# Condensation heat transfer in square, triangular and semi-circular mini-channels

by

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## ABSTRACT

Lightweight and compact condensers have applications in electronics' cooling, especially for approaches using vapor compression cycles, as well as transportation. However, uncertainties in measured condensation heat transfer coefficients can range from ± 20% to ± 40% due to the challenges of measuring condensation heat fluxes and wall temperatures at the micro- and mini-scales; large uncertainties encourage condenser over-design. Typical approaches to measure condensation heat transfer coefficients in the micro/mini-scale utilize fluid-to-fluid heat exchangers, which can have high experimental uncertainties at the low heat duties encountered in micro- and mini-scale condensation. This study measured condensation heat transfer coefficients in three specially designed copper test sections using Fourier's Law to determine heat flux, building off the work of Kedzierski and Worthington (1993). Finite element simulations validated the linear temperature gradient assumption and wall temperature extrapolation, as condensation heat fluxes and wall temperatures are necessary to calculate condensation heat transfer coefficients. Single-phase experiments further confirmed the approach, as fluid-to-fluid and measured energy balances typically agreed within ±5%, and there is good agreement with the Gnielinski (1995) correlation for transitional flow.

Condensation heat transfer coefficients are reported for R134a in three-sided cooled square, triangular, and semi-circular multiple parallel channels with hydraulic diameters of 1 mm. A parametric study was conducted with the following parameters: mass flux (75, 150, 300, 450 kg/m$^2$s), average quality (0.1 to 0.85), saturation pressure (887.5 and 1176 kPa) and heat flux (23,500 to 46,000 W/m$^2$). Mass flux and quality were determined to have significant effect on condensation processes, even at lower mass fluxes, while saturation pressure, heat flux, and channel shape had no significant effect on condensation. Numerical condensation models of Wang and Rose (2005, 2006) showed significant condensation heat transfer enhancement from surface tension at the mini-scale, although this was not observed experimentally. One explanation is that Wang and Rose (2005, 2006) showed most of the enhancement due to liquid thinning at the top surface, as gravity played a small role. However, the present experimental boundary condition was three-sided cooling with an adiabatic top plate; thus, liquid thinning at the top surface would have no effect on the circumferentially averaged heat transfer coeffi-

cient. Because there was no significant surface tension enhancement, the macro-scale Shah (2009) correlation best predicted the data, with an average MAE of 25% for all geometries.