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Regeneration of Liquid Desiccant in Solar Passive Regenerator with Enhanced Performance

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Abstract: *Demand for air conditioning is growing, which many times strains the electricity grid. It is desirable to use technologies like liquid desiccant based air conditioning, which can use waste heat or solar thermal energy. Solar regeneration has challenges like numerous components, higher parasitic power and low efficiency. In this work, a solar passive regenerator is developed and used, which has nominal power consumption for its operation. Its efficiency can be improved significantly by enhanced glass cooling as demonstrated in this work. The moisture removal rate could be improved by more than 100% with this method. The effect of concentration and solar insolation on moisture removal rate was also studied in this work.*

Keywords: *Air conditioning, Liquid desiccant, Regeneration, Solar energy.*

I. INTRODUCTION

Per capita energy consumption of a country is many times considered the indicator to growth of economy. But energy consumption is also related with pollution and climate change concerns. Demand for air conditioning is growing as economy and comfort expectations grow. It would be preferable to use renewable energy source or waste heat source for providing air conditioning rather than depending only on vapour compression refrigeration system, which needs electrical energy. Liquid desiccant (LD) based air conditioning or air dehumidification (LDAD) systems can use solar thermal energy for regeneration of LD. Various methods of regeneration using solar energy, like hot air from solar air heater, hot water from solar water heater, two stage regeneration with in-situ regeneration in evacuated tube collector etc. are reported in literature [1-4].

In-situ regeneration of LD in solar collector would help to reduce system components and parasitic power consumption. Mullick and Gupta preferred flat plate collector for this purpose compared to solar still used by Hollands to improve efficiency [5, 6]. Heavy dependence on weather conditions and dust contamination are limitations of this system. Though efficiency of solar still, which may be called solar passive regenerator, when used for LD regeneration, is less; it has other advantages like nominal power consumption and no dust contamination. Mehta and Gandhi presented simulation as well as experimental results for regeneration of aqueous potassium formate solution in such regenerator [7]. An effort has been done in this work to enhance efficiency of this device and make it a good potential candidate for LD regeneration using solar energy.

II. EXPERIMENTAL SET-UP, PROCEDURE AND INSTRUMENTATION

A fibre reinforced plastic (FRP) solar still with 1 m^2 area available in market was used as a raw device. LD regeneration involves higher temperatures, which can lead to higher losses in such device. So, the device was modified by providing additional thermocol insulation contained in a wooden box. Calcium chloride is a low price and readily available chemical, so aqueous solution of calcium chloride was used as LD in this work. A cooling system with low flow rate of water was developed to cool the solar regenerator glass (Fig.1). This water need not be taken from outside, but the water condensed in process of regeneration can itself be used for this purpose.

The cooling system consists of a source water tank, a diaphragm type of pump with 14 W rating, plastic tubes and small openings for cooling water distribution over the glass cover. Water was pumped at a rate of around 4 kg/h, excess water was collected and recirculated. Two solar passive regenerators, one with cooling and another without cooling were tested by putting them side by side. Experiment started at 9:30 am in morning and ended at 5:30 pm, in the month of June. Concentration of LD was 40% in one such experiment. Another set of experiment was done, taking two difference concentrations of LD in the regenerator and finding the effect of concentration on regeneration rate of LD.

Figure 1: Experiment scheme for solar passive regenerator, with and without glass cooling

The flow rate of water was measured by collecting the water for 5 min in a container and weighing the its mass. Temperature of LD was measured with K type thermocouple whose juction were submerged in LD pool. Surface temperature of glass was also measured with a contact thermometer, K type with digital display. Ambient conditions were measured using humidity and temperature sensor, which were connected with a datalogger.

III. RESULTS AND DISCUSSIONS

Fig. 2 shows variation of LD temperature and glass temperature for solar passive regenerator with and without glass cooling. Experiment was performed in the month of June and concentration of LD was 40% in this case. Solar insolation was 5.645 kW/m^2 over the day as measured at Vallabh Vidyanagar, a town near Vadodara. It is seen that glass temperature for the system with cooling remains around 10^{o}C lower than that without cooling. Lower glass temperature should help higher heat transfer and thus moisture removal rate. It is seen in Fig. 3 that moisture removal rate from LD is much higher for glass cooled solar passive regenerator. It is seen that regeneration in glass-cooled regenerator started much earlier as compared to the other. Total condensate collected in case of glass-cooled regenerator was 1331 *ml* as compared to 661 *ml* for the non-glass-cooled regenerator. Thus, regeneration rate got enhanced by more than 100% due to glass cooling. It is seen that LD temperature also remains lower in glass-cooled regenerator. This is due to higher amount of heat and moisture transfer occurring from LD to glass, which provides higher cooling rate for LD. As LD remains at lower temperature, heat losses to ambient reduce and efficiency would increase.

In another experiment, concentration of LD was taken 37% instead of 40% and solar insolation was 5.916 kW/m^2 on that day. Moisture removal rates were 2014 and 1238 *ml* with and without glass cooling in regenerator respectively. The increased water removal rate is due to higher water vapour pressure exerted by LD at lower concentration. In addition to that, from higher solar insolation also contributed to higher output in this case. To study the effect of only concentration on regeneration rate, another experiment was conducted testing two glass-cooled solar regenerators simultaneously, one with LD concentration equal to 37% and the other with 42%. Moisture removal rates were 1816 and 1409 *ml* respectively. Thus, 5% rise in concentration reduced the moisture removal rate by 22%.

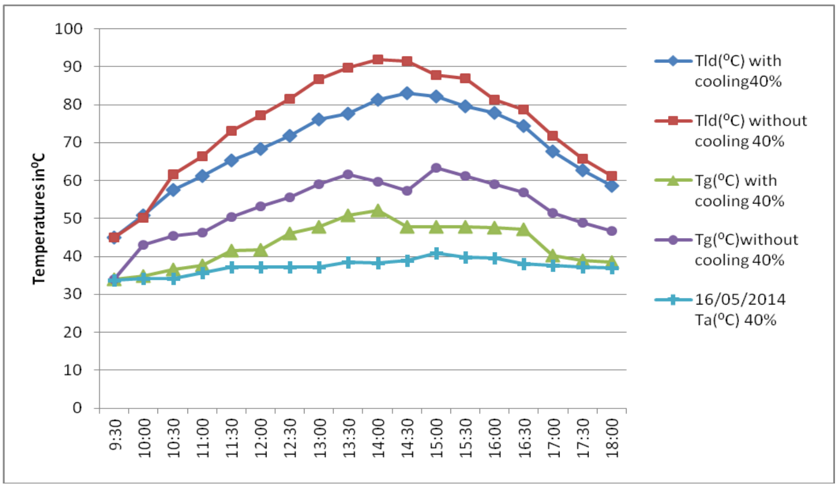

Figure 2: Variation of various parameters for regenerator over the day (T_{ld}: liquid desiccant temperature, T_g: glass temperature, T_a: ambient temperature)

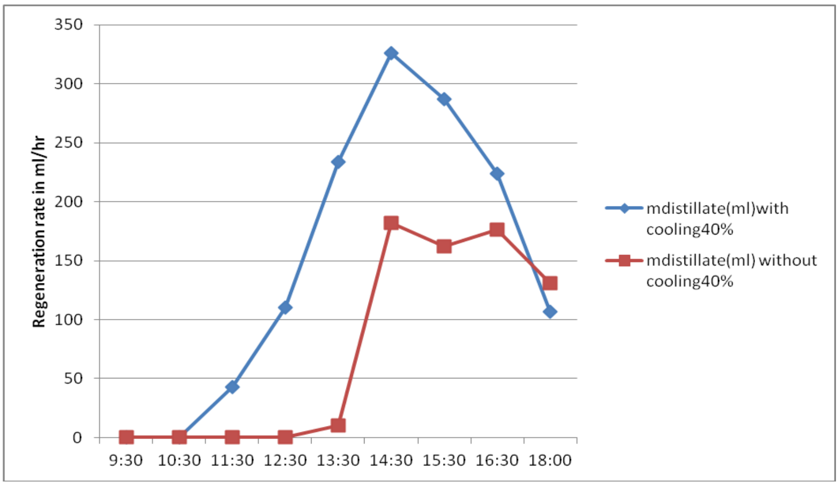

Figure 3: Water removal rate for regenerator over the day ($m_{distillate}$: mass of distillate or water removed from liquid desiccant)

IV. CONCLUSION

A solar passive regenerator with enhanced efficiency due to glass cooling was demonstrated in this work. Glass cooling helped to increase moisture removal rate by more than 100% for 40% concentration solution of calcium chloride. Moisture removal rate as high as 2014 *ml* per day was achieved using the regenerator with enhanced performance. Along with other advantages like non-contamination of LD and low parasitic power consumption, this solar passive regenerator seems a good potential candidate for LD regeneration. The work has also demonstrated that solar insolation and concentration of LD has significant effect on moisture removal rate from a solar regenerator.

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