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Internal Assessment Test 2 – Oct. 2018

Sub:	Energy Engineering				Sub Code:	15ME71	Branch:	Mechanical
Date:	16/10/2018	Duration:	90 min's	Max Marks: 50	Sem/Sec:	7 A & B		OBE

	Answer any FIVE FULL Questions	MARKS	CO	RBT
1	Sketch and explain the working of pyranometer.	[10]	CO3	L1
2	With a neat sketch explain the working principle of solar pond.	[10]	CO3	L1
3	Explain with neat sketch the description and the working principle of liquid flat plate collector.	[10]	CO3	L1
4	With a neat sketch, explain the working principle of horizontal axis wind turbine using two aerodynamic blades.	[10]	CO4	L1

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5	Wind at standard atmospheric pressure and 20°C has velocity of 10m/s. Calculate (i) The total power density in the wind stream, (ii) maximum power density, (iii) Actual power density assuming η = 30%, (iv) Total power produced if the turbine diameter is 120m.	[10]	CO4	L2
6 (a) (b)	A two-blade HAWT is installed at a location with free wind velocity of 20m/s. The rotor diameter is 30m. What rotational speed should be maintained to produce maximum output? A HAWT has the following data: Speed of wind = 10m/s at 1 atm and 15°C, diameter of rotor = 120m, speed of rotor = 40rpm. Calculate the maximum possible torque produced at shaft.	[5] [5]	CO4	L2

CI CCI HoD

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Internal Assessment Test 2 – Oct. 2018

Sub:	Energy Engineering					Sub Code:	15ME71	Branch:	Mech
Date:	16.10.2018	Duration:	90 min's	Max Marks:	50	Sem / Sec:	VII/A&B		OBE

Scheme of evaluation

Q.No	Scheme	Marks
1	Sketch of pyranometer Short note on hyperbolic tower	5 5
2	Plot of density as a function of concentration and temperature Expression for density gradient Short note on the working of solar ponds	4 2 3
3	Sketch of liquid flat plat collector Principle of working Description of working	4 3 3
4	Sketch of horizontal axis wind mill Principle of working	5 5
5	Calculating Density of ambient air Total power density of wind Max power density Actual power density Power produced by turbine	 2 2 2 2 2
6(a) (b)	Calculate optimum tip speed ratio Calculate rotational speed Calculate max power Calculate corresponding torque in shaft	3 2 3 2

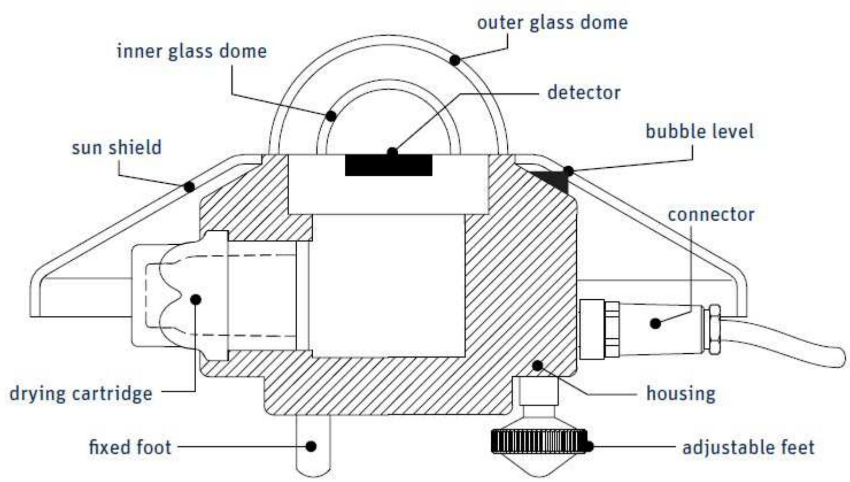
IAT 2

Energy Engineering

Solutions

Q1) Sketch and explain the working of pyranometer.

A pyranometer is designed to measure global radiation, usually on a horizontal surface, but can also be used on an inclined surface. A precision pyranometer is designed to respond to radiation of all wavelengths and hence measures accurately the total power in the incident spectrum. It contains a thermopile whose sensitive surface consists of circular, blackened, hot junctions, exposed to the sun, the cold junctions being completely shaded. The temperature difference between the hot and cold junctions is the function of radiation falling on the sensitive surface. The sensing element is covered by two concentric hemispherical glass domes to shield it from wind and rain. This also reduces the convection currents. A radiation shield surrounding the outer dome and coplanar with the sensing element, prevents direct solar radiation from heating the base of the instrument. A schematic of pyranometer is shown below.



Q2) With a neat sketch explain the working principle of solar pond.

An artificially constructed pond in which significant temperature rises are caused to occur in the lower regions by preventing convection is called a solar pond. The usual method adopted to prevent convection is to dissolve a salt in the water and to maintain a concentration gradient.

The working of a solar pond can be explained with reference to the figure below. Consider a pond of depth L having salts dissolved in the water. We assume that the concentration at the top (C_1) is less than that at the bottom (C_2) and that a concentration gradient exists from the top to the bottom. The variation of density with temperature for the two concentrations is as shown. Let T_1 and P_1 be the temperature and density of the top layer of water indicated by point A, and T_2

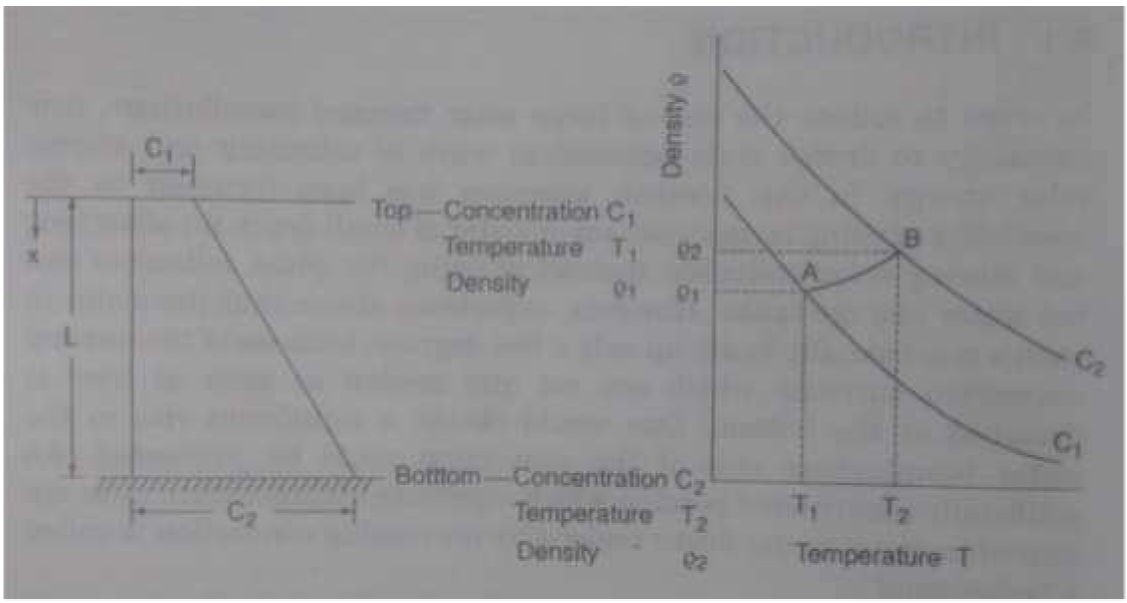
and P_2 be the temperature and density of the bottom layer indicated by point B. Similar points are located for the intermediate layers and the curve AB is drawn showing the variation of density as one moves downwards in the pond. It is obvious that no convection will occur so long as the slope of the curve AB is positive.

$$\frac{d\rho}{dx} > 0$$

Since $\rho = \rho(C, T)$, it follows that the condition for *stability* is

$$\left(\frac{\partial \rho}{\partial C}\right)_T \left(\frac{dC}{dx}\right) + \left(\frac{\partial \rho}{\partial T}\right)_C \left(\frac{dT}{dx}\right) > 0$$

$$\frac{dC}{dx} > -\left(\frac{\partial \rho}{\partial T}\right)_C \left(\frac{dT}{dx}\right) \Big/ \left(\frac{\partial \rho}{\partial C}\right)_T$$

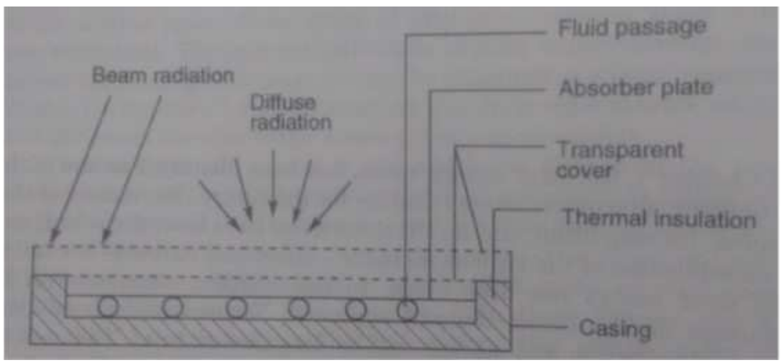


Q3) Explain with neat sketch the description and the working principle of liquid flat plate collector.

A solar thermal collector essentially forms the first unit in a solar thermal system. In any collection device, the principle usually followed is to expose a dark surface to solar radiation so that the radiation is absorbed. A part of the absorbed radiation is then transferred to a fluid like air or water. The fluid then delivers this heat to a thermal storage tank/boiler/heat exchanger to be utilized in the subsequent stages of the system.

When no optical concentration is done, the device in which the collection is achieved is called a flat-plate collector. The flat-plate collector is the most important type of solar collector because it is simple in design, has no moving parts and requires little maintenance. It can be used for a variety of applications in which temperatures ranging from 40˚C to about 100˚C are required.

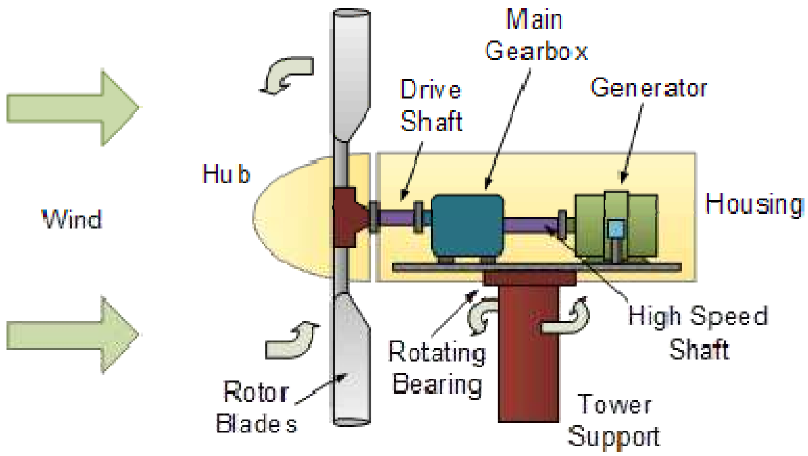
A schematic diagram of a liquid flat-plate collector is shown below. It consists of an absorber plate on which the solar radiation falls after coming through one or more transparent covers (usually made of glass). The absorbed radiation is partly transferred to a liquid flowing through tubes which are fixed to the absorber plate or are integral with it. This energy transfer is the useful gain. The remaining part of the radiation absorbed in the absorber plate is lost by convection and re-radiation to the surroundings from the top surface, and by conduction through the back and the edges. The transparent covers help in reducing the losses by convection and. re-radiation, while thermal insulation on the back and the edges helps in reducing the conduction heat loss. The liquid most commonly used is water.



Q4) With a neat sketch, explain the working principle of horizontal axis wind turbine using two aerodynamic blades.

The figure below shows the schematic of a horizontal axis windmill. The various parts of this windmill are:

a. Rotor
b. Gear box
c. Electric generator
d. Support structure



The turbine blades are made of high-density wood or fibre glass and epoxy composites. They have an aerofoil type cross-section. The blades are slightly twisted from the outer tip to the root to reduce the stall. The central solid portion of the rotor wheel is known as hub. All blades are attached to the hub. The hub is connected to a shaft which in turn is connected to the generator using a gear box. When the shaft rotates, electrical energy is produced in the generator. Thus, mechanical energy is converted to electrical energy. The supporting structure is designed to withstand the wind load. Horizontal axis wind turbines are mounted on towers so as to be above the level of turbulence and other ground related effects.

Q5)

$U_0 = 10 m/s$ $R = 287 J/kgK$

$p = 1 atm = 101.325 \times 10^3 Pa$

$T = 20°C = 293 K$

Density of air $\rho_{air} = \frac{P}{RT} = 1.205 kg/m^3$

Total power density in wind stream $= \frac{\rho_{air} U_0^3}{2} = \frac{1.205 \times 10^3}{2}$

$= 602.47 W/m^2$

maximum power density $= \frac{16}{27} \times$ Total power density

$= 357.02 W/m^2$

Actual power density for $\eta = 30\% = \left(\frac{30}{100}\right) \times$ Total power density

$= 180.74 W/m^2$

Area of turbine $= \frac{\pi d^2}{4}$

$= \frac{\pi}{4} \times 120^2 = 11309 m^2$

Total power produced $= 180.74 \times 11309$

$= 2.04 MW$

Scanned with CamScanner

6(a) $U_0 = 20 m/s$ $n = 2$

$D = 30 m \Rightarrow R = 15 m$

For max power output,

$$\frac{R\omega}{U_0} = \frac{4\pi}{n}$$

$$\Rightarrow \omega = \frac{4\pi}{n}\left(\frac{U_0}{R}\right) = \left(\frac{4\pi}{2}\right)\times\left(\frac{20}{15}\right)$$

$$= 8.377 \text{ rad/s}$$

$$\omega = \frac{2\pi N}{60} \Rightarrow N = \frac{60\omega}{2\pi} = \frac{60 \times 8.377}{2\pi}$$

$$= \underline{\underline{80 rpm}}$$

6(b) $U_0 = 10 m/s$

$P = 101.325 \times 10^3 Pa$

$T = 15°C = 288 K$

$D = 120 m$

$N = 40 rpm$

$$\rho_{air} = \frac{P}{RT} = \frac{101.325 \times 10^3}{287 \times 288} = 1.225 kg/m^3$$

$$\text{max power possible} = \frac{16}{27} \times \left(\frac{\rho_{air} U_0^3}{2}\right) \times \frac{\pi d^2}{4}$$

$$= 4.11 MW$$

$$\text{Max torque } T_{max} = \frac{P_{max}}{\omega} = \frac{P_{max}}{\frac{2\pi N}{60}}$$

$$= \frac{4.11 \times 10^6 \times 60}{2\pi \times 40}$$

$$= \underline{\underline{981 kNm}}$$