ARISE: Advanced Reactors Integral and Separate Effects Tests – An Integrated Research and Education Program

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Program: Reactor Concepts – Molten Salt Reactors

ABSTRACT:

There are two molten salt nuclear reactor categories being developed that are gaining growing interests: (1) Fluoride salt-cooled, High-temperature Reactors (FHRs) having solid fuel with the molten salt used as coolant only and (2) Molten Salt Reactors (MSRs) with the fuel dissolved in the molten salt coolant. To evaluate an MSR or FHR design, safety evaluations are carried out to understand the validity and accuracy of computational methods, the uncertainties, and the safety margin under varying conditions. It is essential to predict behaviors during normal, off normal, and accident conditions as there is much less regulatory experience for an MSR or FHR. Numerous experimental data have been available for identifying nuclear thermal-hydraulic phenomena, validating computational tools, and performing scaling analyses or even validating scaling methods. Separate effects tests (SETs) and integral effects tests (IETs) are key to developing and validating system-level thermal-hydraulic codes for licensing FHRs and MSRs. However, SETs and IETs for MSRs and FHRs are sparse. Many SETs and IETs based on low-temperature surrogate fluids (e.g., heat transfer oil and water) for molten salts provide reasonable scaling strategies and an acceptable methodology. Using surrogate fluids can allow for the investigation of relevant fluid and heat transfer phenomena at significantly low temperatures, fewer required resources, use of available and accurate instrumentation and sensors, eliminating molten salt-related hazards. However, some phenomena attributed only to the high-temperature molten salt have not been considered using surrogate fluids, such as overcooling events, or overheating events, or thermal mixing and stratification, or radiative heat transfer. Overcooling can lead to molten salt freezing phenomena resulting in component damage that could be significant during transients and accidents. Overheating may affect reactor structure causing local heating due to flow maldistribution. Parasitic heat losses may also be significantly different between high-temperature molten salts (550 to 650 °C) and low-temperature surrogate fluids (50 to 90 °C). A number of molten salt test loops are operable in the U.S. and all are used to support development and demonstration of molten salt components such as pump, seals, valves, and heat exchangers, as well as material corrosion test. However, no SET and IET molten salt facility is available to study molten salt accident conditions and molten salt heat transfer and flow have not previously been experimentally investigated for FHR/MSR cores under prototypical conditions. In addition, limited molten salt heat transfer data available with large discrepancies of thermophysical properties have led to misleading conclusions. It is therefore imperative to develop a high-fidelity molten salt flow and heat transfer database for FHR/MSR core and subsystem designs, as well as for accident analyses.

The objective of this integrated research and educational program is to perform SETs and IETs using a reduced-scaled Fluoride-salt Integral Effects and Separate effects Tests Apparatus (FIESTA) to validate system codes in support of the deployment of MSR and FHR technologies and the expanded use of clean nuclear energy worldwide, and to offer students from undergraduate to graduate, especially Native American, Hispanic and underrepresented minorities, various training and education opportunities of advanced reactors, hand-on molten salt experiments, and innovative instrumentation technologies.

To support SETs and IETs of an MSR/FHR, a series of innovative molten salt experiments are proposed to understand molten salt phenomena, enhance the performance of key components, and validate the system performance and analysis codes. FIESTA with an innovative hybrid loop-pool configuration will be designed, constructed, and employed for experiments to validate the system performance under normal, transient, and accident conditions. The facility is designed in the way that can be performed SETs and IETs with one bypass flow loop. Once the facility is completed, SETs will be carried out including salt draining, freezing, melting, thermal mixing and stratification, and heat exchanger testing to better understand and model the phenomena. Detailed experiments are also proposed to examine the temperature distributions in heat exchangers to improve heat exchanger design and modeling. IETs are