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Experimental study of Dehumidifier for close water and open air (CWOA) system using Circular solar collector , Humidification–Dehumidification process

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Abstract — *Coastal area where clean drinking water availability is measured problem, which insist to innovate cheep, decentralized small-scale water production. The geographical conditions of vadodara (22.00N, 72.10E),and kachh, Gujarat are best suitable for humidification-dehumidification (HDH) technique based on closed-water, open-air cycle where air heated system is used. Dehumidifiers is heat exchanger in which heat exchange is takes places between two fluids i.e. hot and cold that are at different temperatures. The heat exchange in the heat exchanger may be in the form of latent heat or sensible heat or combination of both. There are different types of heat exchangers available as dehumidifiers for HDH applications vary but they have required strength to withstand corrosive nature of seawater , there for frames, collecting plates, fins are made of aluminum. In addition, special attention was exercised to avoid leakage of distillate water. The HDH concept are also reviewed and compared. Further, novel proposals for improvement of the HDH cycle are outlined. The surprising result is that dehumidifier effectiveness also has an insignificant influence on system productivity, which has very important implications since the cost of the dehumidifier (air cooled heat exchanger) is a major part of the system's cost.*

Keywords- *Humidification; Solar Radiation; Circular Solar Collector; Dehumidification; Air Heater, Dehumidifier*

1. Introduction

The process air passes through the condenser cooled by cold seawater where water vapor condense s and turns into fresh water The condenser of a fin-tube type one of cross sectional area 1.5*1.5 m was used by Y.J. Dia [81]. Cold seawater flows in the tube channel and fresh water is produced on condensation surface in the condenser at the same time. The effect of the relative humidity on the system productivity is given in Fig. 1

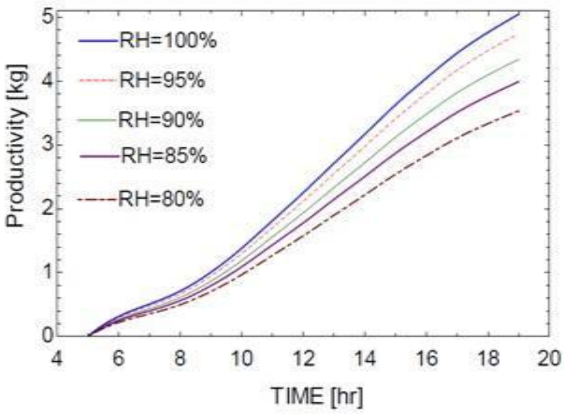

Figure 1 The effect of the relative humidity on the system productivity

In similar study G. Yuan [83] is used two parallel fin tube heat exchanger one above other to strengthen the cooling capacity. Special feature is that humidifier and dehumidifier is composed as single equipment having no physical isolation between them. J. Orfi [53] used. The condenser consists of a chamber with a rectangular cross section. It contains two rows of long cylinders made of copper in which the feed water flows. On outer surface of it saturated water vapor flow along length, during the process (process 2-3 in Fig. 2)

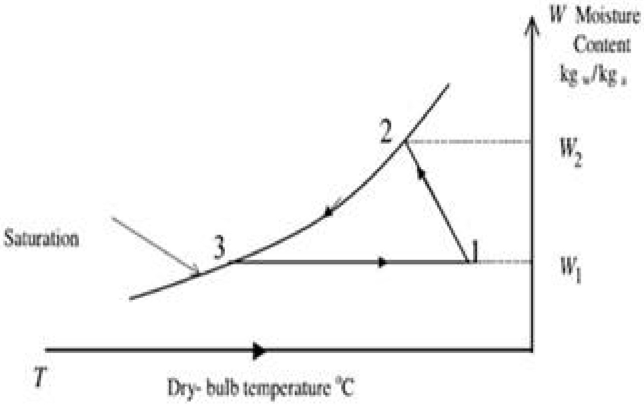

Figure 2 A typical air-heated HDH cycle on psychometric chart

fresh water is recovered and thereby drop in temperature and specific humidity of air. Longitudinal fins were soldered to the outer surface of the cylinders. The condenser is characterized by an exchange surface, 1.5 m 2and 28 m total length. K. Bouroni [84] used horizontal tube bundle through which the brine coolant passes in counter-current flow to the fresh water stream surrounding the tube bundle is the most used configuration. Cemil Yamali [85] worked with three-air cooler heat exchangers manufactured with copper tubes and corrugated aluminum fins were used as a dehumidifier. They were connected to each other with copper tubes in series (exit of one cooler was connected to the inlet of the other cooler). The surface area of each condenser is 3.5 m2 (i.e., the total surface area of the dehumidifier is 10.5 m2). In order to prevent air leakage and heat gain, dehumidifier heat exchanger was placed on an insulated metal box. It was constructed of 2 mm thick galvanized steel by welding. Its dimensions are 40 cm × 47 cm × 34 cm. Chafik [86] used seawater as a coolant wherein the water is heated by the humid air before it is pumped to the humidifiers. Three heat exchangers were used in three different condensation stages. A additional heat exchanger is added at the intake of sea water (low temperature level) for further dehumidification of air. The heat exchangers (dehumidifiers) are finned-tube type air coolers. They developed a theoretical model. The standard method as developed by McQuist on [87] considers finned-tube multi-row multi-column compact heat exchangers and predicts heat and mass transfer rates using Colburn j-factors along with flow rate, dry- and wet-bulb temperatures, fin spacing and other dimensions. The air side heat- transfer coefficient is based on log-mean temperature difference for the dry surface whereas under the condensing conditions, the moist air enthalpy difference is used as a driving potential

2 Construction of dehumidifier

In this type of dehumidifier heat is removed by using natural air circulation. The dehumidifier is made up of aluminum tubing without providing fins . The humidified air flows inside the tubes and the atmospheric air passing over outside the dehumidifier. Dehumidifier contain 16aluminium tube having inside diameter is 6mm and outside diameter is 8 mm ,which are 1000mmlong in size. These tubes are joined by TIG welding precisely, to one end with inlet manifold and other end with outlet manifold. The manifold also made up from aluminum metal plate with the help of hydraulic press also equidistance hole done by radial drilling machine on it. PT100 temperature sensors are used to measured DBT and WBT, which are fix in the two manifold .Dehumidifier arrange between humidifier and reservoir tank .To make air tight joint ‘m’seal adhesive applied . Natural circulation operation is noise free which result in reduction to power consumption.


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Figure 3 Experimental model of dehumidifier

3. Dehumidifier Energy and mass balances equations

Energy and mass balances are applied to a segment of height Δy as shown in Fig.

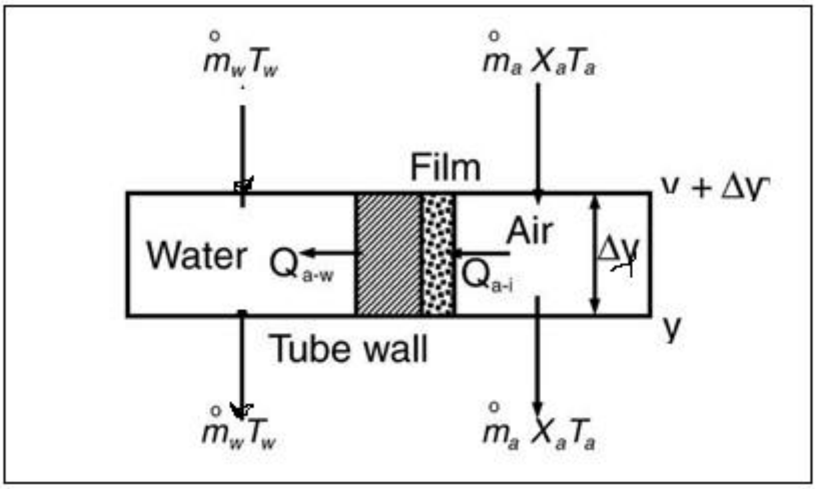

Figure 4. An element of the dehumidifier

$$\mathbf{M_{cw}Cp_{cw}(T_{cwo} - T_{cwi}) = M_a(H_o - H_c)} \quad (1)$$

$$\mathbf{M_{cw}Cp_{cw}(T_{cwo} - T_{cwi}) = U_cA_cLMTD_c} \quad (2)$$

The logarithmic mean

$$\mathbf{LMTDc = \frac{(Tac - Tcwo\ )(\ Tac - \ Tcwi)}{ln\left(\frac{(Tao - Tcwo)}{(Tac - Tcwi)}\right)}}$$

The production of distilled water is given by the following balance equation

$$\mathbf{Md = Ma(Wo - Wc)}$$

Dehumidifier effectiveness η

$$\mathbf{\eta = \frac{T_3 - T_4}{T_3 - T_{amb}}}$$

4. Data collection

The temperatures of the water and air (dry and wet bulb) at different locations in the system were measured by using the PT100 RTD, connected to 8 channel digital temperature indicator recording device. One PT100 RTD, having a minimum scale division of 1°C was used to measure the ambient temperature. Wet-bulb temperature of the air was measured by using a specially prepared RTD . The accuracy of the millimeter is ±0.1%. The process air velocity and wind speed were measured by using a digital battery-powered mini thermo anemometer .The accuracy of the anemometer is ±2%. The mass flow rate of the process air was calculated by using the air velocity. An analog thermo hygrometer was used to measure the relative humidity of the ambient air. Response time of the hygrometer is one minute and its accuracy is ±2%

Figure 5 Experimental model of dehumidifier for (CWOA) using circular solar collector of humidification-dehumidification process

5. Result and discussion.

The experimental setup was run from 20 February 2016 to 30April 2016 during 8.00 am to 6.00 pm and from that data , good Reading collected for the result and discussion. The experiments were conducts by varying flow rate of air.

Table: 1 19/04/2016 Volume flow rate =0.033 m3/s

Time 19/4/2016	Dry Bulb temperature At dehumidifier inlet(°C)	Wet Bulb temperature At dehumidifier inlet(°C)	Dry Bulb temperature At dehumidifier outlet(°C)	Wet Bulb temperature At dehumidifier outlet(°C)	Air inlet temperature (°C)	Water temperature in tank (°C)	Quantity of water (ml)
8	33	25	34	34	34	_	0
9	37	29	41	39	38	_	0
10	40	32	42	40	39	39	5
11	44	36	43	42	40	41	18
12	46	37	44	43	42	42	32
1	47	37	44	43	43	42	43
2	47	38	45	44	43	43	40
3	48	40	46	44	43	42	37
4	48	40	44	43	43	41	29
5	47	39	43	42	42	40	21
6	44	35	41	41	40	39	9

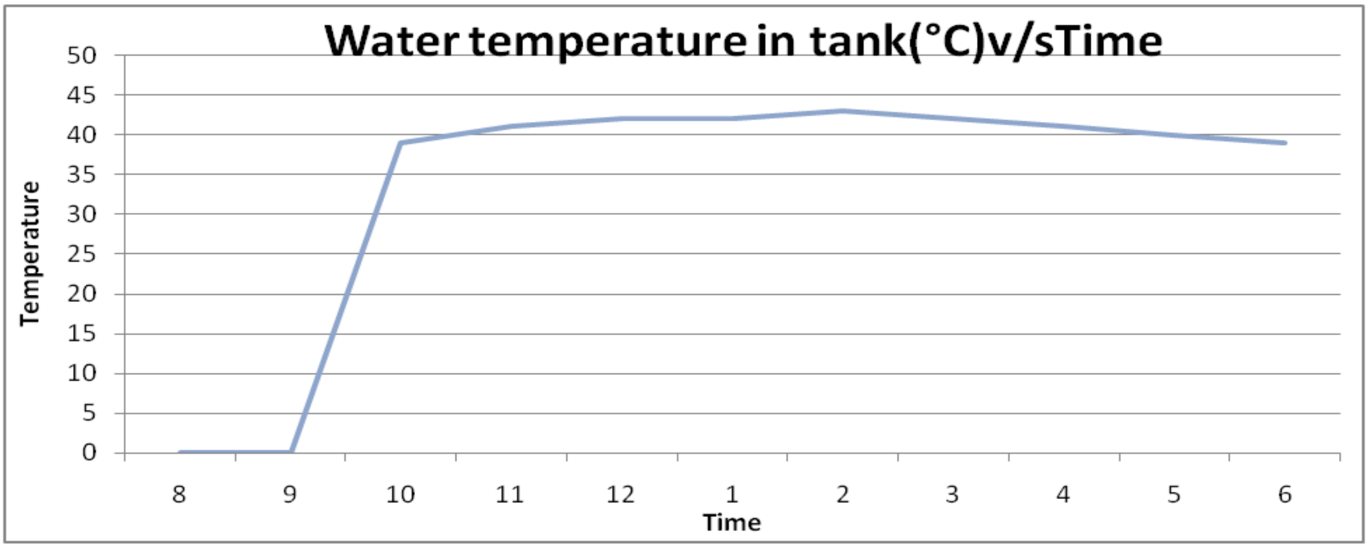

Figure 6 19/04/2016 Volume flow rate =0.033 m3/s

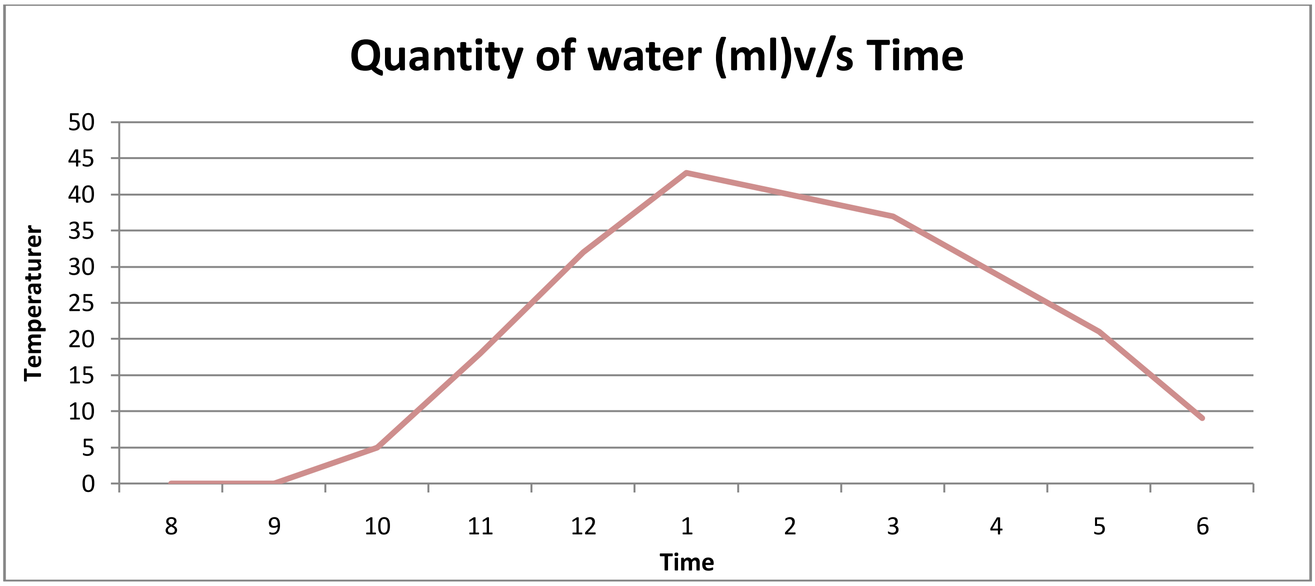

Figure 7 19/04/2016 Volume flow rate =0.033 m3/s

Table: 2 20/04/2016Volume flow rate =0.029 m3/s

Time 20/4/2016	Dry Bulb temperature At dehumidifier inlet(°C)	Wet Bulb temperature At dehumidifier inlet(°C)	Dry Bulb temperature At dehumidifier outlet(°C)	Wet Bulb temperature At dehumidifier outlet(°C)	Air inlet temperature (°C)	Water temperature in tank (°C)	Quantity of water (ml)
8	37	25	36	33	29	_	0
9	38	27	35	34	34	_	0

10	42	32	40	38	39	37	3
11	46	35	43	42	40	40	16
12	48	37	44	43	42	42	25
1	49	38	45	44	43	43	39
2	48	39	44	43	42	42	35
3	47	39	44	43	42	41	30
4	46	38	44	42	41	40	21
5	45	37	44	40	39	39	9
6	43	35	43	39	38	38	6

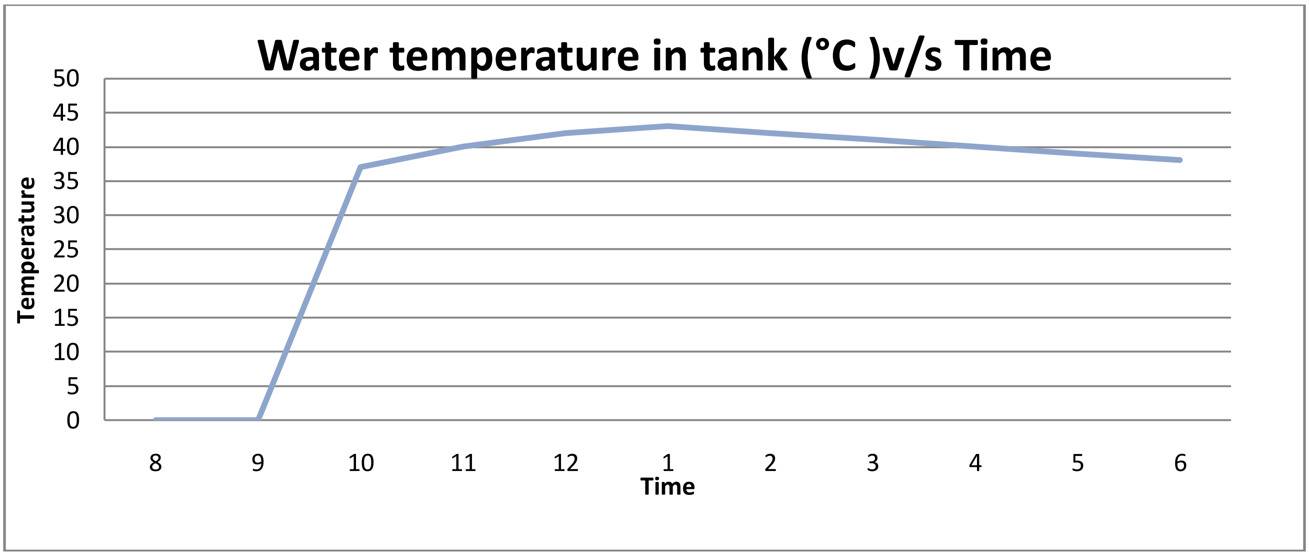

Figure 8 20/04/2016Volume flow rate =0.029 m3/s

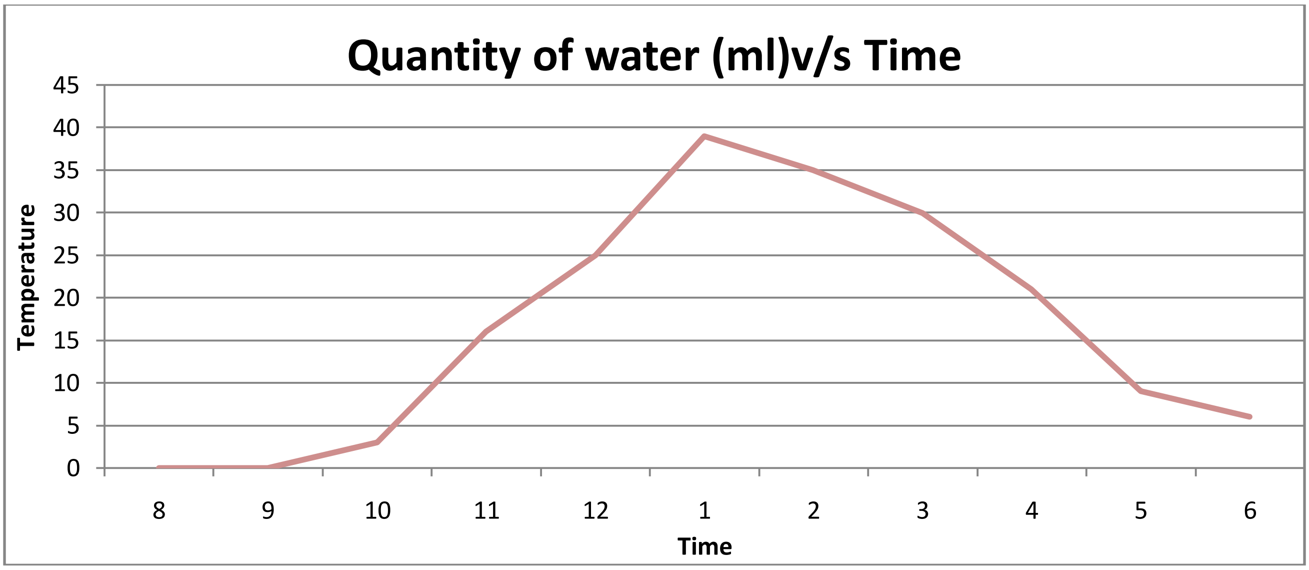

Figure 9 20/04/2016Volume flow rate =0.029 m3/s

Table: 3 21/04/2016Volume flow rate =0.026 m3/s

Time 21/4/2016	Dry Bulb temperature At dehumidifier inlet(°C)	Wet Bulb temperature At dehumidifier inlet(°C)	Dry Bulb temperature At dehumidifier outlet(°C)	Wet Bulb temperature At dehumidifier outlet(°C)	Air inlet temperature (°C)	Water temperature in tank (°C)	Quantity of water (ml)
8	34	25	36	35	33	_	0
9	36	28	39	36	35	_	0
10	40	32	39	38	37	35	7
11	42	34	39	39	37	37	15
12	44	35	39	40	37	39	29
1	46	37	42	41	42	40	36
2	47	38	43	42	42	41	30
3	47	39	42	41	41	40	25
4	46	40	41	40	41	39	20
5	45	41	40	39	40	37	10
6	44	36	39	38	39	36	5

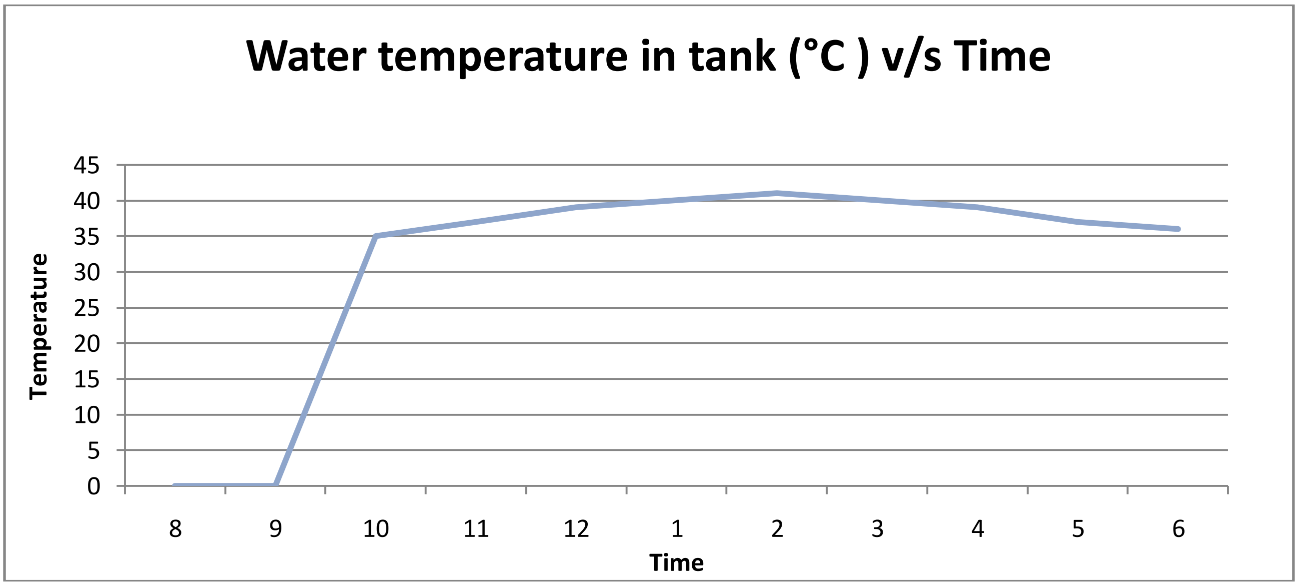

Figure 10 21/04/2016Volume flow rate =0.026 m3/s

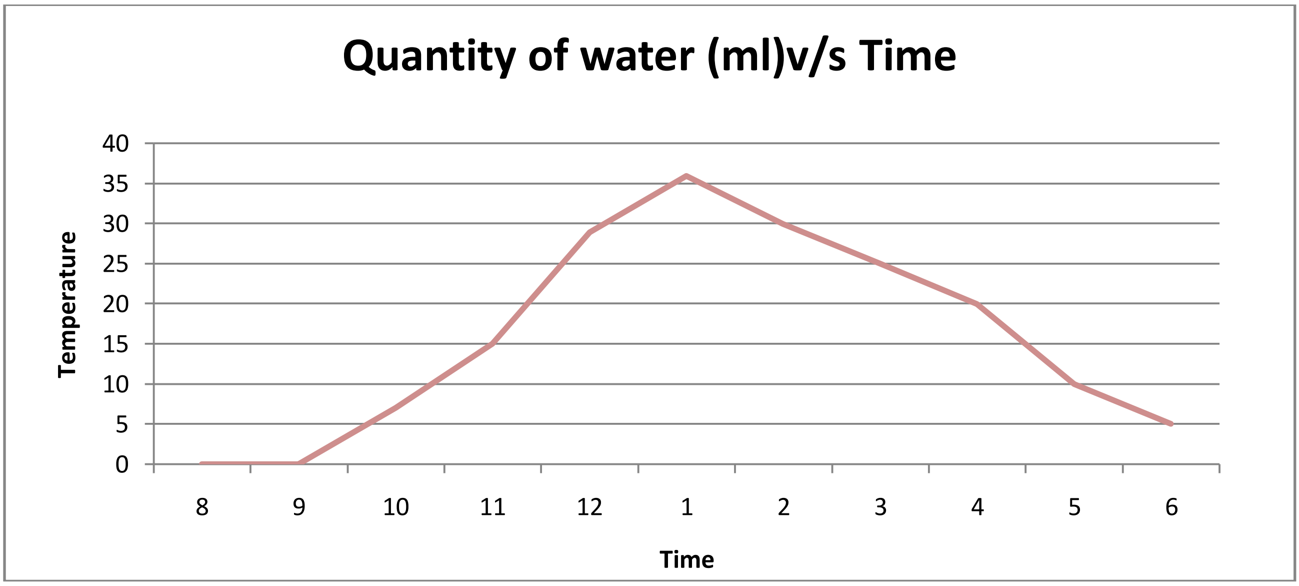

Figure 11 21/04/2016Volume flow rate =0.026 m3/s

Table: 4 22/04/2016 Volume flow rate =0.0202 m3/s

Time 22/4/2016	Dry Bulb temperature At dehumidifier inlet(°C)	Wet Bulb temperature At dehumidifier inlet(°C)	Dry Bulb temperature At dehumidifier outlet(°C)	Wet Bulb temperature At dehumidifier outlet(°C)	Air inlet temperature (°C)	Water temperature in tank (°C)	Quantity of water (ml)
8	33	24	34	33	32	_	0
9	37	29	36	35	35	_	0
10	40	31	41	40	37	39	6
11	44	35	42	41	37	40	14
12	46	37	43	42	38	41	25
1	47	39	44	43	41	42	31
2	50	42	44	42	41	42	25
3	49	42	44	42	42	41	19
4	49	42	43	41	40	40	10
5	49	41	43	41	40	39	8
6	47	38	42	40	38	38	4

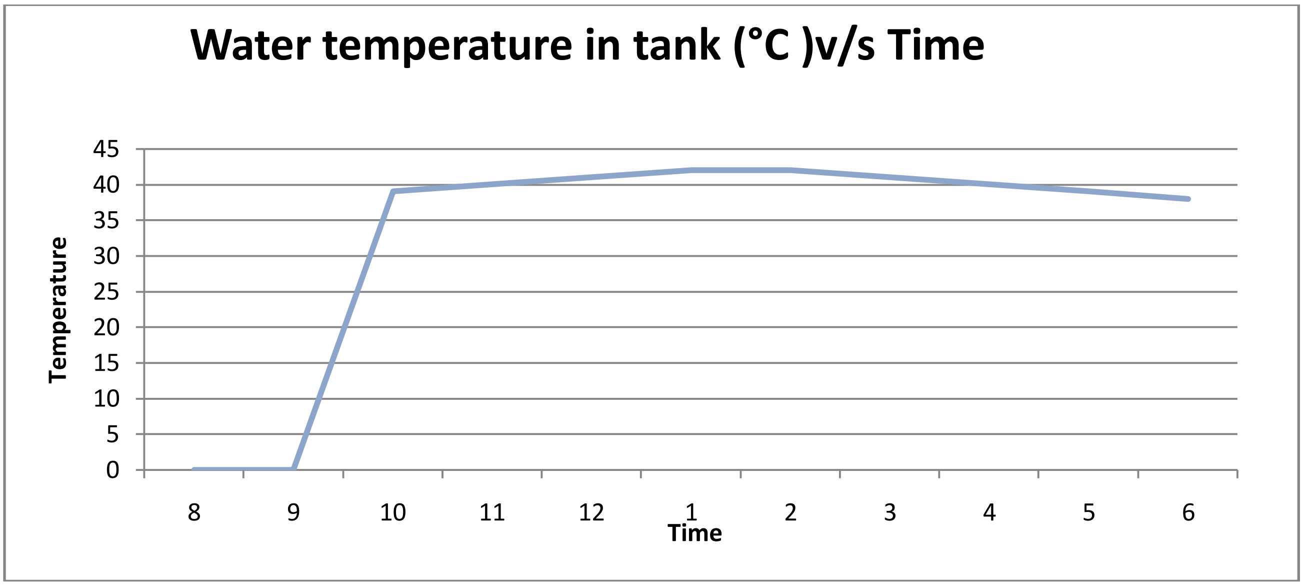

Figure 12 22/04/2016 Volume flow rate =0.0202 m3/s

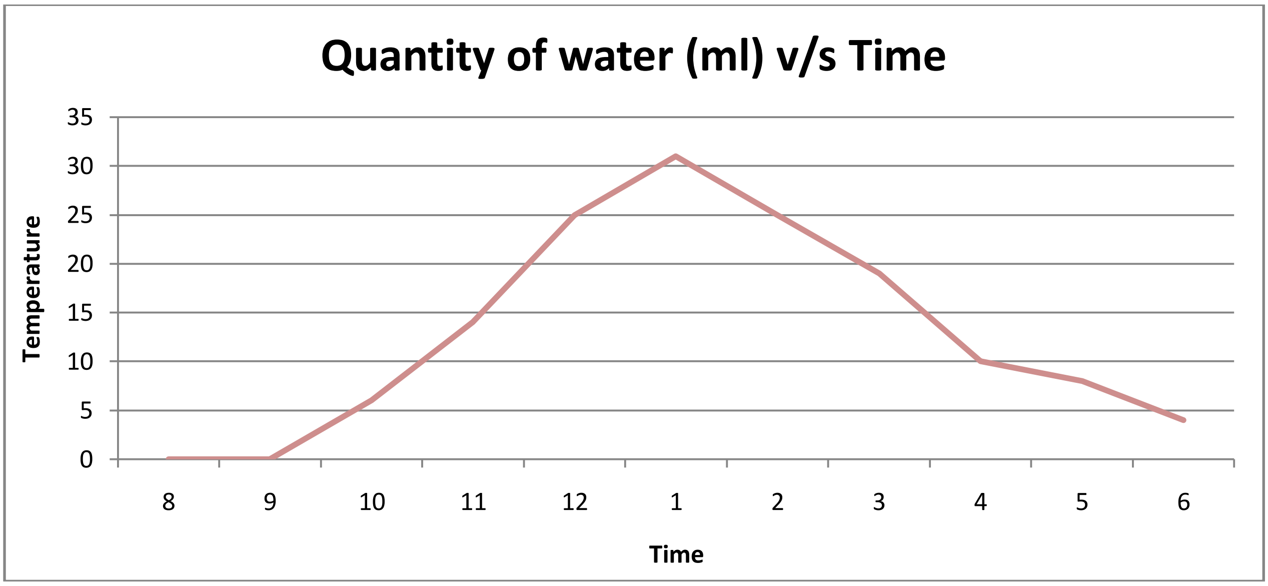

Figure 13 22/04/2016 Volume flow rate =0.0202 m3/s

Water temperature v/s Time

From the graph we can say that water temperature increase till noon and after decrease up to 6.00 pm In the morning, the temperature difference between air and water is very minimum which does not provide sufficient space to water to carry heat .Also difference between air which is condensed and atmospheric air is not much.

Quantity of water v/s Time

The graph give relation between quantity of water production to periodic time In the graph highest quantity of water obtain at 12.00pm to2.00pm which indicate that maximum heat exchange process take place in this time duration. In the morning water production is less and start increase up to 1.00pm then decrease gradually up to6.00pm.

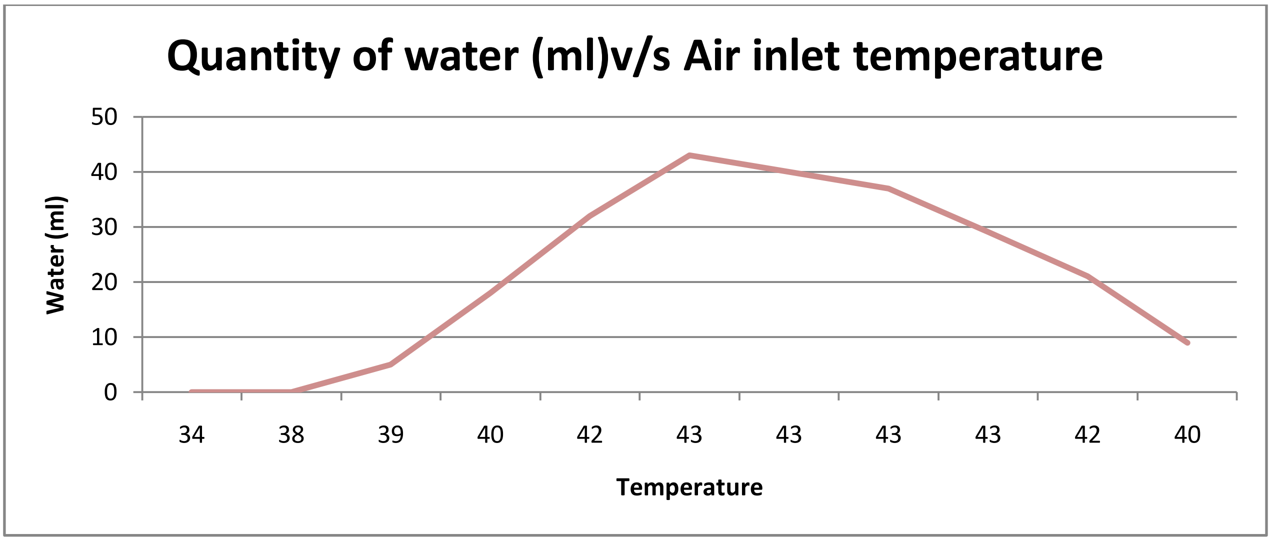

Figure 14 19/04/2016 Volume flow rate =0.033 m3/s

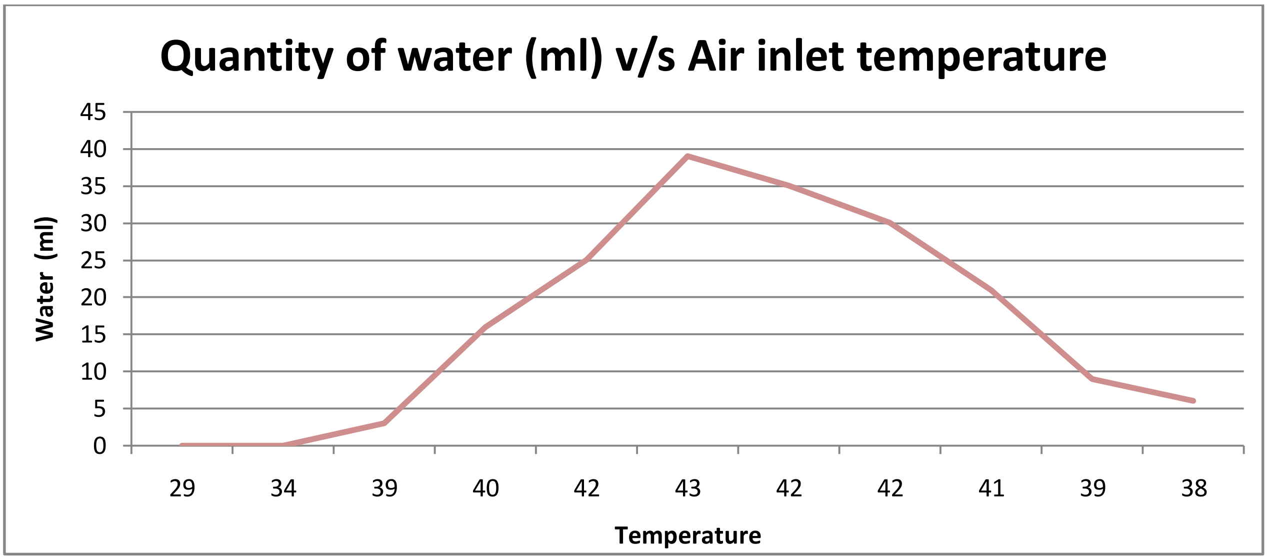

Figure 15 20/04/2016 Volume flow rate =0.029 m3/s

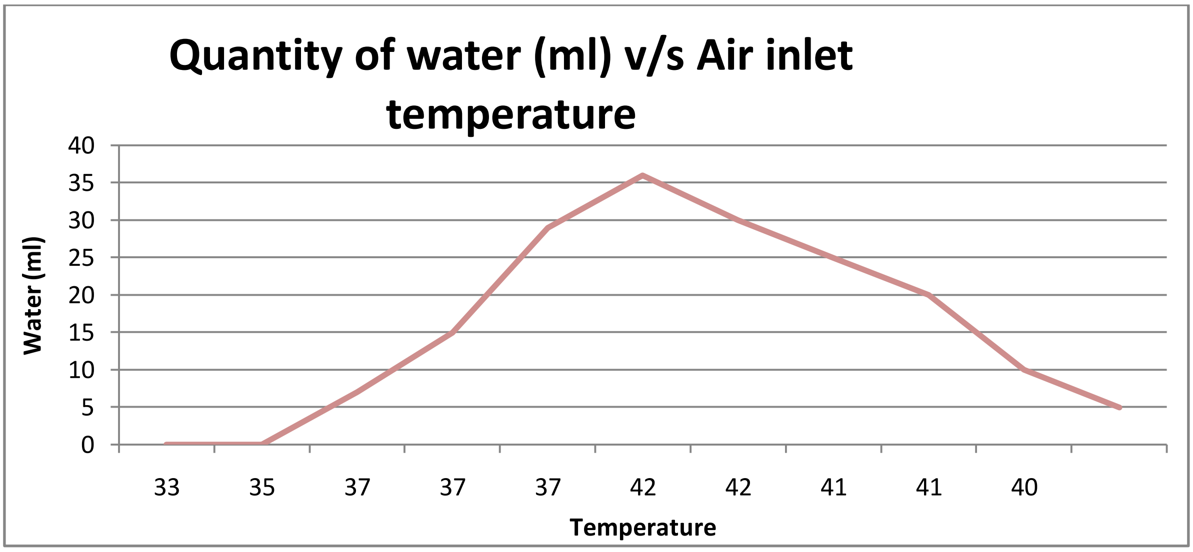

Figure 16 21/04/2016 Volume flow rate =0.026 m3/s

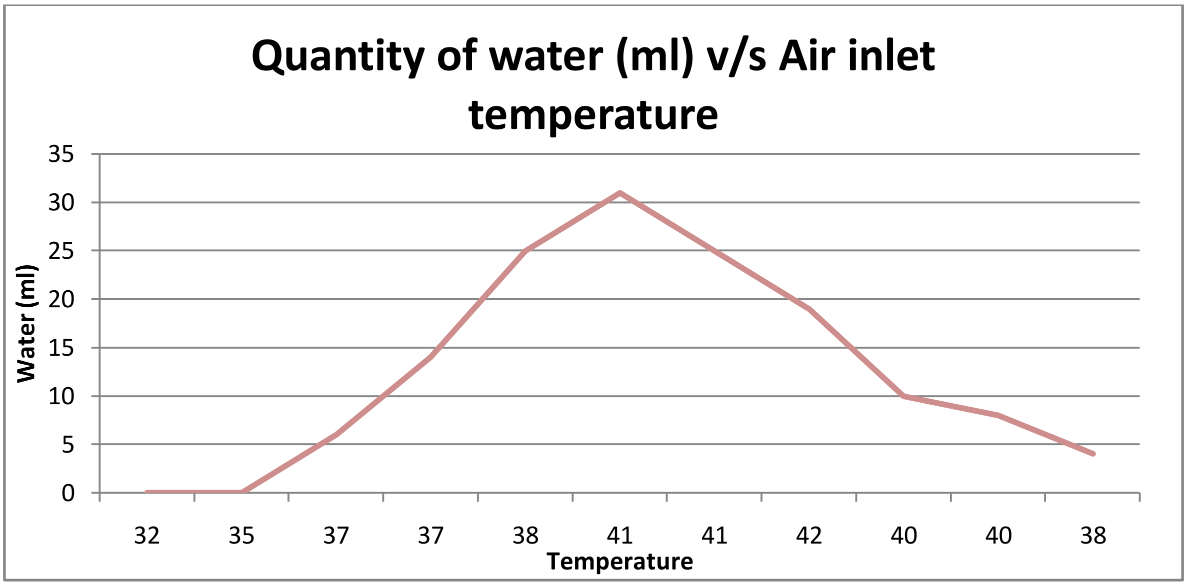

Figure 17 22/04/2016 Volume flow rate =0.0202 m3/s

Water quantity (ml) v/s Air inlet temperature

Graph Figure 14 ,15,16,17 shows that maximum quantity of water produced at 41°C to 43°C of air inlet temperature. Inlet air temperature is increase amount of water production also increase after reaching maximum temperature it is decrease in the evening.

6 Conclusion

The graphs between outlet air temperature and outlet water temperature having 1°C to 2°C difference. As both water droplets and air comes out together from the outlet hence there is not much change between water and air temperature

The maximum amount of water is obtained from the condenser during 12:00pm, to1.00pm this, as we can recall, is the time when the maximum heat exchanger takes place, thus it is the most productive hour throughout the day.

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