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Integral Benchmark Evaluation of Zero-Power Tests and Multi-Cycle Depletion Experimental Data of TVA WB1 Cycles 1-3

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ABSTRACT:

This project proposes to develop an integral benchmark evaluation from available experimental data for zero-power tests and multi-cycle depletion for consistent and comprehensive validation of both novel high-fidelity and traditional multi-physics computational tools. The benchmark evaluation will be based on design, operational, and measured data from the pressurized water reactor Watts Bar Unit 1 (WB1) released by Tennessee Valley Authority (TVA). The established OECD/NEA (Organization for Economic Co-operation and Development, Nuclear Energy Agency) integral benchmark handbooks have two shortcomings: (a) there are very few peer-reviewed and quality-assured benchmark evaluations for commercial-sized operating reactors; and (b) most of the experiments cover single physics (neutronics/reactor physics) in time-independent conditions. A growing area of interest includes evaluation of transient and/or multi-physics benchmark experimental data for light water reactors.

A survey of data and benchmarks available in the handbooks shows that multi-physics multi-cycle integral data are scarce and with incomplete information and limited uncertainty quantification, which the proposed WB1 evaluation intends to compensate. The WB1 data for the first three cycles were released for this integral benchmark evaluation as a basis for the development of OECD/NEA multi-physics benchmark with corresponding specifications in a NEA format. The release of multi-cycle data ensures consistent and comprehensive validation of multi-physics modeling and simulation (M&S) capabilities for different steady states and cycle depletions. The start-up zero power physics tests data allows for validation of stand–alone three-dimensional neutronics model at hot zero power conditions, which is the first single-physics validation level in the multi-physics validation pyramid. In the first cycle of operation, the core consists of only fresh fuel and hence zero power conditions are free of depletion and decay considerations. The beginning of cycle steady state at hot full power with xenon equilibrium conditions allows for a smooth transition between single-physics level to multi-physics level of validation (core neutronics coupled with thermal-hydraulics). The cycle depletion data allow for validation of multi-physics M&S of depletion with incorporated decay, fission product build-up and fission yield. Finally, the fuel shuffle and decay data allow for validation of M&S of the transition between two cycles and demonstration of the complete M&S capabilities for core operations.

All available information from the TVA WB1 reactor will be used and subjected to benchmark evaluation process including uncertainty quantification, extended to multi-physics multi-cycle depletion applications. The multi-physics cycle depletion evaluation protocol will be developed using similar review pathway as the one established in the International Reactor Physics Experiment Evaluation Project (IRPhEP): collecting benchmark experimental data, follow-up benchmark evaluation process, and peer-review. The IRPhEP evaluation format will be used and subsequently the existing IRPhEP Evaluation Guide mechanics will be modified to add a Multi-Physics Depletion Guide. Multi-physics benchmark specifications will be developed to provide the data necessary to construct calculation models.