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EVALUATION OF THE HTC CRITICAL EXPERIMENT DATA

Donald E. Mueller

Nuclear Science and Technology Division, Oak Ridge National Laboratory,[*] P.O. Box 2008, Oak Ridge, TN 37831-6170, MuellerDE@ornl.gov

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Evaluation of the HTC Critical Experiment Data for Spent Nuclear Fuel

Donald E. Mueller

Nuclear Science and Technology Division, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6170, MuellerDE@ornl.gov

INTRODUCTION

This paper summarizes an evaluation of a series of critical experiments that are useful for validation of calculations involving spent nuclear fuel.

In the 1980s, a series of critical experiments referred to as the Haut Taux de Combustion (HTC) experiments was conducted by the Institut de Radioprotection et de Sûreté Nucléaire (IRSN) at the experimental criticality facility in Valduc, France. These experiments were designed to provide a basis for validation of actinide-only burnup credit calculations. The simulated Zr-clad fuel rods used in these experiments contained a mixture of uranium and plutonium oxides. The plutonium-to-uranium ratio and the uranium and plutonium isotopic compositions were designed to be similar to what would be found in typical pressurized-water reactor fuel that initially had an enrichment of 4.5 wt % ^{235}U and was burned to 37,500 MWd/MTU.

The 156 critical configurations were designed to approximate fuel handling, fuel storage rack, and spent fuel shipping cask conditions and were categorized into four phases [1-4]. Phase 1 included 18 configurations, each involving a single square-pitched array of rods with rod pitch varying from 1.3 to 2.3 cm. The arrays were flooded and reflected with clean water. Phase 2 included 41 configurations that were similar to the first group except that the water used as moderator and reflector included either boron or gadolinium in solution. Phase 3 included 26 configurations with the rods arranged into four assemblies in a 2 × 2 array to simulate fuel assembly storage rack conditions. The spacing between assemblies was varied, and some of the configurations had borated stainless steel, Boral®, or cadmium plates attached to all four sides of each assembly, approximating typical flux trap storage rack geometry. Phase 4 simulated cask conditions and included 71 configurations similar to the Phase 3 configurations, except thick steel or lead shields were placed around the outside of the 2 × 2 array of fuel assemblies. Figure 1 is a graphical summary of the experiments.

DESCRIPTION OF THE ACTUAL WORK

An evaluation of the HTC experiment data and reports has been completed. The evaluation included assessments of the completeness and accuracy of the data, the reported experimental uncertainties, and the usefulness of the experiments for determination of bias and bias uncertainty for burnup credit analysis. The evaluation, including recommendations related to data use, is documented in a NUREG/CR report to be issued by the Nuclear Regulatory Commission in the spring of 2008.

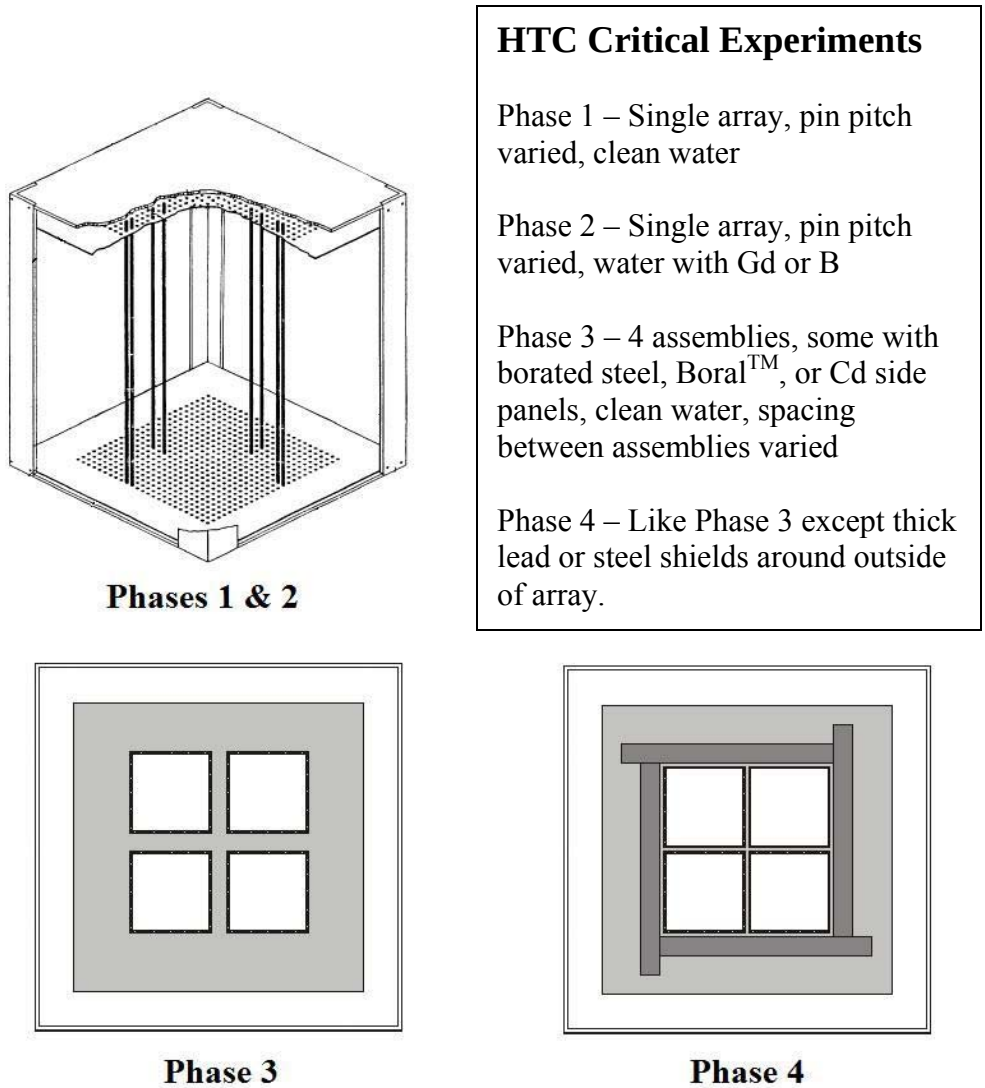

Fig. 1. Description of HTC experiments.

RESULTS

Detailed SCALE 5.1 and MCNP models were prepared to analyze each of the 156 critical configurations. During the modeling effort, Oak Ridge National Laboratory (ORNL) staff worked with IRSN staff to ensure that the reports documenting the HTC experiments included sufficient information to support accurate model generation and bias calculation and were as complete and accurate as possible. The k_{eff} values calculated using the SCALE 5.1 ENDF/B-VI 238-group library and CENTRM/PMC for cross sectional processing averaged 0.9951 and ranged from 0.9894 to 1.0005. The SCALE 5.1 TSUNAMI sensitivity and uncertainty analysis tools were used to assess the similarity of the HTC experiments to criticality safety calculations involving spent nuclear fuel. Figure 2 shows the results from the similarity assessment comparing 1,239 critical configurations to a model of a generic burnup credit cask loaded with 32 Westinghouse 17 × 17 fuel assemblies that had an initial ^{235}U enrichment of 3.8 wt% and were burned to 40 GWd/MTU. In this figure, the c_k value is an integral index quantifying the similarity of each critical configuration with the burnup credit model. A c_k value of 1.0 indicates complete

similarity. Experiments with $c_k \geq 0.9$ and $0.9 > c_k \geq 0.8$ are considered applicable and marginally applicable, respectively, to validation of the safety analysis calculation [5]. The legend in Fig. 2 identifies groups of critical configurations based on the type of fissionable material involved. The analysis showed that the HTC experiments were useful for validating burnup credit calculations.

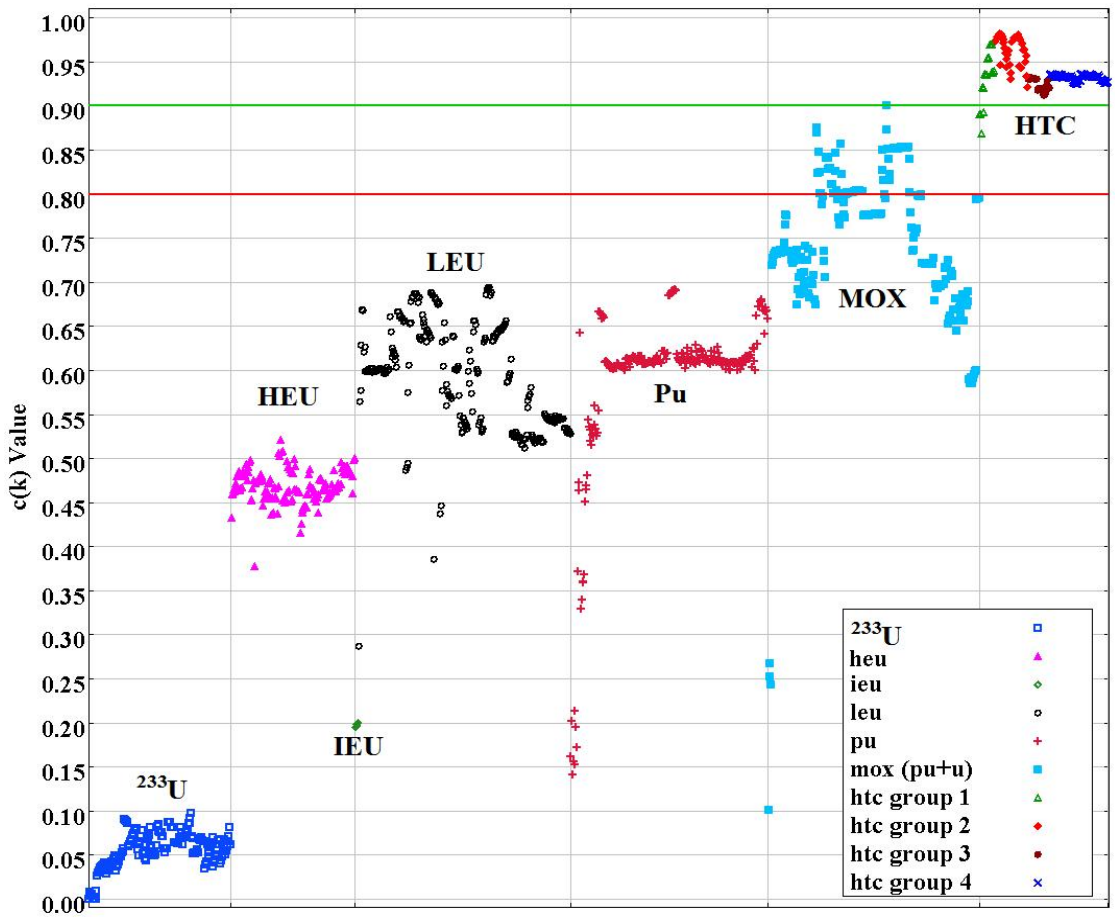

Fig. 2. Similarity assessment results showing applicability of HTC experiments to validation of a burnup credit cask.

ACCESS TO DATA

Rights of use for the HTC experiment data were purchased under an agreement that currently limits release and usage of the information. Consequently, a detailed and complete description of the experiments is not presented in this paper or the NUREG/CR report. Following completion of a non-disclosure agreement, the data may be used in analyses supporting transportation, storage, and disposal of spent nuclear fuel in the United States. At that time, the HTC data will be made available through the Radiation Safety Information Computational Center.

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