# Evaporation Local Heat Transfer Coefficients of Refrigerant HFC-245fa in a Plate Heat Exchanger

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Plate heat exchanger, PHE, have been widely used for chemical reaction process, food processing, dry process, power generation and many other industrial applications due to their good thermal performance, compactness, and cost effective. For geothermal power generation using low temperature heat source such as hot spring, HFC-245fa (R-245fa) is employed as a refrigerant. In the past years, few research groups reported experimental data for evaporation heat transfer using PHE. However, there are very few experimental studies discussing local heat transfer along the plate in the PHE. Djordjevic and Kabel (2008) presented experimental results on evaporation heat transfer for flow boiling of ammonia and of R134a in a chevron-pattern corrugated PHE. The evaluation of a quasi-local heat transfer coefficient along the plate was mearsured, and the two-phase distribution and the heat transfer mechanism during evaporation in a plate channel were discussed. F. Vakili-Farahani *et al.* (2014) and R. L. Amalfi *et al.* (2016) used high-resolution IR camera to measure local PHE wall temperature under simple PHE simulated system by using 1 refrigerant channel and electronic heatin power supply.

In this study, original PHE is made by 3D printing method and thormocouples insert from the sidewall of the each plate for better understanding of heat transfer mechanizum in the PHE. Here we report a local heat transfer coefficients in the case of 1 refrigerant HFC-245fa channel and 2 heat source channels.

Figure 1 shows the flow loop diagram used in this study. The loop mainly consists of a resourver tank, a pump, an accumurator, a pre-heater, a test section and a condenser. The preheater and condenser are used a Brazed Heat Exchanger (BHE, Hisaka Works) to control inlet condition. The system pressure is controlled by the accumulator ranging from 0.4–1.2 MPa, which is corresponding to 54.9-97.8 ℃. of saturated temperature. The volumetric flow

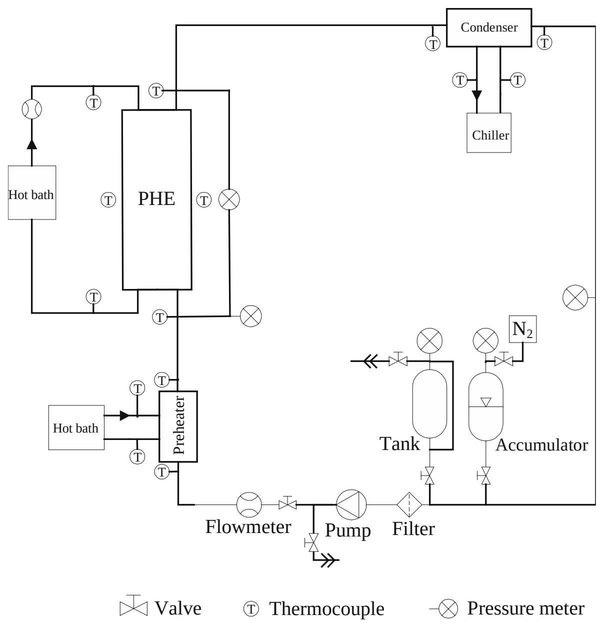


**Figure 1:** Flow loop diagram

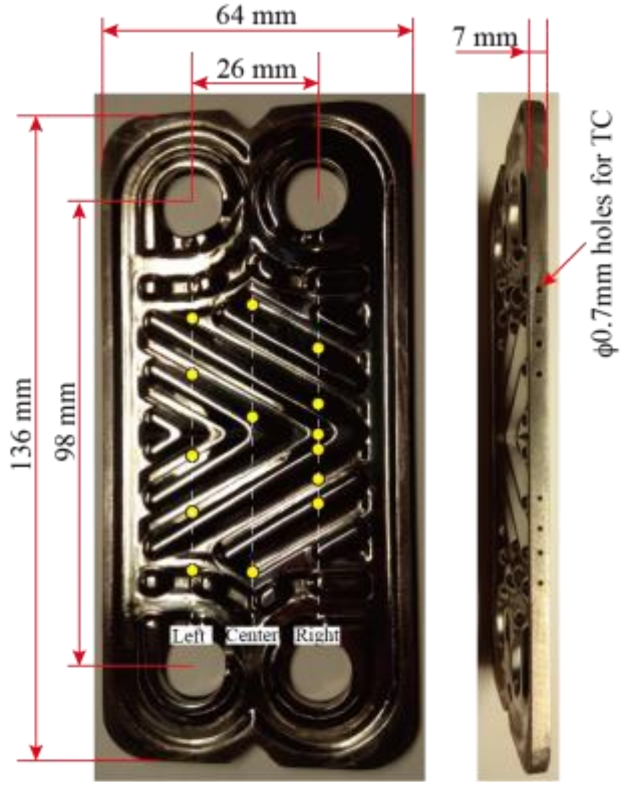


**Figure 2:** An image of the plate. The in-wall temperature measured at 16 locations as pointed by yellow circle.

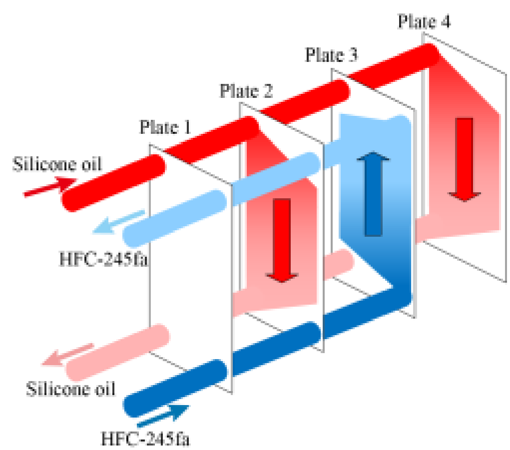


**Figure 3:** Fow configuration in PHE

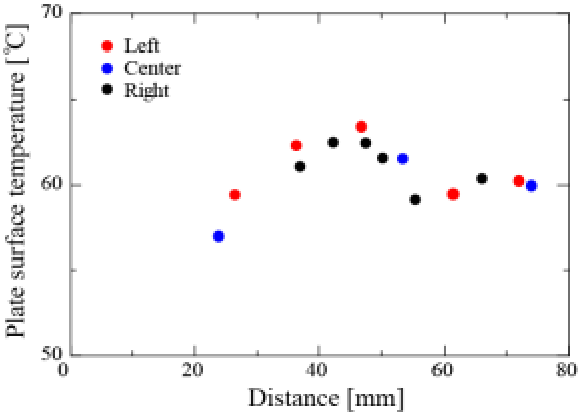


**Figure 4:** Surface temperature of Plate 3 on the HFC-245fa side. “Left”, “Center”, “Right” are corresponding to the locations as pointed in Fig. 2.

rate set at about 30 ml/min. The subcooling temperature of HFC-245fa at the inlet of the PHE is set at 30 K. To heat HFC-245fa, hot silicone oil flows from thermostatic bath to PHE at 90-150 ℃.

The PHE as a test section shows in Fig. 2. The size of heating area of the plate is 0.00406 $m^2$ (W 0.049m×L 0.08286m), and plate thickness is 1.5 mm. The hydraulic equivalent diameter, $D_h$, is 4 mm, and cross-section area of flow channel between plates is 117.6 $mm^2$. The plate is made by direct metal laser-sintering system (EOSINT-M250 Xtended, EOS GmbH), and has 16 holes at the sidewall to insert ϕ0.5 mm thermocouple as shown in Fig. 2. Using those thermocouples, the local temperature in each plate can be measured. Heat flux is drived from the temperature difference and mass velocity of silicone oil. Under constant heat flux condition, local temperature of the plate surface and local heat transfer coefficient can be drived.

Figure 4 shows heated surface temperature distribution of HFC-245fa channel side on the Plate 2 and Plate 3. The horizontal axis indicates the distance from inlet of the PHE. The experimental conditions of this result are heat flux $q$ = 8301 kW/$m^2$, system pressure $P$ = 0.4 MPa, mass flux of HFC-245fa $G_{\mathrm{HFC245fa}}$ = 4.97 kg/$m^2$s, Inlet subcooling of HFC-245fa $\Delta T_{\mathrm{sub}}$ = 28.75 K, inlet temperature of silicone oil $T_{\mathrm{Silicone}}$ = 97.94 ℃. As a result, non-uniform temperature field on the plate along the width direction was not found. Recuction of temperature at 53.4 mm was clealy observed, this point is defined as onset of nucleate boiling (ONB).

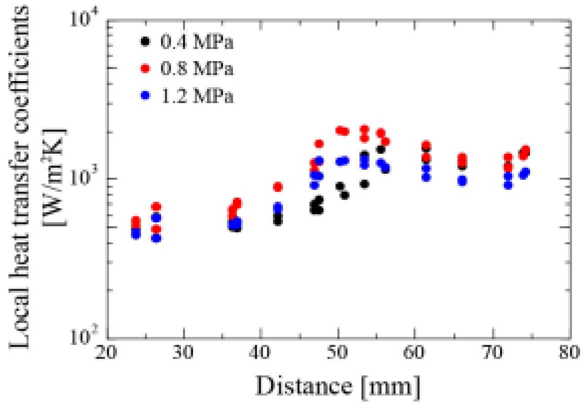


**Figure 5:** Heat transfer coefficients of Plate 2 and Plate 3 on the HFC-245fa side under various pressure conditions at $q$ = 7.6-7.8 kW/$m^2$, $G_{\mathrm{HFC245fa}}$ = 5 kg/$m^2$s, Inlet subcooling of HFC-245fa $\Delta T_{\mathrm{sub}}$ = 30 K.

From the local temperature on the heated surface and HFC-245fa fluid temperature, heat transfer coefficients are calculated as a function of heat flux derived from the temperature difference between inlet and outlet of Silicone oil. The results at three difference pressures, 0.4, 0.8 and 1.2 MPa are shown in Fig. 5. The effects of pressure on the heat transfer coefficient were not observed excepting ONB. In the case of 0.4 MPa, point of ONB is moved to downstream compared with high-pressure cases under present experimental consitions.

## References

E. Djordjevic and S. Kabelac, Flow boiling of R134a and ammonia in a plate heat exchanger, Int. J. Heat Mass Transf., 51, pp. 6235-6242 (2008)

F. Vakili-Farahani, R. L. Amalfi and J. R. Thome, Two-phase flow of R245fa in a 1 mm corrugation depth plate heat exchanger – Part 2: Flow boiling heat transfer, Interfacial Phenomena and Heat Transfer, 2, pp. 343-361 (2014)

R. L. Amalfi, J. R. Thome, V. Solotych and J. Kim, High resolution local heat transfer and pressure drop infrared measurements of two-phase flow of R245fa within a compact plate heat exchanger, Int. J. Heat Mass Transf., 103, pp. 791-806 (2016)