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BURNUP CREDIT FEASIBILITY FOR BWR SPENT FUEL SHIPMENTS*

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INTRODUCTION

Considerable interest in the allowance of reactivity credit for the exposure history of power reactor fuel currently exists. This "burnup credit" issue has the potential to greatly reduce risk and cost when applied to the design and certification of spent fuel casks used for transportation and storage. Analyses[1] have shown the feasibility and estimated the risk and economic incentives for allowing burnup credit in pressurized water reactor (PWR) spent fuel shipping cask applications. This paper summarizes the extension of the previous PWR feasibility assessments to boiling water reactor (BWR) fuel. As with the PWR analysis, the purpose was not verification of burnup credit (see ref. 2 for ongoing work in this area) but a reasonable assessment of the feasibility and potential gains from its use in BWR applications.

This feasibility analysis aims to apply simple methods that adequately characterize the time-dependent isotopic compositions of typical BWR fuel. An initial analysis objective was to identify a simple and reliable method for characterizing BWR spent fuel. The method includes characterization of a typical pin-cell spectrum, using a one-dimensional (1-D) model of a BWR assembly. The calculated spectrum allows burnup-dependent few-group material constants to be generated. Point depletion methods were then used to obtain the time-varying characteristics of the fuel. These simple methods were validated, where practical, with multidimensional methods.

After characterizing the spent fuel at various stages of exposure and decay, three-dimensional (3-D) models for an infinite array of assemblies and, in several cases, infinite arrays of assemblies in a typical shipping cask basket were analyzed. Results for assemblies without a basket provide reactivity control requirements as a function of burnup and decay, while results including the basket allow assessment of typical basket configurations to provide sufficient reactivity control for spent BWR fuel. Resulting basket worths and reactivity trends over time are then evaluated to determine whether burnup credit is needed and feasible in BWR applications.

CALCULATIONAL TOOLS

The primary computational tools used in this analysis were the SAS2H and CSAS25 sequences from Version 4 of the SCALE system.[3,4] The SAS2H sequence comprises the repetitive application of 1-D spectrum/point-depletion computations to obtain isotopic input for multidimensional codes used in performing the criticality analysis in a shipping cask environment.

The multidimensional calculations of an infinite array of BWR assemblies with and without intervening basket materials were performed with the CSAS25 sequence. These calculations were performed for typical shipping cask conditions, although the cask body itself was not modeled.

The base cross-section library used in this study was the SCALE 27-neutron-group ENDF/B-IV library, which was enhanced with additional fission product nuclides appropriate for spent fuel applications.

BASKET REQUIREMENTS AND WORTHS

The BWR assembly used in this analysis was taken from ref. 5 and corresponds to a typical BWR assembly with Gd rods. The initial enrichments evaluated included 2.5%, 2.9%, 3.4%, and 3.8%, corresponding to an average enrichment over the entire BWR fuel element. Maximum burnups were 45, 40, 33, and 28 GWd/MTU for the 3.8%, 3.4%, 2.9%, and 2.5% enrichments, respectively. In all cases, the isotopic information was generated using SAS2H assuming three axial nodes. This isotopic information was then input into a KENO V.a criticality calculation for an infinite array of assemblies.

The control requirements given in Table 1 are appropriate for two-year-cooled fuel at the specified burnups and initial enrichments. These values were obtained by taking the difference between the two-year-cooled k_∞ values and 0.93. An added conservatism was the neglect of the leakage from the cask, which has been estimated[6] to be approximately 3% for a large rail cask and 9% for smaller truck casks. The control requirements range from a near constant 0.10 at the end-of-cycle to 0.50 for the highest enrichment fresh fuel. The trends seen here are slowly increasing control requirements with initial enrichment and rapidly decreasing control requirements with burnup. By comparing these control requirements to the basket worths for various possible basket designs, the range of applicability of each basket is readily determined.

The basket web evaluated was a composite boral/SS-304 taken from ref. 1. The basket worths given in Table 1 show that the 0.5-in. boral/SS-304 web and the 0.25-in. boral/SS-304 web are sufficient to meet the control requirements of fresh fuel up to 4.5% initial enrichment. The SS-304-only web does not meet the control requirements of 3.8% enriched fuel, unless burnup credit is used (a burnup of approximately 40 GWd/MTU is needed to match control requirements with the basket worth).

Table 1. Basket worths for borated and non-borated webs

Initial enrichment	Burnup GWd/MTU	CR[a]	Basket worths, Δk: 0.5 in. b/ss[b]	0.25 in. b/ss	0.5 in. ss[c]
2.5%	fresh	0.35	–	–	–
2.9%	fresh	0.39	–	–	–
3.4%	fresh	0.44	0.56	0.51	–
	21	0.25	0.48	–	–
	40	0.09	0.41	–	–
3.8%	fresh	0.45	0.54	–	0.20
	45	0.10	0.42	–	0.17
4.5%	fresh	0.50	–	0.51	
–					

[a]Control requirements for 2-year-cooled fuel, obtained by subtracting 0.93 from the array k_∞.
[b]Boral/stainless-steel basket material.
[c]Stainless-steel-only basket.

SUMMARY

The results have shown that while the changes in reactivity over the life cycle of BWR fuel are very similar to those of PWR fuel, baskets containing boral are much more effective for BWR fuel than for PWR fuel. This difference stems from the differing sizes and, hence, reactivities of the individual fuel assemblies. The main advantage of burnup credit in BWR fuel is to eliminate the need for complicated basket designs containing external poisons. It is not clear whether there is a significant impact on cask capacities because the practicality of burnup credit for BWR fuel remains an open issue.

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