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Thermal Analysis of Flat Plate Collector in Haryana Climate Region

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Abstract

The present work is based on the sun rays received in murthal region located in the sunny belt of northern India. To ensure choice sources of energy that are clean, reliable steady and sustainable, solar power being rising major need in now a days among the technology of expensive fuels which is used to boil water for industrial and domestic cause . A set up solar water heaters with FPC's (flat plate collector) of 200 liter had been placed in roof top open sky space made available. The data of 12 months have been accumulated and performance of solar flat plate collector analyzed in this paper. It is located that the incoming hot water is about 30˚C higher than the room temperature for the duration of day time all through wintry weather months. This is about 25˚C in afternoon hours

Key Words: Flat plate Collectors, Thermal Analysis, Concentric-Tube, Flat Plate

Nomenclature

m= Mass flow rate of the heat transfer fluid, kg/s

Cp= specific heat of water i.e. 4186kJ/Kcal.

I= solar irradiation

$\Delta T = T_o - T_i$

A = Aperture area of collector

t = Time in sec.

T_i= Temperature of heat transferred fluid entering the collector, ^{o}C

T_o=Temperature of heat transferred fluid leaving collector at specified time t, ^{o}C

F_R = solar collector heat removal factor, dimensionless.
U_L = solar collector overall heat loss coefficient, W/m^2
C = optical efficiency.
$(\tau\alpha)_e$ = represent property of cover-absorber system taking in to account absorptance of the absorber, transmittance of the cover and multiple reflection between the two, dimensionless.

INTRODUCTION

Solar energy is a form of power harnessed from the power and warmness of the sun's rays[1]. It is renewable, and therefore a "green" supply of energy. Greatest amount of solar power is accessible in two large bands encircling the earth between 15˚ and 35 ˚ latitude north and south. The subsequent pleasant function is the equatorial belt between 15˚N and 15˚S latitude[2-3] . Most of the developing countries, being located in these regions, are in a favorable position in admire of solar energy. Average day by day sun irradiation at flat surface is round 5.0 to 7.5 kWh/m2. [4]

Solar energy is a really limitless and inexhaustible useful resource (unlike electricity produced from expendable fossil fuels) Most of the solar energy uses are involved with trapping daylight as photovoltaic[5]. Because of the low power density of sunlight, the higher the temperature wanted the extra difficult and costly the machine will be Depending on the vary of temperature use, solar thermal makes use of are divided into the three huge categories:

1. Low temperature applications (below 100˚C), such as solar drying, hot water , cooking .
2. Medium temperature purposes (below 150˚C), such as refrigeration, industrial heat, etc.
3. High temperature (above 150˚C) applications, such as electricity generation ,power plants.[6]

Solar water heater are the collection device, the precept usually accompanied is to expose a dark surface to solar radiation so that the radiation is absorbed[7]. A part of the absorbed radiation is then transferred to a fluid like air or water. When no optical attention is done, the system in which the series is achieved is called a flat-plate collector. flat-plate collector is the most important kind of solar collector because it is simple in design, has no moving components and requires little maintenance. It can be used for a variety of purposes in which temperatures ranging from 40˚C to about 100˚C are required.[8]

Solar water heaters are used all over the world. Particular in sunny countries the place solar shine is abundant. The warm water is used for household cause and in restaurants, hospitals, dormitories, etc. for cleaning dishes and different works. These heaters are also used for preheating water for industrial purpose. Most of the water heaters are of Chinese beginning and of Indian origin. As the water heaters are installed for 12 months on a building so facts have been accumulated and analyzed. However, the statistics gathered in the wintry weather time contains some beneficial data.

Solar energy collectors are the key component of the so SWHSs (solar water heating systems), and evaluate its thermal performance is vital. A range of research on the performance of FPCs were performed underneath regular nation stipulations and nearly -dynamic take a look at in the following standard EN 12975-2 [1] and ASHRAE 93-86 [9-13]

MATERIAL AND METHOD

In this experiment we determination of gross area (before testing), after it we perform solar flat plate collector outdoor no-flow exposure test, then static pressure leakage test and finally solar flat plate collector thermal efficiency test

DETERMINATION OF GROSS AREA (BEFORE TESTING)

Measuring Equipments Used:

Sr. No.	Equipment	Model No. or Code No.	Valid Calibration
1.	Measuring Tape	Ordinary	Yes
2.	Steel Scale	Length – 12 Inch.	Yes

from the above test ,outcomes is

i) Length of Collector (mm) = i) = 1858, ii) = 1860 mm, iii) = 1861 mm

Average (mm) = **1860** mm

ii) Breadth of Collector (mm) = i) = 1249 mm, ii) = 1250 mm, iii) = 1252 mm

Average (mm) = **1250** mm

Gross Area of Collector (m^2) = **2.33 m^2**

OUTDOOR NO-FLOW EXPOSURE TEST

Measuring Equipments Used:

Sr. No.	Equipment	Model No. or Code No.	Valid Calibration
1.	Pyranometer	127099	Yes
2.	Data Logger	WDL-1002	Yes
3.	RTD-PT-100 for Ambient Temp.	DWT-8102	Yes

Preparation: Clean the glazing of the collector periodically every week.

EXPOSURE TEST

i) Collector is installed facing due south = Yes

ii) Slope of collector from Horizontal is equal to latitude/30° = Yes

iii) Is lower header closed at both ends, Upper header open at both ends and Without water = Yes

STATIC PRESSURE LEAKAGE TEST

Measuring Equipments Used:

Sr. No.	Equipment	Model No. or Code No.	Valid Calibration
1.	Pressure Gauge	Hydraulic Pressure Gauge	Yes
2.	Thermometer	FLUKE-51-II	Yes

Preparation: Ensure that all air is removed from the collector and collector is filled with water

Precautions: i) check whether the gauge is working or not and air hose is open
ii) Protect yourself (stand behind wall/obstructions) from likely hood of bursting the tube.

Observations: i) collector is filled up with tap water (This should be done slowly) = Yes
ii) All air is removed from the collector = Yes
iii) Applied hydraulic pressure of 5 Kg/cm² (or, double the designed working pressure)
iv) Pressure after 10 minutes = same
V) Temperature of water filled = 42°C

SOLAR FLAT PLATE COLLECTOR THERMAL EFFICIENCY TEST

Measuring Equipments Used:

Sr. No.	Equipment	Model No. or Code No.	Valid Calibration
1.	Pyranometer	127099	Yes
2.	Data Logger	WDL-1002	Yes
3.	RTD PT-1000, Inlet Temp.	TS-4	Yes
4.	RTD PT-1000, outlet Temp.	TS-4	Yes
5.	RTD PT-1000, Ambient Temp.	DWT-8102	Yes
6.	PID controller	Simaden	Yes
7.	Anemometer with wind speed	111085 & Model no-DWA-8600M	Yes
8.	Electromagnetic Flow Meter	Flow meter 2011-12/EMFM.15443 Model no-EUMAG-15-T-S-1-L	Yes

Testing procedure:

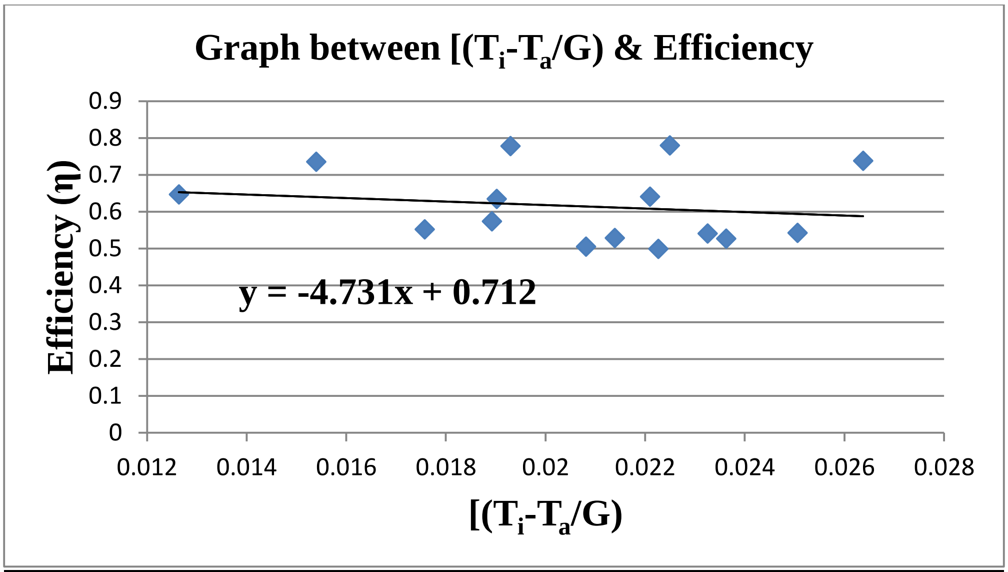
1. Place the collector to be tested on test bed at 30° Inclined, south- Facing. Solar Irradiation must be greater than 600 W/m².
2. Test the collector at five different temperatures. i.e. Ambient temp, Ambient temp + 10°C, Ambient temp + 20°C, Ambient temp + 30°C, Ambient temp + 40°C.
3. Start the motor.
4. Let the water flow in the constant pressure tank. Till the water overflow from the constant pressure tank in the storage water tank.
5. For ambient temp. Set the Electromagnetic flow meter as per the flow rate. Mass flow rate is calculated as =Aperture area x 1.2 lpm.
6. Water will flow from inlet to outlet of the collector and finally to the storage tank.
7. Note down the reading of outlet temperature, inlet temperature, ambient temperature, solar Irradiation by the data logger.
8. Hence calculate the efficiency of collector by using formula—
   $\eta = (m \times Cp \times \Delta T) / (I \times A \times t)$.
   m= Mass flow rate of the heat transfer fluid, kg/s
   Cp= specific heat of water i.e. 4186kJ/Kcal.
   I= solar irradiation

$\Delta T = T_o - T_i$
A = Aperture area of collector
t = Time in sec.
T_i= Temperature of heat transferred fluid entering the collector, °C
T_o=Temperature of heat transferred fluid leaving collector at specified time t, °C

9. Plot the graph between T_i -Ta/I & η.
10. Find the strait line of equation i.e. y = m x +c , where m= $F_R U_L$ I.e. losses & C= F_R $(\tau\alpha)_e$
    F_R = solar collector heat removal factor, dimensionless.
    U_L = solar collector overall heat loss coefficient, W/m^2
    C = optical efficiency.
    $(\tau\alpha)_e$ = represent property of cover-absorber system taking in to account absorptance of the absorber, transmittance of the cover and multiple reflection between the two, dimensionless.
11. Test the collector on second day of testing.
    a. Step I and 2 remains same while testing at ambient temperature.
    b. Set the temperature controller at 50°C.
    c. Also set the PID controller at the temperature already set in temperature controller.
    d. Till the temperature value of temperature controller is attained and the PID controller is off, the water must not flow to inlet.
       After the set value is attained pass the water in collector inlet from electromagnetic flow meter at specified flow rate.
       Mass flow rate is calculated as =Aperture area X 1.2 lpm.
    e. Water will flow from inlet to outlet of the collector and finally to the storage tank.
    f. Note down the reading of outlet temperature, inlet temperature, ambient temperature, solar Irradiation by the data logger.
    g. Hence calculate the efficiency of collector by using formula—
       η = m x Cp x ΔT / I x A x t.
       m= Mass flow rate of the heat transfer fluid, kg/s
       Cp= specific heat of water i.e. 4186kJ/Kcal.
       I= solar irradiation
       $\Delta T = T_o - T_i$
       A = Aperture area of collector
       t = Time in sec.
       T_i= Temperature of heat transferred fluid entering the collector, °C

T_o=Temperature of heat transferred fluid leaving collector at specified time t, ^oC

h. Plot the graph between T_i -Ta/I & η.
Find the strait line of equation i.e. y=m x +c, where m= F_R U_L I.e. losses & C= F_R $(τα)_e$ F_R = solar collector heat removal factor, dimensionless.
U_L = solar collector overall heat loss coefficient, W/m^2
C = optical efficiency.
$(τα)_e$ = represent property of cover-absorber system taking in to account absorbance of the absorber, transmittance of the cover and multiple reflection between the two, dimensionless.



SOLAR FLAT PLATE COLLECTOR DETERMINATION OF TIME CONSTANT

Measuring Equipments Used:

Sr. No.	Equipment	Model No. or Code No.	Valid Calibration
1.	Pyranometer	127099	Yes
2.	Data Logger	WDL-1002	Yes
3.	RTD PT-1000, Inlet Temp.	TS-4	Yes
4.	RTD PT-1000, outlet Temp.	TS-4	Yes
5.	RTD PT-1000, Ambient Temp.	111085 & Model no-DWA-8600M	Yes
6.	Anemometer with wind speed	Model no-DWA-8600M	Yes

Observations:

i) With inlet fluid at temp. equal to ambient ±1°C is brought to steady state for fluid flow rates of the collector systems about 0.02 kg/s outlet and inlet temp., outlet temp. and ambient temp. are recorded.

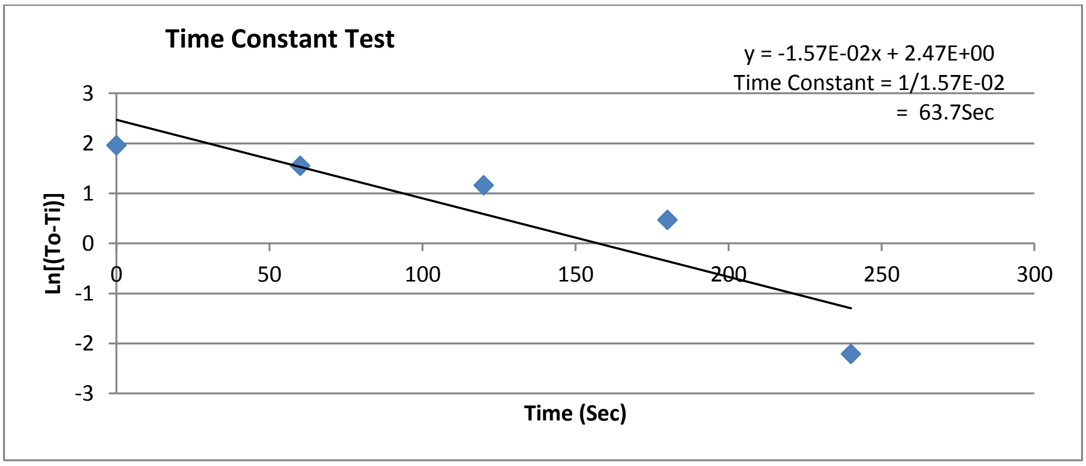
ii) Are the following steady state condition are satisfied = yes

a) Global/ total solar irradiation = ±50 w/m²
b) Surrounding air temp. = ±1°C
c) Fluid mass flow rate = ±1%
d) Collector fluid inlet temp. = ±0.1°C
e) Temperature difference = ±0.1°C
between inlet and outlet fluid temp.

iii) If yes the collector is covered by a white sheet in such a way that air can flow over the collector as prior to use of the cover.

iv) The inlet outlet and ambient temperature are recorded for every 1 min.

v) A graph is plotted between In [(T_o, t-Ti)] and time. Slope of the graph is recorded.



SOLAR FLAT PLATE COLLECTOR INCIDENT ANGLE MODIFIER TEST

Measuring Equipments Used: same as in time constant test

Observations:

Determination of incident angle modifier may be done. During the test, the orientation of the collector shall be maintained to be within ±2.5° of the angle of incident.

1. Place the collector on test bed and the orientation of the collector can be adjusted with respect to the direction of incident solar radiation as per requirement.
2. We take the reading of test for the four test conditions respectively, approximately 0^o, 30^o, 45^o, 60^o in a single day.
3. The inlet temperature of the heat transfer fluid shall be controlled as closely to the ambient temperature, within $\pm 1^o$c
4. Take efficiency values obtained for four values of angles of incidence i.e. 0^o,30^o,45^o,60^o are used, then calculate four values of

   Kv = F_R(Ʈα)e / F_R(Ʈα)e,n

   Kv = The incident angle modifier

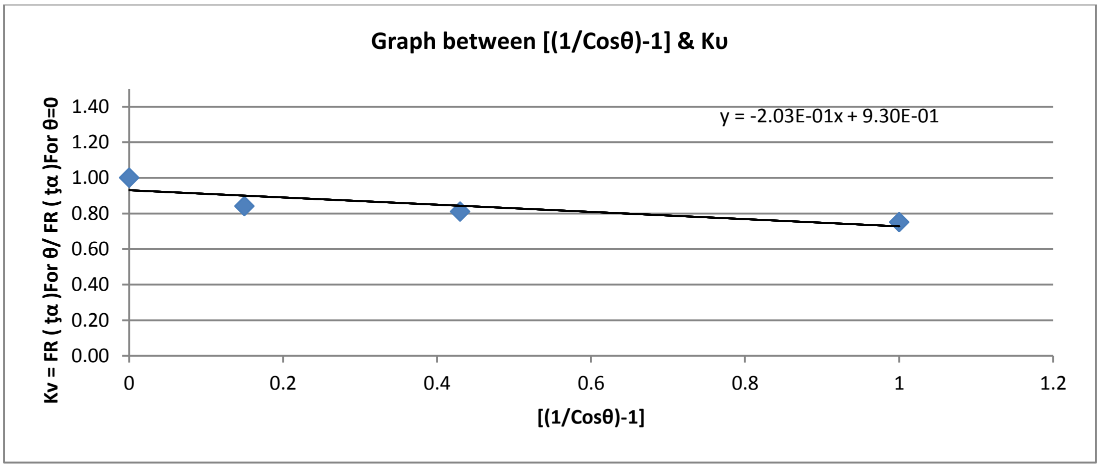
   F_R = Solar collector heat removal

   (Ʈα) e = Represent property of cover-absorber system taking in to account absorptance of the absorber, transmittance of the cover and multiple reflection between the two, dimensionless.

   (Ʈα) e, n = Represent (Ʈα)e at normal incidence

   Kv = 1- b_o [(1/cosɵ)-1]

5. Plotting a graph of values of [(1/cosɵ)-1] on X-axis and the value of Kv on Y-axis.



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RESULT:

1) **Static pressure leakage test :**

a) Any change in pressure after 10 minutes Of time internal = No

b)Swelling, distortion or rapture or riser/ headers =No

2) **Outdoor No-flow exposure Test:**

Break down in rubber gaskets	=	No
Out gassing of insulation material	=	No
Deposition of dust, water vapour	=	No

3) **Thermal Efficiency Test**:

a. FRUL<5.50 W/m² °C
b. FR(άτ) > 0.65

4.) **DETERMINATION OF TIME CONSTANT**

A graph is plotted between In [(T_o, t-Ti)] and time. Slope of the graph is recorded

5.) **INCIDENT ANGLE MODIFIER TEST**

Take efficiency values obtained for four values of angles of incidence i.e. 0^0 ,30^0 ,45^0 ,60^0 are used, then calculate and Plotting a graph of values of [(1/cosɵ)-1] on X-axis and the value of Kν on Y-axis.

CONCLUSION

From the above test we determine the various factors of flat plate collector like no flow exposure test, thermal efficiency test, time constant test and incident angle modifier test and we found all parameters according to the Indian standard and performance was found satisfactory.

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