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Research Article

Fabrication and Performance testing of Evaporative Air Cooler with Solar Liquid Desiccant Dehumidification

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Abstract

The extensive effort has made to fabricate and analyze the evaporative cooler with liquid-desiccant regeneration process. A temperature drop of around 4 degrees and a humidity reduction of around 14-16 percent as compared to direct contact evaporative cooler achieved. The enhanced average cooling efficiency of the evaporative cooler is41.828 % achieved with Average dehumidification capacity obtained at different concentrations of desiccantare: At 20% concentration of desiccant = 4.3695 lph, At 30% concentration of desiccant = 5.4845 lph, At 40% concentration of desiccant = 6.391 lph

Keywords: *Evaporative cooling, Liquid desiccants, Dehumidification cooling*

1. Introduction

In hot and humid areas, interest in utilizing solar powered-cooling systems for air-conditioning and refrigeration purposes has been growing continuously. Being considered as one path towards more sustainable energy systems, solar-cooling is comprised of many attractive features.

This technology can efficiently serve large latent loads and greatly improve indoor air quality by allowing more ventilation while tightly controlling humidity. On the other hand, solar-powered air conditioning has seen renewed interest in recent years due to the growing awareness of environmental problems such as global warming.

Solar collector/regenerator (C/R) systems can achieve liquid regeneration at lower temperatures which is suitable for buildings with high outdoor air requirements in high humidity areas. Several solar-driven refrigeration systems have been proposed and most of them are economically justified. These systems include sorption systems containing liquid/vapor or solid/vapor absorption/adsorption, vapor compression systems, and hybrid desiccant vapor compression systems.

The regenerator is one of the key components in liquid desiccant air-conditioning systems, in which desiccant is concentrated and can be reused in the system. The heat required for regenerating the weak desiccant solution is supplied into the regenerator by either hot air or hot desiccant solution. This heat can be provided by any form of low-grade thermal energy which is suitable for solar thermal applications. Different regenerator designs have been examined and a variety of theoretical models have been employed to analyze the regeneration process.

A parametric analysis of the system has been performed to calculate the rate of evaporation of water from the solution as a function of the system variables and the climatic conditions. The effect of regeneration temperature on the rate of water evaporation from the liquid desiccant shows that an increase in solution temperature increases the vapor pressure on the surface of the solution and consequently the potential of mass transfer.

The extensive research has been carried over dehumidification process using non conventional energy sources.

2. Working Principle of Solar Powered Dehumidification

Figure 1 shows the operational concept and diagram of the desiccant-based ventilation and air-conditioning system. The processed air from the desiccant dehumidifier becomes hot due to the release of the heat of condensation and heat of sorption. Heat recovery devices are used to recover this energy. The condition of the air after the heat recovery becomes warm and dry.

The delivery air from the direct contact evaporative cooler gains humidity during cooling due to absorption of water vapor. This humidified air is made to pass through cold and regenerated desiccant solution dripping through the wood wool honeycomb mesh.
The desiccant absorbs the water vapor or the humidity from the delivery air before supplying it finally to the room.

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This weak desiccant rich in humidity is pumped for regeneration in order to lose the humidity to the outer air. The regeneration process is carried out using hot air, which is in turn heated by circulating hot water using low grade thermal energy to further reduce the cost and increase the coefficient of performance of the system.

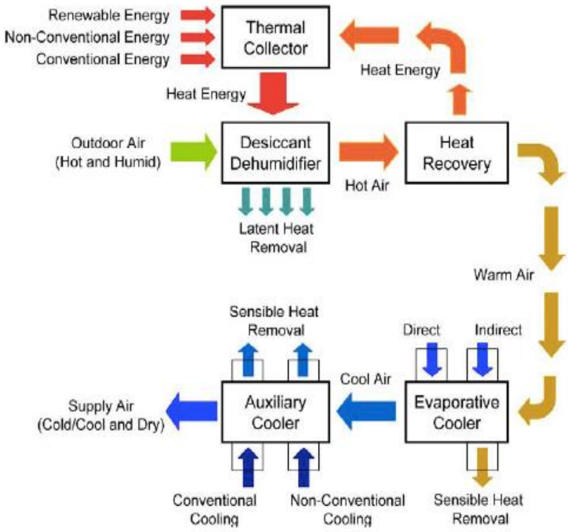

Figure 1 Concept of the thermally activated desiccant cooling technologies

This strong regenerated desiccant solution gains heat and needs to be cooled in order to maintain the cooling efficiency of the evaporative cooler. Therefore it is passed through a heat exchanger before being supplied to the honeycomb mesh at the outlet of the evaporative cooler.

3. Experimental Set-up

The proposed system is presented in Figure 2. The system comprises of two air evaporative coolers. One of the two coolers functions as an absorber (the indoor unit) and the second (the outdoor unit), which is coupled with solar water heater, functions as a desiccant regenerator.

Calcium Chloride solution is regenerated in the evaporative cooler (desiccant regenerator) which is supplied with hot air from a finned tube air/water heat exchanger. Water from the solar water heater is circulated through the heat exchanger to heat the flowing air. Strong solution from the outdoor unit is directed to the indoor unit and weak solution from the indoor unit is pumped to the regenerator via a solution pump. Room humid air is blown and dehumidified in the indoor unit.

This system actually functions as humidity pump. Direct contact between air and desiccant is carried out in the packing used in the evaporative cooler to increase the contact area. For the purpose of heat recovery, solution heat exchanger is applied to cool the strong solution coming out from the regenerator (outdoor unit).

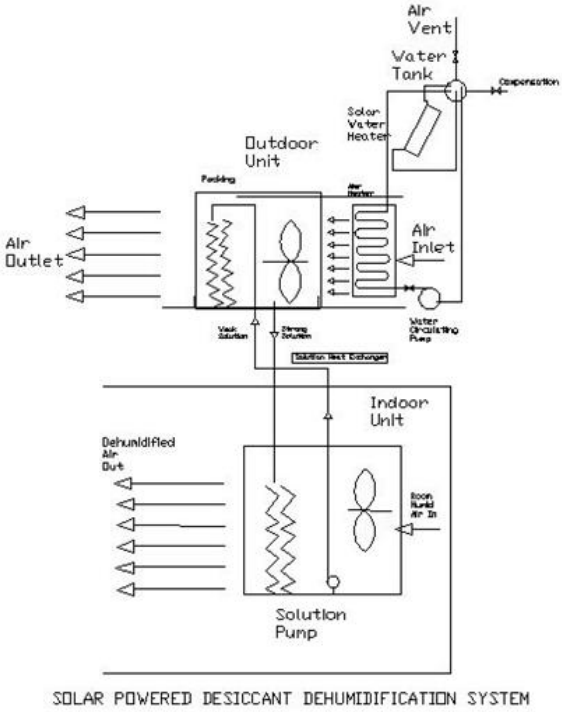

Figure 2 Schematic diagram of solar powered desiccant dehumidification system.

3.1 Components and Specifications

1. Frame: Aluminum frame is used to mount various components of solar powered dehumidification system. Figure 3 represents the frame of a system.
2. Self priming Centrifugal Pump for hot water supply : Single phase 230V,50Hz, 0.5 HP, Power Input 540W, 800 lph, 18m head
3. Evaporative cooler : Power consumption 160W, 20 liters capacity, Air supply of fan 1200 lph.

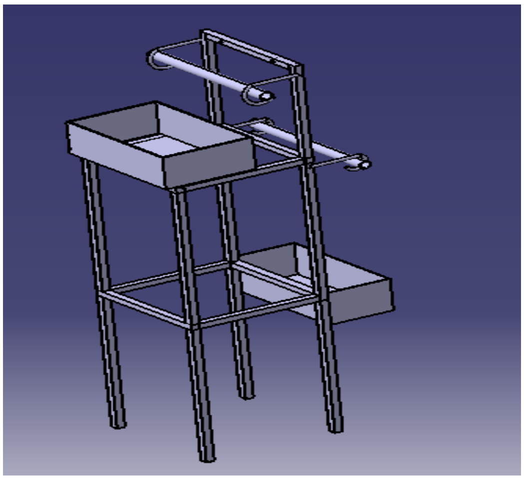

Figure 3 CAD Model of the Frame

4. Fin and tube Heat Exchanger (radiators), two units, one coupled with water heater to regenerate the weak desiccant solution, and one to cool the regenerated strong desiccant solution, downward flow type, Cu

tubes and Cu plates, 37 plates and tube dia 10 mm, capacity 3lt, and cooling fan 1200-2400 rpm,12V DC supply.

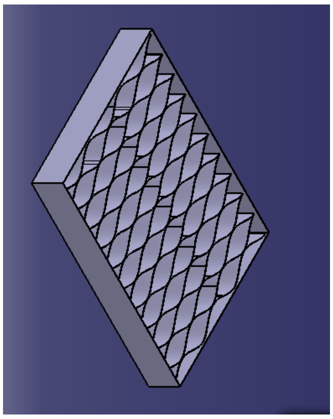

Figure 4 CAD Model of Honeycomb mesh

5. Submersible pumps for liquid desiccant circulation: 2 units, 9W,0.8m head
6. Heating rod 230V, AC, 50Hz,1500W max

3.2 Solar dehumidification with liquid desiccant system

Integrated system used for solar dehumidification is as shown in figure 5 a. and 5 b.

Figure 5 a. Front View of the actual system

Figure 5 b. Side view of the project

4. Performance Analysis

$$\text{Cooling Efficieny} = \frac{\text{DBT(outlet)} - \text{DBT(inlet)}}{\text{DBT(outlet)} - \text{WBT(outlet)}} \times 100$$

$$\text{Heat Flow Rate} = \frac{V(h_i - h_o)}{V_o \times 60}$$

Figure 6 Parabolic Solar Collector

Figure 7 Measurement of RH using Digital Hydrometer

$$\text{Capacity Of Dehumidifier} = \frac{V\,(w_i - w_o) \times 60}{V_o}$$

Where,

V is the air flow rate of the evaporative air cooler (cubic meter per minute).
Vo is the specific volume (cubic meter per kg of dry air).
hi and ho are the specific enthalpies (kJ/kg of dry air) for inlet and outlet respectively.
wi and wo are the specific humidities (%) for inlet and outlet respectively.

The specific enthalpies, specific humidities and the specific volumes at different conditions (inlet and delivery) are calculated from the psychrometric chart

5 Observation Table

The solar dehumidification system is run for different concentration of liquid desiccant and readings were noted after every one hour to check the performance at various input conditions. Table 1 gives the observation for inlet air conditions, delivery air supplied and desicaant temperatures.

Table 1 Obsevation for Inlet and Delivery Air

Inlet Air			Delivery Air		Desiccant temp	
DBT	WBT	RH	Temp	RH	Before reg	After reg
°C	°C	%	°C	%	°C	°C
30.9	22.4	51	27.8	68		
30.8	22.4	50	27.6	69		
30.5	22.3	52	28.1	72		
31.1	22.3	53	27.4	74		
30.7	22.3	52	27.7	56	26.7	32.8
30.7	22.2	53	27.5	58	26.5	31.2
31.4	22.6	52	27.6	54	26.8	32.6
31.1	22.6	52	27.3	55	26.8	32.2
32.9	22.6	52	28.2	54	27.1	31.9
32.6	22.5	52	28.4	56	27.3	32.1
32.3	24.4	52	28.7	51	28.1	34.1
32.3	24.3	52	28.6	52	28.2	33.9
31.4	24.3	50	28.6	53	28.4	33.8
31.2	24.2	50	28.5	53	26.6	33.9

6. Results and Discussion

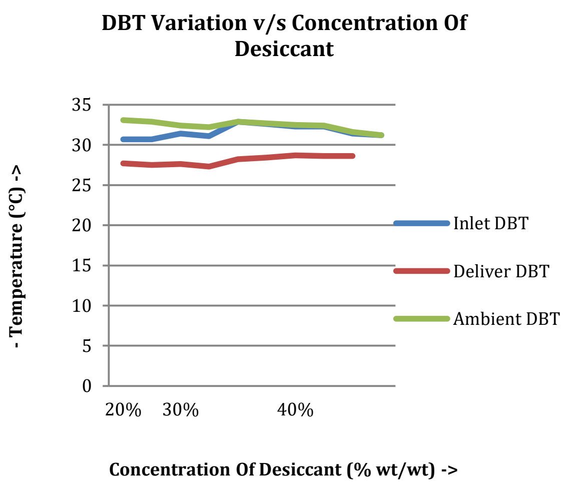

Figure 8 DBT Variation v/s Concentration of Desiccant

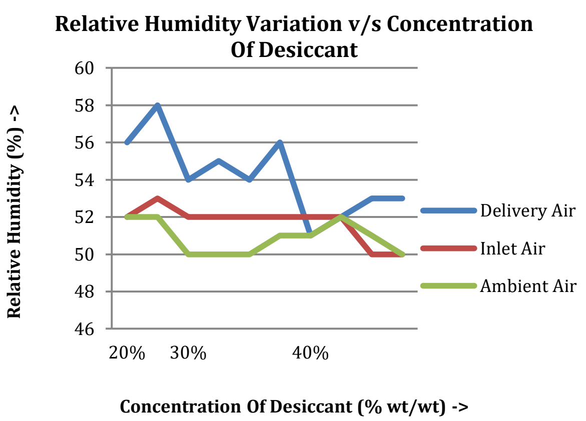

Figure 9 Relative Humidity Variation v/s Concentration of Desiccant

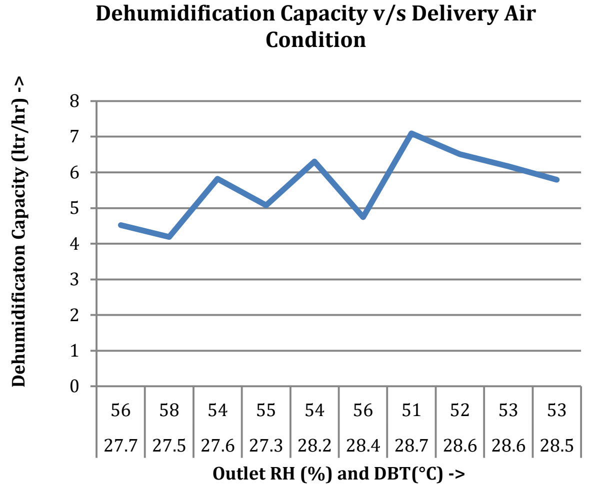

Figure 10 Dehumidification Capacity v/s Delivery Air Condition

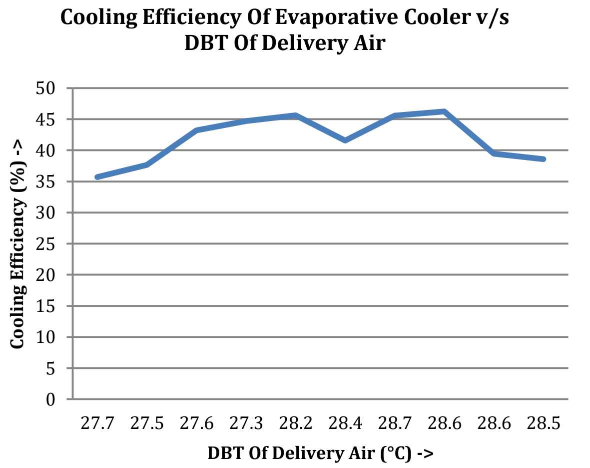

Figure 11 Cooling Efficiency of Evaporative Cooler v/s DBT of Delivery Air

Table 5 Result Table for Dehumidification

Delivery Air				Dehumidification Capacity
DBT	RH	Vo	Wo	
°C	%	m^3/kg	°C	ltr/hr
27.7	56	0.92	0.01381	4.522
27.5	58	0.92	0.01414	4.187
27.6	54	0.92	0.01324	5.817
27.3	55	0.92	0.01325	5.074
28.2	54	0.92	0.01371	6.3
28.4	56	0.92	0.01439	4.747
28.7	51	0.92	0.01333	7.095
28.6	52	0.92	0.01352	6.508
28.6	53	0.92	0.01378	6.169
28.5	53	0.92	0.0137	5.791

Conclusion

Fabrication and analysis of evaporative cooler with liquid-desiccant regeneration was performed. A temperature drop of around 4 degrees and a humidity reduction of around 14-16 percent as compared to direct contact evaporative cooler was achieved. The average cooling efficiency of the evaporative air cooler was found out to be 41.828%. The average dehumidification capacity of the dehumidifier was 4.3695 lph for desiccant concentration of 20%, 5.4845 lph for desiccant concentration of 30% and 6.391 lph for desiccant concentration of 40%.

It is understood from the experimentation that new configurations of the solar regenerator are highly welcome to maximize its benefits. Desiccant applications, such as recovery of water from air, integrated with solar cooling systems increase the system availability and improve the overall performance. The possibility of replacing the mass exchange equipments (absorber and regenerator) by evaporative coolers can be planed for future studies. An alternate concept of evaporative air cooler coupled with solar water heater for dehumidification purposes using a liquid desiccant regeneration is far more energy efficient and eco-friendly as compared to the vapor compression air conditioning equipment.

References

Wang Huajun, Qi Chengying (2010), Experimental study of operation performance of a low power thermoelectric cooling dehumidifier, Internantional Journal of energy and environment, Volume 1, Issue 3, pp.459-466.

Vivek W. Khond (2011), Experimental investigation of desert cooler performance using four different cooling pad materials. American journal of scientific and industrial research, pp.418-421.

Ahmad A. Pesaran(1993), National Renewable Energy Laboratory, A Review of Desiccant Dehumidification Technology, Prepared for Proceedings of EPRI's Electric Dehumidification: Energy Efficient Humidity Control for Commercial and Institutional Buildings Conference,

Eric Kozubal, Jason Woods, Jay Burch, Aaron Boranian, and Tim Merrigan(2011), Desiccant Enhanced Evaporative Air-Conditioning (DEVap): Evaluation of a New Concept in Ultra Efficient Air Conditioning,

John Archibald (2011), A new desiccant evaporative cooling cycle for solar air conditioning and hot water heating, American Solar Roofing Company 8703 Chippendale Court Annandale, Va. 22003.

Talal K. Kassem, Ali S. Alosaimy, Ahmed M. Hamed, Mohammad Fazian(2013), Solar Powered Dehumidification Systems Using Desert Evaporative Coolers: Review, International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-3, Issue-1.

J. R. Camargo and E. Godoy Jr (2005), An Evaporative and Desiccant Cooling System for Air Conditioning in Humid Climates, Vol. XXVII, No. 3, pp. 245-247

W.Z. Gao, Y.P. Cheng , A.G. Jiang, T. Liu , Keith Anderson (2014), Experimental investigation on integrated liquid desiccant e Indirect evaporative air cooling system utilizing the Maisotesenkoe Cycle, Applied Thermal Engineering, Vol. No. 3, pp. 103-109