ENERGY EFFICIENT GREENHOUSE MICROCLIMATE CONTROL USING LIQUID DESICCANT DEHUMIDIFICATION

Sean Seemann
Department of Mechanical and Materials Engineering, Queen's University, Kingston, Ontario

Dr. Stephen Harrison
Department of Mechanical and Materials Engineering, Queen's University, Kingston, Ontario

Introduction

Greenhouse microclimate control, specifically cooling, has been an issue for crop growers in Southern Ontario for many years. High humidity and temperatures inside the greenhouse lead to crop degradation, plant diseases, and ultimately loss of revenue. Tradition methods of cooling include natural ventilation through roof top fenestrations and large-scale evaporative coolers. Both techniques prove ineffective during the summer months when ambient relative humidity can reach 100% at temperatures of 35+°C. While opening roof top vents allows for natural ventilation it also allows pests to enter the structure and damage crops. Chemical absorption cooling represents a dramatic alternative to tradition cooling methods and a viable and economic technology for greenhouse growers.

Background

Traditional vapour compression and fan coil air conditioning systems make up the majority of space cooling technology. Requiring the incoming air to be cooled below its dew point to dehumidify, a vapour compression unit then must reheat the air to the desired conditions. This cycle is very energy intensive and inefficient.

Alternatively chemical absorption cooling is achieved through a liquid desiccant fluid. This aqueous salt solution lowers the vapour pressure of the water in the fluid causing moisture from incoming air to be absorbed. The now diluted solution is regenerated with low-grade heat raising its relative vapour pressure and reject the absorbed moisture.

Flat-plat liquid desiccant machines use a wicking material in a "honeycomb" structure to achieve a laminar flow of liquid desiccant over a relatively large surface area. Process or regeneration air is then blown through the "honeycomb" to collect or reject moisture. This differs from stacked liquid desiccant machines, which spray the liquid desiccant over a stacked medium to increase contact surface area, but causes large carry over of salts into the air.

Heating and cooling loops are required to remove the heat of absorption of water from the process air stream and apply the required heat for regeneration. These loops can be independent of the system requiring external processing or be build into the unit with a heat pump managing the loops. Low-grade heat can be supplied from a variety of sources, but the technology is especially applicable to solar thermal collection. Alternatively most greenhouses are hydraulically heated, the liquid desiccant unit provided the potential to better exploit the hot water facilities already install in the majority of greenhouses.

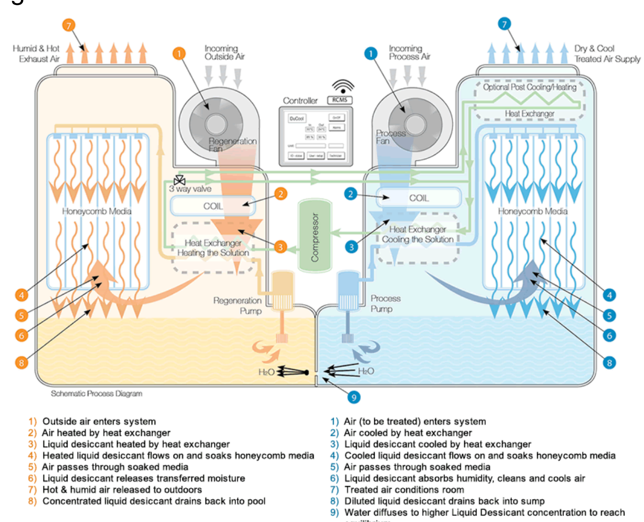

Figure 1: Andvantix Systems DuTreating Unit with Build-In Heat Pump

Greenhouse loads vary greatly when compared to traditional building loads. A standard double-inflated-poly construction can give a U-value of roughly 0.5 W/m^2K and a tightly constructed greenhouse can have an infiltration rate of 0.5 vol./hr. The largest loads originate from the high solar gains (which can reach 800 W/m^2 transmitted into the greenhouse) and the transpiration rate of the plants (Which can reach almost 6 L/m^2/day). These two factors cause large microclimate swings based on crop growing cycle and environmental climate conditions.

Figure 2: research Greenhouse at Greenhouse and Processing Crops Research Centre

The Project

A pilot project run through the Canadian Agricultural Adaptation Council and with funding from Ontario Greenhouse Vegetable Growers aims to determine the feasibility of liquid desiccant technology in greenhouse cooling. A small 50 m^2 greenhouse at the Greenhouse and Processing Crops Research Centre in Harrow, Ontario will be the testing bed for the new technology. A flat plate liquid desiccant unit manufactured by Advantix Systems will be tested to see if can meet the latent cooling loads of the greenhouse and increase crop production. The success of the project will be determined by microclimate condition inside of the greenhouse (temperature and humidity), energy consumption when compared to traditional cooling techniques, and crop production and health.

The project will also investigate the scalability of the liquid desiccant systems. Industrial greenhouses can cover up to 60 acres and require massive amounts of energy to maintain climate control. If the liquid desiccant technology is applicable the potential cost savings could be in the millions of dollars.

References

Harrison, S.J., Mesquita, L., (2008) “Analysis of Flat-Plat, Liquid Desiccant, Dehumidifier and Regenerator” published thesis (Ph.D.), Queen’s University

Harrison, S.J., Jones, B., (2008) “Field Evaluation and Analysis of Liquid Desiccant Air Handling System” published thesis (M.A.Sc.), Queen’s University

Jain, S., Bansal, P.K., “Performance Analysis of Liquid Desiccant Dehumidification Systems” International Journal of Refrigeration (2007).

Medrano, E., Lorenzo, P. et al “Evaluation and Modelling of Greenhouse Cucumber-Crop Transpiration Under High and Low Radiation Conditions” Scientia Horticulturae (2005)