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Performance Study of Flat Plate Collector

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Abstract- **In this paper the application of solar energy using flat plate collector is analyzed. A solar water heater indoor unit is studied. The test was conducted over a period of few hours to determine the performance of the set up. As this solar water heater is an indoor unit, halogen lamp has been used as a source of radiation. One A.C. fan is integrated with the system to generate the artificial wind speed. The wind speed was measured using an anemometer and radiation meter was used to measure the radiation level that is received by the collector. The experiment was conducted by setting the radiation level to the maximum value. The values of overall heat loss coefficient, heat removal factor and collector time constant has been calculated. The values of these parameters were within the standard range. The Flat plate solar collector for hot water generation technology is very useful.**

Keywords-**Flat Plate Collector, Overall heat loss coefficient, Heat removal factor, Collector Time constant, Thermosyphone mode**

I. INTRODUCTION

Solar water heaters are used all over the world specifically in the countries where sunshine is abundant. The hot water is used for household purpose and in dormitories, restaurants etc. For cleaning dishes and other works. [1, 2]These heaters are also used for preheating water for industrial purpose. Solar energy is the prominent energy of the future as the fossil fuel diminishes day by day. Solar flat plate collectors could be used to heat the water up to 100^{o}C. [3] The efficiency of the solar collector depends on many parameters such as number of glass cover, wind velocity, space between absorber plate to the glass cover and overall heat loss coefficient out of which top loss heat transfer coefficient (U_t) plays an important role. [4] Estimation of heat loss coefficient of flat plate collector is important for its performance evaluation.

II. SOLAR WATER HEATER

As 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 .When no optical concentration is done the device in which collection is achieved is called a flat plate collector. It is simple in design and can be used for a variety of applications in which temperatures ranging from 40^{o}C to about 100^{o}C are required. [5]

Thermosyphone- The principle of thermosyphone [6] is like boiling the water. In a flat bed collector cold water flows to the collector, it gets warm by sunshine and flow upwards due to buoyancy and stored in the tank which can be used directly.

Typically a flat plate collector consists of an insulated metal box with glass or plastic cover called glazing and an absorber plate. The absorber plate is normally metallic upon which short wave solar radiation falls and is absorbed while the tubes attached to the absorber plate are used to circulate the liquid required to remove the thermal energy.

III. CHARACTERISTICS OF THE COLLECTOR

Table 1
Calculation of Heat Loss Coefficient U_l [7]

Overall collector Dimension	915x810x95 (mm)
Glazing type	Toughened Glass (Thickness 5mm)
Absorber material	Copper (Thickness 0.12 mm)
Insulation Material	Rockwool
Insulation density	48 g/m
Weight of the collector	13 kg

As the heat that is generated by the collector does not result into useful energy some of the heat get lost to the surroundings. The amount of heat loss to the surroundings depends upon convective, conductive and radiation heat loss coefficients, estimation of heat loss coefficient of flat plate collector is important for its performance evaluation. A higher value of heat loss coefficient indicates lower heat resistance and hence lower efficiency.

It can be expressed as-

$$U_l = U_t + U_e + U_b$$

According to Klein (1975) the top loss coefficient can be calculated by using the formula-

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$$U_f = \left\{ \frac{\frac{1}{N}}{\frac{C}{Tp}\left[\frac{Tp-Ta}{N+f}\right]0.33 + \frac{1}{ha}} \right\} + \left\{ \frac{\sigma(T_p+T_a)(T_p^2+T_a^2)}{[\varepsilon_p+0.05N(1-\varepsilon_p)]^{-1}+\frac{2N+f-1}{\varepsilon g}-N} \right\}$$

Where, Tp= plate temperature (21°C)

Ta = ambient temperature

N= number of glass plate

ε_g = Emissivity of glass cover

ε_p =Emissivity of copper plate absorber

σ = Stefan's constant, 5.67 X 10-8 Watt /m^2K

Where C=365.9(1-0.00883 β +0.0001298 β 2)

f= (1+.04h_a-0.0005 ha2) x (1+0.091 N)

h_a= 5.7+3.8v

Where, β is the tilt angle

v = wind velocity =1.67m/sec

The bottom loss coefficient Ub and the edge loss coefficient Ue can be calculated by the formula

$$U_b = k_b/x_b$$

$$U_e = U_b(A_e/A_c)$$

Where K_b is conductivity of the back insulation

x_b : Back insulation thickness (mm)

A_e: Area of the edge (m^2)

A_c : Area of the collector (m^2)

Observation Table-

S.No.	Time(t, min)	Plate temp(T_p,°C)	Inlet water Temp. (T) T(f_0)	Outlet water temp. T(f_i)	Ambient temperature
1.	5	57.3	19.0	40.6	21°C
2.	10	64.6	19.9	45.4	
3.	15	65.2	19.8	45.9	
4.	20	65.7	20.0	47.1	
5.	25	66.5	20.1	48.5	
6.	30	67.4	20.2	50.7	
7.	35	69.0	20.4	52.3	
8.	40	70.1	20.6	53.2	
9.	45	70.6	20.6	53.8	
10.	50	71.1	20.5	54.1	
11.	55	71.5	20.6	55.1	
12.	60	71.9	20.6	55.6	
13.	65	72.0	20.7	55.9	
14.	70	72.1	20.7	56.4	
15.	75	72.6	20.7	56.8	
16.	80	72.8	20.7	57.8	

Calculations-

Bottom heat loss coefficient U_b

$$Ub = Kb/xb = 0.045/50 \ * 10^{-3}$$

$$Ub = 0.9W/\ m^2K$$

Edge loss coefficient Ue

$$Ue = Ub(Ae/A\epsilon) = 0.9(0.616/2.273)$$

$$Ue = 0.244\ W/m^2K$$

Top loss coefficient U_t

$$Ta(ambient\ temperature) - 21^oC + 273 = 294K$$

$$h_a = 5.7 + 3.8\text{v}$$

$$= 5.7 + 3.8\ \text{x}1.67$$

=12.046

Substituting the values for f and C

We get f=1.5355

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And C=363.302

ε_p =0.12 emissivity of the absorbing plate

ε_g =0.88 emissivity of the glass cover

Taking the mean value of plate temperature

T_p=341.29 K

$$= \left\{ \frac{\frac{1}{1}}{\frac{363.302}{341.29}\left[\frac{341.29-2.94}{1+1.5355}\right]^{0.33} + \frac{1}{12.046}} \right\} + \left\{ \frac{5.67 \text{ X } 10^{-8}[341.29+294][(341.29)^2 + (294)^2}{[0.12+0.05 \text{ x } 1(1\text{-}0.12)\,]^{-1} + \frac{2\text{x}1+1.5355-1}{0.88} - 1} \right\}$$

U_t=1.263

Hence total heat loss coefficient

$U_l = U_t + U_b + U_e$ =1.263+0.9+0.244 =2.4071 W/m^{2}K

IV. Heat Removal Factor

Heat removal factor represents the ratio of the actual useful energy gain to the useful energy gain if the entire collector were at the fluid inlet temperature. For a highly efficient system a higher value of heat removal factor is must.

$$= \frac{m\, C_p\, \{T(f_0) - T(f_i)\}}{A_C\{\, I_t\, T_0\, \alpha_0 - U_L[T(f_i) - T\alpha]\}}$$

Where, m= water mass flow rate (kg/sec)

$$Cp = 4180\, J/kg\ C$$

$T(f_0)$ =outlet water temperature $T(f_i)$ = outlet water temperature at time zero

Ac = Area of collector 0 .74115m^2

Ta = Ambient temperature

α_0.=0.96

Substituting the values in the above equation the value of heat removal factor F_R at two different mass flow rate 0.01kg/sec and 0.006kg/sec is found to be 3.097 and 1.85

V. Collector Time Constant

Collector time constant is used evaluate the transient behavior of a collector.

It is defined as the time required in rising the outlet temperature by 0.632 of the total temperature increase from $T(f_0)$-T_a at time zero to $T(f_0)$-T_a at time infinity i.e.) Time at which the outlet temperature attains a stagnant value. It can be calculated from the curve between R and time.

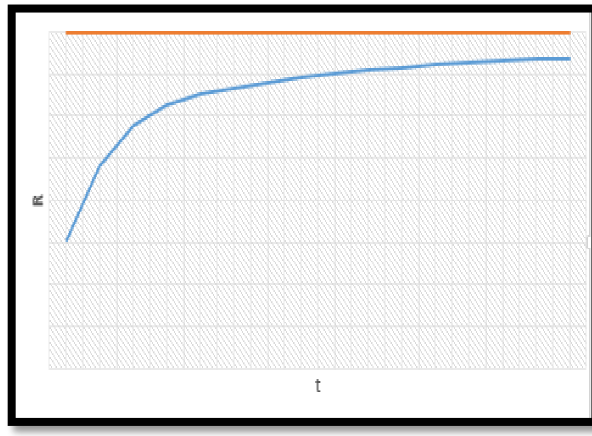

Figure 1.Graph between R and t

R	0.68	0.72	0.82	0.89	0.91	0.95	0.97
t	10	20	30	40	50	60	70

VI. Conclusion

The performance of Flat Plate collector is studied with the maximum radiation level and the values of overall heat loss coefficient, heat removal factor and collector time constant has been calculated .The values were found to be in the given standard range. The top loss coefficient dominates the base loss coefficient and the edge loss coefficient. The base loss coefficient and the edge loss coefficient are constant because the parameter required to calculate them are constant. The heat removal factor F_R depends on the mass flow rate and has been calculated at two values of mass flow rate m=0.01 kg/sec and m=0.006 kg/sec and is found to be 3.097 and 1.85.The graph between R and t shows that in around 10 minutes the value of collector time constant is achieved. It has been found from the study that the flat plate solar collector for hot water generation is very useful.

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REFERENCES

[1] R.Diekmann "Solar and Wind Energy" –International Issue 5 Bielefelder Verlag Gmblt &Co Bielefeld 2008

[2] J.Jimenez Gonzalez A Rivela "Generation displacement Power loss and Emission Reduction due to Solar Thermal Water Heaters proceeding IEEE 37thAnnual Symposium, 23-25 October''

[3] S.P. Sukhatme and J.K.Nayak Solar energy; principles of thermal collection and storage, Third Edition .Tata McGraw –Hill publishing company Limited , 2008

[4] H.Vettrivel,P.Mathiazhagan "Comparison Study of Solar Flat Plate Collector with Single and Double Glazing System IJRER Vol. 7, (2017)

[5] Shahidul Islam Khan, Asif Islam "Performance Analysis of Solar Water Heater" Smart Grid and Renewable Energy, 2011, 2,396-398

[6] S.I.Khan and M.Obaidullah,"Short Course on Fundamentals of Solar Water Heaters ''Energy efficiency Bangladesh University of Engineering and Technology Dhaka, Nov2008 pp20-29

[7] Solar Energy "Fundamentals and Principles"-H.P.Garg