HT Lab Experiment-3: Solar Thermal Water Heater Efficiency

Group-2

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Essential Background

1. **What is the net heat transfer interaction between two black bodies interacting through radiation only?**

   Lets name the two bodies as 1 and 2. Then,

   $$\text{Net Heat Transfer} = \sigma(A_1T_1^4 - A_2T_2^4)$$

   Here, the assumption is that setup is placed in an isolated box, in which the walls reflect back whatever radiation comes to them.

   At equilibrium, energy emitted by black body-1 will be equal to energy emitted by black body-2, i.e.

   $$A_1T_1^4 = A_2T_2^4$$

2. **What if one of the bodies is a ‘gray’ body with emissivity of epsilon, how does the result change?**

In that case,

$$
\begin{gathered}
E_{emitted}: \\
Body_1 = \sigma A_1 T_1^4 \\
Body_2 = \epsilon \sigma A_2 T_2^4 \\
E_{absorbed}: \\
Body_1 = \epsilon \sigma A_2 T_2^4 \\
Body_2 = \sigma A_1 T_1^4
\end{gathered}
$$

$$\text{Net Heat Transfer} = \sigma(A_1 T_1^4 - \epsilon A_2 T_2^4)$$

At equilibrium,

$$A_1 T_1^4 = \epsilon A_2 T_2^4$$

3. **What are the ideal conditions for the design of a solar thermal collector: does the**
   collector have to be a good emitter or good absorber of radiation in the visible and
   infrared portions of the EM spectrum?

   The collector should be a good absorber of both visible light spectrum and infrared spectrum, so that it can absorb as much heat as possible from sun. In order to minimize the loss of heat collected it should also be poor emitter of infrared spectrum radiation.

Experiment

Experimental readings

Inlet Temperature(Degree C)	**Output temperature(Degree C)**	**Flow rate(L/min)**	**Radiation(W/m^2)**
31.9	32.8	5.456-5218	500
32.2	33.1	5.456-5218	470
32.7	33.5	5.456-5218	520
33	34	5.456-5218	465
33.5	34.3	8.30-8.65	420

33.9	34.7	8.30-8.65	430
34.2	35.1	8.30-8.65	400
34.6	35.5	8.30-8.65	430

1. Plot instantaneous efficiency vs. inlet water temperature. Explain the trend observed.

$$\text{Efficiency} = \frac{\text{Energy Absorbed}}{\text{Energy Incident}}$$
$$= \frac{C_p * \Delta T * \rho * \text{flow rate} * t}{\frac{I}{cos\theta} * A * t}$$
$$= \frac{C_p \Delta T \rho V cos\theta}{IA}$$

where,

C_p → Specific Heat of Water $(4200 J/^oCKg)$

ΔT → $T_{out} - T_{in}$

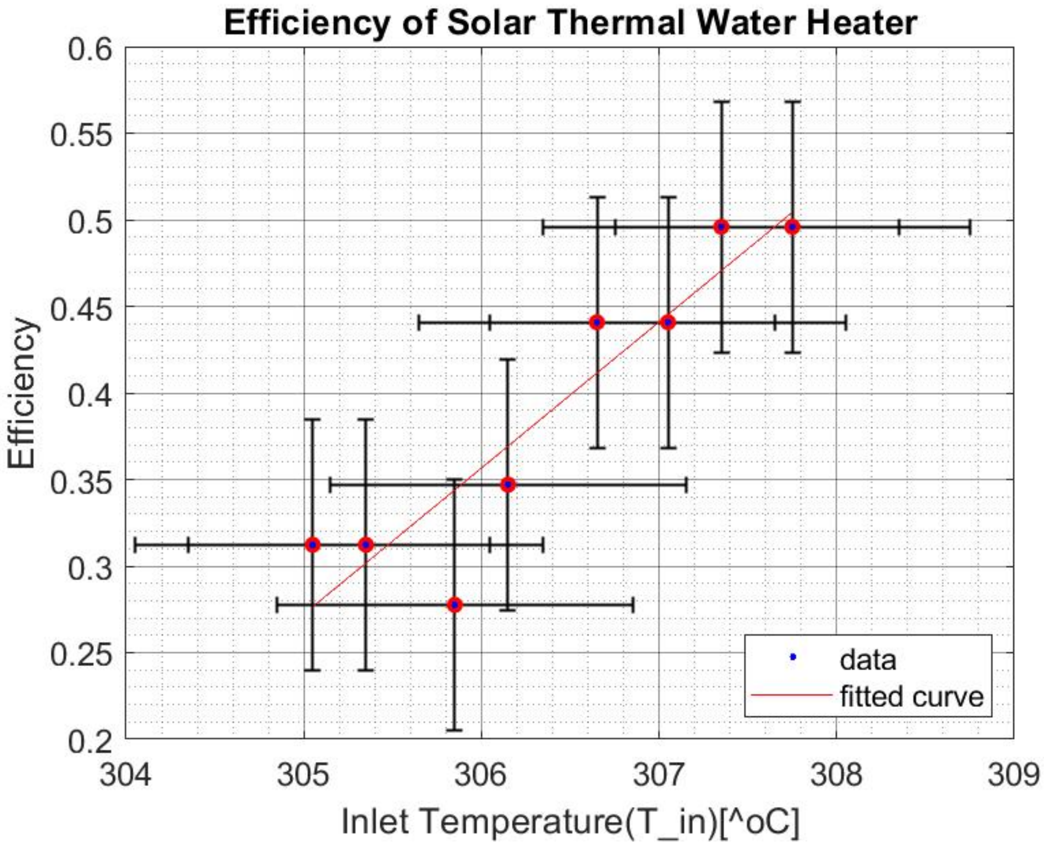
ρ → Density of water ($998 kg/m^3$)

V → Volumetric flow rate of water

θ → Angle of incidence of sunlight over horizontal plane(35^o)

A → Area of the parabolic Mirror $(1.956 m^2)$

$$RE_{\text{efficiency}} = \frac{1}{310} + \frac{1}{8} + \frac{100}{400} + \frac{cos45 - cos35}{cos35}$$
$$= 0.2414$$
$$\Delta e = 0.2414 * 0.3 = 0.0724$$



2. **Is the temperature uniform along the length and across the circumference of the tube?**

   It changes along the length because we are heating by concentrating radiations only on one portion of tube then heat is being transferred across the length.

   Temperature changes across the circumference because the radiations due to sunlight are fall upon only one side of the tube.

3. **How can the efficiency of the collector be improved?**

   a. Improving the absorbent's solar selectivity

   b. Modifying the fluid's flow rate.

   c. Increasing the working fluid and absorber surface in contact's convective heat transfer coefficient.

   d. Lower the thermal losses the collector emits

   e. Modifying the fluid's flow rate.

4. **Can we change the material of construction of the tube? What material and color would be ideal, based on measurements of absorptivity/emissivity?**

There are multiple ways in which we can improve efficiency of collector. one such way is to choosing an appropriate material for it. here are some of the factors that affects efficiency of collector and by studying them we can find appropriate material:

Thermal conductivity, Melting point, Shape and Color, Resistance to UV rays, Density, and Tensile strength

Therefore we can choose the material which has high thermal conductivity, high melting point, high density, high resistance to UV rays, high tensile strength and coloring material with darker shades allows more solar energy to be accumulated.

The most widely utilized materials are economical copper, steel, and aluminum. Copper is typically utilized among the materials indicated above due to its thermal conductivity and resilience to environmental variables like dampness. Plates that act as absorbers can also be made of steel, aluminum, and zinc. The material that can absorb the greatest radiation while emitting the least amount of radiation into the environment is the one that is best suited, in theory. Copper is the greatest alternative that has characteristics that are similar to those listed above.

Color the material with darker shades because it allows more solar energy to be accumulated. since they has high absorptivity and low emissivity.

5. **What about additional insulation, and if so, where?**

We can also employee insulation to areas of less light incidence. This will ensure utmost efficiency since by doing so we are enabling maximum absorption of light. The color will be painted black in order to minimize the emission of light.