Experimental and Modeling Investigation of Overcooling Transients that Include Freezing, in Fluoride-Salt Cooled High-Temperature Reactors (FHRs)

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ABSTRACT:

The proposed work addresses gaps in salt-reactor technology development in two ways: (1) by developing a computational tool for the modeling of freezing and thawing in a system thermal-hydraulic code, so that it can be used for design and safety analysis studies and (2) by expanding the fundamental understanding of freezing phenomenology in molten salts in order to identify ways to take advantage of the inherent properties of the salt in the design of system components that are resilient to freezing and that recover from freezing rapidly and without damage. This work also has applicability to lead-cooled fast reactors, as well as to molten fluoride and molten chloride salt reactors. The following four tasks define the scope of this project:

- Task 1: A methodology for modeling thawing and freezing of the coolant will be demonstrated on the modeling platform MOOSE and implemented and tested with the system analysis code SAM. This work will also represent the first application of SAM to the modeling of FHRs, so we will identify and document the gaps in SAM capabilities to model FHRs and molten salt reactor transients.
- Task 2: Experimental investigation of freezing phenomenology in flibe ($2LiF$-BeF_2) will support the model development by generating closure relations for modeling of phase change. It includes identification of gaps in freezing and thawing phenomenology that will need to be addressed by future projects in order to generate closure laws with a validity domain and an uncertainty that are appropriate for use in licensing.
- Task 3: Scaling analysis will identify potential simulant fluids for overcooling transients, and similitude will be demonstrated through simple separate effects with the proposed simulant fluids. The capability to build low-distortion experiments at reduced temperature, reduced toxicity and reduced scale will more rapidly expand the experimental thermal-hydraulic research community and accelerate the generation of closure laws for freezing and thawing phenomenology.
- Task 4: Using the computational tool developed here, and the new understanding of freezing phenomenology, two design case studies will be performed in the third year of this project. The purpose of the design studies will be to demonstrate ways in which inherent properties of the salt can be leveraged in the component and system design to provide resilience to freezing and recovery from freezing without damage.