Criticality Safety Study for Loss of Single Fuel Rod From WH 14 Type Fuel

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1. Introduction

As of the end of June 2017, 17,574 assemblies of PWR type Spent Nuclear Fuel (SNF) and 430,576 bundles of PHWR type SNF are temporarily stored in the Spent Fuel Pool (SFP). It is expected that the storage capacity of the SFP in the Nuclear Power Plant (NPP) will be saturated in 2024, starting from Kori NPP. Thus it is necessary to transport SNF from NPP site to intermediate storage facilities. The objective of this study, the effect of single failed fuel rod is to confirm on the criticality safety whether is significant.

2. Background and Scope of Work

2.1 NUREG/CR-6835 [1]

The objective of this report is to investigate the consequences of potential fuel failure on criticality safety and external dose rates for SNF storage and transport casks, with emphasis on high-burnup SNF. Analyses were performed to assess the impact of several damaged/failed fuel scenarios on the effective neutron multiplication factor (k_{eff}) and external dose rates.

2.2 Failure Scenarios

For the criticality safety analyses, five different fuel failure scenarios that would impact criticality safety were defined and studied in [1]. Only scenario #1 (Individual fuel rod collapse resulting in rods being absent from the assembly lattice) is studied and will later the other scenarios

3. Analysis Results

3.1 KN-12 Transport Cask Basket Model

Using KENO-VI, a Monte Carlo transport simulation code included in the SCALE computer code system [2], basket-cell model was developed to perform criticality safety calculations for scenario #1. For conservative analysis, the basket was loaded with fresh PWR assemblies enriched to 5 wt% ^{235}U. The fuel assembly types are WH 14×14 fuel assemblies (STD, OFA).

3.2 Assumptions and Analysis results

Full water flooding was assumed, including water in the gap between the fuel pellets and cladding. All of the top and bottom end fittings, grid spacers, and other hardware were removed. The basket-cell models are reflected to form an infinite array (all direction) of fuel baskets conservatively.

Fuel failure scenario #1 was evaluated by comparing the calculated values of k_{eff} with multiplication factors from baseline basket-cell models with intact (undamaged) fuel assemblies. The baseline k_{eff} values are given in Table 1.

Table 1. Baseline calculated k_{eff} values with intact (undamaged) fuel

Fuel Type	Basket-cell model k_{eff}
14OFA	1.00208
14STD	0.99249

This scenario involves fuel failure which an individual fuel rod collapses, resulting in the removal of that rod from the assembly lattice. To conduct the analysis, each single rod in a basket-cell model was removed at a time to quantify its effect on k_{eff}. Fig.1 through 2 show the change in k_{eff} for removal of each single fuel rod in the 14×14 assembly lattice.

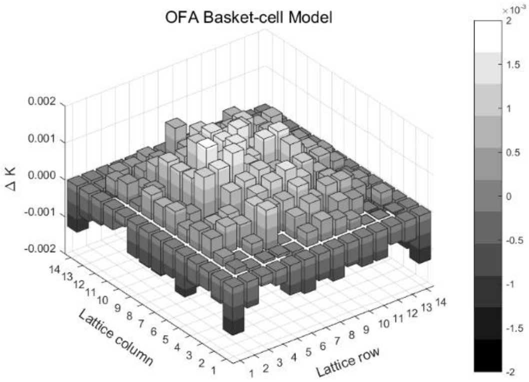

Fig. 1. Change in k_{eff} for single rod removal in the KN-12 basket cell for the 14×14 OFA fuel assembly.

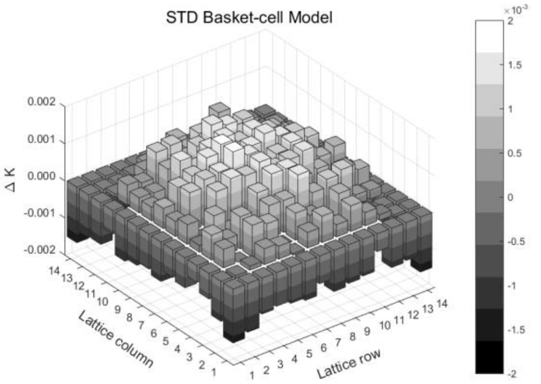

Fig. 2. Change in k_{eff} for single rod removal in the KN-12 basket cell for the 14×14 STD fuel assembly.

4. Conclusion

As a result, the Δk values(baseline – fuel rod loss position) of 14OFA was largest. The Δk values resulting from single rod removal in the basket-cell model range from -0.00129 for rods near the edge of the lattice to +0.00170 for rods near the center. Thus, it is confirmed that the study for the consequences of potential fuel failure is significant because fuel assemblies are designed to be undermoderated, and the loss of a fuel pin from the lattice causes a local area of higher moderation, which can increase k_{eff}.

ACKNOWLEDGEMENT

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[2] B.T. Rearden, M.A. Jessee, “SCALE Code System”, ORNL/TM-2005/39 Version 6.2.1.