Design and development of an experimental facility for the evaluation of heat-transfer fluids and PCM emulsions: Cooling of high-power computing systems

GITSE Ingeniería Térmica y Sistemas Energéticos

Pablo Castellanos, Miguel Navarro, Mónica Delgado y Ana Lázaro

Grupo de Ingeniería Térmica y Sistemas Energéticos, Instituto de Investigación en Ingeniería de Aragón (I3A)

Universidad de Zaragoza, Mariano Esquillor s/n, 50018, Zaragoza, Spain. e-mail: 776409@unizar.es

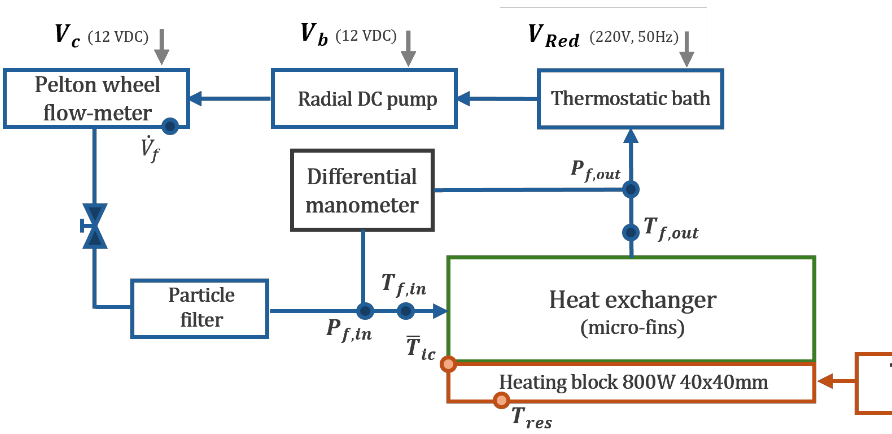
Instituto Universitario de Investigación de Ingeniería de Aragón Universidad Zaragoza

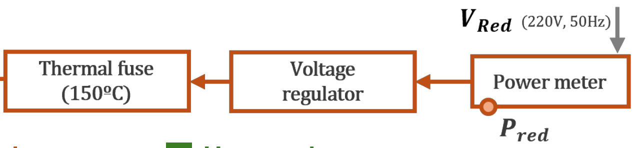
In a conventional Data Processing Cente (DPC) **45% of the energy is consumed by the cooling/thermal-management systems,** whereas **only a 30% is consumed by the IT equipment**.

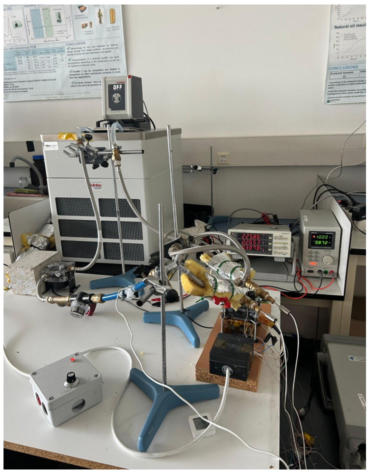
Can we increase the efficiency of the thermal management systems in DPC?

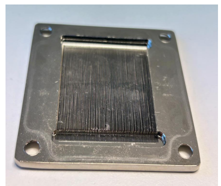
Can we remove more than 50 W/cm^2 from a CPU just using water?

An experimental facility has been designed: It enables the simulation of the various operating conditions under which a heat-transfer fluid functions in a DPC:









Hydraulic sub-system:

- **Deionized water** is used as heat-transfer fluid
- **A thermostatic bath** dissipates heat and **regulates the fluid inlet temperature**
- External DC radial pump circulates the fluid
- Pelton wheel flowmeter and valve to monitor and control the volumetric flow rate
- **PT100 monitor the fluid inlet and outlet temperatures**

Power/heating sub-system:

- 220V, AC, 50Hz Input
- Power-meter to monitor the energy consumption
- Manual potentiometer to regulate the power
- Four 200 W heating resistors placed in a 40x40mm area (**Maximum power density of 50 W/cm^2**)
- Two layers of insulation (Mica and fibre glass)

Heat exchanger:

- HX is made from **copper with a nickel plating**
- Features **80 fins and 80 channels** with dimensions of **1.8×0.2125×68 mm, and the channel width is 0.2125 mm**. The hydraulic diameter is 0.4 mm.
- High-conductivity thermal paste is used to minimize the interfacial thermal resistance between them. Which yields, a **conductive thermal resistance range of 0.0125–0.052 K/W**

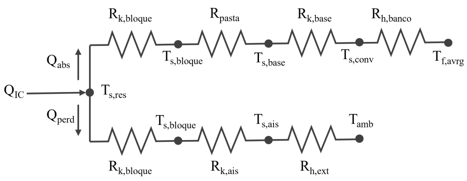
Experimental results :

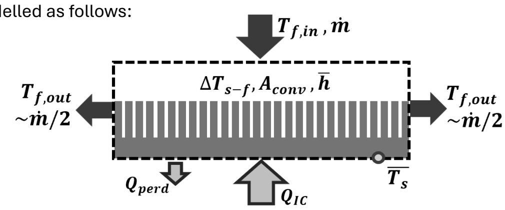
Simulation of operating conditions within DPC:

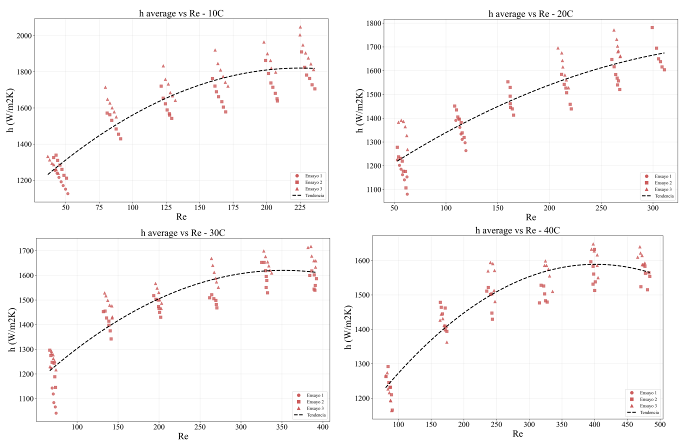
- **6 and 44 W/cm^2**
- **Fluit inlet temperatures 10 to 40 °C**
- **Volumetric flow rates from 0.5 to 3 l/min.**

Average heat transfer coefficients between 1100 and 1900 W/m^{2}K were obtained for the studied ranges of Reynolds and Prandtl numbers.

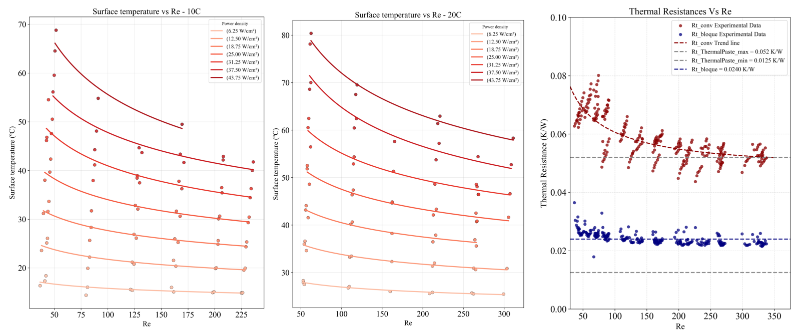
The studied control volume and thermal circuit can be modelled as follows:

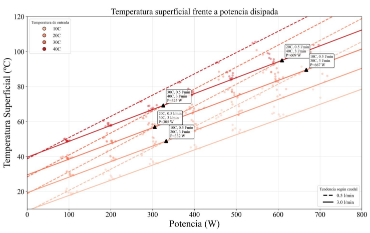






- **Contact surface temperature decreased with increasing flow rate at Re < 120**
- The influence of flow rate became negligible at higher Reynolds numbers (Re > 250)
- Thermal paste contact resistance became the dominant thermal resistance above a critical heat transfer coefficient (h).





- The same contact surface temperature can be reached under different operating conditions.
- Increasing mass flow rate is energetically less costly than increasing active cooling.
- At higher power densities, better cooling efficiency may be achieved by raising mass flow rate.
- A higher inlet temperature may also improve overall cooling efficiency.

Future work:

At the time of this document's publication, further tests are still being carried out to obtain an experimental correlation for the average Nusselt number for the geometry of the HX under study. This project evaluates the performance of water as a cooling fluid, however in future studies, similar tests will be carried out using PCM emulsions. This study will be used as base to compare results and evaluate the performance of shuch emulsions.

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