U.S. DEPARTMENT OF ENERGY
NUCLEAR ENERGY RESEARCH INITIATIVE
ABSTRACT

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Institution: **Framatone ANP**

Title: **Reactor Physics and Criticality Benchmark Evaluations for Advanced Nuclear Fuel**

The current vision for Generation IV commercial reactors is longer fuel cycles that result in lower energy costs and less inventory of spent nuclear fuel. These cycles require higher assembly burnups – up to 100 GWd/mtU – and fuel that is enriched to 5-10wt% ^{235}U.

This project crosses several engineering and science research areas: critical experiments, computational and engineering science, fuel systems/cycle development, materials science, and radioactive waste. Its purpose is to provide reactor physics and criticality benchmarks for fuel for advanced light water reactors (LWRs) using uranium enrichments between 5 and 10wt% ^{235}U. The project will use the critical assembly facility at Sandia National Laboratory (SNL) and take advantage of the supporting infrastructure being developed under a separate NERI project, "Experimental Investigation of Burn-up Credit for Safe Transport, Storage, and Disposal of Spent Nuclear Fuel."

Reactor methods are well benchmarked up to about 5.5wt% ^{235}U. However, the benchmarks used for enrichments of 6-8wt% ^{235}U rely on criticals from research reactors whose fuel configurations bear little similarity to those of commercial reactors. This project will provide the necessary benchmarks for validating reactor-physics methods (codes) and extending the enrichment ceiling to 10wt% ^{235}U.

Higher-enriched fuel may provide significant advantages for thoria/urania (Th/U) or U-only dioxide fuels when used under the conditions projected for higher burnup. For example, it could lead to cost advantages and more proliferation-resistant fuels, as well as decreased separative-work-unit (SWU) loss for the disposition of weapons-grade uranium. Therefore, higher enriched LWR fuel will benefit the DOE's high-enriched uranium (HEU) disposition program. The use of higher-enriched fuel and the extended fuel cycles will directly benefit the DOE's high-level nuclear waste program by decreasing the expected inventory of commercial spent nuclear fuel assemblies.

Framatome ANP (Advanced Nuclear Power) will lead the project in collaboration with SNL, Oak Ridge National Laboratory (ORNL), and the University of Florida (UF). We will design a series of experiments for uranium-dioxide fuel with enrichments of 5wt%, 7.5wt%, and 10wt% ^{235}U. The lattice experiments will use pitches representative of designs for current and future pressurized water reactors (PWRs). The experiments will measure reactor parameters such as control rod worth, boron worth, burnable poison worth, moderator reactivity coefficient, and fission rate. The criticality benchmark experiments will be documented for inclusion in the *International Handbook of Evaluated Criticality Safety Benchmark Experiments.*

The project comprises three phases: design, experiments, and analyses. In Phase I, Framatome ANP, ORNL, and SNL will design the specific experiments, establish the safety authorization basis, and obtain approvals to perform these experiments at the SNL facility. ORNL will apply a newly developed sensitivity/uncertainty methodology to verify the need for particular experiments and the parameters that these experiments need to explore. Important considerations in this phase of the project are the existing facility restrictions, material availability, and industry needs. The experiments will be designed to minimize the number of changes to the physical environment of the existing facilities and to use the existing uranium inventories, as possible.

Phase II encompasses the experiments to be performed. Framatome ANP, ORNL, and UF will analyze the proposed experiments using different reactor-physics methods to predict the critical configurations and reactor-physics parameters. Framatome ANP will use APOLLO and NEMO, standard nuclear design computer codes. UF will use the CASMO/SIMULATE and MCNP methods that are widely accepted in the nuclear industry. These analyses will support the operation of the experiment by predicting the expected experimental values (e.g., number of rods, water height, and moderator-temperature coefficient).

In Phase III, Framatome ANP, ORNL, and UF will compare the results of the calculations to the experimental results. If any discrepancies are discovered, an attempt will be made to find and explain the source of the difference, i.e., inadequate modeling or experimental error. SNL will document the experimental configuration and uncertainties in the experiment.

Three products will result from this project. The first will be a comparison of the results of the analyses and experiments to determine if there are areas where additional experimental data or analysis is needed to establish the desired benchmarks. The second will be the documentation of the experiments as critical benchmarks for inclusion in the *International Handbook of Evaluated Criticality Safety Benchmark Experiments*. The third will be the documentation of the generic nuclear criticality-safety evaluation for typical fuel-processing, storage, and transportation operation.