5a: Testing of an evacuated tube collector (ETC)

INTRODUCTION:

Evacuated tube solar collectors are among the most efficient, reliable and cost-effective solar collectors. There are many types of evacuated tube solar collectors to choose from, making them extremely versatile in the applications they can be used for. This also helps in sizing the systems that they can create and helping with the affordability of the overall solar hot water system.

Evacuated tube systems work by using a heat transfer fluid (HTF - typically a glycol-water solution) that travels in a cycle. First it travels through a manifold, absorbing the captured solar energy produced from the evacuated tubes. The HTF then travels to a water tank, transferring the solar energy to the water, heating it. The HTF then goes back through the evacuated tubes and repeats the cycle.

Because vacuums are nature's best insulator, evacuated tube solar collectors are extremely efficient and cost effective in every climate, including northern climates where freezing temperatures can be the norm. In fact, evacuated tube solar collectors are efficient in all temperatures down to -60^{o}F.

AIM: To characterize Evacuated Tube Collector

APPARATUS: Evacuated Tube Collector set-up, thermocouples, rotameter, pyronameter and d.c. microvoltmeter.

SPECIFICATIONS OF ETC SYSTEM

The experimental set-up consists of evacuated tube collector (ETC), rotameter, water storage and pump. Thermocouples are placed at inlet and outlet. ETC is kept at tilt equal to latitude of the place. Rotameter is used to measure flow rate of water flowing through system.

(i)	Module dimension:	Aperture area = 1.96 m^2
		Dimension: (1.8 x 1.26 x 0.16) m
		Number of Tubes = 12
(ii)	Header dimension:	O.L. = 28.6 mm, I.D. = 26.1 mm
(iii)	Heat transfer to copper header from heat pipes through aluminium heat exchanger.	

THEORY:

The useful heat gain rate (q_u) is given by, $q_u = \dot{m}\, C_P\, (T_{fo} - T_{fi})$ (1)

The efficiency (η) is given by, $\eta = q_u / A_c\, I_T$ (2)

where, $\dot{m}$ = flow rate, C_p = fluid specific heat,

T_{fo} = outlet T_{fi} = Inlet temperature

A_c = aperture area, I_T = solar insolation on the plane of the collector

Also $\eta = F_R\,[\eta_o - U_L\,(T_{fi} - T_a\,)\,/\,I_T]$ (3)

where,

η = Instantaneous efficiency

F_R = Heat removal factor

η_o = optical efficiency

U_L = Overall loss coefficient

T_{fo} = Outlet fluid temperature

T_{fi} = Inlet fluid temperature

T_a = Ambient temperature

I_T = Solar Intensity

A_c = Collector area

Solar intensity, $I_T = I_b r_b + I_d r_d + r_r\,(I_b + I_d)$ (4)

where, I_b = Beam radiation, I_d = Diffuse radiation, r_b, $r_{d,,}$ r_r = Tilt factors

PROCEDURE

1. Clean the surface of glass tubes to remove dust by a soft cloth. Take care of the tubes.

2. Switch on the pump to circulate water through the header of the panel at about 0.02 kg/(s m^2) of collector area

3. Make necessary adjustments for the pyranometer to measure diffuse and global radiation.

4. Record mass flow rate, inlet and outlet fluid temperature, temperatures differences, global and diffuse radiation and ambient air temperature.

5. Repeat the step 4 at every 15 minutes and note down 12 sets of observations in 3 hours of duration keeping same mass flow rate.

6. Switch off the pump.

RESULTS:

Carry out a regression analysis to find out collector characteristic parameters $F_R\eta_o$ and F_RU_L for given mass flow rate.

Comment on $F_R\eta_o$ and F_RU_L values compared to standard flat plate collector values.

Precautions:

1.The readings should be taken only when the steady state has been achieved. There should not be any object whose shadow will fall on the collector.

2.While taking the solar radiation calibration constant must be used.

3. Maintain the flow at fixed value through-out the experiment

QUESTIONS:

1. What are some uses of Evacuated Tube Collectors?
2. What are some advantages and disadvantages of using ETCs?
3. How do ETCs work?
4. Suggest some proposals for increasing efficiency in the present model.

5b: Performance of solar hot water systems with natural circulation

Introduction:

This is the most widely used system configuration. In thermosiphon system, cold water will flow into the system due to pressure difference and therefore the source of the cold water must be placed higher above the terrace level where solar water heater system will be installed.

Aim:

To find out efficiency of natural circulation water heating system and out collector characteristic system constants F_Rڂ$_o$ and $F_R U_L$.

Apparatus:

Solar water heating system, pyranometer, thermocouples, selector switch and DC voltmeter.

Theory:

The laboratory set up for this experiment has a collector connected to tank. The level of tank is higher than that of collectors. The efficiency of the evacuated tube collector and tank system is given by,

$$\eta_{\mathrm{sys}} = Q_{\mathrm{u}}|_{\mathrm{over}\Delta t} / [A_{\mathrm{c}}\, (I_{\mathrm{T}} \cdot \Delta t)] = M\, C_p\, (T_{\mathrm{f}} - T_{\mathrm{i}}) / [A_{\mathrm{c}}\, (I_{\mathrm{T}} \cdot \Delta t)] \qquad (1)$$

And the characterizing equation is,

$$\eta_{\mathrm{sys}} = A - B \cdot X_{\mathrm{c}} \qquad (2)$$

where, A and B are characteristic system constants, and X_{c} is given by

$$X_{\mathrm{c}} = \left\{ \frac{\left(\frac{T_{\mathrm{fi}} + T_{\mathrm{fo}}}{2} - T_{\mathrm{ai}} \right) \cdot \Delta t}{I_{\mathrm{Ti}} * \Delta t} \right\}$$

$M\, C_p$ = Mass and specific heat product for the tank fluid

η_{sys} = Efficiency over the period Δt

T_{f} = Final tank temperature

T_{i} = Initial tank temperature

I_T = Mean Solar Intensity

A_{c} = Collector area

Δt = time interval

$\frac{T_{\mathrm{fi}} + T_{\mathrm{fo}}}{2}$ =Mean tank temperature over the period Δt_{i}

T_{ai} = Ambient temperature at i^{th} time step

I_{Ti}= Solar intensity at i^{th} time step

Δt_i $= i^{th}$ time interval

Solar intensity,

$$I_T = I_b r_b + I_d r_d + r_r (I_b + I_d) \quad (3)$$

where,

I_b = Beam radiation, I_d = Diffuse radiation, r_b, $r_{d,}$, r_r = Tilt factors

Procedure:

1. Fill the storage tank to its full capacity, measure the tank volume.
2. Measure the collector area.
3. Note down the readings for inlet fluid temperature, outlet fluid temperature at collector.
4. Note down the readings for solar radiation (global and diffuse) at the same instant.
5. Note down all readings in interval of 15 minutes. Take about 9-10 set of readings.
6. Calculate the efficiency.

Solar Radiation data:

Sr. No.	Time (IST) h	Diffuse radiation I_d (W/m^2)	Global radiation I_g (W/m^2)
1.			
2.			
…			
8.			

Readings for determining characteristic parameter:

Sr. No.	Time (h)	Flow rate (LPM)	Inlet temperature T_{fi} (mV)	Outlet temperature T_{fo} (mV)	Mean tank temperature (mV)	Ambient temperature (mV)
1.						
2.						

…						
8.						

Precautions:

1. Note that N sets of readings will give you N-1 sets for calculation.
2. Water withdrawal from tank should be stopped (i.e. close the inlet and outlet of tank) before starting the experiment.
3. Do not shadow collector as well as pyranometer during the experiment.

Quiz:

1. Explain the losses.
2. Suggest any two modifications to improve the efficiency.
3. How can you justify your results?
4. On cloudy day which is more effective forced circulation or natural circulation?
5. How does efficiency vary with:
    - Change in capacity of storage
    - Change in area of collector