DOE/RW/00134--M97-019

Conservative Axial Burnup Distributions for Actinide-Only Burnup Credit

CONF-980516--

by

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I. INTRODUCTION

Unlike the fresh fuel approach, which assumes the initial isotopic compositions for criticality analyses, any burnup credit methodology must address the proper treatment of axial burnup distributions. A straightforward way of treating a given axial burnup distribution is to segment the fuel assembly into multiple meshes and to model each burnup mesh with the corresponding isotopic compositions. Although this approach represents a significant increase in modeling efforts compared to the uniform average burnup approach, it can adequately determine the reactivity effect of the axial burnup distribution. A major consideration is what axial burnup distributions are appropriate for use in light of many possible distributions depending on core operating conditions and histories.

This paper summarizes criticality analyses performed to determine conservative axial burnup distributions. The conservative axial burnup distributions presented in this paper are included in the *Topical Report on Actinide-Only Burnup Credit for Pressurized Water Reactor Spent Nuclear Fuel Packages*[1], Revision 1 submitted in May 1997 by the U.S. Department of Energy (DOE) to the U.S. Nuclear Regulatory Commission (NRC). When approved by NRC, the conservative axial burnup distributions may be used to model PWR spent nuclear fuel for the purpose of gaining actinide-only burnup credit.

II. ANALYSIS

The majority of PWR assemblies can be well represented by a relatively flat axial profile at the fuel mid-section and significantly under-burned fuel ends. Some assemblies exposed to axial power shaping rods or control rods during depletion could exhibit somewhat different axial burnup distributions, but these are aberrations. To reflect the realistic axial burnup distributions, a database containing 3169 axial burnup profiles of three PWR vendors (Westinghouse, Combustion Engineering, Babcock and Wilcox) and five fuel types (W 15x15, W 17x17, CE 14x14, CE 16x16, B&W 15x15) has been compiled.[2] This database represents 105 cycles and covers a range of assembly average burnup from slightly over 3 GWd/MTU to 53.3 GWd/MTU and an enrichment range from 1.24 w/o to 4.75 w/o U-235. This database includes early cycle data through cycle data from the mid-1990's and represents fuel assemblies under different operating

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histories and fuel management practices. The axial burnup profiles were obtained from actual core design calculations typically performed as part of reactor-specific core reload analyses. The axial burnup profiles are reported as normalized values at 18 equal-size axial zones.

The bounding profile analysis[3] sorted all qualifying axial burnup profiles in the database into 12 burnup groups and determined the limiting axial burnup profile in each burnup group. These limiting profiles are listed in Table 1. However, the bounding profile analysis did not separate the burnup effects from the profile effects. In other words, it is not known whether profile 1 is more limiting than profile 12. To determine the profile rankings across different burnup groups, a constant burnup has to be assumed regardless of the actual burnups.

The multiplication factors of an infinite array of Westinghouse 17x17 assemblies have been determined applying the axial burnup distributions in Table 1. SCALE 4.2[4] code system has been used for criticality analysis and the burnup was assumed to be 18 GWd/MTU for all cases. Table 2 shows the results. Comparison of Tables 1 and 2 indicates that, in general, the lower the burnup at the top of the assembly, the larger is the multiplication factor. Profile 9, with the lowest burnups at the top two nodes due to the fuel depletion with a control rod inserted at the top of the core, produces the largest multiplication factor. The multiplication factor corresponding to profile 9 is about 3% higher than that of profile 4. Also apparent in Table 2 is that the multiplication factors decrease gradually as burnup increases. This result is consistent with the fact that a highly under-burned fuel top due to rodded depletion in an earlier cycle experiences a higher burnup in later cycles.

Based on results shown in Table 2, conservative axial burnup distributions to be used for PWR spent nuclear fuel modeling can be determined. Profiles 9 and 8 are most limiting in the burnup ranges of 0 to 18 GWd/MTU and 18 to 30 GWd/MTU, respectively. Profile 5 is most limiting for burnups greater than 30 GWd/MTU. These burnup group boundaries approximately correspond to the nominal assembly burnups expected after one and two depletion cycles. The conservative axial burnup distributions are shown in Figure 1.

III. CONCLUSION

A set of conservative axial burnup distributions to be used with the actinide-only burnup credit methodology is determined from a compiled database. Fuel assemblies with lower burnup at the top generally exhibit higher multiplication factors. With the use of conservative axial burnup distributions determined from a large database, bounding treatment of PWR spent nuclear fuel is assured for criticality analyses.

REFERENCES

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3. T. A. Parish and C. H. Chen, "Bounding Profile Analysis for the Topical Report Database," Texas A&M University (May 1997).

4. "SCALE: A Modular Code System for Performing Standardized Computer Analysis for Licensing Evaluations," NUREG/CR-0200, Vol. 1-3, Revision4, Nuclear Regulatory Commission (April 1995).

Table 1. Limiting Axial Burnup Distributions for Each Burnup Group[3]

Axial Position (% of Core Height)	Normalized Burnup of Limiting Axial Profiles in Each Burnup Group											
	Profile 1 (46)	Profile 2 (42 - 46)	Profile 3 (38 - 42)	Profile 4 (34 - 38)	Profile 5 (30 - 34)	Profile 6 (26 - 30)	Profile 7 (22 - 26)	Profile 8 (18 - 22)	Profile 9 (14 - 18)	Profile10 (10 - 14)	Profile 11 (6 - 10)	Profile 12 (0 - 6)
2.78	0.573	0.674	0.660	0.585	0.652	0.619	0.630	0.668	0.649	0.633	0.662	0.574
8.33	0.917	0.949	0.936	0.957	0.967	0.924	0.936	1.034	1.044	0.989	0.930	0.947
13.89	1.066	1.053	1.044	1.091	1.074	1.056	1.066	1.150	1.208	1.019	1.049	1.091
19.44	1.106	1.085	1.080	1.121	1.103	1.097	1.103	1.094	1.215	0.857	1.059	1.105
25.00	1.114	1.095	1.091	1.126	1.108	1.103	1.108	1.053	1.214	0.776	1.108	1.094
30.56	1.111	1.095	1.093	1.111	1.106	1.101	1.109	1.048	1.208	0.754	1.144	1.087
36.11	1.106	1.093	1.092	1.094	1.102	1.103	1.112	1.064	1.197	0.785	1.168	1.086
41.67	1.101	1.091	1.090	1.093	1.097	1.112	1.119	1.095	1.189	1.013	1.183	1.087
47.22	1.097	1.089	1.089	1.092	1.094	1.125	1.126	1.121	1.188	1.185	1.189	1.091
52.78	1.093	1.088	1.088	1.091	1.094	1.136	1.132	1.135	1.192	1.253	1.190	1.096
58.33	1.089	1.086	1.088	1.092	1.095	1.143	1.135	1.140	1.195	1.278	1.183	1.102
63.89	1.086	1.084	1.086	1.099	1.096	1.143	1.135	1.138	1.190	1.283	1.167	1.105
69.44	1.081	1.081	1.084	1.096	1.095	1.136	1.129	1.130	1.156	1.276	1.135	1.105
75.00	1.073	1.073	1.077	1.087	1.086	1.115	1.109	1.106	1.022	1.251	1.079	1.096
80.56	1.051	1.053	1.057	1.073	1.059	1.047	1.041	1.049	0.756	1.193	0.976	1.066
86.11	0.993	0.987	0.996	1.003	0.971	0.882	0.871	0.933	0.614	1.075	0.806	0.986
91.67	0.832	0.800	0.823	0.796	0.738	0.701	0.689	0.669	0.481	0.863	0.596	0.806
97.22	0.512	0.524	0.525	0.393	0.462	0.456	0.448	0.373	0.284	0.515	0.375	0.474

Table 2. Criticality Rankings for Limiting Axial Burnup Distributions

Profile and Burnup Group (GWd/MTU)	Infinite Array k_{eff} (at 18 GWd/MTU)	Ranking
Profile 1 (≥ 46)	1.29085	**10**
Profile 2 (42 - 46)	1.29145	**8**
Profile 3 (38 - 42)	1.29127	**9**
Profile 4 (34 - 38)	1.29071	**12**
Profile 5 (30 - 34)	1.29147	**7**
Profile 6 (26 - 30)	1.29398	**6**
Profile 7 (22 - 26)	1.29510	**5**
Profile 8 (18 - 22)	1.29525	**4**
Profile 9 (14 - 18)	1.32063	**1**
Profile 10 (10 - 14)	1.30892	**2**
Profile 11 (6 - 10)	1.30264	**3**
Profile 12 (0 - 6)	1.29082	**11**

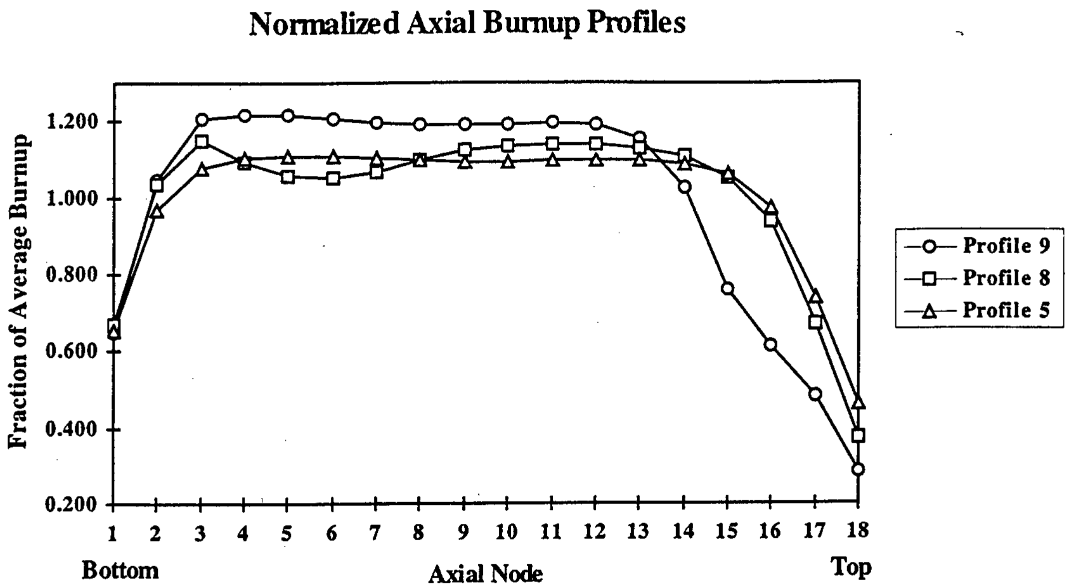

Figure 1. Conservative Axial Burnup Distributions for Actinide-Only Burnup Credit

M98001300

Report Number (14) DOE/RW/00134--M97-019
CONF-980516--

Publ. Date (11) 199711
Sponsor Code (18) DOE/RW, XF
UC Category (19) UC-800, DOE/ER

DOE