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CALCULATION SUMMARY SHEET (CSS)

Document Identifier 32 - 5029773 - 01

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Title CRITICAL LIMIT DEVELOPMENT FOR 21 PWR WASTE PACKAGE

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

This calculation uses regression (CLReg V1.0 computer code) and non-parametric statistical methods, as specified in References 1 and 12, to develop the critical limit (CL) for the 21 Pressurized Water Reactor (PWR) spent nuclear fuel (SNF) waste package (WP) in the proposed geologic repository at Yucca Mountain, Nevada. The CL is a limiting value of the effective neutron multiplication factor (k_{eff}) at which a WP configuration is considered potentially critical. The CL is derived from the bias and uncertainties associated with the employed criticality code (MCNP) and the modeling process.

The results of this calculation support the validation of the MCNP code to accurately predict k_{eff} for a range of conditions that are representative of potential configurations of commercial SNF in a degraded waste package in a geologic repository.

The CL, calculated for five subsets of experiments, applies to the various configurations that a 21 PWR waste package may take over time in the geologic repository. Specifically, the CL applies to configurations where the 21 PWR waste package and its internal structural components have degraded, but the fuel rods remain intact. Representative benchmark criticality experiments, e.g., Commercial Reactor Criticality (CRC) and Laboratory Critical Experiments (LCE), characterize the CL for these configurations and prescribe the basic range of applicability of the results.

Section 6 provides results of the CL calculations. Table 11 (p. 28) summarizes CL values for parameters associated with each subset of experiments. The lowest CL value of 0.96833 occurs with the average energy of the neutron causing fission (AENCF) as a trending parameter for the subset that combines the CRC and LCE experiments.

This engineering calculation supports the burnup credit methodology of the Yucca Mountain Site Characterization Project (Reference 12). The calculations are performed in accordance with the Framatome-ANP administrative procedure for preparing and processing calculations (Reference 8) and the Framatome Fuel Sector Quality Management Manual (Reference 9). This calculation is subject to the Quality Assurance Requirements and Description (Reference 7).

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	
CLREG V1.0		
		☐ 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 9, page 6 of 38.
- Revised title for Reference 9, page 29 of 38.
- Completed Design Verification Checklist to reflect revisions.

1. PURPOSE

The purpose of this calculation is to develop the critical limit (CL) for the 21 Pressurized Water Reactor (PWR) spent nuclear fuel (SNF) waste package (WP) in the proposed geologic repository at Yucca Mountain, Nevada. The CL is a limiting value of the effective neutron multiplication factor (k_{eff}) at which a WP configuration is considered potentially critical. The CL is derived from the bias and uncertainties associated with the employed criticality code (MCNP) and the modeling process.

The results of this calculation support the validation of the MCNP code to accurately predict k_{eff} for a range of conditions that are representative of potential configurations of commercial SNF in a degraded waste package in a geologic repository.

This document is an engineering calculation that supports the burnup credit methodology of the Yucca Mountain Site Characterization Project (Reference 12). The calculations are performed in accordance with the Framatome-ANP administrative procedure for preparing and processing calculations (Reference 8) and the Framatome Fuel Sector Quality Management Manual (Reference 9). This calculation is subject to the Quality Assurance Requirements and Description (Reference 7).

2. METHOD

The methods used for calculating the CL follow Section 2 of Reference 1. This section summarizes some main features of the methods as applied in this calculation.

For WP criticality evaluations, criticality is defined by the CL, which is the value of k_{eff} at which a waste package configuration is considered potentially critical. An essential element of validating the methods and models used for calculating k_{eff} for a WP is the determination of the CL. The value of the CL is established by applying the MCNP criticality model in evaluating critical experiments that are representative of the range of in-package and out-of-package configuration identified by the degradation analyses. The CL is derived from the bias and uncertainties associated with the MCNP criticality code and the modeling process.

The CL in this document is calculated for five subsets of experiments that are applicable to the various configurations that a 21 PWR waste package may take over time in the geologic repository. Specifically, the CL applies to a configuration where the 21 PWR waste package and its internal structural components have degraded, but the fuel rods remain intact. Representative benchmark criticality experiments, e.g., Commercial Reactor Criticality (CRC) and Laboratory Critical Experiments (LCE), characterize the CL for this configuration and prescribe the basic range of applicability of the results.

The CL method follows the process outlined in Figure 1. The process has two pathways for establishing the CL: (1) a regression-based pathway that reflects criticality code results over a set of critical experiments that can be trended, and (2) a random sample-based pathway that applies

7. REFERENCES

1. Framatome ANP Doc. 38-5032047-00, BSC, 2003. *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF.* CAL-DSD-NU-000003 REV 00. Las Vegas, Nevada: Bechtel SAIC Company.

2. Not used.

3. Not used.

4. Framatome ANP Doc. 38-5032050-00, 1998. *Summary Report of Commercial Reactor Critical Analyses Performed for the Disposal Criticality Analysis Methodology.* B00000000-0717-5705-00075 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980825.0001.

5. Framatome ANP Doc.38-5032051-00, 1999. *Laboratory Critical Experiment Reactivity Calculations.* B00000000-01717-0210-00018 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990526.0294.

6. Framatome ANP Doc. 38-5032053-01, 1999. *Range of Neutronic Parameters Calculation File.* B00000000-01717-0210-00028 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990923.0231.

6a. Framatome ANP Doc. 38-5032053-00, 1999. *Range of Neutronic Parameters Calculation File.* B00000000-01717-0210-00028 REV 00. Las Vegas, Nevada: CRWMS M&O.

7. DOE 2002. *Quality Assurance Requirements and Description.* DOE/RW-0333P, Rev. 12, Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020814.0055.

8. Framatome ANP, Administrative Procedure, Number: 0402-01, Preparing and Processing FANP Calculations, February 2003, Framatome ANP, Lynchburg, VA 24506

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

10. Lichtenwalter, J.J.; Bowman, S.M.; DeHart, M.D.; and Hopper, C.M. 1997. *Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages.* NUREG/CR-6361. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 233099.

11. Not used.

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DESIGN VERIFICATION CHECKLIST

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Title Critical Limit Development for 21 PWR Waste Package

		Y	N	N/A
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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DESIGN VERIFICATION CHECKLIST

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Comments:

See Record of Revisions for changes to Reference. No other parts were affected.

Verified By: (First, MI, Last)	Mehmet Saglam	M. Saglam	12/7/04
	Printed / Typed Name	Signature	Date

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