Boiling and condensation heat transfer and two-phase flow of R-134a in circular microchannels

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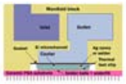
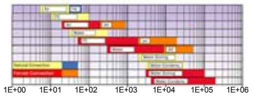
Objectives

- Study experimentally the fundamentals of boiling and condensation heat transfer in circular microchannels.
- Investigate the conditions leading to Critical Heat Flux (CHF).
- Investigate heat transfer coefficients and pressure drops for boiling and condensation of R-134a in circular microchannels.

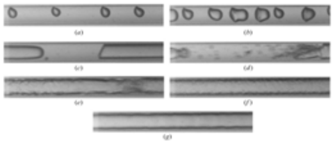
Applications: Compact micro heat sinks for electronic cooling [1]





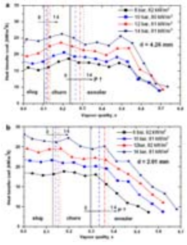
Order of magnitude of heat transfer coefficients depending on cooling technologies.
Unit of heat transfer coefficient: W/m²-K

Two-phase boiling flow patterns in circular microchannels [2]

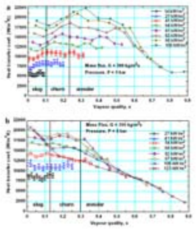


Flow observations for R-134a, *D* = 0.5 mm, *L* = 70.70 mm, G = 500 kg m−2 s−1, *T*sat = 30 ◦C and *T*sub = 3 ◦C, at exit of heater taken with a high definition digital video camera. (*a*) Bubbly flow at *x* = 2%; (*b*) bubbly/slug flow at *x* = 4%; (c) slug flow at *x* = 11%; (*d*) slug/semi-annular flow at *x* = 19%; (*e*) semi-annular flow at *x* = 40%; (*f*) wavy annular flow at *x* = 82%; (*g*) smooth annular flow at *x* = 82%.

Boiling heat transfer coefficient [3]

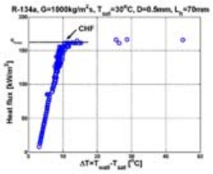


Local heat transfer coefficient as a function of quality for various system pressures.



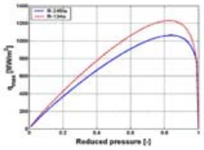
Local heat transfer coefficient as a function of quality at different heat fluxes.

Critical heat flux [4]



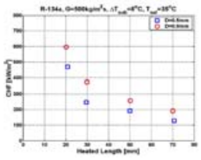
Identifying CHF

$$q_{\max} = \rho_V h_{LV} \sqrt{RT / 2\pi M}$$



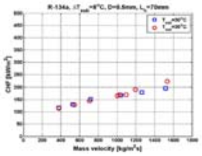
Upper limit of CHF: Theoretical prediction of CHF based on the work of Gambill and Lienhard [1].

Critical heat flux trends [4]



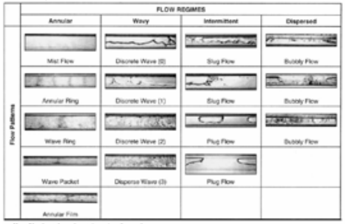
Variation of CHF as a function of the heated length in 0.5 and 0.8 mm ID tubes.

Influence of the refrigerant saturation temperature on CHF.



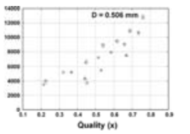
Two-phase condensation flow patterns in circular microchannels [5]

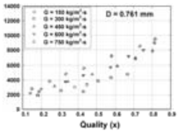
Working fluid: R-134a

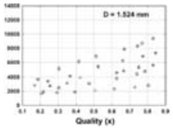


Note: Numbers above denote intensity of secondary waves.

Condensation heat transfer coefficient [6]





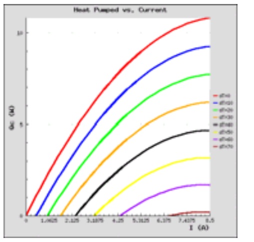


Working fluid: R-134a

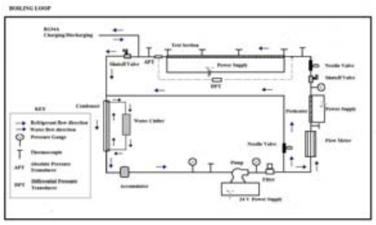
Heat transfer coefficient increases with increasing mass flux and quality, and decreasing channel diameter.

Thermoelectric coolers (TECs)

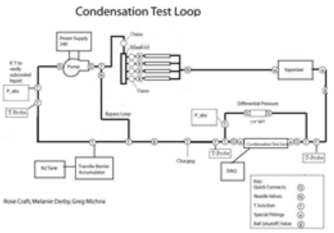
- Thermoelectric Coolers (also known as Peltier coolers): An applied voltage and current causes a temperature difference between the two faces of the cooler, thus cooling one side and heating the other.
- TECs will replace fluid to fluid heat exchangers in the condensation loop
- **Through calibration curves (shown on the right), the heat removed from the test section can be known by electrical measurements, thus giving more accuracy than fluid to fluid heat exchangers**



Boiling loop schematic



Condensation loop schematic



Acknowledgements

This research is supported by the Department of Defense Multidisciplinary University Research Initiative (**MURI**) program.

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[2] R. Revellin and J. R. Thome, A new type of diabatic flow pattern map for boiling heat transfer in microchannels, J. Micromech. Microeng. 17 (2007) 788–796.

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[4] Leszek Wojtan, Re´mi Revellin, John R. Thome, Investigation of saturated critical heat flux in a single, uniformly heated microchannel, J. Micromech. Microeng. 17 (2007) 788–796.

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