SOLAR WATER HEATING SYSTEM PERFORMANCE CHARACTERISTICS AT 40^{0}C COLLECTOR TILT ANGLE USING HALOGEN BULB UNDER DIFFERENT RADIATION INTENSITY

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Abstract - ***Performance characteristic of a solar water heating system with halogen bulb is used to determine the efficiency of the system and the impact of heat removal factor and heat loss transfer coefficient on the system efficiency. At different intensity level from a minimum value to a maximum value the efficiency has been calculated at an angle when the plate is tilted at 40℃. The above procedure will be carried out when the wind speed is kept to a minimum value and when the wind speed is at a maximum value and when winds speed is in intermediate value. And to determine the best efficiency of the collector by comparing the efficiency at different intensity radiation and also the best plate tilted angle at which hot water temperature achieved is maximum.***

Key Words: *Solar water heating system, Non-conventional energy, LPG.*

1. INTRODUCTION

A solar water heating system is the device that uses solar energy for the production of hot water. Solar water heating system is renewable energy technology that are being used in many countries around the world .This type of energy is absolutely free and produce less pollutant and are much economical. A solar water heating system is very much environment friendly. In residential area most energy is required for the production of hot water and also for space heating. Hot water is very important for bathing and for washing utensils in urban as well as rural areas. Heating of water is usually done by firing wood in rural areas and with the help of kerosene oil, LPG, Coal and electricity in urban areas. For best efficiency, collectors should be oriented to face the sun. Although, we receive sun's energy in the form of light which is having shorter wavelengths which is always visible to the human eye. When this radiation intensity strikes a solid or liquid, it is absorbed and transferring this energy into heat energy. The sun emits radiation like a black body whose surface temperature is around 5700 degree centigrade. A 100 lpd system (2 sq.m of collector area) installed in a home can save 4-6 units of electricity/day depending on the place of installation & hot water use. On an average it could be taken as 5 units/day. Maximum average saving with 300 clear days, therefore, could be taken as 1500 units/year. Assuming 300 days of solar hot water use in Bangalore and 150 days in Delhi, the savings could be 1500 & 750 units per year respectively i.e. replacement of a 2 KW electric geyser working for 2 ½ hours in a day. Considering all parts of the country and maximum installations in areas where hot water requirement is more during the year, average saving could be taken as 1200 units/year/100 lpd system. 1 million such systems installed will be able to save 1200 million units of electricity/year. A 100 lpd system (2 sq.m of collector area) installed in an industry can save around 140 litres of diesel in a year.

1.1 Objectives

- Performance characteristics of solar water heating system with halogen bulb under different intensity.
- Performance characteristics when plate is tilted at 40 degree.
- Performance characteristics when intensity is minimum wind speed are constant and tilt angle 40 degree.
- Performance characteristics when intensity is minimum wind speed are maximum and angle is 40 degree.
- Performance characteristics when intensity is maximum wind speed are constant and tilt angle is 40 degree.
- Performance characteristic when intensity is maximum wind speed is maximum and tilt angle 40 degree.

2. SOLAR WATER HEATER

A schematic diagram of solar water heater is shown in the Fig-1. A solar water heating system with tilted flat plate solar collector with water as a transfer fluid is used. The heated water of the collector rises up to the hot water tank and this hot water replaces an equal quantity of cold water and this cold water enters the collectors and the cycle continues. And further all water gets heated due to the movement of water. When hot water is taken from the hot water outlet tank, the same amount of amount of cold water is replaced by cold water make up tank which is fixed just above the hot water tank. This scheme is known as passive heating scheme as water is circulated naturally in the loop due to thermo siphon action. When the collector is fixed above the level of the hot water tank so in this case a pump is required to induce circulation of the water and this is known as active circulation. This is also known as forced circulation. In solar water heater with halogen bulb only difference is the input energy as halogen bulb provides sufficient intensity radiation and the rest all the function are same. For better working the hot water temperature must be within 60 to 80˚ c.

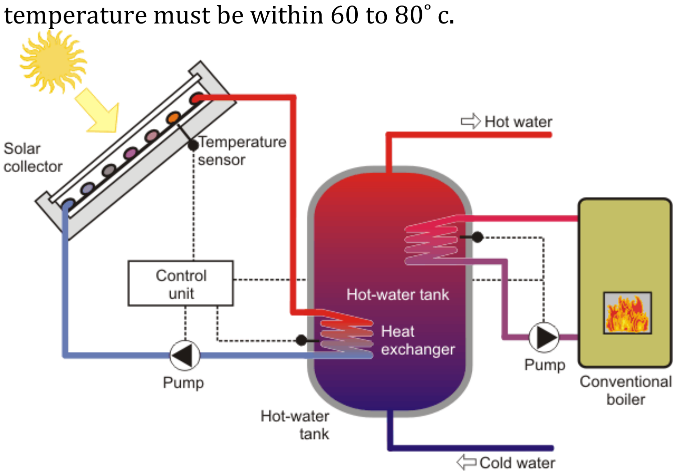

Fig -1: Solar water heater

3. SOLAR COLLECTOR

Solar collector classification is based upon the phenomenon through which they collect radiation. The non-concentrating types absorbs the intensity of radiation as it is received by solar collector and in concentrating collector per unit area the radiation intensity firstly increases before absorbing it. Concentrating type of solar collector is divided into focus and non-focus types. Collector is shown in the Fig-2.

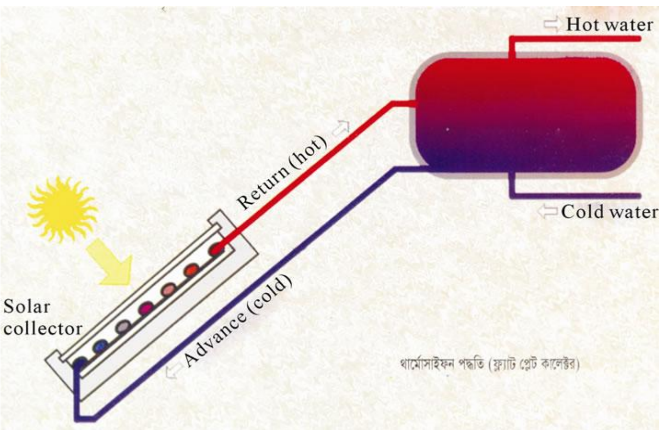

Fig -2: Solar collector

4. EXPERIMENTAL SETUP

Fig -3: Insight solar water heater

Fig -4: Arrangement of halogen bulbs

An insight solar water heater comprises of

- Halogen bulbs- to provide the required radiation (21 bulb)
- Anemometer-to measure the air velocity.
- Radiation meter – to measure intensity
- Insulated piping – for regulating flow of water
- Insulated hot water tank – the function of hot water tank is to store water
- Pump – the function of pump is to deliver water from suction head to delivery head
- Collector plate- the function of collector is to absorb intensity

Overall system specification is given in the Table-1 below

Table -1: Specifications of experimental setup.

COMPONENTS	SPECIFICATION	REMARKS
Water heating system(collector and water tank)	Collector area:0.716 m^2 Tank capacity : 50 L	Collector flat plate To collect and transfer heat Tank: non pressurized aluminium tank To store water
Halogen system	Halogen fixtures area :0.72m^2 Number of halogen lamp: 21 Power :150 watt each Regulator :5000 w	Halogen: To supply the required intensity on the collector. Regulator: To adjust the intensity at the desire level.

Radiation meter	Range :0 to 1999 w/m² Power supply : DC	To measure the radiation level on the collector
External water tank	Capacity : 80 L	To supply cold water to the heating system
Water pump	Power supply : AC POWER : 0.5 hp	To lift water upto the desire level To facilitate the forced mode operation
Water flow meter{for forced mode}	Sensor: Flow range :0.5 to 25 LPM Working voltage :4.5 to 24 VDC Maximum pressure :17.5 bar Working pressure : 0 to 10 bar Max rated current :8mA Withstand current :15mA Working temp: 80 c Storage temperature : 25 to 65° C Accuracy :1%fsd Supply voltage - 230 V AC	Mini turbine wheel based technology To measure the water flow rate during the forced mode operation
Fan	Range : 0 to 5 m/sec Power supply: AC with regulators	To supply the wind at different
Anemometer	Air velocity: Range : 0.4 to 45 m/sec Resolution : 0.1 m/sec Accuracy : $(\pm\% + 0.1\frac{m}{sec})$ Air temperature : Range :14 to 60 c Resolution : 0.1° C Accuracy :0.5° C Power supply : DC 4*1.5 AAA size	The anemometer can measure the air velocity and the ambient air temperature The air flow sensor is a conventional angled vane arms with low friction ball bearing.
Pressure gauges	Sensor: Range : 0 to 6 bar Accuracy : ± 3 KPA Output : 4 to 20mA (±3) Input : 4 to 20mA DC Power : 220 VDC	Semiconductor thin –film based technology Works on the principle of generation of electrical signal due to exertion of pressure To measure the inlet and outlet pressure
Thermometers	Sensor: class A Range : -200 to 650° C Accuracy : ±.15 to .002*(t) Where t is absolute value of temperature in °c Supply voltage : 230 AC	Sensor is RTD based platinum probe Works on the principle of variation of resistance with temperature To measure the inlet , outlet ,plate and tank water temperature

4. PROCEDURE FOR CONDUCTING EXPERIMENT

- Keep all valves closed
- Fill cold water tank no 1
- Open the valves 1 and 2and fill cold water tank 2 by using the pump
- Once the cold water tank 2 is full, open valve 3and 4 and allows the water to flow into the hot water tank and the collector by gravity.
- Once the cold water tank 2 overflows and water comeback to the cold water tank 1 close the valve 1,2 and 3
- Switch on the wind generating fan.
- Measure the win speed at different locations of the collector by using the anemometer. use average value for calculation
- Similar to the wind speed measure the ambient air temperature by using the same anemometer at different locations around the experimental setup. Use an average value for calculation
- Note all the readings
- Switch on the halogen system and set the regulator for different intensity radiation
- Measure the radiation level at different locations on the collector glazing by using the radiation meter. To get the radiation levels at the desired value apply the regulator. Use an average value for calculation.
- Note down the readings after every 15 minutes
- To know the mass flow open rate open the three ways valve and note down the time required to fill a desire amount of water in a beaker.

5. RESULTS AND DISSCUSSION

After conducting the experiment heat removal factor (F_R), heat loss coefficient (U_L) and efficiency (η) were calculated using following formulas.

1. HEAT REMOVAL FACTOR

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

$$F_R = \frac{\dot{m}C_P[T_{fo} - T_{fi}]}{A_c[I_t T_o\alpha_o - U_L(T_{fi} - T_a)]} \dots\dots\dots\dots (1)$$

2. HEAT LOSS COEFFICIENT

$$U_L = U_t + U_b + U_e \dots\dots\dots\dots (2)$$

$$U_t = \left\{\frac{\frac{1}{N}}{\frac{C}{T_p}\left[\frac{T_p - T_a}{N+f}\right]^{1/3} + \frac{1}{h_a}}\right\} + \left\{\frac{\sigma(T_p+T_a)(T_p^2+T_a^2)}{(\varepsilon_p + .05N(1-\varepsilon_p))^{-1} + \frac{2N+f-1}{\varepsilon_g} - N}\right\} \dots\dots (3)$$

$$U_b = \frac{K_b}{X_b} \dots\dots\dots\dots (4)$$

$$U_e = U_b\left(\frac{A_e}{A_c}\right) \dots\dots\dots\dots (5)$$

3. EFFICIENCY

$$\eta = F_R[(T_o\alpha_o) - \frac{U_L(T_i - T_a)}{I_t}] \dots\dots\dots\dots (6)$$

Where,

$C=365.9x\ (1-0.00883ß+0.0001298ß^2)$

$i^2 = (1+0.04h_a - 0.0005h_a^2)\ X(1+0.091N)$

$h_a = 5.7 + 3.8V$

The heat removal factor (F_R), heat loss coefficient (U_L) and efficiency (η) were calculated using above formulas for radiation intensity of 400 w/m², 389.25 w/m² and 290.25 w/m². The calculated readings are shown in the following tables.

1. Radiation intensity = 400 w/m², blade angle = 40 °C Wind speed = 2 m/sec

Table -2: Results at 400w/m² intensity

Time	U_L	F_R	η(%)
At 10:00 am	2.69	2.89	2.27
At 11:00 am	3.45	3.17	2.45
At 12:00 am	4.61	3.99	2.95
At 01:00 pm	4.91	5.02	3.65
At 02:00 pm	5.45	5.58	3.93
At 03:00 pm	5.89	5.97	4.08

2. Radiation intensity = 389.25 w/m², blade angle = 40 °C Wind speed = 1.5 m/sec

Table -3: Results at 389.25w/m² intensity

Time	U_L	F_R	η(%)
At 10:00 am	4.63	3.39	2.87
At 11:00 am	5.01	5.15	4.28
At 12:00 am	5.99	6.20	4.72
At 01:00 pm	6.95	7.30	5.30
At 02:00 pm	7.94	8.19	5.56
At 03:00 pm	8.34	9.40	5.67

3. Radiation intensity = 290.25 w/m², blade angle = 40 °C Wind speed = .25 m/sec

Table -4: Results at 290.25w/m² intensity

Time	U_L	F_R	η(%)
At 10:00 am	2.71	3.30	2.55
At 11:00 am	2.78	4.80	3.66
At 12:00 am	2.97	5.40	4.06
At 01:00 pm	3.05	6.30	4.63
At 02:00 pm	3.08	8.10	5.78
At 03:00 pm	3.19	8.90	6.19

From the tables it can be seen that as the efficieny was increased when the radiation intensity was decreased. Maximum efficiency achieved with radiation intensity of 290.25 w/m² was 6.19 percent because at 290.25 w/m² wind speed is minimum that is .25 m/sec hence efficiency is 6.19 percent. Also following graphs are plotted to make a comparison between Heat removal factor verses efficiency, Plate temperature verses time and Fluid outlet temp verses time.

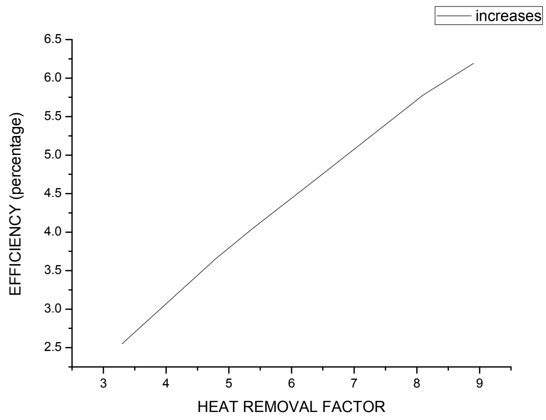

Fig -5: Efficiency verses heat removal factor

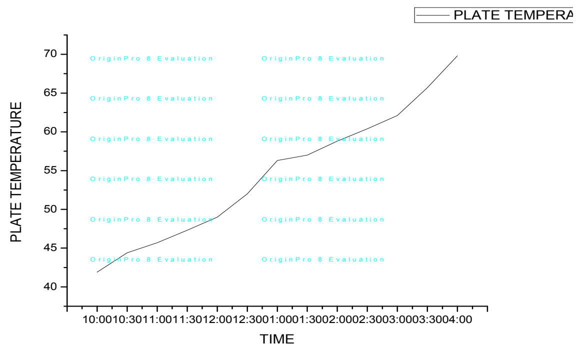

Fig -6: Plate temperature verses time

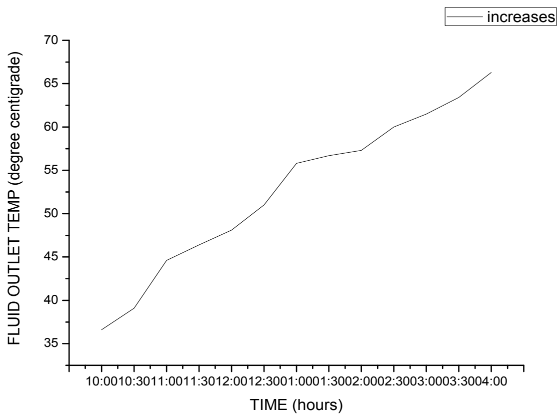

Fig -7: Fluid outlet temp verses time

Fig-5 shows the graph of Heat removal factor verses efficiency where in as heat removal factor increases the efficiency also increases. Fig-6 shows the graph of Plate temperature verses time where in the plate temperature increases with the increase of time. Fig-7 shows the graph of Fluid outlet temp verses time where in the Fluid outlet temp is increasing slowly with respect to time.

5. CONCLUSION

When intensity is 290.25 w/m^2, Wind speed = .25 m/sec Plate tilt = 40 degree following conclusions were drawn from the present work

- With increase in plate temperature efficiency increases.
- Efficiency increase with an increase in heat removal factor.
- Plate temperature increases over a period of time.
- Efficiency decreases with increases with an overall heat loss coefficient.
- Hot water temperature attained so far is 42.5 degree centigrade

REFERENCES

[1]. Rao S and Parulekar B B,(energy technology) Khanna Publisher 2013.
[2]. Ahmad Asraf Bin Ramli, Theoretical Analysis Of Solar Water Heating System, 2010
[3]. Garg H P ˝**S**olar Eergy", Tata McGraw- Hill Publishing
[4]. Fabio Struckmann, Analysis of a Flat- plate Solar Collector, May 08,Lund,Sweden
[5]. Houda Ennaceri , Khalid Loudiyi, Modelling the variation of optimum tilt angles for Flat –plate Solar Collectors in Ifrane, Morocco.
[6]. Shakir Rahmin, Sajedul Hossain Sarker and Saiful Huque, Performance study of an indigenously built Flat plate SWH, University of Dhaka, Dhaka