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Experimental Investigation on Solar Air Heater-Based Humidification-Dehumidification System to Produce Clean Water

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ABSTRACT

Large seawater is available in India. Desalination is becoming a crucial method for producing fresh water. The Humidification-Dehumidification process for water desalination has a number of benefits, including decentralized application, easy installation, low operation costs, flexibility in capacity, and simplicity. With the use of solar air heater, the experimental setup of HDH system was run during the sun shine hours. With Solar air heater the water evaporation rate increases by 2.67 kg/day. Water evaporation rate increases as increases relative humidity of air coming out from humidifying chamber. Efficiency of solar air heater increases with increases in flow rate of air. Heat gain by air depends on mass flow rate of air, it increases by decreases mass flow rate of air and reduce by increasing mass flow rate of air and also heat gain by air depends upon the ambient temperature, as the ambient temperature increases heat gain will decreases which will further decreases the solar air heater efficiency. The experiments were conducted by varying mass flow rate of air and also without solar radiation.

Keywords : Desalination, Humidification, Dehumidification, Solar air heater

I. INTRODUCTION

A clean water supply has become essential to life due to the swift rise of the industrial and agricultural sectors as well as the population. Many reservoirs have dangerously low fresh water levels. The remaining freshwater supplies are contaminated by waste water from industrial facilities, plants, and big city sewage. Glaciers and ice caps make up 2% of the planet's water, whereas fresh water makes up 0.5%. whereas 97% of water is found in the sea. Large seawater is available in India. Desalination is becoming a crucial method for producing fresh water. The Humidification-Dehumidification process for water desalination has a number of benefits, including decentralized application, easy installation, low operation costs, flexibility in capacity, and simplicity. An experimental instigation has been discussed here.

II. METHODOLOGY

The solar assisted waste water evaporation system shown in fig-1. This experimental setup was located Vadodara latitude 22.00° N 73.10 °E, which works on the open-air closed water humidification system. In which evaporation of waste water is taking place by humidification of air which is heated by solar air heater. At stage 1 ambient air is passing through the airtight circular solar air heater where the sensible heat of air is taking place which reduce the relative humidity of air. Now at stage-2 this air is goes to humidification chamber where the water kept at the

bottom and this water is falling from humidification bed using a circulating pump, while passing through falling water air humidified and water evaporated. At stage 3 humidified air comes out through the humidification chamber and goes to dehumidification chamber where fresh water collected. The solar air heater is inclined at 35° south facing and connected to humidification chamber.

Fig.-1 Solar waste water evaporating system

Effect of various parameter on the system:

The experimental setup was run from 12/04/2017 to 29/04/2017 from 07:00 AM to 06:00 PM. The experiments were conducted by varying mass flow rate of air and also without solar radiation, whose results are discussed here.

1. Variation in ambient condition:

Variation in ambient conditions were observed, in which solar radiation received was higher during 12:00 PM to 01:00 PM, and lower during morning and evening. In addition, there was variation in ambient temperature; it was lower during morning period of time and higher during 12:00 PM to 03:30 PM. The relative humidity of ambient air was decreasing from morning to evening. These parameters are used during experiments. Hence it is important to understand the variation of it.

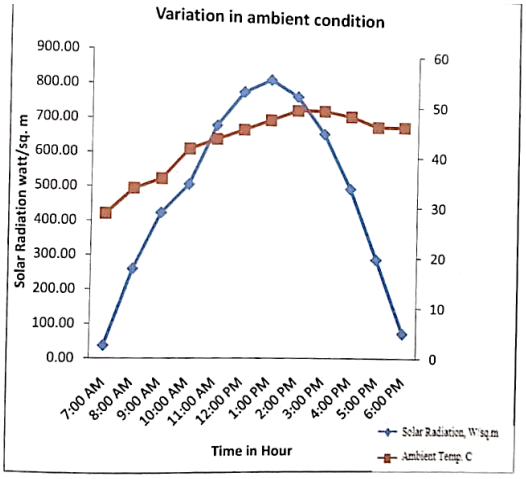

Fig-2 variation in ambient conditions

2. Effect of flow rate of air on efficiency of solar air heater

To know the effect of mass flow rate of air on the efficiency of solar air heater, graph of efficiency of solar air heater Vs time duration is plot for different mass flow rate of air as shown in fig-3. It is observed that the efficiency of solar air heater decreases in afternoon and increases at morning and evening period of time, its due to fact that the heat gain during afternoon is decreased due to increases in ambient temperature and also at the same time duration solar radiation received on collector surface is high.

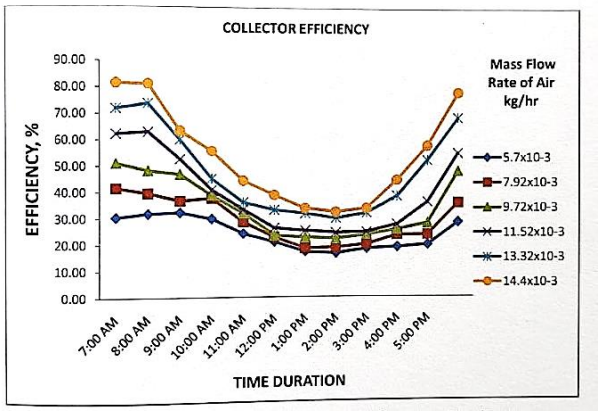

Fig 3 Efficiency of solar air heater for different working hours

3. Effect of mass flow rate on efficiency of solar air heater

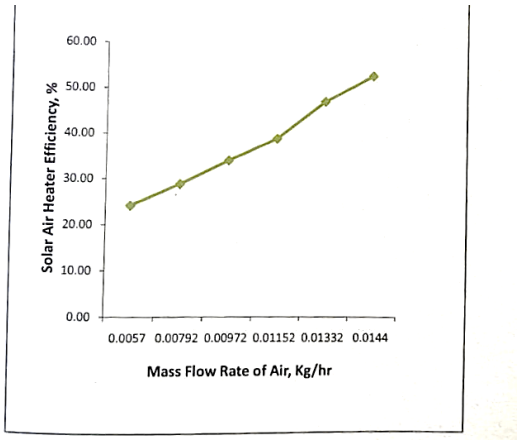

Fig 4 Effect of mass flow rate on efficiency of solar air heater

Table 1 efficiency of solar air heater with different mass flow rate

Date	Flow rate of Air m^3/s	Overall Efficiency in %
12/04/2017	5.3×10^{-3}	24.11
26/04/2017	7.92×10^{-3}	28.97
25/04/2017	9.72×10^{-3}	34.30
23/04/2017	11.52×10^{-3}	39.32
21/04/2017	13.32×10^{-3}	47.81
28/04/2017	14.4×10^{-3}	53.79

It is observed that the efficiency of solar air heater is increased with increased in mass flow rate of air. On 28/04/2017, at 14.4×10^{-3} kg/hr mass flow rate of air, maximum 53.79% efficiency achieved.

4. Effect of flow rate of air on heat gain.

It is observed that the heat gain from solar air heater is decreased with increased of mass flow rate of air. It is because of at lower mass flow rate of air resting time of air in solar air heater is more, which leads more heat gain and at higher mass flow rate of air resting time of air in solar air heater is less, which decreased heat gain. Fig 5 shows the heat gain in solar air heater at different mass flow rate of air for different working hours.

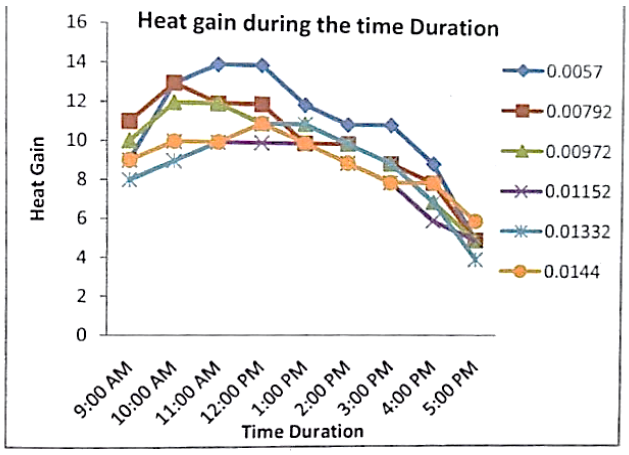

Fig 5 effect of mass flow rate of air on heat gain

Table 2 Heat gain °C for different working hours and mass flow rate of air

Date	Flow rate of Air m^3/s	Temperature gain °C during working hours								
		09:00	10:00	11:00	12:00	01:00	02:00	03:00	04:00	05:00
12/04/2017	5.3×10^{-3}	9	13	14	14	12	11	11	9	5
26/04/2017	7.92×10^{-3}	11	13	12	12	10	10	9	8	5
25/04/2017	9.72×10^{-3}	10	12	12	11	11	10	9	7	5
23/04/2017	11.52×10^{-3}	9	10	10	10	10	9	8	6	5
21/04/2017	13.32×10^{-3}	8	9	10	11	11	10	9	7	4
28/04/2017	14.4×10^{-3}	9	10	10	11	10	9	8	8	6

1. Effect of flow rate of air on water evaporation rate.

It is observed that evaporation rate of water is increased with increased in mass flow rate of air as shown in fig 6. Evaporation rate achieved during working hours 12:00 PM to 03;00 PM is higher compared to other working hours.

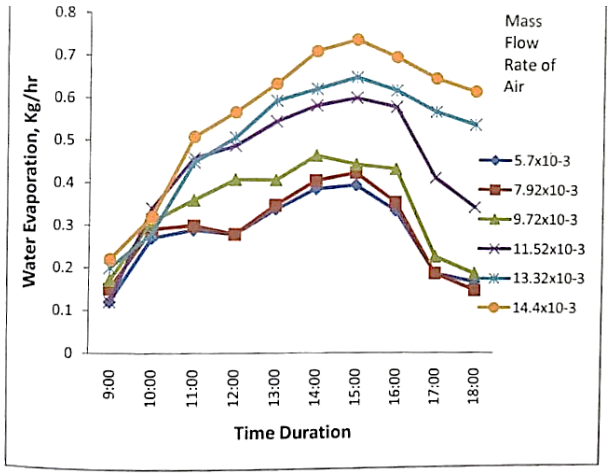

Fig-6 Effect of mass flow rate of air on water evaporation rate

2. Effect of flow rate of air on relative humidity.

Table 3 water evaporation rate during working hours at different mass flow rate of air

Date	Flow rate of Air m^3/s	Water evaporation rate(kg/hr) during working hours										Total
		09:00	10:00	11:00	12:00	01:00	02:00	03:00	04:00	05:00	06:00	
12/04/2017	5.3 x 10^{-3}	0.12	0.27	0.29	0.28	0.34	0.39	0.40	0.34	0.19	0.17	2.62
26/04/2017	7.92 x 10^{-3}	0.15	0.29	0.30	0.28	0.35	0.41	0.43	0.36	0.19	0.15	2.74
25/04/2017	9.72 x 10^{-3}	0.17	0.31	0.36	0.41	0.41	0.47	0.45	0.44	0.23	0.19	3.24
23/04/2017	11.52 x 10^{-3}	0.12	0.34	0.46	0.49	0.55	0.59	0.61	0.59	0.42	0.35	4.16
21/04/2017	13.32 x 10^{-3}	0.20	0.28	0.45	0.51	0.60	0.63	0.66	0.63	0.58	0.55	4.53
28/04/2017	14.4 x 10^{-3}	0.22	0.32	0.51	0.57	0.64	0.72	0.75	0.71	0.66	0.63	5.11

At mass flow rate 14.4 x 10-3 m3/hr of air, evaporation rate achieved highest up to 5.11 kg/day. Table 3 shows the evaporation rate for different working hours at different mass flow rate of air.

Table 4 Relative humidity corresponding to Evaporation rate

Date	Flow rate of Air m^3/s	Water evaporation rate(kg/hr) during working hours										Total	% RH
		09:00	**10:00**	**11:00**	**12:00**	**01:00**	**02:00**	**03:00**	**04:00**	**05:00**	**06:00**		
12/04/2017	5.3 x 10^{-3}	0.12	0.27	0.29	0.28	0.34	0.39	0.40	0.34	0.19	0.17	2.62	**42**
	% RH	32	34	37	45	46	50	55	51	45	40		
26/04/2017	7.92 x 10^{-3}	0.15	0.29	0.30	0.28	0.35	0.41	0.43	0.36	0.19	0.15	2.74	**43.5**
	% RH	34	41	43	47	51	54	59	58	54	50		
25/04/2017	9.72 x 10^{-3}	0.17	0.31	0.36	0.41	0.41	0.47	0.45	0.44	0.23	0.19	3.24	**49**
	% RH	34	35	40	41	46	51	49	47	41	40		
23/04/2017	11.52 x 10^{-3}	0.12	0.34	0.46	0.49	0.55	0.59	0.61	0.59	0.42	0.35	4.16	**52**
	% RH	43	42	47	49	50	56	63	58	54	55		
21/04/2017	13.32 x 10^{-3}	0.20	0.28	0.45	0.51	0.60	0.63	0.66	0.63	0.58	0.55	4.53	**50**
	% RH	41	42	43	49	50	51	58	55	54	53		
28/04/2017	14.4 x 10^{-3}	0.22	0.32	0.51	0.57	0.64	0.72	0.75	0.71	0.66	0.63	5.11	**52.4**
	% RH	40	44	44	47	49	63	64	60	58	55		

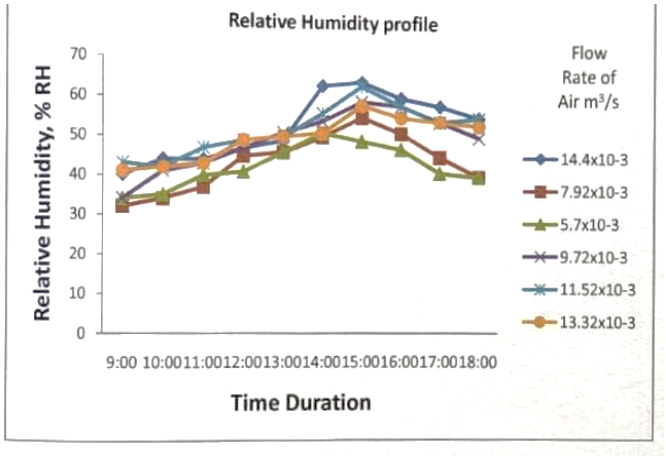

Fig. 7 Relative humidity profile

From the table 4 and figure 7, as mass flow rate of air increased evaporation rate of water increased hence relative humidity increased. Between the working hour 13:00 to 18:00 evaporation rate increases due to that relative humidity inside the humidification chamber increased. The experiment was conducted without use of solar air heater, the collector was covered by wooden sheet. Hence the system was working on ambient air only and without heating of air evaporation of air water depend on ambient temperature and relative humidity only. Table 5 shows the water evaporation without solar air heater. From the experiment it can says that at same mass flow rate of air, evaporation rate is decreased by 2.67 kg/day If solar air heater is not used. Also, it can say that evaporation rate increased by 2.67 kg/day by using solar air heater.

Table 5 Evaporation of water without using solar air heater

Date	Flow rate of Air m^3/s	Water evaporation rate(kg/hr) during working hours										Total
		09:00	10:00	11:00	12:00	01:00	02:00	03:00	04:00	05:00	06:00	
29/04/2017	14.4 x 10^{-3}	0.10	0.21	0.23	0.28	0.32	0.35	0.39	0.28	0.15	0.12	2.44

5. Effect of Air Inlet temperature on solar collector Efficiency

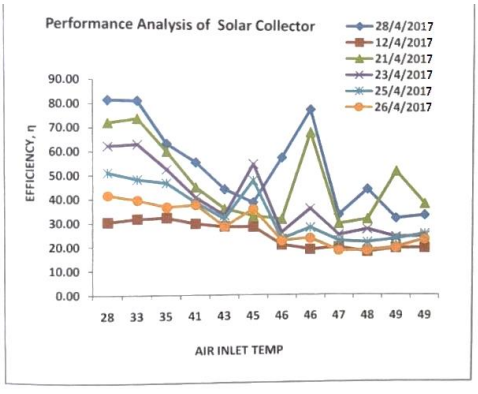

Fig 8 performance analysis of solar collector

Fig-8 shows that the collector efficiency is decreased as inlet air temperature increases, because of air inlet and air outlet temperature increased hence as per efficiency of collector is useful heat gain to solar insolation.

III. CONCLUSION

Following conclusions are obtain from the experimental work.

1. Efficiency of solar air heater increases with increases in flow rate of air.
2. Heat gain by air depends on mass flow rate of air, it increases by decreases mass flow rate of air and

reduce by increasing mass flow rate of air and also heat gain by air depends upon the ambient temperature, as the ambient temperature increases heat gain will decreases which will further decreases the solar air heater efficiency.

3. Water evaporation rate increases as increases relative humidity of air coming out from humidifying chamber.
4. Solar air heater increases the water evaporation rate by 2.67 kg/day.

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