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A Multiphysics, Multi-Cycle Benchmark of the Fast Flux Test Facility (FFTF)

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ABSTRACT:

The Fast Flux Test Facility (FFTF) was a 400 MWth, MOX-fueled, Sodium Fast Reactor (SFR) which operated at PNNL from 1980-1992. The FFTF was designed as a facility to prove out the engineering and operating aspects of SFRs, and collected a wealth of operational data over its 12-cycle lifetime. Not yet included in any other benchmark is highly unique data suitable for validating multiphysics coupling of thermal-hydraulics (T/H) and reactor physics, in conjunction with depletion and reload analysis. **This project will develop a benchmark evaluation of data collected in FFTF cycles 1-12**, providing the first benchmark with (i) direct assessment of multi-cycle burnup effects in SFRs, with hundreds of rod worth, shutdown margin, and critical rod position measurements. Accurate prediction of multi-cycle depletion effects are essential to many design, licensing, and operations criteria such as burnup reactivity loss, decay heat, source term, material damage, and material accountancy. Our benchmark development will also leverage (ii) highly unique full-core multiphysics measurements of fission chamber traversals and bundle temperatures at different combinations of power/flow, filling a major need for multiphysics validation data.

This project entails three tasks. In Task 1, we assembly benchmark specifications from historical PNNL documents, focusing on a three-stage benchmark: (1) validation of multiphysics coupling of T/H and reactor physics as a function of power/flow; (2) verification of depletion and reload operational software for cycles 1-12; and (3) validation of multi-cycle depletion and multiphysics. In Task 2, we develop a benchmark evaluation of this candidate data using the OpenMC Monte Carlo code and the Pronghorn subchannel solver, with uncertainty quantification and model bias assessed using stochastic techniques and multiple simulation versions of FFTF. A useful outcome will be improved understanding of the role of interassembly heat transfer and axial expansion, through hundreds of measurements which allow assessment and meaningful comparison of these important SFR physical phenomena. In Task 3, we then leverage our benchmark to perform a focused validation of the BlueCRAB code suite, in particular the fully-heterogeneous and ring-heterogeneous geometries in the Griffin deterministic neutronics solver.

The outcomes of this project will be (i) an impactful and high-value benchmark specifications and evaluation of the FFTF; (ii) improved confidence in the Nuclear Regulatory Commission's BlueCRAB code suite for SFR uses, and thereby enhanced licensing certainty; and (iii) physics insight into important SFR phenomena and modeling techniques in the areas of interassembly heat transfer, axial expansion, and neutronics homogenization. Education and training of the next generation of nuclear engineers is targeted through a holistic research experience and integration of an undergraduate summer Fellowship program.