USN [| | | | | | | | |] 10ME754

Seventh Semester B.E. Degree Examination, Dec.2015/Jan.2016
Non – Conventional Energy Sources

Time: 3 hrs. Max. Marks:100

Note: ***Answer any FIVE full questions, selecting atleast TWO questions from each part.***

PART - A

1 a. Explain Tar sands and oil shale as energy sources and also mention their limitations. **(10 Marks)**

b. What is the need for alternate energy sources? Explain by considering solar energy. **(05 Marks)**

c. Discuss the limitations of non – conventional sources of energy. **(05 Marks)**

2 a. Define the following : i) Latitude ii) Declination angle iii) Surface azimuth angle iv) Hour angle v) Zenith angle. **(10 Marks)**

b. With a neat sketch, explain the working of pyranometer. **(05 Marks)**

c. Write short notes on spectral distribution of extra terrestrial radiation. **(05 Marks)**

3 a. Calculate the monthly average hourly radiation falling on a flat plate collector facing south ($\gamma = 0^0$) with a slope of 15^0, given the following data :
Location : Chennai (13^0 00' N) ; Month : October ;
Time : 1100 to 1200 (LAT) ; $\bar{I}_g$: 2408 kJ/m^2 – h ; $\bar{I}_d$: 1073 kJ/m^2 – h.
Assume ground reflectivity to be 0.2. **(10 Marks)**

b. Describe solar pond for solar energy collection and storage. **(06 Marks)**

c. Explain how solar energy can be used for drying, with a neat sketch. **(04 Marks)**

4 a. Explain briefly the parameters affecting the performance of flat plate collectors. **(06 Marks)**

b. Derive the expression for transmissivity based on reflection – refraction at the interface of two media. **(08 Marks)**

c. Write short notes on collector efficiency factor and collector heat removal factor . **(06 Marks)**

PART - B

5 a. Describe the main considerations in selecting the site for wind generators. **(08 Marks)**

b. Explain with a neat sketch, the working of a photo – voltaic cell. Draw I – V characteristics. **(06 Marks)**

c. With a neat sketch, explain the horizontal axis wind machine. **(06 Marks)**

6 a. With a neat sketch and T- S diagram, explain the concept of liquid dominated total flow system of generating geothermal energy. **(08 Marks)**

b. Explain with a neat sketch, the working principle of closed cycle OTEC plant. **(06 Marks)**

c. Sketch and explain single basin type tidal power plant operation. **(06 Marks)**

7 a. Explain the process of photosynthesis. What are the conditions which are necessary for it? **(06 Marks)**

b. List the factors affecting bio gas generation. **(04 Marks)**

c. Sketch and explain the working of floating gas holder type biogas plant used in India (KVIC plant). **(10 Marks)**

8 a. Explain the process of electrolytic production of hydrogen, with a neat sketch. **(08 Marks)**

b. Explain briefly the different methods of hydrogen storage. **(06 Marks)**

c. Describe how hydrogen can be used as an alternative fuel for motor vehicles. **(06 Marks)**

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1(a) **Need for non-conventional sources of energy**

* The growing consumption of energy has resulted in the country becoming increasing dependent on fossil fuel such as coal, oil & gas

* Rising prices of oil & gas & their potential storages have raised uncertainties about the energy supply in future, which has serious on the growth of the national economy

* Increassing use of fossile fuels also causes environmental problems. Hence there is a primary needs to use renewable energy sources like solar, wind, biomass, tidal & energy from waste material They are called non conventional sources of energy.

Description of Energy sources & Application of Energy sources

1(b)

① Fossil fuels

These have been formed in the earth's crust from buried plants & micro organisms over millions of years.

These are also nonrenewable source of energy

ex:- coal, petroleum, natural gas etc.

Application of fossil fuels

Fossil fuels produce enormous amount of heat energy on combustion. This can be converted into mechanical Energy in I.C Engines to run automobiles, aircrafts, etc.

~~As~~ Also such heat energy can be converted into mechanical Energy using steam turbines & gas turbines. Further, by coupling these turbines to electrical generators, [thermal power plants]

② Hydral Energy [Hydro Energy]

It is the energy derived from the energy of falling water from higher level to lower level sun is responsible for the hydrological cycle, it is considered as an indirect source of solar energy. Hence it is one of the renewable source of energy.

1(c) Classification of Energy sources

These are the sources which can be exhausted from the earth's crust due to their accumulation over the period of time.

ex:- Fossil fuel, Nuclear fuel etc.

Now such sources are depleting at a faster rate & may get exhausted in the fourth coming years, Hence these are called exhaustible or Non-renewable energy sources.

These are the sources which are freely available in nature.

ex:- Solar, wind, biofuel etc.

As some of these sources are reaching the earth from the outer atmosphere such sources are called incoming or celestial Energy, These are inexhaustible sources.

Comparison of Renewable & non-Renewable energy

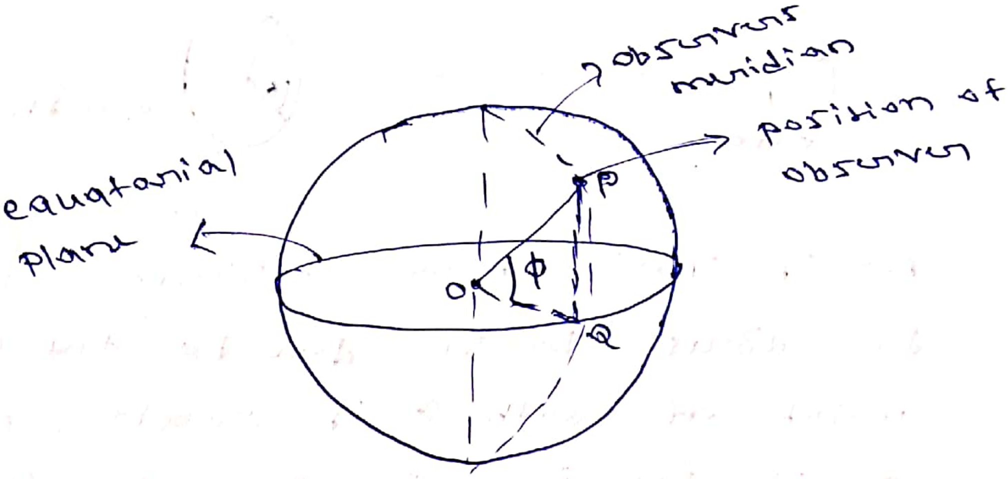
Renewable energy	Non-Renewable energy
① These are inexhaustible	① These are exhaustible
② Freely available & environmental friendly	② Not freely available & hazardous to environment
③ Initial cost is high but maintenance cost is minimum	③ Initial cost is low & maintenance costs are high
④ The energy concentration varies from region to region	④ It is almost constant in all regions.

Solar Radiation Geometry

2 (a) * Latitude (Angle of latitude) (ϕ) :-

It is the angle made by the radial line joining the location to the centre of the earth with its projection on equitorial plane

The latitude is positive for northern hemisphere & negative for southern hemisphere.

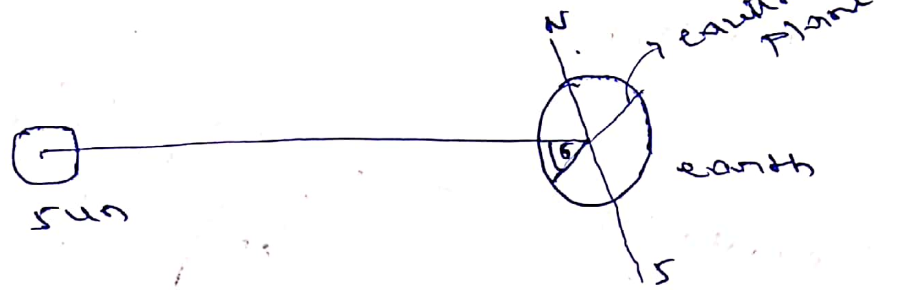


* Longitude :- The angle betn the prime meridian & the meridian of a place is known as the longitude.

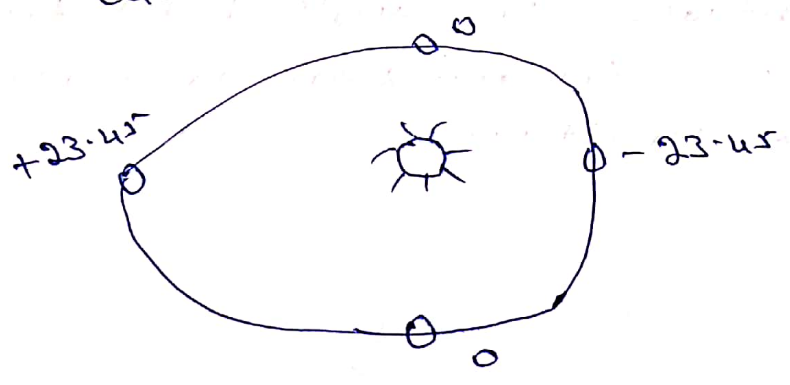
* Declination δ :- It is the angle made by the line joining centre of sun & earth with its projection on equitorial plane or Angular displacement of the sun from the plane of the earth's equator

$$\delta = 23.45 \sin\left[\frac{360}{365}(284 + n)\right] \text{ degrees}$$

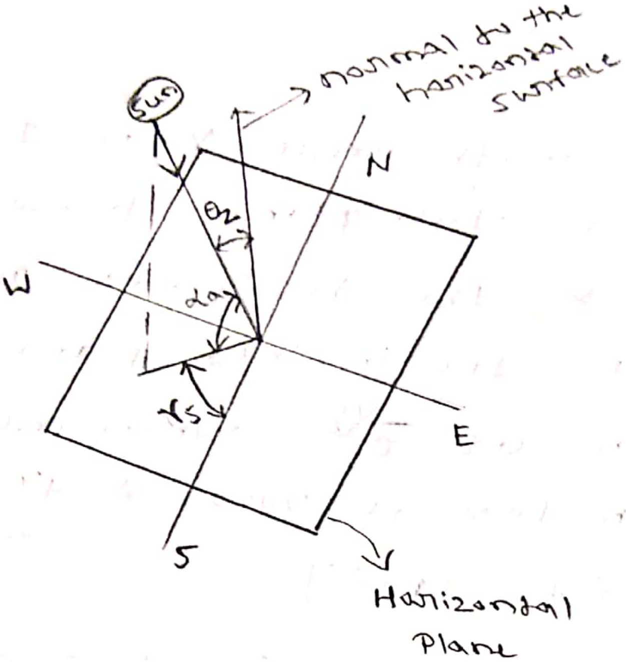
n → day of the year counted from 1st Jan

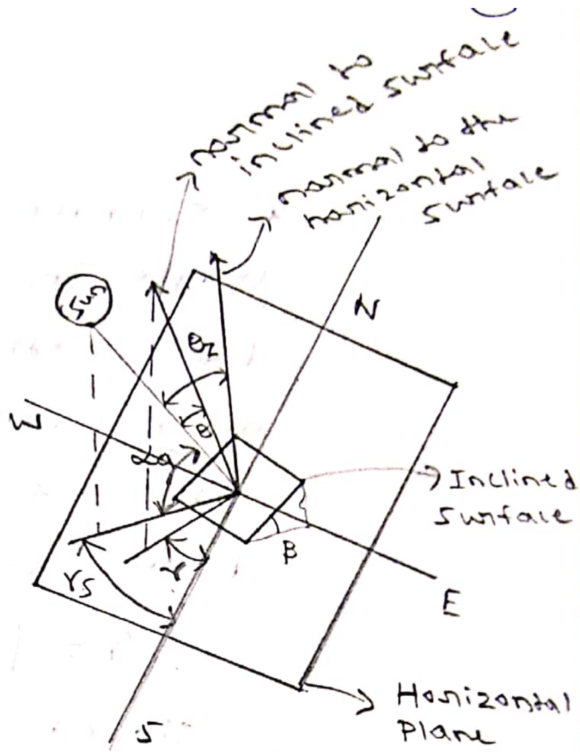


As it varies from +23.45 on June 21 to -23.45 Dec 21 due to the eleptical orbit of earth & it reads '0' on equitorial i.e sep 21 & march 21



δ < 0 → winter
δ > 0 → summer





* Inclination Angle (Altitude), (α) :- The angle between sun's ray & its projection on horizontal surface is known as inclination angle. [equal to $(90^\circ - \theta_z)$]

* Zenith angle (θ_z) :- It is the angle between sun's ray & perpendicular (normal) to the horizontal plane

* For horizontal surface the θ is called as zenith angle i.e θ_z

* Solar Azimuth angle (γ_s) :- It is the angle ~~between inclined plane surface~~, on a horizontal plane, between the line due south & the projection of sun ray on the horizontal plane. It is taken as -ve when measured from south towards west.

2(c) spectral distribution of extraterrestrial & terrestrial radiation

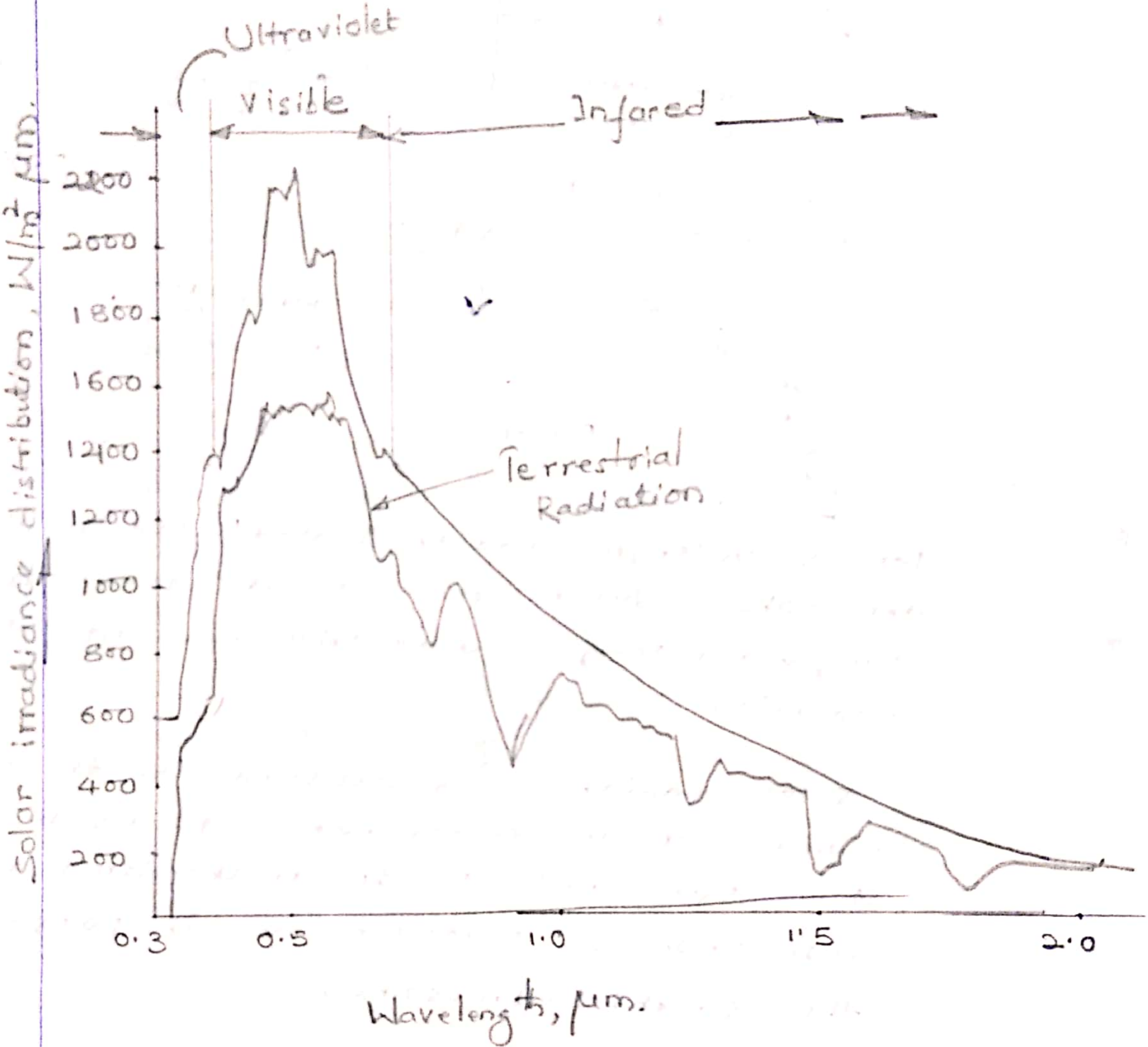
* About 99% of the extraterrestrial radiation has wavelength in the range from 0.2 to 4 μm with maximum spectral intensity at 0.48 μm (green portion of visible range).

* About 6.4% of extraterrestrial radiation energy is contained in ultraviolet region ($\lambda < 0.38$ μm); another 48% is contained in the visible region (0.38 μm $< \lambda < 0.78$ μm) & the remaining 45.6% is contained in the infrared region ($\lambda > 0.78$ μm).

* There is almost complete absorption of short wave radiation in range ($\lambda < 0.29$ μm) & infrared radiation in range ($\lambda > 2.3$ μm) in the atmosphere.

* Thus from the point of view of terrestrial applications of solar energy the radiation only in the range of wavelengths between 0.29 & 2.3 μm is significant.

* The spectral solar irradiation distribution both for extraterrestrial & terrestrial radiation is shown in fig.



Sperical solar irradiation, extraterrestrial and terrestrials

14) Calculate the monthly avg hourly radiation (11)

3(a) falling on a flat plate collector facing south with a slope of 15° with following data. location madras (13°N) month october time 11 to 12 hr LAT. $\bar{I}_g = 2408 \frac{KJ}{m^2\, hr}$ (~~1073~~, ~~day~~)

$\bar{I}_d = 1073 \frac{KJ}{m^2\, hr}$ & $\rho = 0.2$

Soln

$\phi = 13°N$ $\beta = 15°$ $\omega = 7.5$ [In between 11 to 12 time is considerd

only month october is give

consider Representative data in the month october is 15

$n = 288$, $I_T = ?$

$$\delta = 23.45 \sin\left(\frac{360}{365}(284 + 288)\right)$$

$$\boxed{\delta = -9.59}$$

$$r_b = \frac{\sin\delta \sin(\phi-\beta) + \cos\delta \cos\omega \cos(\phi-\beta)}{\sin\phi \sin\delta + \cos\phi \cos\delta \cos\omega}$$

$$= \frac{\sin(-9.59)\sin(13-15) + \cos(-9.59)\cos(7.5)\cos(13-15)}{\sin(13)\sin(-9.59) + \cos(13)\cos(-9.59)\cos(7.5)}$$

$$\boxed{r_b = 1.075}$$

$$r_d = \frac{1+\cos\beta}{2} = \frac{1+\cos 15}{2} = 0.9829$$

$$\boxed{r_d = 0.9829}$$

$$R_r = \frac{\rho(1-\cos\beta)}{2}$$

$$= \frac{0.2(1-\cos 15)}{2}$$

$$\boxed{R_r = 0.0034}$$

$$\frac{I_T}{I_g} = \left(1 - \frac{I_d}{I_g}\right) R_b + \frac{I_d}{I_g} R_d + R_r$$

$$\frac{I_T}{I_g} = \left(1 - \frac{1073}{2408}\right) 1.075 + \left(\frac{1073}{2408}\right) \times 0.982 + 0.0034$$

$$\frac{I_T}{I_g} = 1.03$$

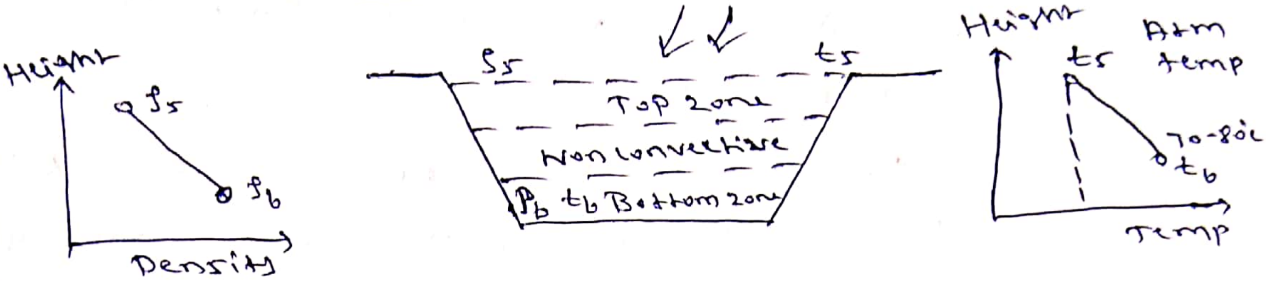
$$\therefore \quad I_T = 1.03 \times I_g$$

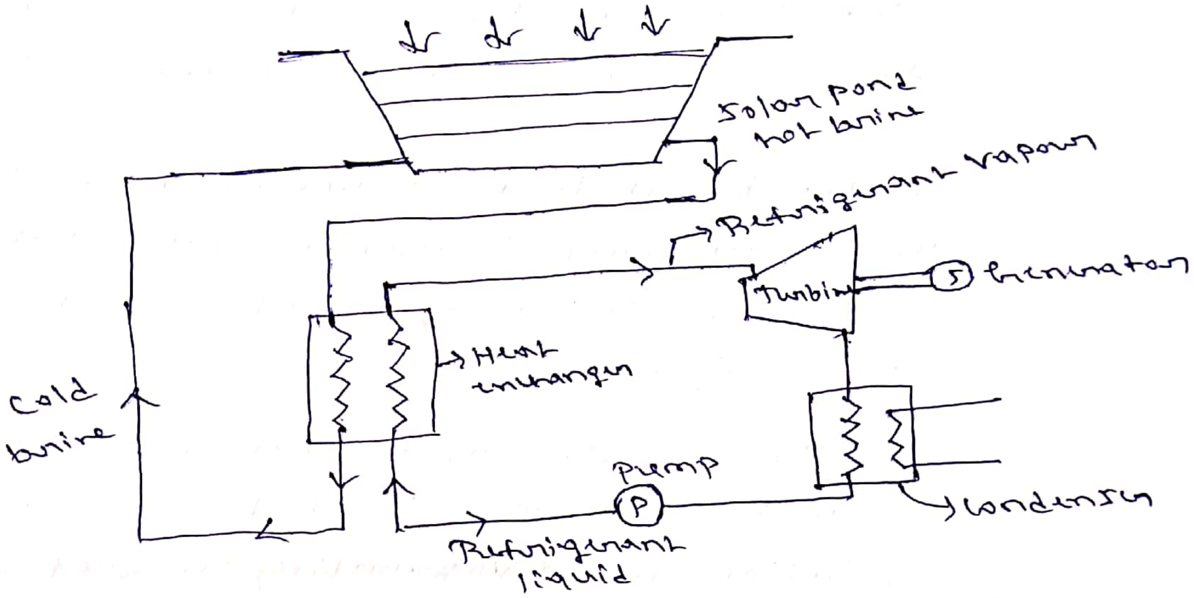
$$= 1.03 \times 2408$$

$$I_T = 2481 \frac{KJ}{m^2.hr}$$

by the condensate channel & drained out from the solar still.

3(b) **Solar pond**





The solar pond technology ensures that heated brine water remains at the bottom of the pond due to more brine concentration & density in it

It consists of a large size brine pond (depth of about 1m) which has salt content -ration gradient in such a way that the most concentrated & dense part of the brine solution is at the bottom of the pond & brine solution concentration gradually reduces from bottom to top of the pond based on the variation of brine solution density

A solar pond has three zones as shown in fig. The top zone is surface zone which has the least salt content & its temp is the atmospheric temp. The bottom zone has the maximum salt content & it has a high temp (70-85°c).

This is the zone that collects & stores the solar energy as heat energy. In between these two zones there is the gradient non-convective zone.

The ~~do~~ hot brine solution from the bottom of solar pond is taken out without disturbing the brine gradient existing in the solar pond.

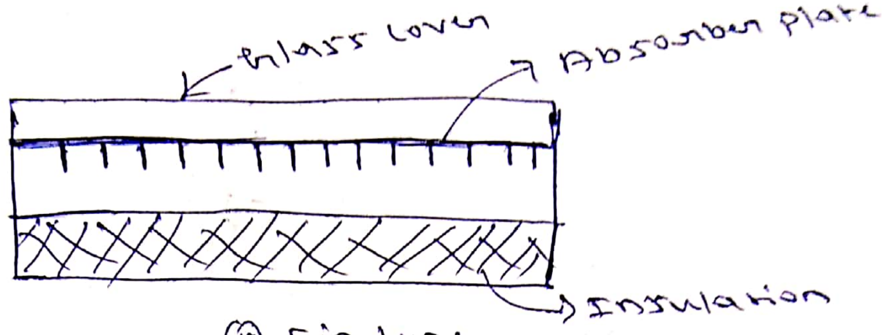
This solution is taken to heat exchanger to remove heat from the brine solution by evaporating a refrigerant in the evaporator.

These vapours are used to run a turbine which is coupled to a generator to generate power.

The refrigerant vapours exiting from the outlet of the turbine are condensed to liquid state in a condenser & pumped to heat exchanger.

3 (c)

Solar Air Heater or Solar Air Collector



(a) Fin type

A solar Air heating collector is ~~smitt~~ similar to a liquid flate plate collector with change in configuration of absorber & tube as shown in fig.

The value of heat transfer coefficient between the absorber plate & the air is low.

For this reason the surfaces are sometimes roughened or longitudinal fins are provided in the airflow passage.

The principle applications of these collectors are drying for agricultural & industrial purposes, & space heating.

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4(a) Effect of various parameters on performance

(a) selective surface :- Absorber plate surface which exhibit the characteristics of high value of absorptivity for incoming solar radition & low value of emissivity for outgoing re-radiation are called selective surfaces. Such surfaces are desirable because they maximize the net energy collection. Some examples of selective surface layers are copper oxide, nickel black & black chrome.

(b) Number of covers :- With increase in the number of covers, the values of both $(\tau\alpha)_b$ & $(\tau\alpha)_d$ decreases & thus the flux absorbed by absorber plate decreases.

The value of heat loss from the absorber plate also decreases. However, the amount of decreases is not the same for each cover. maximum efficiency is obtained with one or two covers.

(c) Spacing :- Heat loss also varies with spacing between two covers & that between temp & also vary with tilt.

Since collectors are designed to operate at different locations with varying tilts & under varying service conditions, an optim-um value of spacing is difficult to specify. Spacing in range from 4 to 8 cm is suggested.

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(d) collector tilt :- Flate plate collectors are normally used in fixed position & do not track the sun.

Therefore, the tilt angle at which they are fixed is very important.

optimum tilt depends on the nature of the applications. usual practice is to recommend value of $(\phi + 10^\circ)$ or $(\phi + 15^\circ)$ for winter applications [e.g water heating, space heating etc] & $(\phi - 10^\circ)$ or $(\phi - 15^\circ)$ for summer applications [e.g absorption refrigeration plat etc]

(e) Dust on the top of the cover :- when a collector is deployed in a practical system, dust gets accumulated over it, reducing transmitted flux through the covers.

this requires continuous cleaning of the cover, which is not possible in practical situation.

For this reason it is recommended that the incident flux be multiplied by a correction factor which allows for the reduction in intensity because of a accumulation of dust.

In general a correction factor from 0.92 to 0.99 seems to be indicated.

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(f) Fluid inlet temp:- The fluid inlet temp is an operational parameter which strongly influences the performance of a flat plate collector.

The fluid inlet temp varying from 30° to 90° C, while the values of the other parameters are held const.

T_{fi} (°C)	30	40	50	60	70	80	90
T_{pm} (K)	326.5	334.8	343	351	359	367	375
U_b (W/m^2-K)	3.78	3.90	4.02	4.1	4.2	4.3	4.39
q_u (W)	1149	1065	977	888	796	703	608
T_{fo} (K)	317.3	326	335	344	353	361	370
η_i (%)	56.4	52.3	48.0	43.6	39.1	34.6	29.9

4(b)

Transmissivity of the cover system

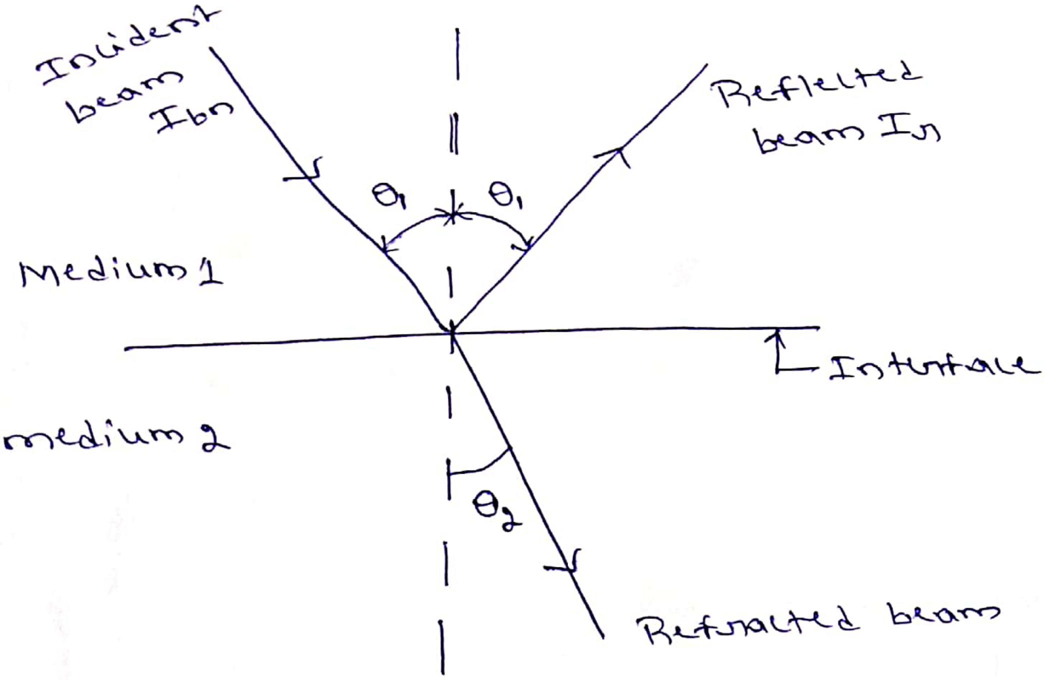
The transmissivity of the cover system of a collector can be obtained by considering reflection - refraction & absorption separately

$$\tau = \tau_r \tau_a$$

τ_r = transmissivity obtained by considering only reflection & refraction

τ_a = transmissivity obtained by considering only absorption.

Transmissivity based on Reflection-Refraction



* When a beam of light of intensity I_{bn} travelling through a transparent medium 1 strikes the interface separating it from another transparent medium 2, it is reflected & refracted.

* The reflected beam has a reduced intensity I_r & has a direction such that the angle of reflection is equal to the angle of incidence.

* On the other hand, the directions of the incident & refracted beams are related to each other by Snell's law which states that

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$

θ_1 = angle of incidence

θ_2 = angle of refraction.

& n_1, n_2 = refractive indices of the two media.

The Reflectivity $\rho = \frac{I_r}{I_{bn}}$ is related to the angles of incidence & refraction by the eqn.

$$\rho = \frac{1}{2}(\rho_1 + \rho_2)$$

$$\rho_1 = \frac{\sin^2(\theta_2-\theta_1)}{\sin^2(\theta_2+\theta_1)}$$

$$\rho_2 = \frac{\tan^2(\theta_2-\theta_1)}{\tan^2(\theta_2+\theta_1)}$$

where ρ_1 & ρ_2 are reflectivities of two components of polarisation

For special case of normal incidence ($\theta_1 = 0°$), it can be shown that

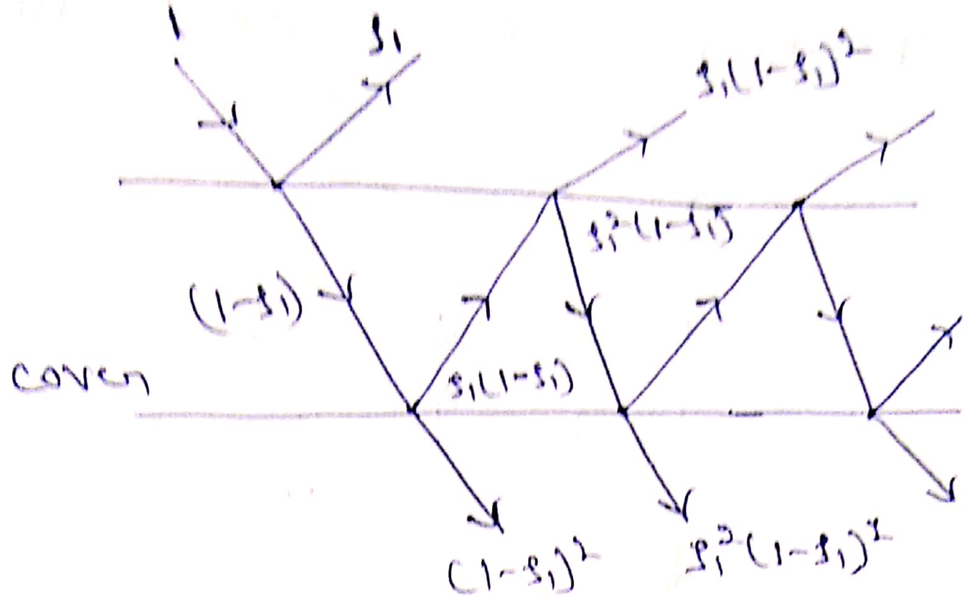
$$\rho = \rho_1 = \rho_2 = \left(\frac{n_1-n_2}{n_1+n_2}\right)^2$$

The transmissivity τ_r is given by an expression similar to that for ρ.

$$\tau_r = \frac{1}{2}(\tau_{r1} + \tau_{r2})$$

where τ_{r1} & τ_{r2} are the transmissivities of the two components of polarisation.

Consider one of the components of polarisation of a beam incident on a single cover. Because of the fact that there are two interfaces, multiple reflections & refraction will occur as shown in fig



$$\tau_{r_1} = (1-\rho_1)^2 + \rho_1^2(1-\rho_1)^2 + \rho_1^4(1-\rho_1)^2 + \cdots$$

$$= (1-\rho_1)^2(1+\rho_1^2+\rho_1^4+\cdots) = \frac{(1-\rho_1)^2}{1-\rho_1^2} = \frac{1-\rho_1}{1+\rho_1}$$

Illy

$$\tau_{r_2} = \frac{1-\rho_2}{1+\rho_2}$$

These results can be readily extended to a system of M covers for which it can be shown that

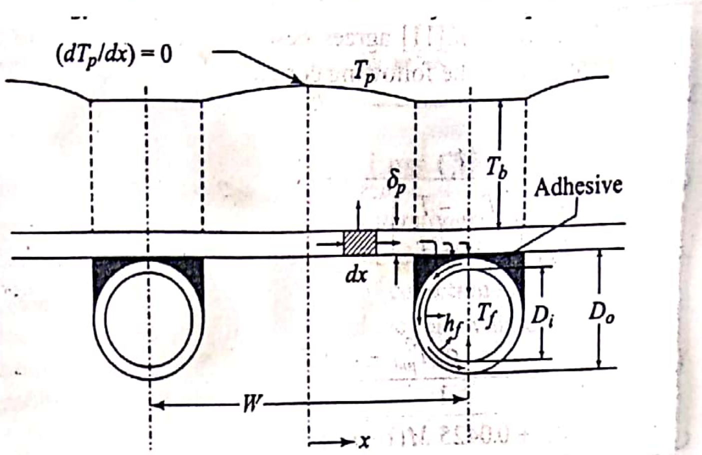
$$\tau_{r_1} = \frac{1-\rho_1}{1+(2M-1)\rho_1}$$

$$\tau_{r_2} = \frac{1-\rho_2}{1+(2M-1)\rho_2}$$

M → No of covers

1(c)

Collector efficiency factor



The heat from a collector can be calculated if the avg plate temp is known but it is very difficult to get this temp. It is necessary to consider the flow of heat in the absorber plate & across the fluid tubes to the fluid. The temp T_{pm} can be related to inlet temp of the fluid, which is a known quantity.

Consider a collector having an absorber plate of length L_1 & width L_2.
Assume that there are N fluid tubes & that the pitch of the tubes is $W (= L_2/N)$. Let D_i & D_o be the inside & outside diameters of the tubes.

consider a section of the absorber plate with two adjacent fluid tubes.

The temp in the plate (T_p) will vary in the x-direction in the manner as shown in fig.

It will be assumed that the same distribution exists between any two tubes.

Above the fluid tubes, the temp will be constant, while in between the tubes, temp will pass through a maximum.

Taking a slice dy along the flow direction & neglecting heat conduction in the plate in that direction, we can write an energy balance for an element dx x dy of the plate.

Net heat conducted into element + Incident energy absorbed = Heat lost from element

$$K_p \delta_p \frac{d^2 T_p}{dx^2} dx dy + S dx dy = U_l dx dy (T_p - T_a)$$

$$K_p \delta_p \frac{d^2 T_p}{dx^2} = U_l dx dy (T_p - T_a) - S dx dy$$

$$\frac{d^2 T_p}{dx^2} = \frac{U_l dx dy (T_p - T_a) - S dx dy}{K_p \delta_p}$$

$$\frac{d^2 T_p}{dx^2} = \frac{U_L}{K_p \delta_p}\left[T_p - T_a - \frac{S}{U_L}\right] \quad \text{--- (1)}$$

Using boundary condition

$x = 0$, $\frac{dT_p}{dx} = 0$ & $x = \frac{W - D_o}{2}$ $T_p = T_{po}$

We get

$$\frac{T_p - \left[T_a + \frac{S}{U_L}\right]}{T_{po} - \left[T_a + \frac{S}{U_L}\right]} = \frac{\cosh mx}{\cosh\left[\frac{m(W-D_o)}{2}\right]}$$

Where

$$m = \left(\frac{U_L}{K_p \delta_p}\right)^{1/2}$$

The rate at which the energy is conducted through the plate one of the fluid tube from both sides

$$= -2 K_p \delta_p \left[\frac{dT_p}{dx}\right]_{x = \frac{W-D_o}{2}} dy$$

$$= 2\left[\frac{K_p \delta_p}{U_L}\right]^{1/2}\left[S - U_L(T_{po} - T_a)\right] \tanh\left[\frac{m(W-D_o)}{2}\right] dy$$

The rate at which energy is absorbed just above the tube equal to

$$= D_o\left[S - U_L(T_{po} - T_a)\right] dy$$

The useful energy gain for all n-tubes for length of dy

$$dQ_u = N\left[S - U_L(T_{po} - T_a)\right] \times \left[2\left(\frac{K_p \delta_p}{U_L}\right)^{1/2} \tanh \frac{m[W - D_o]}{2} + D_o\right] dy \quad — (2)$$

The eqn (2) can be simplified the introdu-cing term as plate effectiveness.

It is the ratio of heat conducted through the plate to the fluid to the heat conducted. If thermal conductivity of plate is (∞) infinity.

$$\text{Plate effectiveness } (\phi) = \frac{\tanh\left[m\frac{(W - D_o)}{2}\right]}{m\frac{(W - D_o)}{2}}$$

$$\frac{1}{N}\frac{dQ_u}{dy} = \left[S - U_L(T_p - T_a)\right]\left[\phi(W - D_o) + D_o\right]$$

Flow of heat from the plate to the fluid to the adhesive bond, tube wall & heat transfer co-eff of inner surface of the tube.

The heat flow equal to

$$\frac{1}{N}\frac{dQ_u}{dy} = \frac{T_{po} - T_f}{\frac{\delta_a}{K_a D_o} + \frac{1}{\pi D_i h_f}}$$

δ_a → thickness of the adhesive (avg)

K_a → thermal conductivity of adhesive

T_f → local fluid temp

h_f → heat transfer coefficient on the inside surface of the tube.

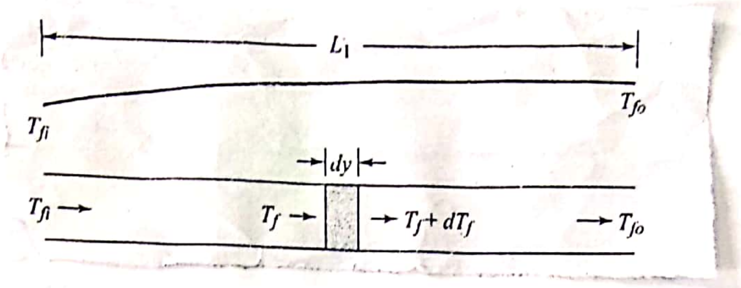
$$\frac{1}{N}\frac{dQ_u}{dy} = \frac{S - U_L(T_f - T_a)}{U_L\left[\frac{1}{U_L(W-D_o)\phi + D_o}\right] + \frac{\delta_a}{K_a D_o} + \frac{1}{\pi D_i h_f}}$$

$$\frac{1}{N}\frac{dQ_u}{dy} = WF'\left[S - U_L(T_f - T_a)\right]$$

$$F' = \frac{1}{WU_L\left[\frac{1}{U_L(W-D_o)\phi + D_o}\right] + \frac{\delta_a}{K_a D_o} + \frac{1}{\pi D_i h_f}}$$

F' → collector efficiency factor which is the ratio of actual usefull gain per tube per unit length to the gain which would occur if the collector absorber plate were at the temp T_f.

4(c) **Collector Heat - Removal Factor**



The final one-dimensional analysis will be performed along the direction of fluid flow with the objective of determining the variation of fluid temp.

This analysis will help in linking the useful heat gain rate with the fluid inlet temp.

Consider as a control volume, an elementary length 'dy' of one tube

Applying the first law of thermodynamics

Rate of change of enthalpy of the fluid flowing through the control volume = Rate of heat transfer to fluid inside the control volume.

$$\frac{\dot{m}}{N} C_p \, dT_f = \frac{1}{N} dQ_u$$

$$= WF' \left[S - U_L (T_f - T_a) \right] dy$$

$$\frac{dT_f}{dy} = \frac{WF' \left[S - U_L (T_f - T_a) \right]}{\frac{\dot{m}}{N} C_p}$$

Integrating. using the inlet condition

$y = 0$, $T_f = T_{fi}$

$$\frac{\left(\frac{S}{U_L} + T_a\right) - T_f}{\left(\frac{S}{U_L} + T_a\right) - T_{fi}} = \exp\left[\frac{-L_2 F' U_L y}{\dot{m} C_p} \right]$$

$L_2 = NW$

To find the fluid temp substitute $T_f = T_{fo}$

$y = L_1$

$$\frac{\left(\frac{S}{U_L} + T_a\right) - T_{fo}}{\left(\frac{S}{U_L} + T_a\right) - T_{fi}} = \exp\left[\frac{-L_2 F' U_L L_1}{\dot{m} C_p} \right]$$

substract both sides unity

$$1 - \frac{\left(\frac{S}{U_L} + T_a\right) - T_{fo}}{\left(\frac{S}{U_L} + T_a\right) - T_{fi}} = 1 - \exp\left[\frac{-F' U_L L_1 L}{\dot{m} C_p}\right]$$

$$\frac{T_{fo} - T_{fi}}{\left[\frac{S}{U_L} + T_a\right] - T_{fi}} = 1 - \exp\left[\frac{-F' U_L A_p}{\dot{m} C_p}\right]$$

useful heat gain

$$Q_U = \dot{m} C_p \left[T_{fo} - T_{fi}\right]$$

$$Q_U = \dot{m} C_p \left[\left(\frac{S}{U_L} + T_a\right) - T_{fi}\right]\left[1 - \exp\left(\frac{-F' U_L A_p}{\dot{m} C_p}\right)\right]$$

$$= \frac{\dot{m} C_p}{U_L}\left[S - U_L (T_{fi} - T_a)\right]\left(1 - \exp\left[\frac{-F' U_L A_p}{\dot{m} C_p}\right]\right)$$

$$Q_U = F_R A_p \left[S - U_L (T_{fi} - T_a)\right]$$

$F_R \rightarrow$ Heat Removal factor

$$F_R = \frac{\dot{m} C_p}{U_L A_p}\left[1 - \exp\left[\frac{-F' U_L A_p}{\dot{m} C_p}\right]\right]$$

The term F_R called the collector heat Removal factor. It is an important design parameter since it is a measure of the thermal resis -tance encountered by the absorbed solar radiation in reaching the collector fluid

It can be seen that F_R Represents the ratio of the actual useful heat gain rate to the gain which would occur if the collector absorber plate was at the temp T_{fi} everywhere.

As such its value ranges between 0 & 1

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

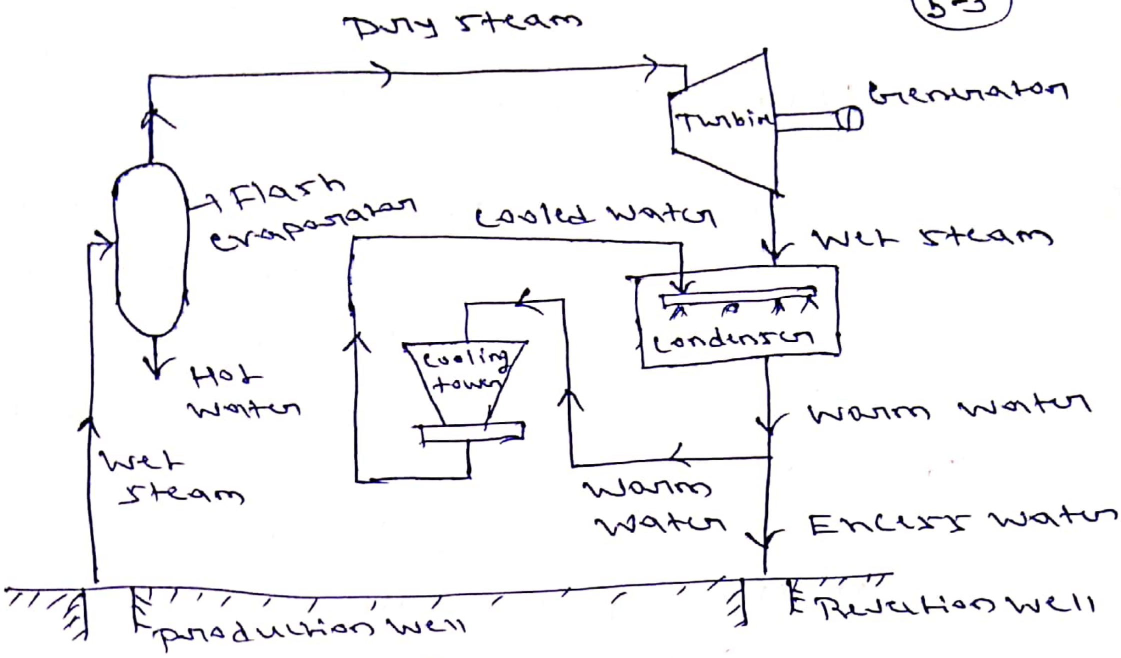
6 (a) <u>liquid dominated high-temp plant</u>

The type of plant is used where hydrothermal reservoir has temp & pressure of 230°C & 40 atm resp. The plant consists of flash evaporator to obtain dry steam from high temp wet steam by lowering pressure in it, turbine with directly coupled generator to extract energy from dry steam, condenser to condense used steam into water & cooling tower to cool the warm water.

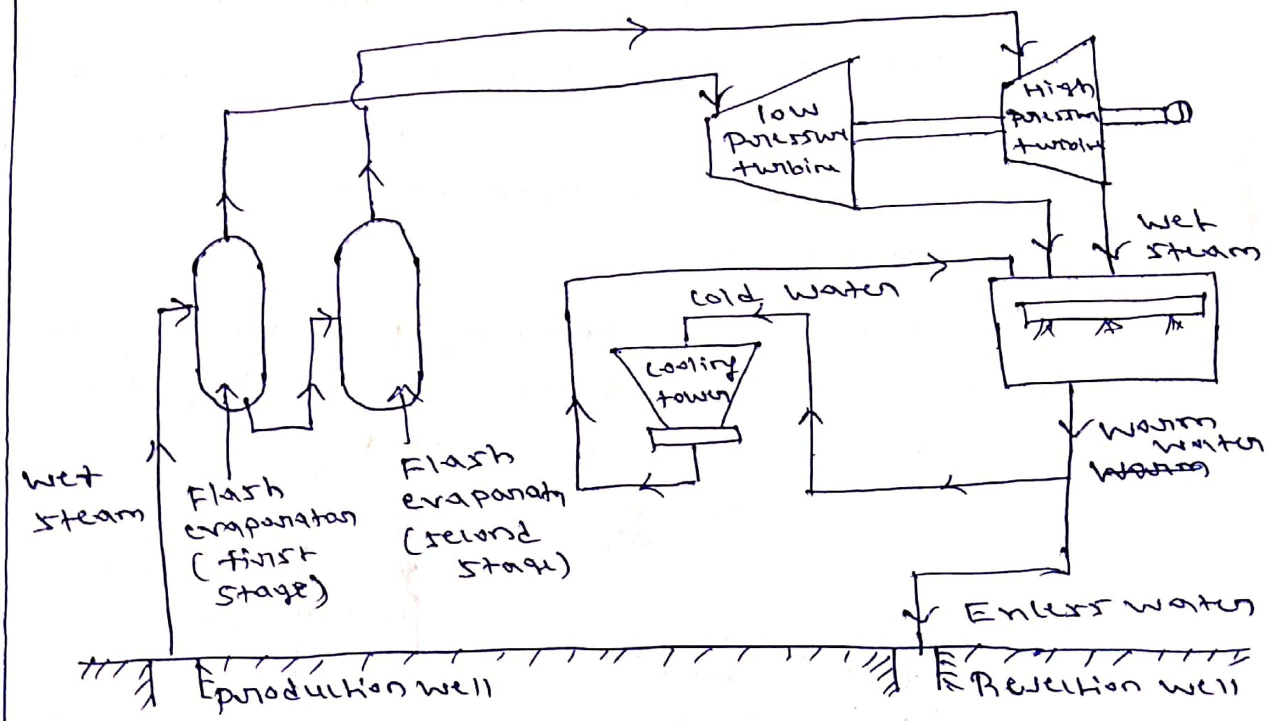
The excess water is disposed of in the ground as shown in fig (i).

In dual flash system, the hot water is flashed in two flash evaporators in two stages.

Steam obtained in the first stage is used in low pressure turbine & steam is again flashed to obtain high pressure to be in high pressure turbine as shown in fig (ii)


Dry steam
Turbine
Generator
Flash evaporator
Cooled water
Wet steam
Condenser
Cooling tower
Hot water
Warm water
Wet steam
Warm water
Excess water
Production well
Rejection well

(i)


low pressure turbine
High pressure turbine
Wet steam
Cold water
Cooling tower
Warm water
Wet steam
Flash evaporator (first stage)
Flash evaporator (second stage)
Excess water
Production well
Rejection well

(ii)

5 (a) It is the kinetic energy associated with movement of large masses of air. These motions result from uneven heating of the atmosphere by the sun.

Which creates temp, density & pressure difference it is an indirect form of solar energy.

[It is estimated that 1% of all the solar radiation falling on the face of the earth is converted into kinetic energy of the atmosphere] Thus it is an indirect form of solar energy.

Winds are generated due to the atmospheric temp difference caused by different areas getting different fluxes of sun-light. Airmass tends to move from hotter to cooler regions for which wind is generated.

During day time, the air over the land mass heats up more than the air over the oceans. Hot air expands & rises while cooler air comes from oceans to fill the space which creates local winds. But at night the process is reversed as the air cools more rapidly over land than water over off shore & causing breeze.

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5(b) ## Photovoltaic conversion

* The devices used in photovoltaic conversion are called solar cells. When solar radiation falls on these devices, it is converted directly into DC electricity.

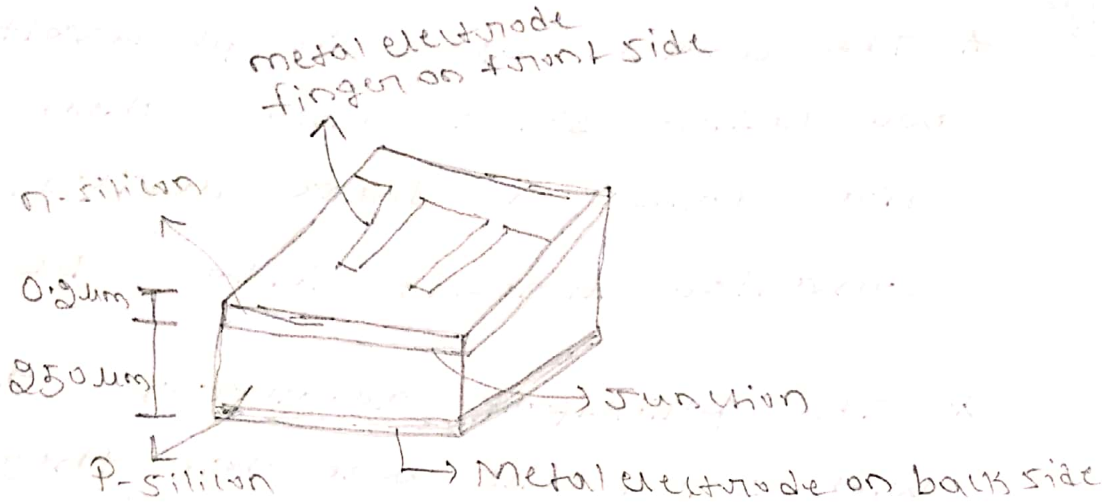
* The principal advantage associated with solar cells are that they have no moving parts, require little maintenance & work quite satisfactorily with beam or diffuse radiation.

Description & principle of working

* The first solar cells were made from single crystal silicon. Even today silicon is the material generally used for making most cells.

* Single crystal silicon cells are thin wafers about 250 μm in thickness, sliced from a single crystal of p-type doped silicon.

* A shal-low junction is formed at one end by diffusion of the n-type impurity. Metal contacts are attached to the front & back side of the cell.



* On the front side, the contact is in the form of a metal grid with fingers which permit the sunlight to go through, while on the back side, the contact completely covers the surfaces.

* Generally for the front contacts, screen printing of a paste consisting of 70% silver, an organic binder & sintered glass is done.

* For the back contact, a paste containing aluminium is screen printed. The cell is placed in a furnace at a temp of about 600 to 700°C so that the metals in the paste diffuse both at the front as well as on the back to make contact with the silicon.

* An anti-reflection coating of silicon nitride or titanium dioxide, having a thickness of about 0.1 μm is applied on the top surface to complete the cell.

* A typical cell develops a voltage of 0.5 - 0.7 V & a current density of 20 - 40 mA/cm².

* In order to obtain higher voltages & currents, individual cells are fixed side by side on a suitable back - up board & connected in series & parallel to form a module.

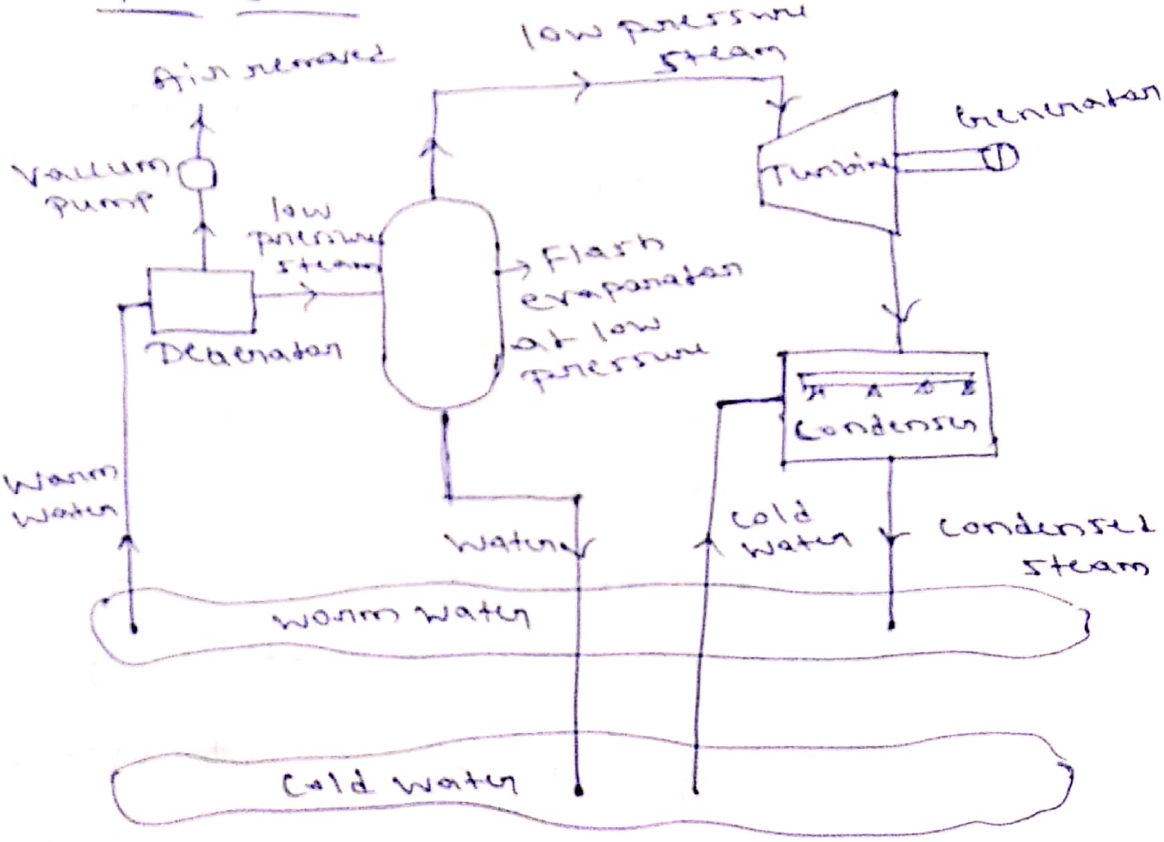
* A number of modules are interconnected to form an array. Earlier the cells used to be circular in shape with diameters ranging from 6 to 15 cm. Now they are often rectangular in shape resulting in more compact modules.

* Apart from single crystal silicon, silicon solar cells are now also made in large numbers from multicrystalline silicon & amorphous silicon.

6(b) Ocean thermal Energy conversion systems (Rankine cycle)

OTEC plants can operate using open cycle (Claude cycle) or closed cycle (Anderson cycle)

Open cycle



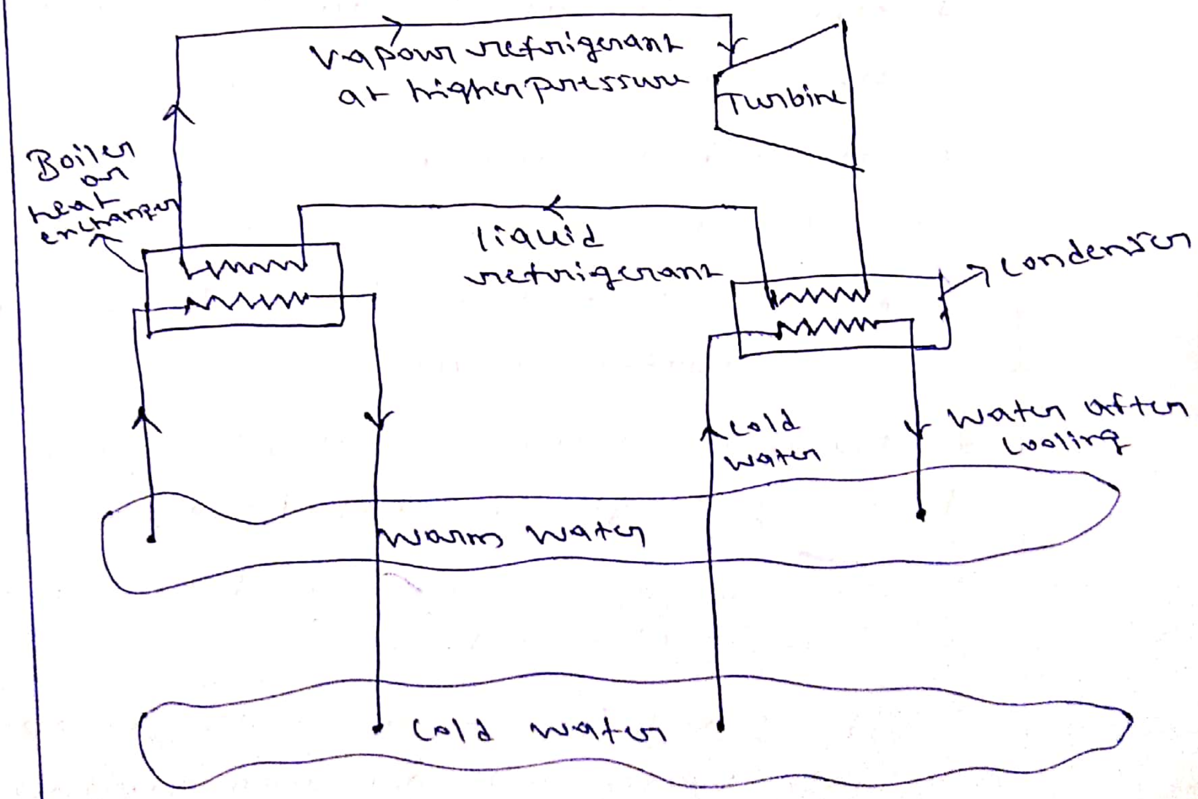
warm water from the top surface is evaporated to obtain low pressure steam by using a flash evaporator maintained at partial vacuum as water can evaporate at the lower temp when pressure is lower than atmospheric pressure.

The low pressure steam obtained from flash evaporator is expanded in a turbine to extract mechanical energy. the steam after energy removal in turbine is condensed into water in a condenser which is cooled by cold water drawn from the depth in the ocean.

Closed cycle

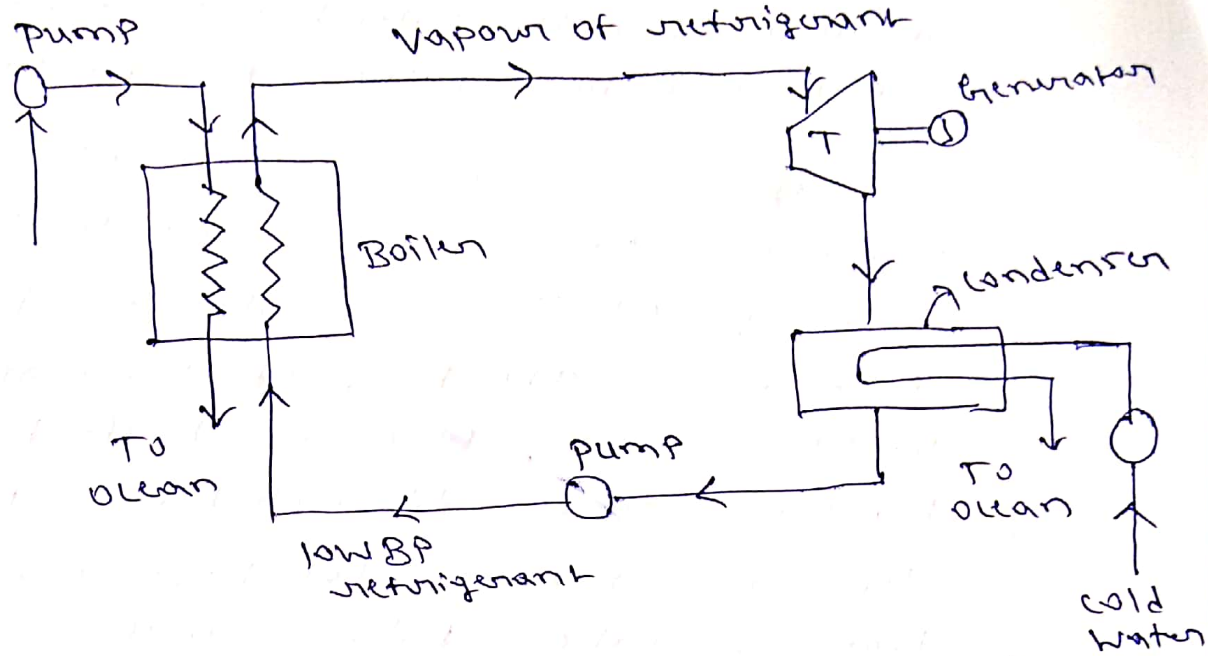
In the closed cycle, warm surface water is used to evaporate a low boiling point refrigerant (ammonia or freon) & refrigerant vapour is made to flow through the turbine to extract energy.

The vapour coming out from the turbine after performing work is cooled & condensed in a condenser cooled by cold water pumped from the ocean depths.



6(c)

Ocean temp Energy conversion [OTEC]



The water at the ocean surface is around 25°C, while it is about 5°C at a depth of 100-200m.

Hence there is a temp gradient of about 20°C between these two levels & this can be used for generation of electricity by OTEC.

A low boiling point liquid such as ammonia propane vapour using the heat of warm water available at the ocean surface into a boiler. The liquid vapour is then used to run a turbine coupled with a generator to produce electricity.

After expansion in the turbine, the liquid vapour is condensed into liquid in the condenser using cold water from the deep ocean at a temp about 5°C.

8(a) Production of Hydrogen

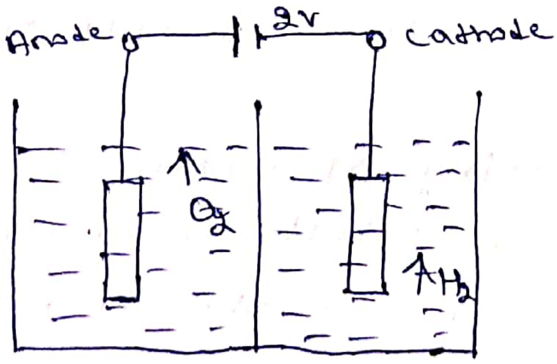
The various methods of production of hydrogen include electrolysis of water, thermochemical or steam reforming of methane, thermal decomposition or thermolysis of water & biophotolysis

Electrolysis of water

It is the simplest method of hydrogen production. The method uses an electrolytic which consist of two electrode immersed in an aqueous conducting solution called electrolyte as shown in fig.

When a direct current is passed through the cell, it decomposes water into hydrogen & oxygen.

Oxygen is formed at anode while hydrogen is formed at cathode. Metal or carbon plates are used as electrodes. The aqueous KOH solution is used as the electrolyte. A decomposition voltage of 2V is applied. The chemical reactions of decomposition of water are as follows



$$4H_2O + 4e^- \rightarrow 2H_2\uparrow + 4OH^-$$ (Cathode)

$$4OH^- \rightarrow O_2\uparrow + 2H_2O + 4e^-$$ (Anode)

8(b) Hydrogen with respect to its utilization as renewable form of energy

* It is a light gas. * It has a low density.
* It liquefies at a very low temp (-253°C)
* The specific energy of hydrogen is superior to gasoline on mass basis, but it is inferior on volume basis.
* It has flame speed during burning which is faster than that of natural gas.
* It needs lower amount of heat energy to initiate combustion compared to that of natural gas.
* It produces water vapour on combustion Hence it is pollution free.

Source of hydrogen

Hydrogen can be produced by using a variety of energy sources such as solar, nuclear & fossil fuels & can be converted to useful energy forms efficiently & without deterimental environmental effects.

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8(c)

Hydrogen energy

Hydrogen is the simplest element. An atom of hydrogen consists of only one proton & one electron. It is also the most plentiful element in the universe. Despite its simplicity & abundance, hydrogen doesn't occur naturally as a gas on the earth - it is always combi-ned with other elements.

ex:- water

Hydrogen holds the potential to provide clean, reliable & affordable energy supply that can enhance economy, environment & security.

It is non toxic & recyclable. Due to these qualities it is considered to be an ideal energy in the future.

properties of Hydrogen

Hydrogen is an odourless & colourless gas. It has the simplest & lightest atom with one proton & one electron & molecular weight of 2.016

* Density - 0.0837 Kg/m^3
* Boiling point - 20.3 K
* lower heating value - 125 MJ/Kg
* Higher heating value - 141.90 MJ/Kg
* Flammable limit %. in air - 4-75
* Flame temp - 2045°C

7(a) Biomass - Energy source of the future

(1) Given the increasingly large gaps betn demand & supply for all forms of energy (i.e electricity, fuel, thermal energy etc.) the new source should preferable be capable of providing all the energy

(2) The source should be available to provide energy at both small scale & large scale

(3) The source should be capable of providing energy on demand.

(4) If the source is to start its contribution almost immediately the gestation periods should be short.

(5) It should not be very capital intensive

Relevance of biomass as an energy source

(1) even with readily available conversion tech. biomass can indeed provide all forms of energy in an effective & efficient manner

(2) The source should be provide energy at both small scale a large scale

(3) Because of the natural & cheap storage of energy in the form of biomass itself.

7(b) Factors affecting biodigestion

(1) temp — tPSLS
(2) PH value — WDCNM
(3) total Solid content — RFtPA
(4) loading rate
(5) Seeding
(6) uniform feeding
(7) Diameter to depth ratio
(8) carbon to nitrogene ratio
(9) nutrients
(10) mixing
(11) Retenation time
(12) type of feed stock
(13) toxicity due to end product
(14) pressure
(15) Acid accumlator.

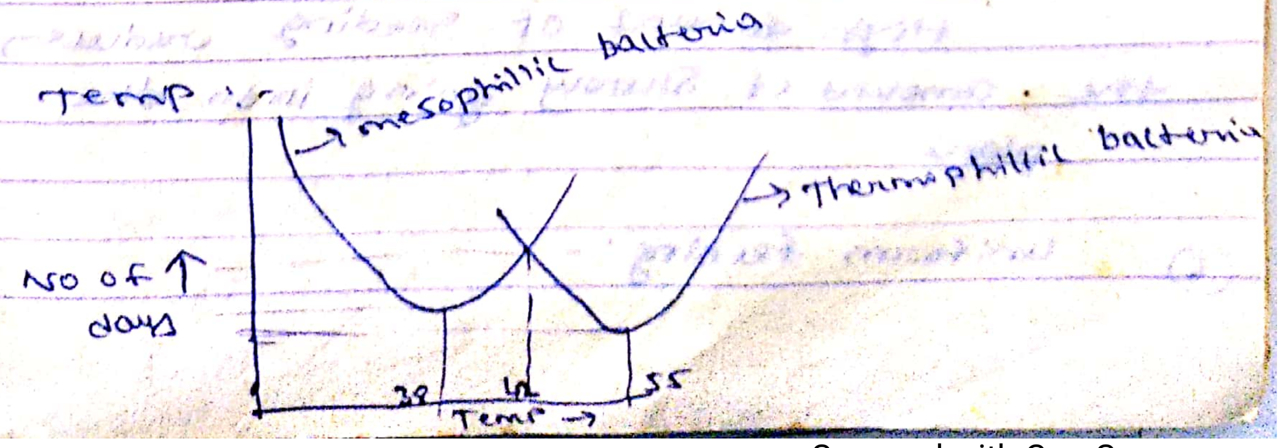
(1) PH value :- Acid forming stage the PH value will be arround 6 → CO_2 is produced.

PH value increases → acid & N_2 get digested producing methane.

Ideal PH value → 6.5 to 7.5 → microbes will be active

No sudden variation in PH value should be ensured.

(5) Temp :-



methane producing bacteria operates best at 35 – 38°C.

gas is not produced below 10°C

The thermophillic ~~bacteria~~ range has not been put to use Because of requirement of heating ~~the~~ the tank.

(3) Solid content :- cow dung & water are mixed in the ratio 1:1 (by wt)

water in the ~~the~~ cow dung is about 80%.

Ideal propotion of water in the slurry is 90%. helps in faster production rate.

(4) loading rate :- normal loading rate 0.5 to 1.6 Kg/m³/day.

High loading rate results in acid accumlation

High acid value → low pH value

But having higher loading rate results in smaller unit &

(5) Seeding :- certain amount of seeding is usefull increasing no of methane farmers. The seeding (~~sludge~~ (digested sludge) should be rich in methane farms.

High amount of Seeding reduces the amount of slurry going into the plant

(6) uniform feeding :-

(7) carbon to nitrogen ratio :- of the input material.

carbon is used for energy for bacteria
nitrogene is for growth

The bacteria ~~use~~ use up carbon about 30 times faster than the ~~use~~ use of nitrogen. To much carbon nitrogen will be

The digester slow down ~~to~~

To much nitrogen → all carbon will be used up ~~&~~ really. The fermentation stops because of lack of energy.

(8) Diameter to depth ratio :- The digester of 16ft depth & 4 to 5ft diameter were reported to be working satisfactorily

At lower level, the activity is not affected by night & day variation in temp.

(9) nutrients :- phospherous → night soil

N_2 → plant - leguminous

~~CO_2~~ & · C, H_2, O_2 & S

night soil has higher value of ~~sul~~ sulphur.

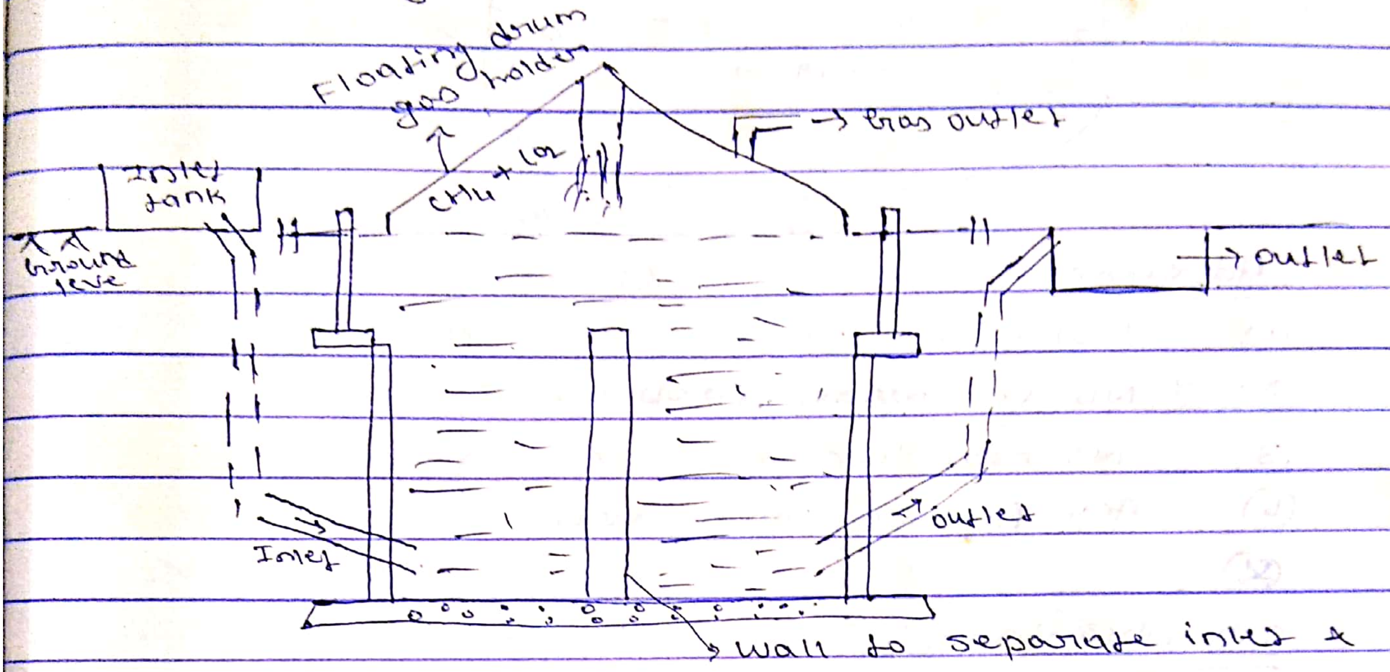
(10) mixing :- or S

is required to ensure the ~~present~~ bacteria gets sufficient food.

(11) Retention time :- Depends upon the kind of material feed stock supplied.

(1) floating drum gas holder type
(2) fixed dome

7(C)
(1) floating drum Biogas plants



mesophyllic & Thermophyllic bacteria is needed to produce ~~to~~ biogas in Biogas plants. & Temp of drum required to maintain at 55°c

Advantages
(1) const gas pressure
(2) No requirement for pressure equalizing device
(3) No gas leakage
(4) No danger of mixing oxygen & gas
(5) less scum formation
(6) scum can be easily broken

Disadvantages
(1) high cost
(2) high heat loss.
(3) Gas holder requires painting.

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✓

The bio-chemical routes works with balteria occurs at temp 50°C to 55°C. each of there being a separate class of balteria mesophyllic & thermophyllic resp.
mesophyllic - 35°C & thermophyllic - 55°C

The reaction stops at temp below @ 10°C.
there are four steps.

① The 1st step involves the fermentative balteria including both anaerobic & facultative (aerobic / anaerobic) micro orga-nism. carbo-hydrates, proteins & some other very complen organic compounds are hydroly-sed, & fermented into monomers, fatty acids, alcholes, CO_2, H_2, NH_3 & sulphides

② In the 2nd step ~~acidogenesis~~ acidogenic - balteria converts the hydrolysed monomers to acids

③ In the 3rd step the acids converted into acetogic acids, propyonic acid, etc & some amount of CO_2 & H_2

④ The 4th step the methogenic balteria reduces CO_2 to CH_4 & another decarbohydrates acetate to CH_4 & CO_2.