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CALCULATION SUMMARY SHEET (CSS)

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Title ANALYSIS OF CRITICAL BENCHMARK EXPERIMENTS FOR CONFIGURATIONS EXTERNAL TO WP

PREPARED BY:				**REVIEWED BY:**			
				METHOD: ☒ DETAILED CHECK ☐ INDEPENDENT CALCULATION			
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COST CENTER	212020	REF. PAGE(S)	59	TM STATEMENT: REVIEWER INDEPENDENCE			

PURPOSE AND SUMMARY OF RESULTS:

The purpose of this calculation is to select and review the critical benchmark experiments that are appropriate for the validation of the criticality calculational methodology that is to be used for assessing the criticality potential of the configurations external to the waste package. For the benchmark experiments associated with each group of external configurations, a lower bound tolerance limit is evaluated using the generic methodology described in Reference 1. The lower bound tolerance limit is derived from the bias and uncertainties associated with the employed criticality code and the modeling process of the critical experiments. All benchmark experiments used in this calculation are from the *International Handbook of Evaluated Criticality Safety Benchmark Experiments* (Reference 5). For critical benchmark experiments that were not previously used in similar analysis, benchmark models and inputs for MCNP neutron transport code have been prepared and run. Five sets of criticality benchmark experiments have been constructed based on the fissile content of the external configurations (HEU, IEU, LEU, U+Pu and ^{233}U). They accommodate large variations in the range of parameters of the external configurations and also provide adequate statistics for the lower bound tolerance limit calculations. The range of applicability of the benchmark experiments is presented for each set of experiments.

The results of this calculation are consisting of values or expressions for the lower bound tolerance limit for each set of benchmark experiments. For the first two sets, the LUTB method (Ref. 10) for calculating the lower bound tolerance limit was identified as applicable and applied as implemented in CLREG code

1. HEU set (187 benchmark cases): f(AENCF) = 0.970611 for 0 MeV<AENCF < 0.247 MeV
   f(AENCF) = -1.7411e-02*AENCF +0.97491 for 0.247 MeV ≤AENCF < 0.902 MeV
2. IEU set (109 benchmark cases): f(AENCF) = 0.97841 for 0 MeV < AENCF < 0.1518 MeV
   f(AENCF) = -1.9322e-02*AENCF +0.981339 for 0.1518 MeV ≤ AENCF < 0.482 MeV

For the last three sets of benchmark experiments, the DFTL method as described in Reference 6 was identified as appropriate to calculate the lower bound tolerance limit:

3. LEU set (96 benchmark cases): f = 0.9842
4. U+Pu set (120 benchmark cases): f = 0.9644
5. ^{233}U set (83 benchmark cases): f = 0.9748

This engineering calculation supports the disposal criticality methodology in Ref. 1 and is performed in accordance with the AREVA/FANP procedure for preparing and processing calculations (Ref. 3) and Fuel Sector Quality Management Manual (Ref. 4).
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:

CODE/VERSION/REV	CODE/VERSION/REV
MCNP4.B2	
CLREG1.0	

THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK

☐ YES ☒ NO

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RECORD OF REVISIONS

Revision Number	Description	Date
00	Original issue	June 2004
01		December 2004

- Revised Calculation Summary Sheet to note that this revision does not affect calculation results in any way.
- Revised title for Reference 4, page 7 of 114.
- Revised title for Reference 4, page 59 of 114.
- Completed Design Verification Checklist to reflect revisions.

1. PURPOSE

The *Disposal Criticality Analysis Methodology Topical Report* (Reference 1) states that the accuracy of the criticality analysis methodology (MCNP Monte Carlo code and cross-section data) designated to assess the potential for criticality of various configurations in the Yucca Mountain proposed repository is established by evaluating appropriately selected benchmark critical experiments.

The purpose of this calculation is to select and review the critical benchmark experiments that are appropriate for the validation of the criticality calculational methodology that is to be used for assessing the criticality potential of the configurations external to the waste package. For the benchmark experiments associated with each group of external configurations, a lower bound tolerance limit is evaluated using the methodology described in Reference 1. The lower bound tolerance limit is derived from the bias and uncertainties associated with the employed criticality code and the modeling process of the critical experiments.

The results of this calculation will be used to validate the MCNP code's ability to accurately predict the effective neutron multiplication factor (k_{eff}) for a range of conditions spanned by various critical configurations representative of the configurations postulated to occur in locations external to the waste packages.

This report is an engineering calculation supporting the validation of the criticality methodology for disposal of commercial and DOE (Department of Energy) spent nuclear fuel in Yucca Mountain (Reference 1). The calculation was performed in accordance with the AREVA/FANP procedure in References 3 and the Framatome Fuel Sector Quality Management Manual (Reference 4).

2. METHOD

An essential element of validating the methods and models used for calculating the effective neutron multiplication factor, k_{eff}, for configurations internal or external to a waste package is the determination of a critical limit for each class of configurations. The critical limit (CL) is the value of k_{eff} at which a configuration is considered potentially critical and accounts for the criticality method bias and uncertainty. The steps that need to be completed in establishing a critical limit are as follows (Reference 1, p.3-44): (1) selection of benchmark experiments; (2) establishment of the range of applicability of the benchmark experiments (identification of physical and spectral parameters that characterize the benchmark experiments); (3) establishment of a lower bound tolerance limit; and (4) establishment of additional uncertainties due to extrapolations or limitations in geometrical or material representations.

This calculation presents a detailed description of the first three steps outlined above for specific groups of benchmark critical experiments selected for the postulated external configurations. The external configurations have been grouped based on the possible fissile material content, which is a criterion not explicitly presented in the external configuration classes description

6. REFERENCES

1. AREVA/FANP Document Number 38-5032055-01, 2003. YMP. *Disposal Criticality Analysis Methodology Topical Report*, YMP/TR-004Q, Rev. 02. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. DOC.20031110.0005.

2. AREVA/FANP Document Number 38-5046377-00, 2004. BSC. *External Criticality Calculation for DOE SNF Codisposal Waste Packages*, CAL-DSD-NU-000001 REV A. Las Vegas, Nevada: Bechtel SAIC Company.

3. AREVA/FANP Administrative Procedure, Number: 0402-01, Preparing and Processing FANP Calculations, November 2003, Framatome ANP, Lynchburg, VA

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

5. Nuclear Energy Agency (NEA) 2003. *International Handbook of Evaluated Criticality Safety Benchmark Experiments*. 2003 Edition. NEA/NSC/DOC(95)03. Paris, France.

6. Dean, J.C., Tayloe, R.W. 2001. *Guide for Validation of Nuclear Criticality Safety Calculational Methodology*. NUREG/CR-6698. Washington, D.C.: U.S. Nuclear Regulatory Commission.

7. Scheaffer, R.L and McClave, J.T 1990. *Probability and Statistics for Engineers*, 3rd Edition. Boston, Massachusetts: PWS-Kent.

8. D'Agostino, R.B. and Stephens, M.A. 1986. *Goodness-of-fit Techniques*. Statistics, Textbooks and Monographs, Volume 68. New York, New York.

9. Natrella, M.G. 1963. *Experimental Statistics.* National Bureau of Standards Handbook 91. Washington, D.C.: U.S. Department of Commerce, National Bureau of Standards.

10. AREVA/FANP Document Number 38-5040670-00, 2004. *Criticality Model Report*. MDL-EBS-NU-000003, Rev.02. Las Vegas, Nevada.

11. AREVA/FANP Document Number 32-5039048-00, 2004. Validation of CLReg Version 1.0.

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

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DESIGN VERIFICATION CHECKLIST

Document Identifier 32 - 5045840 - 01

Title Analysis of Critical Benchmark Experiments for Configurations External to WP

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 page for changes to Reference. No other parts were affected.

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