ENCLOSURE 3

PROPOSED EXEMPTION FROM THE REQUIREMENTS OF 10 CFR 50.68(b)(1)

Criticality Analysis

7 Pages Follow

UNCONTROLLED

TRANSNUCLEAR	Form 3.2-1 Calculation Cover Sheet	Calc. No.:	11030-01		
		Rev. No.:	0		
Calculation Title: Boron Dilution Criticality Analysis for NUHOMS®-32PT with CE 15x15 Fuel		Page:	1	of	11
		Project No.:	11030		
		DCR No.:			

Project Name: NUHOMS® -32PT for Palisades

Number of CDs attached: 1	All the computer cases, spreadsheets and calculation related documents are included in the attached CD.

If original Issue, Is Licensing Review per TIP 3.5 required?

☒ No (explain)	☐ Yes	Licensing Review No.________

This calculation does not involve any changes to the design of the NUHOMS®-32PT DSC. Moreover, the results of the calculation will be utilized to demonstrate compliance with the applicable section of 10CFR50.68. Therefore, a 10CFR72.48 review is not required.

Software utilized: SCALE-PC Version: 4.4

Calculation is complete

Originator's Signature: A. Prakash	Date:06-03-2005

Calculation has been checked for consistency, completeness, and correctness

Checker Signature: [signature] Jack Boshoven	Date: 6/3/05

Calculation is approved for use

Project Engineer Signature: [signature]	Date: 06/03/05

1.0 Purpose

The purpose of this calculation package is to determine the minimum soluble boron concentration (SBC) required to maintain subcriticality of the NUHOMS®-32PT DSC loaded with 32 CE 15x15 fuel assemblies following a boron dilution event. An initial SBC of 2500 ppm was utilized to determine the final boron concentration levels. This calculation is performed for the NUHOMS®-32PT DSC with 16 poison plates and no poison rod assemblies (PRAs) with a maximum initial enrichment of 3.5 wt. % U-235. These results are not applicable to the 24 poison plate configuration. The NUHOMS®-32PT DSC is not authorized to store CE 15x15 class fuel assemblies with PRAs.

2.0 References

2.1 SCALE-4.4, Modular Code System for Performing Standardized Computer Analysis for Licensing Evaluation for Workstations and Personal Computers, CCC-545, ORNL.

2.2 E-20896, "Test Plan for Qualifying of the SCALE-4.4 Computer Program on the Transnuclear PC with Windows XP."

2.3 E-20897, "Test Report for Qualification of the SCALE-4.4 Computer Program on the Transnuclear PC with Windows XP."

2.4 Transnuclear calculation NUH32PT.0600, Rev. 1, "NUHOMS®-32PT Transportable Dry Shielded Canister Criticality Analysis."

2.5 Transnuclear calculation 11021-01, Rev. 0, "Criticality Analysis of the NUHOMS®-32PT with 16 Poison/Aluminum Plates."

2.6 Transnuclear calculation NUH32PT.0606, Rev. 0, "NUHOMS®-32PT Transportable Dry Shielded Canister Criticality Analysis."

2.7 Letter from Suzanne Leblang, NMC to Glenn Guerra, TN, "Request for Technical Support – Minimum Boron Criticality Analysis," No. dfs-tn-05-042, dated May 31st 2005.

2.8 CSAS25 input and output files and EXCEL spreadsheets listed in this calculation.

2.9 Transnuclear Calculation 10499-01, Rev. 0, "Boron Dilution Criticality Analysis for NUHOMS® -32PT."

3.0 Methodology, Design Inputs and Assumptions

3.1 Methodology

The CSAS25 control module of SCALE4.4 (Ref. [2.1]) computer code with 44 Group ENDF-V cross section library is used to calculate the effective multiplication factor (k_{eff}) of the fuel in the NUHOMS®-32PT DSC. The CSAS25 control module allows simplified data input to the functional modules BONAMI-S, NITAWL-S, and KENO V.a.

These modules process the required cross sections and calculate the k_{eff} of the system. BONAMI-S performs resonance self-shielding calculations for nuclides that have Bondarenko data associated with their cross sections. NITAWL-S applies a Nordheim resonance self-shielding correction to nuclides having resonance parameters. Finally, KENO V.a calculates the k_{eff} of a three-dimensional system. A sufficiently large number of neutron histories are run so that the standard deviation is below 0.0010 for all calculations.

The final k_{eff} that is calculated represents the maximum value of the effective multiplication factor with a 95% probability at a 95% confidence level (95/95). Therefore, the "worst case" k_{eff} values from the CSAS25 output are adjusted for uncertainty, such that:

$$k_{eff} = k_{keno} + 2\sigma_{keno}$$

A similar calculation - boron dilution criticality analysis for CE 14x14 fuel assemblies, is documented in reference [2.9]. The calculation methodology employed in reference [2.9] is adapted in this calculation.

3.2 Design Inputs

The NUHOMS®-32PT DSC is designed to store 32 intact PWR fuel assemblies with and without BPRAs (or other non-fuel assembly hardware). A detailed discussion of the design of the NUHOMS®-32PT system is provided in reference [2.4]. All applicable design inputs are identical to those in reference [2.4]. The design basis criticality analysis based on a change in the number and orientation of the poison/aluminum chevrons in the basket is documented in reference [2.5]. The criticality analyses to determine the maximum enrichment as a function of SBC is documented in reference [2.6].

The criteria for subcriticality is obtained from reference [2.7] and is equal to the Upper Subcritical Limit (USL, 0.9411) utilized in reference [2.4], [2.5] and [2.6] without the subcriticality margin of 0.05. The condition for subcriticality is shown below:

$$k_{eff} \le 0.9411 \text{ (USL)} + 0.05 \text{ (margin for subcriticality)}$$
$$\le 0.9911$$

The maximum initial enrichment for CE 15x15 fuel assemblies at an SBC of 2500 ppm, obtained from Table 6.1-1 of reference [2.6], is equal to 3.5 wt. % U-235.

Per reference [2.7], a conservative initial fuel enrichment of 3.6 wt. % U-235 will be utilized to determine the soluble boron requirements.

3.3 Assumptions and Conservatism

All the assumptions and conservatisms detailed in reference [2.4], reference [2.5] and reference [2.6] are valid for this calculation since there is no significant structural change to the DSC geometry. Additional assumptions, if any, in the KENO models are detailed at the relevant sections wherever they are employed.

A conservative initial enrichment of 3.6 wt. % U-235 will be utilized to determine the soluble boron requirements even though the design basis initial enrichment value from reference [2.6] is 3.5 wt. % U-235.

4.0 KENO Models

The starting KENO model to perform the criticality analysis based on the KENO model (*ce15350_16p250_065.in*) documented in reference [2.6] for the CE 15x15 fuel assembly for the 16-poison plate basket.

The only change to the KENO model is in the treatment of the annulus between the transfer cask and the DSC. This region is modeled with internal moderator (borated water with varying density) instead of full density unborated water. This change is expected to result in a slightly conservative calculation of k_{eff}, particularly, at optimum moderator density. The overall effect of this change is expected to be statistically insignificant.

No other changes were made to the KENO model from reference [2.6] except for variation in the SBC and initial enrichment and the same is utilized in this calculation to evaluate the criticality during boron dilution events. .

5.0 Analysis and Results

All the input decks were run with 500 generations with 1000 neutrons per generation with 5 generations skipped and the results are extracted from the KENO output. These values provided for a well converged solution. All input and output files used in this calculation are included on the attached compact disk. The input file listing corresponding to the worst case is provided in Appendix A of this calculation package.

All the results of this calculation are also shown in the EXCEL spreadsheet file *results_nuh32pt_ce15.xls*.

5.1 Results for an Initial Enrichment of 3.60 wt. % U-235

The criticality analysis was carried out at an initial enrichment of 3.60 wt. % U-235 to determine the minimum SBC required for subcriticality. Two different SBC values were determined – one corresponding to a configuration including optimum moderator density and the other corresponding to a fully flooded configuration (full moderator density). The results of this evaluation are shown in Table 5.1-1.

Table 5.1-1 Results for the 3.60 wt. % U-235 Cases

Model Description	k_{KENO}	1σ	k_{eff}	Output File Name
Full Moderator Density, Boron Concentration = 1750 ppm				
Full Density	0.9852	0.0009	0.9870	ce1536_16p175_o100.out:
Optimum Moderator Density, Boron Concentration = 1850 ppm				
60% Density	0.9785	0.0010	0.9805	ce1536_16p185_o060.out:
65% Density	0.9825	0.0011	0.9847	ce1536_16p185_o065.out:
70% Density	0.9858	0.0009	0.9876	ce1536_16p185_o070.out:
75% Density	**0.9860**	**0.0010**	**0.9880**	**ce1536_16p185_o075.out:**
80% Density	0.9844	0.0008	0.9860	ce1536_16p185_o080.out:
90% Density	0.9796	0.0008	0.9812	ce1536_16p185_o090.out:
Full Density	0.9742	0.0010	0.9762	ce1536_16p185_o100.out:

5.2 Results for an Initial Enrichment of 3.50 wt. % U-235

The criticality analysis was also carried out at an initial enrichment of 3.50 wt. % U-235 to determine the minimum SBC required for subcriticality. This analysis was performed to determine the effect of the conservatism in the analysis performed in Section 5.1. Two different SBC values were determined – one corresponding to a configuration including optimum moderator density and the other corresponding to a fully flooded configuration (full moderator density). The results of this evaluation are shown in Table 5.2-1.

Table 5.2-1 Results for the 3.50 wt. % U-235 Cases

Model Description	k_{KENO}	1σ	k_{eff}	Output File Name
Full Moderator Density, Boron Concentration = 1650 ppm				
Full Density	0.9866	0.0009	0.9884	ce1535_16p165_o100.out:
Optimum Moderator Density, Boron Concentration = 1750 ppm				
60% Density	0.9786	0.0009	0.9804	ce1535_16p175_o060.out:
65% Density	0.9802	0.0009	0.9820	ce1535_16p175_o065.out:
70% Density	0.9858	0.0010	0.9878	ce1535_16p175_o070.out:
75% Density	0.9845	0.0009	0.9863	ce1535_16p175_o075.out:
80% Density	**0.9876**	**0.0009**	**0.9894**	**ce1535_16p175_o080.out:**
90% Density	0.9834	0.0010	0.9854	ce1535_16p175_o090.out:
Full Density	0.9777	0.0009	0.9795	ce1535_16p175_o100.out:

6.0 Summary and Conclusions

In summary, the minimum SBC required to maintain subcriticality (k_{eff} below 0.9911) for the NUHOMS®-32PT DSC loaded with 32 design basis CE 15x15 fuel assemblies, for two different fuel assembly enrichments, with an initial SBC of 2500 ppm has been determined.

This analysis is applicable to the NUHOMS®-32PT DSC, loaded with 32 design basis CE 15x15 fuel assemblies, with the 16 poison plate basket configuration containing no PRAs. The results are conservative at lower enrichment and initial SBC levels since the k_{eff} is evaluated at the highest enrichment. In other words, these results are conservative for other initial enrichment – SBC level combinations provided the minimum SBC levels (final values following dilution events) are based on the values shown below.

The following is a summary of the results:

- For an initial enrichment of 3.60 wt. % U235 (initial SBC = 2500 ppm), the minimum SBC with optimum moderation is equal to 1850 ppm. The worst case k_{eff} value is 0.9880.
- For an initial enrichment of 3.50 wt. % U235 (initial SBC = 2500 ppm), the minimum SBC with optimum moderation is equal to 1750 ppm. The worst case k_{eff} value is 0.9894.
- For an initial enrichment of 3.60 wt. % U235 (initial SBC = 2500 ppm), the minimum SBC with full moderation is equal to 1750 ppm. The worst case k_{eff} value is 0.9870.
- For an initial enrichment of 3.50 wt. % U235 (initial SBC = 2500 ppm), the minimum SBC with full moderation is equal to 1650 ppm. The worst case k_{eff} value is 0.9884.

Utilizing a conservative initial enrichment of 3.60 wt. % U-235, instead of the design basis initial enrichment of 3.50 wt. % U-235, results in an increase in the final SBC by 100 ppm.

Boron dilution event with optimum moderation is highly conservative since there are no credible physical circumstances that lead to optimum moderation. Boron dilution with full moderation (DSC being fully flooded at all times during the event) is more realistic and results in a reduction in the minimum soluble boron concentration requirements.