Benchmark Evaluation of PROTEUS Gas-Cooled Reactor Experiments

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Program: MS-NE-1 Integral Benchmark Evaluations

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ABSTRACT:

This project proposes to re-evaluate experiments of gas-cooled fast reactor (GCFR) core designs performed in the 1970s at the PROTEUS reactor and create a series of International Reactor Physics Experiment Evaluation Project (IRPhEP) benchmarks. Currently there are no gas-cooled fast reactor (GCFR) experiments available in the International Handbook of Evaluated Reactor Physics Benchmark Experiments (IRPhEP Handbook). These experiments are excellent candidates for reanalysis and development of multiple benchmarks because these experiments provide high-quality integral nuclear data relevant to the validation and refinement of thorium, neptunium, uranium, plutonium, iron, and graphite cross sections. It would be cost prohibitive to reproduce such a comprehensive suite of experimental data to support any future GCFR endeavors.

This project proposes to construct these benchmarks by analyzing the GCFR-PROTEUS experimental core configurations using modern computational methodologies, primarily via high-fidelity Monte Carlo models of the cores and experiments. The experiments were originally evaluated using 1970s era deterministic codes and have not been re-evaluated using modern analysis. Re-evaluation of the GCFR-PROTEUS experiments will fill a gap in current integral benchmark data. These experiments can provide validation of computational models and nuclear data for next generation gas-cooled fast reactor designs.

The GCFR-PROTEUS experimental program was carried out between April 1972 and April 1979. Different core loading configuration were assembled, including mixed oxide (uranium, plutonium, and thorium) cores with and without breeding blankets. Measurements taken include criticality measurements and integral reactivity, spectral indices, reaction rate measurements. Further experiments explored steam ingress. The measurements were used to determine the adequacy of the calculation methods and related nuclear data libraries used in the design of gas-cooled fast breeder reactors, with the final aim of meeting the target accuracies for k_{eff} and the breeding ratio. This experimental data from the 1970s is critical to next-generation GCFR designs. Whereas experimental techniques have not advanced significantly since these measurements were performed, the computational techniques and evaluated nuclear data libraries have evolved significantly. By re-evaluating these experiments using modern methodologies, a new benchmark to assess cross-section data will be created.

The integral benchmarks have relevance to several other DOE program objectives. The experimental configurations with high Pu content surrounded by the thick reflectors supports validation of stored used nuclear fuel. Re-evaluation of these experiments also contributes to efforts to reduce the technical risk of HTGRs and more generally supports the ARC GCFR, Advanced SMR, and Fuel Cycle R&D.