13. Introduction of Two-Phase Cooling of High-Power Electronics

Course Leader: John R. Thome -- JJ Cooling Innovation

Course Description:
Flow boiling heat transfer in microchannels can reliably cool heat fluxes more than 500 W/cm2 with heat transfer coefficients nearing 100'000 W/m2K with respect to the cold plate's base area. As an example, an air-cooled thermosyphon for a 2U server can cool CPU's up to 750W, presented at ITHERM2021. Presently, an introduction to twophase cooling of electronics covering pumped-driven, gravity-driven (loop thermosyphons) and self-driven (pulsating heat pipes) will be presented. Whilst industry is now accepting flow boiling technology as an option for cooling in datacenters, telecommunications, and power electronics in automotive, aerospace, etc., many thermal specialists are not yet familiar with flow boiling and condensation. Compared to an air-cooled heat sink, air-cooled passive two-phase cooling units reduce energy consumption and noise by the fans. Furthermore, in a thermosyphon or a pulsating heat pipe, the working fluid needs no electrical driver or flow controller, and thus provides high reliability with no moving parts or wiring. This lecture will present an introduction into microchannel flow boiling, condensation and the "workings" of two-phase cooling together with several case studies for illustrative purposes. At the end of this course, you will better understand the ins-and-outs of a two-phase cooled system, which improves the reliability, reduces first cost and operating cost, and increases longevity of cooling devices compared to air-cooling.

Course Outline:

1. Two-Phase Thermodynamics (Vapor pressure curve and P-v diagram)
2. Two-Phase Flow Patterns in Microchannels (Describe flow patterns and show photos)
3. Flow Boiling in Microchannels (Depict some flow boiling test results)
4. Condensation in Microchannels (Depict some test results)
5. Multi-Microchannel Evaporator Cold Plates (Describe cold plates and some test results)
6. Introduction to Pumped-Loop Cooling Systems (Describe some systems)
7. Introduction to Loop Thermosyphons (Working principles and example system)
8. Introduction to Pulsation Heat Pipes (Working principles and example system)
9. Selection of Working Fluid (Discuss pros/cons of selection of fluids)

Who Should Attend
This class is intended for senior undergraduates, graduate students and engineers working in the field of thermal management.

BIO: John R. Thome is co-owner of JJ Cooling Innovation, a two-phase thermal engineering technology development company founded in 2014 in Lausanne, Switzerland, now with six full-time engineers and an experimental prototype test lab. From 1998 to 2018 he was Professor of Heat and Mass Transfer at the Ecole Polytechnique Fédérale de Lausanne (EPFL) in Switzerland. He is currently also a Visiting professor at Brunel University in London, an Honorary professor at the University of Edinburgh, and Chairman of the Brazed Aluminum Plate-Fin Heat Exchanger Manufacturers Association (ALPEMA). He obtained his PhD at Oxford University in 1978. He recently received the 2019 IEEE Richard Chu ITHERM Award for Excellence in Thermal and Thermo-Mechanic Management of Electronics and the 2019 ASME Allan Krause Thermal Management Medal at InterPack. He is the author of five books on two-phase heat transfer and flow and has over 250 journal papers on macroscale and mircoscale boiling/condensation heat transfer and micro-two-phase cooling systems for electronics cooling.

He has done numerous sponsored projects with IBM, ABB, Nokia Bell Labs, Carl Zeiss, CERN, etc. He is editor-in-chief of the 16-volume series Encyclopedia of Two-Phase Heat Transfer and Flow (2016-2018). He founded the Virtual International Research Institute of Two-Phase Flow and Heat Transfer in 2014, now with twenty-five participating university labs to promote research collaboration, sharing of experimental and numerical data, and education.