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CALCULATION SUMMARY SHEET (CSS)

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Title PWR Axial Profile Evaluation

PREPARED BY:		REVIEWED BY:	
		METHOD: ☒ DETAILED CHECK ☐ INDEPENDENT CALCULATION	
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PURPOSE AND SUMMARY OF RESULTS:

This calculation compares results from criticality evaluations for a 21-assembly pressurized water reactor (PWR) waste package based on 12 axial burnup profile representations for commercial spent nuclear fuel (SNF) assemblies. The burnup profiles encompass the axial variations caused by different fuel assembly irradiation histories in a commercial PWR, including end effects, and the concomitant effect on reactivity in the waste package.

The bounding axial burnup profiles in Table 5 of reference 6.3 are used for this analysis. Criticality evaluations are performed using the MCNP computer program (References 6.4 and 6.5). Axial burnup data for the analysis is obtained from reference 6.6. The calculations evaluate five methods for modeling isotopic concentrations representing the bounding axial burnup profiles in a 21-assembly PWR waste package:

1. Axial profiles with best-estimate isotopic concentrations
2. Axial profiles with principal isotope isotopic concentrations
3. Axially homogenized best-estimate isotopic concentrations
4. Axially homogenized principal isotopic concentrations
5. Isotopic concentrations from generic PWR database (reference 6.8)

The waste package model is discussed in Section 5.1 and the MCNP analysis are results are discussed in Section 5.2. The results of the MCNP calculations for k_{eff}, sigma, AENCF, and %Δk/k are summarized in Table 2.

This engineering calculation was performed under Framatome ANP Administrative Procedure 0402-01, Preparing and Processing FANP Calculations (reference 6.1) and Framatome Quality Management Manual (reference 6.2). The best estimate, axial profile k_{eff} values are larger than the best-estimate and principal isotope k_{eff} values for the axially homogenized cases for burnup groups 1 through 9. For the groups with the lower burnup values (groups 10 through 12) this is not always true. For groups 10 through 12 the axially homogenized cases are conservative with respect to the best-estimate, axial profile cases with the exception of the axially homogenized principal isotope case for group 10. Although the isotopic database k_{eff} values are always larger than the corresponding best-estimate, axial profile k_{eff} values (i.e. conservative), they are not always larger than the corresponding principal isotope, axial profile k_{eff} values. This is the case for burnup groups 7 and 9. For group 9, the bounding axial burnup profile is from cycle 1B of Crystal River 3. The k_{eff} value for this assembly is the least conservative of the 12-burnup groups. The %Δk/k value for the isotopic database for this assembly is 0.34. The %Δk/k value for the principal isotope, axial profile case for group 9 is 0.70, which is more conservative than the isotopic database. Thus, the isotopic database is not overly conservative when viewing all 12 burnup groups but is sufficiently conservative.

The conclusion that the isotopic database is sufficiently conservative is based in part on results from reference 6.8. Part of the confirmation of the conservatism in the isotopic database is based on comparisons made with CRC data. From Table 22 of reference 6.8, it is seen that when the isotopic database isotopic concentrations are substituted for the best-estimate values for this fuel assembly k_{eff} increased by 0.13%. Based on measured criticality data the isotopic database is conservative for this and all other assemblies tested in reference 6.8.

This revision affects references only. Calculation results are not affected in any way by this revision.

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:		THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK
CODE/VERSION/REV	CODE/VERSION/REV	
MCNP 4.B.2		
		☐ YES ☒ NO

RECORD OF REVISIONS

Revision Number	Date
00 (Initial)	September 2003
01	December 2004

- Revised Calculation Summary Sheet to note that this revision does not affect calculation results in any way.
- Revised title for Reference 6.2, page 6 of 37.
- Revised title for Reference 6.2, page 13 of 37.
- Completed Design Verification Checklist to reflect revisions.

1. PURPOSE

This calculation provides a comparison of results from criticality evaluations for a 21-assembly pressurized water reactor (PWR) waste package based on 12-axial burnup profile representations for commercial spent nuclear fuel (SNF) assemblies. The burnup profiles encompass the axial variations caused by different fuel assembly irradiation histories in a commercial PWR, including end effects, and the concomitant effect on reactivity in the waste package.

This engineering calculation was performed under Framatome ANP Administrative Procedure 0402-01, Preparing and Processing FANP Calculations (Reference 6.1) and Framatome Fuel Sector Quality Management Manual (Reference 6.2).

2. METHOD

The bounding axial burnup profiles presented in Table 5 of reference 6.3 are used for this analysis. Criticality evaluations are performed using the MCNP computer program (references 6.4 and 6.5). Axial burnup data for the analysis is obtained from reference 6.6. Commercial SNF isotopic concentrations corresponding to the burnup data is taken from reference 6.7.

The bounding axial burnup profiles from reference 6.3 represent various PWR fuel assembly designs, which include variation in enrichment, burnup, and absorber rods, along with varying PWR operating histories. The PWR SNF data from reference 6.6 includes axial burnup, moderator density, and fuel temperature profiles. The data in references 6.6 and 6.7 is used to provide SNF isotopic concentrations for the criticality evaluations for a 21-assembly waste package representing the 12-bounding axial burnup profiles from reference 6.3. The data selected from references 6.6 and 6.7 is from commercial reactor criticality (CRC) statepoints, which represents commercial SNF assemblies in known critical configurations. The selection process for choosing the burnup values corresponding to the 12- burnup groups of reference 6.3 is presented in Appendix A of this document.

The method used for the calculations presented in this document includes the following steps:

1. Select burnup data from the CRC summary report for Crystal River 3 (reference 6.6) that encompass the bounding burnup profiles from Table 5 of reference 6.3. This will necessitate using composite data from several fuel assemblies from the same fuel batch to match the bounding profiles for the various burnup groups. This process is presented in Appendix A of this document.

2. Select isotopic concentrations from the CRC reactivity calculation report for Crystal River 3 (reference 6.7) that correspond to the burnup data selected in step 1. This includes both best-estimate and principal isotope concentrations.

6. REFERENCES

6.1. Framatome ANP, Administrative Procedure, Number: 0402-01, Preparing and Processing FANP Calculations, February 2003, Framatome ANP, Lynchburg, Virginia.

6.2. AREVA/FANP Document Number FQM Rev 01, July 2003. Framatome ANP, Inc. Fuel Sector Quality Management Manual (US Version).

6.3. Wagner, J.C, Dehart, M.D., and Parks, C.V. 2003, *Recommendations for Addressing Axial Burnup in PWR Burnup Credit*. NUREG/CR-6801. Oak Ridge, Tennessee, Oak Ridge National Laboratory.

6.4. Breismeister, J.F., Ed., *MCNP™ – A General Monte Carlo N-Particle Transport Code, Version 4B*. LA-12625-M. Los Alamos National Laboratory (LANL), March 1997.

6.5. Framatome ANP, Administrative Procedure, Number: 0902-06, Software Certification, November 2002, Framatome ANP, Lynchburg, Virginia.

6.6. Framatome ANP Doc. 38-5034259-00, *Summary Report of Commercial Reactor Criticality Data for Crystal River Unit 3*. TDR-UDC-NU-000001 REV 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010702.0087.

6.7. Framatome ANP Doc. 38-5034260-00, *CRC Reactivity Calculations for Crystal River Unit 3*. DI#: B00000000-01717-0210-00002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980728.0004.

6.8. Framatome ANP Doc. 38-5034166-00, *Isotopic Generation and Confirmation of the PWR Application Model*, CAL-DSU-NU-000004 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company.

6.9. Nakamura, S. 1977. *Computational Methods in Engineering and Science*. Page 3. New York, New York: John Wiley & Sons.

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DESIGN VERIFICATION CHECKLIST

Document Identifier 32 – 5033756 - 01

Title PWR Axial Profile Evaluation

1.	Were the inputs correctly selected and incorporated into design or analysis?	☐ Y	☐ N	☒ N/A
2.	Are assumptions necessary to perform the design or analysis activity adequately described and reasonable? Where necessary, are the assumptions identified for subsequent re-verifications when the detailed design activities are completed?	☐ Y	☐ N	☒ N/A
3.	Are the appropriate quality and quality assurance requirements specified? Or, for documents prepared per FANP procedures, have the procedural requirements been met?	☒ Y	☐ N	☐ N/A
4.	If the design or analysis cites or is required to cite requirements or criteria based upon applicable codes, standards, specific regulatory requirements, including issue and addenda, are these properly identified, and are the requirements/criteria for design or analysis met?	☒ Y	☐ N	☐ N/A
5.	Have applicable construction and operating experience been considered?	☐ Y	☐ N	☒ N/A
6.	Have the design interface requirements been satisfied?	☐ Y	☐ N	☒ N/A
7.	Was an appropriate design or analytical method used?	☐ Y	☐ N	☒ N/A
8.	Is the output reasonable compared to inputs?	☐ Y	☐ N	☒ N/A
9.	Are the specified parts, equipment and processes suitable for the required application?	☐ Y	☐ N	☒ N/A
10.	Are the specified materials compatible with each other and the design environmental conditions to which the material will be exposed?	☐ Y	☐ N	☒ N/A
11.	Have adequate maintenance features and requirements been specified?	☐ Y	☐ N	☒ N/A
12.	Are accessibility and other design provisions adequate for performance of needed maintenance and repair?	☐ Y	☐ N	☒ N/A
13.	Has adequate accessibility been provided to perform the in-service inspection expected to be required during the plant life?	☐ Y	☐ N	☒ N/A
14.	Has the design properly considered radiation exposure to the public and plant personnel?	☐ Y	☐ N	☒ N/A
15.	Are the acceptance criteria incorporated in the design documents sufficient to allow verification that design requirements have been satisfactorily accomplished?	☐ Y	☐ N	☒ N/A
16.	Have adequate pre-operational and subsequent periodic test requirements been appropriately specified?	☐ Y	☐ N	☒ N/A
17.	Are adequate handling, storage, cleaning and shipping requirements specified?	☐ Y	☐ N	☒ N/A
18.	Are adequate identification requirements specified?	☐ Y	☐ N	☒ N/A
19.	Is the document prepared and being released under the FANP Quality Assurance Program? If not, are requirements for record preparation review, approval, retention, etc., adequately specified?	☒ Y	☐ N	☐ N/A

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Comments:

See Record of Revisions for change in Reference 6. No other parts were affected.

Verified By:	Mehmet Saglam	M. Saglam	12/8/04
(First, MI, Last)	Printed / Typed Name	Signature	Date