NEUP Nuclear Energy University Program
U.S. Department of Energy

Fuel Salt Sampling Technology Development

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Program: RC-7.1

ABSTRACT:

A necessary activity for the safe and efficient operation of molten salt reactors (MSRs) is the regular sampling of hot, radioactive fuel salt; fuel salt sampling permits the control and monitoring of fuel salt redox conditions, corrosion rates, salt contamination, and fissile material inventory within MSRs. The Molten Salt Reactor Experiment (MSRE) employed the Sampler-Enricher (S-E) to accomplish such sampling. The MSRE S-E was capable of removing small samples of fuel salt from the MSRE pump bowl for testing, introducing small amounts of enriching salt into the reactor to increase reactivity within the MSRE, and facilitating diverse testing methods (pump bowl gas sampling, foreign material fuel salt exposure, gamma ray spectroscopy measurements, etc.). Although the MSRE S-E exhibited the flexible capabilities that a fuel salt sampling system needs to provide, it displayed unsatisfactory reliability; failures of the MSRE S-E occurred frequently and twice necessitated the shutdown of the entire MSRE for repair. The objective of Workscope RC-7.1 is to utilize the “lessons learned” from the Molten Salt Reactor Experiment (MSRE) Sampler-Enricher (S-E) and other historical molten salt sampling systems to develop and demonstrate, in a non-radioactive environment, a modern equivalent system that displays improved reliability and could be used as a model for future MSR designs.

The proposed work will use insights from the MSRE along with decades of technological advancements into an initial modern-day Sampler Enricher (MD S-E) concept and develop/test a flexible, reliable, and workable SE design. The objectives of the proposed project include (1) applying systems engineering principles, available molten salt sampling technical documentation, ASTM standards, and stakeholder input to develop a conceptual model and design prototype of a modern-day equivalent to the MSRE S-E; (2) validating the conceptual S-E design by performing preliminary testing of the proposed design prototype(s) in a non-radioactive water-based environment for general functionality and reliability; and (3) demonstrating that the design meets required functionality and reliability by performing secondary testing in a non-radioactive, fluoride-based molten salt environment. The major deliverables of the proposed work include a tested, optimized, and documented modern-day S-E (MD S-E) design concept, functional requirement documentation for the MD S-E, and a documented safety/reliability assessment of the MD S-E. Vanderbilt University will lead the project through the design, prototype, and hot salt testing phases. The University of Michigan will help integrate and test the prototype in an existing salt loop and provide peer review during the design process. Input from Idaho National Laboratory stemming from their previous work in sampling within high-temperature and radioactive environments and in developing components that must withstand a molten salt environment will be incorporated during the design process. Southern Company will act as a no-cost collaborator and provide industry insight and guidance during the design process.

The development of a model modern-day S-E impacts the advanced reactor community by both furthering the scientific understanding of a critical MSR technology and reducing the technical uncertainty associated with the molten salt sampling process. Furthermore, the development of model MD S-E will support ongoing industry development of at scale facilities and test components for verifying MSR system functionality and will provide design guidance to entities currently working to develop MSR designs.