Recent Progress in Sockeye

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Sockeye Introduction

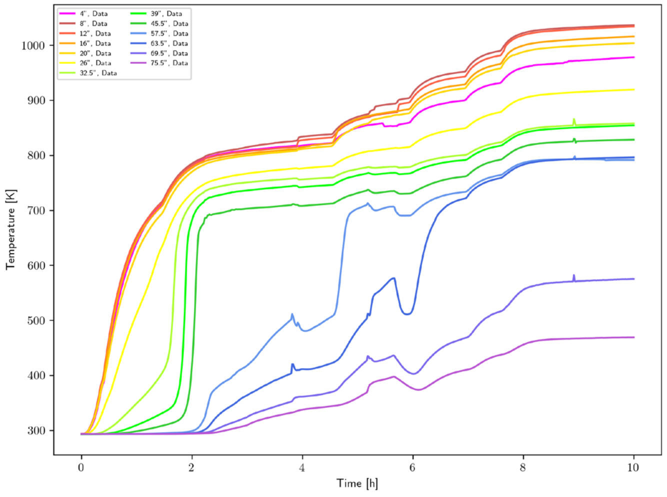
- Engineering scale heat pipe application for the analysis of heat pipes in microreactors.
  - Focus is on high-temperature, cylindrical heat pipes with screen/mesh wicks.
  - Supported working fluids: sodium, potassium, water
- Based on the MOOSE framework:
  - Finite element framework upon which many relevant applications are based:
    - Griffin: Radiation transport
    - BISON: Thermomechanics
    - Pronghorn: Fluid mechanics
  - Relatively simple coupling to other MOOSE-based applications.

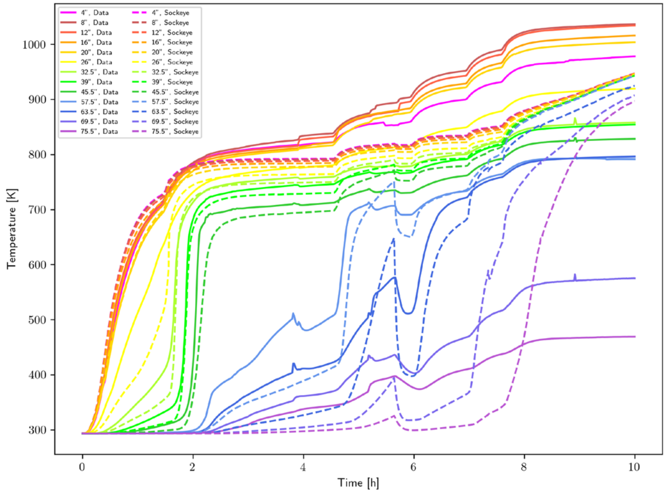
MRP Microreactor Program

SPHERE Validation

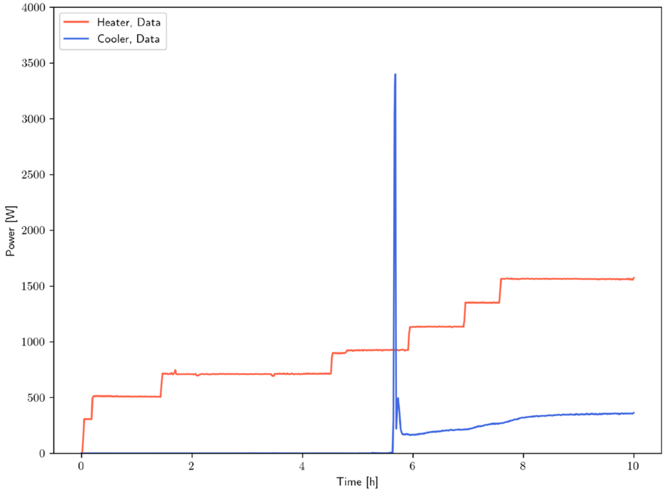
- Startup of sodium heat pipe from room temperature
- Radiative heating and cooling
- Investigation of inactive phenomena
- Able to provide feedback directly to team for next steps

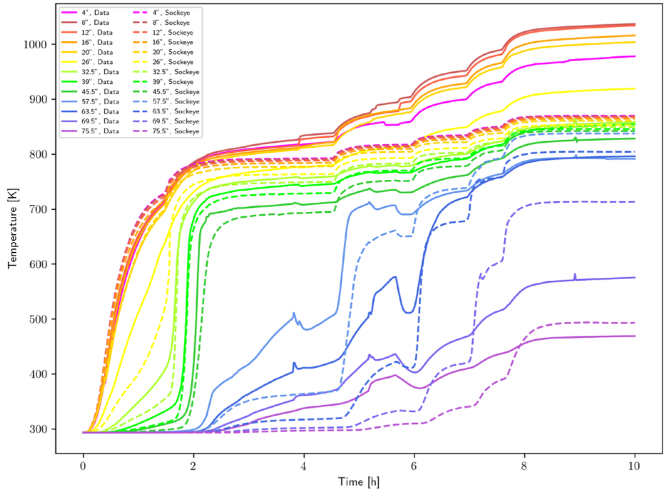
Data only



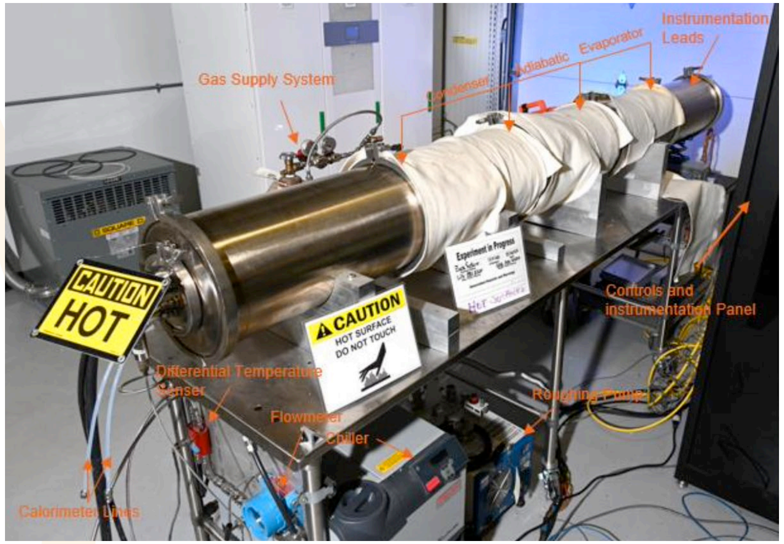


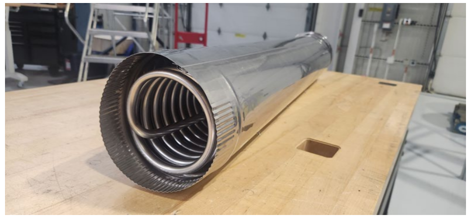
Sockeye using measured cooling rate





Sockeye using cooling model





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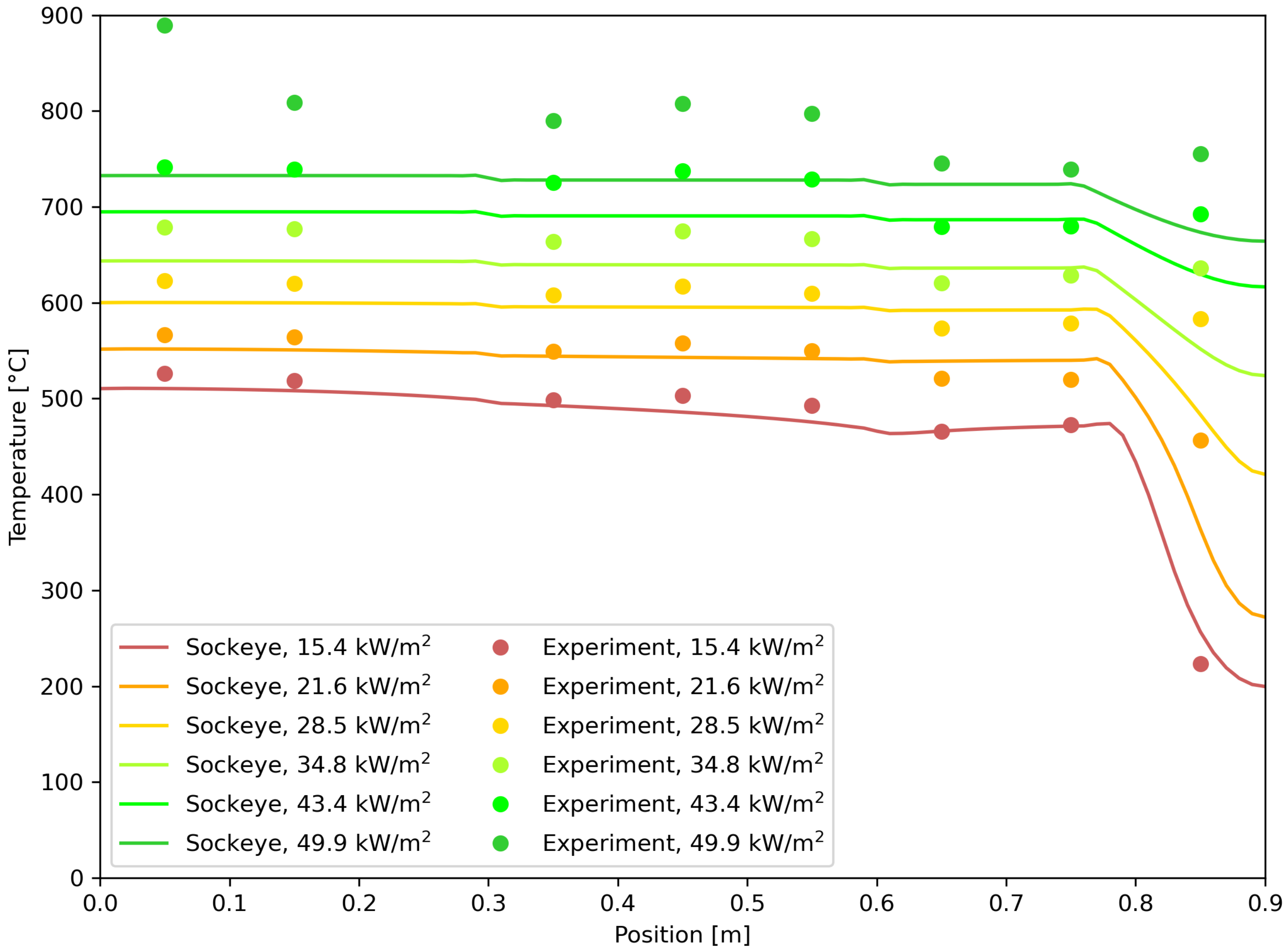
UNIST Validation

- Sodium heat pipe with 172% fill ratio
- Dryout occurs in highest power case
- Inactive length effect observed for 2 lowest power cases



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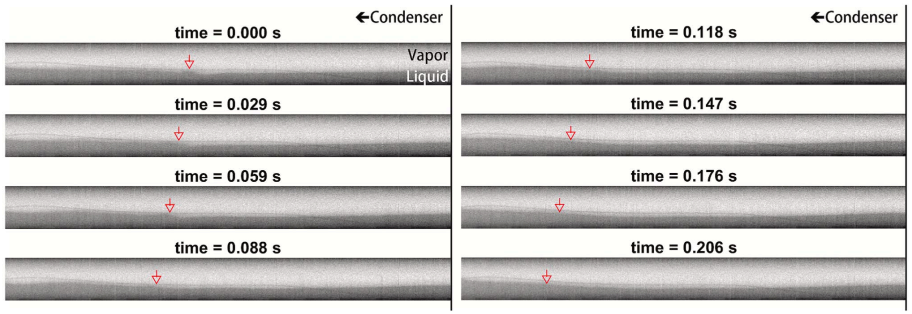
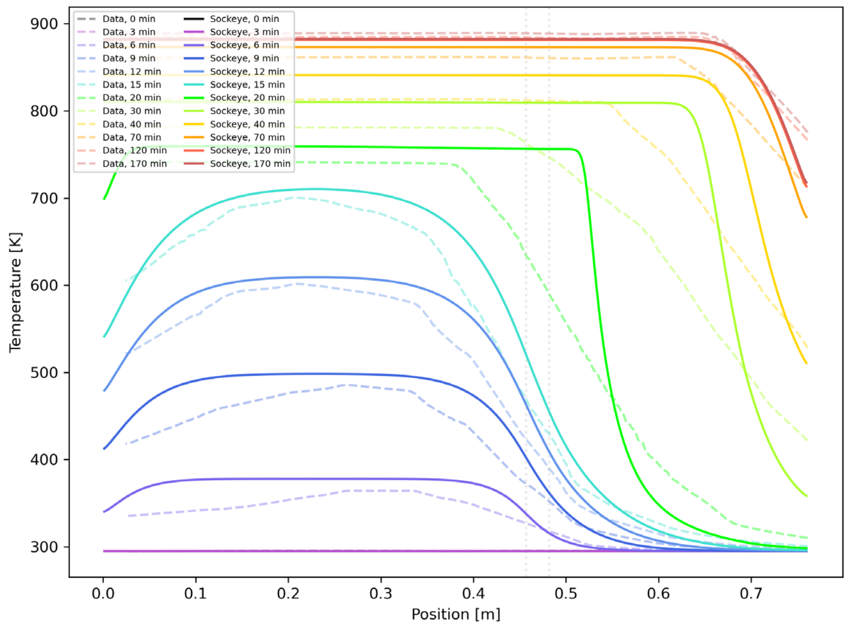
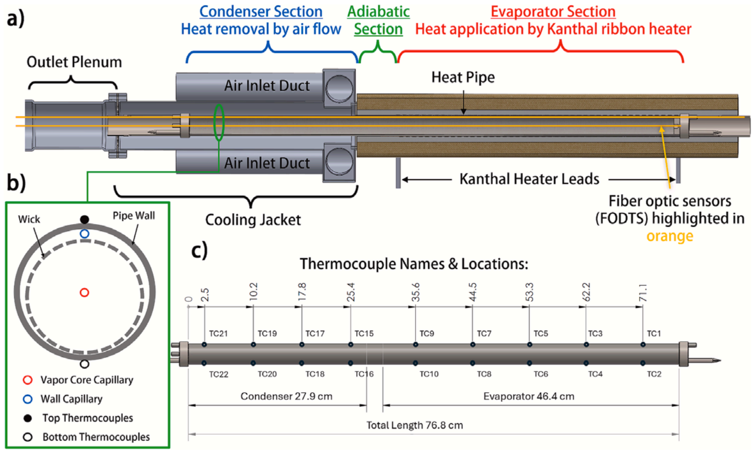
University of Wisconsin-Madison Validation

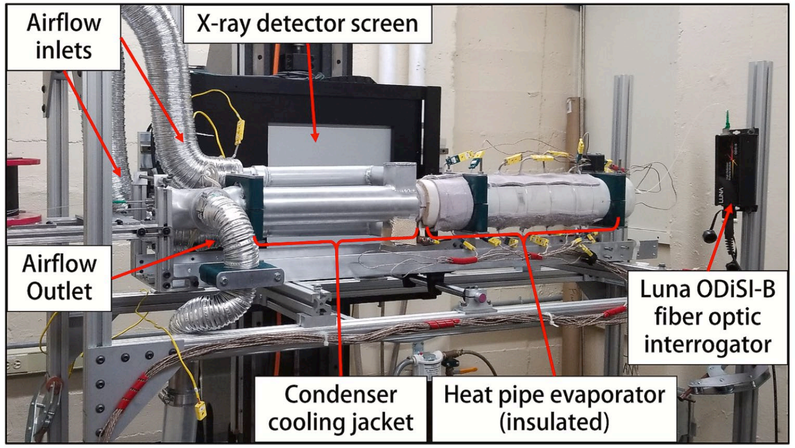
- NEUP to investigate sodium heat pipe operation with high fidelity measurements:
  - Fiber optic distributed temperature sensors:
    - Vapor centerline
    - Inner heat pipe wall
    - Outer heat pipe wall
  - X-ray imaging of condenser



Condenser working fluid X-ray imaging







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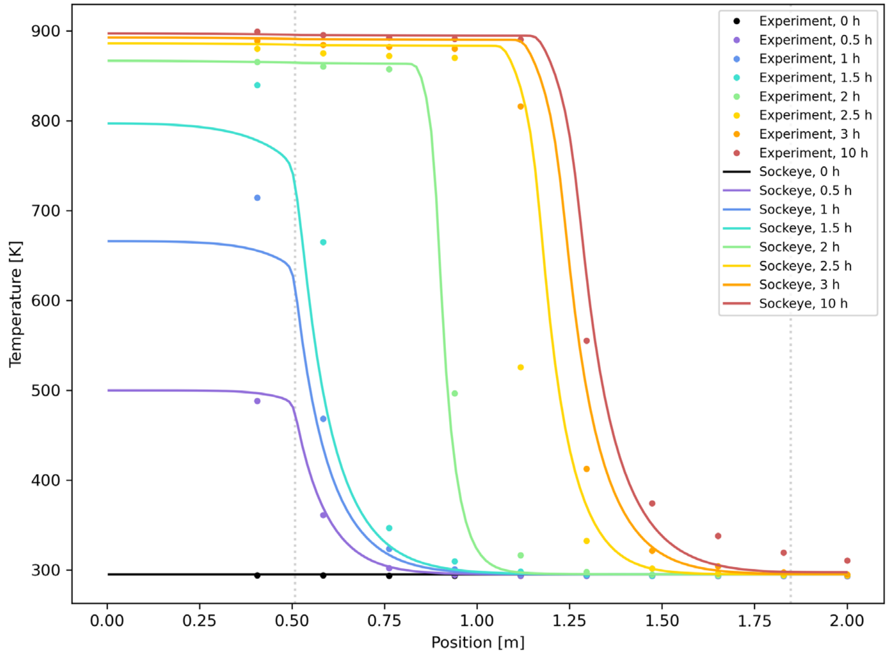
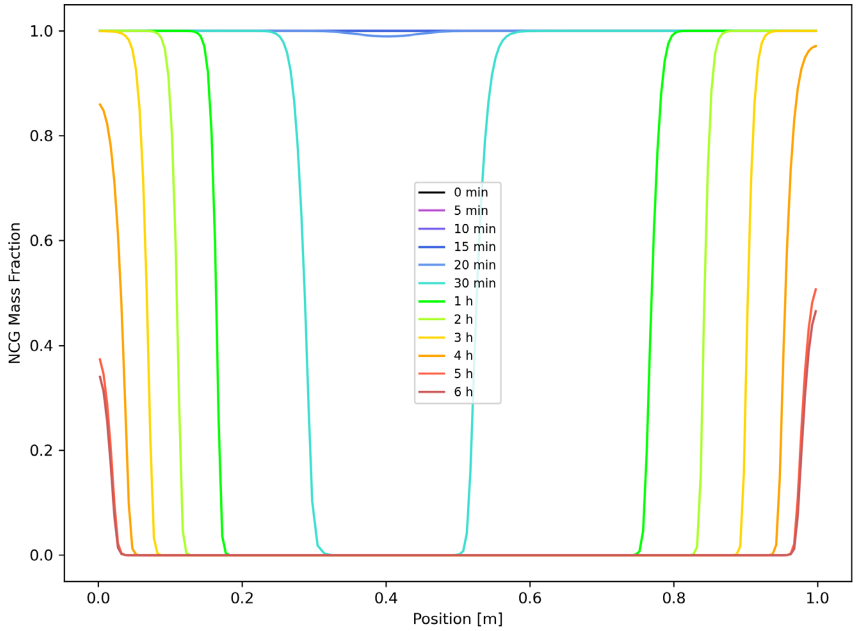
Added Mixture Model for Noncondensable Gas Support

- Before, used a "flat-front" approach to NCG:
  - Modeled pure vapor in core
  - Assumed NCG was all in a pool at condenser end
  - Computed length of pool dynamically based on temperatures/pressures
  - Imposed wall boundary condition for vapor at pool interface

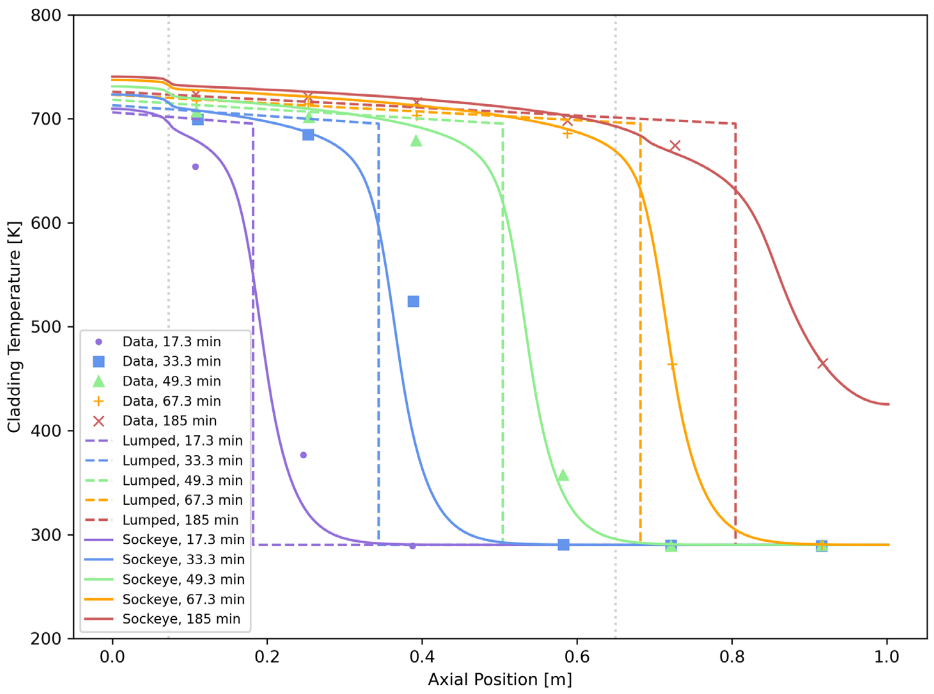
- Now, there is an option to model a gas mixture
  - NCG front(s) can develop dynamically
  - No assumptions made on pool locations
  - More accurate interface location
  - More robust

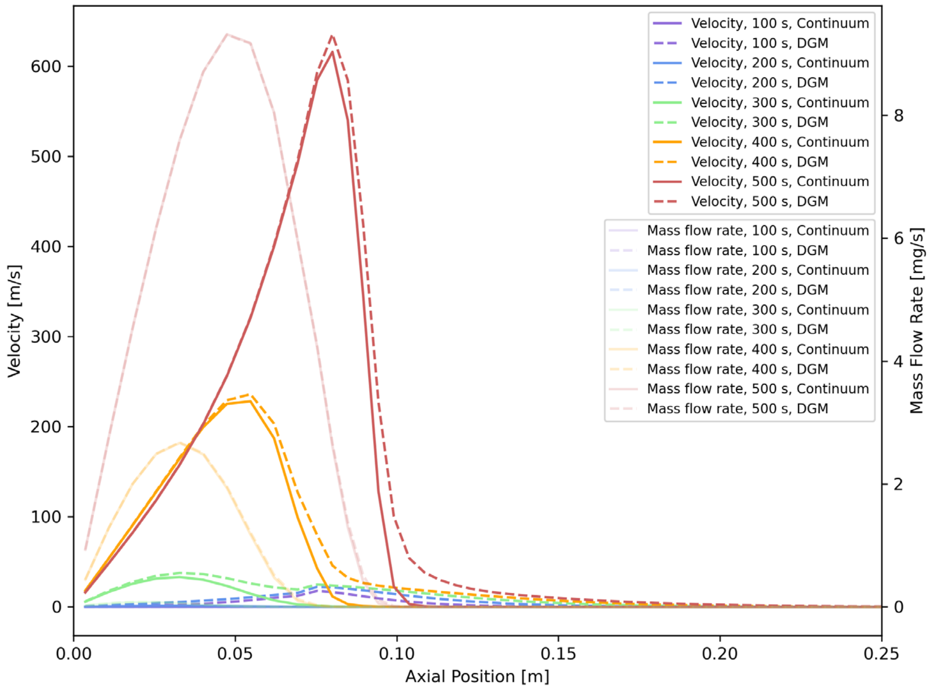




Modeling Rarefied Gas Transition

- At low pressures such as those during startup, vapor is in rarefied gas regime
- Used Dusty Gas Model (DGM) to model the transition from rarefied gas to continuum flow
  - Accomplished using a friction factor closure within existing system of equations
- Comparing DGM approach vs. continuum approach:
  - Velocities differ, but only where density is miniscule anyway
  - Temperature results indistinguishable





Current and Future Work

- Current work:
  - Working on robust 2-phase capability
    - LCVF robust and reasonably accurate, but capillary limit is largely analytic, not mechanistic
  - Validation for gravity-assisted heat pipes
  - Other relevant validation in response to need

- Possible future work:
  - Support non-conventional heat pipes
  - Multidimensional flow modeling
  - Long-term degradation effects

Remaining Validation Needs

- Resolve UWM validation discrepancies
- Capillary limit data
  - Possibly dryout modeling
- Desirable measurements:
  - Internal temperature (e.g., fiber optic distributed temperature sensors)
  - Working fluid distribution (e.g., x-ray imaging)
  - External thermocouples with minimal thermal resistance
    - Various locations external to heat pipe

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