Molten Salt Reactor Test Bed with Neutron Irradiation

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Program: Reactor Concepts

ABSTRACT:

Several companies are developing salt-cooled reactors for multiple reasons. Heat is delivered to the power cycle in the range of 550 to 700°C resulting in higher heat-to-electricity efficiency than other reactor concepts. Salt coolants operate at atmospheric pressure—a major safety and economic advantage. The salts dissolve fission products and actinides, trapping the radionuclides and providing a very high level of safety in the event of an accident. Some salt reactor systems have major fuel cycle advantages including very efficient use of uranium and thorium resources.

The original development of salt reactors occurred in the 1960s and 1970s with the construction of the 8-MWt Molten Salt Reactor Experiment at Oak Ridge National Laboratory. In the last decade there has been renewed interest in salt reactors including (1) the Fluoride-salt-cooled High-Temperature Reactor (FHR) that uses clean salt coolant and solid fuel and (2) Molten Salt Reactors (MSRs) with the fuel dissolved in a fluoride or chloride salt. Some of these reactor systems are significantly different than the systems examined in the 1970s with characteristics that may improve economics, operations, and safety.

This Integrated Research Project (IRP) will build a general purpose loop at the MIT research reactor where salt flowing through the loop is irradiated by neutrons from the reactor. The neutrons interact with the salt to create various radionuclides in the salt including tritium, helium and noble metal fission products—depending upon the salt being irradiated. The loop creates conditions similar to those in the primary coolant circuit of MSRs and FHRs, to allow experimenters to (1) understand salt behavior in a reactor, (2) test redox control and other chemistry control systems designed to minimize corrosion, (3) test salt cleanup systems, (4) test instrumentation systems and other equipment for salt reactors, and (5) collect data to validate models of radionuclide transport in salt systems. The IRP has three objectives.

- *Design, build, and test a general-purpose instrumented molten salt test loop at the MIT reactor where flowing salt is irradiated by neutrons to duplicate conditions in a salt reactor*. The loop will include heated and cooled sections to simulate the temperature differences of salt in the primary system of a salt-cooled reactor system. No such loop has existed in over 40 years in the United States. The development of this loop provides (1) unique test capabilities and (2) the experience for development of future salt-reactor test loops at the DOE Advanced Test Reactor (ATR), the proposed DOE Versatile Test

Reactor (VTR) and other university reactors. The development of a general-purpose test loop allows different salts, clean or with dissolved uranium and thorium, to be tested.

- *Provide experimental data on tritium and fission product retention, diffusion and transport properties*. Neutron interactions with salts containing lithium or beryllium generate tritium and helium. Neutron interactions with salts containing uranium and thorium generate fission product gases and noble metal fission products. These radionuclides are generated in-situ in the salt. A loop irradiated with neutrons is the only way to realistically duplicate the conditions in a reactor and thus provide realistic data on behavior of these radionuclides.

- *Provide an experimental test bed for chemistry control, salt cleanup, tritium control and instrumentation*. Many technologies are being developed to support future operation of salt reactors. The loop provides realistic conditions for testing at small fraction of the cost of building a small test reactor. The loop also provides a platform for testing of future tritium control and chemistry control systems. The loop also provides user-ports for testing of instrumentation in temperature, flow, and radiation environments that would be representative of conditions in a primary coolant circuit (ex-core) of an MSR or FHR.

The major project deliverables are: (1) definition of what experiments the loop should be capable of conducting, (2) definition of loop requirements, (2) design of the loop, (3) development and testing of technologies required for loop operation [instrumentation, salt redox control], (4) building the loop and (5) initial operation of the loop. The operation of the loop will first provide scientific results on tritium behavior and later on fission product behavior. The initial operation of the loop requires the development and testing of instrumentation to measure operating conditions to understand results.

The IRP team has been chosen to provide the different capabilities required to build a high-performance salt loop. MIT provides the reactor. The MIT team has experience in building loops using other coolants and salt capsule (static salt) irradiation experience. North Carolina State University has built instrumentation to measure gaseous fission products from irradiating uranium dioxide. They will develop instrumentation to measure activation and fission product gases in the off-gas from the molten salt. The University of California at Berkeley has been characterizing liquid salts and tritium transport in FHRs and MSRs and will develop systems to measure and control salt chemistry and tritium transport in the loop. Oak Ridge National Laboratory is currently operating non-radioactive liquid salt loops in the laboratory and will share experience that will be used for design of the MIT loop.

The benefits are (1) a salt-loop test facility to better understand salts under neutron irradiaiton, (2) initial results from loop operation to aid the development of all salt reactor concepts and (3) the experience to enable the construction and operation of added salt loops at MIT or elsewhere as needed.