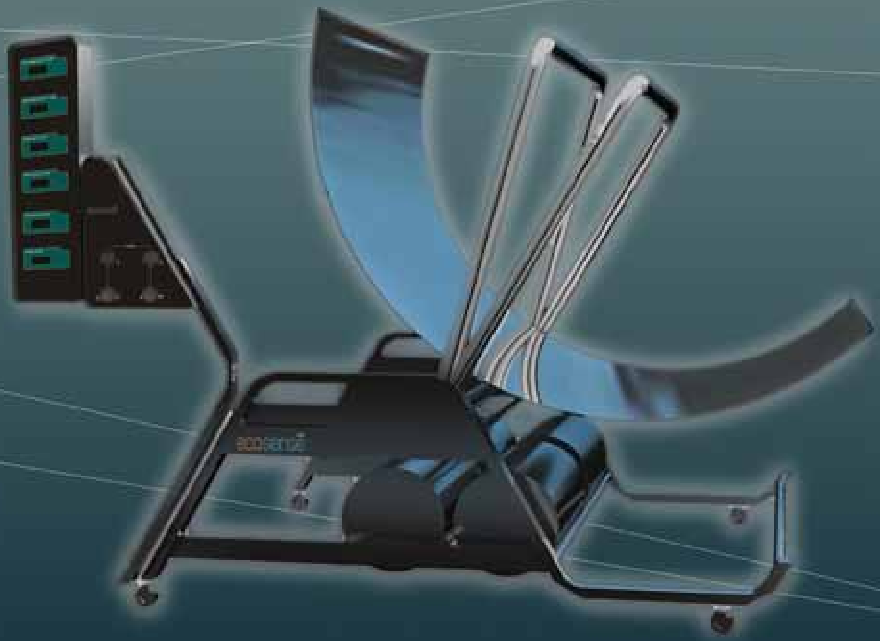
ecosense

INSIGHT SOLAR



Solar Concentrator

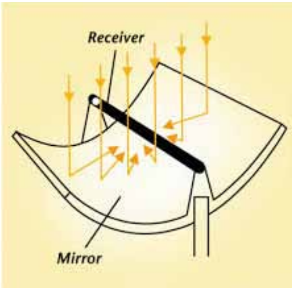
Training System

Experiment Manual

includes 8 experiments with step by step guidance

Insight Solar
Introduction:

A parabolic trough is a type of solar thermal collector that is straight in one dimension and curved as a parabola in the other two, lined with a polished metal mirror. The energy of sunlight which enters the mirror parallel to its plane of symmetry is focused along the focal line, where an absorber tube is placed for collecting the solar radiation. The mirror is oriented so that sunlight which it reflects is concentrated on the tube, which contains a fluid which is heated to a high temperature by the energy of the sunlight. The hot fluid can be used for many purposes. Often, it is piped to a heat engine, which uses the heat energy to drive machinery or to generate electricity.



Theory:

Parabolic trough system consists of following components:

- Parabolic reflector:

It is the mirror in the form of parabolic shape which reflects all the radiation at the focus of a parabola. This reflector is mounted over a structure which can move from east to west with the help of sun tracker.

- Absorber tube or receiver:

It is a metal pipe or tube coated with black nickel or chromium and sealed with glass tube. Black coating increases the absorption of tube while glass glazing decreases the convection losses from tube.

☺DOs

- Always set the reflector direction normal to sun radiation beam before starting the experiment with the help of switches in tracking system.
- Both storage tanks should be completely filled before starting the experiment.
- Receiver tube should be completely filled with oil and water.
- Always set the required receiver tube at the focus before starting of experiment
- All three way valves and close valve should be at right position through out the experiment.
- FRP switches for sensor selection should be at right position through out the experiment.
- Insulation jackets should cover storage tank completely and should be tight enough to prevent the convective losses.

☹DON’Ts

- Don’t look at the reflector without sunglasses
- Don’t start any of the pumps before selecting the three way valve position
- Don’t pump the oil through receiver tube after filling the indicator vent
- Don’t pump the water through receiver tube after filling the indicator vent of tank
- Don’t start the experiment without setting the reflector sheet normal to sun rays
- Don’t shade the reflector sheet at any point of time during the experiment
- Don’t touch the receiver tube during the experiment

- Sun tracker:

It is the device which rotates the complete structure from east to west direction. It works on timer algorithm and sensor based algorithm.

Table-1: Overall Specifications of the system

S.No.	Components	Specifications
1	**Heat generating unit with tracking system**	
	Parabolic reflector • Length • Arc length (perimeter) • Depth • Focal length • Material	 4 ft 6 ft 0.68 ft 1.99 ft SS with mirror film
	Sun tracker	**Single axis**
	Absorber tube • Length • Diameter • Absorber material • Insulation material (for pipe) • Piping material	 4 ft 1 inch Copper, SS PUF GI and copper
2	**Storage unit**	
	Supply tanks • Capacity • Material **Storage tank** • capacity • material • Insulation used • Tank insulation thickness • Pipe insulation thickness • Working fluid	2 (one for water and another for oil) 46 ltr (for water) and 10 ltr (for oil) SS 2 (one with Heat exchanger and other without heat exchanger) 28 ltr SS Glass wool with rexene 2cm 1cm Water and oil
3	**Control unit**	
	Pump (for water) • Power rating • Head **Pump (for oil)** • Power rating • Head	 0.1 HP 6 m 0.5 HP 10m
	Different meters • Thermometers • Flow meter • Radiation meter • Anemometer	
4	**Accessories**	
	• Experimental manual • Tools for piping and connections • Oil	

Important parameters of a parabolic trough heating system:

The performance of a parabolic trough system depends upon different design and atmospheric parameters.

The meaning and importance of some of the most dominating parameters are described below.

Overall Heat Loss Coefficient (U_L):

All the heat that is received by the receiver tube does not result into useful energy. Some of the heat gets lost to the surrounding. The amount of heat loss depends upon the convective, conductive and radiative heat loss coefficients.

Estimation of heat loss coefficient of the system is important for its performance evaluation. A higher value of heat loss coefficient indicates the lower heat resistance and hence the lower efficiency.

Among all heat loss parameters the top loss contributes the most. The top heat loss coefficient is a function of various parameters which includes the temperature of the receiver tube, ambient temperature, wind speed, emissivity of the receiver tube.

Heat Removal Factor (F_R):

Heat removal factor represents the ratio of the actual useful energy gain to the useful energy gain if the entire receiver were at the fluid inlet temperature. It depends upon the factors like inlet and outlet fluid temperature, the ambient temperature, area of the tube etc. The importance of heat removal factors remains with the efficiency of the system. For a highly efficient system a higher value of heat removal factor is must.

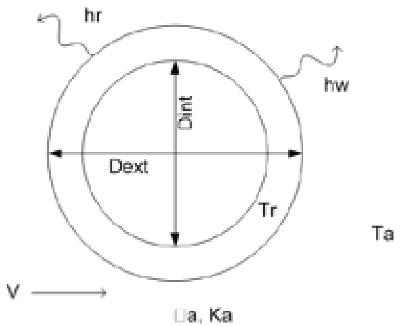
Efficiency (η):

Efficiency is the most important factor for a system. This factor determines the system's output. For a parabolic trough system the efficiency is defined as the ratio of the useful energy delivered to the energy incident on the aperture of trough.

Basic Equations to calculate different parameters:

A. Heat Loss coefficient (U_L)

U_L is the overall heat transfer coefficient from the receiver tube to the ambient air. This is very important and complex factor which tells us the heat loss per unit area per unit temp difference from receiver tube to ambient. In our case there is no glass glazing therefore, U_L will be expressed in two terms only (as shown below). By multiplying this factor with tube area and temp diff. between tube and ambient, we will get the total heat loss from the tube to ambient.



Cross sectional view of receiver tube

$$U_L = h_w + h_r \qquad \text{(eq. 1)}$$

Where,

h_w: Convective heat transfer coefficient between tube and atmosphere

h_r: Radiative Heat transfer coefficient of radiation

h_w and h_r can be expressed by using following formulae

$$h_w = Nu_a \cdot K_a / D_{ext}$$

Where, Nu_a can be calculated by following formulae

For $0.1 < Re_a < 1000$, $\quad Nu_a = 0.4 + 0.54 \times Re_a^{0.6}$

For $1000 < Re_a < 50000$, $\quad Nu_a = 0.3 \times Re_a^{0.6}$

Where $\quad Re_a = V \cdot D_{ext} / \nu_a$

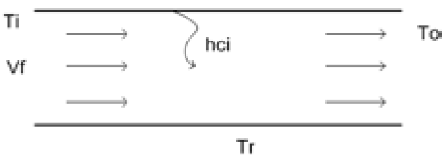
$$h_r = \varepsilon \cdot \sigma \cdot (T_r + T_a) \cdot (T_r^2 + T_a^2)$$

By putting fix values of some parameters, U_L can be expressed by following equations

$$U_L = 1.7 \cdot 10^{-8} \cdot (T_r + T_a)(T_r^2 + T_a^2) + 25.746 \cdot (V)^{0.8} \text{ ...... for } V < 0.67 \quad (1A)$$

$$U_L = 1.7 \cdot 10^{-8} \cdot (T_r + T_a)(T_r^2 + T_a^2) + 0.427 + 277.76 \cdot (V)^{0.82} \text{ ..for } V > 0.67 \quad (1B)$$

B. F factors of a receiver tube (F/, FR,)



Flow in receiver tube

1. **Collector efficiency factor (F'):** Collector efficiency factor is constant for any collector design and fluid flow rate. This represents the ratio of actual useful energy gain to the useful energy gain that would result if the receiver tube surface temperature had been at the fluid temperature.

F' = (Actual useful heat collection rate)/ (Usefull heat collection rate when the absorbing plate is at the local fluid temperature)

Mathematically,

$$F' = \frac{\frac{1}{U_L}}{\left[\frac{1}{U_L} + \frac{D_{ext}}{h_{ci} D_{int}} + \frac{D \cdot \ln(D_{ext}/D_{int})}{2 \cdot K_r}\right]} \quad \text{Equ. 2}$$

h_{ci} calculation:

For water:

$$h_{ci(w)} = \frac{K_w}{D_{int}} \cdot \left[3.66 + \frac{0.0668 \cdot (D_{int}/L) \cdot Re_w Pr_w}{1 + 0.04 \cdot [(D_{int}/L) \cdot Re_w Pr_w]^{2/3}}\right]$$

$$Re_w = V_w \cdot D_{int} / \nu_w$$

$$V_w = \dot{m} / (\rho_w \cdot 3.14 \cdot \frac{D_{int}^2}{4})$$

$$Pr_w = \mu_w \cdot C_{p(w)} / K_w$$

$$\mu_w = 0.0168 \cdot \rho_w \cdot (T_i - 273)^{-0.88}$$

$$\rho_w = 1000 \cdot \left[1 - \frac{(T_i + 15.94)}{508929.2 \cdot (T_i - 204.87)} \cdot (T_i - 277)^2\right]$$

$$Pr_w = 112.55 \left[1 - \frac{(T_i + 15.94)}{508929.2 \cdot (T_i - 204.87) \cdot (T_i - 277)^2}\right] \cdot (T_i - 273)^{-0.88}$$

For oil:

$$h_{ci(oil)} = \frac{K_{oil}}{D_{int}} \cdot Nu_{oil}$$

$$Nu_{oil} = 3.66 + \frac{0.065 \cdot \left(\frac{D_{int}}{L}\right) \cdot Re \cdot Pr}{1 + 0.04 \cdot \left[\left(\frac{D_{int}}{L}\right) \cdot Re \cdot Pr\right]^{2/3}}$$

$$Re = V_{oil} \cdot D_i / \nu_{oil}$$

$$V_{oil} = \frac{\dot{m}_{oil}}{\rho_{oil} \cdot A_{Cu}}$$

$$Pr_{oil} = \mu_{oil} \cdot C_{p(oil)} / K_{oil}$$

Heat Removal Factor (FR): Heat removal factor is constant for any collector design and fluid flow rate. This represents the ratio of actual useful energy gain to the useful energy gain that would result if the receiver tube surface temperature had been at the fluid inlet temperature.

$$F_R = \frac{\text{Actual usefull energy gain}}{\text{useful energy gain if the entire collector were at the fluid inlet temperature}}$$

Mathematically,

Another formula for F_R,

$$F_R = \frac{\dot{m} C_p}{A_{int} U_L} \left[1 - \exp\left(-\frac{U_L F' A_{int}}{\dot{m} C_p}\right)\right] \quad \text{(eq.3)}$$

For water

$$F_R = 2.04 \cdot 10^{4} \cdot \frac{\dot m_w}{A_c}[1 - \exp\left(-4.91 \cdot 10^{-3} \cdot \frac{U_L F'}{\dot m_w}\right)] \quad \text{(eq.3A)}$$

For oil

$$F_R = 4.2 \cdot 10^{4} \cdot \frac{\dot m_w}{A_c}[1 - \exp\left(-2.38 \cdot 10^{-7} \cdot \frac{U_L F'}{\dot m_w}\right)] \quad \text{(eq.3B)}$$

C. Thermal Efficiency of the collector (η)

It is the ratio of the Useful heat gain to the Total input solar energy

Mathematically,

$$\eta = m * Cp * \frac{T_o - T_i}{A_a * I_b} \quad \text{(eq.4)}$$

For water:

$$\eta = 2024 * \dot m * \frac{T_o - T_i}{I_b} \quad \text{(eq.4A)}$$

For oil:

$$\eta = 996.62 * \dot m * \frac{T_o - T_i}{I_b} \quad \text{(eq.4B)}$$

D. Comparison of theoretically achieved and experimentally achieved temperature values

Experimental values will be obtained by using different thermometers while theoretical values can be achieved by using following formulae

$$T_r = T_m + \frac{\dot m * C_p * (T_o - T_i)}{h_{ci} * \pi * D_{ext} * L} \quad \text{(eq.5A)}$$

$$T_m = \frac{T_i + T_o}{2} \quad \text{(eq.5B)}$$

$$T_o = T_i + \frac{Q_u}{\dot m * C_p} \quad \text{(eq.5C)}$$

Values of m, C_p and h_{ci} can be obtained from above formulae.

E. Heat loss in piping

For water:

$$\text{Loss in piping} = 4187 * \dot m * (T_o - T_{i\,tank}) \quad \text{(eq.6A)}$$

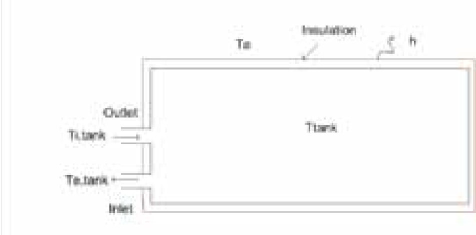
For oil:

$$\text{Loss in piping} = -2061 * \dot m * (T_o - T_{i\,tank}) \quad \text{(eq.6B)}$$

Rate of heat loss in piping = $m^* C_p{}^*(T_o - T_{i\,tank})$ (eq.6)

F. Heat loss in storage tank

For water:

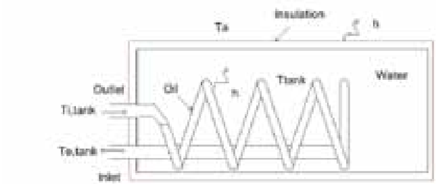


Heat transfer eq. for tank water

$$T^{*}_{tank,x} = \frac{28 * T_{tank,x} - \dot m * T_{i\,tank}}{28 - \dot m}$$

$$\text{Heat loss in tank (in t sec)} = 28 * C_p * (T_{tank,x-1} - T^{*}_{tank,x}) \quad \text{(eq.7A)}$$

For oil: Heat exchanger calculation



$$T_{e,tank} = T_{tank} - (T_{tank} - T_{i,tank}) * \exp\left(-h_{ci(oil)} * \frac{A_{Cu}}{\dot m_{oil} * C_{p(oil)}}\right)$$

$$h_{ci(oil)} = \frac{K_{oil}}{D_{int}} * Nu_{oil}$$

$$Nu_{oil} = 3.66 + \frac{0.065 * \left(\frac{D_{int}}{L}\right) * Re * Pr}{1 + 0.04 * [\left(\frac{D_{int}}{L}\right) * Re * Pr]^{2/3}}$$

$$Re = V_{oil} * D_i / \upsilon_{oil}$$

$$V_{oil} = \frac{\dot m_{oil}}{\rho_{oil} * A_{Cu}}$$

$$Pr_{oil} = \mu_{oil} * C_{p(oil)} / K_{oil}$$

Sensible heat delivered to water by oil

$$Q_{oil} = \dot m_{oil} * C_{p(oil)} * (T_{i,tank} - T_{e,tank})$$

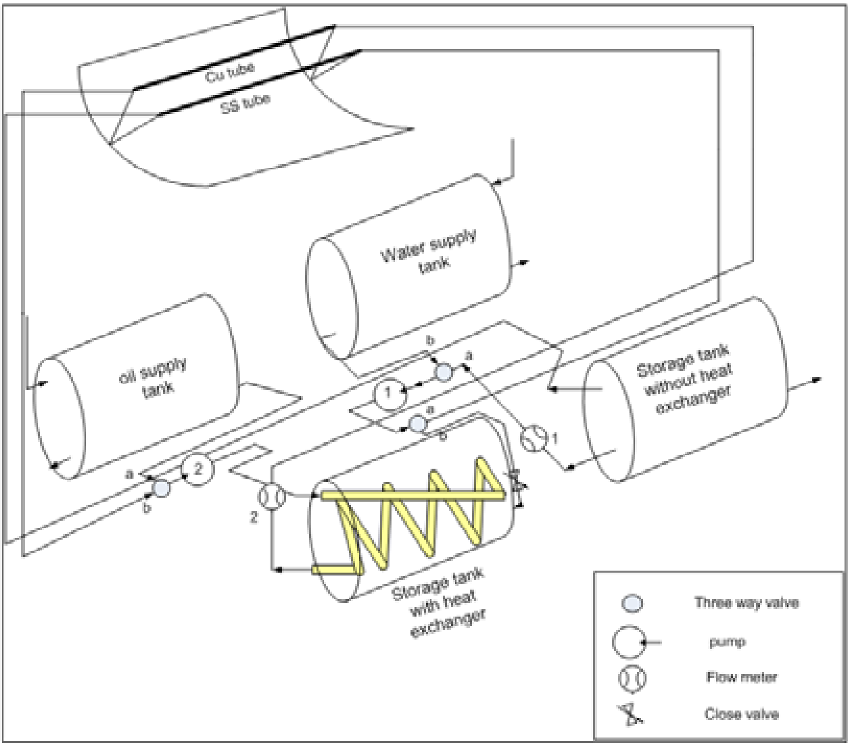
This sensible heat will raise the temperature of water from previous one

$$Q_{oil} = \dot m_w * C_{p(w)} * (T_{tank,x} - T^{*}_{tank,x})$$

$$\text{Heat loss in tank (in t sec)} = 27 * C_p * (T_{tank,x-1} - T^{*}_{tank,x}) \quad \text{(eq.7B)}$$

Experimental set-up: Different components of parabolic trough system are connected to each other in following manner.

There are two types of parameters viz. weather parameters (radiation and wind speed) and user defined parameters (flow rate, insulation thickness and inlet water temperature).



Weather parameters cannot be changed by user so user has to perform the experiment in parts (different time of day). During a part of experiment, weather parameters will be same (or will remain unchanged) but will be changed in other part of the experiment. Fixed parameter will remain the same during the complete experiment.

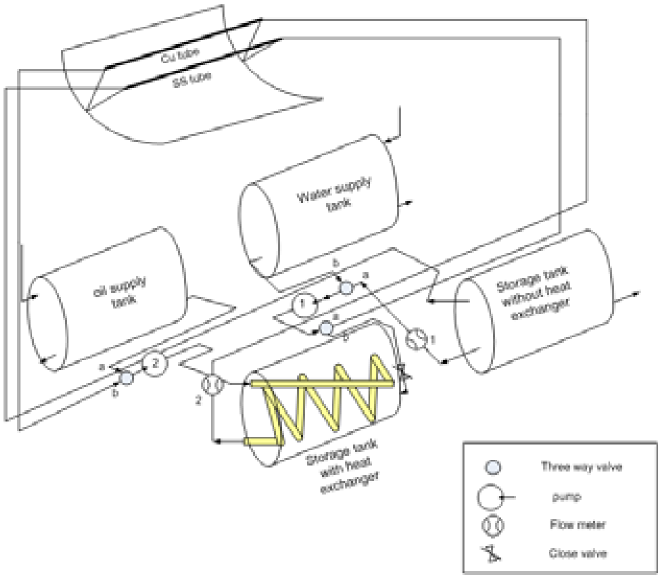
Insight Solar
Experiment No. 1

Objective: Determine the Performance (U_L, F_R, η) of the Parabolic Trough collector with fixed parameters with (i) Water and (ii) Oil as working fluid.

Experimental set-up: Set-up for this experiment will remain the same as discussed earlier in the starting of this manual. But for this experiment, we have to make tank and receiver tube selection.

(i) For this, we have to fix the V-clamp such that SS receiver tube will remain at focus of parabolic reflector. Valve-1 will be positioned at 'b' condition and valve-2 will be positioned at 'a' condition. Insulation thickness (of tank and pipe) will not be changed during this experiment.

(ii) For this, we have to fix the V-clamp such that Copper receiver tube will remain at focus of parabolic reflector. Valve-2 can be positioned at any position as a close valve is present there in the middle of valve-2 and heat exchanger tank. Close valve will cut the connection of this tank from water tank (tank no.1). Valve-3 will be positioned at 'b' condition. Insulation thickness (of tank and pipe) will not be changed during this experiment.



Observations:

Tank insulation thickness =

Pipe insulation thickness =

Set A: Water as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Set B: Oil as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Calculations: Mass flow rate, wind velocity, solar insolation and insulation thickness will remain the same during the calculation of different parameters. If any of weather parameter changes, do the calculation in parts in which all parameters remain constant all the time. Following equations will be used for evaluation of different parameters.

(i) Water as working fluid: Performance parameters will be evaluated with the help of eq. 1A, 2, 3A, 4A, 5A, B, C, 6A and 7A.

UL = 1.7*10^{-9}* $(T_r + T_a)(T_r^2 + T_a^2)$ + 25.746*$(V)^{0.6}$…… for V <0.67

UL = 1.7*10^{-9}* $(T_r + T_a)(T_r^2 + T_a^2)$ + 0.427 + 277.76*$(V)^{0.53}$…… for V >0.67

$$F' = \frac{\frac{1}{U_L}}{\left[\frac{1}{U_L} + \frac{D_{ext}}{h_{ci} D_{int}} + \frac{D \cdot \ln\left(D_{ext}/D_{int}\right)}{2 \cdot K_r}\right]}$$

$$F_R = 2.04 \cdot 10^6 \cdot \frac{\dot{m}_w}{U_L}\left[1 - \exp\left(-4.91 \cdot 10^{-7} \cdot \frac{U_L F'}{\dot{m}_w}\right)\right]$$

$$\eta = 2024 \cdot \dot{m} \cdot \frac{T_o - T_i}{I_b}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m} * C_p * (T_o - T_i)}{h_{ci} * \pi * D_{ext} * L}$$

$$T_m = \frac{T_i + T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m} * C_p}$$

Loss in piping =4187 *m*$(T_o - T_{i\,tank})$

Heat loss in tank (in t sec) = 28*C_p* $(T_{tank,x}$-1-T*$_{tank,x})$

(ii) Oil as working fluid: Performance parameters will be evaluated with the help of eq. 1B, 2, 3B, 4B, 5A, B, C, 6B and 7B.

UL = 1.7*10^{-9}* $(T_r + T_a)(T_r^2 + T_a^2)$ + 25.746*$(V)^{0.6}$…… for V <0.67

UL = 1.7*10^{-9}* $(T_r + T_a)(T_r^2 + T_a^2)$ + 0.427 + 277.76*$(V)^{0.53}$…… for V >0.67

$$F' = \frac{\frac{1}{U_L}}{\left[\frac{1}{U_L} + \frac{D_{ext}}{h_{ci} D_{int}} + \frac{D \cdot \ln\left(D_{ext}/D_{int}\right)}{2 \cdot K_r}\right]}$$

$$F_R = 4.2 \cdot 10^6 \cdot \frac{\dot{m}_w}{U_L}\left[1 - \exp\left(-2.38 \cdot 10^{-7} \cdot \frac{U_L F'}{\dot{m}_w}\right)\right]$$

$$\eta = 996.62 \cdot \dot{m} \cdot \frac{T_o - T_i}{I_b}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m} \cdot C_p \cdot (T_o - T_i)}{h_{ci} \cdot \pi \cdot D_{ext} \cdot L}$$

$$T_m = \frac{T_i + T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m} \cdot C_p}$$

Loss in piping $= 2061 \cdot \dot{m} \cdot (T_o - T_{i\,tank})$

Heat loss in tank (in t sec) $= 27 \cdot C_p \cdot (T_{tank,x-1} - T'_{tank,x})$

Results: Calculate all performance parameters of this system.

Notes

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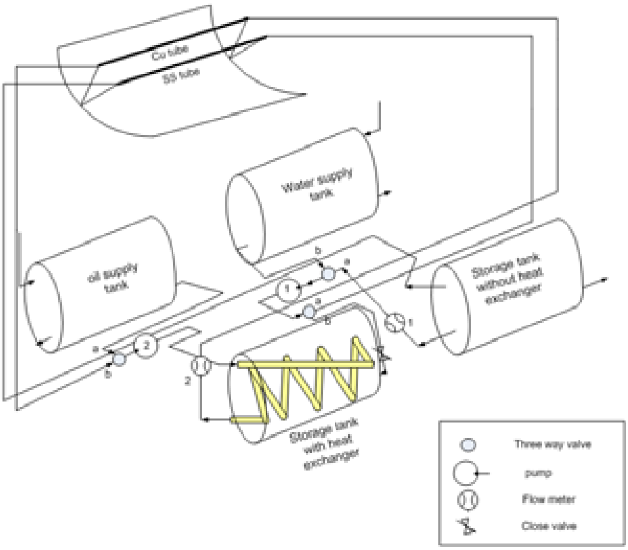
Insight Solar
Experiment No. 2

Objective: Determine the Performance (UL, FR, η) of the Parabolic Trough collector with varying solar insolation with (i) Water and (ii) Oil as working fluid.

Experimental set-up: Set-up for this experiment will remain same as discussed earlier in the starting of this manual. But for this experiment, we have to make tank and receiver tube selection.

(i) For this, we have to fix the V-clamp such that SS receiver tube will remain at focus of parabolic reflector. Valve-1 will be positioned at 'b' direction and valve-2 will be positioned at 'a' direction. So that water will flow from pump 1 to receiver tube 'SS'. Insulation thickness (of tank and pipe) will not be change during this experiment.

(ii) For this, we have to fix the V-clamp such that Copper receiver tube will remain at focus of parabolic reflector. Valve 1 will be position at 'a' direction. Valve 2 will be position at 'b' direction so that water will flow form pump 1 to heat exchanger tank. Close valve will cut the connection of this tank from water tank (tank no.1). Valve-3 will be positioned at 'b' direction. Insulation thickness (of tank and pipe) will not be changed during this experiment.



Observations:

Tank insulation thickness =

Pipe insulation thickness =

Set A: Water as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Set B: Oil as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Calculations: Mass flow rate, wind velocity, solar insolation and insulation thickness will remain the same during the calculation of different parameters. If any of weather parameter changes, do the calculation in parts in which all parameters remain constant all the time. Evaluate the performance parameters for each set keeping solar insolation constant for this set. Following equations will be used for evaluation of different parameters.

(i) **Water as working fluid:** Performance parameters will be evaluated with the help of eq. 1A, 2, 3A, 4A, 5A, B, C, 6A and 7A.

$UL = 1.7*10^{-9}* (T_r+ T_a) (T_r^2+ T_a^2) + 25.746*(V)^{0.6}$…… for $V <0.67$

$UL = 1.7*10^{-9}* (T_r+ T_a) (T_r^2+ T_a^2) + 0.427 + 277.76*(V)^{0.53}$ …… for $V >0.67$

$$F' = \frac{\frac{1}{U_L}}{\left[\frac{1}{U_L} + \frac{D_{ext}}{h_{ci} D_{int}} + \frac{D \cdot \ln(D_{ext}/D_{int})}{2 \cdot K_T}\right]}$$

$$F_R = 2.04 \cdot 10^6 \cdot \frac{\dot{m}_w}{U_L}\left[1 - \exp\left(-4.91 \cdot 10^{-7} \cdot \frac{U_L F'}{\dot{m}_w}\right)\right]$$

$$\eta = 2024 \cdot \dot{m} \cdot \frac{T_o - T_i}{I_b}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m} * C_p * (T_o - T_i)}{h_{ci} * \pi * D_{ext} * L}$$

$$T_m = \frac{T_i + T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m} * C_p}$$

Loss in piping $=4187 *m*(T_o-T_{i\ tank})$

Heat loss in tank (in t sec) $= 28*C_p*(T_{tank,x}-1-T*_{tank,x})$

(ii) **Oil as working fluid:** Performance parameters will be evaluated with the help of eq. 1B, 2, 3B, 4B, 5A, B, C, 6B and 7B.

$UL = 1.7*10^{-9}* (T_r+ T_a) (T_r^2+ T_a^2) + 25.746*(V)^{0.6}$…… for $V <0.67$

$UL = 1.7*10^{-9}* (T_r+ T_a) (T_r^2+ T_a^2) + 0.427 + 277.76*(V)^{0.53}$…… for $V >0.67$

$$F' = \frac{\frac{1}{U_L}}{\left[\frac{1}{U_L} + \frac{D_{ext}}{h_{ci} D_{int}} + \frac{D \cdot \ln(D_{ext}/D_{int})}{2 \cdot K_T}\right]}$$

$$F_R = 4.2 \cdot 10^6 \cdot \frac{\dot{m}_w}{U_L}\left[1 - \exp\left(-2.38 \cdot 10^{-7} \cdot \frac{U_L F'}{\dot{m}_w}\right)\right]$$

$$\eta = 996.62 \cdot \dot{m} \cdot \frac{T_o - T_i}{I_b}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m} * C_p * (T_o - T_i)}{h_{ci} * \pi * D_{ext} * L}$$

$$T_m = \frac{T_i + T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m} * C_p}$$

Loss in piping $= 2061 \cdot \dot{m} \cdot (T_o - T_{i\ tank})$

Heat loss in tank (in t sec) $= 27 \cdot C_p \cdot (T_{tank,x-1} - T'_{tank,x})$

Results: Calculate values of different parameters.

Notes

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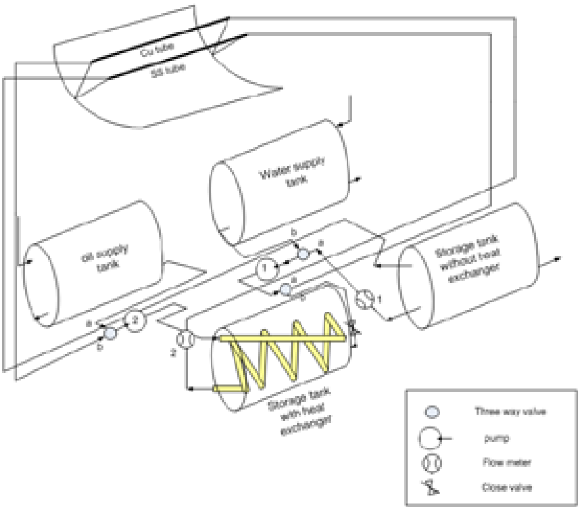
Insight Solar
Experiment No. 3

Objective: Determine the Performance (U_L, F_R, η) of the Parabolic Trough collector with varying flow rate of fluid with (i) Water and (ii) Oil as working fluid.

Experimental set-up: Set-up for this experiment will remain the same as discussed earlier in the starting of this manual. But for this experiment, we have to make tank and receiver tube selection.

(i) For this, we have to fix the V-clamp such that SS receiver tube will remain at focus of parabolic reflector. Valve-1 will be positioned at 'b' direction and valve-2 will be positioned at 'a' direction. So that water will flow from pump 1 to receiver tube 'SS'. Insulation thickness (of tank and pipe) will not be change during this experiment. Flow rate of water can be changed by changing voltage of pump A.

(ii) For this, we have to fix the V-clamp such that Copper receiver tube will remain at focus of parabolic reflector. Valve 1 will be position at 'a' direction. Valve 2 will be position at 'b' direction so that water will flow form pump 1 to heat exchanger tank. Close valve will cut the connection of this tank from water tank (tank no.1). Valve-3 will be positioned at 'b' direction. Insulation thickness (of tank and pipe) will not be change during this experiment. Flow rate of oil can be changed by changing voltage of pump B.



Observations:

Tank insulation thickness =

Pipe insulation thickness =

Set A: Water as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Set B: Oil as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Calculations: Mass flow rate, wind velocity, solar insolation and insulation thickness will remain the same during the calculation of different parameters. If any of weather parameter changes, do the calculation in parts in which all parameters remain constant all the time. Calculate all the parameters for each set by keeping mass flow rate constant in a set. Following equations will be used for evaluation of different parameters.

(i) Water as working fluid: Performance parameters will be evaluated with the help of eq. 1A, 2, 3A, 4A, 5A, B, C, 6A and 7A.

$UL = 1.7*10^{-9}* (T_r+ T_a) (T_r^2+ T_a^2) + 25.746*(V)^{0.6}$…… for V <0.67

$UL = 1.7*10^{-9}* (T_r+ T_a) (T_r^2+ T_a^2) + 0.427 + 277.76*(V)^{0.53}$ …… for V >0.67

$$F' = \frac{\frac{1}{U_L}}{\left[\frac{1}{U_L}+\frac{D_{ext}}{h_{ci}D_{int}}+\frac{D\cdot\ln\left(D_{ext}/D_{int}\right)}{2\cdot K_r}\right]}$$

$$F_R = 2.04\cdot 10^6\cdot\frac{\dot{m}_w}{U_L}\left[1-\exp\left(-4.91\cdot 10^{-7}\cdot\frac{U_L F'}{\dot{m}_w}\right)\right]$$

$$\eta = 2024\cdot\dot{m}\cdot\frac{T_o-T_i}{I_b}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m} * C_p * (T_o - T_i)}{h_{ci} * \pi * D_{ext} * L}$$

$$T_m = \frac{T_i+T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m}*C_p}$$

Loss in piping $=4187 *m*(T_o-T_{i\ tank})$

Heat loss in tank (in t sec) $= 28*C_p*(T_{tank,x}-1-T*_{tank,x})$

(ii) Oil as working fluid: Performance parameters will be evaluated with the help of eq. 1B, 2, 3B, 4B, 5A, B, C, 6B and 7B.

$UL = 1.7*10^{-9}* (T_r+ T_a) (T_r^2+ T_a^2) + 25.746*(V)^{0.6}$…… for V <0.67

$UL = 1.7*10^{-9}* (T_r+ T_a) (T_r^2+ T_a^2) + 0.427 + 277.76*(V)^{0.53}$…… for V >0.67

$$F' = \frac{\frac{1}{U_L}}{\left[\frac{1}{U_L}+\frac{D_{ext}}{h_{ci}D_{int}}+\frac{D\cdot\ln\left(D_{ext}/D_{int}\right)}{2\cdot K_r}\right]}$$

$$F_R = 4.2\cdot 10^6\cdot\frac{\dot{m}_w}{U_L}\left[1-\exp\left(-2.38\cdot 10^{-7}\cdot\frac{U_L F'}{\dot{m}_w}\right)\right]$$

$$\eta = 996.62\cdot\dot{m}\cdot\frac{T_o-T_i}{I_b}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m}\cdot C_p\cdot(T_o - T_i)}{h_{ci}\cdot\pi\cdot D_{ext}\cdot L}$$

$$T_m = \frac{T_i+T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m}\cdot C_p}$$

Loss in piping $=2061\cdot\dot{m}\cdot(T_o - T_{i\ tank})$

Heat loss in tank (in t sec) $= 27\cdot C_p\cdot(T_{tank,x-1} - T'_{tank,x})$

Results: Calculate different parameters values.

Notes

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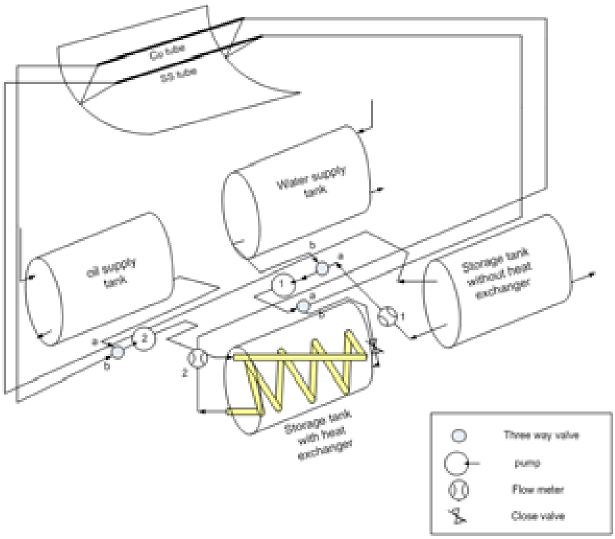
Insight Solar
Experiment No. 4

Objective: Determine the Performance (U_L, F_R, η) of the Parabolic Trough collector with changing insulation thickness with (i) water and (ii) oil as working fluid

Experimental set-up: Set-up for this experiment will remain the same as discussed earlier in the starting of this manual. But for this experiment, we have to make tank and receiver tube selection.

(i) For this, we have to fix the V-clamp such that SS receiver tube will remain at focus of parabolic reflector. Valve-1 will be positioned at 'b' direction and valve-2 will be positioned at 'a' direction. So that water will flow from pump 1 to receiver tube 'SS'. Insulation thickness (of tank and pipe) will not be change during this experiment. Flow rate of water can be changed by changing voltage of pump A.

(ii) For this, we have to fix the V-clamp such that Copper receiver tube will remain at focus of parabolic reflector. Valve 1 will be position at 'a' direction. Valve 2 will be position at 'b' direction so that water will flow form pump 1 to heat exchanger tank. Close valve will cut the connection of this tank from water tank (tank no.1). Valve-3 will be positioned at 'b' direction. Insulation thickness (of tank and pipe) will not be change during this experiment. Flow rate of oil can be changed by changing voltage of pump B.



Observations:

(i). For insulation of some fix thickness

Tank insulation thickness =

Pipe insulation thickness =

Set A: Water as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Set B: Oil as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

(ii). For insulation of other thickness

Tank insulation thickness =

Pipe insulation thickness =

Set A: Water as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Set B: Oil as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Calculations: Mass flow rate, wind velocity, solar insolation and insulation thickness will remain the same during the calculation of different parameters. If any of weather parameter changes, do the calculation in parts in which all parameters remain constant all the time. Calculate all parameters for each set by keeping same insulation thickness in a set. Following equations will be used for evaluation of different parameters.

(i) **Water as working fluid:** Performance parameters will be evaluated with the help of eq. 1A, 2, 3A, 4A, 5A, B, C, 6A and 7A.

UL = $1.7*10^{-9}*(T_r+T_a)(T_r^2+T_a^2)+25.746*(V)^{0.6}$...... for V <0.67

UL = $1.7*10^{-9}*(T_r+T_a)(T_r^2+T_a^2)+0.427+277.76*(V)^{0.53}$ ...... for V >0.67

$$F^{/}=\frac{\frac{1}{U_L}}{\left[\frac{1}{U_L}+\frac{D_{ext}}{h_{ci}D_{int}}+\frac{D\cdot\ln\left[D_{ext}/D_{int}\right]}{2\cdot K_r}\right]}$$

$$F_R=2.04\cdot10^6\cdot\frac{\dot{m}_w}{U_L}\left[1-\exp\left(-4.91\cdot10^{-7}\cdot\frac{U_LF^{/}}{\dot{m}_w}\right)\right]$$

$$\eta=2024\cdot\dot{m}\cdot\frac{T_o-T_i}{I_b}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m}*C_p*(T_o - T_i)}{h_{ci}*\pi*D_{ext}*L}$$

$$T_m = \frac{T_i+T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m}*C_p}$$

Loss in piping =4187 $*m*(T_o-T_{i\ tank})$

Heat loss in tank (in t sec) = 28$*C_p*$ ($T_{tank,x}$-1-$T*_{tank,x}$)

(ii) **Oil as working fluid:** Performance parameters will be evaluated with the help of eq. 1B, 2, 3B, 4B, 5A, B, C, 6B and 7B.

UL = $1.7*10^{-9}*(T_r+T_a)(T_r^2+T_a^2)+25.746*(V)^{0.6}$...... for V <0.67

UL = $1.7*10^{-9}*(T_r+T_a)(T_r^2+T_a^2)+0.427+277.76*(V)^{0.53}$...... for V >0.67

$$F^{/}=\frac{\frac{1}{U_L}}{\left[\frac{1}{U_L}+\frac{D_{ext}}{h_{ci}D_{int}}+\frac{D\cdot\ln\left[D_{ext}/D_{int}\right]}{2\cdot K_r}\right]}$$

$$F_R=4.2\cdot10^6\cdot\frac{\dot{m}_w}{U_L}\left[1-\exp\left(-2.38\cdot10^{-7}\cdot\frac{U_LF^{/}}{\dot{m}_w}\right)\right]$$

$$\eta=996.62\cdot\dot{m}\cdot\frac{T_o-T_i}{I_b}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m}\cdot C_p\cdot(T_o - T_i)}{h_{ci}\cdot\pi\cdot D_{ext}\cdot L}$$

$$T_m = \frac{T_i+T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m}\cdot C_p}$$

Loss in piping $=2061\cdot\dot{m}\cdot(T_o-T_{i\ tank})$

Heat loss in tank (in t sec) $=27\cdot C_p\cdot(T_{tank,x-1}-T'_{tank,x})$

Results: Calculate values of different parameters.

Notes

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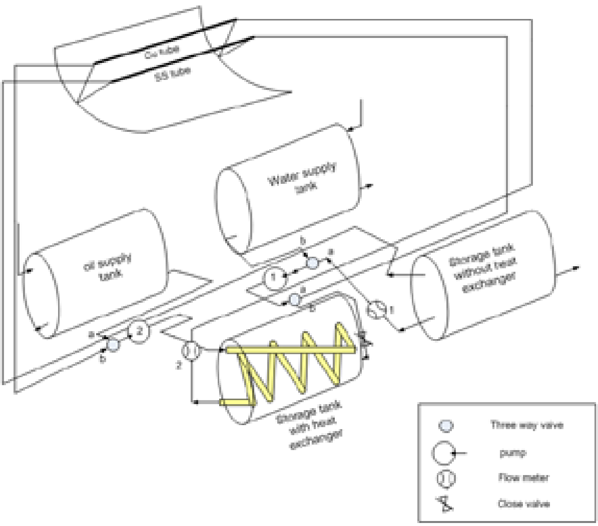
Insight Solar
Experiment No. 5

Objective: Determine the Performance (U_L, F_R, η) of the Parabolic Trough collector with different inlet water temperature with (i) water and (ii) oil as working fluid.

Experimental set-up: Set-up for this experiment will remain the same as discussed earlier in the starting of this manual. But for this experiment, we have to make tank and receiver tube selection.

(i) For this, we have to fix the V-clamp such that SS receiver tube will remain at focus of parabolic reflector. Valve-1 will be positioned at ‘b’ direction and valve-2 will be positioned at ‘a’ direction. So that water will flow from pump 1 to receiver tube 'SS'. Insulation thickness (of tank and pipe) will not be change during this experiment. Flow rate of water can be changed by changing voltage of pump A.

(ii) For this, we have to fix the V-clamp such that Copper receiver tube will remain at focus of parabolic reflector. Valve 1 will be position at 'a' direction. Valve 2 will be position at 'b' direction so that water will flow form pump 1 to heat exchanger tank. Close valve will cut the connection of this tank from water tank (tank no.1). Valve-3 will be positioned at ‘b’ direction. Insulation thickness (of tank and pipe) will not be change during this experiment. Flow rate of oil can be changed by changing voltage of pump B.



Observations:

(i). For inlet water temperature =

Tank insulation thickness =

Pipe insulation thickness =

Set A: Water as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\ tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Set B: Oil as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\ tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

(ii). For inlet water temperature

Tank insulation thickness =

Pipe insulation thickness =

Set A: Water as working fluid

S. no.	Time (sec)	Solar insolation (W/m^2)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Set B: Oil as working fluid

S. no.	Time (sec)	Solar insolation (W/m^2)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Calculations: Mass flow rate, wind velocity, solar insolation and insulation thickness will remain the same during the calculation of different parameters. If any of weather parameter changes, do the calculation in parts in which all parameters remain constant all the time. Calculate all parameters for each set by keeping particular inlet water temperature in a set. Following equations will be used for evaluation of different parameters.

(i) **Water as working fluid:** Performance parameters will be evaluated with the help of eq. 1A, 2, 3A, 4A, 5A, B, C, 6A and 7A.

$UL = 1.7*10^{-9}* (T_r + T_a)(T_r^2 + T_a^2) + 25.746*(V)^{0.6}$...... for V <0.67

$UL = 1.7*10^{-9}* (T_r + T_a)(T_r^2 + T_a^2) + 0.427 + 277.76*(V)^{0.53}$ ...... for V >0.67

$$F' = \frac{\frac{1}{U_L}}{\left[\frac{1}{U_L} + \frac{D_{ext}}{h_{ci} D_{int}} + \frac{D \cdot \ln\left(D_{ext}/D_{int}\right)}{2 \cdot K_r}\right]}$$

$$F_R = 2.04 \cdot 10^6 \cdot \frac{\dot{m}_w}{U_L}\left[1 - \exp\left(-4.91 \cdot 10^{-7} \cdot \frac{U_L F'}{\dot{m}_w}\right)\right]$$

$$\eta = 2024 \cdot \dot{m} \cdot \frac{T_o - T_i}{I_b}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m} * C_p * (T_o - T_i)}{h_{ci} * \pi * D_{ext} * L}$$

$$T_m = \frac{T_i + T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m} * C_p}$$

Loss in piping =4187 *m*(T_o-$T_{i\ tank}$)

Heat loss in tank (in t sec) = 28*C_p* ($T_{tank,x}$-1-T*$_{tank,x}$)

(ii) **Oil as working fluid:** Performance parameters will be evaluated with the help of eq. 1B, 2, 3B, 4B, 5A, B, C, 6B and 7B.

$UL = 1.7*10^{-9}* (T_r + T_a)(T_r^2 + T_a^2) + 25.746*(V)^{0.6}$...... for V <0.67

$UL = 1.7*10^{-9}* (T_r + T_a)(T_r^2 + T_a^2) + 0.427 + 277.76*(V)^{0.53}$...... for V >0.67

$$F' = \frac{\frac{1}{U_L}}{\left[\frac{1}{U_L} + \frac{D_{ext}}{h_{ci} D_{int}} + \frac{D \cdot \ln\left(D_{ext}/D_{int}\right)}{2 \cdot K_r}\right]}$$

$$F_R = 4.2 \cdot 10^6 \cdot \frac{\dot{m}_w}{U_L}\left[1 - \exp\left(-2.38 \cdot 10^{-7} \cdot \frac{U_L F'}{\dot{m}_w}\right)\right]$$

$$\eta = 996.62 \cdot \dot{m} \cdot \frac{T_o - T_i}{I_b}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m} * C_p * (T_o - T_i)}{h_{ci} * \pi * D_{ext} * L}$$

$$T_m = \frac{T_i + T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m} * C_p}$$

Loss in piping $= 2061 \cdot \dot{m} \cdot (T_o - T_{i\ tank})$

Heat loss in tank (in t sec) $= 27 \cdot C_p \cdot (T_{tank,x-1} - T^*_{tank,x})$

Results: Calculate values of different parameters.

Notes

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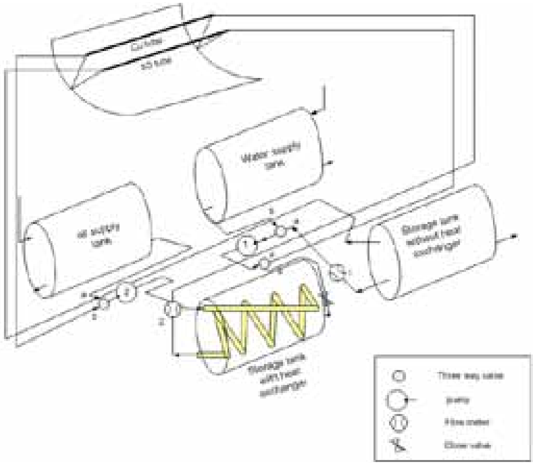
Insight Solar
Experiment No. 6

Objective: Determine the Performance (UL, FR, η) of the Parabolic Trough collector with different wind speed with (i) water and (ii) oil as working fluid.

Experimental set-up: Set-up for this experiment will remain the same as discussed earlier in the starting of this manual. But for this experiment, we have to make tank and receiver tube selection.

(i) For this, we have to fix the V-clamp such that SS receiver tube will remain at focus of parabolic reflector. Valve-1 will be positioned at 'b' direction and valve-2 will be positioned at 'a' direction. So that water will flow from pump 1 to receiver tube 'SS'. Insulation thickness (of tank and pipe) will not be change during this experiment. Wind speed can't be changed by user but this experiment can be performed at different time of a day or different day to see the effect of performance in different wind speed.

(ii) For this, we have to fix the V-clamp such that Copper receiver tube will remain at focus of parabolic reflector. Valve 1 will be position at 'a' direction. Valve 2 will be position at 'b' direction so that water will flow form pump 1 to heat exchanger tank. Close valve will cut the connection of this tank from water tank (tank no.1). Valve-3 will be positioned at 'b' direction. Insulation thickness (of tank and pipe) will not be change during this experiment. Wind speed can't be changed by user but this experiment can be performed at different time of a day or different day to see the change in wind speed.



Observations:

(i). For wind speed =

Tank insulation thickness =

Pipe insulation thickness =

Set A: Water as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Set B: Oil as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

(ii). For wind speed =

Tank insulation thickness =

Pipe insulation thickness =

Set A: Water as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\ tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Set B: Oil as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\ tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Calculations: Mass flow rate, wind velocity, solar insolation and insulation thickness will remain the same during the calculation of different parameters. If any of weather parameter changes, do the calculation in parts in which all parameters remain constant all the time. Calculate all parameters for each set by keeping constant wind speed for a set. Following equations will be used for evaluation of different parameters.

(i) **Water as working fluid:** Performance parameters will be evaluated with the help of eq. 1A, 2, 3A, 4A, 5A, B, C, 6A and 7A.

UL = 1.7*10^{-9}* (T_r+ T_a) (T_r^2+ T_a^2) + 25.746*$(V)^{0.6}$…… for V <0.67

UL = 1.7*10^{-9}* (T_r+ T_a) (T_r^2+ T_a^2) + 0.427 + 277.76*$(V)^{0.53}$ …… for V >0.67

$$F' = \frac{\frac{1}{U_L}}{\left[\frac{1}{U_L}+\frac{D_{ext}}{h_{ci}D_{int}}+\frac{D\cdot\ln\left(D_{ext}/D_{int}\right)}{2\cdot K_r}\right]}$$

$$F_R = 2.04\cdot 10^{6}\cdot\frac{\dot{m}_w}{U_L}\left[1-\exp\left(-4.91\cdot 10^{-7}\cdot\frac{U_L F'}{\dot{m}_w}\right)\right]$$

$$\eta = 2024\cdot\dot{m}\cdot\frac{T_o-T_i}{I_s}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m}*C_p*(T_o - T_i)}{h_{ci}*\pi*D_{ext}*L}$$

$$T_m = \frac{T_i+T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m}*C_p}$$

Loss in piping =4187 *m*(T_o-$T_{i\ tank}$)

Heat loss in tank (in t sec) = 28*C_p* ($T_{tank,x}$-1-T*$_{tank,x}$)

(ii) **Oil as working fluid:** Performance parameters will be evaluated with the help of eq. 1B, 2, 3B, 4B, 5A, B, C, 6B and 7B.

UL = 1.7*10^{-9}* (T_r+ T_a) (T_r^2+ T_a^2) + 25.746*$(V)^{0.6}$…… for V <0.67

UL = 1.7*10^{-9}* (T_r+ T_a) (T_r^2+ T_a^2) + 0.427 + 277.76*$(V)^{0.53}$…… for V >0.67

$$F' = \frac{\frac{1}{U_L}}{\left[\frac{1}{U_L}+\frac{D_{ext}}{h_{ci}D_{int}}+\frac{D\cdot\ln\left(D_{ext}/D_{int}\right)}{2\cdot K_r}\right]}$$

$$F_R = 4.2\cdot 10^{6}\cdot\frac{\dot{m}_w}{U_L}\left[1-\exp\left(-2.38\cdot 10^{-7}\cdot\frac{U_L F'}{\dot{m}_w}\right)\right]$$

$$\eta = 996.62\cdot\dot{m}\cdot\frac{T_o-T_i}{I_b}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m}*C_p*(T_o - T_i)}{h_{ci}*\pi*D_{ext}*L}$$

$$T_m = \frac{T_i+T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m}*C_p}$$

Loss in piping $=2061\cdot\dot{m}\cdot(T_o - T_{i\ tank})$

Heat loss in tank (in t sec) $= 27\cdot C_p\cdot(T_{tank,x-1} - T'_{tank,x})$

Results: Calculate values of different parameters.

Notes

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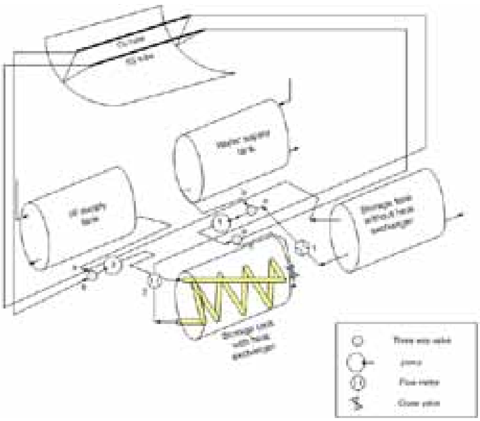
Insight Solar
Experiment No. 7

Objective: Determine the Performance (UL, FR, η) of the Parabolic Trough collector with different ambient temperature with (i) water and (ii) oil as working fluid.

Experimental set-up: Set-up for this experiment will remain the same as discussed earlier in the starting of this manual. But for this experiment, we have to make tank and receiver tube selection.

(i) For this, we have to fix the V-clamp such that SS receiver tube will remain at focus of parabolic reflector. Valve-1 will be positioned at 'b' direction and valve-2 will be positioned at 'a' direction. So that water will flow from pump 1 to receiver tube 'SS'. Insulation thickness (of tank and pipe) will not be change during this experiment. Ambient temperature can't be changed by user but this experiment can be performed at different time of a day or different day to see the impact on performance at different ambient temperature.

(ii) For this, we have to fix the V-clamp such that Copper receiver tube will remain at focus of parabolic reflector. Valve 1 will be position at 'a' direction. Valve 2 will be position at 'b' direction so that water will flow form pump 1 to heat exchanger tank. Close valve will cut the connection of this tank from water tank (tank no.1). Valve-3 will be positioned at 'b' direction. Insulation thickness (of tank and pipe) will not be change during this experiment. Ambient temperature can't be changed by user but this experiment can be performed at different time of a day or different day to see the change in ambient temperature.



Observations:

(i). For ambient temperature =

Tank insulation thickness =

Pipe insulation thickness =

Set A: Water as working fluid

S. no.	Time (sec)	Solar insolation (W/m^2)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Set B: Oil as working fluid

S. no.	Time (sec)	Solar insolation (W/m^2)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

(ii). For ambient temperature =

Tank insulation thickness =

Pipe insulation thickness =

Set A: Water as working fluid

S. no.	Time (sec)	Solar insolation (W/m^2)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Set B: Oil as working fluid

S. no.	Time (sec)	Solar insolation (W/m^2)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Calculations: Mass flow rate, wind velocity, solar insolation and insulation thickness will remain the same during the calculation of different parameters. If any of weather parameter changes, do the calculation in parts in which all parameters remain constant all the time. Calculate all parameters for each set for constant ambient temperature. Following equations will be used for evaluation of different parameters.

(i) **Water as working fluid:** Performance parameters will be evaluated with the help of eq. 1A, 2, 3A, 4A, 5A, B, C, 6A and 7A.

$UL = 1.7*10^{-9}*(T_r + T_a)(T_r^2 + T_a^2) + 25.746*(V)^{0.6}$ …… for V <0.67

$UL = 1.7*10^{-9}*(T_r + T_a)(T_r^2 + T_a^2) + 0.427 + 277.76*(V)^{0.53}$ …… for V >0.67

$$F' = \frac{\frac{1}{U_L}}{\left[\frac{1}{U_L} + \frac{D_{ext}}{h_{ci} D_{int}} + \frac{D \cdot \ln\left(D_{ext}/D_{int}\right)}{2 \cdot K_r}\right]}$$

$$F_R = 2.04 \cdot 10^6 \cdot \frac{\dot{m}_w}{U_L}\left[1 - \exp\left(-4.91 \cdot 10^{-7} \cdot \frac{U_L F'}{\dot{m}_w}\right)\right]$$

$$\eta = 2024 \cdot \dot{m} \cdot \frac{T_o - T_i}{I_b}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m} * C_p * (T_o - T_i)}{h_{ci} * \pi * D_{ext} * L}$$

$$T_m = \frac{T_i + T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m} * C_p}$$

Loss in piping $= 4187 * m * (T_o - T_{i\ tank})$

Heat loss in tank (in t sec) $= 28 * C_p * (T_{tank,x} - 1 - T^*_{tank,x})$

(ii) **Oil as working fluid:** Performance parameters will be evaluated with the help of eq. 1B, 2, 3B, 4B, 5A, B, C, 6B and 7B.

$UL = 1.7*10^{-9}*(T_r + T_a)(T_r^2 + T_a^2) + 25.746*(V)^{0.6}$ …… for V <0.67

$UL = 1.7*10^{-9}*(T_r + T_a)(T_r^2 + T_a^2) + 0.427 + 277.76*(V)^{0.53}$ …… for V >0.67

$$F' = \frac{\frac{1}{U_L}}{\left[\frac{1}{U_L} + \frac{D_{ext}}{h_{ci} D_{int}} + \frac{D \cdot \ln\left(D_{ext}/D_{int}\right)}{2 \cdot K_r}\right]}$$

$$F_R = 4.2 \cdot 10^6 \cdot \frac{\dot{m}_w}{U_L}\left[1 - \exp\left(-2.38 \cdot 10^{-7} \cdot \frac{U_L F'}{\dot{m}_w}\right)\right]$$

$$\eta = 996.62 \cdot \dot{m} \cdot \frac{T_o - T_i}{I_b}$$

Theoretical values of different temperature values

$$T_r = T_m + \frac{\dot{m} \cdot C_p \cdot (T_o - T_i)}{h_{ci} \cdot \pi \cdot D_{ext} \cdot L}$$

$$T_m = \frac{T_i + T_o}{2}$$

$$T_o = T_i + \frac{Q_u}{\dot{m} \cdot C_p}$$

Loss in piping $= 2061 \cdot \dot{m} \cdot (T_o - T_{i\ tank})$

Heat loss in tank (in t sec) $= 27 \cdot C_p \cdot (T_{tank,x-1} - T'_{tank,x})$

Results: Calculate values of different parameters.

Notes

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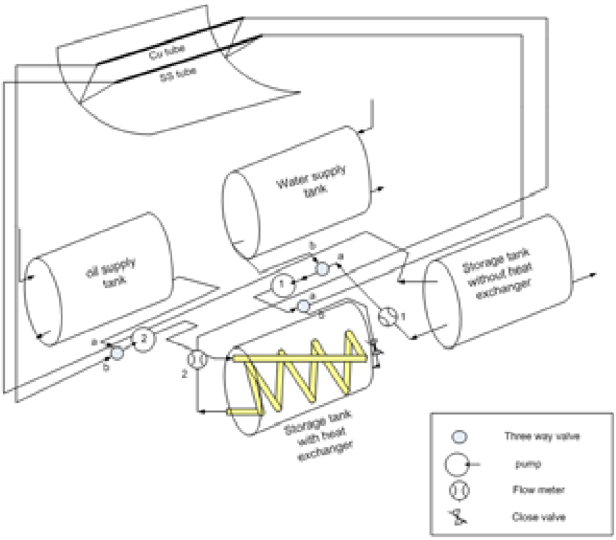
Insight Solar
Experiment No. 8

Objective: Find an optimum flow rate of fluid for getting minimum heat losses (or maximum heat gain) for different insulation thickness with (i) water and (ii) oil as working fluid.

Experimental set-up: Set-up for this experiment will remain the same as discussed earlier in the starting of this manual. But for this experiment, we have to make tank and receiver tube selection.

(i) For this, we have to fix the V-clamp such that SS receiver tube will remain at focus of parabolic reflector. Valve-1 will be positioned at 'b' direction and valve-2 will be positioned at 'a' direction. So that water will flow from pump 1 to receiver tube 'SS'. Insulation thickness (of tank and pipe) will not be change during this experiment. Tank insulation thickness will not be changed for one set of observation.

(ii) For this, we have to fix the V-clamp such that Copper receiver tube will remain at focus of parabolic reflector. Valve 1 will be position at 'a' direction. Valve 2 will be position at 'b' direction so that water will flow form pump 1 to heat exchanger tank. Close valve will cut the connection of this tank from water tank (tank no.1). Valve-3 will be positioned at 'b' direction. Tank insulation thickness will not be changed for one set of observation.



Observations:

(i). For insulation thickness=

Tank insulation thickness =

Pipe insulation thickness =

Set A: Water as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Set B: Oil as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\,tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

(ii). For insulation thickness =

Tank insulation thickness =

Pipe insulation thickness =

Set A: Water as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\ tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Set B: Oil as working fluid

S. no.	Time (sec)	Solar insolation (W/m²)	Wind velocity (m/sec)	T_a	T_r	T_i	T_o	$T_{i\ tank}$	T_{tank}	Mass flow rate (Kg/sec)
Set 1										
1										
2										
3										
Set 2										
1										
2										
3										

Calculations: Mass flow rate, wind velocity, solar insolation and insulation thickness will remain the same during the calculation of different parameters. If any of weather parameter changes, do the calculation in parts in which all parameters remain constant all the time. Following equations will be used for evaluation of different parameters.

(i) Water as working fluid:

Heat gain by fluid in receiver tube = $\dot{m}$*$C_{p(w)}$*(T_o – T_i)

Loss in piping =$4187 * \dot{m} * (T_o - T_{i\ tank})$

Net heat gain = $\dot{m}$*$C_{p(w)}$*(T_o – T_i) - $4187 * \dot{m} * (T_o - T_{i\ tank})$

(ii) Oil as working fluid:

Heat gain by fluid in receiver tube = $\dot{m}$*$C_{p(oil)}$*(T_o – T_i)

Loss in piping =$2061 * \dot{m} * (T_o - T_{i\ tank})$

Net heat gain = $\dot{m}$*$C_{p(oil)}$*(T_o – T_i) - $2061 * \dot{m} * (T_o - T_{i\ tank})$

Notes

Insight Solar
Nomenclatures:

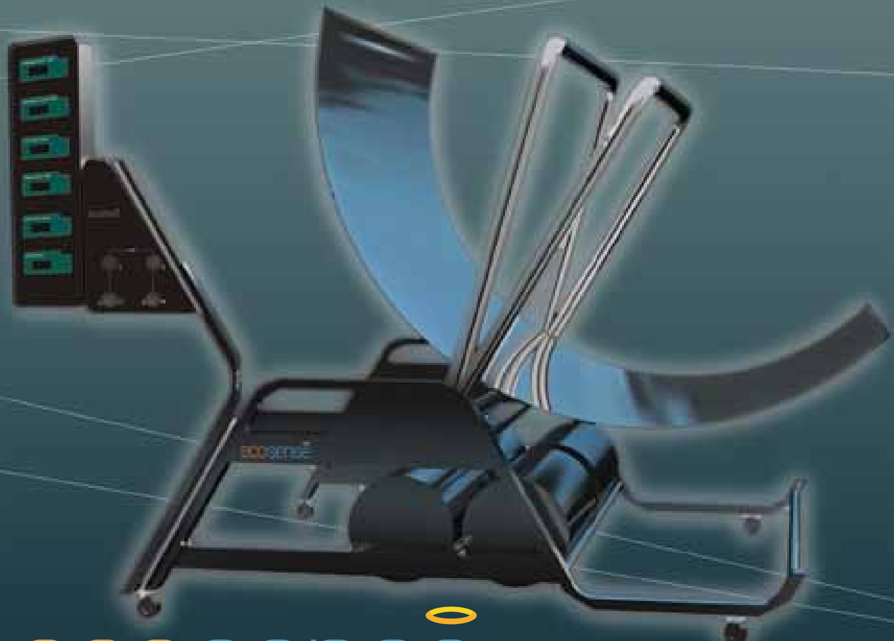
h_w	Convective heat transfer coefficient between tube and atmosphere
h_r	Radiative Heat transfer coefficient of radiation
T_r	Receiver tube temp.
T_a	Ambient temp.
K_a	Thermal conductivity of air (0.026W/m/K)
V	wind velocity
Nu_a	Nusselt no. of air
Re_a	Reynolds no. of air
υ_a	Kinematic viscosity of air (1.6*10-5m2/s)
ε	Emissivity of receiver tube material (black nickel = 0.66)
σ	Stefan-Boltzman constant (5.67×10−8 W m−2 K−4)
U_L	overall heat transfer coefficient (can be calculated by eq.1)
D_{ext}	External diameter of receiver tube (0.025m)
D_{int}	Internal diameter of receiver tube (0.023m)
h_{ci}	Convective heat transfer coefficient between receiver tube and water
K_r	Thermal conductivity of receiver tube material (copper and stainless steel in our system)
L	Length of receiver tube (1.2m)
Re_w	Reynolds no. of water
Pr_w	Prandtl no. of water
v_w	Water velocity
υ_w	Kinematic viscosity of water (16.68*10-6m2/s)
V_w	Water flow velocity
ρ_w	Density of water
μ_w	Dynamic viscosity of water
$Cp_{(w)}$	Specific heat of water (4.187KJ/Kg/0K)
K_w	Thermal conductivity of water (0.6 W/m/0K)
Re_{oil}	Reynolds no. of oil
Pr_{oil}	Prandtl no. of oil
V_{oil}	Oil velocity
υ_{oil}	Kinematic viscosity of oil (3.0*10-5m2/s)
ρ_{oil}	Density of oil (900 Kg/m3)
μ_{oil}	Dynamic viscosity of oil (0.027Ns/m2)
$Cp_{(oil)}$	Specific heat of oil (2061J/Kg/0K))
K_{oil}	Thermal conductivity of oil (0.165 W/m/0K)
A_{int}	Internal cross sectional area of receiver tube (3.14*(0.0125)^2= 0.00049m^2)
m	Flow rate of fluid (in Kg/sec)
C_p	Specific heat of fluid (water or oil)
A_a	Aperture area of parabolic reflector (1.695*1.22 = 2.068 m2)
T_0	Receiver tube outlet temp.
T_i	Receiver tube inlet temp.
T_r	Receiver tube temp
T_i	Tube inlet temp.
T_o	Tube outlet temp.
$T_{tank,x}$	Instantaneous reading of tank water temperature
$T_{tank,x}{}^*$	Supposed to be previous tank water temperature before mixing of hot incoming water
$T_{tank,x}$	Previous reading of tank water temperature
t	Time (in sec) between current reading an previous reading

Notes

Notes

About Ecosense

Ecosense provides world class training solutions in renewable energy and clean environment. As a group of engineers, researchers and designers, Ecosense has developed cutting edge products to create skilled human resource for renewable energy sector. Founded by group of IIT graduates, Ecosense is dedicated towards building mechanisms that will develop highly skilled workforce that enables the development of clean environment for human race.



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