



Experimental study of nucleate pool boiling heat transfer to ammonia–water–lithium bromide solution

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ABSTRACT

Visualization of bubble nucleation during nucleate pool boiling outside a vertical cylindrical heated surface was done for ammonia–water binary and ammonia–water–lithium bromide ternary mixture in order to obtain a descriptive behavior of the boiling which was directly compared with the measured heat transfer coefficient at low pressure of 4–8 bar and at low ammonia mass fraction of $0 < x_{\text{NH}_3} < 0.3$ and at different heat flux. The lithium bromide concentration of the solution was chosen in the range of 10–50% of mass ratio of lithium bromide in pure water. The effect of concentrations, heat flux and pressure on boiling heat transfer coefficient was studied. Still images taken with high speed camera are used to demonstrate the increase in boiling heat transfer coefficient with the addition of lithium bromide salt to ammonia–water mixture. Further work is required to obtain quantitative information about bubble nucleation parameters.

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1. Introduction

Absorption refrigeration systems have attracted increasing research interests in recent years. Unlike mechanical vapor compression refrigerators, these systems cause no ozone depletion and reduce demand on electricity supply. Besides, heat powered systems could be superior to electricity powered systems in that they harness inexpensive waste heat, solar, biomass or geothermal energy sources for which the cost of supply is negligible in many cases. This makes heat powered refrigeration a viable and economic option. The most common absorption systems are H₂O–LiBr and NH₃–H₂O cycles.

The NH₃–H₂O pair possesses very good heat and mass transfer characteristics but requires rectification to remove water vapor from the ammonia rich refrigerant vapor. Lithium bromide, on the other hand, is a non-volatile salt that can act as an absorber for both ammonia as well as water due to ion formation and complexing. Therefore, ternary NH₃–H₂O–LiBr mixtures with high salt concentrations could offer better performance by absorbing ammonia and water thus reducing rectification losses, especially at higher operating temperatures.

The thermodynamic properties of the NH₃–H₂O–LiBr system (principally for a LiBr/H₂O ratio of 60/40 weight percent) have been

investigated by Radermacher [1]. McLinden and Radermacher [2] compared the performance of an absorption heat pump operating with NH₃–H₂O and NH₃–H₂O–LiBr mixtures. Although the COP of the heat pump operating with ternary mixture was lower than with the binary system, there were indications of lower water content in the refrigerant vapor entering the rectifier with the ternary mixture.

Peters et al. [3,4] investigated the effects of lithium bromide on the NH₃–H₂O system using a static method to measure vapor–liquid equilibrium data of NH₃–H₂O–LiBr mixtures over temperatures between 303.15 and 423.15 K, and pressures up to 1.5 MPa. They reported reduction in partial pressure of both ammonia and water in the vapor phase compared to respective pressures in binary NH₃–H₂O system. They developed a quasi-chemical reaction model to correlate experimental data. The correlation was in good agreement with the experimental data.

Yuyuan et al. [5] measured vapor–liquid equilibrium (VLE) data for NH₃–H₂O–LiBr system at 10 temperature points between 15 and 85 °C, and pressures up to 2 MPa. The LiBr concentration of the solution was chosen in the range of 5–60% of mass ratio of LiBr in pure water. The VLE for the NH₃–H₂O–LiBr ternary solution was measured statically. It was seen that at the same temperature and ammonia concentration, vapor pressure of ternary NH₃–H₂O–LiBr mixture solution was lower than that of the binary NH₃–H₂O solution. The ammonia content in the vapor phase of ternary NH₃–H₂O–LiBr mixture solution was higher than that in the binary NH₃–H₂O solution without lithium bromide.

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