Experiments for Modeling and Validation of Liquid-Metal Heat Pipe Simulation Tools for Micro-Reactors

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ABSTRACT:

In the Nuclear Energy Advanced Modeling and Simulation (NEAMS) program, Sockeye, a joint Los Alamos National Laboratory (LANL) and Idaho National Laboratory (INL) heat-pipe simulation program built on top of the MOOSE framework, is being developed to support the micro-reactor design and licensing activities. Sockeye is intended to model the full operating modes of a liquid-metal heat-pipe including startup and shutdown transients with 3-phase phenomena. However, there is a lack of liquid metal heat pipe validation data, thus, generating more test data is strongly encouraged. The proposed work aims to produce high-fidelity liquid-metal heat-pipe experimental data for the validation of the simulation tool, Sockeye, through both single heat-pipe and integrated heat-pipe experiments. In accordance with this objective, the following three categories of heat-pipe experimental data will be generated as the main deliverables.

1. Single liquid-metal heat-pipe pressure, temperature, and phase distribution data
2. Wick characteristics including capillary rise, wall friction, and pressure drop form factor.
3. Multiple liquid-metal heat-pipes (integrated system performance) experimental database under various operational scenarios.

The proposed experimental activities will be conducted by TAMU and UWM. For the single liquid-metal heat-pipe experiment the transient behavior of frozen startup, shutdown, and re-start as well as the normal operation mode will be investigated intensively by scanning phase distribution with X-ray systems and measuring pressure and temperature distribution inside the heat-pipe. Temperature distribution in the core, wick, annular gap, and external wall surface will be measured by a Fiber-optic Distributed Temperature Sensor (FO-DTS) system and thermocouples. To measure the pressure in the liquid-metal heat-pipe, which is a challenging task due to the temperature and the size of the pipe, we will apply pressure-transfer-liquid techniques. For the wick characteristics, three small test sections will be used to separately measure wall friction, wick friction/form loss, and wick capillary rise height. An integrated test assembly with seven liquid-metal heat-pipes will be constructed to measure temperatures at multiple locations in the heating block and at the locations learned from the single heat-pipe experiments. The heating block will be equipped with separately controlled electric heaters, which enables simulating various reactor core heat transfer scenarios such as partial failure of constituent heat pipes and non-uniform heating and cooling.

Collaboration with INL & LANL is of paramount importance from the design phase of the proposed experiments through the measurement planning and data analysis, in order to end up achieving the most desirable data sets for validation, since INL & LANL are leading the micro-reactor modeling/simulation and experimental research supported by the U.S. Department of Energy (DOE).