Refrigerant spray cooling of electronics

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Competent heat management is one of the major challenges in the development of modern electronics, which can be critical for the efficient operation and reliability of the equipment. Active thermal management options are required in cases of very high power densities. Spray cooling with water has been considered with good results in several cases. The use of refrigerants presents the advantage of low reference temperatures and is currently intensely researched [1, 2].

Spray heat transfer depends on the flow pattern over the impinging surface, which is influenced by the interplay of the spray flow and the flow conditions established in the spraying chamber. In this work the spray cooling performance of R410A is studied experimentally.

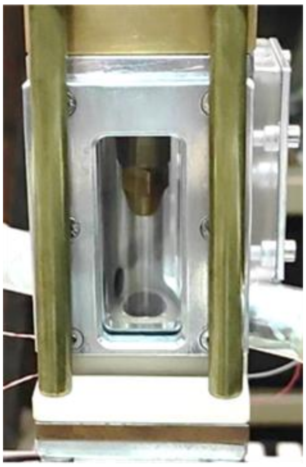

Fig. 1: The spray chamber

A copper surface, heated from below with the aid of heating resistors, simulates the electronic device which has to be cooled. The spray is produced by a pressure swirl nozzle (Danfoss OD 5 USgal/hr, 60° solid cone), within an aluminum spray chamber, equipped with Perspex windows (Fig. 1). The whole assembly is covered with thick layers of insulating material (not shown for presentation purposes), to minimize ambient conditions effect and heat losses.

The experimental apparatus is a residential inverter HVAC unit, of 3.5 kW thermal capacity, in which the expansion valve has been replaced by the spray chamber. The refrigeration circuit is equipped at several locations with valves and regulators to control system operation, and measuring devices to monitor pressure, temperature and flow rate. Measurements are recorded and stored in computer memory for further processing, via suitable data acquisition hardware and software.

Experiments have been performed, at several heat fluxes, for different refrigerant mass flow rates and nozzle to surface distances. The refrigeration cycle was operated between 30 bar and 5.3 bar, the latter corresponding to a temperature of −12 °C for the spray mixture. Measurements were obtained when the system reached steady state operation at the imposed conditions.

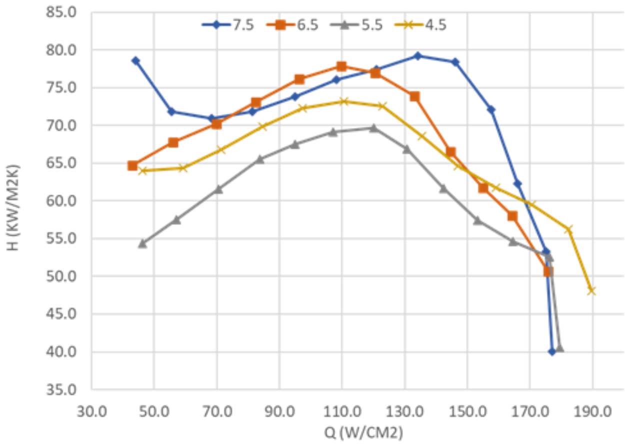

Fig. 2: Mass flow rate effect on heat flux vs heat transfer coefficient for 20 mm nozzle distance

In Fig. 2 a sample of the obtained measurements is presented, depicting the relation between the imposed heat flux (Q) and the heat transfer coefficient (H), obtained at four refrigerant mass flow rates (g/s), for a nozzle to surface distance of 20 mm.

Results regarding mainly the relation between the imposed heat flux, the heat transfer coefficient and the surface superheat will be presented for several nozzle to surface distances. The discussion will attempt to highlight the effect of flow patterns and the impact of the sprayed droplets on the mode of heat transfer (liquid film evaporation, turbulent forced convection, primary and secondary nucleation sites' formation).

References

[1] Y. K. Lin, Z. F. Zhou, Y. Fang, H. L. Tang, and B. Chen, Heat transfer performance and optimization of a close-loop R410A flash evaporation spray cooling, Applied Thermal Engineering, 159 (113966): 1-7, 2019

[2] S. Wang, Z. Zhou, B. Chen, T. Panidis, A. Romeos, A. Giannadakis, Dynamic thermal management of flashing spray cooling by the frequency conversion of compressor, Applied Thermal Engineering, 218 (119322), 2023