SAND2011-1470P

Seven Percent Critical Experiment (7uPCX)

7uPCX 0.855 cm Pitch, Pure Water Moderator

Description of application/purpose

This experiment request is for the 7uPCX series with pure water moderator (no dissolved boron) with a square fuel rod pitch of 0.855 cm. This is the second IER in the 7uPCX series – the first 7uPCX IER was # 135.

The nuclear industry interest in advanced fuel and reactor design often drives towards fuel with uranium enrichments greater than 5 wt% U-235. Unfortunately, little data exists, in the form of reactor physics and criticality benchmarks, for uranium enrichments ranging between 5 and 10 wt% U-235. The primary purpose of this set of critical experiments is to provide benchmarks for fuel similar to what may be required for advanced light water reactors (LWRs) in square-pitched fully-reflected fuel pin arrays that are amenable to modeling with the current generation of commercial fuel element physics codes. These experiments will also provide additional information for application to the criticality-safety bases for commercial fuel facilities handling greater than 5 wt% U-235 fuel.

Because these experiments are designed primarily to be reactor physics benchmarks, and not just criticality benchmarks, it is desired to include measurements of critical boron concentration, relative pin powers, relative assembly flux, burnable absorber worth, and isothermal temperature coefficients, for each configuration. Guidelines for developing an appropriate experimental configuration include bounding current pressurized water and boiling water reactor (PWR and BWR, respectively) fuel-to-water and metal-to-water ratios and maintaining consistency between experiment geometry and current PWR and BWR analysis tools used for reload designs (e.g., CASMO/SIMULATE).

The experiments proposed here were started as part of the Nuclear Energy Research Initiative (NERI) Project 01-0124. Documentation of the overall project and results of the analytical part of the project are given in the Areva document TDR-3000849-000 "*Reactor Physics and Criticality Benchmark Evaluations for Advanced Nuclear Fuel – Final Technical Report*" (September 10, 2008). The first two paragraphs above were taken from this reference with some editing. Documentation of the S/U analysis done as part of the project is documented in Vol. 151 of **Nuclear Technology** in "*Use of Sensitivity and Uncertainty Analysis in the Design of Reactor Physics and Criticality Benchmarks for Advanced Nuclear Fuel*" authored by B. T. Rearden (ORNL), W. J. Anderson (Framatome ANP at the time, now Areva), and G. A. Harms (SNL). Details regarding the goals of the experiments, the design of the experiments, and the applicability of the experiments to the desired commercial fuel element configurations are included in these references.

User Assessment of Available Integral Data (ICSBEP, Published, UnPublished, etc.)

The Nuclear Technology paper assessed the similarity of the following published ICSBEP evaluations with pin-type UO2 fuel in the desired enrichment range to several commercial fuel elements: LCT18, LCT19, LCT20, LCT21, LCT22, LCT23, LCT24, LCT25, LCT26, and LCT32. The paper concluded the following:

Although the TSUNAMI techniques identify a number of existing experiments as applicable to the prototypic commercial fuel designs, these experiments are not suitable for modeling with U.S. commercial reactor physics codes. The vast majority of experiments with c_k values exceeding 0.9 are hexagonally pitched arrays of fuel rods. Many commercial reactor physics codes only model square-pitched arrays. The hexagonally-pitched arrays are suitable for modeling in Monte Carlo codes commonly used for criticality safety analyses. For the two square-pitched array lattice configurations, Experiment 2 [LCT18] was not fully flooded and the rods were arranged in a circular pattern, and Experiment 32 [LCT24 case 2], although fully flooded, contains one row with a different number of fuel rods from the remainder of the critical lattice. Neither of these experiments could be suitably modeled in many commercial reactor physics codes.

Experiments that have been added to the ICSBEP collection since the inception of the NERI project with fuel in the desired enrichment range include LCT47, LCT70, LCT75, LCT85, and LCT94. For the same reasons given above, none of these benchmarks is amenable to modeling with the current generation of commercial reactor physics codes.

The following text was extracted from a draft of the original NERI proposal:

Studies exist that show the potential benefits of higher burnups for nuclear fuels. The Electric Power Research Institutes (EPRI) report, *Optimum Discharge Burnup for Nuclear Fuel: A Comprehensive Study of Duke Power’s Reactors*, documents an economic analysis of two pressurized water reactors (PWRs) and demonstrates that significant cost benefits can result from higher discharge burnup levels. Further, this report concludes that these “optimum burnup levels may not be achievable without exceeding the current limit on enrichment” (5 wt% U-235).

Another report, *Burnup Optimization in the 60 to 70MWD/kgU Range*, documented by CKA Associates, recommends two potential economic benefits of higher burnup. “First, it can accommodate higher cycle energy designs and/or longer cycle lengths. And, it can reduce certain fuel cycle services requirements for a given cycle length.” This report also indicates that the benefits of these higher burnups may require an increase in the standard industry enrichment cap. The CKA associates report includes warnings that the transition to the higher burnup levels will result in core designs that are more difficult to configure and in margins to regulatory safety limits that are smaller. These will require that the reactor physics methods be more accurate and better benchmarked.

Suggested Experiment Concept

Detailed design of the water-moderated, pin-fueled, square-pitched Seven Percent Critical Experiment (7uPCX) was carried out as part of the NERI project as was the fabrication of the experiment hardware. Approximately 2200 aluminum-clad fuel rods with 6.90% enriched UO_2 fuel were fabricated at SNL from fuel stock obtained from the Pennsylvania State University. The Sandia Pulsed Reactor Facility Critical Experiments (SPRF/CX) critical assembly was modified to accommodate the new fuel rods and to perform the experiments. The grid plates fabricated for the experiments have a 45x45 square-pitched array of fuel rod locations that can be used to simulate a 3x3 array of 15x15 mockups of commercial fuel elements. Details of the experiment design are given in the two references cited above.

Backup text, text from references, etc.