ENERGY FROM OCEANS

Broadly the ocean sources of energy are

i) ocean Thermal Energy energy Conversion (OTEC)
ii) wave energy
iii) Tidal Energy

These energy Resources except tidal are the result of absorption of Solar radiation by the water bodies, which causes ocean Currents and moderate temperature gradients from the water surface especially in tropical water. The Ocean and sea Constitute 70% of earth's surface area. So they represent a largest storage reservoir of solar input.

The Conversion of solar energy stored as heat in the ocean into electrical energy by making use of temperature difference between warmer surface and Cold deeper water is Ocean Thermal Energy (OTEC) (or) Solar Sea power plant(SSPP)

The operation of OTEC plant is based on Thermo dynamic principle.

If heat source is available at high temperature and heat sink is at lower temperature, it is possible to utilize the temperature difference in turbine that can convert a part of heat to mechanical and into electrical Energy. In OTEC warmer surface Water is heat source and deeper cold water provides the Sink. The temperature gradient Can be utilized in the heat engine to generate power.

i) Ocean Thermal Energy Conversion (OTEC):

① The availability of thermo Energy System can be estimated as follows.

Total extra terristrial radiation received by earth $= 1.1516 \times 10^{18}$ Kwh/year

Avg clearness index $= 0.5$

Fraction of area of ocean $= 0.7$

∴ Total terristrial ocean thermal energy $= 1.1516 \times 10^{18} \times 0.5 \times 0.7$

$= 0.53 \times 10^{18}$ Kwh/year

Average terrestrial ocean thermal energy is 50% at solar constant

$= 1353\ W/m^2 \times 0.5$

$= 676\ W/m^2$

Annual evaporation $= 120\ cm$

$= 120\ cm^3/cm^2$

$= 1.20\ m^3/m^2$

The latent heat of vaporization $= 24\cancel{4}^{5}4\ kJ/kg$

Sea water density $= 1000\ kg/m^3$

Total annual energy absorbed $= 1.20 \times 1000 \times 24\cancel{4}^{5}4$

$= 3 \times 10^6\ kJ/m^2$

$= 95\ W/m^2$

Total absorbed energy $= \frac{95}{676} \times 100$

$= 14\%$

Ocean Power:

What is OTEC?

- OTEC, or Ocean Thermal Energy Conversion, is an energy technology that converts solar radiation to electric power.
- OTEC systems use the ocean's natural thermal gradient—the fact that the ocean's layers of water have different temperatures—to drive a power-producing cycle.
- As long as the temperature between the warm surface water and the cold deep water differs by about 20°C (36°F), an OTEC system can produce a significant amount of power with a maximum Efficiency of about 6.7%.

Lambert's Law

Solar Energy absorption by the water takes place according to Lambert's Law of absorption, which states that each layer of equal thickness absorbs the same fraction of light that passes through it.

$$\frac{-dI_{(x)}}{dx} = kI$$

$$I_{(x)} = I_0 e^{-kx}$$

Where I_o and $I_{(x)}$ are intensities of radiation at the surface(x=0) and at a distance x below the surface. K is the extinction coefficient and it has the value 0.05 for very clear fresh water, 0.27 for turbid fresh water and 0.5 for very salty water.

- ➢ Intensity decreases exponentially with depth and depending upon K value almost all the absorption takes place very close to the surface water. Maximum temperature occur just below the top surface of water.
- ➢ Deep water remains cool
- ➢ There will not be thermal convection currents between the warmer, lighter surface water and cool heavier water at the depth
- ❖ In the tropics, the ocean surface temperature often exceeds 25 C while 1Km below temperature is not higher than 10C

- ❖ A heat engine can be made to work between these two temperatures and power can be obtained

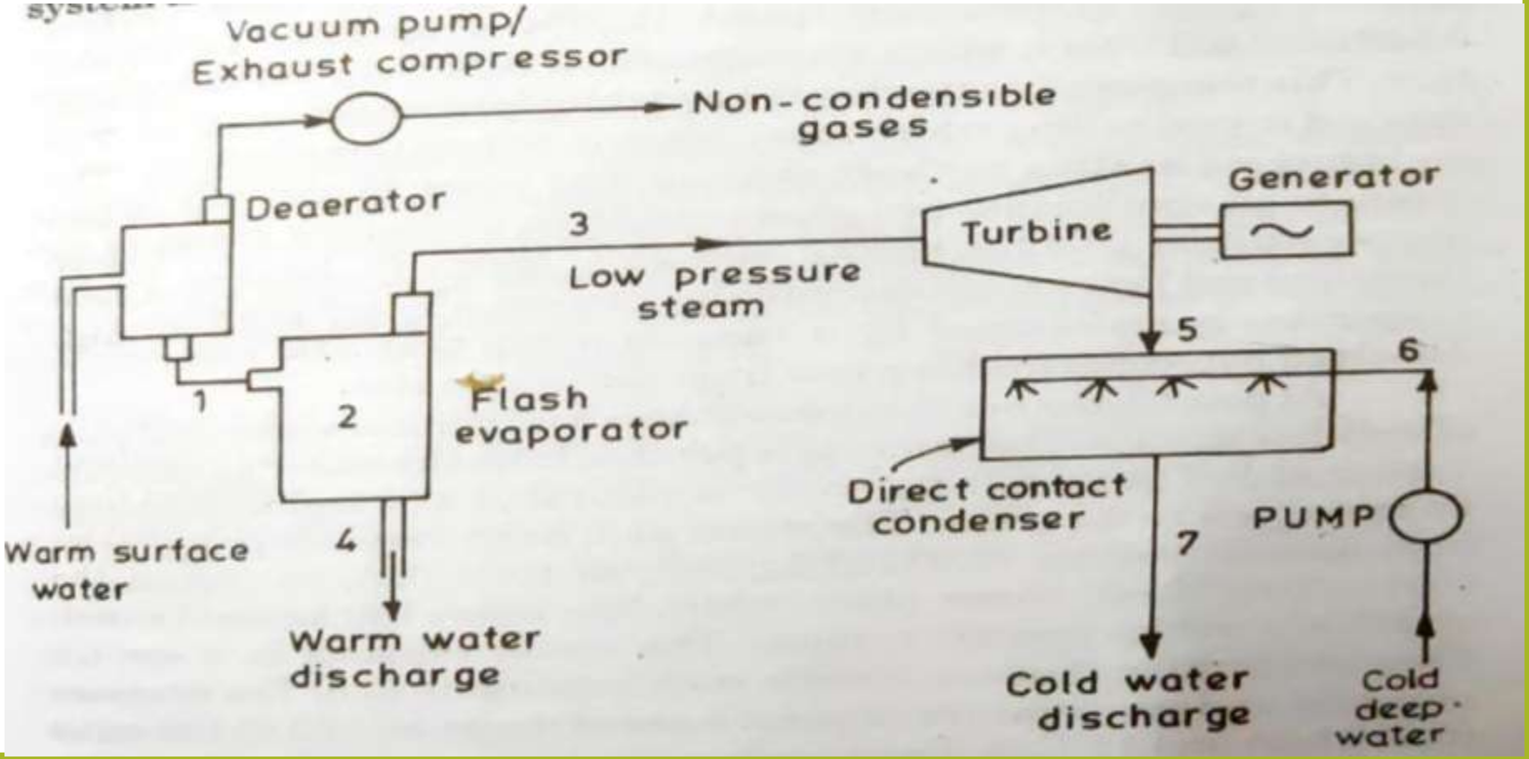
Methods of ocean thermal electric power generation

- There are two rather different methods for harnessing ocean thermal differences. One is the open cycle, also known as the Claude cycle, and
- Other is the closed cycle system, also known as the Anderson

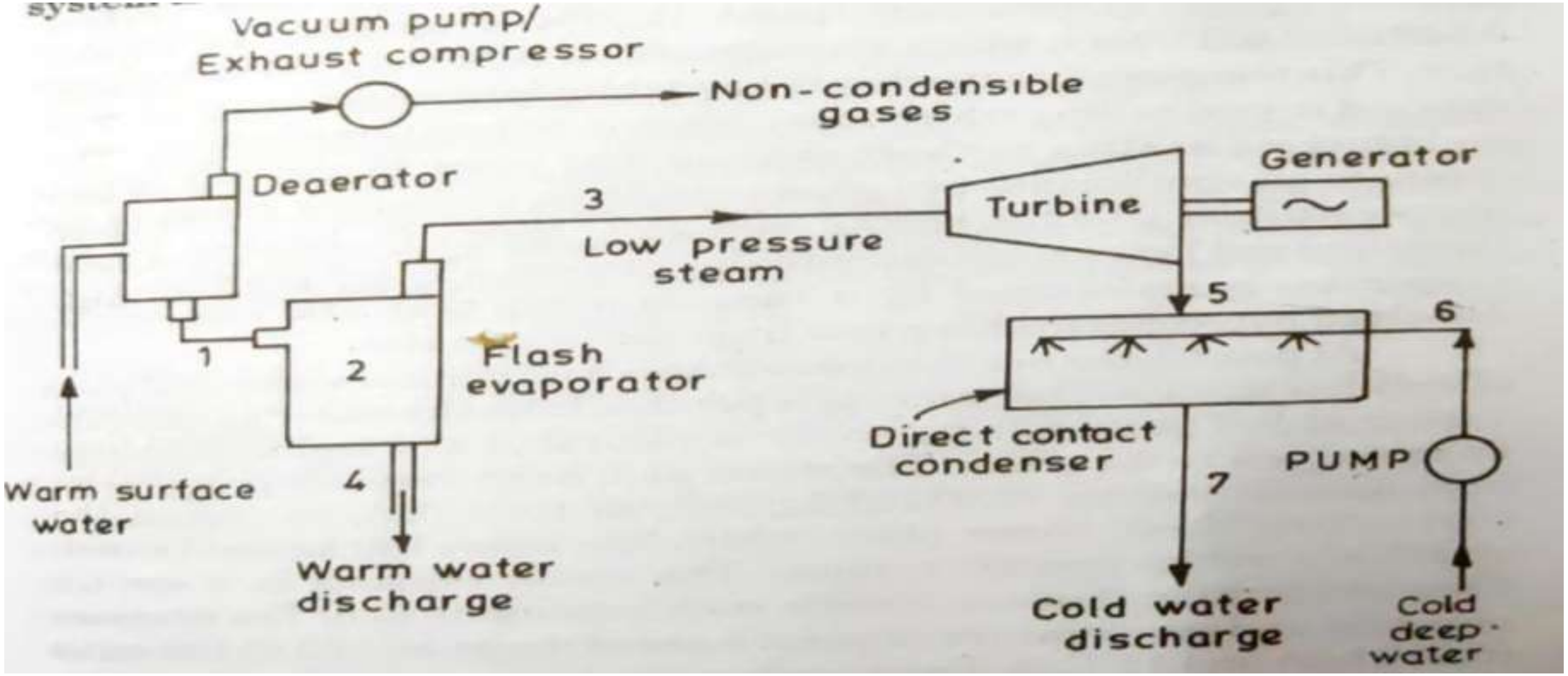
Open cycle OTEC System (Claude cycle)

"Open cycle' refers to the utilization of sea water as the working fluid, wherein sea water is flash evaporated under a partial vacuum.

The low pressure steam is passed through a turbine, which extracts energy from it, and then the spent vapour is cooled in a condenser. This cycle drives the name 'open' from the fact that the condensate need not be returned to the evaporator, as in the case of the closed cycle'.



Instead, the condensate, can be utilized as desalinated water if a surface con denser is used, or if a spray (direct-contact) condenser is used, the condensate is mixed with the cooling water and the mixture is discharged back into the ocean. A schematic diagram of the open cycle system is shown in Fig. (9.2.3.1).



Because of the need in the open cycle to harness the energy low pressure steam, extremely large turbines (compared to wind turbines) must be utilized. Furthermore degasifiers (deaerators) must be used to remove the gases dissolved in the sea water unless one is willing to accept large losses in efficiency. On the other hand, since there are no heat transfer problems in the evaporator, the problem of losses is minimized. The cost of an open-cycle system for providing substantial number of megawatts is presently regarded by most OTEC workers as being significantly greater than for closed cycle system. The turbine cost constituted almost half the cost of the power system, but may be amenable to reductions that could result from design innovations.

The Closed or Anderson OTEC Cycle

A schematic of a closed-cycle OTEC power plant is shown in Fie 9.24 1. Heat exchanger known as evaporators and condensers are key ingredient. since extensive areas of material are needed to transfer significant amount of low quality heat of the low temperature differences being exploited. In other words large volumes of water must be circulated through the OTEC power plant requiring commensurately large heat exchangers.

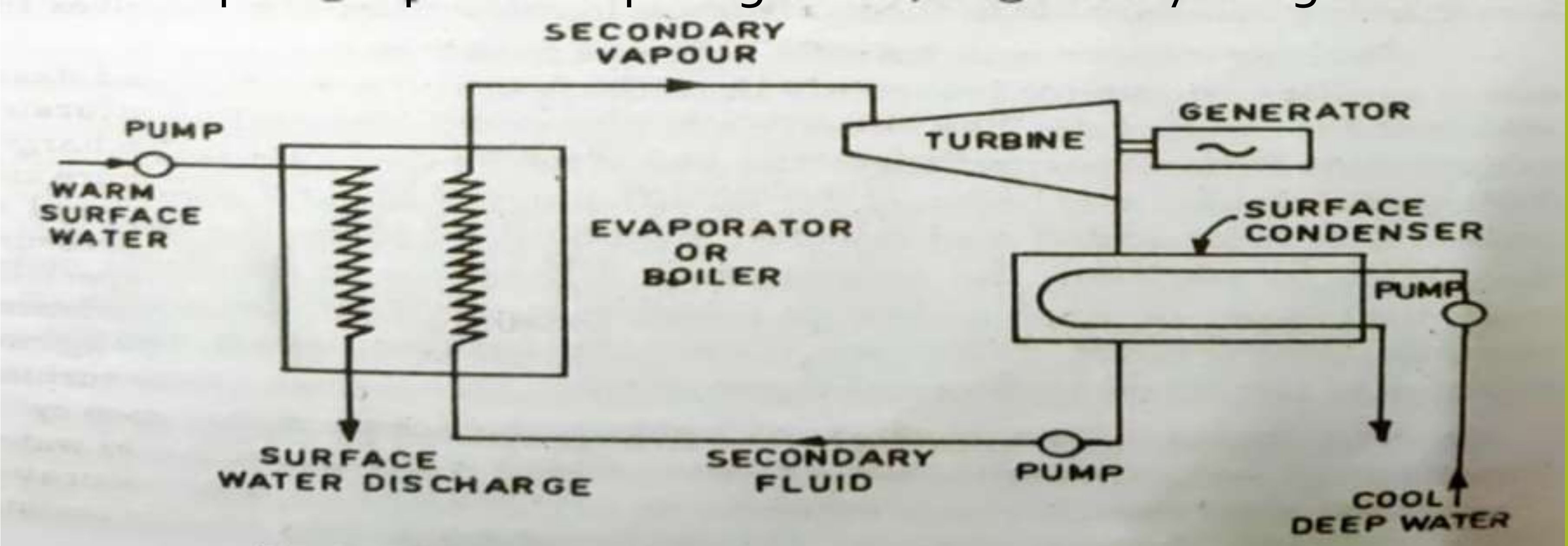


Fig. 9.2.4.1. Schematic of an OTEC closed cycle system.

This cycle requires separate working fluid that receives and rejects heat to the source and sink via heat exchangers (boiler or evaporator and surface condenser). The working fluid may be ammonia, propane, or a Freon. The operation (saturation) pressure of such fluids at the boiler and condenser temperatures are much higher than those of water, being roughly 10 kg/em²e10 bar) at the boiler, and their specific volumes are much lower, being comparable to those of steam in conventional power plant.

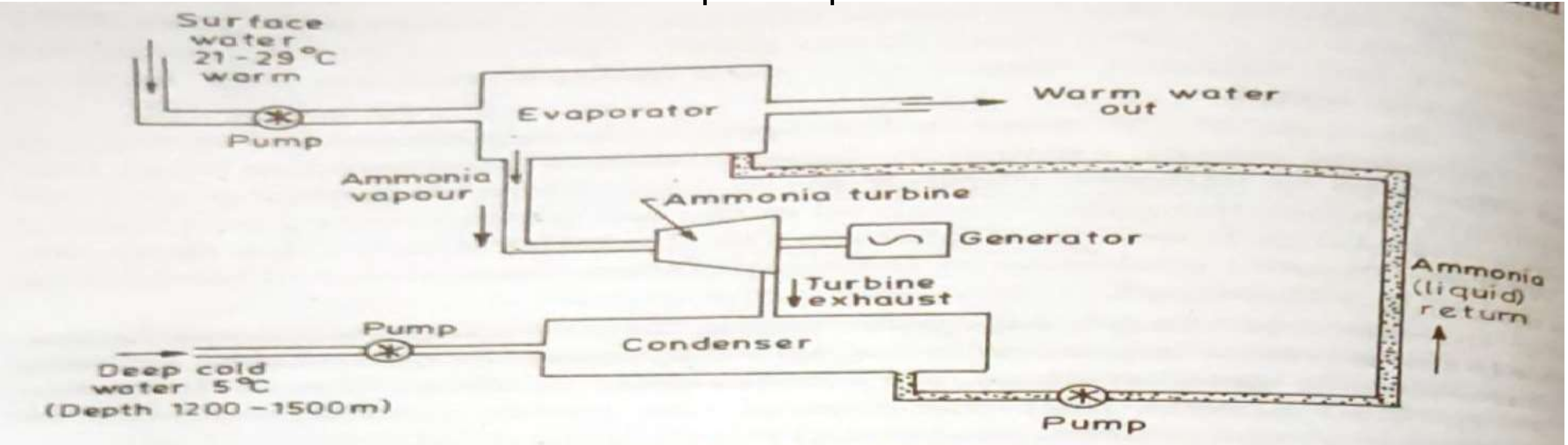


Fig. 9.2.4.2. Schematic of a closed OTEC ammonia cycle.

Such pressure and specific volumes result in turbines that are much smaller and hence less costly than those that use the low pressure steam of the open cycle. The closed cycle also avoids the problems of the evaporator. Although both closed-and open cycle turbine systems are being explored, it appears that closed-cycle systems offer the most promise for the near future. Each of the possible working fluids (i.e. ammonia and propane) has advantages and disadvantages. Ammonia has better operating characteristics than propane and it is much less flammable. On the other hand ammonia forms a noxious vapour and probably could not be used with copper heat exchanger (see below). Propane is compatible with most heat- exchanger materials, but it is highly flammable and forms an explosive mixture with air. Ammonia has been used as the working fluid in successful tests of the OTEC concept with closed cycle systems.

Site Selection

In selecting a site for an OTEC facility, the primary consideration is, of course, a significant temperature difference at least about 20°C between surface and deep ocean waters (for 700-900 m depth or more) that will permit year round operation. The greater the difference, the lower will be the cost of generating electricity. The best sites are in the tropical belt between about 20°N and 20°S latitude. There are, however, several locations outside this area, that might be suitable for OTEC plants. In choosing a site, consideration should be given to the potential for bio-fouling effects as noted earlier. As a general rule, an OTEC plant would be located offshore in order to provide access to the deep colder water. Most of the installation could then be more conveniently build on land.

Prospects of Ocean Thermal Energy Conversion in India

OTEC project cell established at IIT, Madras has completed the preliminary feasibility study for establishing a, 1 MW OTEC plant in Lakshadweep Island at Minicoy. Preliminary oceanographic studies on eastern side of Lakshadweep Island suggest the possibility of the establishment of shore based OTEC plant at the island with a cold water pipe line running down the slope to a depth of 800-1000 m. Both the island have large lagoons on the western side. The lagoons are very shallow with hardly any nutrient in the sea water. The proposed OTEC plant will bring up the water from 1000 m depth which has high nutrient value. After providing cooling effect in the condenser, a part of deep sea water is proposed to be diverted to the lagoons for the development of aqua culture. A hydrographic survey of the proposed site was undertaken by National Hydrographic Office, Dehradun. The preliminary assessment of survey indicates the availability of suitable conditions for establishment of OTEC plant.

Hybrid Cycle

There are several variations on the standard OTEC open-cycle system. One variation is the "hybrid cycle" which is an attempt to combine the best features and avoid the worst features of the open and closed cycles. sea water is flash evaporated to steam, as in the open cycle. The heat in the resulting steam is then transferred to ammonia in an otherwise conventional closed Rankine cycle system.

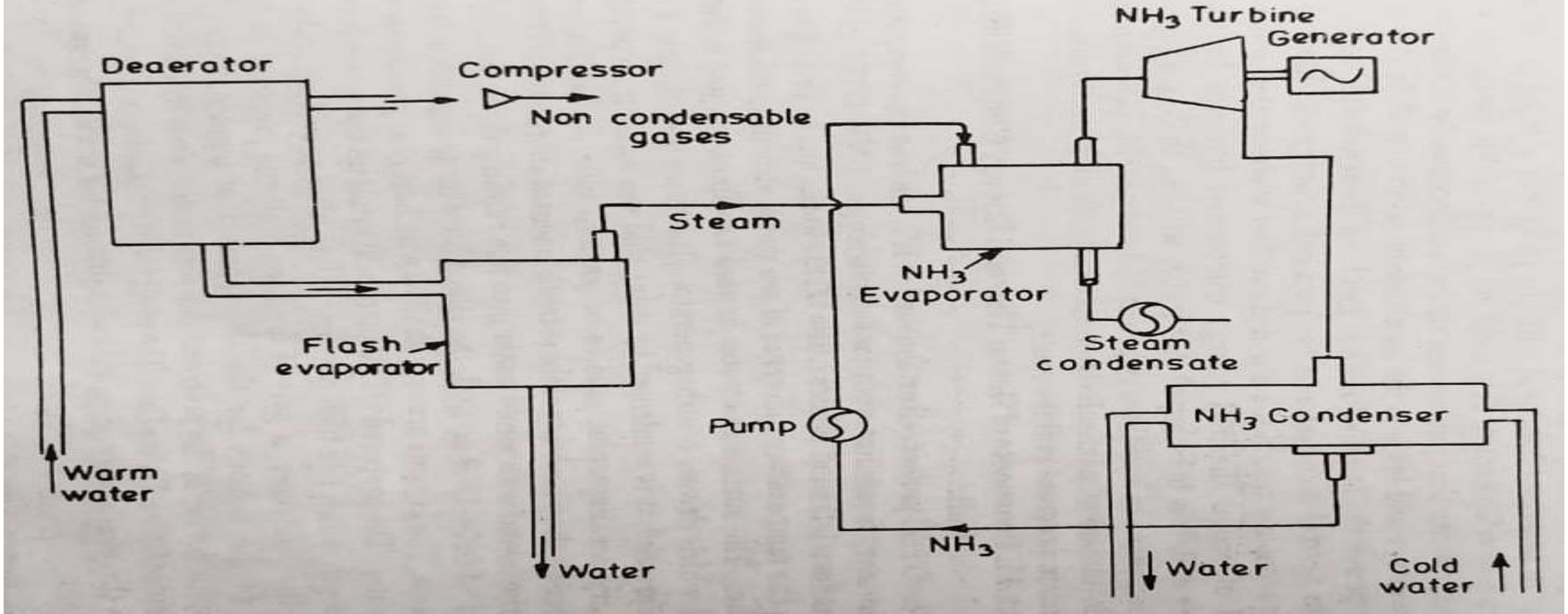


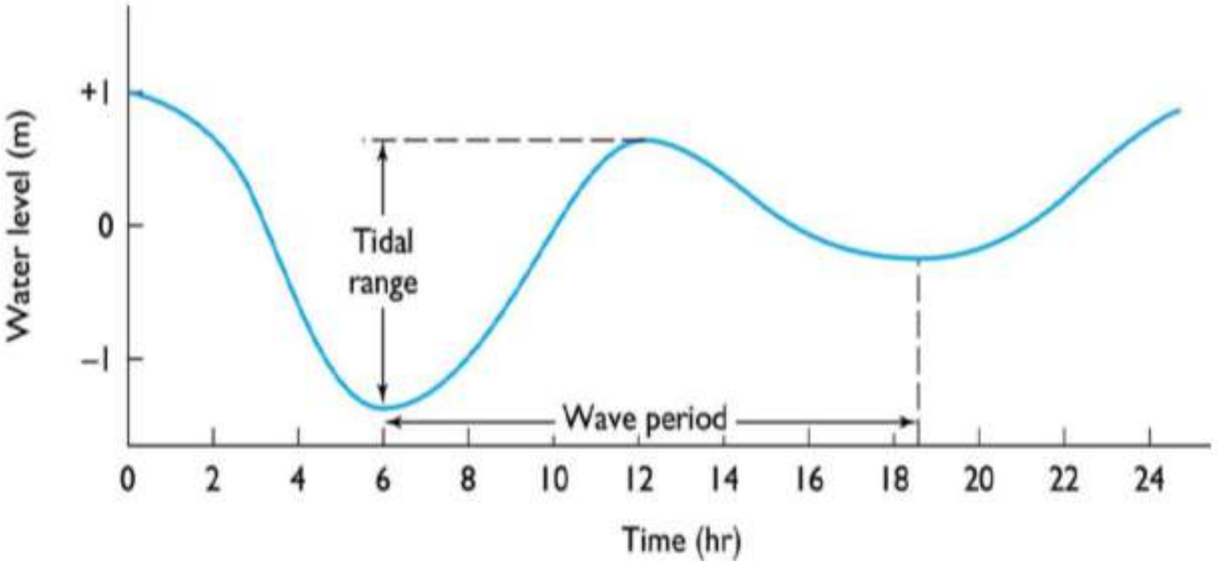
Fig. 9.2.5.1. Hybrid Cycle.

TIDAL POWER

What is tidal power? Tide is periodic rise and fall of the water level of the sea. Tides occur due to the attraction of seawater by the moon. These tides can be used to produce electrical power which is known as tidal power.

- Tides have a wave form, but differ from other waves because they are caused by the interactions between the ocean, Sun and Moon.
- Crest of the wave form is high tide and trough is low tide.
- The vertical difference between high tide and low tide is the tidal range.
- Tidal period is the time between consecutive high or low tides and varies between 12 hrs 25 min to 24 hrs 50 min.

When the water is above the mean sea level, it is called high tide and when the level is below the mean level, it is called low tide. A dam is constructed in such a away that a basin gets separated from the sea and a difference in the water level is obtained between the basin and sea. The constructed basin is filled during high tide and emptied during low tide passing through sluices and turbine respectively. The Potential energy of the water stored in the basin is used to drive the turbine which in turn generates electricity as it is directly coupled to an alternator.



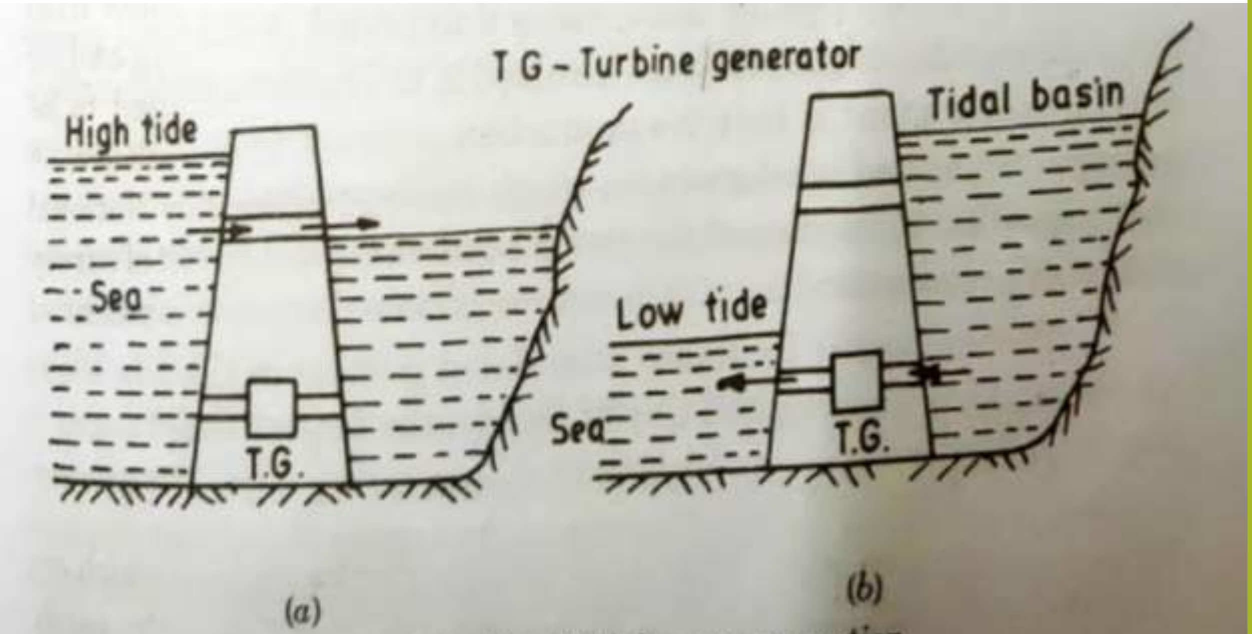


Fig. 9.3.1. Principle of Tidal power generation.

Factors affecting the suitability of the site for tidal power plant

1. The power produced by a tidal plant depends mainly on the range of tide and tidal flow during a tidal cycle which can be stored.
2. The minimum average tide range required for economical power production is more.

3. The site should be such that with a minimum cost of barrage it should be possible to create maximum storage volume. In addition to this, the site selected should be well protected from waves action.

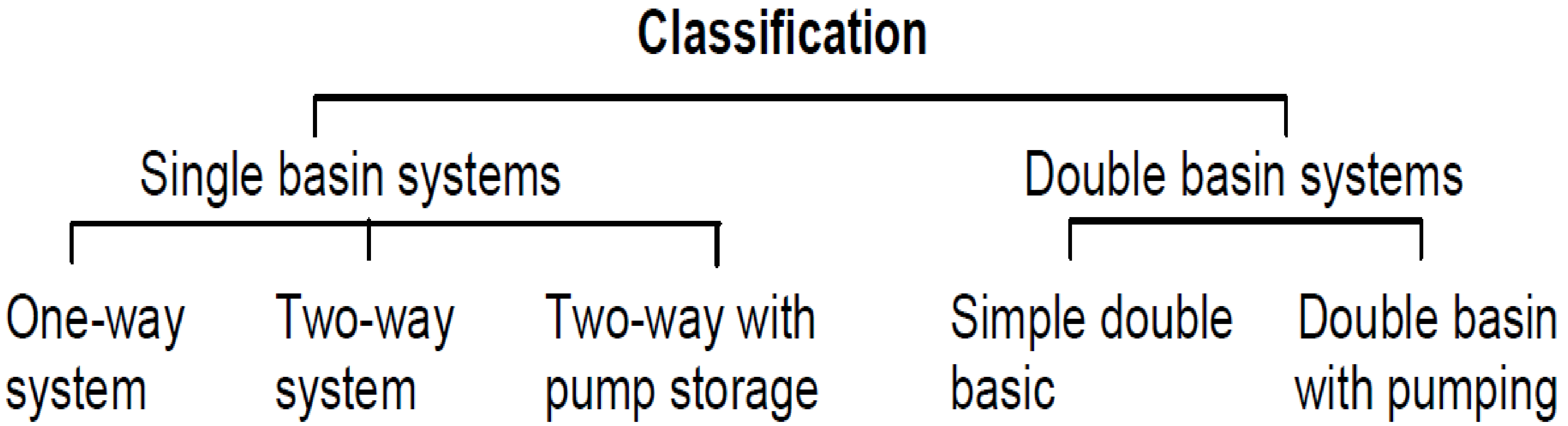
4. The site should not create interruption to the shipping traffic running through the estuary other wise the cost of the plant will increase as locks are to be provided.

5. Silt index of the water of the estuary should be as small as possible to avoid the siltation troubles.

Classification of tidal Power Plants

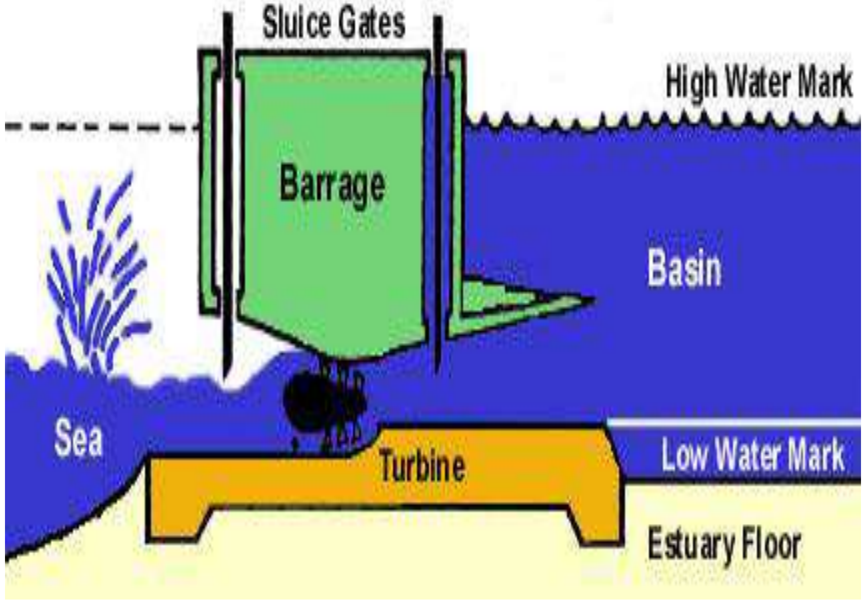
The tidal power plants are generally classified on the basis of the number of basins used for the power generation. They are further subdivided as one-way or two-way system as per the cycle of operation for power generation.

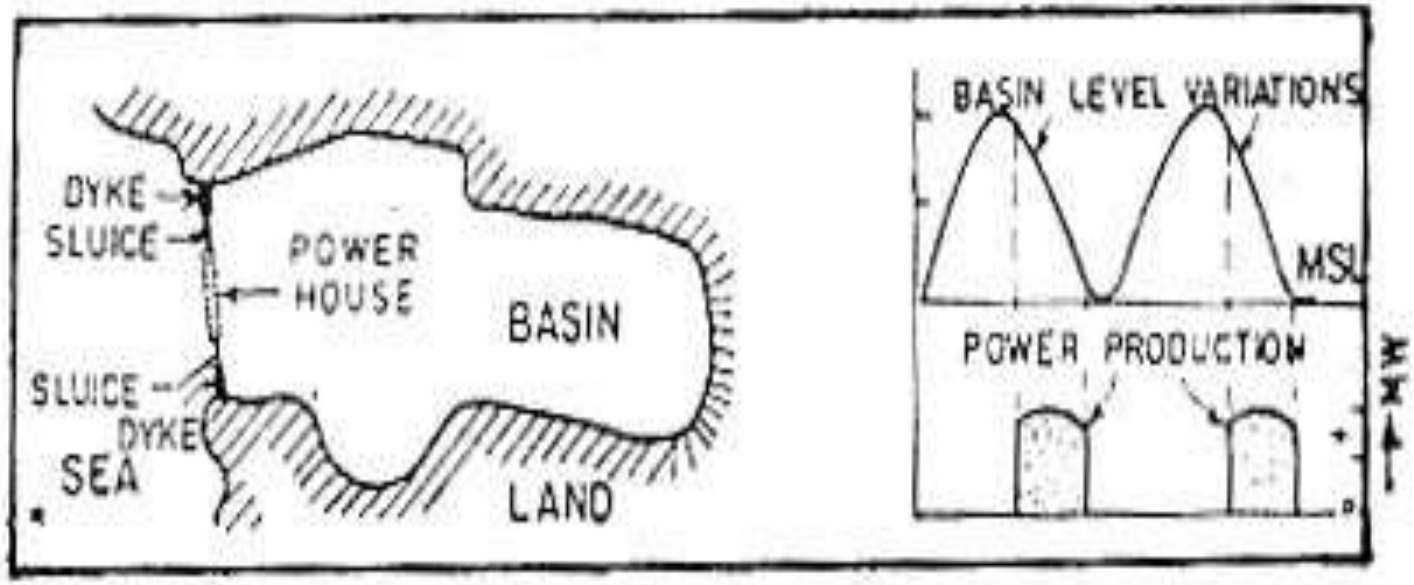
The classification is represented with the help of a line diagram as given below



Single basin-One-way cycle

This is the simplest form of tidal power plant. In this system, a basin is allowed to get filled during flood tide and during the ebb tide. The water flows from the basin to the sea passing through the turbine and generates power. The power is available for a short duration during ebb tide.



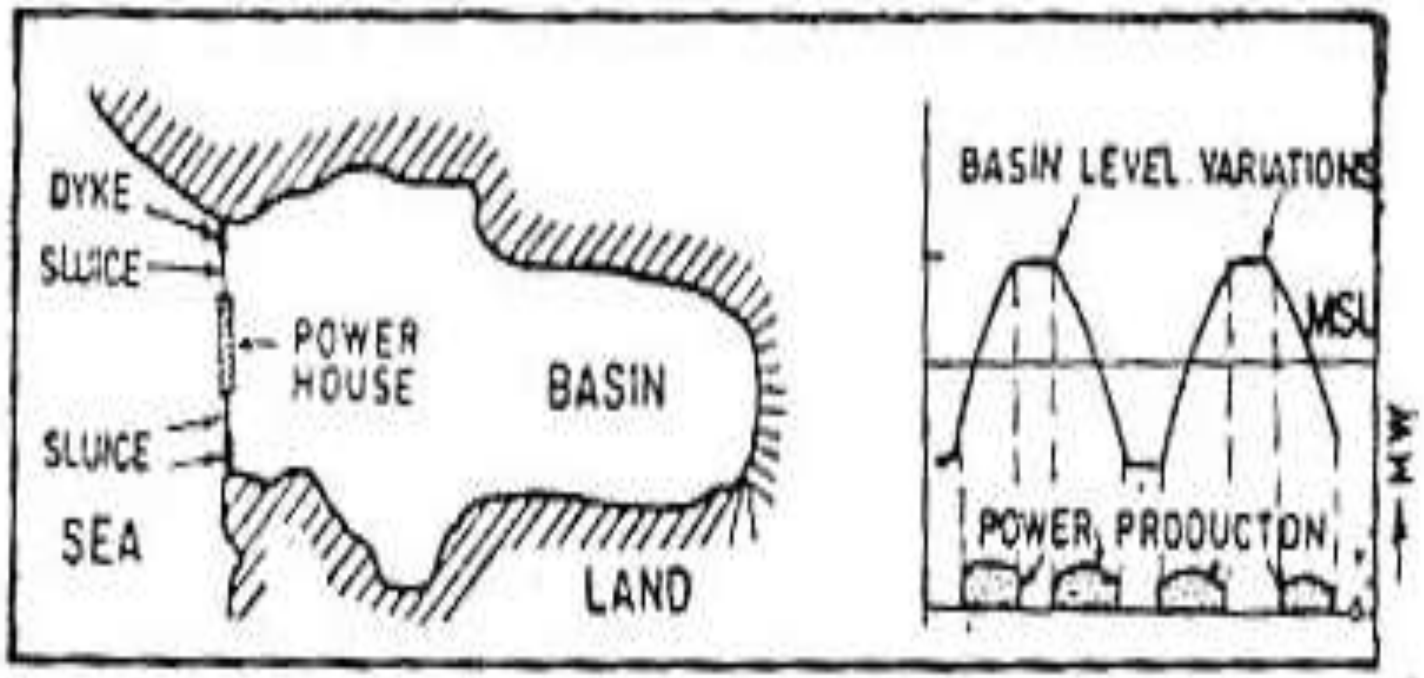


(b) Single basin, one-way tidal power plant.

Single-basin two-way cycle

In this arrangement power is generated both during flood tide as well as ebb tide also. The power generation is also intermittent but generation period is increased compared with one-way cycle. However the peak power obtained is less than the one-way cycle.

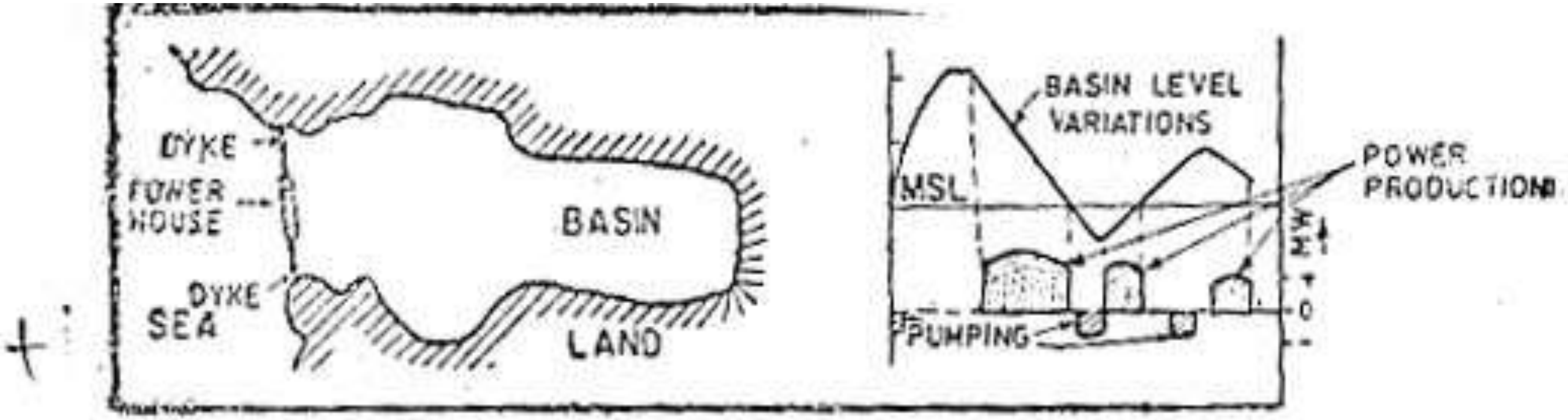
The main difficulty with this arrangement, the same turbine must be used as Prime mover as ebb and tide flows pass through the turbine in opposite directions. Variable pitch turbine and dual rotation generator are used for such schemes.



Single-basin two-way tidal power plant.

Single-basin two-way cycle with pump storage

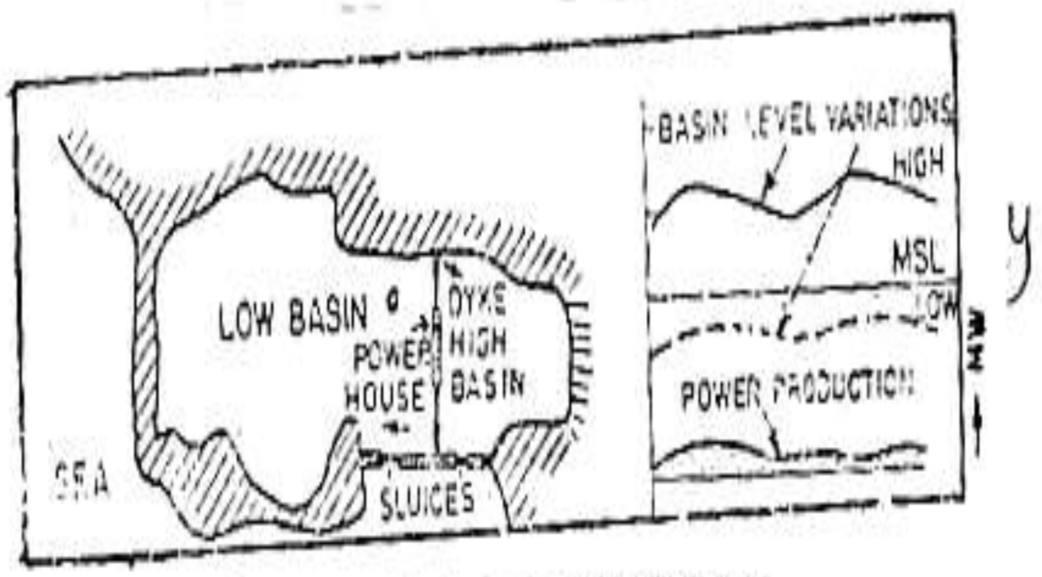
In this system, power is generated both during flood and ebb tides. Complex machines capable of generation Power and Pumping the water in either directions are used. A part of the energy produced is used for introducing the difference in the water levels between the basin and the sea at any time of the tide and this is done by pumping water into the basin up or down. The period of power production with this system is much longer than the other two described earlier.



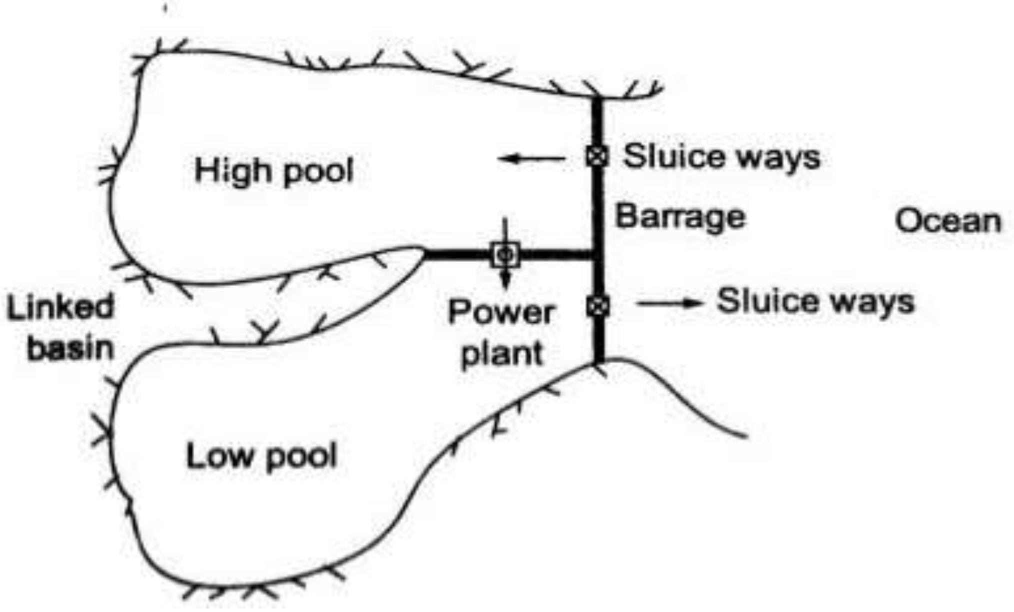
Single-basin, two-way tidal plant coupled with pump storage system.

Double basin type

In this arrangement, the turbine is set up between the two basins .one basin is intermittently filled by the flood tide and other is intermittently drained by the ebb tide. Therefore a small capacity but continuos power is made available with this system as shown in Fig. The main disadvantage of this system is that 50% of the Potential energy is sacrificed in introducing the variation in the water levels of the two basins.



Double basin, one-way tidal plant.



Double basin with Pumping

In this case, off peak power from the base load plant in a interconnected transmission system is used either to pump the water up the high basin. Net energy gain is possible with such a system if the pumping head is lower than the basin-to-basin turbine generating head.

Advantages and disadvantages of Tidal Power Plants

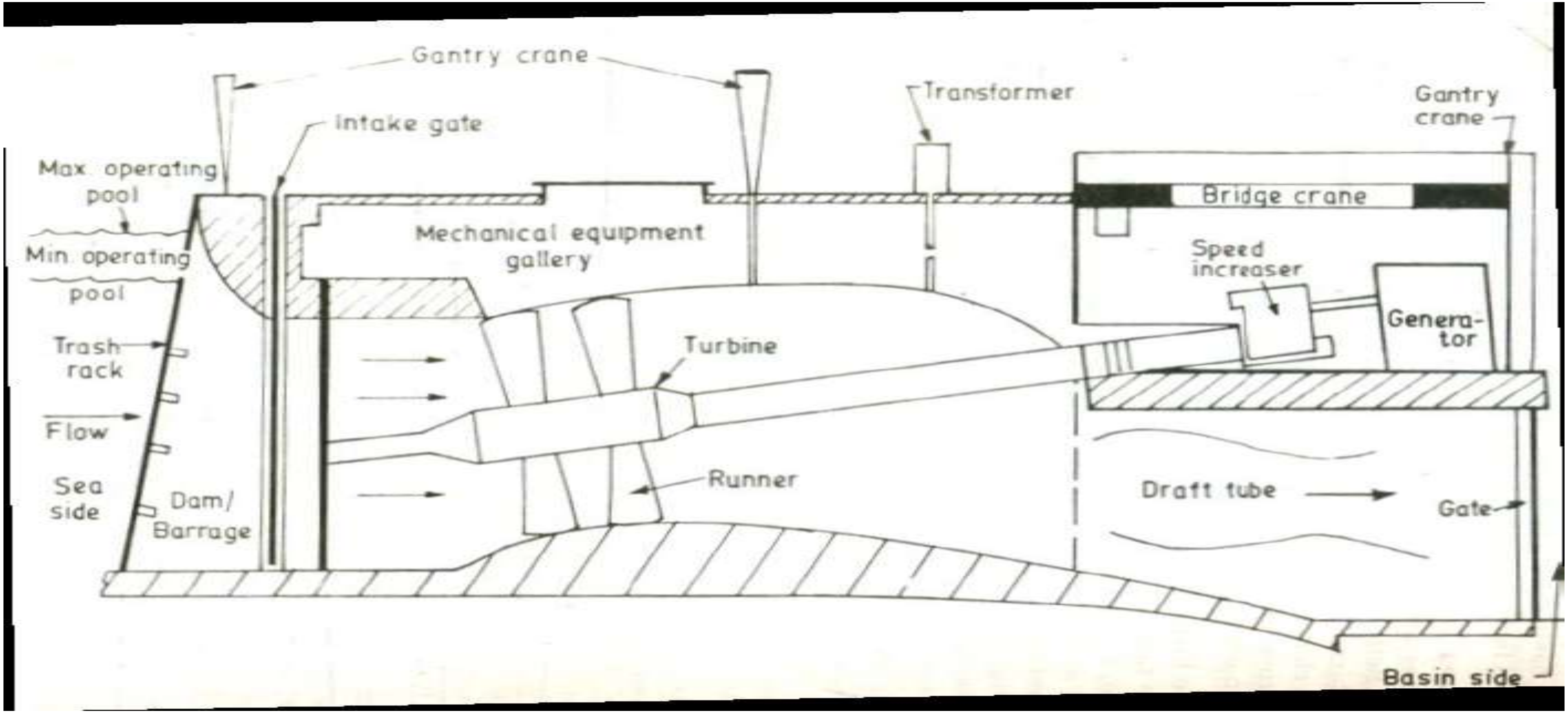
Advantages

1. Exploitation of tidal energy will in no case make demand for large area of valuable land because they are on bays.
2. It is free from pollution as it does not use any fuel.
3. It is much superior to hydro-power plant as it is totally independent of rain which always fluctuates year to year. Therefore, there is certainty of power supply a the tide cycle is very definite.
4. As in every form of water power, this will also not produce any unhealthy waste like gases, ash, atomic refuse which entails heavy removal costs.
5. Tidal Power is superior to conventional hydro power as the hydro plants are know for their large seasonal and yearly fluctuations in the output of energy because they are entirely dependent upon the nature's cycle of rainfall, which is not the case with tidal as monthly certain power is assured. The tides are totally independent on nature's cycle of rainfall.

Disadvantages

1. These Power plants can be developed only if natural sites are available.
2. As the sites are available on the bay which will be always far away from the load centers. The power generated must be transported to long distances. This increases the transportation cost.
3. The supply of power is not continuous as it depends upon the timing of tides. Therefore some arrangements (double basin or double basin with pump storage) must be made to supply the continuous power. This also further increases the capital cost of the plant.
4. The capital cost of the plant (Rs.5000/kw) is considerably large compared with conventional-power plants (hydro, thermal)
5. Sedimentation and siltration of the basins are some of the added problems with tidal power plants.
6. The navigation is obstructed.

Components of a tidal power station:



(i) Power House
(ii) The Dam or Barrage
(iii) Sluice ways from basin to sea and vice versa

POWER HOUSE:

Large size turbines are needed to because of small head available. Hence power house will also be large structure. The types of turbines used are

(i)Bulb type:

In systems with a bulb turbine, water flows around the turbine, making access for maintenance difficult, as the water must be prevented from flowing past the turbine.

(ii) Rim type:

Rim turbines reduce these problems as the generator is mounted in the barrage, at right angles to the turbine blades. Unfortunately, it is difficult to regulate the performance of these turbines and it is unsuitable for use in pumping.

(iii)Tubular type:

Tubular turbines have been proposed for use some UK projects. In this configuration, the blades are connected to a long shaft and orientated at an angle so that the generator is sitting on top of the barrage.

DAM (Barrage):

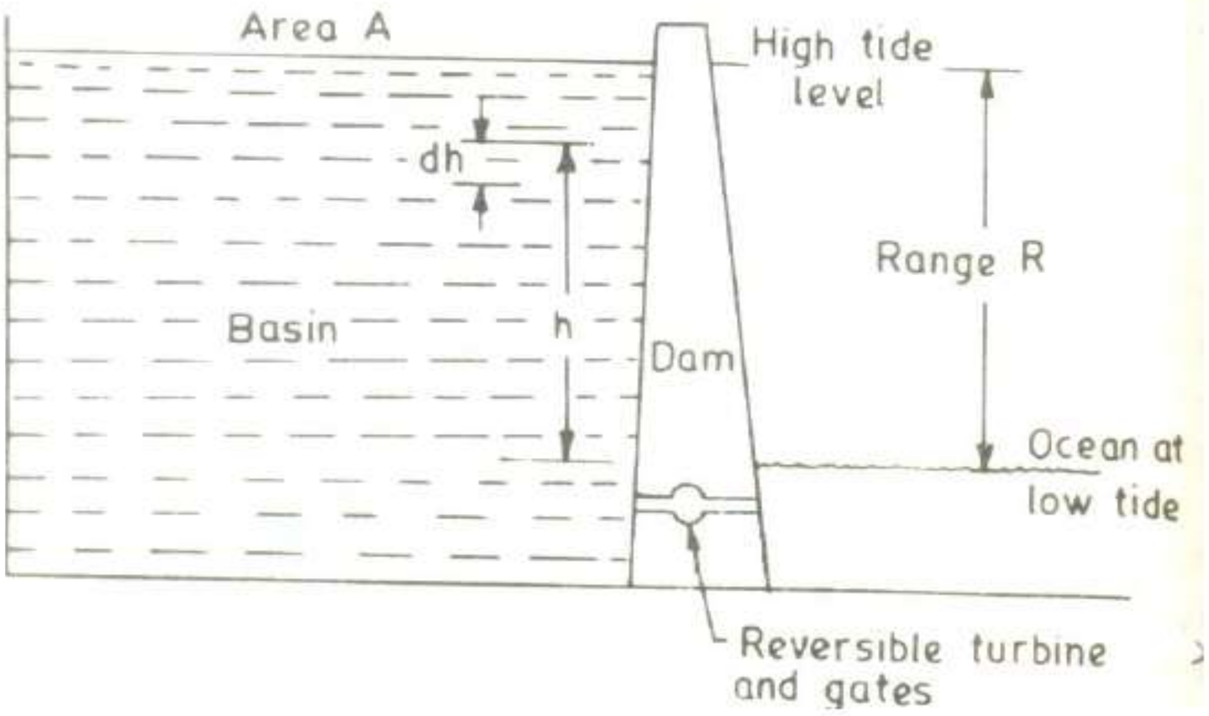
The barrages store water behind them. The barrages should provide channels for the turbines, gates and locks. The tidal power barrages should be of shorter length. The length should be less than resonant length of tidal waves. The tidal barrages require sites where a sufficiently high tidal range is available. The barrages require flat bottom.

Gates and Locks

Tidal power basins have to be filled and emptied. Gates are opened regularly and frequently but heads very in height and on the side where they occur, which is not the case with conventional river projects. The gates must be opened and closed rapidly and this operation should use a minimum of power. Leakage, is tolerable for gates and barrages. Since we are dealing with seawater, corrosion problems are actuate, they have been very successfully solved by the catholic protection and where not possible by paint. Gate structures can be floated as modular units into place.

The sluice ways are used either to fill the basin during the high tide or empty the basin during the low tide, as per operational requirement. These are gate controlled devices.

Estimation of tidal power:
Single basin system:



We can write

$$dw = dm.g.h$$

$$dm = -\rho A\, dh$$

$$dw = -\rho A\, dh\, g\, h$$

Where

W=work done by water in joules

g=gravitational constant

m=mass flowing through the turbine, Kg

h=head. m

ρ=water density,Kg/m^3

A=basin surface area in m^2

The total amount of work during a full emptying or filling is given by

$$W = \int_R^0 dw = -g\rho A \int_R^0 h\, dh$$

$$= \frac{1}{2} g\rho A\, R^2$$

The power is rate of doing work. The time taken for producing power once is tidal period. Tidal wave has period equal to6h,12.5min i.e,22350seconds.

$$P_{av} = \frac{W}{Time} = \frac{\frac{1}{2}}{22350} g\rho A\, R^2$$

$$= \frac{1}{44700}\, g\rho A\, R^2$$

Assuming an average water density as 1025Kg/m³, The average power per unit basin area is given by, Assuming an average water density as 1025Kg/m³, The average power per unit basin area is given by,

$$\frac{P_{av}}{A} = \frac{1}{44700} \times 9.81 \times 1025 \times R^2$$

$$= 0.225R^2 \text{ watts/m}^2$$

Example problem:

A Tidal power plant of the simple single basin type has a basin area of $30X10^6$ m^2. The tide has a range of 12m. The turbine however stops operating when the head falls below three meters.Calculate the energy generated in one filling(or emptying) process, in KW hours if the generator efficiency is 0.73.

Solution

The total theoretical Work $W = \int_R^r dw$

Here R=12m

R=the head below turbine stops operating=3m

$$W = \int_R^r -g\rho Ah\, dh = -g\rho A \int_R^r h\, dh$$

$= \frac{1}{2}\, g\rho A(R^2 - r^2)$

Thus the average power

$$P_{av} = \frac{W}{time}$$

$$= \frac{\frac{1}{2}\, g\rho A(R^2 - r^2)}{44700}$$

The average power generated

$$= \frac{1}{44700} \times 9.81 \times 1025 \times 30 \times 10^6 \times (12^2 - 3^2) Watts$$

$= \frac{1}{44700} \times 9.81 \times 1025 \times 30 \times 10^6 \times 135\, watts$

$$= 911.25 \times 10^6 \text{ watts} = \frac{911.25}{1000} \times 3600 \times 10^6 \text{kWh}$$

$$= 3280.5 \times 10^6 kWh$$

Considering turbine generator efficiency, the energy generated

$$= 3280.5 \times 10^6 \times 0.73 = 2395 \times 10^6\ kWh$$

9.3.6. Estimation of Energy and Power in a double cycle system

In a double cycle system, the estimate of energy and power can be made as per usual calculation of power in a hydropower plant, *i.e.* considering the average discharge and available head at any instant. Then total energy can be obtained by integrating the value of instantaneous power. The energy that is available for a tidal plant depends upon the range of the tide and volumetric capacity of the basin. The power from the plant is generally obtained in parts, in duration of 3 to $3\frac{1}{2}$ hrs in a flood tide cycle and for equal duration in an ebb cycle. There are approximately 705 full tidal cycle in a year. The power or total energy is first calculated per tidal cycle and then yearly total energy generated can be obtained as explained below :

Let V be the volume of the basin

$$V = Ah_0 \qquad \text{...(9.3.6.1)}$$

where A is the average cross sectional area of the basin in m^2, and h_0 is the difference between maximum and minimum water levels.

$$\therefore \text{ Average discharge } Q = \frac{Ah_0}{t} \qquad \text{...(9.3.6.2)}$$

t is the total duration of generation in one filling/emptying operation.

Now power generated at any instant

$$P = \frac{\rho Q h}{75} \times \eta_0, \text{ H.P.} \quad \text{...(9.3.6.3 } a)$$

$$= \frac{\rho Q h}{75} \times \eta_0 \times 0.736, \text{ kW} \quad \text{...(9.3.6.3 } b)$$

where ρ is the average density of sea water = 1025 kg/m^3,

h is the available heat at the instant,

Then total energy

$$= \int_0^t P\,dt = \int_0^t \frac{\rho Q h}{75}\,dt \times \eta_0 \times 0.736 \text{ kW per tidal cycle} \quad \text{...(9.3.6.4)}$$

Then yearly power generation

$$= \int_0^t \frac{\rho Q h}{75}\,dt \times \eta_0 \times 0.736 \times 705 \text{ kWh/year.}$$

Example 9.3.6.1. The observed difference between the high and low water tide is 8.5 m, for a proposed tidal site. The basin area is about 0.5 sq km which can generate power for 3 hours in each cycle. The average available head is assumed to be 8 m, and the overall efficiency of the generation to be 70%. Calculate the power in h.p. at any instant and the yearly power output. Average specific weight of sea water is *assumed* to be 1025 kg/m^3.

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Solution. Volume of the basin $= Ah_0$

$$= 0.5 \times 10^6 \times 8.5 = 4.25 \times 10^6 \text{ m}^3$$

Average discharge $Q = \dfrac{\text{volume}}{\text{time period}} = \dfrac{Ah_0}{t}$

$$= \frac{4.25 \times 10^6}{3 \times 3600} = 0.03704 \times 10^6$$

$$= 393.5 \text{ m}^3/\text{s}$$

Power at any instant

$$P = \frac{Q\rho h}{75} \eta_0 \text{ h.p.}$$

$$= \frac{393.5 \times 1025 \times 8}{75} \times 0.70$$

$$= 310.15 \times 10^2 \text{ h.p. } \textbf{Ans.}$$

The total energy in kWh/tidal cycle

$$E = 301.15 \times 10^2 \times 0.736 \times 3 = 664.93 \times 10^2$$

Total number of tidal cycle in a year = 705

Therefore total output per annum

$$= 664.93 \times 10^2 \times 705$$

$$= 468.78 \times 10^5 \text{ kWh/year. } \textbf{Ans.}$$

Wave Energy

Wave energy is an irregular and oscillating low frequency energy source that can be converted to a 50 Hertz frequency and can then be added to the electric utility grid. Waves get their energy from the wind, which comes from solar energy. Waves gather, store, and transmit this energy thousands of kilometers with very little loss. Though it varies in intensity, it is available twenty four hours a day all round the year. Wave power is renewable, pollution free and environment friendly. Its net potential is better than wind, solar, small hydro or biomass power. Wave energy technologies rely on the up-and-down motion of waves to generate electricity.

The advantages of wave energy are as follows:

1. Because waves originate from storms far out to sea and can travel long distances without significant energy loss, power produced from them is much steadier and more predictable day to day and season to season.

2. Wave energy contains about 1000 times the kinetic energy of wind.

3. Unlike wind and solar energy, energy from ocean waves continues to be produced round the clock.

4. Wave power production is much smoother and more consistent than wind or solar resulting in higher overall capacity factors.

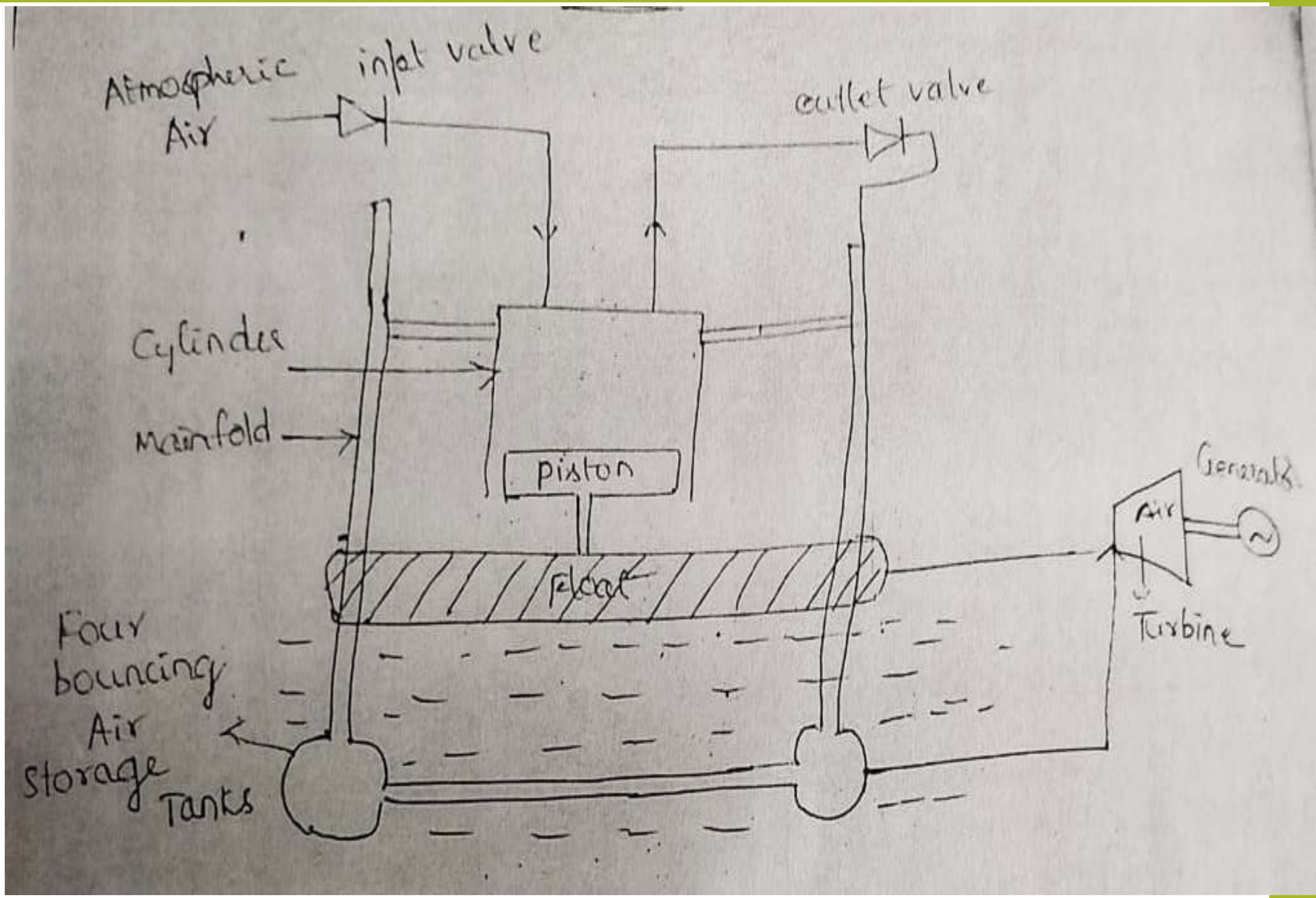
5. Wave energy varies as the square of wave height whereas wind power varies with the cube of air speed. Water being 850 times as dense as air, this result in much higher power production from waves averaged over time.

6. Because wave energy needs only 1/200 the land area of wind and requires no access roads, infrastructure costs are less.

WAVE ENERGY CONVERSION DEVICES

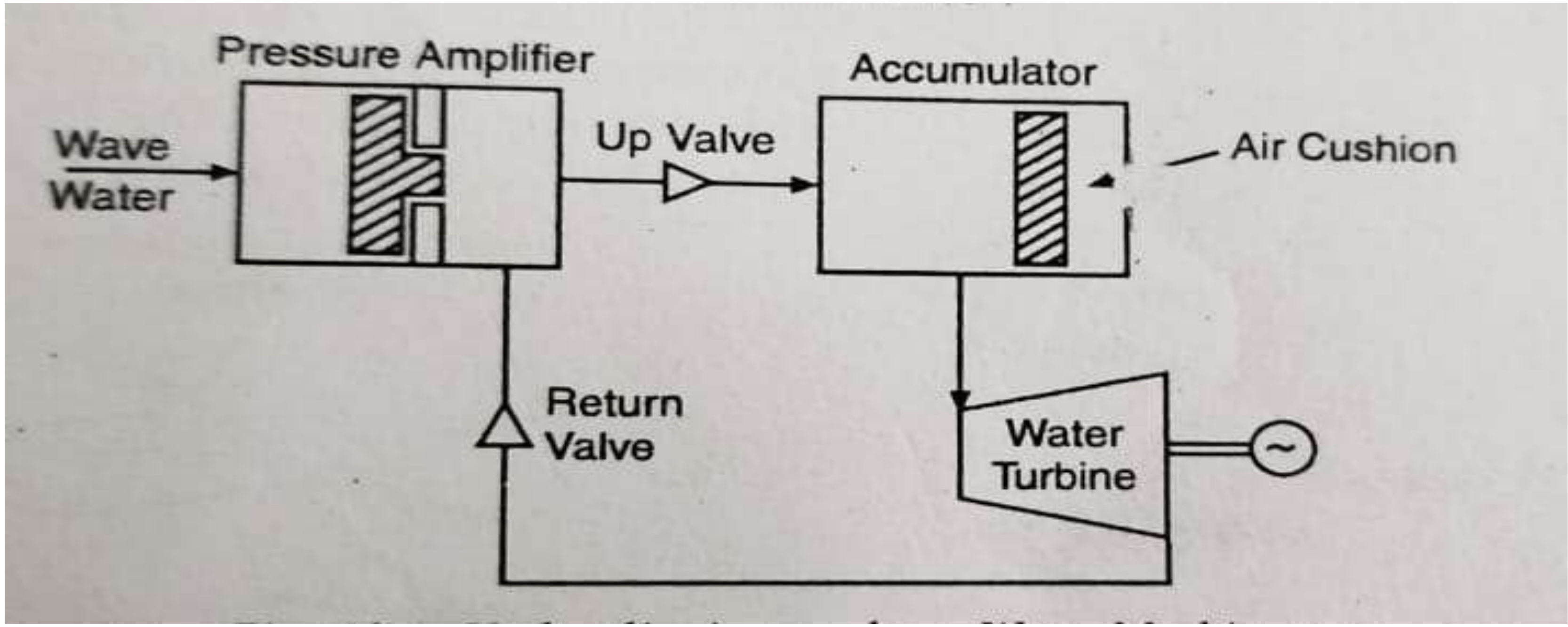
1. Float Wave Power Machine

In this machine, float moves up &down in the water. Four vertical mainfolds that are Part of platform guide the flow. A piston is attached to the float which Compress the air in the cylinder which is stationary in stationary.



The downward motion of piston draws air into the cylinder through inlet valve. The upward motion compresses the air & send it through outlet to the storage tank. The four storage tanks serves dual purpose of air storage and bouncing (Tendency to flow) The Compressed air is used to drive air turbine that dives an electrical generator. The electric current is transferred to the store areas through underground cable.

Hydraulic Accumulator Wave Machine



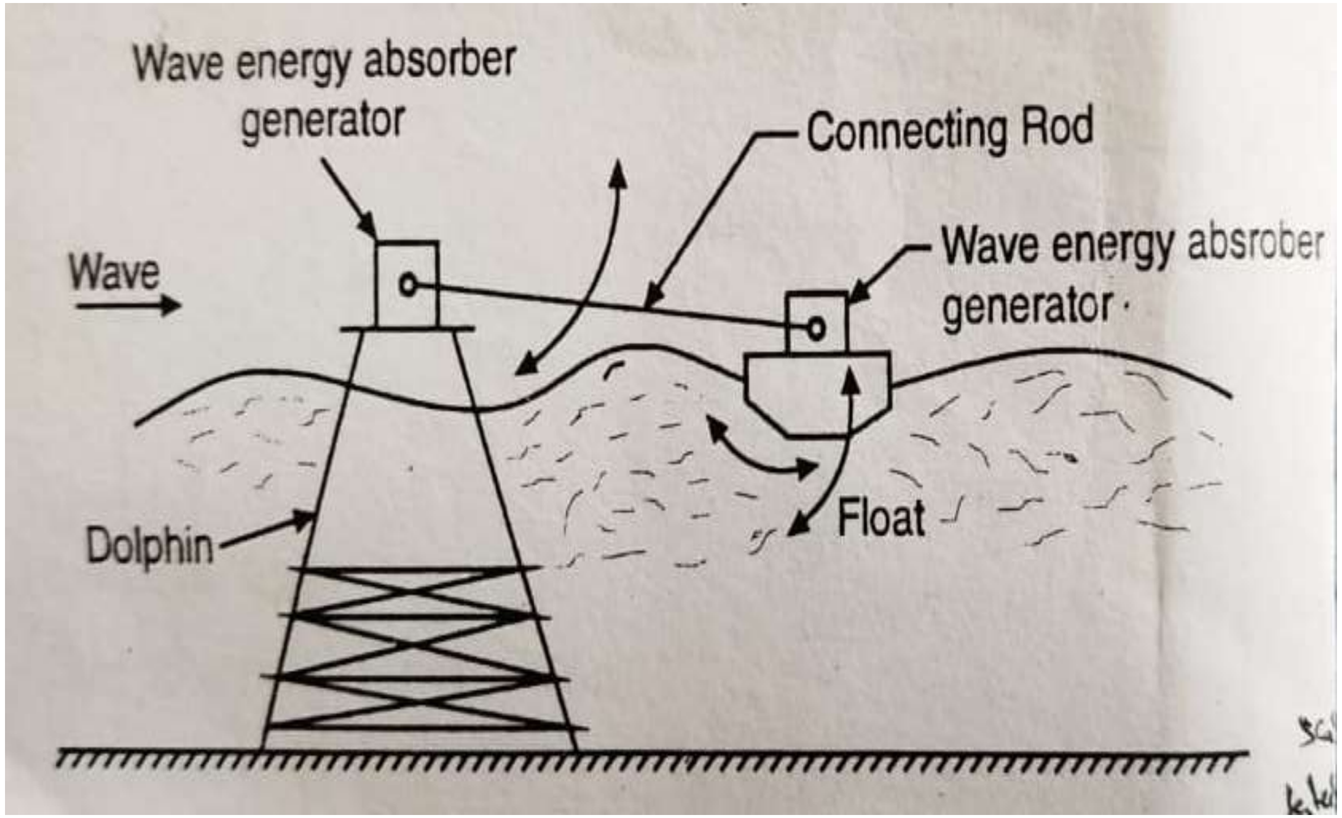
The machine consists of the following main components

1. **Pressure Amplifier** The waves enter the cylinder of pressure amplifier at the bottom and move the main piston. The pressure of the closed loop fluid is amplified to about 5 bar
2. **Hydraulic Accumulator** The high-pressure fluid is conducted through a one-way up valve to a hydraulic accumulator. The accumulator has air cushions on the top which helps to maintain a constant pressure.

Pelton Turbine Part of high-pressure fluid flows through a Pelton wheel or Francis hydraulic turbine that drives an electrical generator

On the trough of the wave, the composite piston is pushed downward by thr high fluid pressure. The exhaust water is sucked via return valve. The capacity of hydraulic accumulator is large enough to permit continuous turbine operation though the waves are cyclic.

The Dolphin-Type Wave-Power Machine



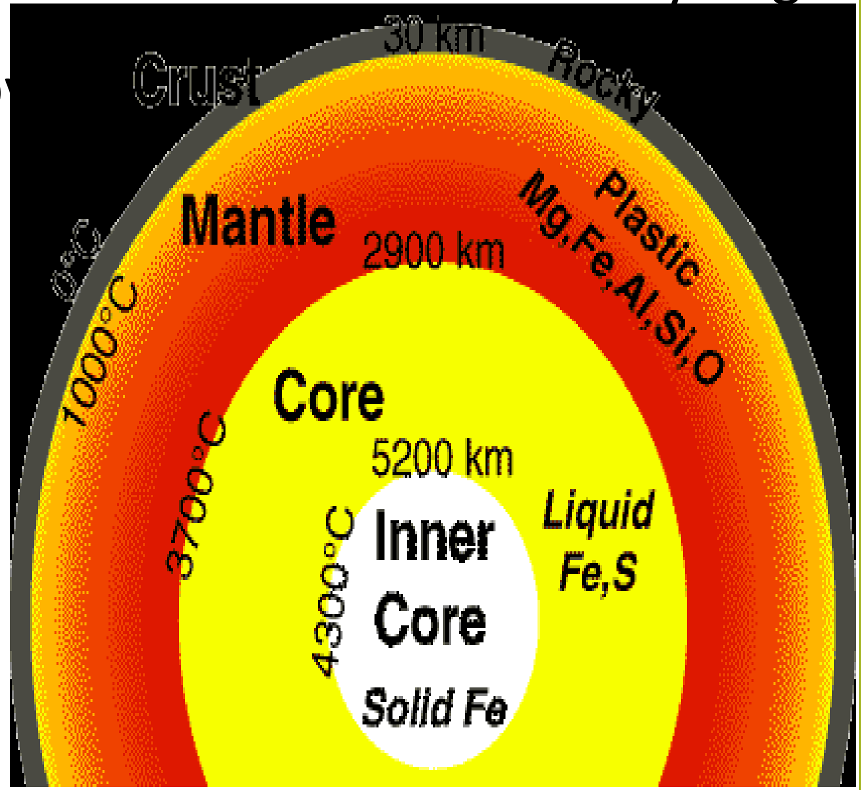
The major components of the system are a dolphin, a float, a connecting rod and two electrical generators.

The float has two motions. The rolling motion about its own fulcrum with the connecting rod is amplified and converted into continuous rotary motion with the help of gears. The electrical generator is driven. The other vertical motion is also amplified and converted into rotary motion to drive the gears.

GEOTHERMAL ENERGY

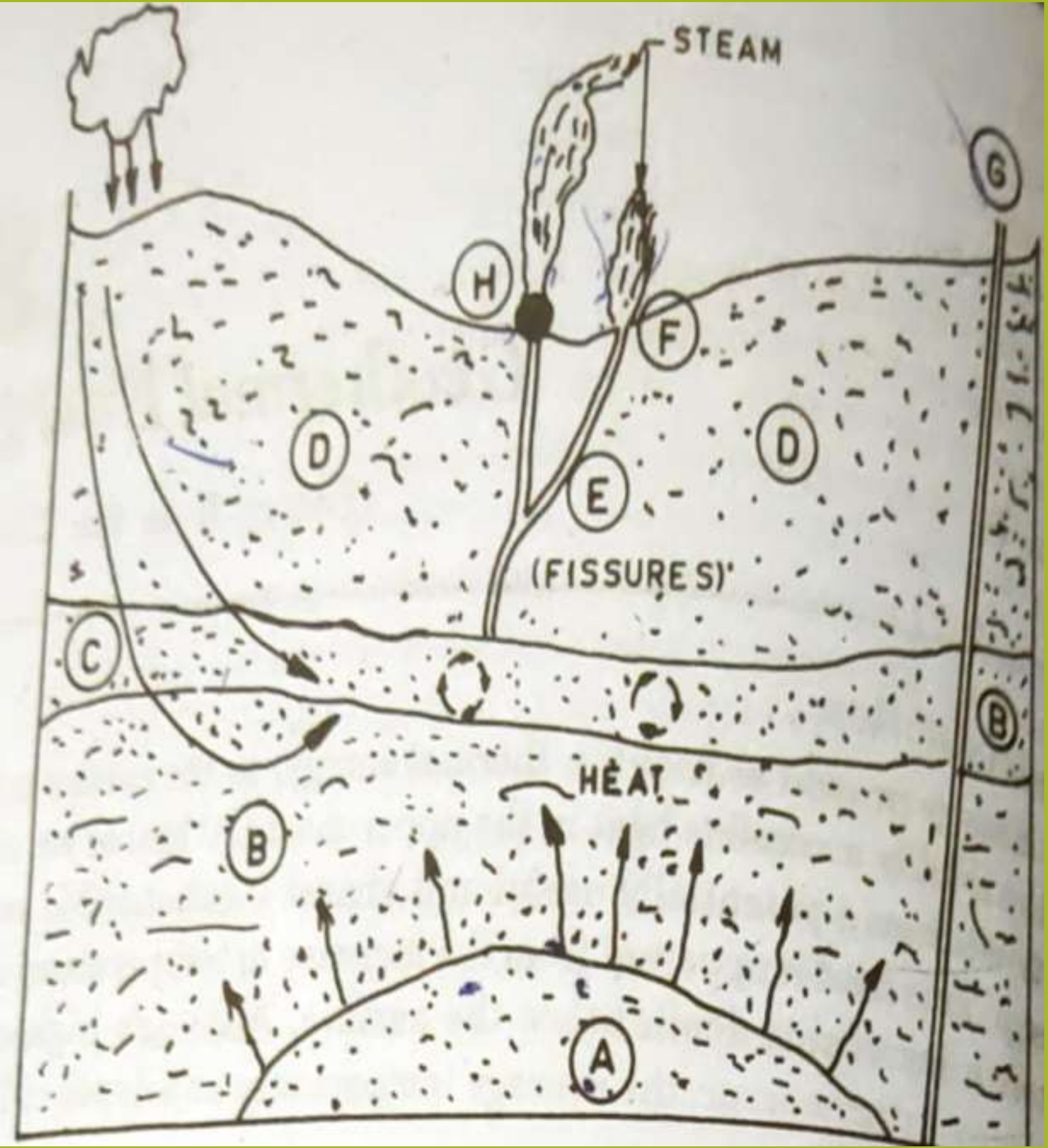
The word geothermal comes from the Greek words *geo* (Earth) and *therme* (heat). Geothermal energy is heat from within the Earth. Geothermal energy is generated in the Earth's **core**, almost 4,000miles beneath the Earth's surface. The double-layered core is made up of very hot **magma** (melted rock) surrounding a solid iron center. Very high temperatures are continuously produced inside the Earth by

particles. This process is natural in all rocks.

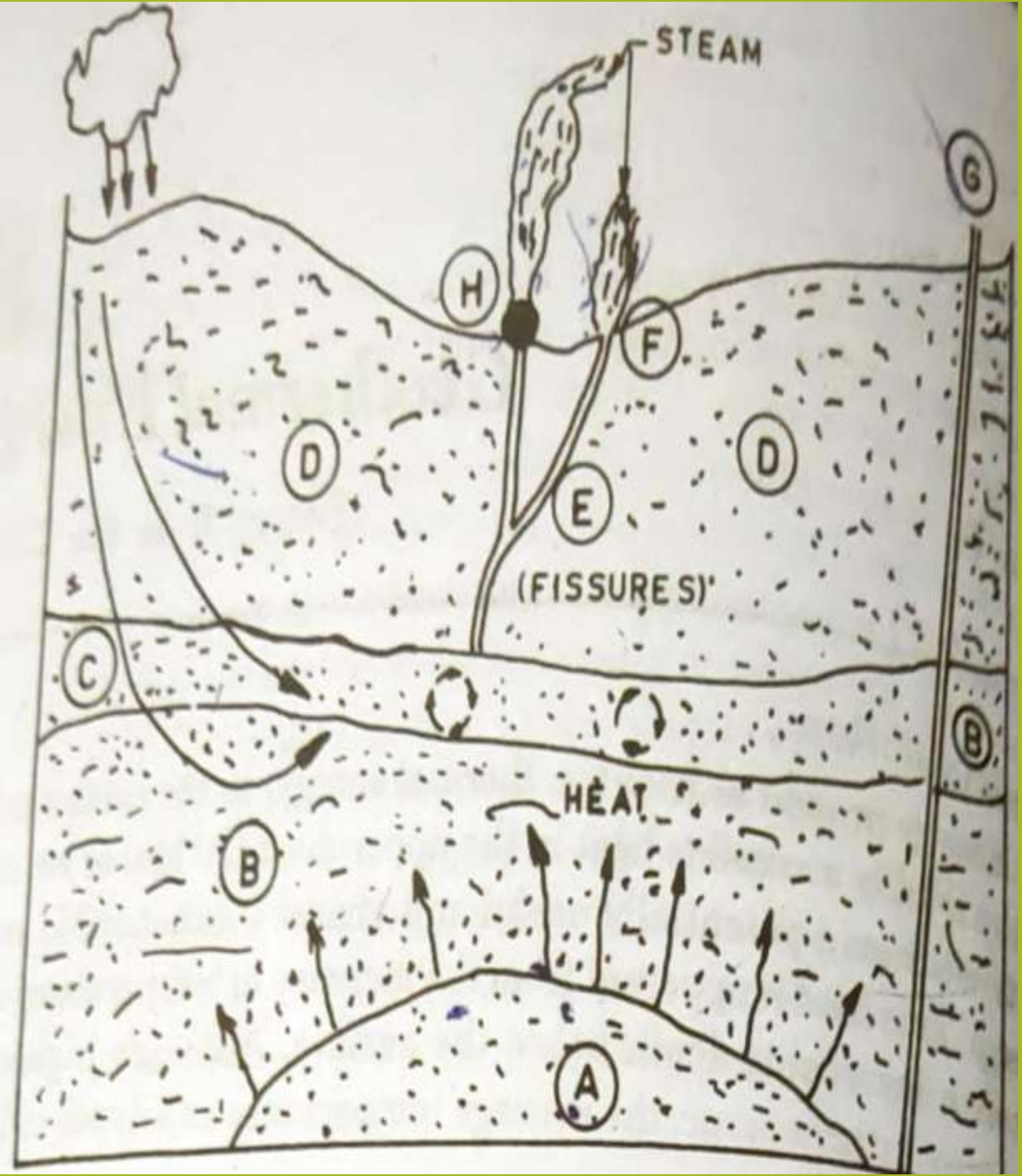


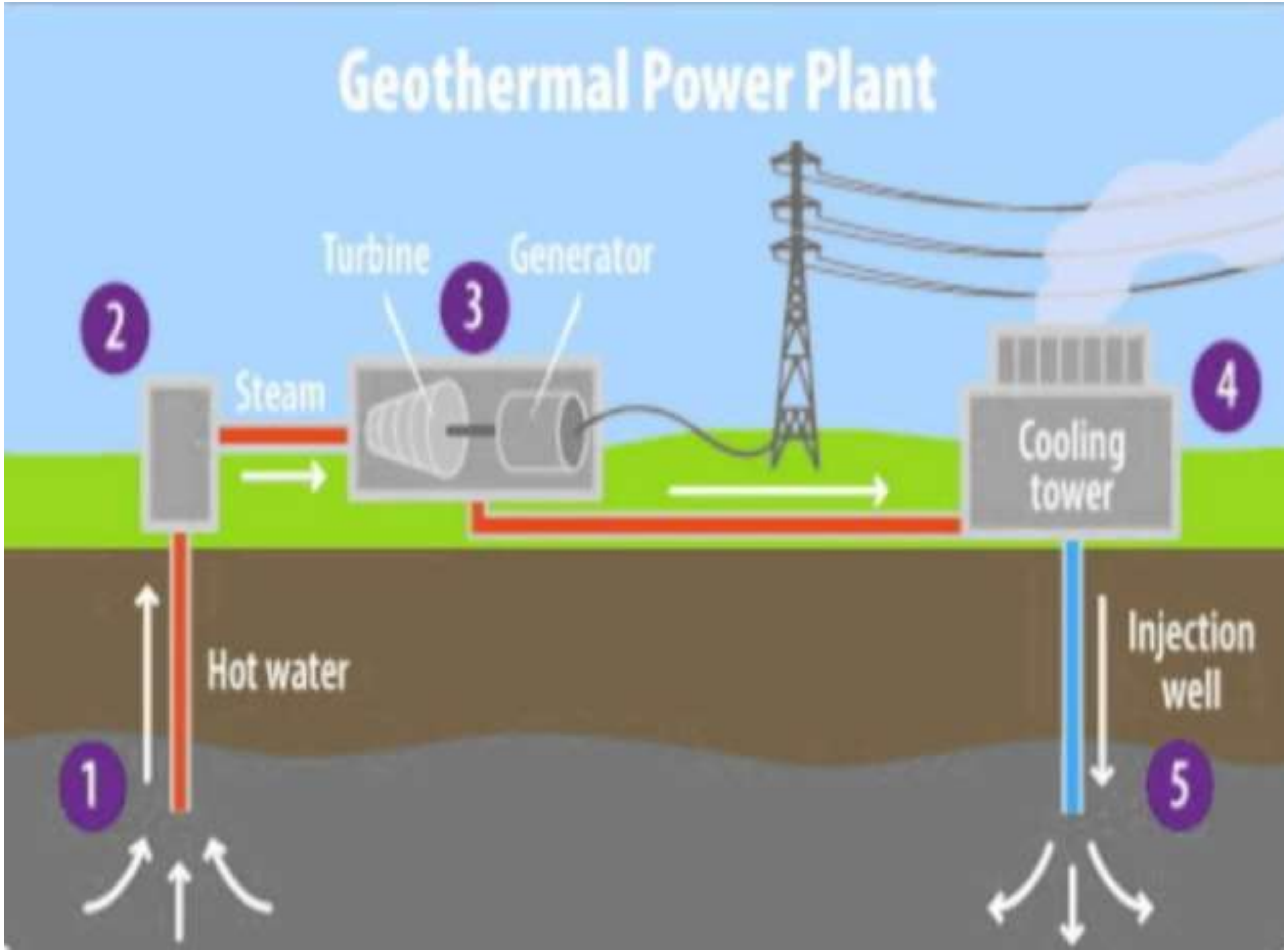
Basic Geothermal Systems Take Advantage of:
Heat Differential Between Ground and Indoor Air Temperatures – Heat Pump
Earth as a Natural Heat Source – Power Plants

Fig. shows a typical geothermal field. The hot magma (molten mass) near the surface (A) solidifies into igneous rock (B). Igneous is Latin word, igneous meaning "of fire" specially formed by volcanic action or great heat. (Igneous rock found at the surface is called volcanic action rock). 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 and steam emanating from the magma. The heated water will then rise convectively upward and into a porous and 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 giant underground boiler. The vents show up at the surface as geysers fumarols (F) (steam is continuously vented through fissures in the ground, these vents are called fumarols) or hot spring (G). A well(H) taps steam from the fissures for use in a geothermal power plant.




Geothermal Power Plant
Turbine
Generator
2
3
Steam
4
Cooling tower
Hot water
Injection well
1
5

Geothermal Power Plant (Advantages and Disdvantages)

Advantages :

Does not need any fuel for production of electricity.

This saves expenses on fuels.

Does not pollute the environment.

It requires minimum land space as compared to other plants.

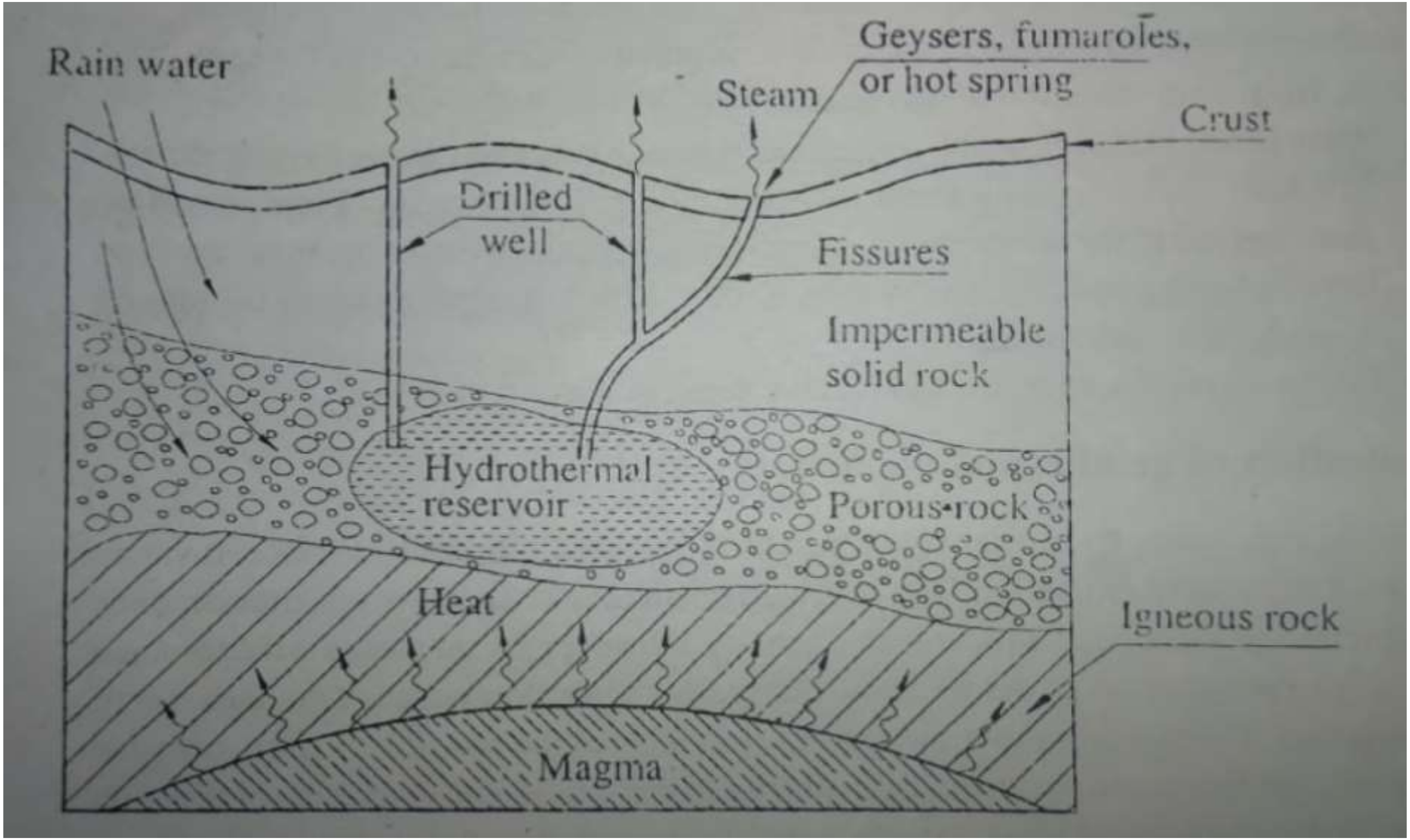
Disadvantages :

As geothermal fields are not available universally, these power plants are found rarely.

The cost of infrastructure and drilling is also very high.

Geothermal Energy in India

- Geothermal provinces are estimated to produce 10,600 MW of power (experts are confident only to the extent of 100 MW)
- Geothermal provinces in India: the Himalayas, Sohana, Westcoast, Cambay, Son-Narmada-Tapi , Godavari, and Mahanadi Reykjavík Geothermal will assist Thermax to set up a pilot project in Puga Valley, Ladakh (Jammu & Kashmir)
- First operational commercial geothermal power plant is likelyto come up in AP with a capacity of 25 MW by Geosyndicate Pvt Ltd.


Rain water
Geysers, fumaroles,
or hot spring
Steam
Crust
Drilled
well
Fissures
Impermeable
solid rock
Hydrothermal
reservoir
Porous rock
Heat
Igneous rock
Magma

Classification

It can be seen that geothermal steam is of two kinds:

•that originating from the magma itself, called magmatic steam, and

•that from ground water heated by the magma, called meteoritic steam.

The latter is the largest source of geothermal steam.

Not all geothermal sources produce steam as described above. Some are lower in temperature so that there is only hot water. Some receive no ground water at all and contain only hot rock. Geothermal sources are therefore of three basic kinds;

(1) hydrothermal,

(2) geopressured, and

(3) petrothermal.

Hydrothermal Systems Hydrothermal systems are those in which water is heated by contact with the hot rock as explained above. Hydrothermal systems are in turn subdivided into (1) vapor dominated and (2) liquid-dominated systems.

A) Vapor-dominated systems In these systems the water is vaporized into steam that reaches the surface in a relatively dry condition at about 400°F (205°C) and rarely above 8 bar. This steam is the most suitable for use in turboelectric power plants, with the least cost. It does, however, suffer problems similar to those encountered by all geothermal systems, namely, the presence of corrosive gases and erosive material and environmental problems (see below). Vapor-dominated systems, there are only five known sites in the world to date. These system account for about 5 percent of all U.S. geothermal resources. The Geysers plant in the United States, the largest in the world today, and Larderello in Italy, are both vapor-dominated systems.

(b) Liquid-dominated systems In these systems the hot water circulating and trapped underground is at a temperature range of 350 to 600°F (174 to 315°C). When tapped by wells drilled in the right places and to the right depths, the water flows either naturally to the surface or is pumped up to it. The drop in pressure, usually to 100 psig (8 bar) or less, causes it to partially flash to a two-phase mixture of low quality, i.e., liquid-dominated. It contains relatively large concentrations of dissolved solids ranging between 3000 to 25,000 ppm and sometimes higher. Power production is adversely affected by these solids because they precipitate and cause scaling in pipes and heat-exchange surfaces, thus reducing flow and heat transfer. Liquid-dominated systems, however, are much more plentiful than vapor-dominated systems and, next to them, require the least extension of technology. The U.S. Geological Survey [109]shows from 900 to 1400 quads (Q) (1Q 1015 Btu, about 10 J) of energy available from liquid-dominated systems with liquid above 300°F (150°C). The hydrothermal systems, of both kinds, are the only ones in commercial operation today. Figure 12-4 shows the major high-temperature hydrothermal areas of the world.

Geopressured Systems Geopressured systems are sources of water, or brine, that has been heated in a manner similar to hydrothermal water, except that geopressured water is trapped in much deeper underground acquifers, at depths between 8000 to 30,000 ft. (about 2400 to 9100 m). This water is thought to be at the relatively low temperature of about 325°F (160°C) and is under very high pressure, from the overlying formations above, of about 15,000 psia (more than 1000 bar). It has a relatively high salinity of 4 to 10 percent and is often referred to as brine. In addition, it is saturated with natural gas, mostly methane CH., thought to be the result of decomposition of organic matter. Such water is thought to have thermal and mechanical potential to generate electricity. The temperature, however, is not high enough and the depth so great that there is little economic justification of drilling for this water for its thermal potential alone. What is drawing attention, however, is the amount of recoverable methane in solution that can be used for electric generation. The U.S. Geological Survey estimates 100 Q of electricity from the thermal content of geopressured water and 500 Q of energy in the gas. Studies have been under way to determine the economic feasibility of generating electricity by a combined cycle, one that involves the combustion of the methane as well as heat from the thermal content of the water.

Petrothermal Systems Magma lying relatively close to the earth's surface heats overlying rock as previously explained When no underground water exists, there is simply hot, dry rock (HDR). The known temperatures of HDR vary between 300 and 550°F (-150 to 290°C). This energy, called petrothermal energy represents by far the largest resource of geothermal energy of any type, as it accounts for about 85 percent of the geothermal resource base of the United States. Other estimates put the ratio of steam:hot water:HDR at 1:10:1000 [111].Much of the HDR occurs at moderate depths, but it is largely impermeable. In order to extract thermal energy out of it, water (or other fluid, but water most likely) will have to be pumped into it and back out to the surface. It is necessary for the heat transport mechanism that a way be found to render the impermeable rock into a permeable structure with a large heat-transfer surface. A large surface is particularly necessary because of the low thermal conductivity of the rock. Rendering the rock permeable is to be done by fracturing it. Fracturing methods that have been considered involve drilling wells into the rock and then fracturing by (1) high-pressure water or (2) nuclear explosives.

High-pressure water Fracturing by high-pressure water is done by injecting water into HDR at very high pressure. This water widens existing fractures and creates new ones through rock displacement. This method is successfully used by the oil industry to facilitate the path of underground oil. The oil-bearing stratum is sedimentary rock that is softer than HDR. The cost to the oil companies is thus lower and, in addition justified by the additional oil it produces.

Nuclear explosives Fracturing by nuclear explosives is a scheme that has been considered as part of a program for using such explosives for peaceful uses, such as natural gas and oil stimulation, creating cavities for gas storage, canal, and harbor construction, and many other applications. In this method would require digging in shafts suitable for introducing and sealing nuclear explosives. The principal hazards associated with this are the ground shocks, the danger of radioactivity releases to the environment, and the radioactive material that would surface with the heated water and steam. A variation of the above concept would be to generate heat by the nuclear explosions themselves in deep salt formations. This would create an underground pool of molten salt that may be exploited for many years. Both schemes have many problems that are difficult to assess without actual experimentation. Not much progress has been made beyond the study stage.

VAPOR-DOMINATED SYSTEMS

As indicated previously, vapor-dominated systems are the rarest form of geothermal energy but the most suitable for electricity generation and the most developed of all geothermal systems. They have the lowest cost and the least number of serious problems. Dry steam from the well at perhaps 400°F (200°C) is used. It is nearly saturated at the bottom of the well and may have a shut-off pressure up to -35 bar. Pressure drops through the well causes it to slightly superheat at the well head. The pressure there rarely exceeds -7 bar. It then goes through a centrifugal separation to remove particulate matter and then enters the turbine after an additional pressure drop. The steam expands through the turbine and enters the condenser. Because turbine flow is not returned to the cycle but reinjected back into the earth a direct contact condenser of the barometric or low level type may be used Direct-contact condensers are more effective and less expensive than surface-type condensers.

The turbine exhaust steam at 4 mixes with the cooling water (7) that comes from a cooling tower). (The mixture of 7 and 4 is saturated water (5) that is pumped to the cooling tower (6). The greater part of the cooled water at 7 is recirculated to the condenser. The balance, which would normally be returned to the cycle in a conventional plant, is reinjected into the ground either before or after the cooling tower.

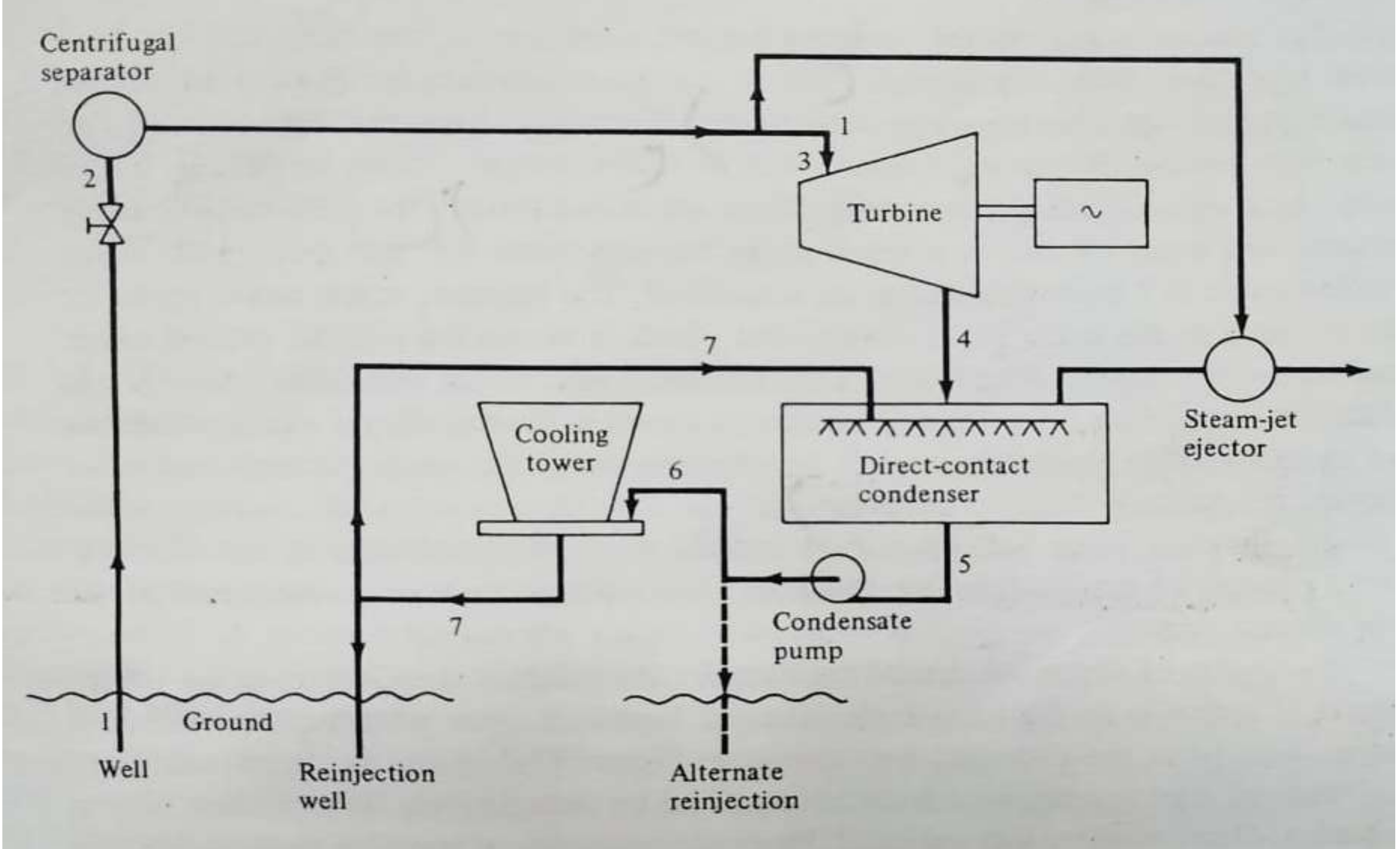


Figure 12-5 Schematic of a vapor-dominated powerplant.

The mass-flow rate of the reinjected water is less than that originating from the well because of losses in the centrifugal separator, steam jet ejector (SJE), evaporation, drift and blow down in the cooling tower, and other losses. No makeup water is necessary.

LIQUID-DOMINATED SYSTEMS:

Although the largest geothermal power generation to date comes from vapor dominated systems, these systems are rare, and the natural expansion of generation must come from liquid-dominated systems, which are much more abundant, though not so much as geopressured or petrothermal systems. However, as indicated earlier, liquid-dominated systems require the least extension of technology. The known resources show that water is available above 300°F (150°C), with some up to 600°F (315°C). When tapped, the water can flow naturally under its own pressure or be pumped to the surface. The drop in pressure causes it to partially flash into steam and arrive at the well head as a low-quality, i.e., liquid-dominated, two-phase mixture. The water comes with various degrees of salinity, ranging from 3000 to 280,000 ppm of dissolved solids, and at various temperatures. There are, therefore, various systems for converting liquid-dominated systems into useful work that depend upon these variables. Two methods stand out: (1) the flashed-steam system, suitable for water in the higher-temperature range, and (2) the binary cycle system, suitable for water at moderate temperatures. A third method, called the total-flow system, awaits further development

The Flashed-Steam System

This system, reserved for water in the higher-temperature range. Water from the underground reservoir at 1 reaches the well head at 2 at a lower pressure. Process 1-2 is essentially a constant enthalpy throttling process that results in a two-phase mixture of low quality at 2. This is throttled further in a flash separator resulting in a still low but slightly higher quality at 3. This mixture is now separated into dry saturated steam at 4 and saturated brineat 5. The latter is reinjected into the ground. The dry steam, a small fraction of the total well discharge (because of the low quality at 3), and usually at pressures below 100 psig (8 bar), is expanded in a turbine to 6 and mixed with cooling water in a direct-contact condenser with the mixture at 7 going to a cooling tower in the same fashion as the vapor-dominated system. The balance of the condensate after the cooling water is recirculated to the condenser is reinjected into the ground.

The flashed-steam system is a more difficult proposition than the vapor-dominated system for several reasons: (1) much larger total mass-flow rates through the well, (2) a greater degree of ground surface subsidence as a result of such large flows; (3) a greater degree of precipitation of minerals from the brine, resulting in the necessity for design of valves, pumps, separator internals, and other equipment for operation under scaling conditions; and (4) greater corrosion of piping, well casing, and other conduits.

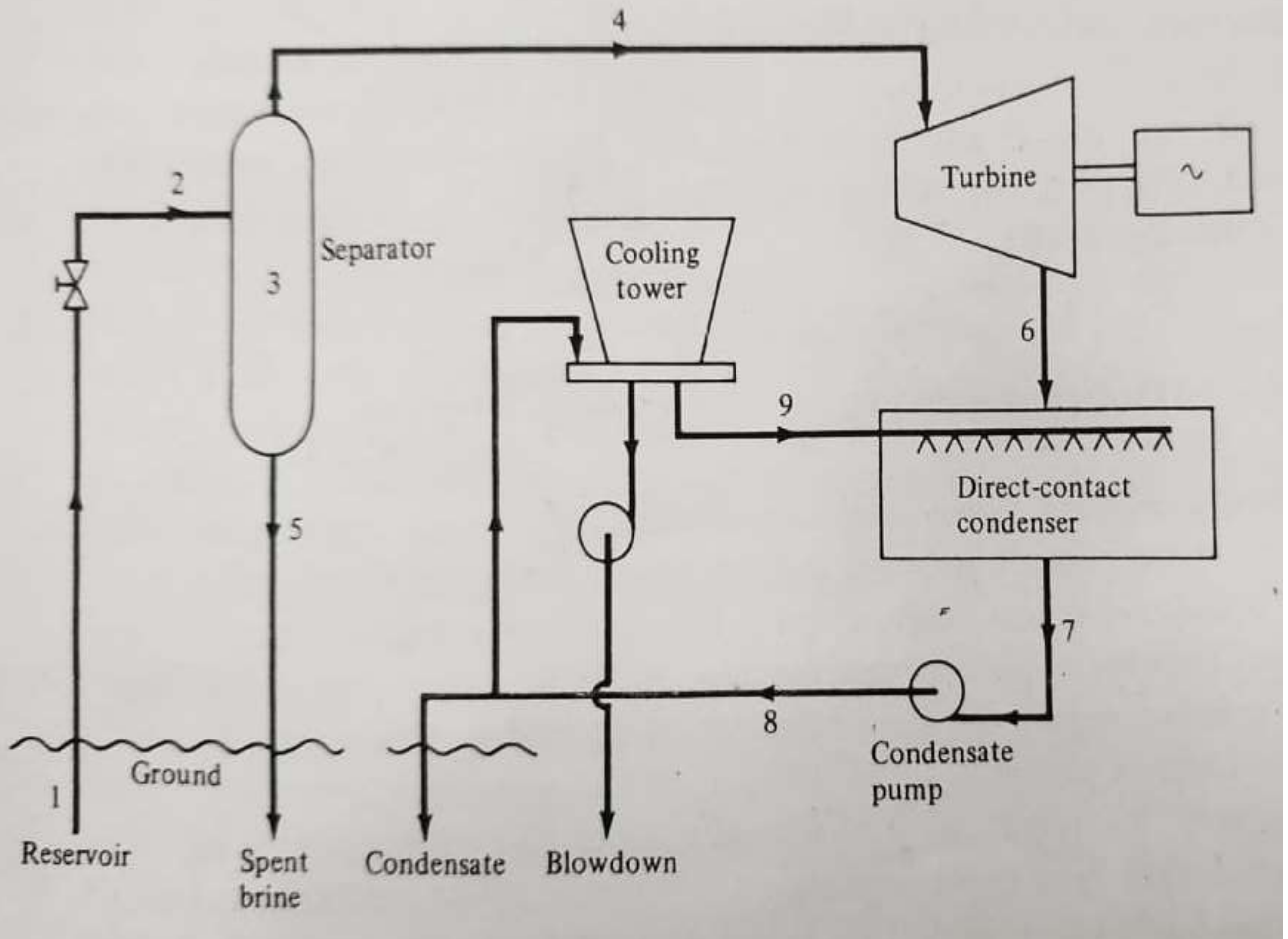


Figure 12-8 Schematic of a liquid-dominated single-flash steam system.

Flashed-steam systems have been widely used in Japan, New Zealand, Italy, Mexico, and elsewhere.

Improvements in the Flashed-Steam System

The spent brine leaving the separator at 5 (Fig. 12-8) has a large mass-flow rate and a large total energy compared with that in the steam used to drive the turbine at 4. In Example 12-2, the ratio of the brine enthalpy to the steam enthalpy was found to be 1.31:1. Improvements in the cycle would therefore use some of this otherwise lost energy in the cycle. Two methods are being developed:1. Double flash. Depending upon the original water conditions, the brine at 5 is admitted to a second, lower-pressure separator, where it flashes to a lower-pressure steam that would be admitted to a low-pressure stage in the turbine. The new lower pressure brine carries less energy with it and represents a reduced energy loss to the cycle. Figures 12-10 show a schematic flow diagram of a double flash steam system.

The saturated brine from the first stage flash separator at 5 is reflashed in a second-stage separator at lower pressure to 6. The lower-pressure steam from that separator is admitted to the admission turbine at a lower-pressure stage. The remaining spent brine at 8 is reinjected into the ground. An example of the double flash system is the 50-MW Hatchobaru plant built on the island of Kyushu in Japan.

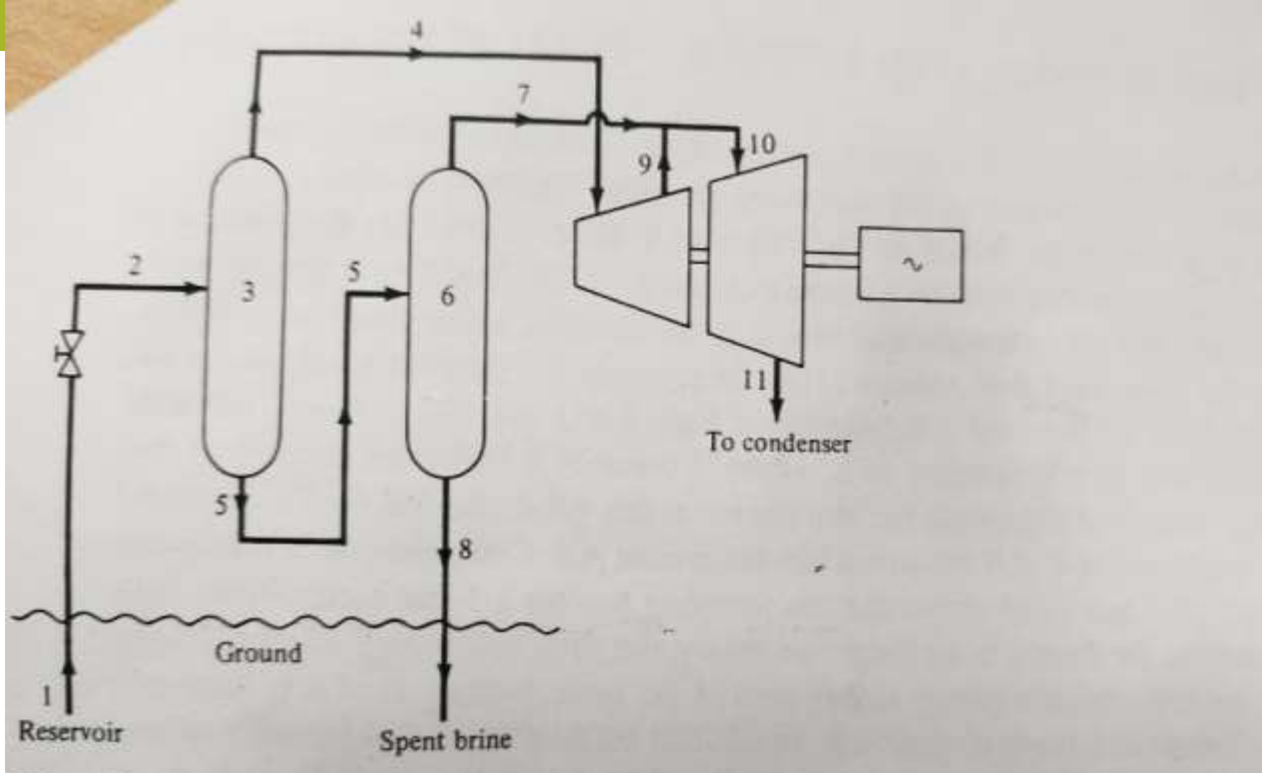


Figure 12-10 Schematic of a liquid-dominated, double-flash steam system. The cycle below the turbine is the same as in Fig. 12-8.

It uses an innovative steam condenser and gas extraction system and a dual-admission, double-flow steam turbine. 2. Water turbine. Here the spent brine at 5, still at high pressure, is used instead to drive a water turbine and an additional electric generator operating in parallel with the steam-turbine generator. A variation of this principle, being development under an EPRI contract, uses a so-called rotary separator turbine (RST).

LIQUID-DOMINATED SYSTEMS: BINARY CYCLE

About 50 percent of hydrothermal water is in the moderate temperature range of 300 to 400°F (-150 to 205°C). If used in a flashed-steam system, it would have to be throttled down to such low pressures that result in excessively large specific volume flows as well as even poorer cycle efficiencies.

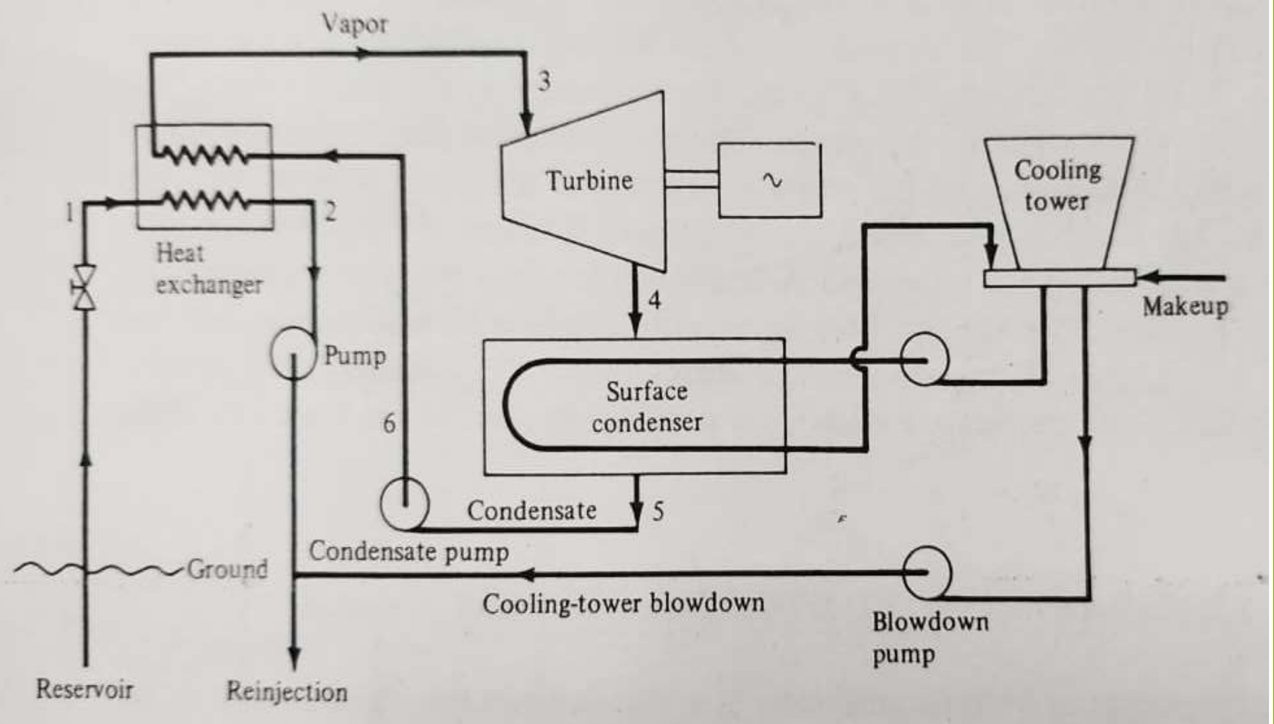


Figure 12-12 Schematic of liquid-dominated binary-cycle system.

Instead this water is used as a heat source for a closed cycle that uses another working fluid that has suitable pressure temperature-volume characteristics. This is likely to be an organic with a low boiling point, such as isobutane, Freon-12 ,propane (App. D).

The working fluid would operate at higher pressures, corresponding to the source-water and heat-sink temperatures)Figure 12-12 shows a schematic flow diagram of a binary-cycle system. (Hot water or brine from the underground reservoir circulates through a heat exchanger and is pumped back to the ground. In the heat exchanger it transfers its heat to the organic fluid thus converting it to a superheated vapor that is used in a standard closed Rankine cycle. The vapor drives the turbine and is condensed in a surface condenser; the condensate is pumped back to the heat exchanger. The condenser is cooled by water from a natural source, if available, or a cooling-tower circulation system. The blow- brine) down from the tower may be reinjected to the ground with the cooled brine, Makeup of the cooling tower water must be provided, however.

(In the binary cycle there are no problems of corrosion or scaling in the working cycle components, such as the turbine and condenser. Such problems are confined only to the well casing and the heat exchanger. The heat exchanger is a shell-and tube unit so that no contact between brine and working fluid takes place.The first binary cycle was installed in the Soviet Union on the Kamchatka peninsula in 1967. It had a gross output of 680 kW using a low-temperature water reservoir at 80°C (176°F) and Freon-12 as working fluid. The in-plant power consumption (pumping, etc.) was 35 percent; the net output was 440 kW. The first binary cycle to be built in the United States is an 11-MW plant built by the Magma Company at East Mesa, in the Imperial Valley site in California. The site has a potential of 10,000 MW, but a more conservative projection is about 1500 MW, including a 260-MW unit at East Mesa as well as others at Heber, Westmoreland, Brawley, and Salton Sea.

Biomass and Biogas

The energy obtained from organic matter, derived from biological organisms (Plants and animals) is known as biomass energy. Animals feed on plants, and plants grow through the photosynthesis process using solar energy. Thus, photosynthesis process is primarily responsible for the generation of biomass energy. A small portion of the solar radiation is captured and stored in the plants during photosynthesis process. Therefore, it is an indirect form of solar into biomass energy is estimated to be 0.5 – 1.0%. To use biomass energy, the initial biomass may be transformed by chemical or biological processes to produce intermediate bio-fuels such as methane, ethanol and charcoal etc. On combustion it reacts with oxygen to release heat, may be non-polluting and sustainable. It is estimated that the biomass, which is 90% in trees, is equivalent to the proven current extractable fossil fuels reserves in the world.

Biomass mainly in the form of wood, is mankind's oldest form of energy. It has traditionally been used both in domestic as well as industrial activities, basically by direct combustion. As industrial activities increased, the growing demand for energy depleted the biomass natural reserves. The development of new, more concentrated and more convenient sources of energy has led to its replacement to a large extent by other sources. Though biomass energy share in primary energy supply for the industrialized countries is not more than 3%, a number of developing countries still use a substantial amount of it, mostly in the form of non-commercial energy.

Main advantages of biomass energy are:
i. It is a renewable source.
ii. The energy storage is an in-built feature of it.
iii. It is an indigenous source requiring little or no foreign exchange.
iv. The pollutant emissions from combustion of biomass are usually lower than those from fossil fuels.

v. Commercial use of biomass may avoid or reduce the problems of waste disposal in other industries, particularly municipal solid waste in urban centers.

vi. The nitrogen rich bio-digested slurry and sludge from biogas plant serves as a very good soil conditioner and improves the fertility of the soil.

Main disadvantages are:

i. It is a dispersed and land intensive source.

ii. It is often of low energy density.

iii. It is also labour intensive, and the cost of collecting large quantities for commercial application is significant.

Biomass: It is the organic matter consisting of plant animal matter. Any matter which is biodegradable is known as biomass or organic matter. Generation of energy from biomass is referred to as Photo chemical' harnessing of solar radiation since to generate biomass; solar radiation is a must as seen from the following equation

Solar radiation ⟶ Photosynthesis ⟶ Biomass ⟶ Energy

Energy from the biomass is generated in three different forms namely)

Direct burning, ii) Liquefaction, iii) Gas generation.

<u>Direct burning:</u> When biomass is directly burnt, energy is generated as given by the following expression,

$$CO_2 + O_2 \xrightarrow{\text{sun's radiation (photosynthesis)}} CH_2O + O_2$$

$$CH_2O + O_2 \longrightarrow CO_2 + H_2O + \text{Energy}$$

Thus when photosynthesis reaction is reversed energy is liberated.

Liquefaction:

Biomass is liquefied either by thermo-chemical method or biochemical method to generate alcohols like methyl and ethyl alcohol. These are mixed with petrol and used in IC Engines as fuels.

Bio gas:

Biomass is converted to biogas by the process of digestion or fermentation in the presence of micro-organisms. This biogas mainly contains methane which is a good combustible gas.

Biogas consists of 50-55% of methane, 30-35% of CO_2 and remaining waste gases like H_2, N_2, H_2S etc. since it contains a hydrocarbon gas it is a very good fuel and hence can be used in IC engines. It is a slow burning gas with calorific value of 5000-5500 Kcal/kg. the raw material used to generate this are algae, crop residue, garbage, kitchen waste, paper waste, waste from sugar cane refinery, water hyacinth etc. apart from the above mentioned raw materials excreta of cattle, piggery waste and poultry droppings are also used as raw materials.

Biogas is generated by fermentation or digestion of organic matter in the presence of aerobic and anaerobic micro-organisms. Fermentation is the process of breaking down the complex organic structure of the biomass to simple structures by the action of micro-organisms either in the presence of O_2 or in the absence of O_2. The container in which the digestion takes place is known as the digester.

Advantages

- The initial investment is low for the construction of biogas plant.
- The technology is very suitable for rural areas.
- Biogas is locally generated and can be easily distributed for domestic use.
- Biogas reduces the rural poor from dependence on traditional fuel sources, which lead to deforestation.
- The use of biogas in village helps in improving the sanitary condition and checks environmental pollution.
- The by-products like nitrogen rich manure can be used with advantage.
- Biogas reduces the drudgery of women and lowers incidence of eye and lung diseases.

The digestion takes place in the following steps
i) Enzymatic hydrolysis ii) Acid formation iii) Methane formation.

i) **Enzymatic hydrolysis:** In this step the complex organic matter like starch, protein, fat, carbohydrates etc are broken down to simple structures using anaerobic micro-organisms.

ii) **Acid formation:** In this step the simple structures formed in the enzymatic hydrolysis step are further reacted by anaerobic and facultative microorganisms (which thrive in both the presence and absence of oxygen) to generate acids.

iii) **Methane formation:** In this step the organic acids formed are further converted to methane and CO_2 by anaerobic micro-organisms (anaerobes).

Process of Bio gas, generation – Wet Process, dry Process

(i) Wet process

(a) **Anaerobic digestion** Bio gas is produced by the bacterial decomposition of wet sewage sludge, animal dung or green plants in the absence of oxygen. Feed stocks like – wood shavings, straw, and refuse maybe used, but digestion takes much longer. The natural decay process 'anaerobic decomposition' can be speeded up by using a thermally insulated, air-tight tank with a stirrer Unit and heating system. The gas collect in the digester tank above the slurry and can be piped off continuously. At the optimum temperature (35oC) complete decomposition of animal or human farces takes around 10 days. Gas yields depend critically on the nature of the waste-Pig manure, for example, is better than cow dung or house hold refuse. The residue left after digestion is valuable fertilizer. It is also rich in protein and could be dried and used as animal feed-supplement.

(b) **Fermentation** As stated, ethanol or ethyl alcohol is produced by the Fermentation of sugar solution by natural yeast's. After 30 hours of fermentation the brew or Non-Conventional Energy Sources 'beer' contains 6-10% alcohol and this can readily by removed by distillation. Traditionally, the fibrous residues from plant crops like sugar cane bagasse have been burnt to provide the heat.

Suitable feed stocks include crushed sugar came and beet, fruit etc sugar can also be manufactured from vegetable starches and Cellulose, Maize, Wheat grain, or Potatoes. For they must be ground or pulped and then cooked with enzymes to release the starch and convert it to fermentable sugars. Cellulose materials like wood, paper waste or straw, require harsher pre-treatment typically milling and hydrolysis with hot acid. One tonne of sugar will produce up to 520 liters of Alcohol, a tonne of grain, 350 liters and a tonne of wood, an estimated 260 to 540 liters. After fermentation, the residue from grains and other feed syffs contains high protein content and is a useful cattle-feed supplement.

The hydrolysis and distillation step require a high energy input; for woody feed stocks direct combustion or pyrolysis is probably more productive at present, although stem treatment and new low-energy enzymatic hydrolysis techniques are under development. The energy requirement for distillation is also likely to be cut drastically. Alcohol can be separated from the beer by many methods which are now under intensive development. These include solvent extraction, reverse osmosis, molecular sieves and use of new desiccants for alcohol drying. It may soon be possible to have the energy required for alcohol production to produce a greater net energy gain.

(ii) **Dry Process** Pyrolysis A wide range of energy-rich fuels can be produced by roasting dry woody matter like straw and wood-chips. The material is fed into a reactor vessel or retort in a pulverized or shredded form and heated in the absence of air. As the temperature rises the cellulose and lignin break down to simpler substances which are driven off leaving a char residue behind. This process has been used for continues to produce charcoal. The end products of the reaction depend critically on the conditions employed, at lower temperatures around 5000C, organic liquid predominate, whilst at temperatures nearer 10000C combustible mixture of gases results.

Raw Materials available for Bio gas Fermentation

(i) Manure: This kind of Material is available from animal waste and poultry waste. Their compositions vary with the feeding stuff. In chines rural areas, the fresh manure is used to be fermented with shorter retention time (about two months). The manure from human, cattle, chicken and pigs are subject to inhabitation when fermented without other Carbon source. Manures can be used as Bio mass.

(ii) Plants: Most of the Plants of the grass family can be used for fermentation. Both aqnolic and terrestrial plants can be used as Bio mass. As such they are difficult to be biodegraded. In order to ferment them more easily, pretreatment and a longer retention time are generally needed. Adequate amount of nitrogen rich elements urea etc; should be added for the fermentation.

(iii) Industrial Organic Waste Water: Industrial effluents from food processing, biochemical pharmacy, paper making etc; can be treated by anaerobic fermentation. Most organic matters of these liquid are soluble and their composition are more stable than that of agricultural wastes, while the water quantities may fluctuate. Some effluents may be nutrient deficient or even toxic. Thus pretreatment, such as the elimination of toxicity, adding nutritional additives and so on, or necessary for anaerobic digestion. In food processing Industries planty of organic waste will available. By utilizing two organic waste we can produce Bio gas by anaerobic digestion.

(iv) Organic Matter in Municipal Wastes: They are in solid and inorganic contents need separation. Organic matter is available in Municipal wastes. By utilizing this organic matter. Bio-gas can be produced.

Classification

Classification of the biogas plants:

- 1) Continuous and Batch type
  - Single stage
  - Double stage
- 2) Dome and drum type
  - Floating gas holder or KVIC model
  - Fixed dome type or Chainese model or Janatha model

The entire process of conversion of complex organic compounds into biogas in completed in a single chamber. This chamber is regularly fed with the raw materials while the spent residue keeps moving out. Serious problems are encountered with agricultural residues when fermented in a single stage continuous process.

Single stage continuous plant:

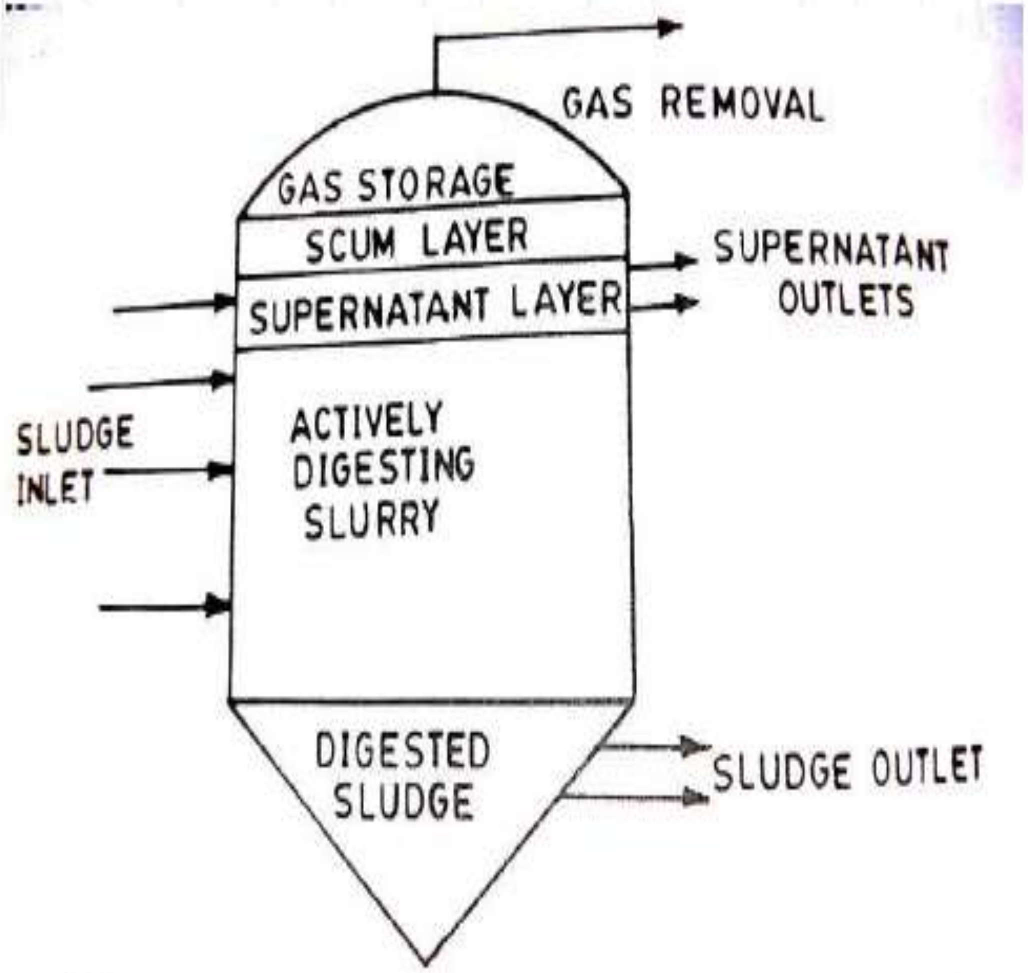


Fig. 7.6.1. Schematic of single process conventional digester.

The acidogenic stage and methanogenic stage are physically separated into two chambers. Thus the first stage of acid production is carried out in a separate chamber and only the diluted acids are fed into the second chamber where bio-methanation takes place and the biogas can be collected from the second chamber. Considering the problems encountered in fermenting fibrous plant waste materials the two stage process may offer higher potential of success. However, appropriate technology suiting to rural India is needed to be developed based on the double stage process.

Two stage continuous plant: (i)Acid & ii) Methane forming:

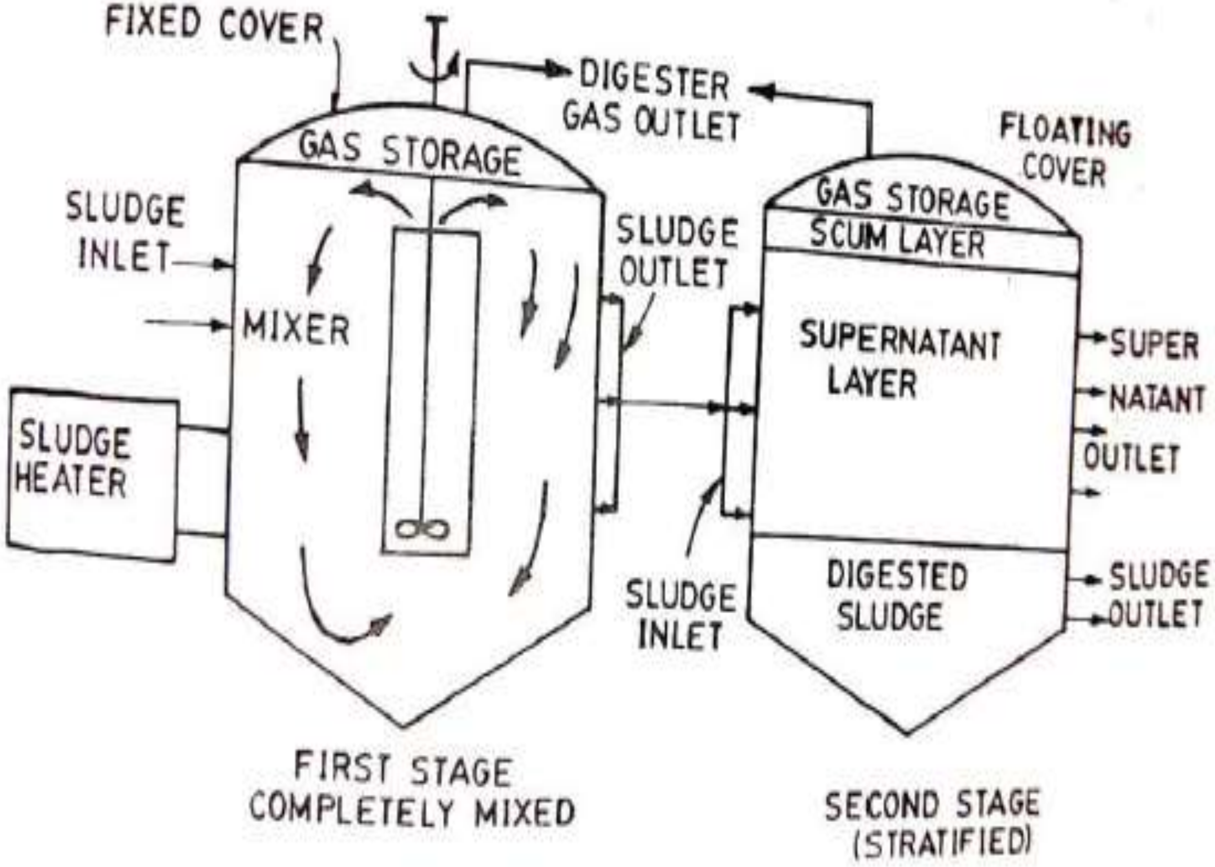


Fig. 7.6.2. Schematic of two-stage digestion process.

The main features of continuous plant are that:

1) It will produce gas continuously;

2) It requires small digestion chambers;

3) It needs lesser period for digestion;

4) It has fewer problems compared to batch type and it is easier in operation.

Indian Digester (Floating drum type/Khadi Ville Commission Plant (KVIC)):

This mainly consists of a digester or pit for fermentation and a floating drum for the collection of gas. Digester is 3.5-6.5 m in depth and 1.2 to 1.6 m in diameter. There is a partition wall in the center, which divides the digester vertically and submerges in the slurry when it is full. The digester is connected to the inlet and outlet by two pipes. Through the inlet, the dung is mixed with water (4:5) and loaded into the digester. The fermented material will flow out through outlet pipe. The outlet is generally connected to a compost pit. The gas generation takes place slowly and in two stages.

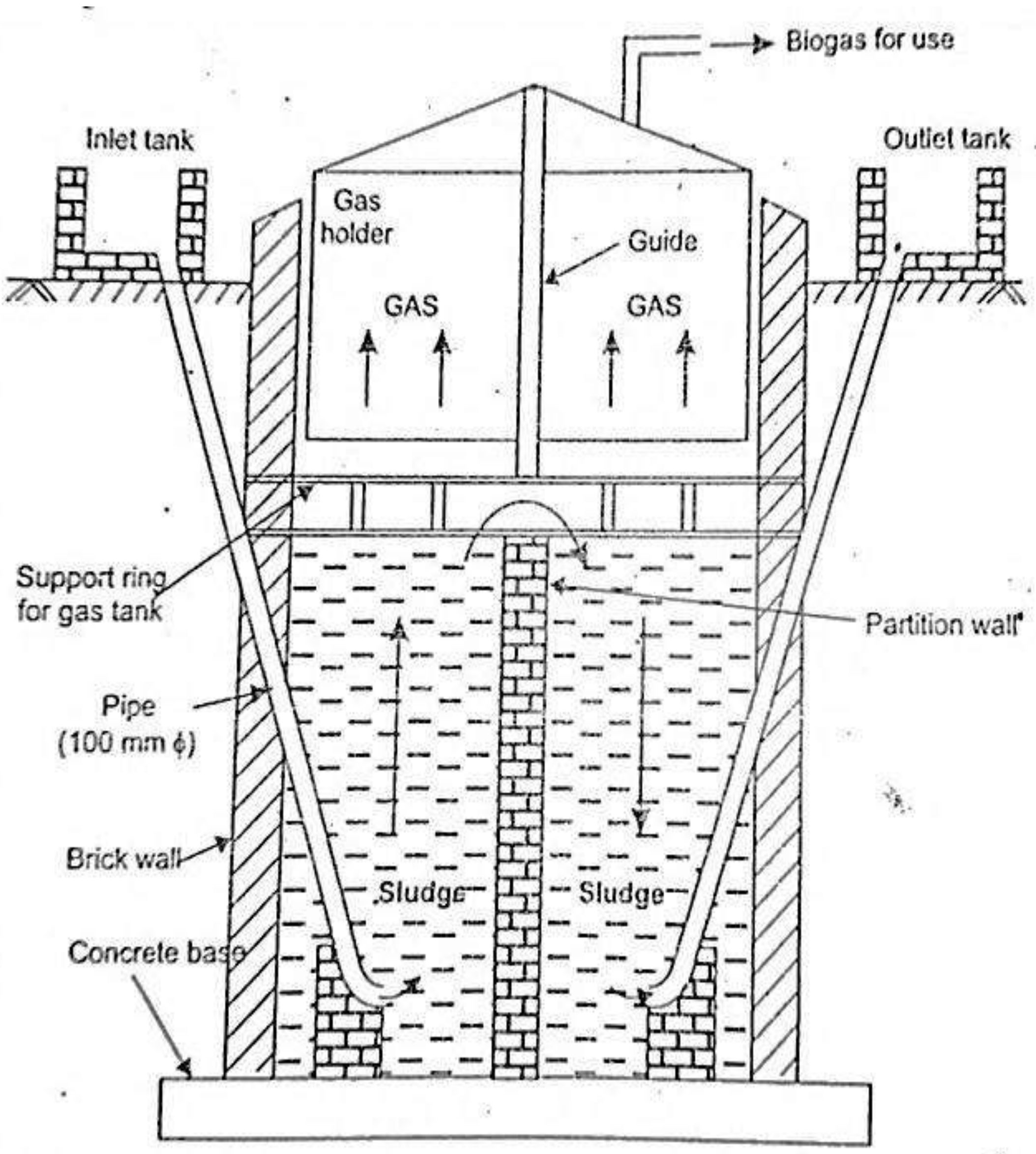


Fig. 8-6. Indian Design Digestor

In the first stage, the complex, organic substances contained in the waste are acted upon by a certain kind of bacteria, called acid formers and broken up into small-chain simple acids. In the second stage, these acids are acted upon by another kind of bacteria, called methane formers and produce methane and carbon dioxide.

Gas holder:

The gas holder is a drum constructed of mild steel sheets. This is cylindrical in shape with concave top. The top is supported radially with angular iron stripes. The holder fits into the digester like a stopper. It sinks into the slurry due to its own weight and rests upon the ring constructed for this purpose. When gas is generated the holder rises and floats freely on the surface of slurry. A central guide pipe is provided to prevent the holder from tilting. The holder also acts as a seal for the gas. The gas pressure varies between 7 and 9 cm of water column. Under shallow water table conditions, the adopted diameter of digester is more and depth is reduced. The cost of drum is about 40% of total cost of plant. It requires periodical maintenance. The unit cost of KVIC model with a capacity of 2 m3/day costs approximately Rs.14, 000/.

Janata type biogas plant (Chinese):

The design of this plant is of Chinese origin but it has been introduced under the name —Janata biogas plantll by Gobar Gas Research Station, Ajitmal in view of its reduced cost. This is a plant where no steel is used, there is no moving part in it and maintenance cost is low. The plant can be constructed by village mason taking some pre-explained precautions and using all the indigenously available building materials. Good quality of bricks and cement should be used to avoid the afterward structural problems like cracking of the dome and leakage of gas. This model have a higher capacity when compared with KVIC model, hence it can be used as a community biogas plant. This design has longer life than KVIC models. Substrates other than cattle dung such as municipal waste and plant residues can also be used in janata type plants.

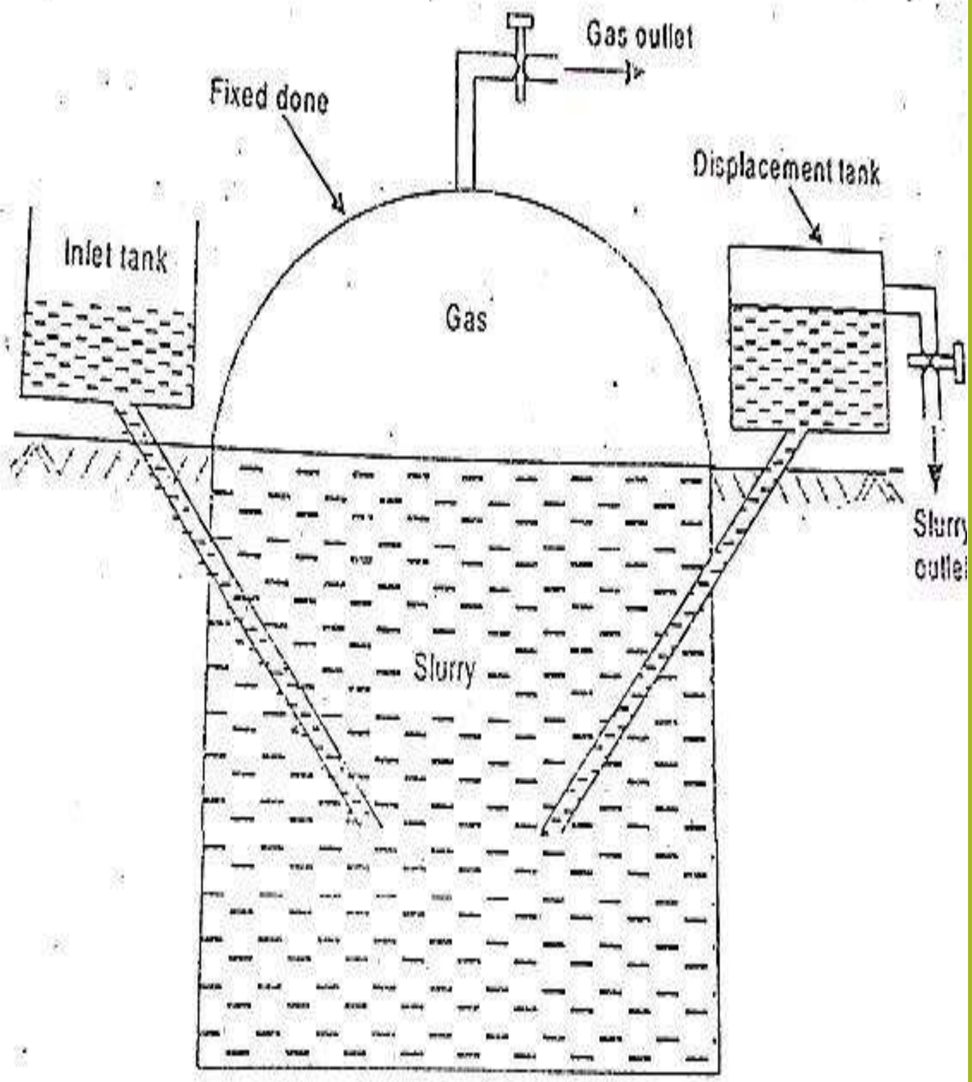
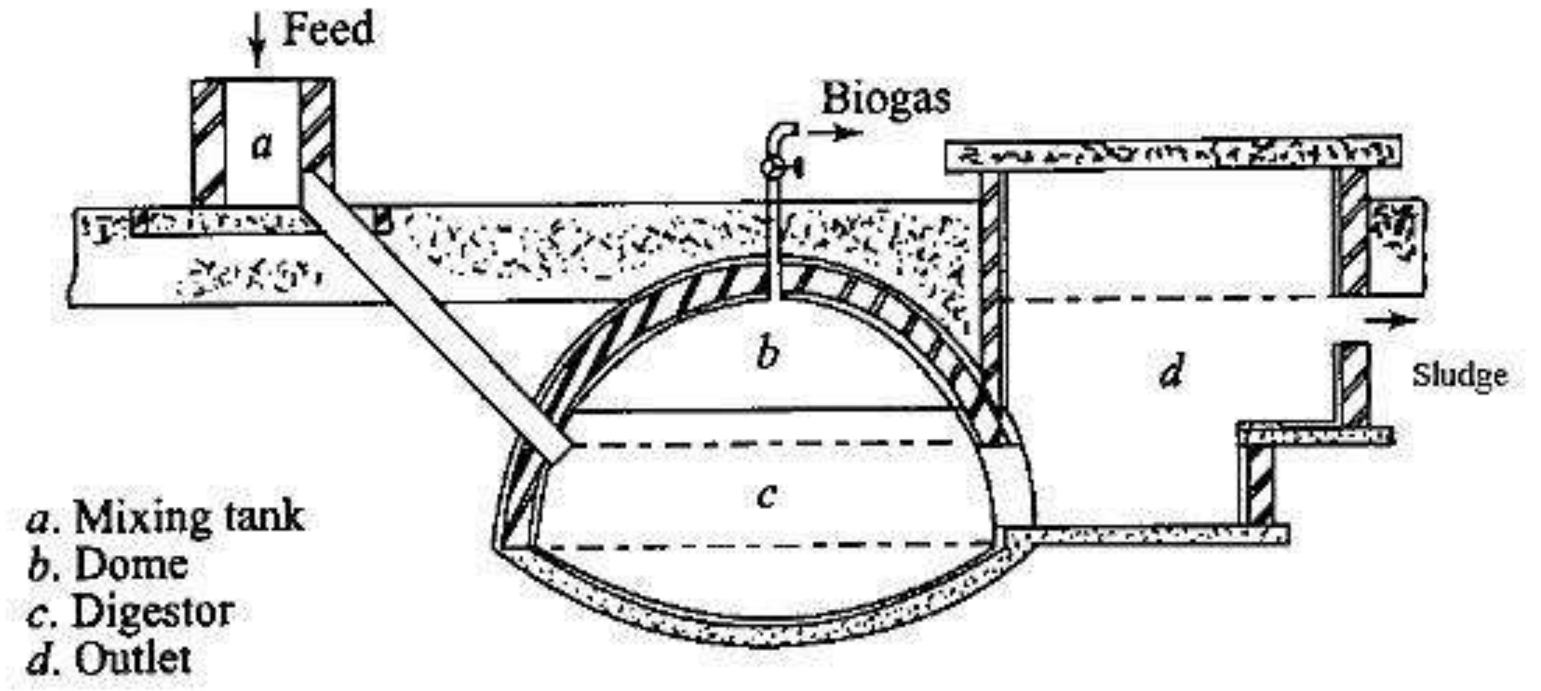


Fig. 8-7. Chinese design biogas plant

The plant consists of an underground well sort of digester made of bricks and cement having a dome shaped roof which remains below the ground level is shown in figure. At almost middle of the digester, there are two rectangular openings facing each other and coming up to a little above the ground level, act as an inlet and outlet of the plant. Dome shaped roof is fitted with a pipe at its top which is the gas outlet of the plant. The principle of gas production is same as that of KVIC model. The biogas is collected in the restricted space of the fixed dome; hence the pressure of gas is much higher,
which is around 90 cm of water column.

Deenbandhu biogas plant:



Deenbandhu model was developed in 1984, by Action for Food Production (AFPRO), a voluntary organization based in New Delhi. Schematic diagram of a Deenabandhu biogas plant entire biogas programme of India as it reduced the cost of the plant half of that of KVIC model and brought biogas technology within the reach of even the poorer sections of the population. The cost reduction has been achieved by minimizing the surface area through joining the segments of two spheres of different diameters at their bases. The cost of a Deenbandhu plant having a capacity of 2 m3/day is about Rs.8000/.

The Deenbandhu biogas plant has a hemispherical fixeddome type of gas holder, unlike the floating dome of the KVIC-design is shown. The dome is made from pre-fabricated Ferro cement or reinforced concrete and attached to the digester, which has a curved bottom. The slurry is fed from a mixing tank through an inlet pipe connected to the digester. After fermentation, the biogas collects in the space under the dome. It is taken out for use through a pipe connected to the top of the dome, while the sludge, which is a by-product, comes out through an opening in the side of the digester. About 90% of the biogas plants in India are of the Deenbandhu type.

Problems Related to Bio-gas Plants:

Some problems are natural and some are created by the persons biogas plants owners but all are controllable.

1. Handling of effluent slurry is major problem if the person is not having sufficient open space or compost pits to get the slurry dry. Use of press filters and transportation is expensive and out of reach of poor farmers. For a domestic plant, 200 litres capacity oil drums can be used to carry this effluent to the fields but this will require some human-animal labour or consumption of diesel if a auto vehicle is used.

2. The gas forming-methanogenic bacteria are very sensitive towards the temperature compared to those of non-methanogenic. During winter as the temperature falls, there is decrease in the activity of methanogenic bacteria and subsequently fall in gas production rate. Many methods have been suggested to overcome this temperature problem as described earlier, e.g.,

a) Use of solar heated hot water to make a slurry of influent but the temperature of water should not exceed 60oC otherwise the mesophilic bacteria will die.
b) Circulation of hot water obtained either from solar heater or I.C. engine heat exchanger, through pipes inside the digester.
c) Green house effect also give good results but it is costlier and after few years the polythene sheet used in it becomes opaque.
d) Addition of various nutrients for bacteria.
e) Converting the biogas plant by straw bags during night hours.

3. Due to lack of proper training to the bio-gas plant owners for the operation of plant, a lot of problems arises. It has been noticed that many persons increase the loading rate and some also do not try to mix the cattle dung with water, keeping in mind more gas production. Due to this, the flow of slurry from inlet towards outlet is very slow or even stops. This may cause accumulation of volatile fatty acids and drop in Ph and then failure of digester. Also it is not possible to stir the digester content of high solid concentration.
4. Some persons add urea-fertilizer in large quantities due to which toxicity of ammonia nitrogen may cause a decrease in gas production.

5. pH and volatile fatty acids play an important role in anaerobic digestion and should remain under optimum range otherwise this may cause upsetting of digester and even its failure. pH can be checked from time to time by the use of cheep and easily available pH paper but volatile fatty acids can only be determined in a laboratory having its testing facilities. For controlling pH in optimum range, it tends to fall below 7.0, lime has been suggested, as it is easily available cheap material and does not harm the activity of bacteria.

6. Leakage of gas from gas holder especially in case of Janta type biogas plants is a major and very common problem. When there is quite enough gas in a gas holder, the leakage should be checked by using water and the points marked and then get repaired. During repairing there should be no gas inside the gas holder and the stop cock remains open till repaired points get dry. Quality of constructing material such as cement is important.

Advantages of Biogas:

1. Biogas is an energy carrier which can be used for several energy applications (eg. electricity generation, heat production, combine heat and power production, transport fuel, injection to the natural gas grid).

2. Biogas can contribute to several sectors:

i) Environment
(eg. Fight against Climate change)
ii) Energy
(eg. Energy security, local source)
iii) Agriculture
(eg. Sustainable cultivation and animal breeding)
iv) Society
(eg. Employment enhancement, rural development)

3. Some Environmental benefits of biogas:

i) Reduced emissions of greenhouse gases, direct and indirect (eg. CO_2, CH_4 and nitrous oxide –N_2O).

ii) Water and Waste management (Reduced consumption of resources and increased recycling, reduced water environment pollution from leaching of nutrients, environmental friendly solution to the waste disposal problem).

iii) Reduced odour and flies

4. Emissions reduction of greenhouse gases (eg. CO_2, CH_4 and nitrous oxide –N_2O).