CHAPTER 6

CONCLUDING REMARKS AND RECOMMENDATION FOR FUTURE WORK

6.1 Concluding Remarks

We have carried out experiments to unravel the flow boiling heat transfer characteristics (including subcooled and saturated boiling) and associated bubble characteristics of R-134a in a horizontal narrow annular duct. The effects of the refrigerant mass flux, imposed heat flux, refrigerant saturated temperature, inlet subcooling, and gap size of the duct have been examined in detail. A summary of the major findings from the present results is given in the following.

(1). The temperature undershoot at ONB are significant for the subcooled flow boiling of R-134a in the horizontal narrow annular duct, but are insignificant for the saturated flow boiling.

(2). The subcooled boiling heat transfer coefficient increases with a decrease in the gap size, but decreases with an increase in the inlet liquid subcooling. Besides, raising the imposed heat flux can cause a significant increase in the subcooled flow boiling heat transfer coefficient. However, the effects of the refrigerant mass flux and saturated temperature on the boiling heat transfer coefficient are small.

(3). The saturated boiling heat transfer coefficient of R-134a also increases with a decrease in the gap size. Besides, raising the imposed heat flux can also cause a significant increase in the saturated flow boiling heat transfer coefficient. However, the effects of the refrigerant mass flux and saturated temperature on the boiling heat transfer coefficient are also small.

(4). Visualization of the subcooled flow boiling processes reveals that the bubbles are suppressed by raising the refrigerant mass flux and inlet liquid subcooling. Moreover, raising the imposed heat flux produces positive effects on the bubble population, coalescence and departure frequency. The increase in the saturated temperature of the refrigerant results in reductions in the bubble departure frequency and active

nucleation site density. Moreover, the bubble departure frequency and mean speed of the big bubbles in the slug flow increase for a reduction in the gap of the duct.

(5). The results from the flow visualization of the bubble behavior in the saturated flow boiling show that the mean diameter of the bubbles departing from the heating surface decreases slightly at increasing refrigerant mass flux. Besides, at a high imposed heat flux many bubbles generated from the cavities in the heating surface tend to merge together to form a big bubbles. The mean bubble departure frequency and speed of the big bubbles in the slug flow are also higher in the smaller duct.

(6). The results from the flow visualization in the subcooled flow boiling also show that the flow pattern changes from bubbly flow to slug flow when the gap size is reduced to 0.2 and 0.5 mm for the ducts subject to a high heat flux. In the slug flow the interface evaporation of the thin liquid film between the confined bubbles and heating surface is very effective for heat transfer.

(7). Empirical correlations for the flow boiling heat transfer coefficients for R-134a in the narrow annular duct has been provided. Correlating equations have also been proposed for some bubble characteristics in the subcooled and saturated boiling of R-134a in the narrow annular duct.

6.2 Recommendation for Future Work

During the course of the this study it is realized that in addition to the investigation of the flow boiling of the refrigerant R-134a in the narrow annular duct, the HFC refrigerants such as R-407C and R-410A have the potential to be used in the many air conditioning and refrigeration systems. Besides, the stability of the boiling flow is becoming an important issue for using them in air-conditioning and refrigeration systems. Recommendation for the possible future work is given in the following.

(1) The flow boiling heat transfer and associated bubble characteristics for R-407C and R-410A in small ducts.

(2) Condensation heat transfer, pressure drop and associated two-phase characteristics of R-407C and R-410A in small ducts.

(3) Unstable flow boiling of HFC refrigerants and associated heat transfer in small ducts.
(4) Methods to enhance the boiling heat transfer of HFC and natural refrigerants.