manifold designs, which will affect the flow distribution in the channels. Explanation on this will be welcomed.

The present authors have used the Shah correlation [5] to predict the Yan and Lin data for $T_{sat} = 31$ °C, $q'' = 5$ kW/m^2, and 100 and 200 kg/s m^2 mass velocity (G). This comparison shows that the Yan and Lin data for $G = 100$ kg/s m^2 and $x = 0.2$ are approximately five times that predicted by the Shah equation. However, at 0.8 vapor quality, the predicted values for both mass velocities are approximately equal and are 25% above the Shah correlation prediction. One may expect nucleate boiling to influence the evaporation coefficient at low vapor quality. However, the $q'' = 5$ kW/m^2 is sufficiently small that one would not expect significant nucleate boiling enhancement at this heat flux. The authors explanation of this will be appreciated.

References

[1] Y.-Y. Yan, T.-.F. Lin, Evaporation heat transfer and pressure drop of refrigerant 134A in a small pipe, Int. J. Heat Mass Transfer 41 (1998) 4183–4194.

[2] C.-C. Wang, S.-K. Chiang, Y.-J. Chang, T.-W. Chung, Two-phase flow resistance of refrigerants R-22, R-410A and R-407C in small diameter tubes, Trans. IChemE, Part A 79 (2001) 553–560.

[3] S.G. Kandlikar, A general correlation for saturated two-phase flow boiling heat transfer inside horizontal and vertical tubes, J. Heat Transfer 112 (1990) 219–228.

[4] Y.Y. Yan, private communication, December 2001.

[5] M.M. Shah, Chart correlation for saturated boiling heat transfer: equation and further study, ASHRAE Trans. 88 (1982) 185–196.

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Reply to Prof. R.L. Webb's and Dr. J.W. Paek's comments

Dr. Yan and I examine the comments from Prof. Webb and Dr. Paek carefully. Here is our response. We appreciate their comments to point out our mistakes.

(1) By checking all the measured raw data and the data reduction procedures leading to the evaporation heat transfer coefficient h_r and friction coefficient f_{tp} with extreme care, the results presented in Figs. 13 and 14 of the article for the comparison between the correlations proposed by Yan and Lin (1998) and the measured data are noted to be in mistake. More specifically, the error in f_{tp} ($\equiv -\Delta P_f/(2G^2 v_m L/D_i)$) is due to the incorrect evaluation of the specific volume v_m for the two-phase R-134a liquid–vapor mixture. The measured data for the frictional pressure drop ΔP_f, however, are correct, so are the heat transfer coefficient h_r. Moreover, the correlation for h_r given in the article of Yan and Lin (1998) is also incorrect. This correlation is too complicate to use conveniently and there are 36 values of the empirical constants involved in the equation. Some mistakes were made in the curve-fitting procedures in missing the final step to bring the data well above and well below the correlation together.

(2) A new and simpler correlation for h_r is proposed here. For $X_m \leqq 0.7$

$$h_r = 4.36\frac{k_l}{D_i}Pr_l^{1/3}(1 - X_m)^{-0.5}(C_1 \cdot Re_{eq} + C_2)(C_3 \cdot Bo + C_4) \tag{1}$$

and for $X_m > 0.7$

$$h_r = 4.36\frac{k_l}{D_i}Pr_l^{1/3}(1 - X_m)^{-0.5}(C_1 \cdot Re_{eq} + C_2) \tag{2}$$

Here the coefficients C_1 to C_4 are expressed as

$$C_1 = -0.0124G^{-0.368} \tag{3}$$

$$C_2 = 1.49G^{0.514} \tag{4}$$

$$C_3 = -1166X_m + 1028 \tag{5}$$

$$C_4 = 0.53\,e^{0.931X_m} \tag{6}$$

Note that the unit for the mass flux of R-134a G is kg/m^2 s, and Re_{eq} and Bo are respectively the equivalent Reynolds number and Boiling number, which have been defined in the article. Meanwhile, a new correlation is provided here for the friction factor as

$$f_{tp} = 0.127Re_{eq}^{-0.1925} \tag{7}$$

The comparison of the above correlations with the correct measured data for h_r and f_{tp} is shown in Figs. 1 and 2. The results show that the root-mean-square deviations between the above correlations and measured data are 18% for the heat transfer coefficient h_r and 22% for the friction factor f_{tp}.

(3) The refrigerant R-134a is sent into the 28 small pipes in a row by an upstream plenum, which is a horizontal large cylindrical container with two openings of 84 mm wide and 2 mm high to allow the refrigerant to

move into the small pipe from the container and to allow the refrigerant to move into the container from the refrigerant loop. This inlet flow arrangement is not expected to cause significant flow maldistribution at the inlet of the pipes.

(4) The large discrepancy between the present data for h_r and the Shah correlation at low heat flux q''_w, low mass flux G and low quality X_m can be made clear by visualizing the boiling flow in the small pipes. However, we do not conduct flow visualization here and hence do not have information on this question. Visualization of boiling flow in a small channel is currently in the stage of experimental system design in our laboratory. We plan to start the experiment in about 18 months.

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