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Comparative Analysis of Flat Plate Solar Collector

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Abstract- A flat-plate collector is a non-tracking (fixed) type of the collector with a glass or plastic cover (called glazing) on top side and an absorber plate (painted dark) on the bottom. Solar radiations passes through the glazing and being absorbed by the absorber plate is then transferred to the liquid flowing through the pipes and is thus utilized for raising the temperature of liquid. An attempt has been made in this paper to analyze the performance of flat plate solar collector in terms of its efficiency. A comparison of flat plate collector with and without reflector sheets is also presented in this study.

Index Terms- Flat Plate Collector; Performance analysis; Efficiency.

1. INTRODUCTION

Solar energy is one of the most vital forms of renewable energy. One of the easiest ways to utilize solar energy is by converting it into thermal energy by using solar collectors. A solar water heater works by absorbing sunlight and converting it into usable thermal energy. Depending upon their position in relation to the sun, a solar collector can be classified as non-tracking or tracking solar collector. A flat-plate collector is a non-tracking (fixed) type of the collector with a glass or plastic cover (called glazing) on top side and a dark-colored absorber plate on the bottom. Solar radiations passes through the glazing and strikes the absorber plate, which heats up, changing solar energy into heat energy. The heat is transferred to liquid passing through pipes attached to the absorber plate [1]. These collectors heat liquid or air at temperatures less than 80°C.

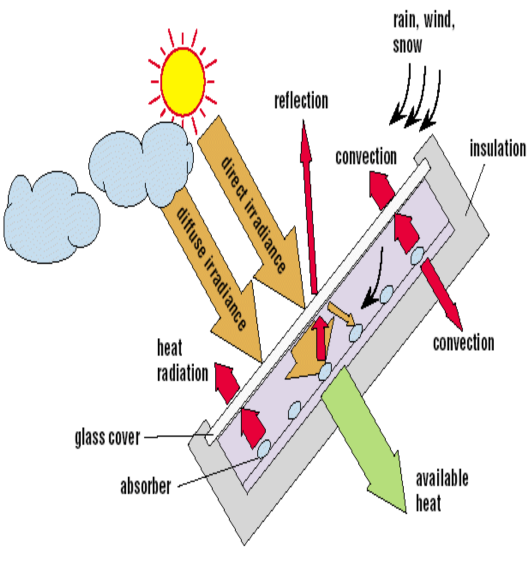

Fig.1. Elements of Flat plate solar collector [2]

Exergic optimization was carried out under design considerations and optimum values of mass flow rate, absorber plate area and the maximum energy efficiency were found by [3]. By increasing the incident solar energy per unit area of the absorber plate, the exergy efficiency was found to be increased and it decreased rapidly when the ambient temperature and the wind speed were increased.

The efficiency of solar collector was increased approximately 10% to 30% in comparison with the conventional solar collector by using the passive techniques such as dividing three or six sheets to absorber surface, attaching fins on absorber surface and giving an oblique angle (2°) to the three sheets absorber surface [4].

The performance of the solar collector was optimized by changing the shape of the collector plate and the area of the plate [5]. Also the cost varies with the change in area of the plate of the solar collector and it was deduced that cost can be minimized by reducing the size.

Theoretical and experimental analysis was performed on a flat plate collector with a single glass cover [6]. It was concluded that the emissivity of the absorber plate had a significant impact on the top loss coefficient and consequently on the efficiency of the Flat plate collector. The efficiency of flat plate collector was found to increase with increasing ambient temperature. There was no significant impact of tilt angle on the top loss coefficient.

The study presented in this paper aims to analyze the performance of flat plate solar collector. A comparison of flat plate collector with and without reflector sheets is also presented in this study.

2. DATA COLLECTION

Fig. 2 shows the actual pictures of the flat plate collector mounted on rooftop at following location: Chandigarh (30.764 degree N,76.766 degree E)

Fig. 2(a) Actual picture of flat plate collector mounted on rooftop having angle of tilt 30.76 degree.

Fig. 2(b) Actual picture of flat plate collector with reflector attached on top (upper) side at an angle of 135 degree to the collector top surface.

The components of the flat plate collector and detailed specifications of the collector used for the study is presented in Table 1 and Table 2 respectively.

Table 1. Components of Surya Shakti Solar Water Heating System

Solar Flat Plate Collector	Thermo-syphon type Surya Shakti Water Heating System(ISI marked)
Double Walled Insulated Hot Water Storage Tank	Stainless Steel (SS 304) Storage Tank
Piping in between the system	Copper Coil Heat Exchanger with Feeder Tank having Thermic fluid/Anti-freeze solution
Collectors & Tank Stands	Over Head Cold Water Tank with Stand

Table 2. Detailed specifications of the flat plate collector

Components	**Specifications**
Collector Box	
Area	2.3 m^2
Length*Breadth*Height	186cm*124cm*11cm
Weight	48kg
Absorber	
Area	2.16 sq. m.
Material	Copper
Thickness of Sheet	0.20
Risers	
Material	Copper
Diameter	12.7mm
Thickness	0.56mm
Number	10
Header	
Material	Copper
Diameter	25.4mm
Thickness	0.71mm
Projection Outside	40mm
Space between riser tubes	120mm
Coating	
Material	Black Chrome
Absorbitivity	0.94
Emissivity	0.12
Assembly Testing	Hydraulic
Working Pressure	5 kg/cm^2
Static Pressure	10 kg/cm^2
Collector Box	
Material	Aluminium
Extruded Al. Channel	100mm*25mm*1.5mm
Extruded Al. Angle	25mm*25mm*1.5mm
Bottom Sheet	0.71mm
Collector Box Insulation	
Back insulation	Rockwool
Thickness	50mm

Density	48kg/cu.m.
Thermal conductivity value	0.029W/mK
R. Value	1.67m C/W
Foil Thick	0.015mm
Side Insulation and thickness	Rockwool, 25mm thick
Front Glazing	4 mm toughened glass
Transmissivity	85%
Header Flanges	
Material	Brass
Diameter	65mm
Thickness	4mm
Gaskets	Neoprene
Grommets	EPDM
Seal	Silicon
Collector Tilt	30.76 degree

Sample data regarding inlet temperature of water, outlet temperature, solar irradiance have been collected for different days of various months of a year. Since it will be difficult to produce all data in tabular form, so some of the sample data is presented in tabular form and rest shown in the form of graphs.

Table 3. Water Inlet temperature reading at different point of time during the month of August and September

	↓ Inlet Temperature	Time →			
Period	9am	11am	1 pm	3pm	5pm
2017,Aug12	73	84	94	88	78
2017,Aug13	71	83	94	87	74
2017,Aug14	69	81	96	85	75
2017,Aug15	67	78	97	83	73
2017,Aug16	66	79	95	83	72
2017,Aug17	64	75	94	79	69
2017,Aug18	66	77	94	81	71
2017,Aug19	63	73	96	77	68
2017,Aug20	65	78	95	80	72
2017,Aug21	63	74	93	77	69
2017,Aug22	66	78	90	81	73
2017,Aug23	62	73	91	76	67
2017,Aug24	62	74	92	78	69
2017,Aug25	63	74	90	79	68
2017,Aug26	63	75	87	78	69
2017,Aug27	63	73	88	77	67
2017,Aug28	59	72	88	75	66
2017,Aug29	63	74	85	77	68
2017,Aug30	63	74	86	78	69
2017,Aug31	59	71	85	76	66
2017,Sept 1	63	77	81	78	71
2017,Sept 2	62	75	83	77	69
2017,Sept 4	61	72	81	75	66
2017,Sept 5	59	70	87	74	64
2017,Sept 6	62	75	81	78	69
2017,Sept 7	60	73	82	77	67
2017,Sept 8	58	71	78	74	65
2017,Sept 9	59	70	80	75	64
2017,Sept 10	57	71	80	75	65
2017,Sept 11	55	68	86	77	62
2017,Sept 12	55	68	82	76	61
2017,Sept 13	53	65	78	70	59
2017,Sept 14	57	68	79	72	62
2017,Sept 15	57	69	78	73	63
2017,Sept 16	57	68	76	71	61
2017,Sept 17	59	73	71	77	66
2017,Sept 18	56	68	76	72	61
2017,Sept 19	57	68	78	73	63
2017,Sept 20	49	60	77	65	54
2017,Sept 21	49	61	77	66	55

Table 4. Water Outlet temperature reading (without reflector) at different point of time during the month of August and September

	↓ Outlet Temperature			Time →	
Period	9am	11am	1 pm	3pm	5pm
2017,Aug12	124.3	141.78	180.4	142.36	139.92
2017,Aug13	137.78	155.9	180.4	172.14	137.36
2017,Aug14	130.56	146.7	183.48	156.1	140.7
2017,Aug15	133.78	150.18	185.2	141.68	130.78
2017,Aug16	126.48	148.12	171.68	168.68	134.1
2017,Aug17	114.22	131.7	180.22	142.54	135.06
2017,Aug18	119.28	139.46	178.78	148.32	132.92
2017,Aug19	113.22	133.3	183.48	147.56	126.32
2017,Aug20	133.22	149.64	173.12	154.16	132.66
2017,Aug21	121.86	143.12	175.26	152.78	132.18
2017,Aug22	130.26	148.92	174.96	151.92	137.98
2017,Aug23	123.02	143.56	167.5	143.14	128.38
2017,Aug24	119.42	139.52	178.4	150	129.12
2017,Aug25	128.52	143.66	176.4	152.98	126.68
2017,Aug26	127.62	147.18	170.16	146.76	134.52
2017,Aug27	122.58	142.48	172.96	147.38	126.94
2017,Aug28	117.68	138.96	174.4	149.34	123.96
2017,Aug29	123.66	138.98	171.76	144.5	130.1
2017,Aug30	127.62	148.88	165.56	146.76	133.98
2017,Aug31	126.5	144.08	170.5	147.64	126.84
2017,Sept 1	113.58	135.68	165.42	150.18	132.92
2017,Sept 2	119.42	144.3	166.88	153.14	129.48
2017,Sept 4	123.64	143.28	165.96	149.34	130.62
2017,Sept 5	123.08	139.84	169.26	146.18	120.52
2017,Sept 6	119.42	143.22	165.06	148.56	129.48
2017,Sept 7	120.12	143.56	166.42	147.02	128.38
2017,Sept 8	122.26	143.18	160.44	146.18	124.94
2017,Sept 9	121.28	139.66	160.64	148.98	126.1
2017,Sept 10	117.48	142.46	164.06	150.06	125.48
2017,Sept 11	121.78	140.54	171.32	149.18	124.1
2017,Sept 12	114.04	136.04	168.04	146.92	124.36
2017,Sept 13	118.34	136.1	164.58	139.12	123.98
2017,Sept 14	118.56	137.84	164.32	143.28	122.66
2017,Sept 15	121.44	141.36	162.42	145.18	125.46
2017,Sept 16	113.34	134.06	161.5	145.34	124.72
2017,Sept 17	117.5	141.04	153.44	153.14	131.16
2017,Sept 18	116.84	139.28	159.7	142.92	125.08
2017,Sept 19	118.92	140.54	163.32	143.02	125.64
2017,Sept 20	107.32	128.94	163.58	132.86	114.84
2017,Sept 21	110.38	132.28	160.7	134.94	115.3

Table 5. Water Outlet temperature reading (with reflector) at different point of time during the month of August and September

	Outlet Temperature	Time →			
Period	9am	11am	1 pm	3pm	5pm
2017,Aug12	126.82	144.66	184.18	145.6	142.44
2017,Aug13	140.48	158.96	184.54	175.74	140.06
2017,Aug14	132.54	149.94	187.26	160.42	143.22
2017,Aug15	136.3	153.24	189.16	144.92	133.48
2017,Aug16	128.82	151.72	175.64	172.46	136.44
2017,Aug17	117.1	135.48	184.18	147.04	137.58
2017,Aug18	122.7	142.7	182.74	151.92	135.8
2017,Aug19	115.38	137.26	187.26	150.98	129.2
2017,Aug20	135.92	152.88	176.72	158.12	135.54
2017,Aug21	124.2	146.54	179.04	156.2	134.88
2017,Aug22	132.78	152.88	179.1	155.16	140.68
2017,Aug23	125.54	146.8	171.28	147.1	131.26
2017,Aug24	121.94	143.3	182.36	153.42	131.82
2017,Aug25	131.22	146.72	180.54	156.94	129.56
2017,Aug26	129.96	150.78	174.3	150.18	138.12
2017,Aug27	125.28	145.36	176.74	151.7	131.26
2017,Aug28	122	142.74	178.54	152.94	126.12
2017,Aug29	130.32	142.4	175.9	148.28	132.62
2017,Aug30	129.96	151.94	169.88	150	136.86
2017,Aug31	128.84	147.32	174.28	151.42	130.08
2017,Sept 1	115.92	139.64	169.2	154.14	134.9
2017,Sept 2	121.76	148.08	170.66	156.92	132
2017,Sept 4	125.98	146.88	169.92	151.14	133.32
2017,Sept 5	125.42	143.08	173.04	149.96	123.4
2017,Sept 6	122.12	147	169.02	151.8	132.18
2017,Sept 7	122.46	147.34	170.2	150.98	131.26
2017,Sept 8	124.6	146.6	164.22	150.14	128
2017,Sept 9	123.62	143.62	164.42	152.4	128.98
2017,Sept 10	126.12	145.88	168.02	154.02	128.54
2017,Sept 11	124.12	143.78	175.46	153.5	126.44
2017,Sept 12	116.38	139.82	189.82	150.16	127.42
2017,Sept 13	120.68	140.06	168.72	142.18	126.68
2017,Sept 14	121.26	141.62	168.46	147.06	125.18
2017,Sept 15	123.78	144.6	166.56	149.14	128.16
2017,Sept 16	115.86	137.3	165.28	149.3	127.6
2017,Sept 17	120.02	144.82	157.4	156.38	133.14
2017,Sept 18	119.18	142.7	163.66	146.16	127.78
2017,Sept 19	103.26	143.78	167.1	147.16	128.52
2017,Sept 20	109.84	133.08	167.72	136.82	119.34
2017,Sept 21	113.08	136.42	164.84	138.9	117.64

3. ANALYSIS OF DATA

Following equations were used for analyzing the collected information.

$\eta = q_u / A_C * I_T$ Eq. (1)

$q_u = A_P S - q_l$ Eq. (2)

$I_T = I_b * r_b + I_d * r_d + (I_b + I_d) r_r$ Eq. (3)

$q_l = U_l A_p (T_{pm} - T_a)$ Eq. (4)

4. RESULTS

The data tabulated above is presented in the form of graphs in order to extract useful information regarding performance of flat plate collector used in the study.

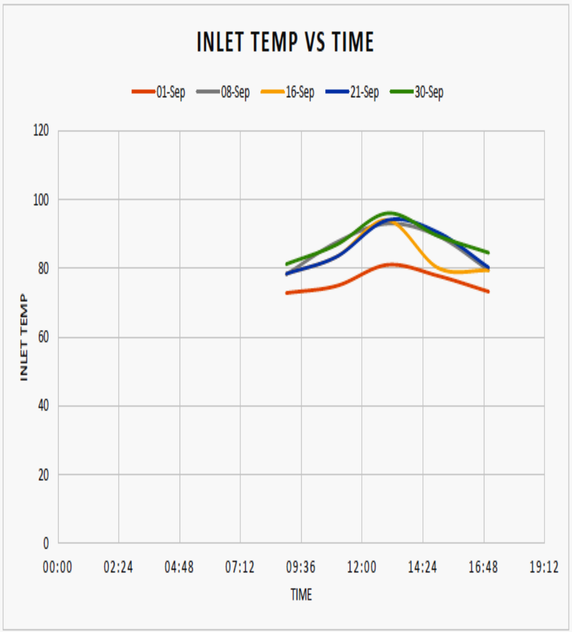

Fig.2 Variation of inlet temperature with time during different days of month of September, 2017.

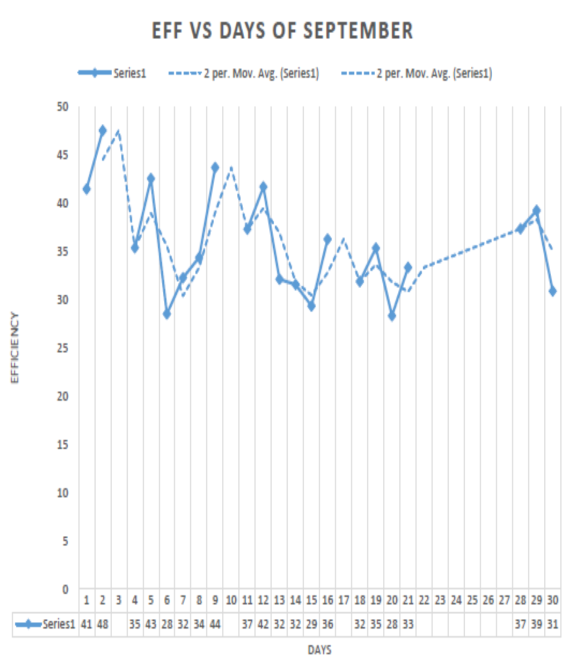

Fig.3 Variation of efficiency during different days of month of September, 2017

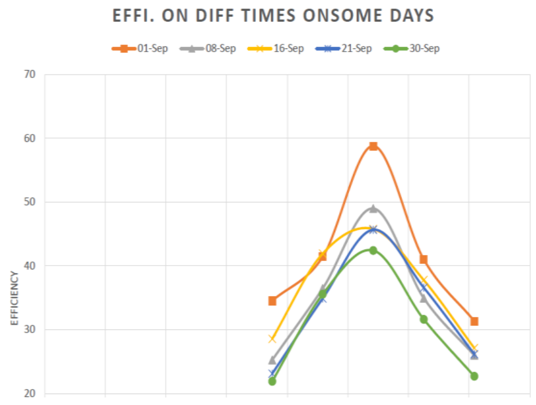

Fig.4 Sample set showing variation of efficiency during different days of month at fixed point of time.

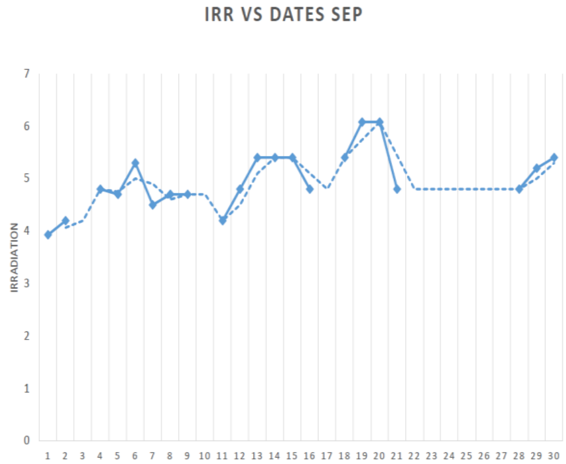

Fig.5 Variation of Solar Irradiance falling on the surface on different days of month of Sept, 2017.

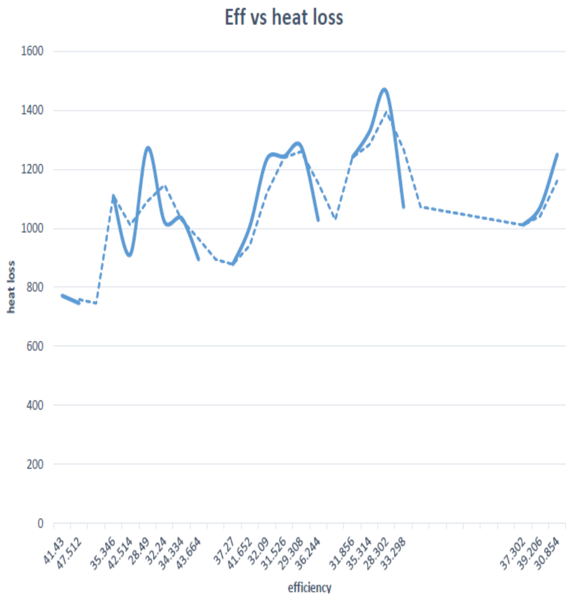

Fig.6 Efficiency of flat plate collector v/s heat loss

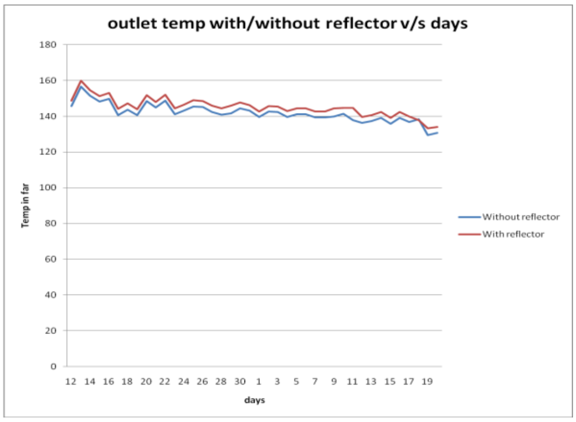

Fig.7. Comparison of outlet temperature obtained at the exit of collector tubing for actual collector without reflector sheet and with reflector sheet.

5. CONCLUSIONS

From the analysis, following interpretation can be drawn:

1. Efficiency of the solar collector is higher during noon between 1 pm to 2 pm. Hence maximum utilization of the solar collector should be done during 12pm to 2pm to obtain best use of the solar energy.
2. With increase in solar irradiance falling on the collector surface, the outlet temperature, useful heat gain and efficiency of the collectors increases.
3. A comparative analysis shown in Fig. 7 has confirmed that the efficiency of the collector can be increased by mounting a reflector on the top side.
4. Heat loss occurring from the side of the collector can be prevented by shielding/using some coatings.

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