Review of design, development and performance of humidification-dehumidification desalination system

[1]Jigar D Patel, [2]Jay M Patel

[1]M.E. Student, [2]Assistant Professor
Mechanical Engineering Department,
Mahatma Gandhi Institute of Technical Education & Research Centre, Navsari, India

***Abstract*— Now a day one problem is increasing day by day in the world is shortage of drinking water. So the various type of water desalination process has been developed but a humidification-dehumidification desalination system is more efficient for other technique of desalination process because of that this technique is low temperature process, simple operation & maintenance, low in cost in installation, reliable and work at atmospheric pressure. A theoretical model and experimental setup for HDH system will be develop in present work. In humidification two types of humidifier are taken for experiment which is bubble column humidifier and packed-bed humidifier (honeycomb wooden slates packing material). In dehumidification part of the HDH system a shell and coil condenser is used & electric heater is used for water heating.**

***Index Terms*— humidification, Dehumidification, electric heater, desalination**

I. INTRODUCTION

Water is the basic necessity of life. Human needs water for many purposes such as domestic purposes, agriculture and industrial processes. The world health organization (WHO) recommends that one person should have less than 15-20 Liters of fresh water per day for basic needs such as drinking, food preparation and the washing of clothes, however this defined value cannot sustain various requirement and so should be increased to about 50 Liters per person each day. Water is considered potable when its TDS is below 500 mg/L. Seawater has a TDS of about 35,000 mg/L and brackish water has a TDS between that of potable water and seawater. More than 97% of the earth's water is salty; rest around 2.6% is fresh water. Less than 1% fresh water is within human reach. Purification of saline water involves chemical separation processes for removing dissolved ions from water. These processes are more energy consumption than the standard treatment processes for freshwater supplies. In many settings where fresh water resources or water supply infrastructure are inadequate, fossil energy costs may be high whereas solar energy is abundant. In the industrialized world, particularly the European Union, government policies increasingly emphasize the replacement of fossil energy by renewable, low-carbon energy, and so desalination systems as a supplement to existing fresh water supplies has been developed.

II. DESALINATION SYSTEM

It has been used to provide potable water from salt water or brackish water. Different desalination system is divided into thermal and membrane type, were proposed and developed continuously. In thermal desalination, saline water or brackish water is heated in an evaporator and generate water vapour free of salts or brackish. This generated vapour is condensed in a condenser then fresh water is collected. Water air or both can be heated by conventional energy source or by renewable energy source such as solar energy. Membrane technology includes several processes but the principal difference between them lies in the size of the entities, ions, molecules and suspended particles that are retained or allowed to pass through the membranes. Typical separation processes are Nanofiltration, ultra filtration, micro filtration and filtration used in the pre-treatment stages of desalination to remove large particles, bacteria, ions, and for water softening. Multistage Flash (MSF) desalination, Multiple Effect Distillation (MED), Vapour Compression (VC) desalination, Reverse osmosis (RO) and Electro-dialysis (ED) are only suitable for large and medium capacities and are too expensive to be applied to small capacities. In contrast, the Humidification-Dehumidification (HDH) desalination, technique is appropriate for a small capacity.

III. HUMIDIIFCATION-DEHUMIDIFICATION SYSTEM

In air humidification chamber, where heated air flows upwards in a counter-flow direction to the spray warm seawater or brackish downwards direction, for large contact surface area, air-seawater, the humidification chamber is filled with increasing interface contact material like packing material. Water is evaporated and air is loaded with water vapour form up to saturation conditions. The dehumidification chamber where air is cooled by the incoming seawater or brackish water feed in a heat exchanger (shell and coil heat exchanger) condensing water vapour forming fresh water production. Heat exchangers incorporate with copper coil better heat transfer. From a packed material inside the humidification chamber to create large contact area of water-air interface. A heat exchanger or coils, depending on the systems size, inside the dehumidification chamber to preheat the incoming seawater

by the condensing water vapour. The energy required to evaporated and condense sea water can be obtained from thermal, geothermal and combination of renewable energy source. Air is driven in this system by forced or natural convection.

IV. APPLICATION

1. Humidification-dehumidification desalination system is low temperature process, easy for installation.
2. This system is small scads application for home scads application.
3. This system improve the fresh water productivity by using a thermal, geo-thermal energy and reduce the energy consumption.

V. LITERATURE REVIEW

Hossam A ahmed *et al.* [2] experimental investigated of humidification-dehumidification system with using a corrugated aluminum zig-zag packing material. The humidifier inlet temperature of air and water is increased then the fresh water production rate is increased, and they obtained the inlet cooling temperature significantly enhances the yield from 10 to15 l/h as the inlet cooling temperature reduces from 28.5 to 17^0C.

Al-Hallaj *et al.* [3] conducted an experimental investigation to determine the production of desalinated water using a HDH unit with wooden packing. According to their results, the yield of fresh water was higher than with the use of the single- basin stills. Furthermore, using high air temperature with high forced circulation had an insignificant effect on the unit's performance

Amer *et al.* [4] have designed a humidifier of 200 cm height, 80 cm length, and 50 cm width. A packing material is fixed inside the humidifier to have a surface area of approximately 6 m2. The packing is supported such that it does not block the air flow and remains continuously wet. The water has been sprayed on the packing material using a hydraulic grid. A movable door has been provided to facilitate the changing of packing material easily to achieve a max of productivity of 5.8 l/hr.

Zhania *et al.* [5] in the desalination prototype is aped on the cross sectional area of the pad is 0.6 m × 0.8 m, while its height is 0.56 m. At the top, there is a liquid distributor, which can feed the pad with hot brackish water coming from solar water collectors while at the bottom there is a liquid collector, where brine is collected as it drains down the pad. Thus, the hot brackish water flows downward, while the air passes in a cross-flow direction. Textile (Viscose) of a 14 m2 (52 m2/m3) surface is used as packing to increase the inter-face area between the air and water, which form the wet-ted surface. On the outside, the humidifier is covered with a polyethylene sheet of thickness 15 mm and insulated with a layer of arm flex.

T. rajaseenivasan *et al.* [6] is investigated bubble column humidification with biomass energy. It is obtained that the better specific humidity is recorded with a bubble pipe hole diameter is 1mm,water depth of 170mm and water temperature of 60^0C.highest distillation of 6.1 kg/h and 3.5 kg/h is collected with preheated air and without pre-heater air supply respectively.

A. Khalil *et al.* [7] A bubble column HDH desalination integrated with a solar water heater was produced the fresh water yield of 21 kg/day at inlet water temperature is 62^0C the best performance is observed from 1mm hole diameter at which the outlet of the air from the bubble column is always saturation.

VI. DATA COLLECTION

An attempt is made in the paper to design and perform the humidification dehumidification desalination system. Packed bed Humidifier is constructed by galvanized 2mm thickness with 650×650 cross section area and height is 1050mm. Inside the humidification chamber 6mm of the hole diameter of the wooden slates packing material with honeycomb shape. Bubble column humidifier is constructed using a galvanised steel sheet 2mm an 0.24m×0.24m cross section area and 0.65m height. And 0.0254m diameter bubble pipe is used. Dehumidifier is shell and coil heat exchanger and it is constructed by galvanized sheet 1.5mmwith 17cm diameter of shell and 1 meter length of the shell. Three 6 mm copper coil is spiralled in the outer diameters of 0.05m, 0.08m, and 0.11m and concentrically placed in the shell. 500W air blower is used.

Fig.1- Experimental setup of the packed bed humidifier

Fig.2- Experimental setup of the bubble column humidifier

VII. INSTRUMENTATION

0-250 ^{0} C k-type thermocouple is used to sense water and air temperature in the system and temperature indicator to indicate temperature. 0-800 LPH rotameter is used to measure flowrate of saline water and cooling water. Hygrometer is used to measure relative humidity and hygrometer range is 10-99 % RH. Orifice meter is used to measure air mass flowrate.

VIII. RESULTS

For (1)bubble column humidifier, and (2) packed bed humidifier.

Table 1with water and air preheater

TIME	$\dot{m}_a$	T_1	T_2	T_3	T_4	RH1	RH2	RH3	$\dot{m}_{cw}$	m_d
12:00	0.000119	34	37	26	14	32	68	39	150	3
12:15		35	31	24	14	32	69	38		
12:30		36	30	22	18	31	70	50		
12:45		36	29	20	25	27	74	51		
1:00		37	29	17	14	23	67	35		
1:15		37	29	16	19	28	65	35		
1:30		37	29	16	18	27	66	34		
1:45		37	30	16	19	25	67	35		
2:00		38	30	16	20	26	67	36		

Sr. No.	TIME	Mass flow rate of air	Temperatures (°C)						Relative Humidity (%)			Cooling water mass flow rate	Water flow rate	productivity
			Humidifier		Cooling Water		Humidifer water	Preheated Air	Humidifier		Dehumidifier			
			Inlet	Outlet	Inlet	Outlet			Inlet	Outlet	Outlet			
			T1	T2	T3	T4	T5	T6	RH1	RH2	RH4			
1	12:00	0.0036	34	37	16	14	36	46	32	68	39	300	500	3
2	12:10		35	31	18	14	49	58	32	69	38			
3	12:20		36	30	20	18	54	66	31	78	50			
4	12:20		36	29	27	25	58	65	27	74	51			
5	12:40		37	29	17	14	61	60	23	67	35			
6	12:50		37	29	16	19	65	70	28	65	35			
7	01:00		37	29	16	18	69	71	27	66	34			

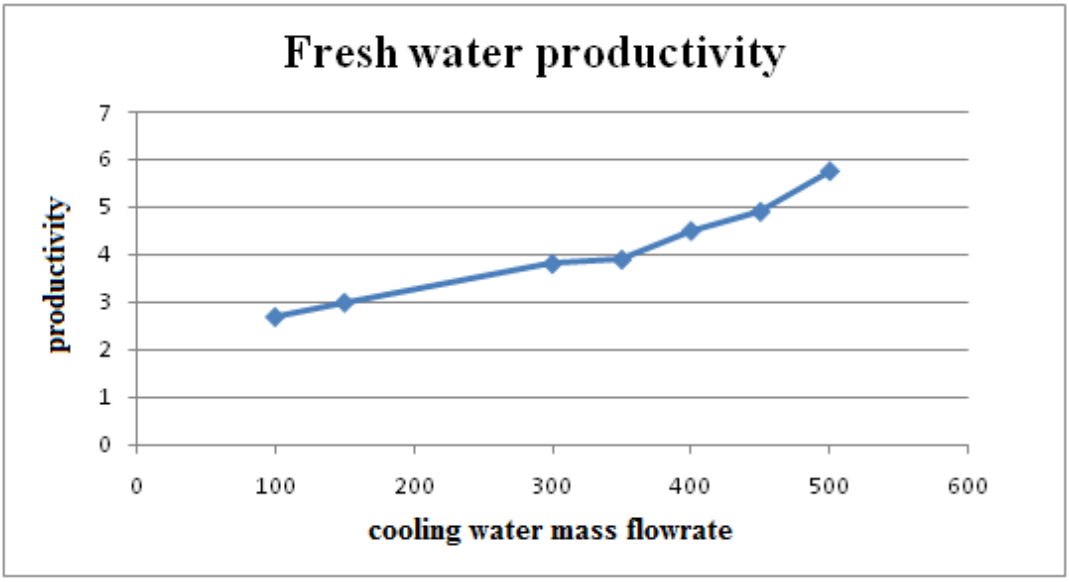

Fig.3- Cooling water mass flow rate vs fresh water productivity

Figure 3 shows that the cooling water mass flowrate is increased than the productivity of fresh water is increased. At constant temperature of the humidifier outlet 53^{0}C than the mass flow rate of is increased 100-500 LPH than the productivity of fresh water production is increased 2.8 – 5.9 litre/h.

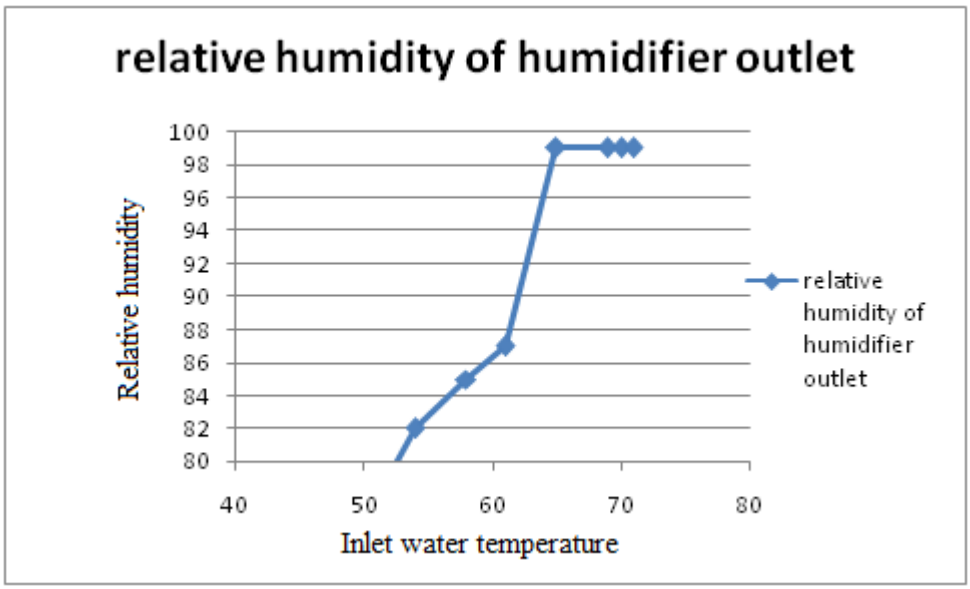

Fig.4- inlet water temperature of humidifier vs relative humidity

Figure 4 shows that the inlet temperature of humidifier is increased than the relative humidity of humidity outlet is increased. When the inlet water temperature of humidifier is increased 50- 72 ^{0}C than the relative humidity of air is increased 80-99 % RH. Maximum relative humidity is 99 % RH is obtain when the inlet water temperature of humidifier is 72 ^{0}C.

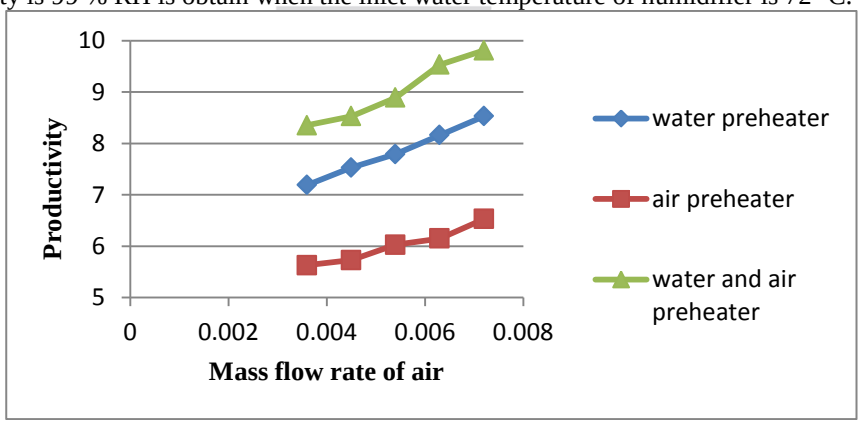

Fig.5- Mass flowrate of air vs fresh water productivity

Figure 5 shows that the mass flowrate of air is increased than the productivity is increased. It can also observed that the increased the fresh water productivity when the air and water preheater is used. Three case of the system is used and it is observed that the water and air preheater both combined used than maximum result.

IX. CONCLUSION

1. The production rate of fresh water is increased by raising the inlet temperature, mass flowrate of air water entering the humidifier, and the rate of cooling water in the dehumidifier.
2. HDH system with air preheater, and HDH system with water preheater is lower comparison with the HDH system with air and water both preheater is used.
3. In this paper the packed bed humidifier with HDH system is higher productivity of bubble column humidifier with HDH system.
4. The maximum fresh water productivity is achieved when the water inlet temperature is 72^0C, and mass flow rate of air, water, and cooling water is 0.0072 kg/m^3, 500 LPH, and 300 LPH.

REFERENCES

[1] A.E kabeel.et al "water desalination using a humidification-dehumidification technique—A detailed review", natural recources 249 (2013) 286–305.

[2] Hossam A. Ahmed.et al "Experimental investigation of humidification-dehumidification desalination system with corrugated packing in the humidifier", Desalination 410 (2017) 19–29.

[3] Naser Kh. Nawayseh.et al, "solar desalination based on humidification process-1. Evaluating the heat and mass transfer coefficient", Energy conservation & management 40,1423-1439 (1999)

[4] E.H. Amer.et al "Theoretical and experimental investigation of humidification–dehumidification desalination unit", Desalination 249 (2009) 949–959.

[5] K. zhani.et al "experimental investigation of a new solar desalination prototype using the humidification dehumidification principle", Renewable Energy35(2010) 2610-2617.

[6] T. Rajaseenivasan.et al "An investigation into a laboratory scale bubble column humidification dehumidification desalination system powered by biomass energy", Energy Conservation and Management 39 (2017) 232-244.

[7] A. Khalil.et al "Solar water desalination using an air bubble column humidifier", Desalination 372 (2015) 7–16.