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Performance Analysis of Dehumidifier of Liquid Desiccant Air Conditioning System using $Cacl_2$ as Desiccant with Two different Plates

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Abstract—*The growing demand of the energy day by day has insisted our society to focus on the renewable sources of energy to meet our needs than to rely on conventional fossil fuels. Liquid desiccant systems are the means by which we can control the humidity of the air with the use of renewable sources for its operation as solar energy. Its helps in energy savings by the use of solar energy and helps to reduce the ill effects of the conventional sources on the environment.*

This work represents the comparison of the dehumidifier, one having a plate with a pattern impressed on it to that of a simpler one for the dehumidification of the air. The performance was measured for both cases by differing the pace of the flowing air stream over the dehumidifier plate. The main aim was to have better utilization of the liquid desiccant material. When the simple plate was used for the dehumidification of air by varying its pace the observed change in the humidity was in range of 8.50-6.72 gm/kg and the rate of moisture removal was in range 0.06477-0.07096 gm/s. The effectiveness of the dehumidifier as calculated was of around 0.259. When the same flow of the liquid desiccant was made on the plate with a pattern imposed on the plate the observed humidity change of the air as it flows through the dehumidifier was in range from 9.01-7.05gm/kg and the rate of moisture removal as 0.0686-0.0745 kg/s. The effectiveness of this dehumidifier with the imposed pattern was around 0.272. The improved values of various performance parameters were observed in modified plate due to better utilization of the desiccant film as more volume of it was involved in the dehumidification process as compared to the simpler one.

Keywords*: - Dehumidifier, Effectiveness, Desiccant.*

1. INTRODUCTION

Energy demand is rising day by day due to the drastic increase in no. of humans on this planetand the increasing economic development[1]. In order to meet these energy requirements some renewable sources have to be utilized for the needs in spite of relying on the fossil fuels only. Air conditioning is one of the sectors in energy demands. Its importance can be observed from the fact that in a building half of the requirement of power is required for conditioning of air[1, 2]. The quality of air inside the room is decisive in the productivity of the occupants. A system has to be developed which not helps in reducing the energy requirements but also helps out to reduce the ill effects of the refrigerants used in the conventional systems which are harmful for the environment. Liquid desiccant air conditioning systems are one of them which can be operated on low grade energy sources as solar ones or the waste heats obtained from various processes and can help to reduce our energy demands without any much damage to the environmental conditions[3]. One of the earliest system developed was by Lof[4] used with triethylene glycol as desiccant. In the conventional air conditioning systems in order to remove the moisture from the air, the coils are required which are required to be maintained below the dew point temperature of the air at that pressure in order to condense the moisture from the air[5]. This leads to the wetting of the coils where there is possibility of germs growth which may influence the incoming air to the required space. After cooling again the air has to be heated to the required temperature which involves a lot of energy consumption. So in order to tackle this latent load of conditioning especially in hot and humid where latent load is more than sensible one [6]an efficient system is required.

2. DESICCANTS

Desiccants are the substances which are used to absorb moisture from the air stream. These are hygroscopic in nature. These are mainly in the form of solid salts and some of them are as calcium chloride, lithium bromide, lithium chloride etc.[7, 8] The capacity of a desiccant material to absorb the water vapour or moisture depends on the equilibrium humidity ratio and the concentration of the solution. This humidity ratio tells about the direction of the transfer of the water particles i.e. if the ratio of the desiccant solution current is lower than that of air water particles will precede towards the desiccant stream from the air. Now selection of the desiccant includes various factors as surface vapor pressure, cost and its tendency to form crystals in the solution etc. Other desirable properties that a desiccant should have are high moisture retaining capability, low viscosity, and lesser regeneration temperature.

3. DEHUMIDIFIER/REGENERATOR

Dehumidifier and regenerator are the main parts of the liquid desiccant air conditioning systems. Dehumidifier is the portion where dehumidification of the air is done with the help of the desiccant material and regenerator is the portion where the desiccant is again concentrated by pulling out the water particles through it by raising its temperature to the regeneration temperature in order to vary its surface vapor pressure. This is done in order to again use the desiccant material for the dehumidification process. They are mainly classified as direct contact type and indirect contact types. Direct contact types are simpler than the indirect ones. These parts may be of single stage to multiple stages.

3.1 Direct contact type

In direct type of dehumidifiers and regenerators the desiccant material stream is allowed to come in direct contact with the air flow and there is a direct transfer of the moisture. These are the ones which were initially developed due to its easy designs.Some of them were falling film, spray tower, packed bed [9-12]. The main drawback of these systems were the carry-over of the desiccant solution particles with the air stream which may results in inhalation of it to the occupants and also loss of desiccant solution.

3.2 Indirect contact type

In this type of system there is not a direct contact between the desiccant solution stream and the moist air and as a result it prevents the carry-over problem as faced in the direct contact types. Liquid to air membrane energy exchanger(LAMEE) is one of the types which uses hydrophobic semi-permeable membranes which allow only the transfer of water particles and prevent that of desiccant solution to restrict its carry over[13]. Similarly other ones as Electrodialysis and reverse osmosis are the ones which have been recently developed in this field to have more better usage of the desiccant material[14].

4. DESCRIPTION OF THE LDAC SYSTEM

In liquid desiccant air conditioning system, the liquid desiccant material is obtained by having a desired percentage by weight ratio as required. Then this desiccant material is allowed to flow inside the dehumidifier. Desiccant film, spray tower are one of the various options to do so. The desiccant material removes the water particles from moist air and dehumidifies it. Now this desiccant material stream is brought to the regeneration temperature with the help of solar energy or waste heat whichever to be used. After reaching the regeneration temperature the desiccant material gives of its water vapors to an external air stream which is used in case of regenerator to help out to again enhance the concentration of the desiccant material so that it can be again utilized for dehumidification. In this system besides dehumidifier and regenerator an external source of heat, some pumps and some piping is required in order to pull out functioning of the system. However, these systems are in initial stages of its development and yet a lot of development has to be made in order to enhance its performance.

4.1 Governing equations

a. Moisture removal rate: - It basically tells about the rate at which the moisture is removed from the air stream that is required to be conditioned. It can be calculated as follows.

Change in specific humidity $\Delta w = w_{outlet} - w_{inlet}$

So moisture removal rate MRR = $m_{air}(w_{air, in} – w_{air, out})$

b. Effectiveness: - It basically tells about how effectively the system works out in dehumidifying the air i.e. it's a ratio to the absorbed moisture with the maximum possible it can be.

$$\epsilon_{regen} = \frac{\omega_{out} - \omega_{in}}{\omega_{in}}$$

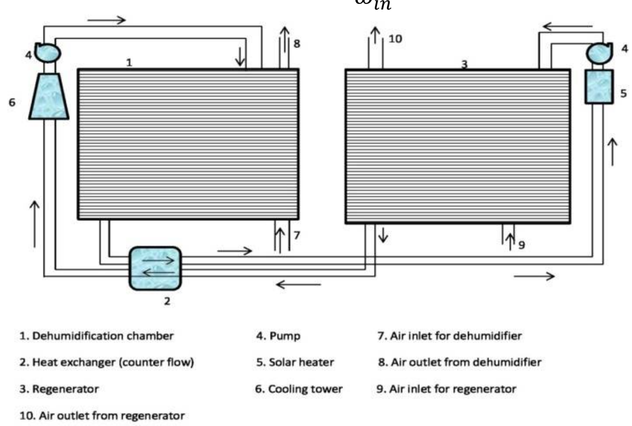


Fig. 1: Schematic view of liquid desiccant air conditioning system

5. OBSERVATIONS

Table 1:-Experimental observations with simple plate of dehumidifier

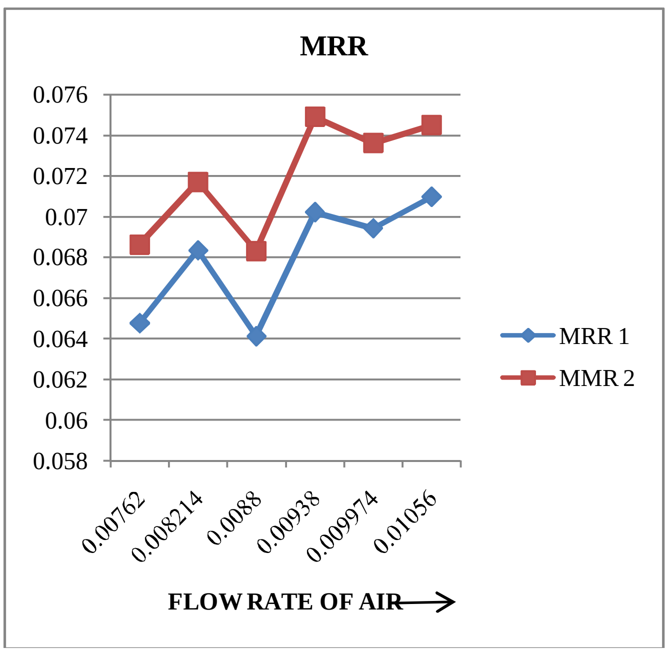
S.No.	Time (min)	Velocity (m/s)	Mass flow rate (kg/s)	Specific Humidity Inlet (gm./kg d.a.)	Specific Humidity outlet (gm./kg of d.a.)	Moisture Removal rate (gm./s)	Effectiveness of regenerator	Δ w (gm./kg)
1	5	1.3	0.00762	29.86	21.36	0.06477	0.285	8.50
2	10	1.4	0.00821	29.50	21.18	0.06834	0.282	8.32
3	15	1.5	0.00880	29.32	21.31	0.06413	0.273	8.01

4	20	1.6	0.00938	29.46	21.98	0.07021	0.254	7.48
5	25	1.7	0.00997	29.60	22.64	0.06942	0.235	6.96
6	30	1.8	0.01056	30.01	23.29	0.07096	0.224	6.72

Table 2:-Experimental observations with plate having pattern impressed over it

S.No.	Time (min)	Velocity (m/s)	Mass flow rate (kg/s)	Specific Humidity Inlet (gm./kg d.a.)	Specific Humidity outlet (gm./kg of d.a.)	Moisture Removal rate (gm./s)	Effectiveness of regenerator	Δ w (gm./kg)
1	5	1.3	0.00762	30.02	21.01	0.0686	0.300	9.01
2	10	1.4	0.00821	29.81	21.074	0.0717	0.293	8.74
3	15	1.5	0.00880	29.40	20.87	0.0683	0.290	8.53
4	20	1.6	0.00938	29.72	21.74	0.0749	0.268	7.98
5	25	1.7	0.00997	30.12	22.742	0.0736	0.245	7.34
6	30	1.8	0.01056	30.10	23.044	0.0745	0.234	7.06

6. RESULTS



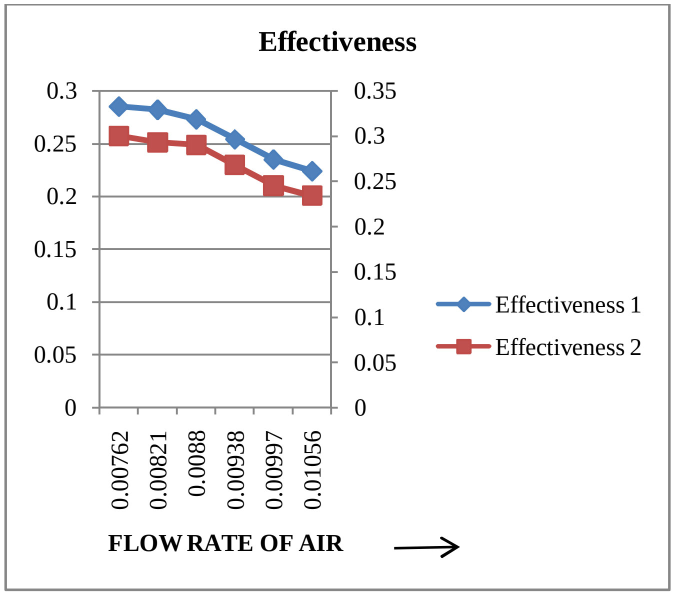


Fig. 2: Comparison of moisture removal rate and effectiveness in both cases

From the above shown results it can be observed that in case of the dehumidifier plate with a pattern impressed on it the air dehumidification was more than the case of simpler one. The results shows a slight increase in the observed values attributed to the fact that the utilization of the desiccant material was better as more no. of particles of the desiccant material was involved the process of dehumidification.

7. CONCLUSION

The study conducted had shown thatin the case of dehumidifier with modification in the surface texture of the dehumidifier plate the flow of the desiccant material can be improvised and it may result out in the a more enhanced values. The dehumidification obtained is little finer as is seen in the observations as the values of moisture removal rate enhancing from 0.0647 to 0.0686 kg/s and the effectiveness enhancing from 0.285 to 0.300. Similar observations were observed in the other readings with slight increment in the change of humidity of the required processed air.

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