EXECUTIVE SUMMARY
Electro-osmosis for Dehumidification: Final Report

Electroosmosis has been proposed for dehumidification in air conditioning systems (Mina, 2003). This would allow the sensible and latent loads to be handled separately and may lead to improvements in energy efficiency and comfort control. In electroosmosis, water is pumped through channels or pores in solid material by the application of a voltage. A membrane composed of a desiccant material could remove moisture from air to be conditioned. Then, electroosmotic pumping could move the moisture across the membrane and reject it on the other side.

Earlier work on this project is recorded in the interim Phase 1 report (Gerlach, 2006). In Phase 1, literature pertinent to electroosmotic dehumidification was reviewed. A model was developed that computes the flow rate through the membrane as well as the water concentration and electrical potential profiles inside the membrane. In addition, experiments were proposed to test the validity of the model, prove the concept, and measure the membrane material properties. This report details further modeling, experiments completed, and a comparison of an electroosmotic dehumidification system to a current technology air conditioning system.

This report separately covers flow in inorganic media such as silica gel where there is bulk flow due to viscous drag and flow in organic ionomers where the flow is primarily the water in the solvation sheath of the mobile ions.

The model developed in Phase 1 for silica gel membranes has been transferred to Comsol (formerly Femlab), a finite element code allowing the modification and writing of the governing differential equations. This allows an increased number of elements in order to determine grid independence. The highly nonlinear relationship of relative humidity to silica gel electrical conductivity leads to highly nonlinear behavior in the model and instability.

A bench top experiment was developed to screen promising membrane materials and to provide data for model validation. Two sealed humidity chambers were separated by a membrane. The changes in the humidity were measured as current was applied to the membrane. A variety of membrane materials based on silica gel, Plaster of Paris, or zeolites were investigated. The most successful inorganic membrane was a silica gel concrete using Plaster of Paris as the cement and silica gel particles as the aggregate. The calculated total flux was 0.0015 mol/s-m^2 with an energy per mol of water pumped of 2 J/mol

Nafion®, a sulfonated tetrafluoroethylene copolymer produced by DuPont, was tested in the same manner. Although, the electroosmotic flux was much higher than for the inorganic membranes, it was still is three orders of magnitude smaller than that predicted. Further research is needed to reconcile the experimental data and modeling in order to determine feasibility.

The performance of an air conditioning system using an electroosmotic dehumidification system in series with a conventional vapor compression cycle was modeled. The electroosmotic system handles the entire latent load and the vapor compression system handles the entire sensible cooling load. Performance of the system was compared to a conventional vapor compression air conditioner that handles both the latent and sensible loads with a single evaporator coil. Modeling indicates the feasibility of electroosmotic dehumidification for separating the control of latent and sensible load in air conditioning systems. The total COP of the system, neglecting fan power, can be 1-2 times higher (depending on airflow rate) than a system using an evaporator for latent and sensible load.