Final Report ARTI 612-10050

FUNDAMENTAL UNDERSTANDING OF HEAT AND MASS TRANSFER IN THE AMMONIA/WATER ABSORBER

EXECUTIVE SUMMARY

An experimental investigation of heat and mass transfer in a horizontal tube falling-film ammonia-water absorber was conducted. A tube bank consisting of four columns of six 9.5 mm (3/8") nominal OD, 0.292 m (11.5") long tubes was installed in an absorber shell that allowed heat and mass transfer measurements and optical access. A test facility consisting of all the components of a functional absorption chiller was fabricated specifically for this investigation. Thus, a steam-heated desorber was used to generate ammonia-water vapor over a wide range of conditions. The ammonia-water vapor was rectified and condensed, followed by recuperative heat exchange before being expanded to the evaporator pressure. The cooling load was supplied to the evaporator by a combination of resistance heating and closed loop fluid heating. The evaporated refrigerant was preheated recuperatively by the fluid exiting the condenser and then flowed to the absorber to be absorbed in the test section. A solution heat exchanger between the absorber and desorber (and in some tests, a solution pre-conditioner upstream of the absorber) completed the ammonia-water loop.

Several variations of the basic system set up were fabricated to enable testing over the wide range of conditions (nominally, desorber solution outlet concentrations of 5 - 40% for three nominal absorber pressures of 150, 345 and 500 kPa, over solution flow rates of 0.019 – 0.034 kg/s.) Heat transfer rates were measured independently for both sides of each component and energy balances were rigorously established based on mass, species and enthalpy balances for each component before test results were deemed acceptable. Care was also taken throughout the study to not only establish the desired conditions, but also to maintain the solution-side thermal resistance as the governing resistance so that absorption heat and mass transfer phenomena could be measured accurately. Component level measurements at the absorber were used to determine heat transfer rates, overall thermal conductances, solution-side heat and vapor-side mass transfer coefficients for each test condition. The local measurements allowed dividing the absorber into segments that were analyzed to obtain the variations in heat and mass transfer rates along the solution flow path. The trends in heat and mass transfer coefficients were discussed, highlighting the effect of solution flow rate, solution concentration and absorber pressure on the heat and mass transfer coefficients. For the range of experiments conducted, the solution heat transfer coefficient varied from 923 to 2857 W/m^2-K while the vapor mass transfer coefficient varied from 0.0026 to 0.25 m/s (at the component level), depending on the test condition. The solution heat transfer coefficient increased with increasing solution flow rate, both at the component and segmental levels; however, the vapor mass transfer coefficient seems to remain unaffected with the variations in solution flow rate and was found to be primarily determined by the vapor and solution properties.

Pertinent dimensionless parameters were also computed from the measured solution heat and vapor mass transfer coefficients. The experimental heat and mass transfer coefficients were compared with the relevant studies from the literature. Based on the observed trends in the experimental data and from comparisons with the other studies, heat transfer correlations at the component and local levels, and mass transfer correlations at the component level were developed to predict heat and mass transfer coefficients for the range of experimental conditions tested. These correlations can be used to design horizontal tube falling-film absorbers for ammonia-water absorption systems.