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Effect of Air inlet temperature on performance of circular solar collector for close-water open-air (CWOA) air heated humidification –dehumidification process

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Abstact: *The solar air heater is newly developed air tight circular collector in which dull black powder coated aluminum tube of thickness 1.0 mm is used as absorber. The absorber tube is placed cocentrically in borosilicate glass tube, and at the both ends of these tubes neoprene rubber are place which will act as sealent to the air preasent between absorber and glass tubes and neoprene rubber also maintain gape between absorber and glass tube. These type of 04 assamblies are placed into the frame.A air inlet pipe conect four assamlies at bottom with air blower whoses speeds are regulat by ressistance regulator. Four assamlies are open in air outlet unit Efficiency evaluations were conducted during daylight hours over a 2-month period and included extensive monitoring and recording of temperatures with type- RTD (PT 100) placed at key locations throughout the system. The results confirmed the anticipated fluctuation in collector efficiency dependent on the time of day, solar energy irradiation, ambient temperature and circular tube surface mean temperature. An efficiency of approximately 78% was achieved.*

Keywords*: Circular Solar Collector, Air Inlet Temperature, Heat Loss*

I. INTRODUCTION

Solar air heaters are used for space heating and drying .In different solar heating system, air heater is an important components. Thermodynamics properties like heat transfer coefficients for air heater is low. Other way low convective heat transfer between airs is flowing in heater and absorber plate. Also high heat losses among absorber plate and surrounding environment which results in decrease of the efficiency. Heat transfer coefficient can be improved by providing fully turbulent flow in experimental system. Collector lengths, type of absorber plate, collector depth, wind speed and glass cover plate are important factor which help to improve the efficiency of solar air heater. The design of solar air heater is depend on various parameter such as an absorber plate shape factor, dimension. Efficiency of air heater increase by providing large shape area which improve heat transfer to flowing air in collector ,beside higher pressure drop in system result in more power consumption.[1.]Different design with various shapes and dimensions of air flow passages for plate type solar air collector were checked[2-7].Obstruction are fitted in air channel duct which increase in heat transfer between absorber plate and air steam , result in improvement of thermal performance of solar collector of air heater[5]. Design of obstructions provide uniforms air distribution to the system [8, 9]. Second law of thermodynamics is used to analyse the design of thermal system analysis[10]. First law of thermodynamics applied to typical thermodynamics design based on energy balance of the system. Second law of thermodynamic analysis associate with a standard design development lead to important idea into the operation of system. First and Second law of thermodynamics give exergy analysis in comparisons with energy analysis ,it mean how much quality of energy is transferred. The main aim of exergy analysis is to evaluate the cause of problem of the chemical and thermal processes.A powerful tool to design a system is exergy analysis because of optimization and performance evaluation of energy utilization are easily achieved .The main source of exergy loss and production of entropy can be minimized by this analysis, in a given thermodynamic process where material as well as transfer of energy is important[11,12]. Dincer and Rosen suggested [13] the design and analysis of thermodynamics system ,using energy principle and conversation of mass are together with second law of thermodynamics where energy analysis is an important . Exergy analysis gives ideas , definitions and approvable technique. With the help of them it is possible forn a more efficient design[14,17].Demirel and Ozturk [18] explained this by practical performance of air heater with Raschig rings. They noticed that efficiency of exergy and energy for packed bed solar air heater increases as outlet temperature of heat transfer is increased. Seasonal latent heat storage system for greenhouse heating with the solar air heater ,Ozturk narrate experimental evalution of exergy and energy efficiency[19].Ucar and Inalli introduced passive augmentation technique for exergy and thermal analysis.In this paper we present result obtained by the circular solar collector air heater for significant variables.

II. DESCRIPTION OF THE SYSTEM

Air heater is manufactured by assembly of different parts like absorber tubes, glass tube covers, neoprene rubbers,air inlet unit,air outlet unit,support cover, axcial blower, speed regulator for axcial blower and iron stand. It is instrumented by RTD (PT 100) at various locations which are associated with Temperature Indicator for getting tmperature during uniform time interval as well as Anemometer which is used for measurement of air speed (wind), Pyranometer is help to obtain radiation intensity.

Table 1: Characteristics of Solar Air Heater

Absorber tube		Glass tubes	
No. of tubes	4	No. of tubes	4
Material	Aluminum	Material	Borosilicate glass
Coating	Dull black powder coating	Emissivity	0.7
Emissivity	0.38	Transmissivity	0.9
Absorptivity	0.9	Thickness	1.5 mm
Thickness	1.0 mm	Length	1500 mm
Diameter	36mm(ID)	Diameter	54 mm(ID)
	38 mm(OD)		60 mm(OD)
Length	1600 mm	Collector area	0.5652 m^2
Spacing between two tubes	120 mm	Spacing between two tubes	60 mm

Fig 1. Air Heater

Fire work is done on both end of glass tube to prevent fracure at the time of assemly. Borosilicate glass tube used as a collector cover for reducing convectional and radiation heat losses. The absorber tube is placed cocentrically in borosilicate glass tube, and at the both ends are sealed with neoprene rubber, which will act as sealent to the air preasent between absorber and glass tubes .Neoprene rubber also maintain gape between absorber and glass tube. Air inlet unit is manufactured from mild steel cylinder, having 760 mm length ,120 mm inside diameter and 123.2 mm out side diameter. It supports four absorber tubes as well air blower. Air outlet unit also made from Aluminum rectangular section 85mm×45mm .There are four circular holes drilled for joining absorber tubes.It is closed at one end with cover and other end of duct is connected with Humidification chamber. Air outlet unit having 830 mm length.Two support cover are made from MS sheet which are bend on hydraulic press and punched six circular holes. They are supports to solar circular collectors , air inlet unit and air out let unit.They are clamped on frame having slope of 35^0 with horizontal surface.

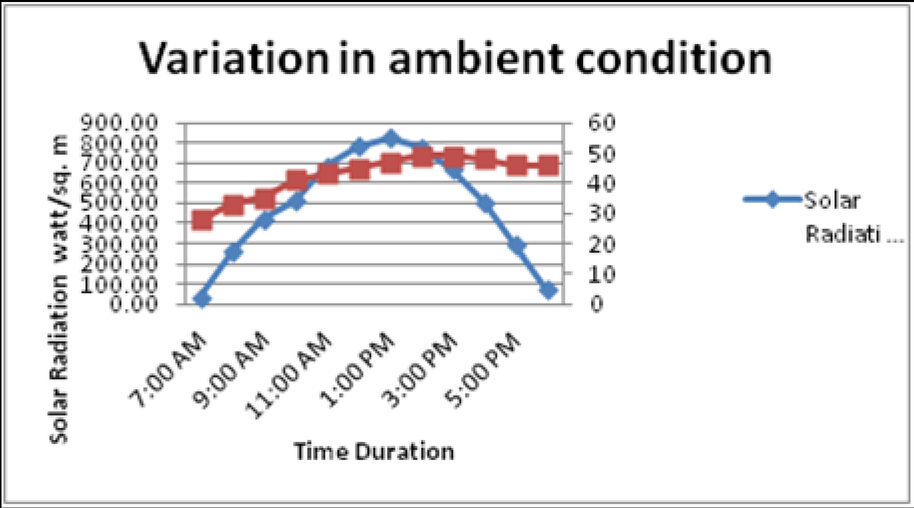
III PROCEDURE

The experimental apparatus is located at Vadodara latitude 22.000 N 73.10° E. The air heater is inclined at 35^0 south facing and connected to humidification chamber. The whole assambly is mounted on the fixed stand. The experimental setup was run from 07:00 Am To 06:00 pm. Every one hour interval temperature on four absorber outer surface have been taken. Simultaneously four outer surface temperatures on glass tube are noted. Also air inlet temperature and out let temperature are readied by Digital temperature indicator. The experiments are conducts by varying flow rate of air of $5.7x10^{-3} m^3/s$,$7.92x10^{-3} m^3/s$,$9.72x10^{-3} m^3/s$,$11.52x10^{-3} m^3/s$, $13.32x10^{-3} m^3/s$, $14.4x10^{-3} m^3/s$ and the measurements of solar radiation using pyranometer with some assumptions like climate conditions averaged per hour, no air leakage, time dependent performance, heat loss or gain from edges of the solar air heater to ambient are neglected

IV RESULT AND DISCUSSION

As per the system arrangement and following procedures, result obtained for variant ambient condition and air inlet temperature for different air flow.

Table 2 : Variation in ambient condition on 12th April 2014



12-04-14		
Solar Isolation, W/m²	Ambient Temperature, °C	Time
37.25	28	7.00 am
260	33	8.00 am
425	35	9.00 am
509.73	41	10.00 am
685.93	43	11.00 am
785.85	45	12.00 pm
824.12	47	01.00 pm
775.7	49	02.00 pm
667.4	49	03.00 pm
504.5	48	04.00 pm
293.5	46	05.00 pm
73.99	46	06.00 pm

Figure 2: Variation in ambient condition on 12th April 2014

4.1 Effect of air inlet temperature on efficiency for different dates

Table 3: Effect of air inlet temperature on efficiency

At Air Flow Rate= 0.0057 m³/s								
Date	Time Hr.	Air Inlet Temp, °C	Absorber tube Temp, °C	Glass Tube Inner Temp, °C	Heat Loss, W	Solar, radiation W/m2	Incident Solar radiation ,W	Collector efficiency, %
12-04-14	7:00	23	26.25	26	0.47	39.64	22.4	78.9
	8:00	27	38.75	32	25.29	222.36	125.68	60.88
	9:00	32	50.25	36.5	60.1	325	183.69	48.28
	10:00	36	57.75	40	83.85	489.38	276.6	50.69
	11:00	39	61.25	43	84.87	647.78	366.13	57.82
	12:00	42	64	46	83.57	743.32	420.12	61.11
	13:00	43	65.25	47	87.06	766.1	433	60.89
	14:00	43	63.5	46	80.75	730.35	412.79	61.44
	15:00	43	63.5	47	75.2	657.29	371.5	60.76
	16:00	43	60	47	57.55	526.78	297.74	61.67
	17:00	43	54.25	47	28.42	280	158.26	63.04
	18:00	41	43.75	43	1.84	39.25	22.18	72.71

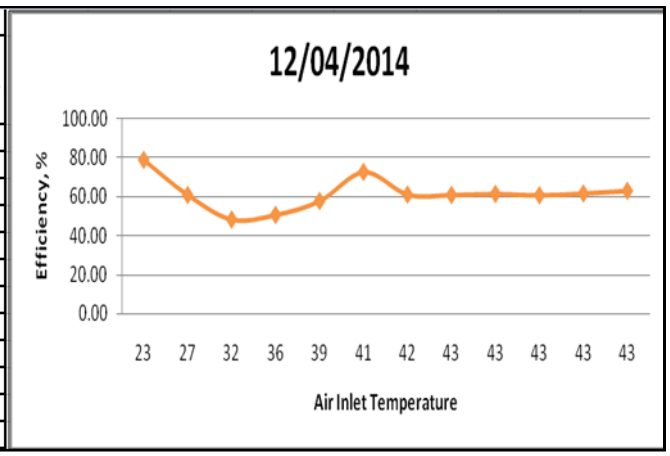


Figure 3: Effect of air inlet temperature on efficiency

Table 4: Effect of air inlet temperature on efficiency

At Air Flow Rate= 0.01332m³/s									
Date	Time Hr.	Air Inlet Temp, °C	Absorber tube Temp, °C	Glass Tube Inner Temp, °C	Heat Loss, W	Solar radiation W/m2	Incident Solar radiation ,W	collector efficiency, %
21-04-14	7:00	27	31	30.5	1.08	38.99	22.04	76.09
	8:00	31	41.25	34.5	25.33	189	106.82	57.29
	9:00	33	47.25	36	47.05	362.28	204.76	58.02
	10:00	36	52.75	39	61.68	522.36	295.24	60.11
	11:00	40	55.25	43.5	64.48	779.07	440.33	66.36
	12:00	41	60.25	44.5	70.98	851.16	481.08	66.25
	13:00	43	61.5	47	64.26	889.65	502.83	68.22
	14:00	44	61.25	47	62.91	860.9	486.58	68.07
	15:00	46	61	48.5	53.68	731.78	413.6	68.02
	16:00	47	57.75	49	35.59	472.54	267.08	67.67
	17:00	46	51.5	46	19.83	200	113.04	63.45
	18:00	43	44.5	44	1.13	39	22.04	75.85

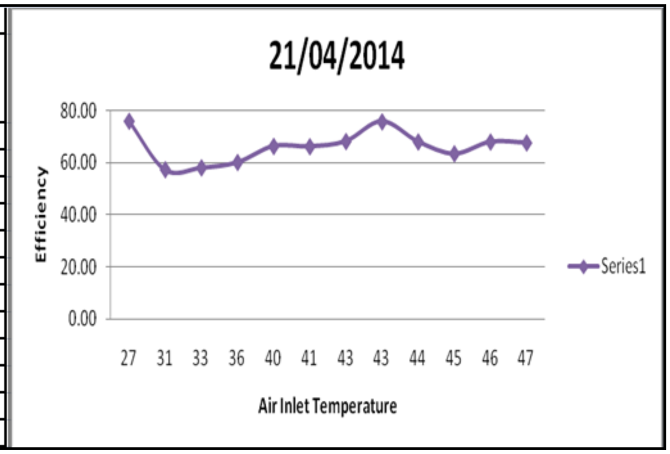


Figure 4: Effect of air inlet temperature on efficiency

Table 5: Effect of air inlet temperature on efficiency

At Air Flow Rate= 0.01152m³/s								
Date	Time Hr.	Air Inlet Temp, °C	Absorber tube Temp, °C	Glass Tube Inner Temp, °C	Heat Loss, W	Solar, radiation W/m2	Incident Solar radiation ,W	collector efficiency, %
23-04-14	7:00	28	30	29.5	1.08	39	22.04	76.1
	8:00	33	41.5	35.5	21.96	187.34	105.88	60.26
	9:00	35	50	38	50.95	402.5	227.49	58.61
	10:00	40	54.5	43.5	54.99	555.73	314.1	63.49
	11:00	43	60.25	47	57.58	729.8	412.48	67.04
	12:00	44	61	47	68.47	847.4	478.95	66.7
	13:00	47	64.75	49	72.83	881.7	498.34	66.39
	14:00	48	63.25	50.5	55.05	820.51	463.75	69.13
	15:00	48	62.25	50	52.42	727.6	411.24	68.25
	16:00	47	56.5	49	28.92	488.32	276	70.52
	17:00	45	53.5	48	20.33	311.56	176.09	69.45
	18:00	43	45.25	45	0.49	42	23.74	78.95

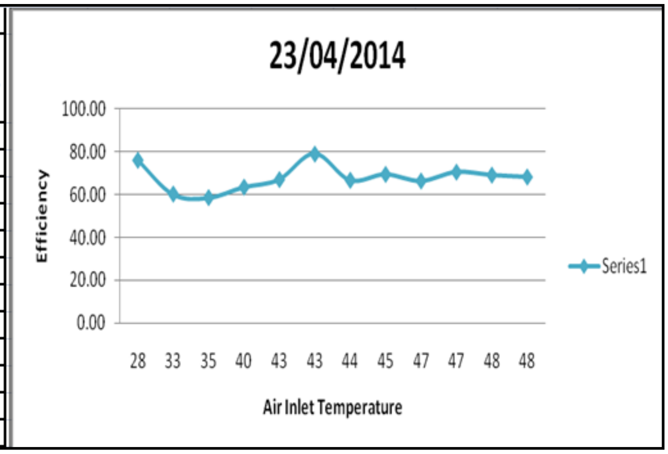


Figure 5: Effect of air inlet temperature on efficiency

Table 6: Effect of air inlet temperature on efficiency

At Air Flow Rate= 0.00972 m³/s								
Date	Time Hr.	Air Inlet Temp, °C	Absorber tube Temp, °C	Glass Tube Inner Temp, °C	Heat Loss, W	Solar, radiation W/m2	Incident Solar radiation ,W	collector efficiency, %
25-04-14	7:00	28	30.25	30	0.47	38.24	21.61	78.81
	8:00	33	43.5	35.5	32.02	201	113.61	52.81
	9:00	36	52	40	51.03	404	228.34	58.65
	10:00	38	56	42	61.54	564.86	319.26	61.72
	11:00	42	61.75	44	82.08	735.5	415.7	61.25
	12:00	45	63.25	48	68.36	837.27	473.23	66.55
	13:00	46	65	47.5	82.74	865.5	489.18	64.09
	14:00	47	63.75	50.5	57.69	809.9	457.76	68.4
	15:00	48	62.5	51	48.58	685.8	387.61	68.47
	16:00	48	60	52	31.98	490.8	277.4	69.47
	17:00	45	54	49	18.13	321.3	181.6	71.02
	18:00	42	43	42.5	1.1	77.21	43.64	78.48

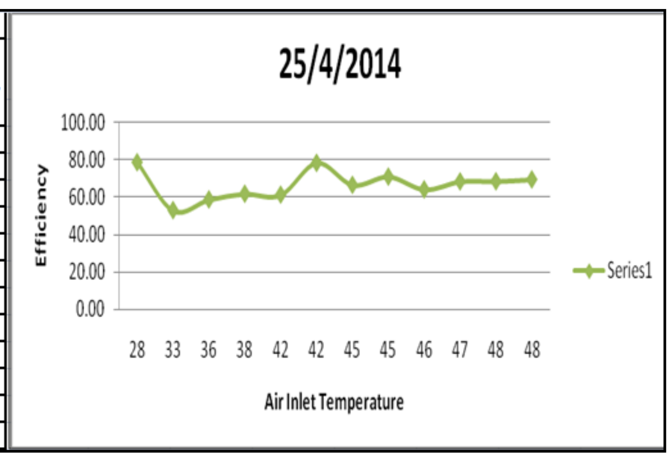


Figure 6: Effect of air inlet temperature on efficiency

Table 7: Effect of air inlet temperature on efficiency

At Air Flow Rate= 0.00792 m^3/s								
Date	Time Hr.	Air Inlet Temp, °C	Absorber tube Temp, °C	Glass Tube Inner Temp, °C	Heat Loss, W	Solar radiation W/m2	Incident Solar radiation ,W	collector efficiency, %
26-04-14	7:00	27	28.5	28	1.08	40.25	22.75	76.26
	8:00	32	43.5	35	34.47	251.68	142.25	56.77
	9:00	34	51	38	56.2	485.15	274.21	60.5
	10:00	38	57.25	42	69.74	537.85	303.99	58.06
	11:00	43	62	45	77.91	702.4	397	61.37
	12:00	45	65.5	48	82.76	804.8	454.87	62.81
	13:00	48	66	50	74.28	825.6	466.63	65.08
	14:00	48	65.75	51	67.31	816.6	461.54	66.42
	15:00	48	63.25	52	47.32	696.05	393.41	68.97
	16:00	48	61	52	36.09	524.6	296.5	68.83
	17:00	46	54.75	49	21.47	327	184.82	69.38
	18:00	44	46.75	45	4.96	88.18	49.84	71.05

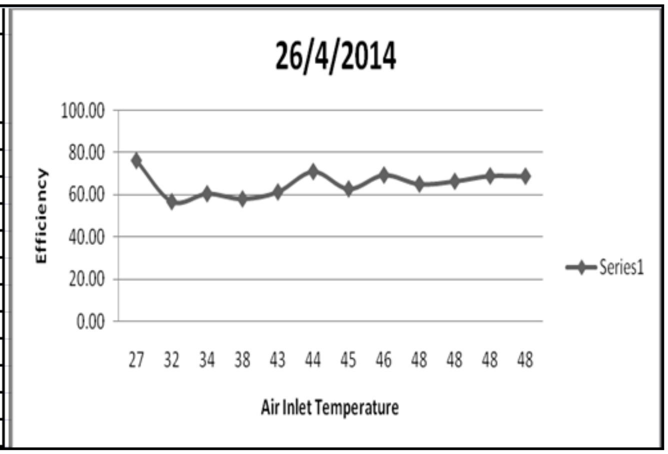


Figure 7: Effect of air inlet temperature on efficiency

Table 8: Effect of air inlet temperature on efficiency

At Air Flow Rate= 0.01442 m^3/s								
Date	Time Hr.	Air Inlet Temp, °C	Absorber tube Temp, °C	Glass Tube Inner Temp, °C	Heat Loss, W	Solar radiation W/m2	Incident Solar radiation ,W	collector efficiency, %
28-04-14	7:00	28	33.25	32.5	1.77	37.25	21.05	72.58
	8:00	33	42.25	35	28.4	260	146.95	61.68
	9:00	35	50.25	39	47.12	425	240.21	61.39
	10:00	41	55.25	44	57.55	509.73	288.1	61.03
	11:00	43	60.75	45	70.99	685.93	387.69	62.69
	12:00	45	62.75	48	67.21	785.85	444.16	65.87
	13:00	47	63.75	50	61.76	824.12	465.79	67.74
	14:00	49	64.5	52	55.06	775.7	438.43	68.44
	15:00	49	63	52	46.05	667.4	377.21	68.79
	16:00	48	60.5	51	38.51	504.5	285.14	67.49
	17:00	47	55.25	49	23.76	293.5	165.89	66.68
	18:00	46	47.75	46.5	3.32	73.99	41.82	73.07

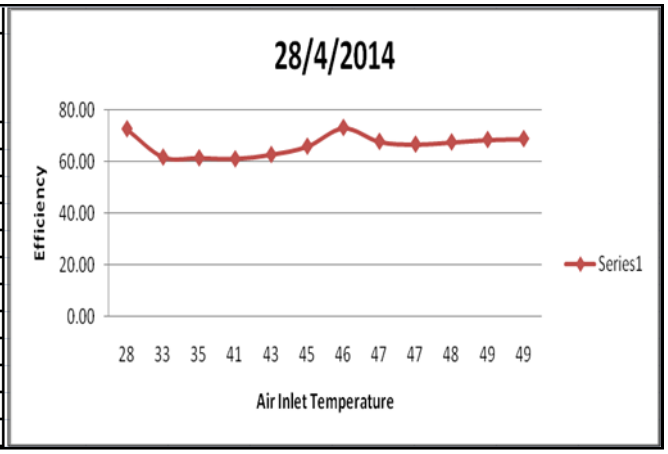


Figure 8: Effect of air inlet temperature on efficiency

V SAMPLE CALCULATION

Date:-28/04/2014, at 01:00 PM

Data:
Air inlet temperature = T_{in} = 47 °C
Absorber tube temperature = T_{abs} = 63.75 °C
Glass tube inner temperature = T_{gi} = 50 °C
Glass tube diameter= D_{ci} = 54 mm
Absorber tube outside diameter = D_o = 38 mm
Mean Temperature,

$$T_{mean} = \frac{T_{abs} + T_{gi}}{2}$$

= 329.88 °K.

At, T_{mean} = 329.88 °K Property of Air from table A-4[1] are,
Thermal Conductivity K= 0.0282 W/mK,
Prandalt No =0.695,
Kinematic Viscosity = 18.21 X 10^{-6} m^2/s,
Temperature Difference Δt,
Temperature Difference Δt = T_{abs} - T_{gi}
= 63.75 – 50
= 13.75 °C

Rayleigh number:

$$R_a = \frac{g \; X \; \Delta t \; X \; (D_{ci} - D_o)^3 X \; Pr}{T_{mean} \; X \; v^2}$$

$$R_a = \frac{9.81 \; X \; 13.75 \; X \; 4.096X10^{-6} X \; 0.695}{329.88 \; X \; (18.21 \; X \; 10^{-6})^2}$$

$$R_a = 3510.32$$

Modified Rayleigh number:

$$(R_a{}^*)^{1/4} = \frac{\ln (D_{ci}/D_o)}{b^{3/4}\left(\frac{1}{D_o{}^{3/5}} + \frac{1}{D_{ci}{}^{3/5}}\right)^{5/4}} X \; R_a{}^{1/4}$$

$= 0.5389 \; X \; R_a{}^{1/4}$

= 4.15

Effective Thermal Conductivity (K_{eff}),

$$K_{eff} = K \; X 0.317 (R_a{}^*)^{1/4}$$

= 0.04

Heat transfer coefficient (h_{p-c})

$$h_{p-c} = \frac{2 \; X \; K_{eff}}{D_o \ln\left(\frac{D_{ci}}{D_o}\right)}$$

$$h_{p-c} = 5.77$$

Overall heat loss coefficient (q/l),

$$\frac{q}{l} = \left\{ h_{p-c}(T_{mean} - T_{gi}) + \frac{\sigma \pi D_o (T_{mean}{}^4 - T_{gi}{}^4)}{\left\{\frac{1}{\varepsilon_p} + \frac{D_o}{D_{ci}}\left(\frac{1}{\varepsilon_c} - 1\right)\right\}} \right\}$$

Where, ε_p = *Emissivity of absorber tube* = 0.38
ε_c = *Emissivity of glass cover* = 0.7

Heat loss, (q)

$$q = \frac{q}{l} \; X \; no.of \; tube \; X \; length \; of \; tube$$

$$q = 61.76 \; W$$

Collector Efficiency (% η), τα = 0.9×0.9 = 0.81

$$Collector \; Efficiency = \eta = \frac{A_c \; X \; IT \; X \; 0.81 - q}{A_c \; X \; IT}$$

$$\eta = 0.6774$$

$$\eta = 67.74 \%$$

VI CONCLUSION

The air inlet temperature is an operational parameter which strongly influences the performance of collector .It is seen from above graphs , that the efficiency of the collector decrease as the air inlet temperature increase .In graph 40°C to 44°C temperature efficiency increase due to ambient condition.

Variations in ambient conditions were observe, in which solar radiation received was higher during 12:00 pm to 1:00 pm, lower during morning, and evening. In addition, there is variation in ambient temperature; it was lower during morning periods and higher during 12:00 pm to 03:30 pm.. These parameters are use during experiments and hence it is important to understand the variation of that.

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