Modelling and Experimental Evaluation of a Liquid Desiccant Air-conditioning System with Solar Thermal Regeneration

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Synopsis
As part of an ongoing project that aims to demonstrate the benefits of solar cooling in Canada, a 95m² vacuum tube solar array was installed and instrumented to drive a pre-commercial Liquid Desiccant Air Conditioner (LDAC). In phase one of the study, the LDAC was tested using a gas-fired boiler and the performance was characterized. The second phase, now in progress, involves connecting the previously studied LDAC to an evacuated tube solar array. The array was designed and installed during the summer of 2011 and operating data is currently being collected.

Introduction
Air conditioning systems consume a significant amount of energy and contribute to peak electrical loads. Thermally driven systems using solar energy are an attractive alternative to traditional systems since the peak solar energy closely coincides with the air conditioning load. Liquid desiccant systems utilize the hygroscopic properties of a salt solution to dehumidify air. Ventilation air is brought into contact with concentrated desiccant solution in the conditioner, where water vapour is absorbed. This process releases the latent heat of condensation, which must be removed to maintain conditioner effectiveness. The diluted desiccant is then regenerated using low-grade heat. The novel low-flow LDAC system used for this demonstration consists of two parallel plate heat and mass exchangers, which are internally cooled and heated. Desiccant flows in a thin wick over the outside of the plates, while air is blown horizontally between the plates to allow for absorption and desorption of water vapour. The low desiccant flow rates eliminate carryover of desiccant into the air stream, and increase the desiccant storage capacity. Storage is an important benefit of liquid desiccant systems when compared with solid desiccant or rotary wheel dehumidifiers; solar energy can be stored in the form of concentrated desiccant, which provides high-density (~1000MJ/m²) loss-less energy storage [1].

Methods and Results
Phase I testing of the system used a 90kW gas fired boiler as a heat source for the regenerator. Regeneration temperatures were varied from 50-90°C, similar to temperatures produced by flat plate and evacuated tube solar collectors. The performance was characterized using experimental results and modeled in TRNSYS. Higher regeneration temperatures were found to increase the system capacity and coefficient of performance. As a result, the solar array was designed using evacuated tubes solar collectors [2]. The system was designed and installed to have variable configurations. Figure 1 shows a simplified schematic of the solar driven desiccant system. The ground mount solar array (shown in Fig. 2) consists of 24 evacuated tube solar collectors, which provide 61m² of absorber area and cover a gross area of 95m². The collector circulator pump (P1) and pump between storage and regenerator (P2) are high efficiency, variable speed pumps that provide additional testing and control configurations. The gas-fired boiler provides auxiliary power for the LDAC and can be configured in series or parallel. The 65kW cooling tower is used to provide cooling water to the conditioner.

TRNSYS was used to model the solar LDAC system and simulations were used as a design tool to help size the array and storage tank components. It was predicted that the solar array would provide 65% of the required thermal input with solar collector efficiency (based on absorber area) of 65%. The LDAC unit was predicted to have an average thermal COP of 0.52 and latent cooling power between 13-23kW. The array is currently being operated with the dry cooler rejecting collected heat. Figure 3 shows the experimental operating data for September 18th 2011.

Future Work
Simulations of solar LDAC for different operating conditions will be validated with experimental data. The system will be improved and expanded by replacing inefficient pumps and fans and incorporating desiccant storage. Storage integration is expected to increase both solar fraction and solar utilization. The array will be monitored during the winter of 2011 to determine its capacity for space heating and evaluate the potential of a solar combi-system which provides space heating, cooling, and domestic hot water.

References