High Power Irradiation Testing of TRISO Fuel Particles with UCO and UO_2 Kernels in Miniature Fuel Specimen Capsules in HFIR

PI: Ryan Latta, Kairos Power LLC

Program: NSUF-2.2: Nuclear Fuel Behavior and Advanced Nuclear Fuel Development

Collaborators/Key Personnel: Micah Hackett - Kairos Power LLC, Blaise Collin - Kairos Power LLC, Nicholas Brown – UT Knoxville, Tyler Gerczak - ORNL, Christian Petrie – ORNL, John Hunn – ORNL, Grant Helmreich – ORNL

ABSTRACT:

This irradiation experiment demonstrates very high particle power capability for tristructural-isotropic (TRISO) particles with temperatures relevant to fluoride-salt-cooled high-temperature reactors (FHR). The heat transfer properties of molten salt enable high-power density (>20MW/m^3), resulting in significantly higher particle powers than are typical in high temperature gas reactors (HTGRs) which have low-power densities (4-6MW/m^3) [1,2]. The high-power density of the FHR reduces the size of the core volume and reactor vessel decreasing the capital cost. Furthermore, the ability of fluoride salt in FHRs to retain fission products allows for a higher fuel particle failure proportion to be tolerated during normal operation and accident scenarios. These attributes lower plant capital and electricity costs while maintaining a high level of safety, which are primary challenges in the nuclear industry.

A critical need for advanced TRISO fuel application in an FHR is experimental data to validate fuel performance models and predict the fuel particle failure proportion during high particle-power operation. The test objective is to conduct a very high-power TRISO particle irradiation test demonstrating significant performance margin to current Advanced Gas Reactor (AGR) tests. The proposed test is exploratory in nature and designed to support long-term advanced FHR designs with very high particle powers. The irradiation test is to be performed at Oak Ridge National Laboratory (ORNL) in the High Flux Isotope Reactor (HFIR) using the miniature-fuel specimen capsule [3]. The TRISO particle powers (peak >1,000mW/particle) are considerably greater than the AGR test program (peak ~200mW/particle) with capsule temperatures of 500ºC, 700ºC, and 900ºC, which are relevant FHR temperatures.

A comparison of particles with different kernel compositions, UCO and UO_2, is explored with the miniature-fuel capsule concept. The test setup enables separate effects testing where presumably fuel performance is improved in TRISO particles with UCO kernels. The UO_2 TRISO particles serve as a test control having historically been the standard for high temperature fuel particles. Specific fuel performance phenomena of interest include mitigation of $CO_{(g)}$ generation, kernel migration, fission product stabilization, interaction of fission products with coating layers, and athermal and diffusive release of fission products. The difference in kernel composition can alter these phenomena as they affect fuel particle failure and the release of fission products. The work scope of this proposal performs the initial PIE to indicate the general trend in test specimen performance. A second phase of PIE outside the scope of this proposal will be pursued to further investigate fuel performance behavior through well-established post-irradiation examination (PIE) techniques using multi-scale characterization PIE methods [4,5].

[1] Forsberg C., Hu L.W., Peterson P., and Sridharan K. "Flouride-Salt-Cooled High-Temperature Reactor (FHR) for Power and Process Heat" MIT-ANP-TR-157, December 2014.
[2] Andreades C. *et al.* "Design Summary of the Mark-I Pebble Bed, Fluoride Salt-Cooled, High Temperature Reactor Commercial Power Plant" Nucl. Tech., Vol. 195, p223-238, September 2016.
[3] Petrie C.M. *et al.* "Irradiation of Miniature Fuel Specimens in the High Flux Isotope Reactor" ORNL/SR-2018/844, June 2018.
[4] Demkowicz P.A. *et al.* "AGR-1 Post Irradiation Examination Final Report" INL/EXT-15-36407, August 2015.
[5] Hunn J.D. *et al.* "Detection and Analysis of Particles with Failed SiC in AGR-1 Fuel Compacts" Nucl. Eng. Des., 306 (2016) 36-46.