about at the interval of 50–60 days. Digesters in a batch biogas plants is shown in fig.

Continuous type biogas plant: — In continuous type biogas plant, a certain quantity of biomass slurry is fed daily into the digester. This is made possible by the removal of digested slurry through an outlet so that the digester can have space to intake fresh biomass slurry. The biogas produced is either stored in digester or removed to be stored in a gas holder.



"Continuous type biogas"

The plant operates continuously & it is stoped only for the removal of sludge. The layer of scum at the top of the biomass slurry is periodically broken with the help of the stirrer as shown in fig. The stirring also help in better mixing of biomass slurry to speed up the digestion process. This type of plant is most suitable for individual house owners as the daily wastage can meet the biomass feed requirement of the digester.

Floating drum type biogas plant (Constt. Pressure) or:— It consists of an inverted mettalic drum of function as gas holder & an underground digester constructed from masonry with a partition wall as shown in fig.

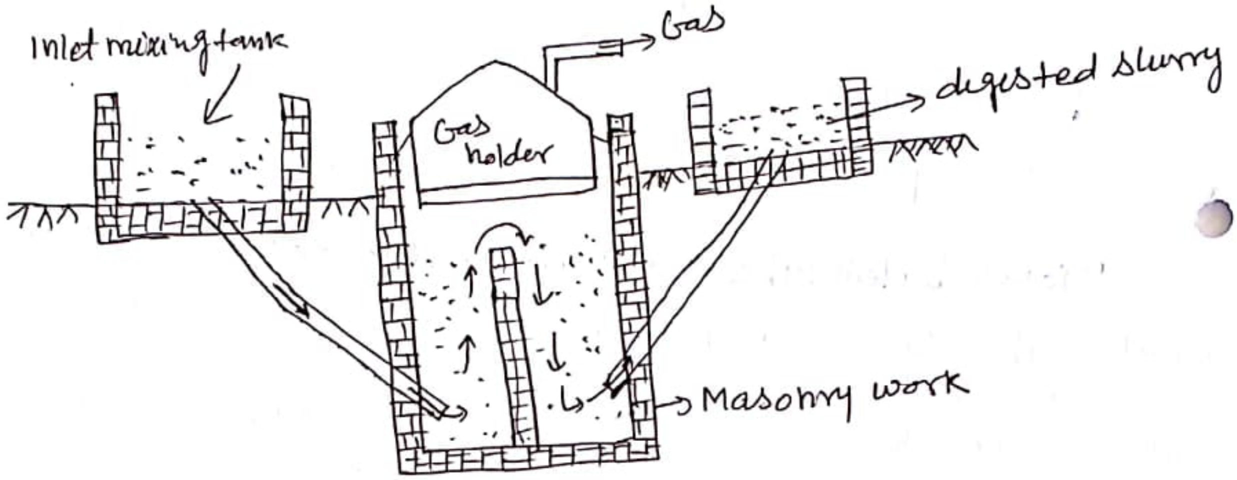
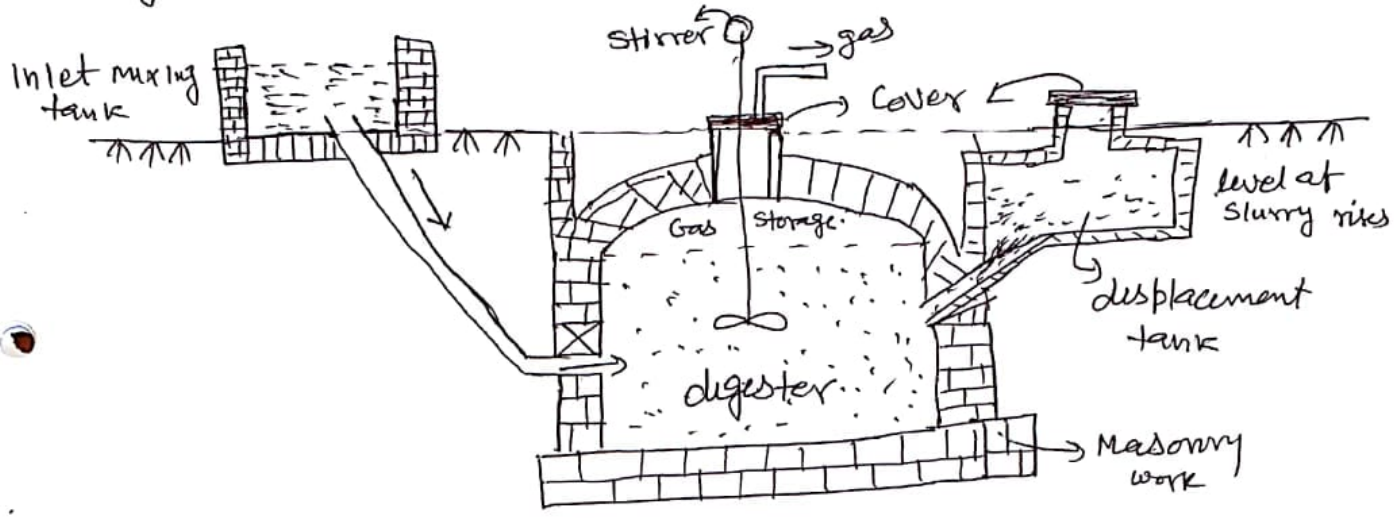


Fig: "Floating drum type biogas plant."

The digester chamber is provided with a partition wall at the centre so that optimum condition for growth of acid forming bacteria & CH_4 forming bacteria can be provided in the partitioned portions as biomass slurry should be acidic & basic for acid forming & CH_4 forming bacteria respectively. The pipe arrangements are provided to the digester for the supply of fresh feed of biomass slurry & the removal of digested slurry. As the digester has floating gas holder, the pressure inside the digester remains constt. There is no risk of explosion due to prevailing low pressure of gas.

Fixed dome type Biogas plant or (Constt. volume) — It has constt volume but varying pressure inside the digester as it has no movable type gas holder but fixed dome at the upper portion of the digester as shown in fig. The Biomass & water are mixed into slurry in inlet mixing tank, which is fed into the digester through inlet pipe. A stirrer is provided in the digester tank to mix the slurry inside the digester. which also help in mixing of scum floating on the slurry. The generated biogas accumulated in the fixed dome of digester & it is taken out by an outlet pipe. The residual digested slurry is taken out from an opening in the digester.

In the modified fixed dome type biogas plant, a displacement tank is also provided which is connected to the digester. As the pressure of gas in the fixed dome increases, the level of the slurry inside the digester goes down & it forces the slurry to rise in the displacement tank. This arrangment helps in maintaining a constt pressure inside the digester about 1 m of water column & the removal of digested slurry from the displacement tank.



Community Biogas plant: — The Community biogas plants can help in transforming village life & providing not only efficient cooking fuel but also electricity for i) lighting ii) operating cottage industries iii) irrigation iv) supply drinking water (v) maintaining sanitation & vi) fertilizers for improving agriculture. To improve the productivity & efficiency of biogas plants, following suggestions are being considered.

a) Biogas is to be used in dual fuel engine to generate power which can be sold to the state electricity boards.

b) The hot exhaust of power generating system should be used to operate biogas plants at higher temp, thereby increasing biogas production

c) The use of additional materials such as water plants with animal waste to generate biogas

d) The new methods of biogas generation using bacterial support structures & recycling of spent slurry help in reducing cost of biogas generator.

Biodiesel from oil producing seeds/algae : —
Energy from waste :- Incinerators for Agricultural wastes.

Ocean Thermal Energy

Introduction:— it is created by solar energy when ocean water absorbs solar radiation. The absorption of solar radiation causes a moderate temperature gradient to develop in water from the top surface to the bottom surface of the ocean. This temperature gradient can be utilized using a heat engine to generate power. This process of conversion is called ocean thermal energy conversion (OTEC). The surface water acts as the heat source & the deep water acts as the heat sink & heat engine can operate b/w these source & sink. A minimum temperature difference of 20°C is required b/w source & sink so that heat engine can effectively operate to generate power.

Working principle of OTEC :— It is indirect method of utilizing of solar energy. A large amount of solar energy as thermal energy is collected & stored in tropical oceans. The surface of water acts as the collector of solar heat. The upper water layer in the ocean acts as an infinite heat storage reservoir or a hot temperature source while the deep water layer in ocean acts as a lower temperature sink. Solar heat absorption in the ocean water takes place according to Lambert's law of absorption. According to this law, each layer of equal water thickness in ocean absorbs the same fraction of solar heat when solar radiation passes through ocean water. The radiation intensity (I) in water falls with depth (x) according to the following relation:

$$\frac{dI}{dx} = \mu I_0$$

I_0 = solar radiation intensity at $x=0$
μ = absorption coefficient

on integration, we get

$$\boxed{I = I_0 e^{-\mu x}}$$

A heat engine can work b/w this heat source & heat sink to convert heat into mechanical work. The efficiency of heat engine is limited to Carnot engine efficiency, which is given by

$$\eta = \frac{T_1 - T_2}{T_1}$$

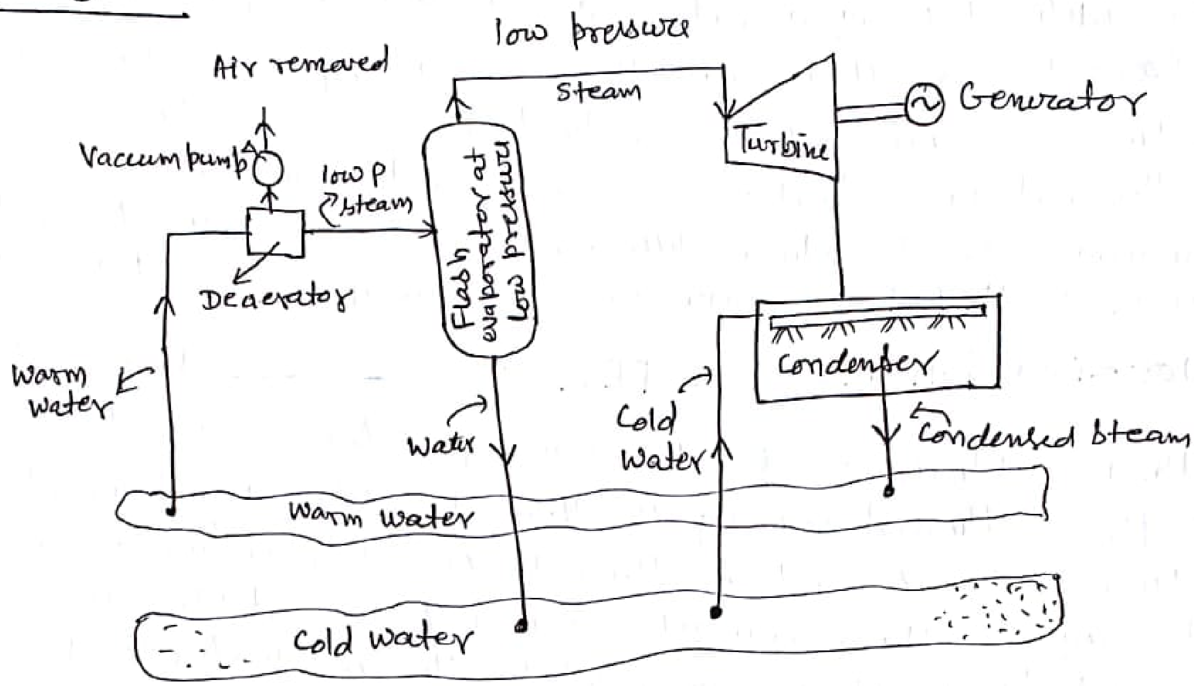
T_1 = source temp (K)
T_2 = sink temp (K)

In case we take $T_1 = 27°C$ & $T_2 = 7°C$

$$\eta = \frac{(27+273)-(7+273)}{(27+273)} = 6.67\%$$

Ocean Thermal energy Conversion Systems:- OTEC plants can operate using open cycle or closed cycle. The open cycle is also known as the Claude cycle while the close cycle is also known as Anderson cycle.

Open cycle: —



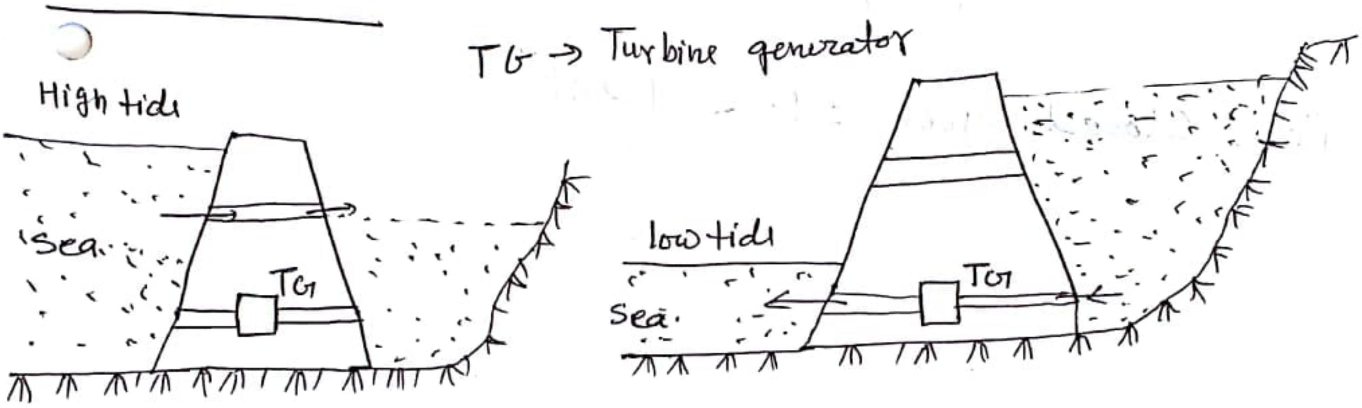
Warm water from the top surface is evaporated to obtain low pressure steam by using a flash evaporator maintained by partial vacuum as water can evaporate at the low temperature when pressure is lower than atmospheric pressure. The low pressure steam obtained from flash evaporator is expanded in a turbine to extract mechanical energy. The steam after energy removal in turbine is condented into water in a condenser which is cooled by cold water drawn from the depths in the ocean.

Closed cycle: — In the closed cycle, warm surface water is used to evaporate a low boiling point refrigerant (NH_3 or Freon) & refrigerant vapor is made to flow through the turbine to extract energy. The vapor coming out from the turbine after performing work is cooled & condensed in a condenser cooled by cold water pumped from the ocean depths.

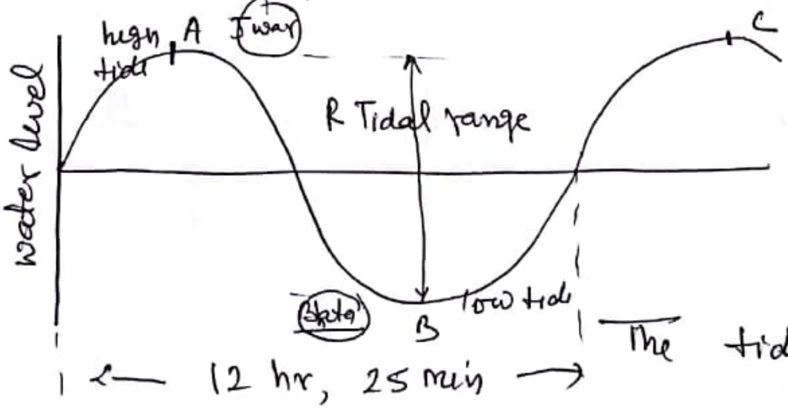
Tidal energy

Tides are produced by gravitational attraction of the moon & the sun acting on the rotating earth. Tides are periodic rise & fall of the water level in the oceans due to various positions of rotating moon & sun. oceans cover nearly 70% of earths surface. The water level difference is caused in ocean due to the tides & tides contain a large amount of potential energy. The difference in the level b/w high & low tide is called the tidal range and tidal range of 5-15m can be easily used to drive turbine coupled with generator to generate electric power.

Energy from Tides: —



Basic principle of Tidal power: — Tides are produced mainly by the gravitational attraction of the moon & the sun on the water of solid earth & the oceans. About 70% of the tide producing force due to the moon & 30% to the sun. The moon is thus the major factor in the tide formation. surface water is pulled away from the earth on the side facing the moon, & at the same time the solid earth is pulled away from the water on the opposite side. Thus higher tides occur in these two areas with low tides at intermediate points. As the earth rotates, the position of a given area relative to the moon changes, & so also do the tides



The tides of sea.

* The full moon as well as no moon produce a high tide.
* In 24 hrs 50 min, there are two high tides & two low tides
* R → difference b/w high & low water levels is called the range of tide.

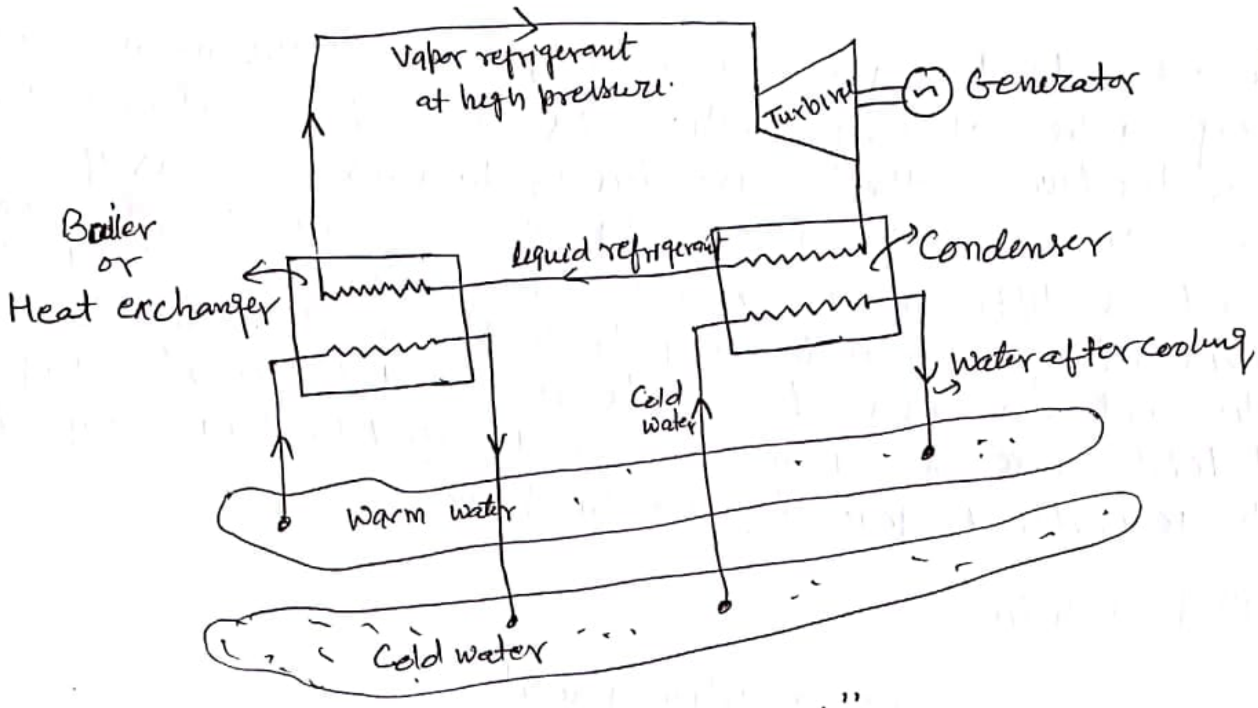


Fig: Closed cycle OTEC plant"

Scanned by CamScanner

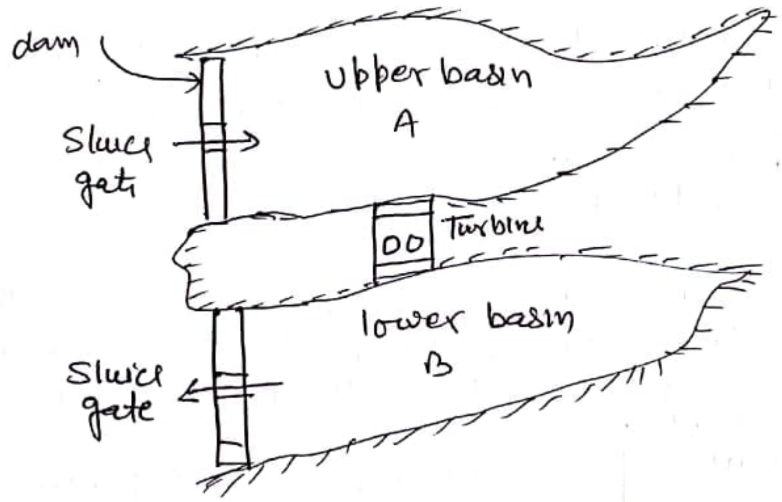
Components of Tidal power plant: — There are three component

i) The power house
ii) The dam or barrage (low wall) to form pool or basin.
iii) Sluice ways from the basins to the sea & vice-versa.

The turbines, electric generators & other auxiliary equipments are main equipments of a power house. The function of dam to form a barrier b/w the sea and the basin or b/w one basin & the other in case of multiple basins.

The sluice ways are used either to fill the basin during high tide or empty the basin during low tide, as per operational requirment.

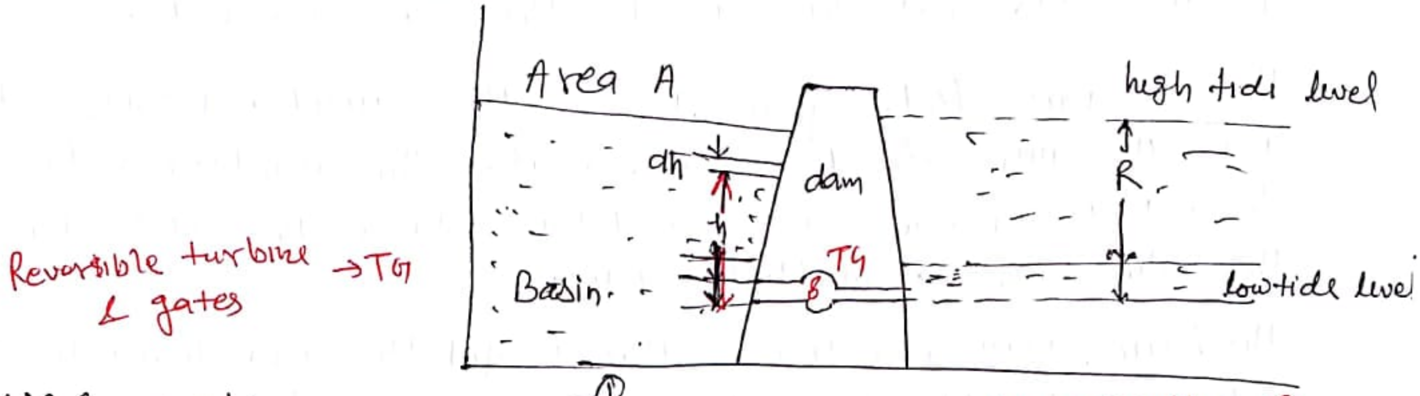
Double Basin arrangement: — It requires two separate but adjacent basins. In one basin called upper basin (or high pool), the water level is maintained above that in the other, the low basin (or low pool). Because there is always a head b/w upper & lower basins, electricity can be generated continuously through at a variable rate.



In this system the turbines are located in b/w the two adjacents basins, while sluice gates are as usual embodied in the dam across the mouths of the two estuaries. At the beginning of the flood tide, the turbines are shut down, the gates of upper basin A are opened & those at the lower basin B are closed. The basin A is thus filled up while the basin B remains empty. As soon as the rising water level in A provides sufficient difference of head b/w two basins, the turbines are started. The water flows from A to B through the turbines, generating power

Estimate of energy & power in ~~Sign~~ Single basin tidal system:—

Considering a tidal range R, & intermediate head, at given time, the amount of work is calculated, considering a small head dh, for a intermediate head h.



we can write $dw = dm\, g\, h$ ~~&dm = ρ A dh~~ —(I) $dm = \rho A dh$ —(II)

$dw = +\rho A dh \cdot g h$ —(III)

where W = work done by water (Joule) or (kcal/kg) g = gravitational const, m = mass flowing through turbine (kg) h = head (m) ρ = water density ($\frac{kg}{m^3}$), A = basin surface area (m^2)

The total theor work during a full empting (or filling) period is obtained by integrating eqn (III)

$$W = \int_0^R dw = +\rho g A \int_0^R h\, dh = \frac{1}{2} g A \rho R^2$$

The avg theoretical power delivered by the water is W divided by total time it takes each period to repeat itself. Duration is 6 hr, 12.5 min

Thus average theoretical power in watts

$$P_{avg} = \frac{W}{time} = \frac{g \rho A R^2}{2 * 22350\,sec}$$

Q A tidal power plant of the simple single basin type, has a basin area of $30*10^6 m^2$. The tide has a range of 12 m. The turbine, however, stop operating when the head on it falls below 3 m. Calculate the energy generated on filling (or empting) process, in kWh if the turbine efficiency is 0.73.

Soln: Total theoretical work W

$= \int_r^R dw$ R = 12 m

r → head below turbine stop operating = 3 m

$$W = \int_r^R + g \rho A h\, dh = \frac{1}{2} g \rho A (R^2 - r^2)$$

Thus avg power $P_{avg} = \frac{g \rho A (R^2 - r^2)}{2 * 22350}$

$= \frac{1}{44700} * 9.8 * 1025 * 30*10^6 (12^2 - 3^2)$

$= 911.25 * 10^6$ watt

$= \frac{911.25}{1000} * 3600 * 10^6$ kWh.

$= 3280.5 * 10^6$ kWh.

Considering turbine generator efficiency, the energy generated

$= 3280.5 * 10^6 * 0.73$

$= 2395 * 10^6$ kWh Ans

Hydro Energy

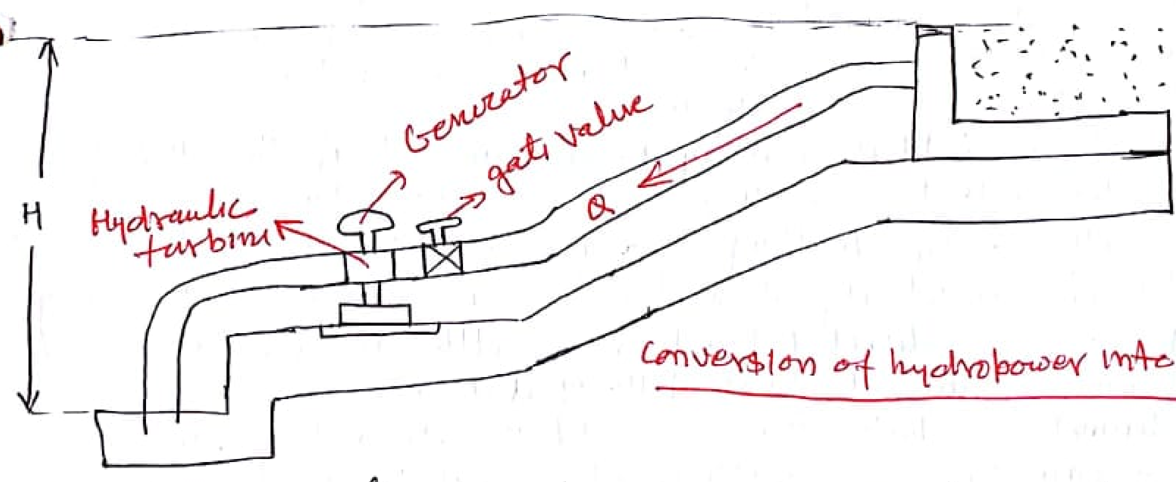
Hydroenergy is the energy derived from the power of moving water. Today large hydro electric power plants generate about 15% of the world electricity by extracting the potential energy which comes from the vertical distance that water drops is called the head.

Type of hydroelectric plants: Hydroelectric power plants are classified into three basic types according to the way they are operating

1) ~~Run~~ Run-of-River hydro plants. → Make separate canal for producing p.p.
II) Storage hydro plant ⟶ Through dam.
III) Pumped storage plants. → Through water pumped in reservoir

Conversion of hydro-power or Electric power generated from hydropower:

Electric power is generated when water from height is made to flow through hydraulic turbine. The hydraulic turbine converts the potential energy of water or kinetic energy of flowing stream into mechanical energy on its rotating shaft. The old style water wheels used the impulse generated by the weight of falling water for their rotation, but modern hydraulic turbines operated on the principle of impulse & reaction to convert kinetic energy & potential energy respectively into mechanical energy. The work done per second or power given by the flowing water can be given by following expression



Conversion of hydropower into energy

P = Potential energy of flowing water in turbine $= mgh$

$\because m$ = discharge * density $= Q * \rho$

$$P = \rho Q g H$$

An electric generator is directly coupled to the hydraulic turbine which converts the mechanical energy into electrical energy.

Q. A tidal power plant has reservoir of area $50*10^6\ m^2$. The tide has tidal range of 10 m. The turbine can be operational with a head of 3 m. The turbine generator has efficiency of 80%. Estimate the total power in on filling and emptying cycle.

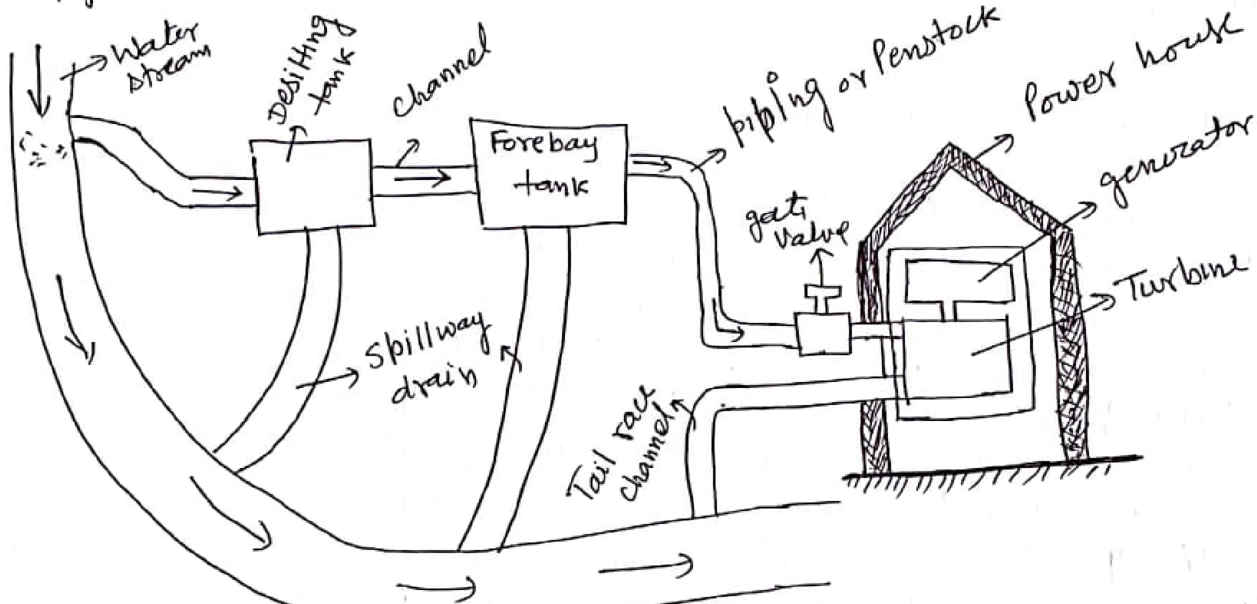
Sol^n

$$E = \rho g A \int_3^{10} h\,dh = \frac{91}{2} \rho g A = \frac{91*1025*9.8*50*10^6}{2} J$$

$$Power = \frac{E}{t} = \frac{91*9.81*1025*5*10^6}{2*22350} = \underline{1.024\ MW}$$

Various components of a hydropower plant or a microhydel scheme? :—

The components or features of microhydel schemes & their layout are shown in figure.



I) Diversion Structure: — small dams, barrages, salid boulder structures & trench type wiers are usually constructed to divert the required flow from the water streams into the intake structures. The diversion structure should be designed in such a way that it can be supplied water in all seasons & it should be reasonably safe against large floods.

II) Desilting tank — It is necessary to remove & trap the suspended matters, silt & pebbles so that no erosion or damage to the turbine can take place by these matters. The desilting tank is provided in the initial length of water channel. The velocity of water flow is reduced considerably in desilting tank for desilted matters to settle down. These are flushed out whenever required using spillway drain.

III) Water channel or conductor system: — It is design to ensure that the water flow can take place with least loss of head & loss of water. RCC duct, steel pipes ~~can be~~ & open tiled channel can be used as water conductor system

IV) Forebay tank: — Forebay is provided as a reservoir to hold sufficient water so that it can meet the water requirement to run the turbine for 4-6 hrs. It is also meant to ensure minimum head over the penstock intake is maintained so as to prevent any air entry into penstock. An overflow arrangement in the forebay tank is provided to discharge surplus water when water is not required by the turbine. (30)

V) Penstock: — The water from forebay tank is carried through penstock or pipeline to the turbine. MS pipe or RCC pipes can be used as the penstock.

VI) Tail race channel: — The water existing from the turbine is discharged through the tail race channel to water stream.