Dehumidification of Air using Liquid Desiccant System

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Abstract— This paper gives a detailed account of the general features of the major desiccant regeneration techniques and configurations of the related systems; meanwhile, attention has been paid to both technological development of solar powered regenerator, which is a key component of the liquid-desiccant dehumidification system. Studies to improve the system performance have been discussed. Benefits and conditions of the use of liquid desiccant for dehumidification purposes have been stated. It is clear from the survey that the desiccant dehumidification is more energy-efficient compared with the conventional vapour compression system. Moreover, new configurations of the solar regenerator, to improve the system performance, have been demonstrated. Some new hybrid systems that greatly expand the desiccant in residential applications, as well as effectively promoting the single system's performance, are also introduced.

Key words: Dehumidification, Cooling, Liquid Desiccant, Regenerator

I. Introduction

A. *Objective:*

1) Design and installation of a solar water heating system coupled with an air heater and evaporative cooler for regeneration of Silica gel desiccant solution.
2) Study and discuss the operation of the proposed system and evaluate the possibility of steady state operation with application of hot water storage tank.

B. *Types of Dehumidification*

1) *Liquid sorption:*

The air is passed through sprays of liquid sorbent, such as lithium chloride or glycol solution. The sorbent in its active state has a vapor pressure below that of the air being dehumidified and thus absorbs moisture from the air stream. The sorbent must be continually regenerated by using heat to drive off the absorbed moisture.

2) *Solid sorption (desiccant):*

This method utilizes either granular beds or fixed desiccant structures that are employed in automatic machines through which the air is passed. This desiccant also needs to be reactivated by heat to release the previously absorbed moisture to an outdoor stream.

3) *Compression of the air:*

This will reduce the absolute moisture content of the air but will generally produce a saturated condition at the elevated pressure. Expansion of this high pressure air will result in a lower dew point at the lower pressure because of the increase in actual volume. This is similar to what one experiences with an air compressor. The removal of the condensed water is accomplished by use of water traps and after coolers. However, the amount of air treated does not make this a viable alternative for dehumidification within the industrial marketplace.

4) *Condensation-based (Refrigerant):*

This type unit, pictured above, chills the air below its dew point, causing moisture to form as condensation on the cold surface of the cooling coil and thus removes water from the air.

II. Literature review

Experimental studies have been carried out on Evaporative Air Coolers coupled with Solar Water Heater by Alosaimy (2013), in which Calcium Chloride and water solution was used as desiccant. It was found that, desiccant minimum temperature was proportional to the humidity potential between the indoor and outdoor conditions (temperature and humidity). The experimental results were show that, Calcium Chloride solution with 30% concentration can be regenerated up to 48% using solar energy.

Experimental studies have been carried out on a liquid-desiccant air dehumidifier by Bakhtiar et al. (2011), in which Lithium Chloride was used as desiccant. It was found that, the higher air velocity was obtained faster air dehumidification and the higher desiccant flow obtained larger effectiveness but effectiveness slowly came down after some time of experiment.

Kaushik (1989) suggested that a solar desiccant cooling system was more effective than the conventional air conditioning system due to the property of various adsorbents used in it. These adsorbents could be easily regenerated at low temperature which could be easily achieved by solar collector.

Al-Hallaj et al (1998) have used a solar collector (tubeless flat plate type of 2 m2) to heat the water to 50-70 Â°C. They found that at low top temperatures forced circulation of air was advantageous and at higher top temperatures natural circulation gives better performance.

Ben-Amara et al. (2004) tested the spray tower humidifier by varying the ratio of water-to-dry air mass flow rate and keeping the inlet water temperature and absolute humidity constant. The inlet air temperature (80Â°C) was higher than the water temperature (60Â°C). They found that increasing the amount of water sprayed increased the absolute outlet humidity. However, further increase in the water quantity resulted in air cooling and this condensed some of the water vapour content in the air. This means a decrease in the absolute humidity, although the outlet air is always saturated. Therefore, for air heated HDH cycles there is an optimum value of the mass flow ratio which gives maximum air humidity

Kishore and Dilip (2013) experimentally analyzed the liquid desiccant dehumidifier, in which Calcium Chloride was used as desiccant. It was found that,

As the regeneration temperature was increased, moisture absorbing capacity of air was increased.

As the regeneration temperature was increased, the dehumidification rate in the absorber was increased.

The moisture removal rate was increased with the increasing in regeneration.

A the inlet temperature of desiccant (absorber) was increased, the dehumidification was reduced in the absorber, indicated the reduction in moisture removal capacity.

III. METHODOLOGY

A. *Principle of Dehumidification of Air using desiccant*

The dehumidification system consist of a conditioner to dry the outside air taken into the room to replace that exhausted for ventilation purposed and a concentrator(re-generator) which transfers the moisture from the diluted liquid desiccant to exhaust air.

In the conditioner, outside air is passed through a spray of desiccant where it is dried. The heat of condensation released there is removed by the coil containing cold water. This supply of cool and dry air then enters the room by the fan or conventional air conditioning system. The liquid desiccant is continuously pumped between the conditioner and the concentrator through a liquid to liquid heat exchanger. In the concentrator the desiccant is sprayed on coils heated by solar system. The water evaporated from the desiccant is in the process is transferred to the air being exhausted from the room.

IV. DESIGN AND SPECIFICATION OF COMPONENTS

A. *Tanks*

1) *Heating Tank:*

Heating tank is used to store hot desiccant which is being used for the regeneration process in regenerator.

2) *Cooling Tank:*

Cooling tank is used to store cooled desiccant which is used in Absorber for the moisture absorption process.

B. *Towers (Regenerator & Absorber)*

1) Material-Fiber Reinforced Plastic Sheet
2) Height-75 cm
3) Lenth-10 cm
4) Width-10 cm

C. *Packing: (For Absorber and Regenerator)*

1) Material-Cellulose Pads
2) Height-30cm
3) Diameter-cm

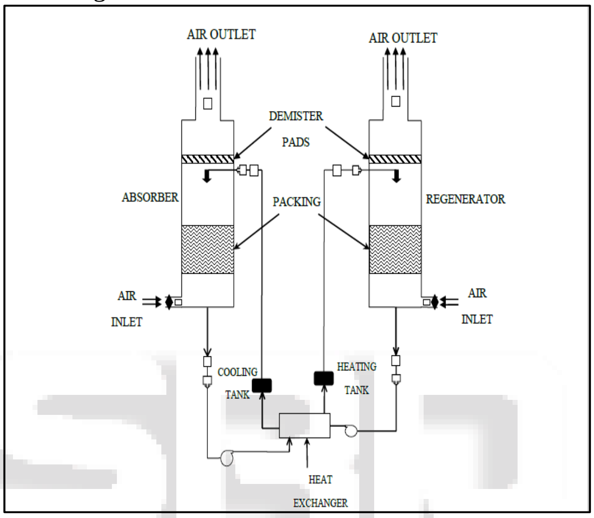
D. *Pump:*

1) Voltage- 220-240V
2) Frequency-50Hz
3) Power-15W
4) Pumping Height (Maximum)-153cm (5ft)
5) Output-1800Ltr/Hr

V. EXPERIMENTAL SETUP

A. *Interconnection between Components:*

– The outlet of the Absorber is in Heating Tank.
– The Desiccant pumps to the water heater with the help of pump placed between the Heating Tank and the water heater.
– The outlet of the water heater is connected to the heating tank.
– The hot desiccant is supplied to the Regenerator through the pump placed between the Inlet of the Regenerator and the Heating Tank.
– The outlet of the Regenerator is in the Cooling tank.
– The cooling tank is used to supply the cold desiccant to the Absorber through the pump placed between the Cooling Tank and the Absorber.



VI. RESULTS & DISCUSSIONS

We experimentally analyze in our project-

1) Effect of Regeneration Temperature (Hot Tank) on Temperature increase of outlet air.
2) Effect of Regeneration Temperature (Hot Tank) on Humidity Reduction (regenerator).
3) Effect of Regeneration Temperature (Hot Tank) on Humidity Decrease in the Absorber.

Ambient Conditions:
Lab Temperature-37˚C Relative Humidity-51%
Concentration Ratio:
For Regenerator: - H2O:SILICA GEL ::100:4
For Absorber: - H2O:SILICA GEL ::100:4

For observations for the effect of the regeneration temperature on the humidity reduction in absorber and regenerator, we maintain the mass flow rate of the desiccant is constant and the speed of the fan is kept constant.

A. *Observation Table:*

Hot Tank	Cold tank	Absorber	Absorber	Regenerator	Regenerator	Time
Temp	Temp	RH%	Temp of outlet air(˚C)	RH%	Temp of outlet air(˚C)	Time
48	20	43	35	55	38	12:25pm
45	23	44	36	50	37.5	12:30pm
40	25	44.5	36.6	48	37.3	12:35pm
39	26	45	37	44	36.7	12:40pm
38	32	46	37.5	41	36.5	12:45pm

B. Effect of Regeneration Temperature (Hot Tank) on Temperature increase of outlet air.

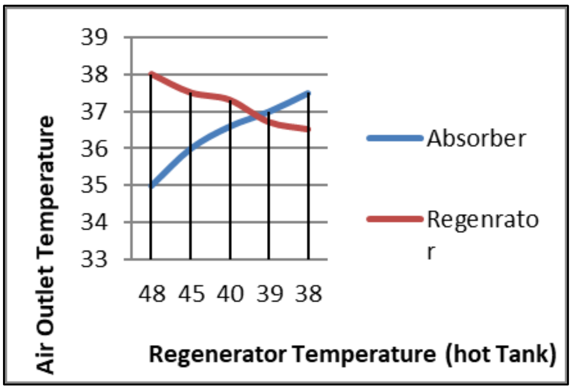


Fig. 6.1: Effect of Regeneration Temperature (Hot Tank) on Temperature Increase of Outlet Air

As seen in Fig. 6.1, we found that as the hot tank temperature decreases, temperature of the outlet air of the absorber increases and the temperature of the outlet air of the regenerator decreases. Resulting, high temperature of hot tank gives the lower temperature for absorber thus the dehumidification increases by increasing the temperature of hot tank.

C. Effect of Regeneration Temperature (Hot Tank) on Humidity Reduction.

As seen in Fig. 6.2, we found that the humidity of the outlet air from the absorber increases with reduction in the temperature of the hot tank, whereas in the regenerator, humidity of the outlet air from the regenerator decreases with the reduction in the temperature of the hot tank.

So for good dehumidification we need a static high temperature of the hot tank for their operation time and it's about 60 to 70˚C. As high temperature of the regeneration (hot tank), as good humidity reduction in absorber and regeneration of the desiccant solution.

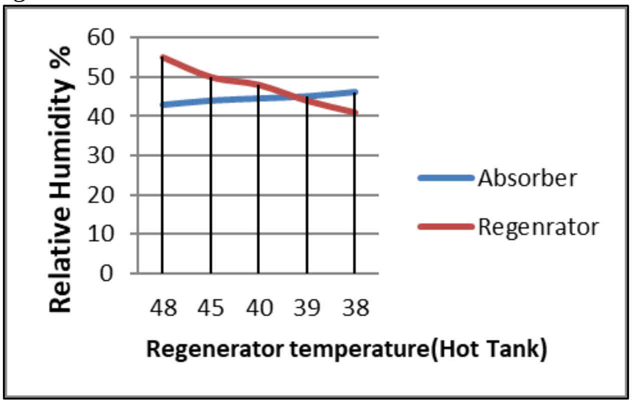


Fig. 6.2: Effect of Regeneration Temperature (Hot Tank) on Humidity Reduction in Absorber and Regenerator

VII. Conclusion

The experimental work has been carried out and results have been discussed in above section. And it is seen from the above discussions, the moisture removal rate increases with the regeneration of desiccant. The moisture removal decreases when the inlet temperature of desiccant in absorber increases. The maximum temperature for the regeneration is obtained for black chrome coating in solar plate. These results are compared with the existing standard results and found that they are approximately same. The water condensation rate doesn't change much with the air inlet temperature and desiccant temperature. It almost remains constant. The water condensation rate increases with increasing desiccant inlet concentration.

The use of solar energy reduces the cost of operation of the system. The demand of the energy is increasing day by day and it is more sense to use solar driven systems which are very economical as compared to the conventionally electrically driven systems. In solar driven dehumidifier we use solar energy for the regeneration of the desiccant instead of electrical energy and Calcium Chloride is used as desiccant. Resulting, this system can be used as Air Conditioning systems and it is not expensive.

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