B.Tech Degree Examination

UNIVERSITY EXAMINATION – MAY 2022

18EEO301T- SUSTAINABLE ENERGY (30.05.2022) –Answer Key

Part-A

Q.No	Option	Answer
1	A	Solar distillation
2	A	1016 W
3	A	Pyrheliometer
4	B	Zenith
5	D	20%
6	A	Cubically
7	D	Cut-in Speed and Cut-out Speed
8	B,C,D	To control generator in terms of Reactive power, To control generator in terms of Real power.To control the DC link voltage
9	D	The output power increases
10	A	Full Variable
11	C	Dog Feed
12	B	Logging residues
13	C	Anaerobic digestion and fermentation
14	B	Producer gas
15	B	Methylated spirit
16	B	Kalpan turbine
17	C	Spring tide
18	C	The sihwa lake tidal power station
19	D	Tidal lagoons, tidal streams and tidal barrages
20	A	Wave Energy
21	A	Eliminates combustion of fuel
22	D	Catalytic effects of reaction container
23	A	-1.23 V
24	D	H_2O
25	D	Take part in chemical reactions

Part-B

26(a) Different types of concentrating type collectorsand explain Flat plate

Types – 3 Marks

Flat plate – 7 Marks

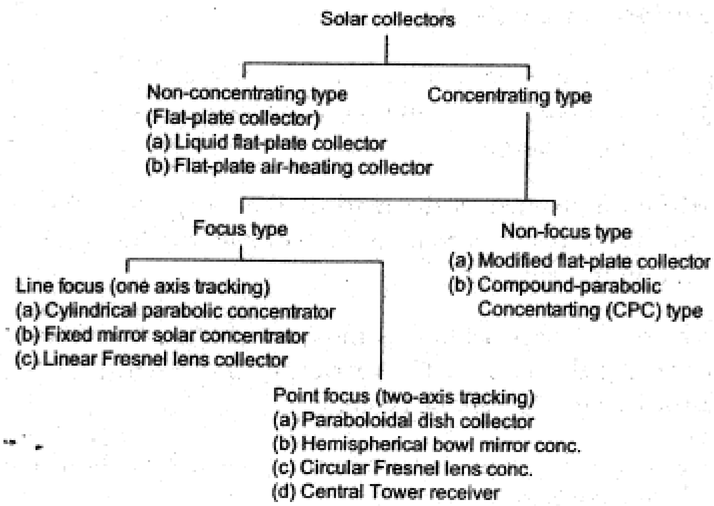


Fig. 5.1 *Types of solar collectors*

5.1.8 Modified Flat-Plate Collector (Flat-Plate Collector with Booster Mirrors)

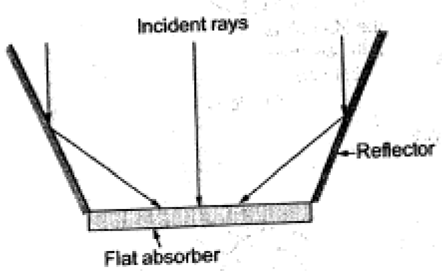


Fig. 5.9 *Modified flat-plate collector*

By providing plane reflectors at the edges of a flat-plate collector to reflect additional radiation into the receiver, the concentration of solar radiation can be increased. These mirrors are also called booster mirrors. The concentration ratio of these concentrators has a maximum value of 4. Such a design (V-trough) is aligned in the east–west direction and requires periodic tilt adjustment. Different optimum depth to base width ratio and cone angles are possible depending on the frequency of seasonal tilt adjustment. The schematic diagram is shown in Fig. 5.9.

<u>26 (b) Low Temperature thermal electric production using solar pond</u>

Diagram - 3 Marks

Explanation- 7 Marks

4.3. Solar Pond

4.3.1. Introduction. A natural or artificial body of water for collecting and absorbing solar radiation energy and storing it as heat. Thus a solar pond combines solar energy collection and sensible heat storage.

The simplest type of solar pond is very shallow, about 5 to 10 cm deep, with a radiation absorbing (*e.g.*, black plastic) bottom. A bed of insulating material under the pond minimizes loss of heat to the ground. A curved cover, made of transparent fibre glass, over the pond permits entry of solar radiation but reduces losses by radiation and convection (*i.e.*, air movement). In a suitable climate, all the pond water can become hot enough for use in space heating and agricultural and other processes.

In shallow solar pond, as described above, the water soon acquires a fairly uniform temperature. However, experience shows that the water in such a pond usually heats up only a few degrees, because of the natural convection currents which are set into motion as soon as heat is absorbed at the bottom. In a deeper pond also temperature variations generally exist. Loss of heat from the surface, especially at night, then results in circulation of water by convection. The situation is changed if the pond contains salt water at the bottom with a layer of fresh water above it. Because of its salt content, the solar pond bottom water is more dense than the cooler fresh water at the top, and hence it does not tend to rise. A relatively stable layer of heated salt water is thus produced at the bottom of the pond with a lighter layer of cooler fresh water, which acts as a heat insulator, above it. Thus a 'solar pond' is defined as an artificially constructed pond in which significant temperature rises are caused to occur in the lower regions by preventing convection. The more specific terms 'salt-gradient solar pond' or 'non-convecting solar pond' are also often used, as to distinguish these ponds from 'shallow solar pond'.

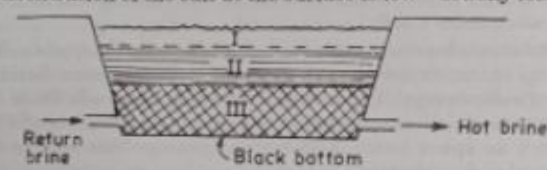
Solar ponds promise an economical way over flat-plate collectors and energy storage by employing a mass of water for both collection and storage of solar energy. The energy is stored in low grade (60 to 100°C) thermal form which, in self, might be suitable for a variety of applications such as space heating, industrial process heat and to obtain mechanical and/or electrical energy.

Ponds have been studied experimentally and analytically at the National Physical Laboratory of Israel and by others. Tabour (1964) outlines the general concept and the major problems. Tabour and Merz (1965) carried out theoretical investigations of underlying physics of the solar pond and laboratory and field tests, to study the many factors affecting pond performance. At MIT, Stolzenbach (1968) developed numerical methods to predict temperature distributions within the solar pond. A group of Russian scientists at the Uzbek SSR Accademy of Science (1973) has been actively engaged in very detailed and sophisticated research of the relevant physics. In India Dr. G.C. Jain (1973) has designed and is operating a solar pond for use in production of salt at the Central Salt and Marine Chemical Research Institute in Bhavnagar. Work has also been done at Pondicheri, where experimental studies have been conducted on a pond 100 m^2 in area and 2 m deep.

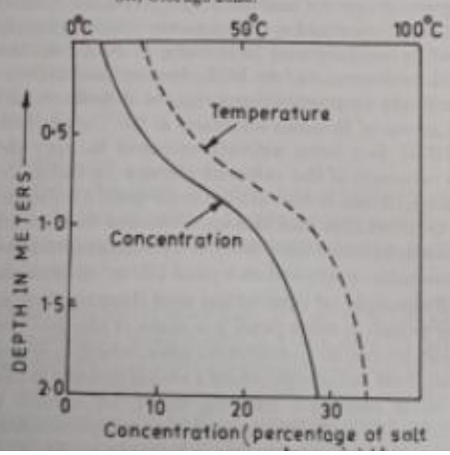
4.3.2. Principle of operation and description of non-convective solar pond. A solar pond is a mass of shallow water about 1 or 2 metres deep with a large collection area, which acts as a heat trap. It contains dissolved salts to generate a stable density gradient. Part of the incident solar radiation entering the pond surface is absorbed throughout the depth and the remainder which penetrates the pond is absorbed at the black bottom. If the pond were initially filled with fresh water, the lower layers would heat up, expand and rise to the surface.

Because of the convective mixing and heat loss at the surface, only a small temperature rise in the pond could be realized. On the other hand, convection can be eliminated by initially creating a sufficiently strong salt concentration gradient. In this case, thermal expansion in the hotter lower layers is insufficient to destabilize the pond. With convection suppressed, the heat is lost from the lower layers only by conduction. Because of the relatively low conductivity, the water acts as an insulator and permits high temperature (over 90°C) to develop in the bottom layers. At the bottom of the pond, a thick durable plastic liner is laid. Materials used for the liner include butyl rubber, black polyethylene and hypalon reinforced with nylon mesh. Salts like magnesium chloride, sodium chloride or sodium nitrate are dissolved in the water, the concentration varying from 20 to 30 per cent at the bottom to almost zero at the top.

In the salt-gradient solar ponds, dissolved salt is used to create layer of water with different densities—the more salt, the denser water. The concentration of the salt at the surface is low—usually less than 5



(i) Surface convective zone.
(ii) Non-convective zone.
(iii) Storage zone.



27 (a) Maximum Power is Generated Derivation – 10 Marks

6.2.2. The power in the Wind

Wind possesses energy by virtue of its motion. Any device capable of slowing down the mass of moving air, like a sail or propeller, can extract part of the energy and convert is into useful work. Three factors determine the output from a wind energy converter :

(*i*) the wind speed ;

(*ii*) the cross-section of wind swept by rotor ; and

(*iii*) the overall conversion efficiency of the rotor, transmission system and generator or pump.

No device, however well-designed, can extract *all* of the wind's energy because the wind would have to be brought to a halt and this would prevent the passage of more air through the rotor. The most that is possible is for the rotor to decelerate the whole horizontal column of intercepted air to about one-third of its free velocity. A 100% efficient aerogenerator would therefore only be able to convert up to a maximum of around 60% of the available energy in wind into mechanical energy. Well-designed blades will typically extract 70% of the theretical maximum, but losses incurred in the gearbox, transmission system and generator or pump could decrease overall wind turbine efficiency to 35% or loss.

The power in the wind can be computed by using the concept of kinetics. The wind mill works on the principle of converting kinetic *amounts of power should have large rotors and be located in areas of high wind speeds.* Where low or moderate powers are adequate, these requirements can be relaxed.

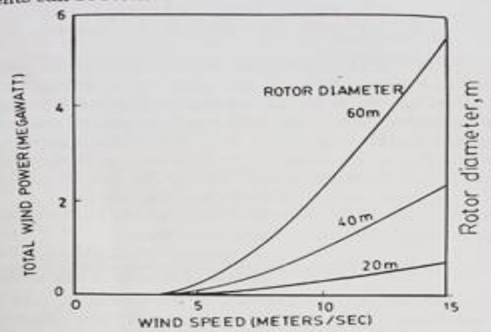


Fig. 6.2.1. Dependence of wind-rotor power on wind speed and rotor diameter.

The physical conditions in a wind turbine are such that only a fraction of the available wind power can be converted into useful power. As the free wind stream encounters and passes through a rotor, the wind transfer some of its energy to the rotor and its speed decreases to a minimum in the rotor wake. Subsequently, the wind stream regains energy from the surrounding air and at a sufficient distance from the rotor the free wind speed is restored (Fig. 6.2.2 upper curve). While the

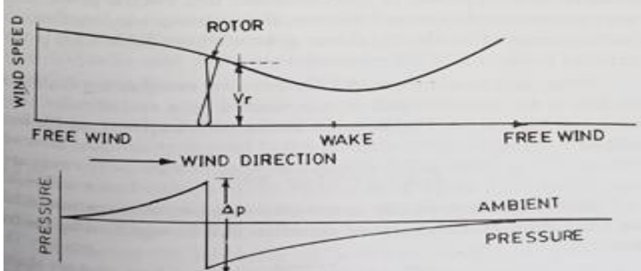


Fig. 6.2.2. Conditions in traversing a wind rotor.

The fraction of the [illegible] by a rotor is called the *power-coefficient*; thus

$$\text{Power coefficient} = \frac{\text{Power of wind rotor}}{\text{Power available in the wind}}$$

where power available is calculated from the air density, rotor diameter, and free wind speed as shown above. The maximum theoretical power coefficient is equal to 16/27 or 0.593. This value cannot be exceeded by a rotor in a free-flow wind-stream. (It can be exceeded under specific conditions, as will be seen later).

As an ideal rotor, with propeller-type blades of proper areodynamic design, would have a power coefficient approaching 0.59. But such a rotor would not be strong enough to withstand the stresses to which it is subjected when rotating at a high rate in a high-speed wind stream. For the best practical rotors, the power coefficient is about 0.4 to 0.45, so that the rotors cannot use more than 40 to 45 percent of the available wind power. In the conversion into electric power, some of the rotor energy is lost and the overall electric power, coefficient of an aerogenerator (*i.e.* electric power generated/available wind power) in practice is about 0.35 (35 percent).

Returning to equation (6.2.2), but now recognizing that V, in actuality, is not constant but is represented by a statistically 'noisy' wind speed time curve, $V_{(t)}$, then the instantaneous power, in the wind would be

$$P_{a(t)} = \frac{1}{2}\rho A[V_{(t)}]^3 \text{ watts} \quad \text{...(6.2.4)}$$

Since we are normally more interested in average power, we must time average both sides of equation (6.2.4), signified by the bar below

$$\overline{P_{a(t)}} = \frac{1}{2}\rho A\,\overline{[V_{(t)}]^3} \text{ watts} \quad \text{...(6.2.5)}$$

to ambient), that the potential energy is zero, and no heat or work are added or removed between i and a, the general energy equation reduces to the kinetic and flow energy-terms only :

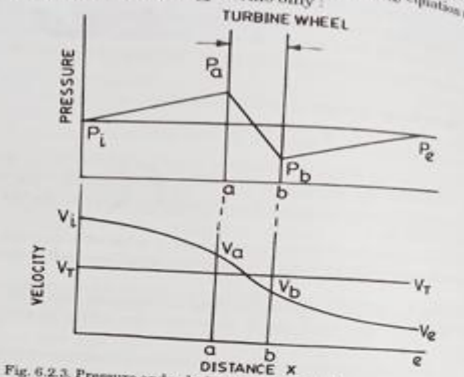


Fig. 6.2.3. Pressure and velocity profiles of wind moving through a horizontal-axis propeller-type wind turbine.

Thus
$$P_i v + \frac{V_i^2}{2g_c} = P_a v + \frac{V_a^2}{2g_c} \quad \text{...(6.2.7 a)}$$

[The general energy equation for steady state flow for unit mass (for a control volume) is :

$$Z_1 + \frac{V_1^2}{2g} + u + P_1 v_1 + \Delta q = Z_2 + \frac{V_2^2}{2g} + u_2 + P_2 v_2 + \Delta W s f$$

where
Z_1 = potential energy
$\frac{V^2}{2g}$ = kinetic energy
u = internal energy
Pv = flow energy
Δq = net heat added
ΔW_{sf} = net steady flow mechanical workdone of the system]

or
$$P_i + \rho \frac{V_i^2}{2g_c} = P_a + \rho \frac{V_a^2}{2g_c} \quad \text{...(6.2.7 b)}$$

where v and ρ are the specific volume and its reciprocal, the density, respectively, both considered to be constant.

27 (b) Problem10 – Marks

(i) The total power density in the wind stream 613 W/m^3

(ii) The maximum obtainable power density assuming efficiency as 40 %. 363 W/m^3

(iii) The total power produced (in kW)2770 kW

<u>28 (a) Energy is generated using Two stage digestion process and its advantages</u>

Diagram - 3 Marks

Explain - 5 Marks

Advantage – 2 Marks

1. Continuous and batch types

(a) *Continuous plant.* There is a single digester in which raw material are charged regularly and the process goes on without interruption except for repair and cleaning etc. In this case the raw material is self buffered (like cow dung) or otherwise thoroughly mixed with the digesting mass where dilution prevents souring and the biogas production is maintained. The continuous process may be completed in a single stage or separated into two stages.

(i) *Single stage process.* 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. Refer Fig. (7.6.1).

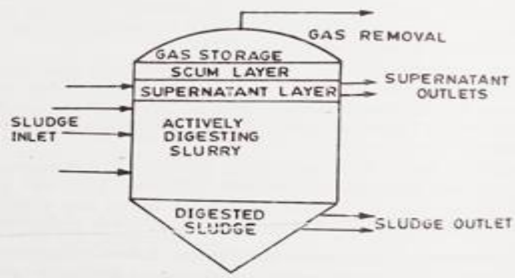


Fig. 7.6.1. Schematic of single process conventional digester.

(ii) *Double stage process.* 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. Refer Fig. 7.6.2. 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.

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 less problems compared to batch type and it is easier in operation.

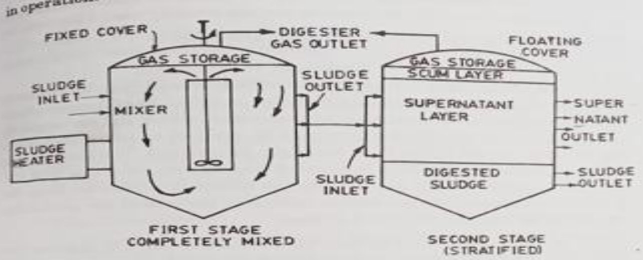


Fig. 7.6.2. Schematic of two-stage digestion process.

(b) *The batch Plant.* The feeding is between intervals, the plant is emptied once the process of digestion is complete. In this type, a battery of digesters are charged along with lime, urea etc. and allowed to produce gas for 40-50 days. These are charged and emptied one by one in a synchronous manner which maintains a regular supply of the gas through a common gas holder. Sometimes the freshly charged digester is aerated for a few days after which it is closed to atmosphere. The biogas supply may be utilised after 8-10 days. Obviously such a plant would be expensive to install and unless operated on large scale it would not be economical. Such systems have been generally installed in European countries. Their installation and operation being capital and labour intensive. They are totally unsuitable for Indian conditions, except when it is taken as a commercial venture.

The main features of the *batch plant* are :

(i) The gas production in it, is intermittent, depending upon the clearing of the digester.

(ii) It needs several digesters or chambers for continuous gas production, these are fed alternately.

(iii) Batch plants are good for long fibrous materials.

(iv) This plant needs addition of fermented slurry to start the digestion process. There may be a direct change to the acid phase in absence of the fermented slurry, which affects formation of methane.

28 (b) Define anerobic digestion. Explain KVIC digestor

Define - 3 Marks

Explain - 7 Marks

7.9. Types of Biogas Plants

As stated earlier there are numerous models of a biogas plant. But they can be grouped under two broad heads—one with the floating gas holder and the other with a fixed dome digester. In floating gas holder plant, the gas holder is separate from the digester. But in the

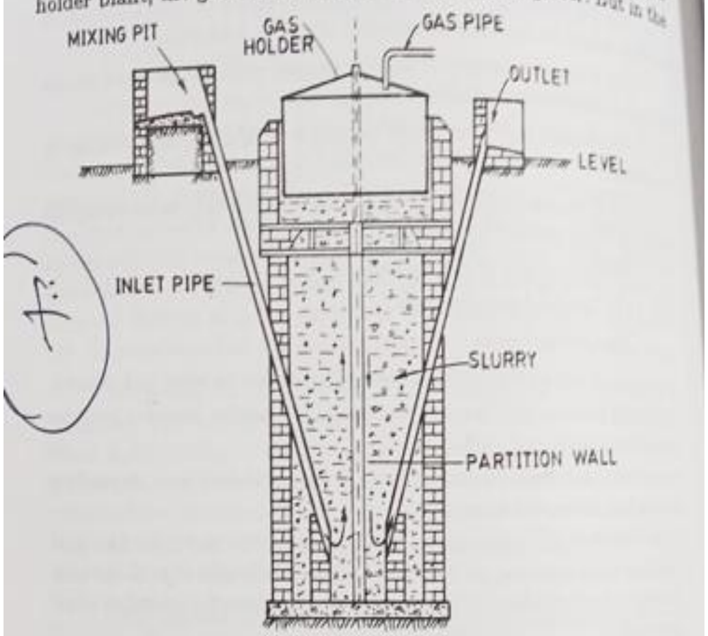


Fig. 7.9.1. Common circular digester with floating gas holder and no water seal (India). (KVIC digester).

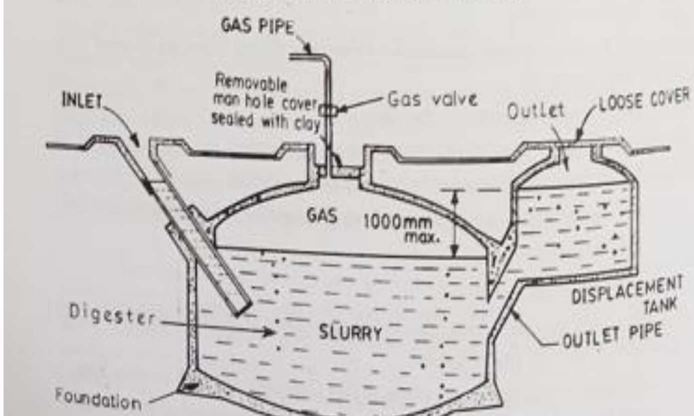


Fig. 7.9.2. Common circular fixed dome digester (China).

fixed dome digester, the gas holder and the digester are combined. The family size biogas plants available today in India are broadly of two types. The Khadi Village Industries Commission (KVIC) model and Janta model which are shown in Figs. (7.9.1) and (7.9.2). The KVIC plant is of steel drum type or floating gas holder design, in which the digestion takes place in a masonry well and the drum floats as the gas collects and is taken out from the top.

The Janta model or fixed dome digester (also called Chinese plant) is a drumless type similar in construction to the KVIC model except that the steel drum is replaced by a fixed dome roof of masonry construction. The floating gas holder digester developed in India is of masonry construction with gas holder made of M.S. plates. The drum in the KVIC model is the costliest component and its life is comparatively less (about 10 years). The dome roof in the Janta model requires specialised design and skilled masonry construction. A poorly constructed roof generally leads to leakage from top and junction of the roof with the digester wall, thereby causing drop in gas yield. The overall cost of both types varies from Rs. 5000 to Rs. 15,000 depending upon the capacity of the biogas plant and subsoil conditions.

In addition to the aforesaid cost and construction material problems, there are constructional problems which the farmers or beneficiaries face. The construction of biogas plants especially in Janta type needs the services of skilled masons who are becoming rather scarce in rural areas. It is observed that plants constructed by unskilled masons or untrained workers have structurally failed or unable to retain dung slurry, gas or even both while the failure of such plants adversely affects plants owners. The prospective plant owners are seldom sure about the correct choice of the plant. Besides the construction of the plant, there are some operational and maintenance problems which almost hinder progress of biomass development.

Fig. (7.9.3) shows a flexible bag digester. The digester is made of plastic material and can be easily installed. The short life of the material due to the effect of ultraviolet rays is a main drawback.

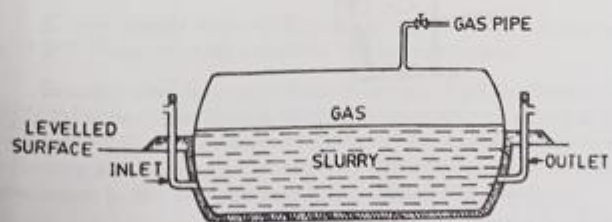


Fig. 7.9.3. Flexible bag type combined digester/gas holder.

Digester type	Advantages
Fixed dome digester	• Low initial cost • Long useful lifespan • No moving or rusting parts involved • Compact basic design • Less land required if built underground • Low maintenance

29 (a) Construction and working of closed cycle thermal power plate and its difference

Construction and working - 7 Marks

Difference - 3 Marks

9.2.3. 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 condenser 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). Its corresponding T-S diagram is also

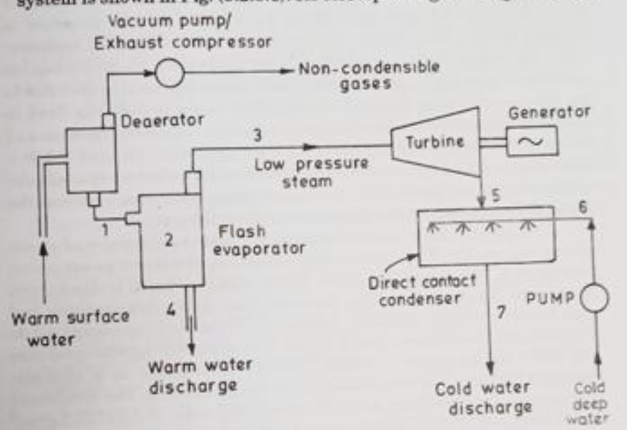


Fig. 9.2.3.1. Schematic of the OTEC open cycle.

shown in the Fig. (9.2.3.2). In the cycle shown warm surface water at say 27°C is admitted into an evaporator in which the pressure is maintained at a value slightly below the saturation pressure

9.2.4. The Closed or Anderson, OTEC Cycle

A schematic of a closed-cycle OTEC power plant is shown in Fig. 9.2.4.1. Heat exchanger known as evaporators and condensers are a key ingredient, since extensive areas of material are needed to transfer significant amounts of low quality heat of the low temperature differences being exploited. In other words, large volumes of water must

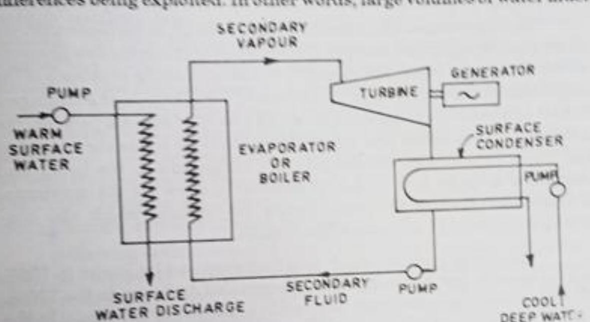


Fig. 9.2.4.1. Schematic of an OTEC closed cycle system.

<u>29 (b) working of single basin single effect type tidal power plate and its limitation</u>

Diagram - 3 Marks

Explain - 5 Marks

Limitation – 2 Marks

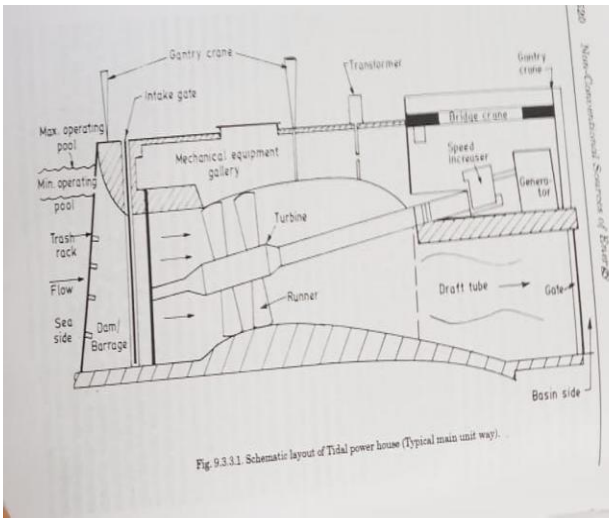


Fig. 9.3.3.1. Schematic layout of Tidal power house (Typical main unit way).

9.3.4. Operation Methods of Utilization of Tidal Energy

The generation of electricity from water power requires that there should be a difference in levels (or heads) between which water flows. A number of concepts have been proposed for generating electricity by utilizing the head that can be produced by the rise and fall of the tides to operate a hydraulic turbine. The power generation from tides involves flow between an artificially developed basin and the sea. However in order to have a more or less continuous generation, this basic scheme can be elaborated by having two or more basins. Accordingly we can distinguish the following types of arrangements :

(1) Single basin arrangement,

(2) Double basin arrangement.

Single-basin schemes can generate power only intermittently, but a double basin scheme can provide power continuously, or on demand, which is a tremendous advantage. The drawback is that the civil works become more extensive. In the simplest double-basin scheme there must be a dam between each basin and the sea, and also a dam between the basins, containing the power house. One basin is maintained always at a lower level than the other. The lower reservoir empties at low tide, and the upper reservoir is replenished at high tide. If the generating capacity is to be large, the reservoirs must be large, which usually means that the dams will be long.

(1) Single Basin Arrangement

The simplest way to generate tidal power is to use a single basin with a retaining dam in the following manner :

In a single basin arrangement there is only one basin interacting with the sea. The two are separated by a dam (or barrage) and the flow between 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 a dam across it, thereby creating a reservoir. The dam or barrage embodies a number of 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, or

(*b*) Single tide-cycle system, or

(*c*) Double cycle system.

(*a*) *Single ebb cycle system*. When the flood tide (high tide) comes in, the sluice gates are opened to permit sea-water to enter the basin or reservoir, while the turbine sets are shut. The reservoir thus starts filling while its level rises, till the maximum tide level is reached. At the beginning of the ebb tide the sluice gates are closed. Then the generation of power takes place when the sea is ebbing (flowing back of tide) and the water from the basin flows over the turbines into the lower level sea water. After two or three hours when there is sufficient

<u>30 (a) Construction and working of alkaline and phosphoric acid of fuel</u>

Diagram - 5 Marks

Explain - 5 Marks

12.1.12 Fuel Cell Power Plant

The block diagram showing the main components of a fuel-cell power plant is given in Fig. 12.7. Electrical energy is generated from primary fossil fuels through a fuel cell. Fuel is managed and supplied by a fuel processing unit. In this unit, fuel is received, stored, reformed, purified and supplied to fuel–cell modules. Fuel–cell modules convert fuel energy electrochemically into dc power using ambient air as oxidant. Basic configurations of cell, module and plant are shown in Fig. 12.8. A number of cells are stacked to form a module. Several modules are interconnected to form a power-generating unit. Fuel gas and air are supplied to modules from common supply pipes. The exhaust is collected in a common pipe and discharged to the atmosphere either directly or after recovery of heat in a cogeneration unit. The power-generating unit generates electrical power as dc. Industrial/commercial loads are rated for standard ac supply such as 3 ph., 400 V, 50/60 Hz or 1 ph., 230/110 V, 50/60 Hz. The electrical power-conditioning unit, converts dc output of fuel cell to ac using inverter and also controls and regulates it.

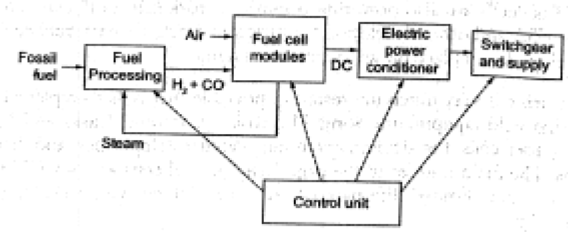


Fig. 12.7 *Fuel-cell based electrical power-generation scheme*

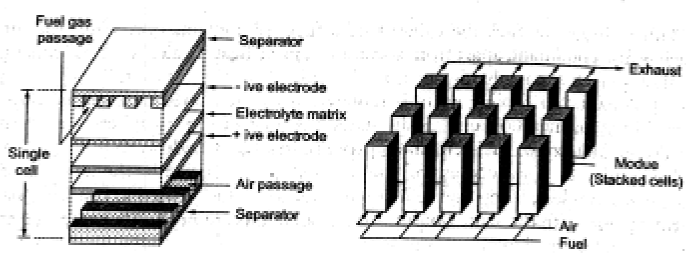


Fig. 12.8 *Power-generation unit*

<u>30 (b) Principle of working of a fuel cell with H_2 – O_2 and its applications</u>

Explain - 7 Marks

Application - 3 Marks

should make it possible to construct plants of various capacities for different requirements.

If fuel cells of reasonably low cost and long life can be produced, a major use might be by electric utilities for load leveling as explained below. A long term possibility is a central-station power plant in which coat is gasified and the gas is used to generate electricity directly by means of fuel cells. Such an installation is expected to have a higher efficiency for fuel utilization than a conventional steam-electric plant.

Portable generating sets seem to be a favourable field for fuel cells. Here, already, fuel cells appear to be competitive as compared with conventional sources. Low temperature fuel cells have a favourable position for operating times of 3,000 to 4,000 hours per year, using methanol as a fuel.

Large generating stations operate most efficiently at a steady (rated) power output, but the demand for power is variable. When the demand or load is less than the rated output, the excess would be used to generate hydrogen by electrolysis of water. At times when the load is greater than the power supply, the hydrogen would be used in fuel cells to satisfy the additional demand. By siting fuel cells near load centres where the demand exists, electrical transmission and distribution costs would be reduced, although there would be some cost for transporting the hydrogen. Sometimes new load centres are formed as a result of housing and industrial developments. To satisfy the power demand utilities, will either built additional large plants, which require considerable capital expenditures, or utilized diesel engines or gas turbines operated by natural gas or a petroleum fuel. The same fuel might be utilized more economically in fuel cells located near the new load centre.

Fuel sources have been proposed for remote or rural areas or unattended locations, for mobile and emergency power sources, and for vehicle propulsion. The high temperature batteries may be the best candidates for vehicle propulsion in the long term, but certain fuel cells are potential alternatives to storage batteries for electric vehicles. Such vehicles may have longer travel ranges than those with the most advanced storage batteries. The fuel cells of special interest are the aluminium-air, methanol-air, and the hydrogen-oxygen cell. The aluminium-air cell is of special interest for electric vehicle propulsion because of the high specific energy that is possible. An aluminium-air battery, and associated equipment may weigh roughly the same as the gasoline engine and fuel in a medium size automobile. A five passenger electric vehicle is expected to have a travel range of atleast 1600 km before replacement of the aluminium electrodes is necessary. However, the aluminium hydroxide produced when the cell operates. It must be removed every 400 to 600 km, and water must be added at similar intervals.

$= -116{,}700$ kcal/kg mole. Ans

10.2.9. Applications of Fuel Cells

The applications of fuel cell may be discussed with reference to the following :

(*i*) Domestic use

(*ii*) Central power stations

(*iii*) Automotive vehicles

(*iv*) Special applications.

The e.m.f. or voltage of a fuel cell depends to some extent on the discharge current strength. The average voltage per cell is 0.75 volt. By joining a number of cells in series and parallel can provide any reasonable voltage and current. Fuel cells generate direct current which can be used for electric lamps and some small applications such as heat pumps, motors etc., conversion into alternating current by means of an inverter might be necessary.

Fuel cells can be made in modules of different size that are readily transportable. They can then be assembled at any location to provide a specified voltage and power output. The modular design should make it possible to construct plants of various capacities for different requirements.

If fuel cells of reasonably low cost and long life can be produced, a major use might be by electric utilities for load leveling as explained below. A long term possibility is a central-station power plant in which coat is gasified and the gas is used to generate electricity directly by means of fuel cells. Such an installation is expected to have a higher efficiency for fuel utilization than a conventional steam-electric plant.

Portable generating sets seem to be a favourable field for fuel cells. Here, already, fuel cells appear to be competitive as compared with conventional sources. Low temperature fuel cells have a favourable position for operating times of 3,000 to 4,000 hours per year, using methanol as a fuel.

Large generating stations operate most efficiently at a steady (rated) power output, but the demand for power is variable. When the demand or load is less than the rated output, the excess would be used to generate hydrogen by electrolysis of water. At times when the load is greater than the power supply, the hydrogen would be used in fuel cells to satisfy the additional demand. By siting fuel cells near load centres where the demand exists, electrical transmission and distribution costs would be reduced, although there would be some cost for transporting the hydrogen. Sometimes new load centres are formed as a result of housing and industrial developments. To satisfy the power demand utilities, will either built additional large plants, which require considerable capital expenditures, or utilized diesel engines or gas turbines operated by natural gas or a petroleum fuel. The same fuel might be utilized more economically in fuel cells located near the new load centre.

Fuel sources have been proposed for remote or rural areas or unattended locations, for mobile and emergency power sources, and for vehicle propulsion. The high temperature batteries may be the best candidates for vehicle propulsion in the long term, but certain fuel cells are potential alternatives to storage batteries for electric vehicles. Such vehicles may have longer travel ranges than those with the most advanced storage batteries. The fuel cells of special interest are the aluminium-air, methanol-air, and the hydrogen-oxygen cell. The aluminium-air cell is of special interest for electric vehicle propulsion because of the high specific energy that is possible. An aluminium-air battery, and associated equipment may weigh roughly the same as the gasoline engine and fuel in a medium size automobile. A five passenger electric vehicle is expected to have a travel range of atleast 1600 km before replacement of the aluminium electrodes is necessary. However, the aluminium hydroxide produced when the cell operates. It must be removed every 400 to 600 km, and water must be added at similar intervals.