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New CERN CO2 test facility for mini- and micro-channels

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The benefits of the thermal management of tracking detectors through CO₂ boiling flows in evaporators of small diameter have been successfully demonstrated multiple times within the research community. However, the current predictive models for two-phase flows have a wide range of accuracy, in particular when dealing with micro-channels. Due to the lack of reliable experimental data, the difficulty faced by the designer of new evaporators based on channels of very small size is even more critical when CO₂ is the planned refrigerant. There is indeed no agreement, even in the most advanced available literature, on the definition of the dimensional limits of macro-, mini- and micro scale dominated phenomena.

A long-term study has been launched with the ambitious objective of developing a deeper understanding of the properties of boiling flows of CO₂ in view of their actual application in simple small diameter tubular evaporators as well as in complex silicon-substrate multi-microchannel cooling devices. Only a thorough and basic understanding of the physical processes occurring in mini- and micro-channels can help to optimize the design parameters of future applications.

A new test stand has been designed for testing mini- and micro-channel cooling with boiling CO₂ with an unprecedented level of accuracy. A purpose-built test circuit is housed in a vacuum vessel to guarantee adiabatic test conditions. In combination with this test circuit, a recently developed refrigeration loop for CO₂ investigations can deliver stably controlled flows at saturation temperatures ranging from -25˚C to +20˚C. High precision sensors account for pressure drop, heat transfer and mass flow rate within and along the tested tubes. Efforts were undertaken to achieve an outstanding accuracy level within the field of research. RTD sensors (Pt100), calibrated to measure within an uncertainty of 0.015˚C, provide direct measurements of the fluid temperature before and after the test section, while point-like K-type thermocouples measure the outer wall temperature of the test section with an uncertainty of 0.1˚C. A high-end differential pressure sensor in combination with a highly accurate read-out system can measure pressure drops along the tubes within an uncertainty of 1.5 mbar for a maximum of 3 bar diff. The installed mass flow meter can measure flow rates from 0.16 down to 0.003 g/s with an accuracy of 0.2 % of reading. Stainless steel tubing ranging from 2.15 mm to 0.13 mm will be tested with mass fluxes ranging from 200 to 1200 kg/m2s and heat fluxes from 5 to 50 kW/m². As a subsequent step multi-micro channels explicitly designed for possible use in tracking detectors will be tested to quantify the expected high thermal figure of merit of these devices compared to conventional detector cooling methods.

First results of pressure drop and heat transfer coefficient will be discussed in detail and compared with forecasts from existing correlations, as an essential step towards new and more reliable models for boiling flows of CO₂ in mini- and micro-channels and towards more efficient detector cooling.

Authors: HELLENSCHMIDT, Desiree (Universität Bonn (DE)); PETAGNA, Paolo (CERN)

Presenter: HELLENSCHMIDT, Desiree (Universität Bonn (DE))