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Study of the heat pipe vapor flow using the MOOSE application Sockeye and the CFD code Nek5000

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Changing the World's Energy Future

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Study of the heat pipe vapor flow using the MOOSE application Sockeye and the CFD code Nek5000

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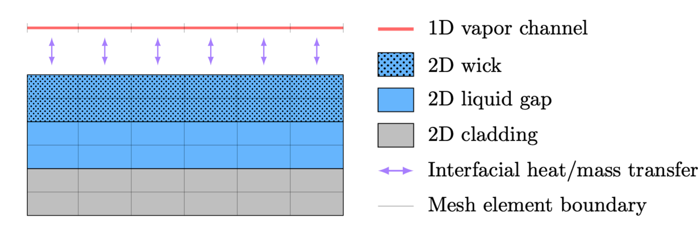
INTRODUCTION

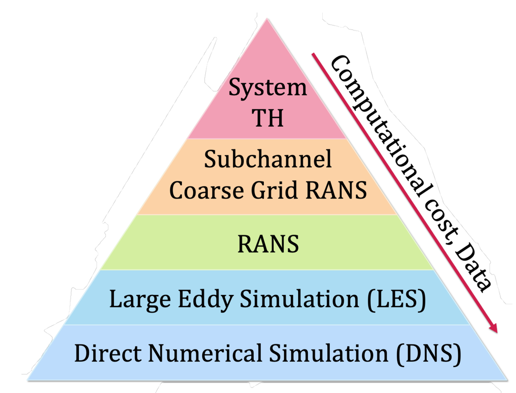
- Heat pipes are efficient heat transfer devices used in various applications, including nuclear microreactors.
- Heat pipe-cooled microreactors offer advantages in size and cost, which can significantly accelerate their deployment and adoption.
- Developing accurate models of heat pipes is crucial for a heat pipe-cooled microreactor design and operation.

METHODOLOGY

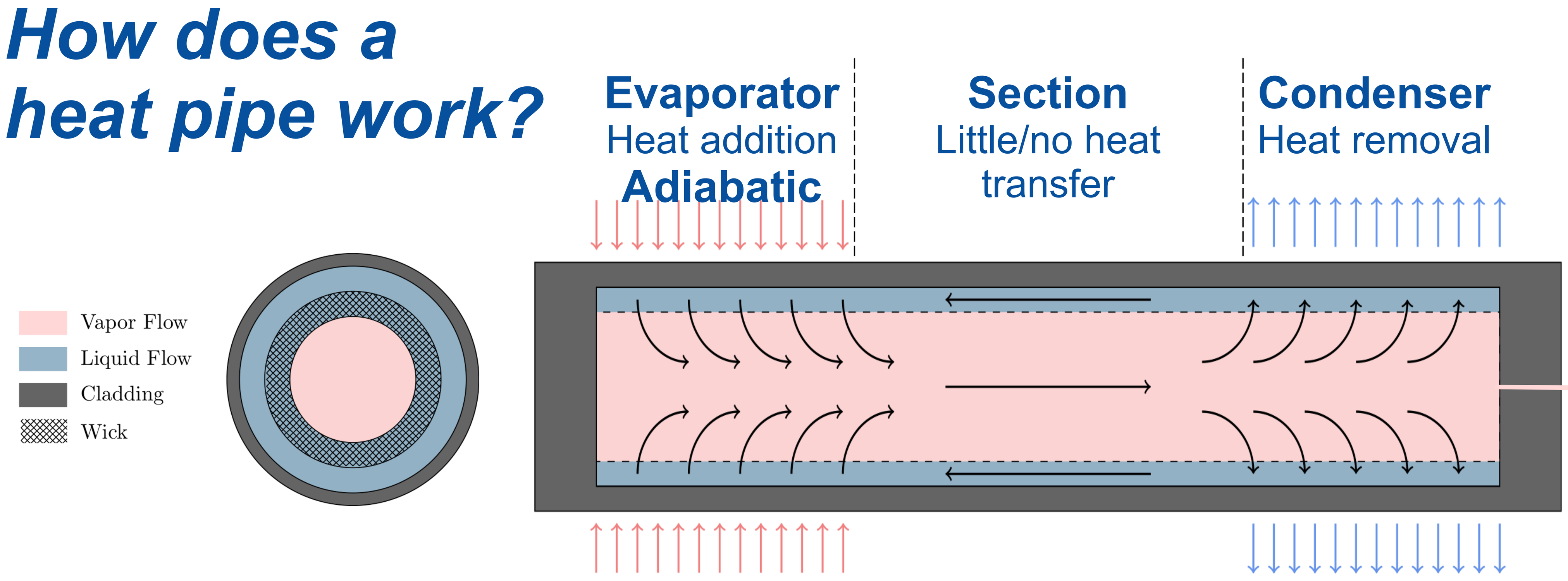
Simulations were performed using two different computational methods:

- The heat pipe code Sockeye, built on the MOOSE finite element framework, provides engineering scale heat pipe models. Those simulations employed the Liquid Conduction Vapor Flow (LCVF) model, which consists of a simplified liquid phase approximation with a 1D, transient, compressible flow model for the vapor phase.
- Reynolds-Averaged Navier Stokes (RANS) and Large Eddy Simulations (LES) were performed using Nek5000, a spectral element Computational Fluid Dynamics (CFD) code.

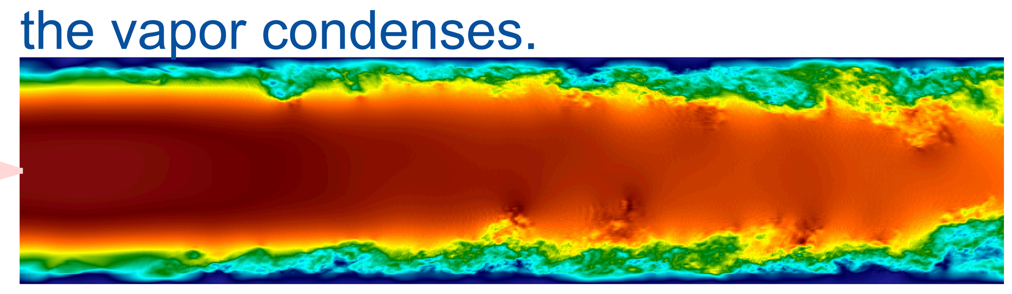




How does a heat pipe work?

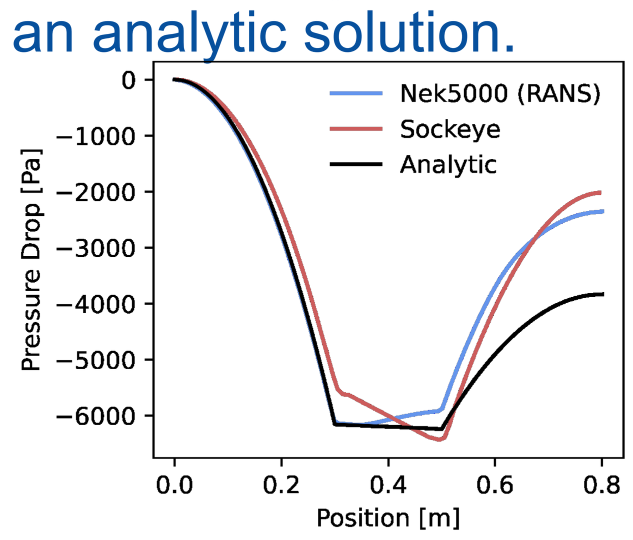


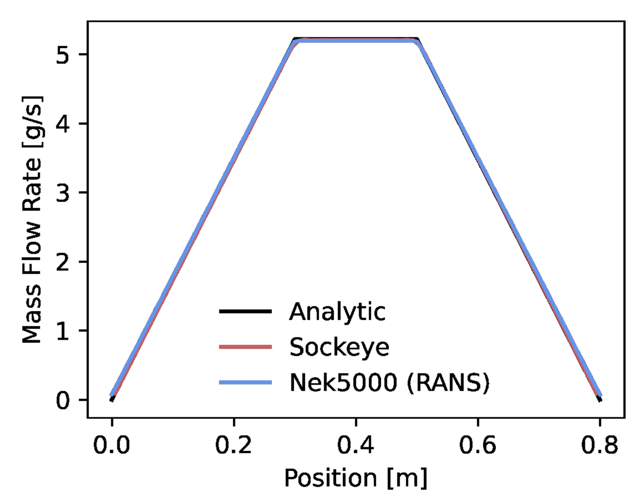
A cross-section of the vapor core of a heat pipe, using LES in Nek5000, shows the transition to turbulent flow between the end of the adiabatic section and the beginning of the condenser section as the vapor condenses.



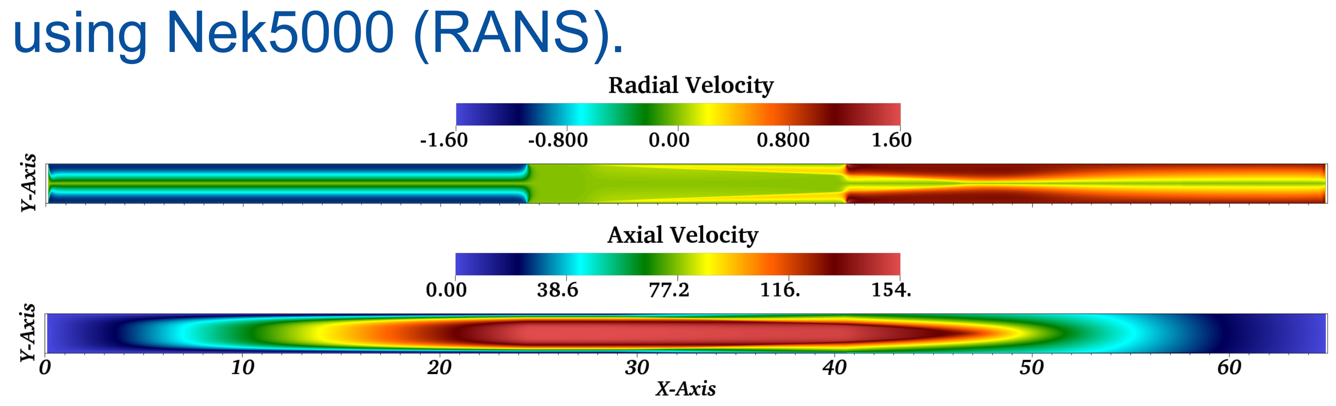
RESULTS: VERIFICATION AND VALIDATION

An annular-wick heat pipe was used as a code verification model. Below, the pressure and mass flow rate distributions for this heat pipe are compared against Sockeye, Nek5000 (RANS), and an analytic solution.

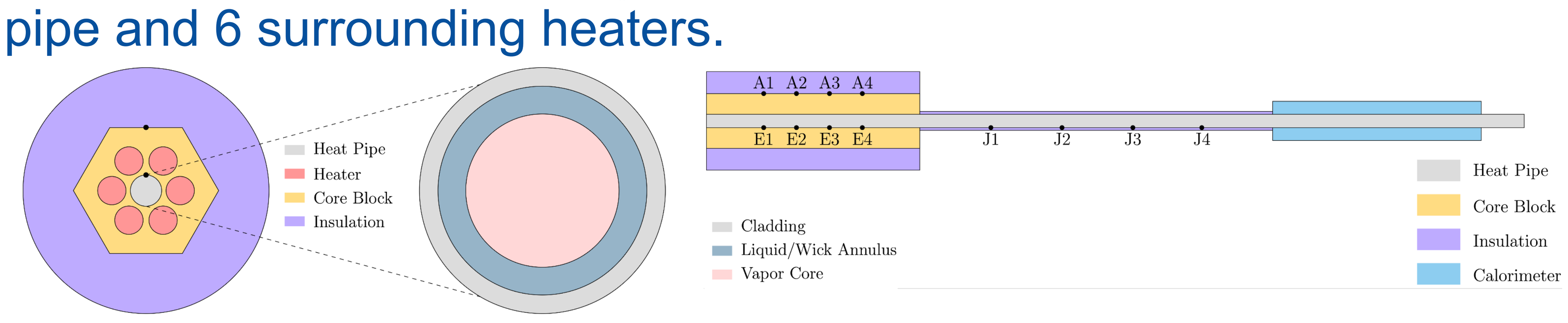




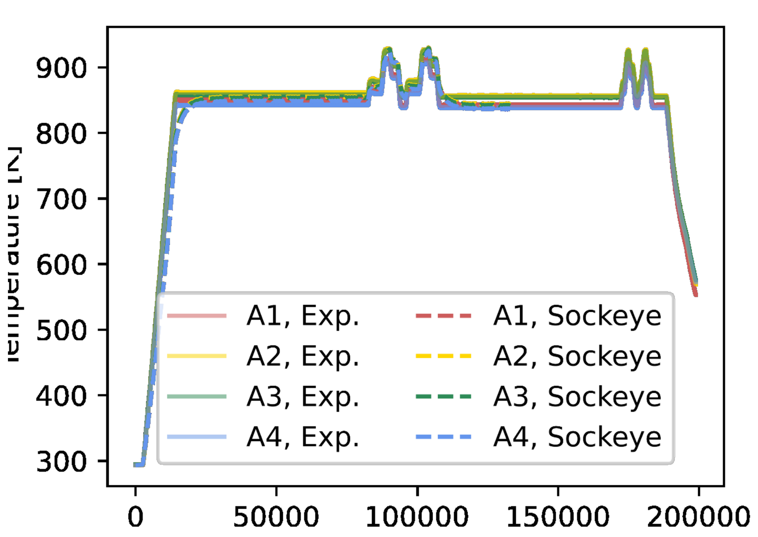
The figure shows cross-sections of non-dimensional velocity components in the heat pipe vapor core using Nek5000 (RANS).

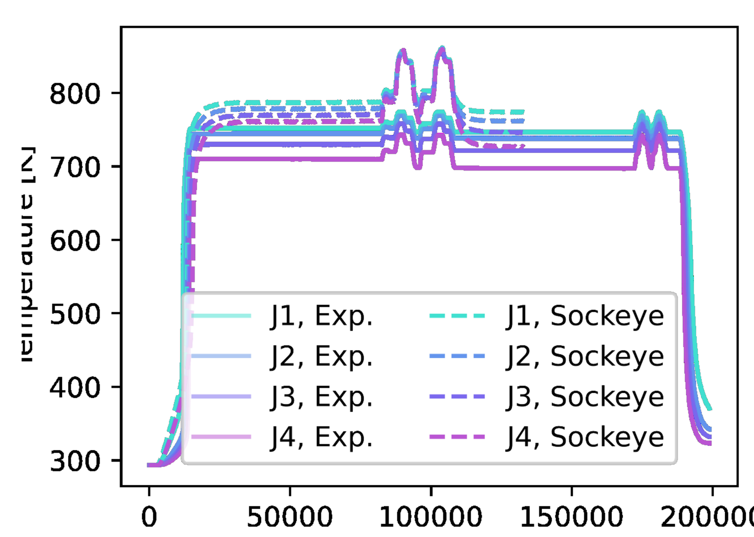


Experiments conducted at the SPHERE facility at INL [1] validated the heat pipe temperature distribution. The setup consists of a 7-hole hexagonal core block with a central heat pipe and 6 surrounding heaters.



The temperature distribution was obtained by thermocouples located in the core block, evaporator, and adiabatic section.





[1] Piyush Sabharwall, Jeremy Hartvigsen, Terry Morton, Zach Sellers, and Jun Soo Yoo. SPHERE assembly and operation demonstration. Technical Report INL/EXT-20-60782, Idaho National Laboratory, December 2020.

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Sockeye

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