



Project Title

Integrated Effects of Irradiation and Flibe Salt on Fuel Pebble and Structural Graphite Materials for Molten Salt Reactors

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ABSTRACT:

The project's scope is to investigate the neutron irradiation response of F-Li-Be (Flibe) molten salt/graphite and Flibe/fuel carbon matrix systems with a focus on irradiation-affected salt infiltration and its potential effect on graphite/carbon matrix microstructure under irradiation. The project's objectives are to quantify the irradiation-induced changes in Flibe infiltration behavior into graphite/carbon matrix and quantify the influence of infiltration under irradiation on microstructure, mechanical properties, and tritium management of graphite. Several liquid salt fuel and molten salt-cooled reactor designs use graphite as materials in their cores and can face salt infiltration challenges. As porous materials, graphite and carbon matrix can become infiltrated with salt under certain conditions. In liquid salt fuel reactors, salt infiltration into graphite needs to be avoided for many reasons, including avoiding the accumulation of fission products in the graphite for liquid salt fuel reactors, which can cause neutron poisoning. An example of molten salt-cooled reactor design is the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor (KP-FHR). In the KP-FHR, Flibe salt is used as a coolant, an iso-molded graphite (ETU-10) is used for structural graphite reflectors and a pressed carbon matrix (A3-KP) is used for fuel-containing pebbles and for non-fuel containing reflector pebbles that increase fuel utilization and burnup. In molten salt-cooled designs, the salt is free of fission products, but infiltration still needs to be understood and managed. Indeed, fuel and non-fuel pebbles and graphite reflectors are buoyant in salt, thanks to their lower density ($\sim 1.75 \text{ g/cm}^3$ for both) than Flibe ($\sim 1.94 \text{ g/cm}^3$). Infiltration could reduce buoyancy and affect pebble flow and forces exerted by the external metallic structures on the graphite reflectors. Tritium generated by neutron irradiation of Flibe can be transported and retained into graphite, especially if it is infiltrated with Flibe. The retention of tritium in graphite is desirable from a plant-scale tritium management perspective due to the significantly lower mobility, and thus potential for release, of tritium in graphite compared to other reactor materials. However, the buildup of tritium inventory in core graphite components represents a potential source term concern. In this project, several graphitic materials used in liquid fuel and molten salt-cooled reactor designs will be tested to clarify the effect of pore diameter and graphite microstructure on irradiation-affected infiltration. They include structural graphites used for reflector structures and pressed graphites used as reflector materials in the core. A non-fuel bearing ^7Li -enriched Flibe salt will be used at two hydrostatic pressures to elucidate the role of overpressure on infiltration under neutron irradiation. To test for chemistry effects, two different Flibe compositions will be tested: a nominal Flibe and a reducing Flibe. The graphites immersed in Flibe will be irradiated for 1,000 hours at the MIT Reactor. Post-irradiation examination will consist of a range of complementary techniques able to detect F, Li, and Be including scanning electron microscopy coupled with energy and wavelength dispersive spectrometers. Hard x-ray photoelectron spectroscopy will be used to investigate potential graphite reactions with Flibe. These techniques will allow to characterize irradiation-affected Flibe infiltration and its potential effects on mechanical properties, graphite stability, and microstructure.