An Empirical Approach to Bounding the Axial Reactivity Effects of PWR Spent Nuclear Fuel

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INTRODUCTION

One of the significant issues yet to be resolved for using burnup credit (BUC) for spent nuclear fuel (SNF) is establishing a set of depletion parameters that produce an adequately conservative representation of the fuel's isotopic inventory. Depletion parameters (such as local power, fuel temperature, moderator temperature, burnable poison rod history, and soluble boron concentration) affect the isotopic inventory of fuel that is depleted in a pressurized water reactor (PWR). However, obtaining the detailed operating histories needed to model all PWR fuel assemblies to which BUC would be applied is an onerous and costly task. Simplifications therefore have been suggested that could lead to using "bounding" depletion parameters that could be broadly applied to different fuel assemblies. This paper presents a method for determining a set of bounding depletion parameters for use in criticality analyses for SNF.

DESCRIPTION

The general method for determining a set of bounding depletion parameters can be accomplished in six steps. Step one involves identifying the fuel type to which the BUC will be applied. In step two, a statistically significant number of representative fuel-depletion operating histories are surveyed. Information about burnup, fuel temperature, soluble boron, moderator density, burnable poison use, and control-rod insertion history are collected for each fuel assembly. Step three analyzes the survey results to determine the range of expected values, including a mean and standard deviation (where applicable). Step four identifies the bounding values for each depletion parameter and step five uses these depletion parameters as input to an isotopic depletion computer code such as SAS2H(1) or CASMO-3(2) to determine the discharge isotopic inventory. Finally, step six uses this isotopic inventory in a waste package MCNP(3) computer model to determine k-effective for a sample loading of SNF. A parallel set of isotopics is determined from a depletion calculation based on actual depletion history conditions for selected assemblies. The results from these calculations are compared to demonstrate that the reactivity of the SNF in a waste package using the bounding model is always greater than the WP reactivity calculation using the actual depletion history isotopic inventory.

RESULTS

The operating histories from approximately 3400 individual PWR fuel assemblies were surveyed to demonstrate this method. Fuel-cycle boron letdown curves, average fuel power densities, burnable poison history (BPH), control rod history (CRH), and moderator temperature data were collected for individual fuel assemblies from a total of seven different reactors designed by either Babcock & Wilcox (B&W) or Westinghouse. The survey provides an "expected range of values" for each depletion parameter as a function of axial position. A fuel model was depleted using a bounding maximum or minimum value for each parameter. The nature of the bounding value was determined by its tendency to increase reactivity, generally as a result of neutron spectrum hardening. The sensitivity on k-effective was evaluated for two different assemblies according to the conditions described in Table 1. Assembly F6 is a 15x15 B&W assembly with an initial enrichment of 3.49 weight percent (wt%) ^{235}U. This assembly used burnable poison rods (BPRs) for one cycle and it was depleted to an average burnup of 16.8 GWd/mtU. Assembly F27 is also a 15x15 B&W assembly with an initial enrichment of 3.49 wt% ^{235}U. This assembly had no BPRs and it was depleted to an average burnup of 33.6 GWd/mtU. Figure 1 presents the results of the sensitivity calculations, which show a wide variation in conservatism relative to the actual depletion conditions. Case 1 represents the base case (actual) for each assembly. Case 2 results indicate that using bounding values for all of the depletion parameters produces very conservative results, perhaps too much so. The other Cases show sensitivities for each depletion parameter selected.

This study demonstrates that operating-history information provides a realistic basis for establishing "bounding" values. Many different models can be developed to conservatively bound the expected reactivity of PWR SNF. End-user design/licensing criteria will determine the most appropriate for their needs.

REFERENCES

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2. *CASMO-3, A Fuel Assembly Burnup Program, Version 4.8*, Studsvik/NFA-89/3, November 1996.
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Table 1. Summary of Bounding Depletion Parameters

	Depletion Parameters				
CASE	Assembly Burnup	Fuel Temperature	Moderator Density	Soluble Boron	Burnable Poison Rod History
1	Actual	Actual	Actual	Actual	Actual
2	Minimum	Maximum	Minimum	Maximum	Inserted 1'st cycle
3	Minimum	Maximum	Minimum	Maximum	None
4	Minimum	Actual	Actual	Actual	Actual
5	Minimum	Actual	Actual	Actual	None
6	Actual	Maximum	Actual	Actual	Actual
7	Actual	Actual	Minimum	Actual	Actual

Figure 1. Summary of Depletion Parameter Sensitivity Evaluations