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UNIT-IV - ENERGY FROM OCEANS

Introduction :- Broadly the ocean sources of energy are Ocean thermal Energy Conversion and the Tidal energy, wave energy and fourth form of energy that emanates from the sun-ocean system stems from the mechanism of surface water evaporation by solar heating i.e hydrological cycle. The oceans and seas constitute some 70% of the earth's surface area, so they represents a rather large storage reservoir of solar input. The conversion of solar energy stored as heat in the ocean into electrical energy by making use of the temperature difference between the warm surface water and the colder deep water. The operation of OTEC plant is based on a well established physical (thermodynamic) principle. If a heat source is available at a higher temperature and a heat sink at a lower temperature, it is possible in principle, to utilize the temp. difference in a machine or prime mover (e.g. a turbine) that converts part of the heat taken up from the source into mechanical energy and hence the electrical energy. The residual heat is discharged to the sink at the lower temp.

*** Lambert's Law of Absorption :⟹** 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.

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

$$I(x) = I_0 e^{-kx} \quad \text{——— (i)}$$

where I_0 and $I(x)$ are the intensities of radiation at the surface ($x=0$) and a distance 'x' below the surface. K - is the extinction coefficient or absorption coefficient. that unit L^{-1}, K has a values of $0.05\ m^{-1}$ for very clear fresh water, 0.27 for turbid fresh water, and $0.50\ m^{-1}$ for very salty water. Thus the intensity decreases exponentialy with depth and depending upon K, almost all of the absorption occurs very close to the surface of deep waters.

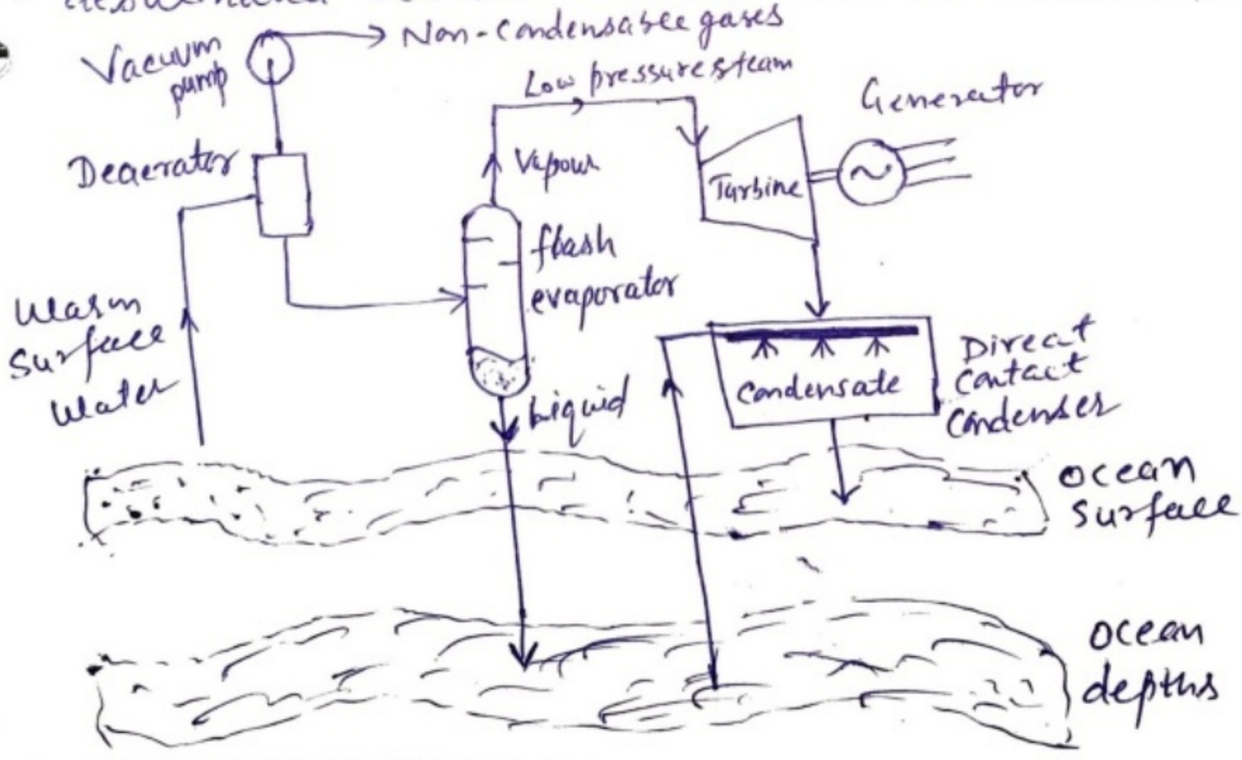
* Ocean Thermal Electric Conversion (OTEC) :-

The ocean thermal energy concept was proposed as early as 1881 by french physicist Jacques d'Arsonval. The surface of the water at sea acts as the collector for solar heat while the upper layer of the sea constitutes infinite heat storage reservior. The temperature difference between the warm surface water of the tropical oceans and the colder waters in the depths is about 20-25°K. This warm surface water could be used to heat some boiling organic fluid, the vapour of which would run a heat engine. The exit vapours would condensed by pumping cold water from the deeper regions.

Methods of Ocean thermal electric power Generation

There are two rather different methods for harnessing Ocena thermal differences. One is 'Open cycle' also known as claude cycle, and other is 'Closed cycle' system, also known as 'Andersons cycle'.

① **Open Cycle OTEC :→** In an open cycle plant, warm water from the ocean surface is flash evaporated under partial vacuum. Low pressure steam obtained is sepreated and passed through a turbine to extract energy. The exhausto turbine is condensated in a direct contact condenser. Cold water drawn from a depth of about 1000 mtr. is used as cooling water in a direct contact condenser. The resulting mixture of used cooling water and condensate is disposed in the sea. If a surface contact condenser is employed, the condensate would be used as desalinated water. The scheme is shown in below fig.



(2) Closed Cycle (Anderson Cycle) :⟹ In a closed cycle plant, warm surface water is used to evaporate a low boiling point working fluid such as ammonia, freon or propane. The vapour flows through the turbine and is then cooled and condensed by cold water pumped from the ocean depths. Because of the low quality of heat, large surface areas of heat exchangers (evaporator and condenser) are required to transfer significant amount of heat and a large amount of water needs to circulated. The schematic diagram is shown in figure.

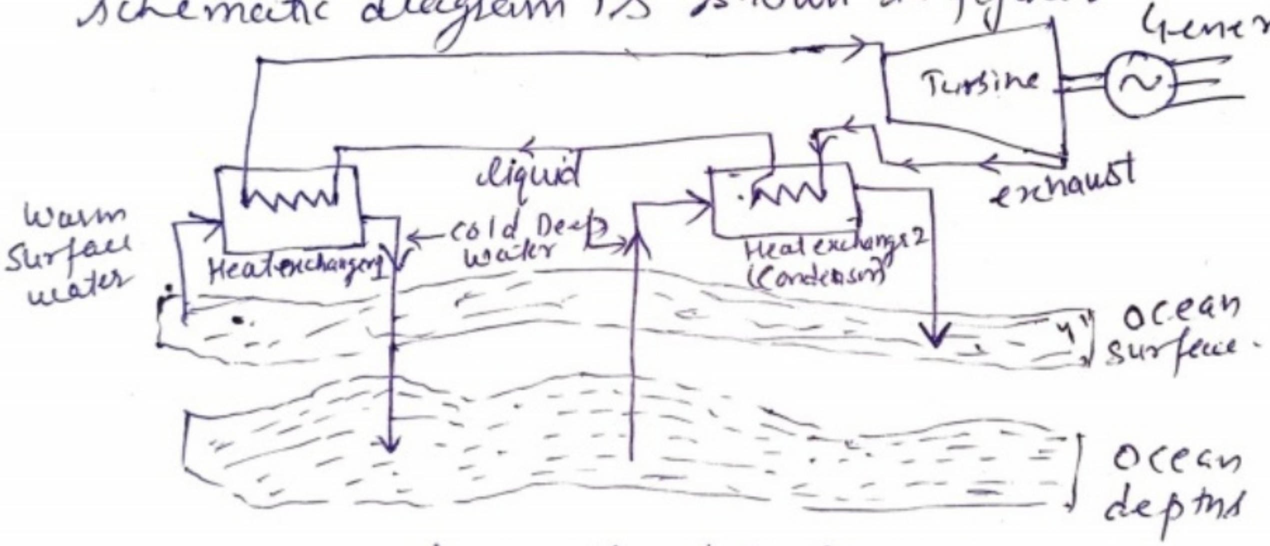


fig.(3) Closed Cycle OTEC

⟹ Advantages of OTEC :⟹ (1) The energy o/p is constant, reliable and environment friendly, as it does not discharge any CO_2, but works as a CO_2 sink.

(2) OTEC brings various economic benefits through co-product such as potable water, enhanced fish farming, Its massive release of mineral rich Deep sea water is applicable to industries such as pharmaceuticals, aquaculture & cosmetics.

(3) Sea water life including salmon, abalone, lobster, flatfish and edible seaweeds can be harvested for food using the cold water pipes that would be available from OTEC plants.

③

Challenges of Problems for OTEC :-

① Enviormental concerns include habitat destruction from the installation of mooming, cables, and pipes; biota toxic response from biocide / ammonia release; Interference from platform. noise and electromagnetic field. One major concern is the leakage of harmful substance (ammonia or chloride) into the ocean if pipes were to ever be damaged.

② There are also other obstacles faced by almost all new technologies as they are introduced like lack of experience with operation of OTEC plant, of sufficient size, time required to build up investor confidence and to better assess environmental benefits as well the limits of source.

③ OTEC community should planned to suit various economic ventures associated with OTEC projects. This includes fresh water production, air conditioning and refrigeration, aqua culture and cold water agriculture.

* **Energy from Tides :⇒** Introduction :→ Tide is a periodic rise and fall of the water level of sea which are carried by the action of the sun and moon on the water of the earth.

The large scale up and down movement of sea water represents an unlimited source of energy. The main feature of the tidal cycle is the difference in water surface elevations at the high tide and at the low tide. If this differential head is utilized in operating a hydraulic turbine, the tidal energy could be converted into electrical energy by means of an attached generator.

Basic Principal of Tidal ~~power~~ ⇒ Tides are produced mainly by the gravitational attraction of the moon and the sun on the water of solid earth and the oceans. About 70% of the tide producing force is due to the moon and 30% to the sun. Surface water is pulled away from the earth on the side facing the moon and at the same time the solid earth is pulled away from the water on the opposite side. Thus high tides occurs in these two areas of a given area relative to the moon changes, and so also do the tides.

The rise and fall of the water level follows a sinusoidal curve, shown with point 'A' indicating the high tide point and point 'B' indicating the low tide point. The average time for the water level to fall from 'A' to 'B' and then rise to 'C' is approximately 6 hours 12.5 min.

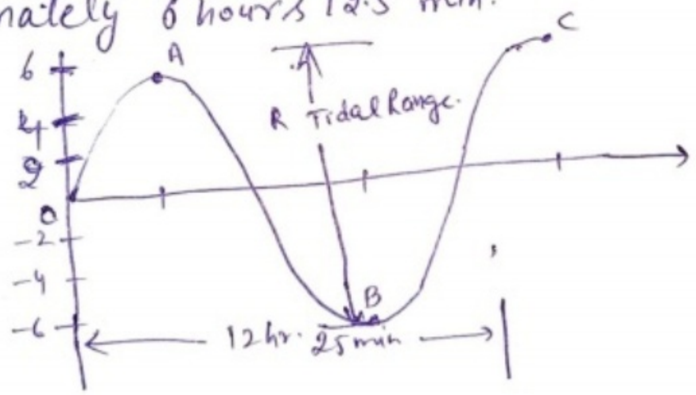


fig: The Tides of sea.

The difference between high and lower water level is called the **range of the tide:** The tidal range 'R' is defined as:

R = water elevation at high tide − water elevation at low tide

At times near full or new moon, when sun, moon and earth are approximately in a line, the gravitational force of sun and moon enhance each other. The tidal range is the exceptionally large, the high tides are higher and low tides are lower than the average. These High tides are called spring tides. on the other hand, near the first and third quarter of moon, when the sun and moon are at right angles with respect to ~~others~~ earth, neap tides occurs. The tidal range varies the 29.5 day lunar month being maximum at the time of new and full moons, called the **spring tides**; and minimum at the time of first and third quarter moons called the neap tides. The spring-neap cycle lasts one half of a lunar month.

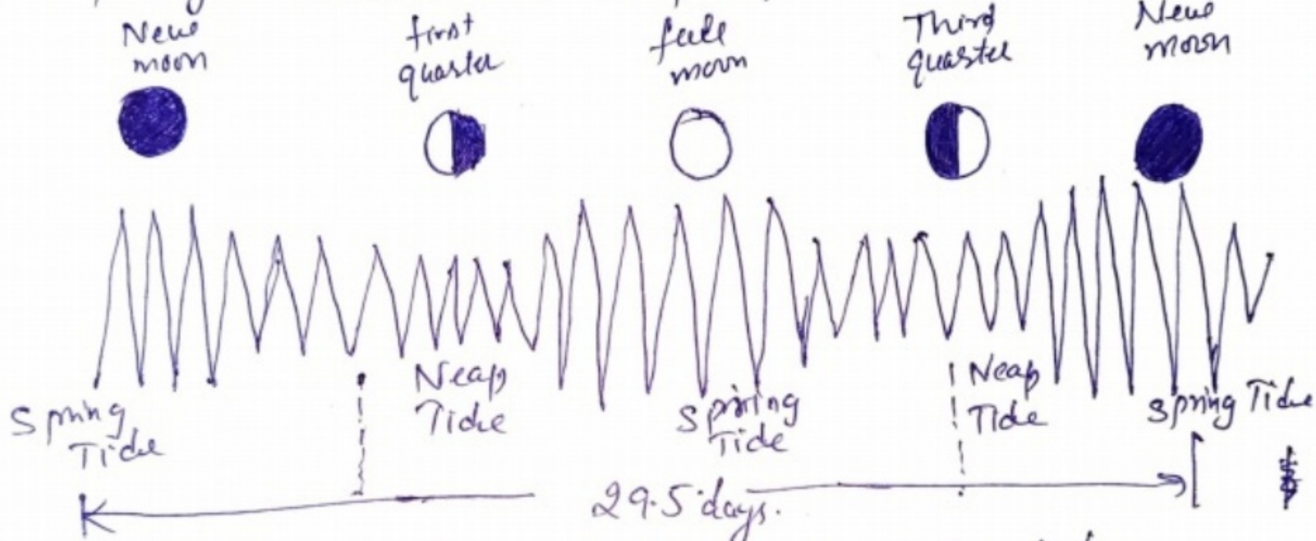


fig – Relative High and low tides showing variation in range during lunar month

* Components of Tidal Power Plants: → There are three main components of a tidal Power plant i.e

(i) The power house
(ii) The dam or barrage to form pool or basin
(iii) Sluice ways from the basin to sea and vice versa.

(1) Power House: ⇒ The turbines electric generator and other auxiliary equipments are the main components of a power house. Because small heads are available large size turbines are needed: Hence the power

is also a large structure. Both the french and soviet operating plants use the bulb type of turbines of the ~~propel~~ propeller type, with reversible blades, bulbs have horizontal shafts coupled to a single generator.

② The dam or barrage :⇒ Dam and barrage are synonymous terms. Barrage has been suggested as a more accurate term for tidal power schemes. Tidal power barrage ~~length~~ ~~adds~~ have to resist waves whose shock can be severe and where pressure changes sides, continiously. The barrage needs to provide channels for the turbines in prestressed or reinforced concrete. Construction of a barrage usually will influence the tidal amplitude. The location of the barrage is important, because the energy available is related to the size of the trapped basin and square of the tidal range. The nearer it is built to the mouth of an estuary or bay, the larger the basin, but smaller the tidal range. A balance must also be struck betn increased output and increased meterial requirements and construction coasts.

③ The sluice ways :⇒ 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. It is generally convenient to have the power house as well as the sluice ways in alignment with dam.

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* Operational Methods of Utilization of Tidal Energy →

Accordingly we can distinguish the following types of arrangements:-

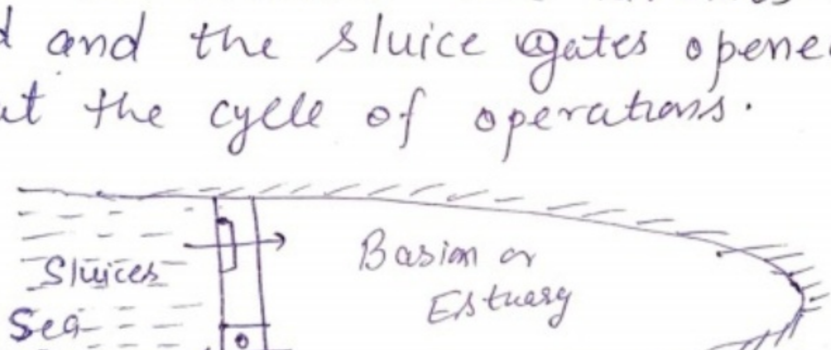
(i) Single Basin Arrangement
(ii) Double Basin Arrangement.

Single Basin schemes can generate power only intermittently but a double basin scheme can provide power continiously or on demand which is a tremendous advantage.

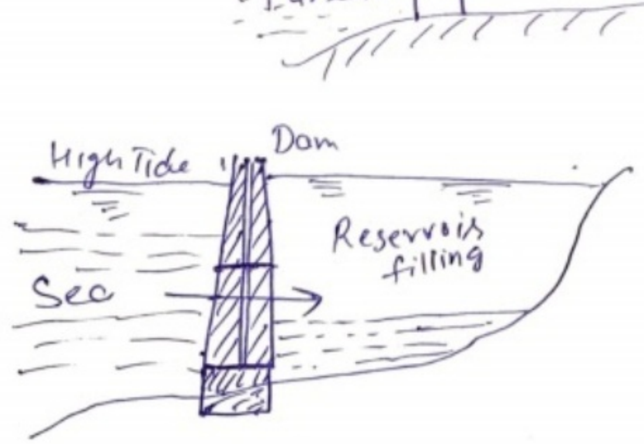
(1) Single Basin Arrangement :⇒ The simplest way to generate tidal power is to use a single basin with a retaing dam. In a single basin arrangement there is only one basin interacting with the sea. The two are seprated by a dam and flow betn them is through sluice ways located conveniently along the dam. Potential head is provided by rise and fall of tidal water levels, this is usually accomplished by blocking the mouth of a long narrow estuary with dam across it. The dam embodies a number of a sluice gates and low head turbine sets. The generation of power can be achieved in a single basin arrangement either as a:-

(a) Single ebb cycle system
(b) Single tide-cycle system
(c) Double cycle system.

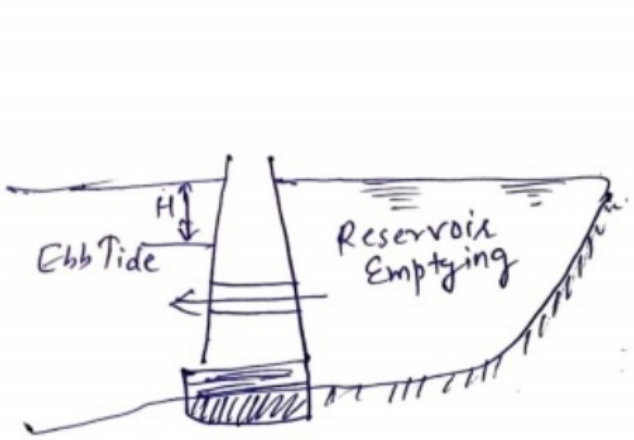
(a) Single ebb Cycle System ⟶ When the flood tide comes in, the sluice gates are opened to permit sea water to enter the basin or reservois, while the turbines sets are shut. The reservois thus starts filling while its level rises, till the maximum tide level is reached. At the ~~beggin~~ beginning of the ebb tide the sluice gates are closed. Then the generation of power takes place when sea is ebbing and the water from the basin flows over the turbines into the lower level of sea water. After two or three hours when there is sufficient difference betn the full reservoir level and falling tide level, to run the turbines, they are started and keep working untill the rising level of next flood tide and the falling reservois level togethes reduce the effective head on the turbine. The turbines are then closed and the sluice gates opened again to repeat the cycle of operations.



(a) Tidal plant operation



(b) Sluice gate open, Turbine shutoff



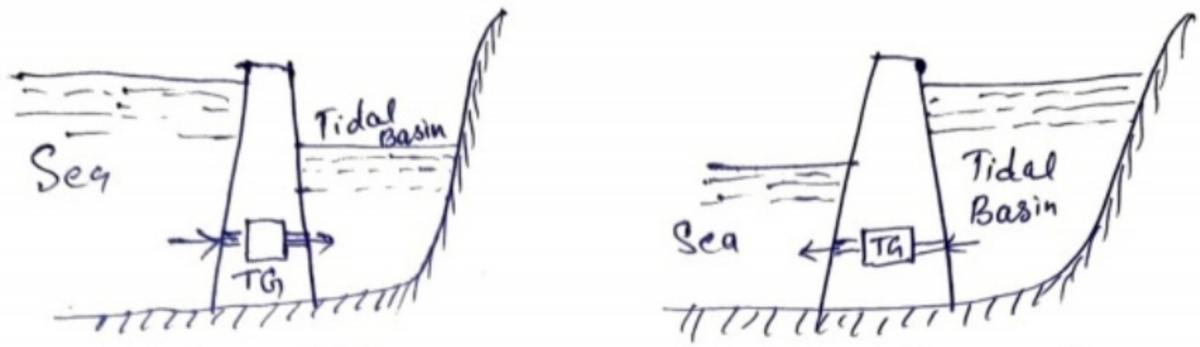
(C) Sluice Gates shut Turbine operation

- - ** Single Basin Operations ** - -

(2) Single tide Cycle System: ⟹ In single tide cycle system, the generation is affected when the sea is at flood tide. The water of the sea is admitted into basin over the turbines. As the flood tide period is over and sea level starts falling again the generation is stopped. The basin is drained into the sea through the sluice ways.

The main disadvantage of both ebb cycle as well as the tide cycle systems is the intermittent nature of their operation.

(3) Double Cycle System. ⟹ In double cycle system, the power generation is affected during the ebb as well as in flood tides.. The direction of flow through the turbines during the ebb and flood tides alternates. but the machine acts as a turbine for either direction of flow. Both filling and emptying processes take place during during a short period of time. The flow of water in both directions is used to drive a number of reversible water turbines, each driving an electrical generator. Electric power thus be generated during two short period during each tidal period of 12h, 25 min. or once every 6 hr. 19.5 min.



(a) High Tide (b) low Tide.

fig – Double Cycle System.

* Double Basin Arrangement :

It requires two separate but adjacent basins. In one basin called "upper basin" the water level is maintained above that in the other, the low basin (or low pool). Because there is always a head betn upper and lower basins, electricity can be generated continiously, although at a variable rate.

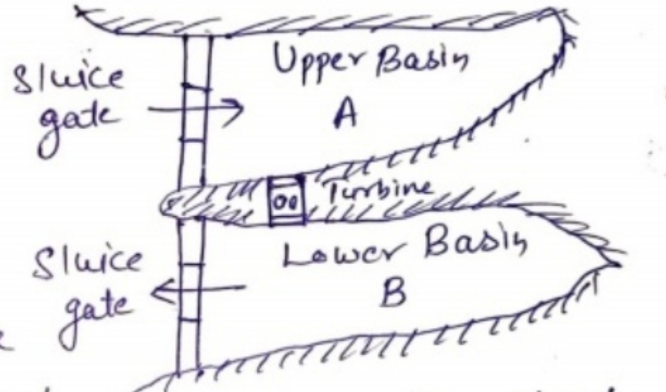


fig – Tidal Power Plant Double Basin Operation.

The turbines are located in between the two adjacent basins, while the 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 and those of 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 betn the two basins, the turbines are started.

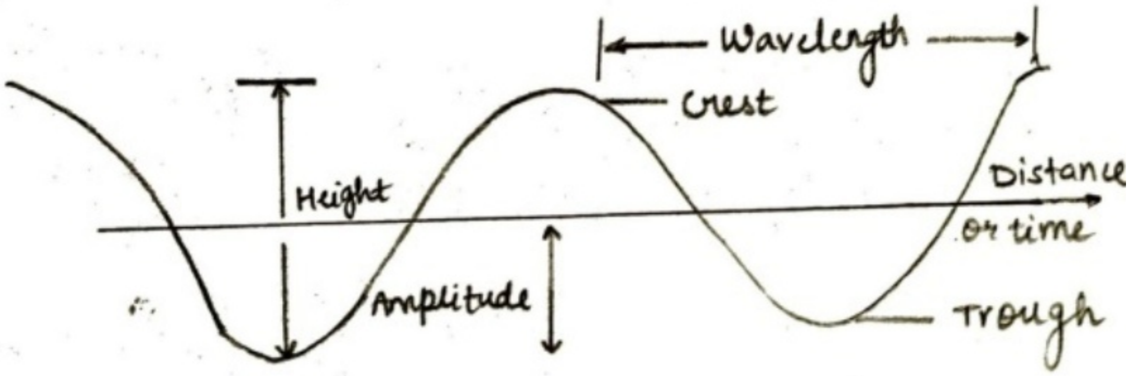
The water flows from A to B through the turbines, generating power. At the end of the flood tide. when 'A' is full and water level in it is the maximum, its sluice gates are closed. When the ebb tide level gets lower than the water level in B, its sluice gates are opened whereby the water level in 'B', which was arising and reducing the operating head, starts falling with the ebb. This continues untill the head and water level in 'A' is sufficient to run the turbines. With the next flood tide the cycle repeats itself. With twin basin system, a longer and more continious ~~power~~ period of generation per day is possible.

Wave Energy

Wave Energy also known as Ocean wave Energy is another type of ocean based renewable energy source that uses the power of the waves to generate electricity. unlike tidal energy which uses the ebb and flow of tides, wave energy uses the vertical movement of the surface water that produces tidal waves. Wave power converts the periodic up-and-down movement of the ocean waves into electricity by passing or placing equipment on the surface of the oceans that captures the energy produced by the wave movement and converts this mechanical energy into electrical power.

wave energy is actually a concentrated form of solar power generated by the action of the wind blowing across the surface of the oceans water which can then be used as a renewable source of energy. As the sun rays strike the Earth's atmosphere, they warm it up. Differences in the temperature of the air masses around the globe causes the air to move from the hotter regions to the cooler regions, resulting in winds.

In simplest terms, an ocean wave is the up-and-down vertical movement of the sea water which varies sinusoidally with time. This sinusoidal wave has high points called crests and low points called troughs.



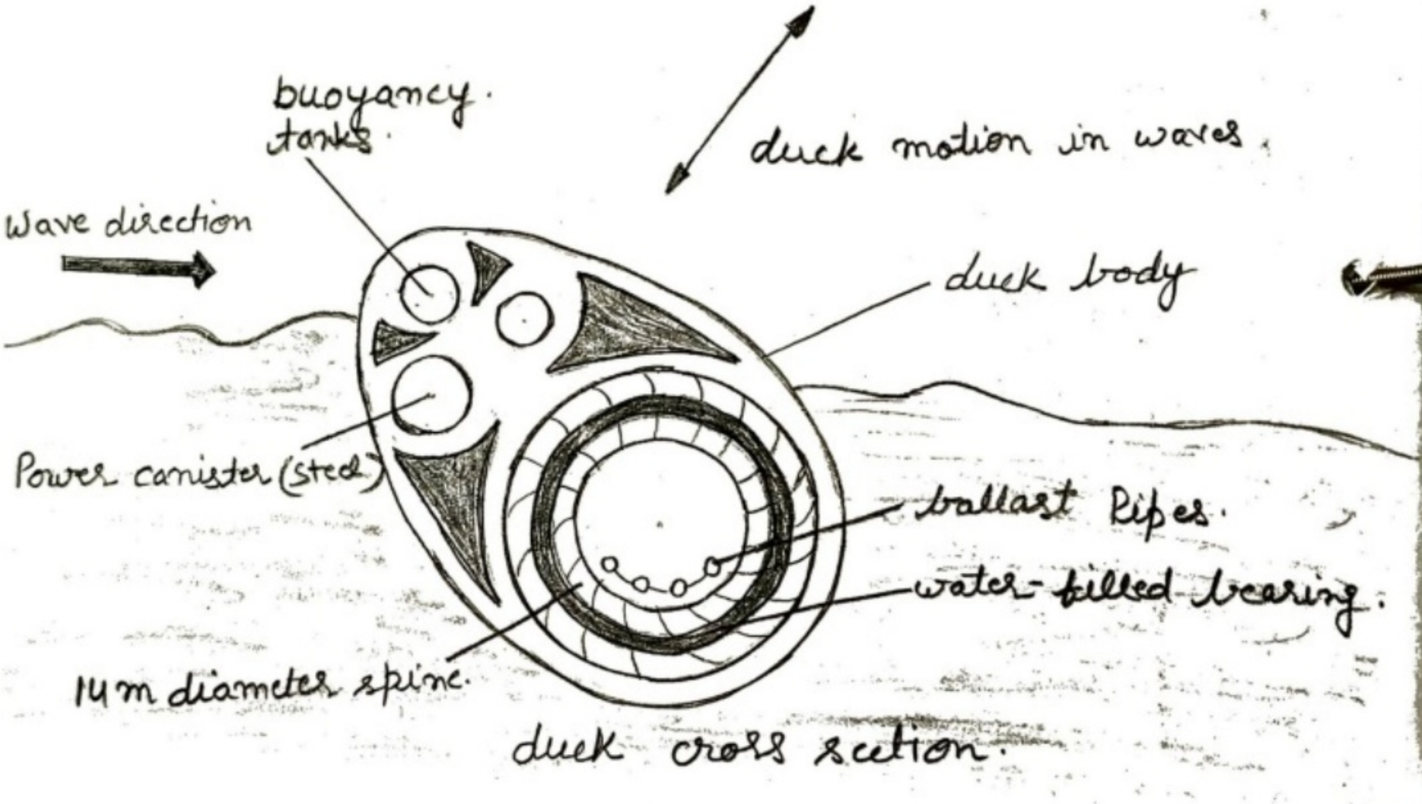
wave characteristic

The difference in height of a wave between the crest and the trough is called the peak-to-peak amplitude; then the waves amplitude or height is the centre of these two points and corresponds to the actual sea level when there is no movement of the water, in other words, a calm sea.

The amplitude of an ocean wave, another important characteristic, depends on the weather conditions at that time, as the amplitude of a smooth wave, or swell, will be small in calm weather but much larger in stormy weather with strong gales as the sea water moves up and down.

The amplitude of a wave is also the distance between each successive crest or trough, known as the wave period, (T). This wave period is the time in seconds between each crest of the wave. Then for a gentle swell this time period may be very long, but for a stormy sea this time period may be very short as each wave crashes onto the one in front.

The reciprocal of this time (1/T) gives us the fundamental frequency of the ocean wave relative to some static point. Smaller periodic waves generated or superimposed onto this fundamental wave such as reflected waves are called harmonic waves.



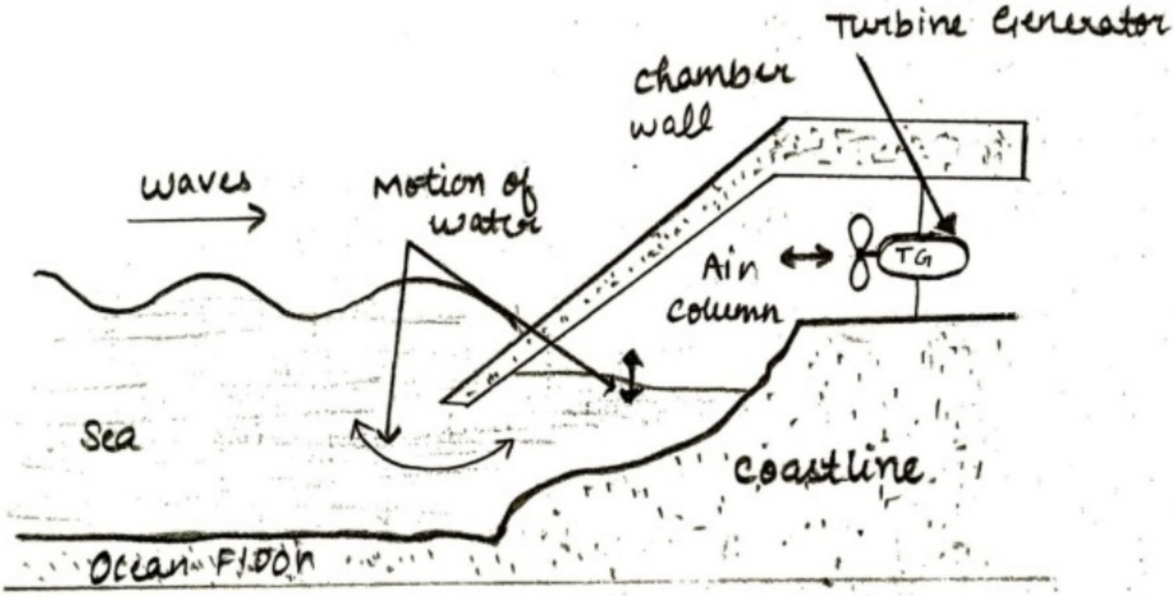
Salter's Duck

Different Wave Energy Convertors

- Saltor's Duck -

Salter's Duck is just one of many concepts for a wave energy converter (WEC), which can potentially convert wave power to usable energy. But inthe 1970s, when alternative energy was gaining a lot of hype, it was the most exciting possibility. since then, some companies have successfully implemented other WECs, like the farm of Pelamis devices off Portugal.

The Duck itself is shaped liked a teardrop, and many of these "teardrops" attach to a long spine to make up the whole Salter's system. The nose of the teardrop faces incoming waves and bobs as they pass. Essentially, this involves a transfer, or "capture", of the wave's energy. In theory, this bobbing action would capture as much as 90 percent of the wave's massive energy and uses that energy to keep pistons running. The pistons in turn pressurize hydraulic oil. When pressurized enough, the oil enters a hydraulic motor, which generates electricity. The system would theoretically use 90 percent of the captured energy. The high efficiency makes the Duck the Holy Grail of WECs.

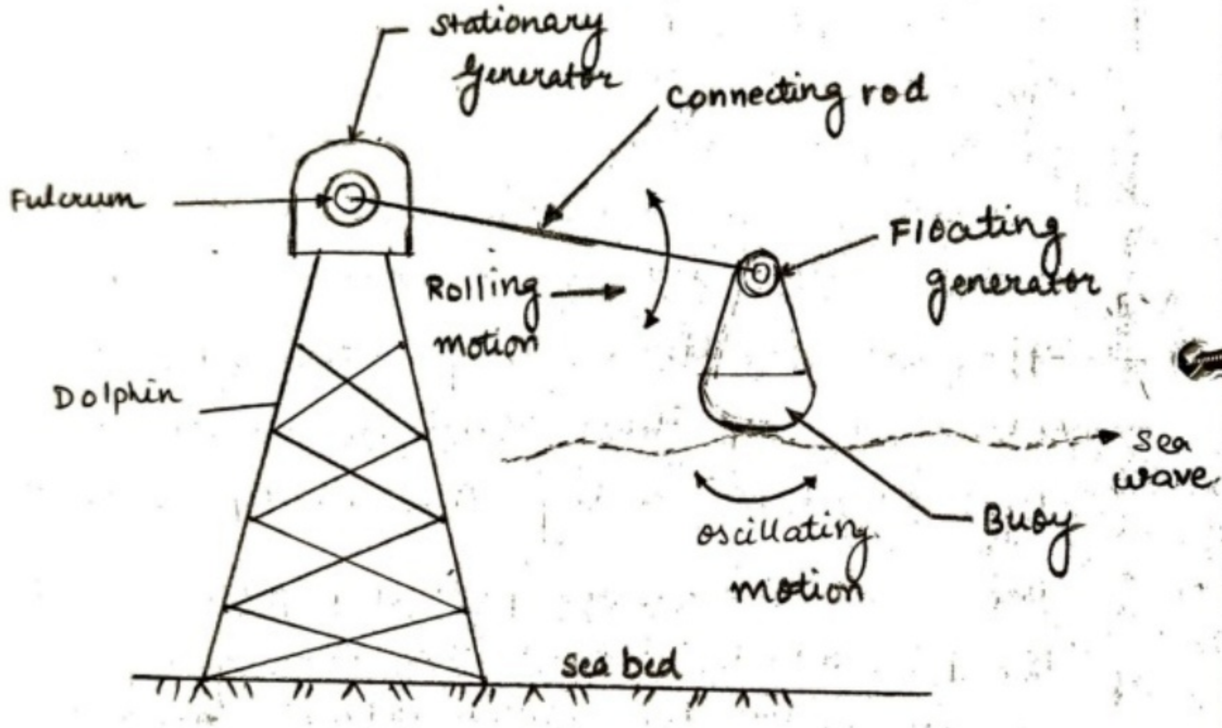


Oscillating water column

- Oscillating Water Column -

An oscillating water column (OWC) is a wave energy converting technology that can be installed onshore preferably on rocky shores; nearshore in up to 10m of water; or offshore in 40-80 m deep water.
The device consists of a large wave capture chamber, a platform for an air turbine, a lip, wing walls, and an air chamber. When waves approach the device, they enter under the partially submerged lip that traps air in a piston type system, forcing the air upwards through the air turbine. The pressure forces the turbine to spin, which is how the energy is harnessed by waves. As the waves retreat, air enters back into the air chamber from the other side of the turbine.

OWCs have shown a promise as a renewable energy source with low environmental impact. Because of this, multiple companies have been working to design increasingly efficient OWC models. OWC are devices with a continuous movement force, a bidirectional stream of high velocity air which is channelled through a Power-take-off (PTO).



Dolphin Type Wave Energy converter

ADVANTAGES and DISADVANTAGES OF TIDAL POWER PLANT:

- **ADVANTAGES:**
  1. Tidal power is completely independent of the precipitation (rain) and its uncertainty.
  2. Large area of valuable land is not required.
  3. It is inexhaustible and a renewable source of energy.
  4. It is free from pollution.
  5. When a tidal power plant works in combination with thermal or hydroelectric system, peak demand can be effectively met with.
  6. The net-cost of power generated is quite low.
- **DISADVANTAGES:**
  1. Due to variation in tidal range the output is not uniform.
  2. Since the turbines have to work on a wide range of head variation (due to variable tidal range) the plant efficiency is affected.
  3. There is a fear of machinery being corroded due to corrosive sea water.
  4. It is difficult to carry out construction in sea.
  5. As compared to other sources of energy, the tidal power plant is costly.
  6. Sedimentation and silteration of basins are the problems associated with tidal power plants.
  7. The power transmission cost is high because the tidal power plants are located away from load centres.

❑ OCEAN THERMAL ENERGY CONVERSION (OTEC) POWER PLANT

- Ocean thermal energy exists in the form of temperature difference between the warm surface water and the colder deep water. A heat engine generates power utilizing well established thermodynamic principle, where heat flows from high temperature source to low temperature sink through engine, converting a part of the heat into work. In the present case the surface water works as heat source and deep water as heat sink to convert part of the heat to mechanical energy and hence into electrical energy. The facility proposed to achieve this conversion is known as OTEC (ocean thermal energy conversion). A minimum temperature difference of 20 °C is required for practical energy conversion.

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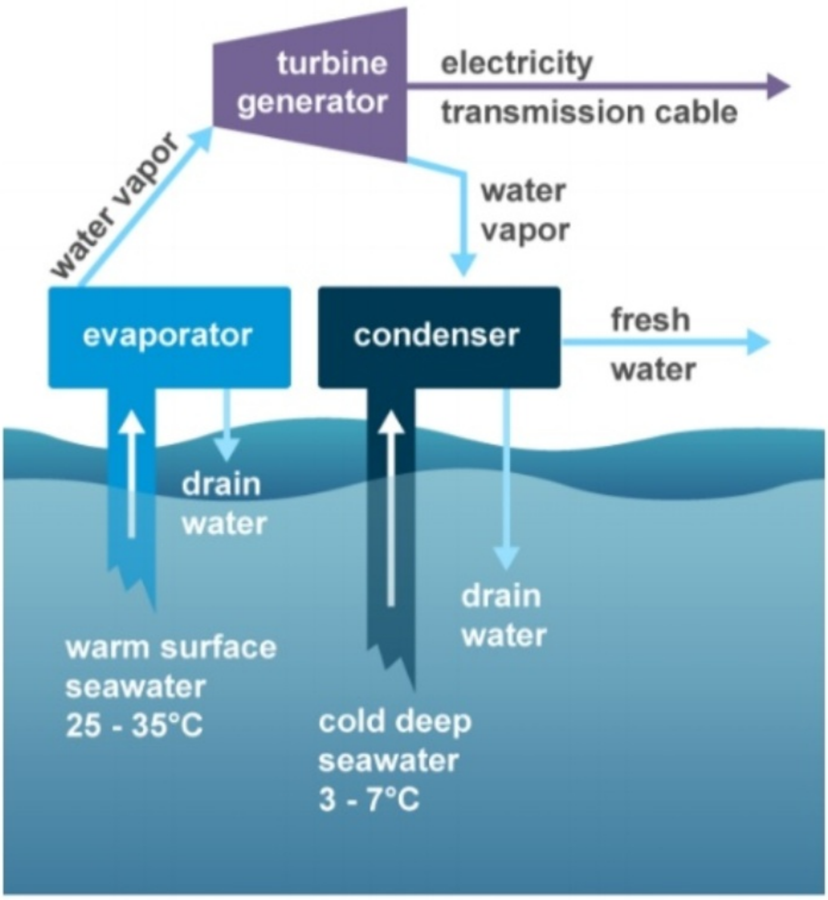
SCHEMATIC DIAGRAM OF OTEC POWER PLANT



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❑ DOLPHIN TYPE WAVE POWER MACHINE

Dolphin-type wave-power machine (generator)

This wave-power machine was designed by a research laboratory in Japan. It consists of the following components (Fig.):

1. A dolphin;
2. A float;
3. A connecting rod;
4. Two electrical generators.

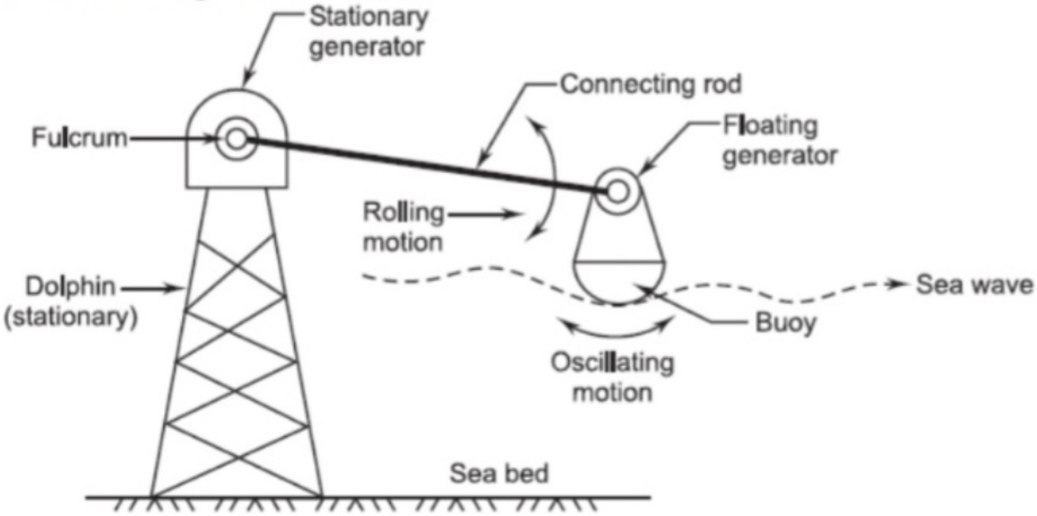

Fig. Dolphin-type wave-power machine.

— A *"stationary generator"*, installed on the top of the structure, collects wave energy from the *"connecting rod"* with *rolling motion*. This generator has a *gear arrangement* which *rotates the rotor to generate electric power*.

— The *"buoy"* which is at the other end of the connecting rod float has two motions, namely *rolling motion* and *oscillatory motion*. The *"floating generator"* collects wave energy from the buoy through a gear arrangement and generates electric power continuously.

The power density (P/B) is given by the relation:

$$\frac{P}{B} = 1740a^2 \text{ T } W/m$$

where, P = Power, W

B = Wave width, m

a = Amptitude of the wave, m, and

T = Wave period, s.

- The capacity of one dolphin type wave energy generator, normally, is 100 kW.