Enclosure 3 to E-44592

Responses to Request for Additional Information

(Public Version)

Chapter 3 – Structural Evaluation

1. Clarify the use of "Limit Load Analysis" as a sensitivity study to supplement the stress categorization evaluation of the top cover plates-to-shell welds.

By removing the two sentences, "Figure 3.9.1-24 and Figure 3.9.1.1-25…The last converged solution …" from page 3.9.1-10, there appears no basis for making a conclusion in Section 3.9.1.6 of the SAR, which states, "The results of the limit load analysis show that there is sufficient margin compared to the design loads." If the applicant intends to continue to use the limit load analysis in addition to the "strain criteria" to supplement the welds evaluation, sufficient evaluation results should be presented in the SAR for staff review.

This information is needed to demonstrate compliance with 10 CFR 72.236.

RESPONSE TO RAI 3-1

The two sentences referenced in this RAI were deleted in the prior response to RAI 3-5 (Enclosure 2 to E-43624 [1]) to prevent possible confusion. However, in order to provide support for the conclusion in Section 3.9.1.6, the supporting evaluation results, including Figures 3.9.1-24 and 3.9.1-25, have been added back to SAR Section 3.9.1.2.6.

References:

1. Letter E-43624 from Paul Triska (AREVA Inc.) to U.S. NRC Document Control Desk, "Revision 4 to Application for Approval of the Spent Fuel Cask Design for the NUHOMS® EOS System, Response to Request for Additional Information (Docket No. 72-1042, TAC No. L25028)," December 18, 2015.

Application Impact:

SAR Section 3.9.1.2.6 has been revised as described in the response.

SAR Figures 3.9.1-24 and 25 have been added as described in the response.

2. Clarify the design criteria for the trunnion weld.

Section 3.9.5.4.1 states that the trunnions are designed in accordance with the allowable stress defined by ANSI N14.6 for a non-redundant lifting device. Section 4.2.1.1 of ANSI N14.6-1993 states that the acceptance criteria shall apply to the load-bearing members of the special lifting device. ANSI N14.6 further defines load-bearing members as any part in the load path of the special lifting device in which the induced stress is directly affected by the weight of the container connected to it. Based on this definition and the description in the SAR, the trunnion welds should be evaluated against the same design criteria as the trunnions.

This information is needed to demonstrate compliance with 10 CFR 72.236(l).

RESPONSE TO RAI 3-2

The evaluation of the trunnion welds in Section 3.9.5.4 of the SAR has been revised to consider the ANSI N14.6 design criteria for the critical 1g (plus dynamic load factor) lift load case. The trunnion weld size has been increased (revised Sheet 5 of Drawing EOS01-2001-SAR and revised Sheet 5 of Drawing EOS01-2011-SAR) to accommodate the greater design factors required by ANSI N14.6. The associated methodology, criteria, results, and tables (Tables 3.9.5-4 and 3.9.5-5) in Section 3.9.5 of the SAR have also been updated accordingly. In addition, SAR Section 8.2.1.2 has been revised to clarify that the upper lifting trunnions and the trunnion welds are designed in accordance with the ANSI N14.6 stress allowables for a non-redundant lifting device.

Application Impact:

SAR Sections 3.9.5.1, 3.9.5.4.1, 3.9.5.4.2, 3.9.5.4.4 and 8.2.1.2 have been revised as described in the response.

SAR Tables 3.9.5-4 and 3.9.5-5 have been revised as described in the response.

Drawings EOS01-2001-SAR and EOS01-2011-SAR in Section 1.3.4 of the SAR have been revised as described in the response.

3. Justify the seismic inertial loads used in the EOS-HSM stability calculations.

In Section 3.9.7.1.8.3 of the SAR, seismic load values of 0.3g horizontal and 0.2g vertical are used to compute the factor of safety against HSM overturning and sliding as well as DSC stability. These values are different from the stated design basis values of 0.5g horizontal and 0.33g vertical. The staff substituted the design basis values into the equations used in Section 3.9.7.1.8.3 of the SAR and computed factors of safety of 1.02, 1.04 and 1.00 against overturning, sliding and DSC stability. For the Horizontal Storage Module stability, NUREG-1536 requires the factor of safety to be greater than 1.1. Additionally, for the DSC stability calculation, the term margin of safety is used while the factor of safety is presented. The staff notes that the margin of safety is calculated as follows:

$$Margin\ of\ Safety = \frac{Allowable\ Value}{Calculated\ Value} - 1$$

This information is needed to demonstrate compliance with 10 CFR 72.236(l).

RESPONSE TO RAI 3-3

The horizontal storage module (HSM) stability evaluation in Section 3.9.7.1.8.3 of the SAR has been updated to incorporate a minimum safety factor of 1.1. This resulted in a reduction of the seismic loads to 0.45g horizontal and 0.30g vertical. The change to the seismic loads was reflected where applicable throughout Section 3.9.7 of the SAR. The design criteria in Section 2.3.4 of the SAR have been updated to reflect the lower seismic loads. The seismic evaluation in Section 3.9.4.9.2 and Tables 3.9.4-3 and 3.9.4-4 maintains the conservative values of 0.50g horizontal and 0.33g vertical and now includes a note stating that these values are conservative compared to the updated values. Additionally, the accident analysis as a result of a seismic event in Section 12.3.2 has been updated to reflect the revised seismic loads.

Application Impact:

SAR Sections 2.3.4, 3.9.4.9.2, 3.9.7.1.7.1, 3.9.7.1.8.3, 3.9.7.1.9, and 12.3.2 have been revised as described in the response.

SAR Tables 3.9.4-3, 3.9.4-4, and 3.9.7-4 have been revised as described in the response.

4. Provide the values used in the stability calculation of the Transfer Cask (TC) against overturning due to a seismic event.

   In the stability determination for the EOS-TC in Section 3.9.7.2.6.4 of the SAR, only the equations are presented. The values for the variables in the equations are not shown for the staff to evaluate to verify the factor of safety.

   This information is needed to demonstrate compliance with 10 CFR 72.236(l).

   RESPONSE TO RAI 3-4

   Section 3.9.7.2.6.4 has been updated to define all values used for the seismic stability evaluation of the transfer cask.

   Additionally, the TC stability evaluation and results in Appendix 3.9.7 have been updated to reflect the revised design basis seismic loading of 0.45g horizontal and 0.30g vertical and the 1.1 safety factor for overturning and stability (per Table 3-3 of NUREG-1536) as specified in the response to RAI 3-3. The TC tornado wind and seismic stability methodology in Sections 3.9.7.2.5 and 3.9.7.2.6 have also been revised for consistency with the HSM seismic stability methodology in Section 3.9.7.1. The safety factor against overturning during a tornado missile accident in Section 12.3.4 has also been updated to reflect the revised analysis.

   Application Impact:

   SAR Sections 3.9.7.2.5, 3.9.7.2.6, and 12.3.4 have been revised as described in the response.

5. Revise, as appropriate, the page 3.9.1-29 conclusion statement, “The results of the strain criteria analysis show that there is sufficient margin compared to the uniform and maximum strain criteria limits,” by also noting that a “strain safety margin of 2.6” would be calculated for the subject welds.

The maximum strain evaluation results as summarized in Table 3.9.1-15 should properly be captured in the SAR to make a substantive conclusion in the SAR.

This information is needed to demonstrate compliance with 10 CFR 72.236.

RESPONSE TO RAI 3-5

The conclusions in SAR Section 3.9.1.6 have been revised for clarity and completeness to substantiate the dry shielded canister (DSC) shell structural analysis results. The calculated minimum factor of safety of 2.6 for the strain criteria analysis has been added with further explanation of how this value was calculated. In addition, SAR Table 3.9.1-15 has been revised to add a column defining the safety margin (factor of safety).

Application Impact:

SAR Section 3.9.1.6 has been revised as described in the response.

SAR Table 3.9.1-15 has been revised as described in the response.

Chapter 4 – Thermal Evaluation

1. Demonstrate that the developed thermal model adequately captures the wind impact on the thermal performance of the EOS-HSM storage system.

The applicant analyzed the wind impact on the cooling of the NUHOMS-EOS with wind speeds of [ ] mph and predicted a peak cladding temperature of 735°F at a side wind speed of [ ]. The applicant proposed the TS 5.5 for requirements of installing the wind deflectors: “If the heat load is less than 50 kW, the user can decide to install wind deflector or the need for wind deflectors can be determined by an evaluation using the methodology documented in the SAR.”

The staff reviewed the 1st-round RAI response and the analysis described in SAR Appendix 4.9.4 <u>Wind Impact on the Thermal Performance of the EOS-HSM</u> and examined Figure 4.9.4-2(c) for side wind exterior boundary conditions. The wind effect analyses presented by the applicant does not appear to be adequate to predict the peak cladding temperature (PCT).

The applicant used [ ] at the canister wall to perform the analysis and an [ ] to predict the PCT. The values they used [ ], were obtained for different configurations and different ambient conditions and therefore, they may not be directly applicable to the peak cladding temperature calculation when wind effect is considered. This [ ] method is inconsistent and may introduce additional unknown errors. The errors need to be known and bounded as the predicted peak cladding temperature margin is very small.

To avoid additional uncertainties in the analysis, the applicant needs to include the canister internals in the thermal model (including the fuel region).

Due to the small margin and uncertainty of the calculations, the staff requests that the applicant applies an appropriate reduction factor for additional safety margin for requirements of installing the EOS-HSM wind deflectors. A reduction factor to the design basis heat load (e.g., 20%) could be adequate to have acceptable margin.

The applicant needs to provide all thermal analysis files used to perform the wind calculations for review.

This information is needed to demonstrate compliance with 10 CFR 72.236(f).

RESPONSE TO RAI 4-1

To address the staff’s concerns with regard to the thermal evaluation for the impact of wind on the EOS-HSM, the following changes have been made to the application:

1.a Technical Specifications:

Proposed Technical Specification (TS) 5.5 has been modified to eliminate any user calculations with regard to the requirements for installing the wind deflectors. The modified language also includes a reduction factor for the requirements of installing the wind deflectors as requested in the RAI question. The following statement replaces the existing language in the revised proposed TS 5.5:

> *"If the heat load of a DSC during STORAGE OPERATIONS is greater than 41.8 kW, wind deflectors shall be installed on the EOS-HSM."*

The maximum fuel cladding temperature is 689 °F based on the evaluation presented in Section 4.9.4.7 of the application for the EOS-HSM with the EOS-37PTH DSC at a heat load of 41.8 kW and without the wind deflectors. This provides assurance that at heat loads less than or equal to 41.8 kW, there is significant margin to the maximum fuel cladding temperature limit of 752 °F even under the worst case wind conditions without the installation of the wind deflectors.

For heat loads greater than 41.8kW and up to 50 kW, the above requirement of installing the EOS-HSM wind deflectors provides an additional safety margin since the bounding thermal evaluations are based on a heat load of 50 kW. It also eliminates ambiguity and provides clear instructions to the users on the requirements for installing the wind deflectors.

1.b Safety Analysis Report:

Sections 4.9.4.1, 4.9.4.2, 4.9.4.7 and Table 4.9.4-1 and Table 4.9.4-2 have been revised to delete heat load zone configuration (HLZC) #3. Load Case #2 described in Table 4.9.4-1 is redefined to evaluate the maximum heat load at which the wind deflectors are not needed.

2. Thermal Model:

a. Canister Internals:

[ ]

[ ] This evaluation is presented in new Section 4.9.4.6.1 of the application. [ ] This confirms that the original evaluation is conservative.

In addition, to support the changes to TS 5.5 (as discussed in Item 1), an additional evaluation has been performed for the EOS-HSM with the EOS-37PTH DSC based on HLZC # 2 (41.8 kW) in Section 4.9.4.7. [

] However, the heat generation rates for this evaluation are adjusted based on HLZC # 2 with a maximum heat load of 41.8 kW and the wind deflectors eliminated. The maximum fuel cladding temperature determined from this evaluation is 689 °F. Therefore, for heat loads less than or equal to 41.8 kW, wind deflectors are not needed.

b. [

]

As a part of these new added sections, Figure 4.9.4-7 has been replaced and Table 4.9.3-3 and Figures 4.9.3-3, 4.9.4-8 and 4.9.4-9 have been added. The added sections also caused a renumbering of the corresponding reference sections in Appendices 4.9.3 and 4.9.4.

All computer files associated with the above discussion are submitted for NRC staff review as part of this RAI response in Enclosure 11. Enclosure 10 contains a listing and a description of the thermal files provided in Enclosure 11.

Amendment Application Impact:

Technical Specification 5.5 has been revised as described in the response.

SAR Appendices 4.9.3 and 4.9.4 have been revised as described in the response. Tables 4.9.4-1 and 4.9.4-2 have been revised as described in the response. Figure 4.9.4-7 has been revised as described in the response. Table 4.9.3-3 and Figures 4.9.3-3, 4.9.4-8 and 4.9.4-9 have been added as described in the response.

Chapter 8 - Materials Evaluation

1. Revise SAR Section 8.2.5.3 and include an assessment of the corrosion of the A506 type 4130 internals under conditions that are relevant for the actual use of the system. Include consideration of the range of temperatures that the type 4130 will be exposed during spent fuel loading. Section 8.2.5.3 of the SAR addresses the behavior of ASTM A506 Grade 4130 in deionized water. Drawing EOS01-1010-SAR shows that the EOS 37PTH also uses an A506 Grade 4130 steel basket that will be exposed to PWR spent fuel water chemistry according to the CoC application Section 8.1.2.

In response to RAI 8-16 Section 8.2.5.3 was revised and states:

> *NUREG/CR-6875 references a Moscow Power Institute series of tests immersing carbon steel plates in aerated and deaerated borated water for up to 1000 h. They reported long–term corrosion rates of 0.005 mm/y in aerated water with 3000 ppm B at 310 °C and 0.008 mm/y in aerated water with 1000 ppm B at 200 °C. To apply the long-term corrosion rate from the testing, we can assume a rate of 0.008 mm/year for the full 1000 hours that testing was performed (about 10X longer than the time of immersion during fuel loading). This yields a thickness reduction of 0.0009 mm ($6x10^{-5}$ inch), which would have no effect on structural performance.*

The cited data is the result of a study that obtained data at temperatures that are likely to be well above those observed in spent fuel loading operations. EPRI-1000975, Boric Acid Corrosion Guidebook, Revision 1 notes that the test results obtained from the Moscow Power Institute (1970) also showed corrosion rates vary as a function of test duration. This is illustrated in EPRI-1000975 Figures 4-9 and 4-10 that show high average corrosion rates for short test durations and lower average corrosion rates for longer test durations.

EPRI-1000975 Boric Acid Corrosion Guidebook, Revision 1 Figure 4-3 has a summary of the available boric acid corrosion test data. Corrosion rates vary from 0.050 mm/yr at 21 °C (70 °F) in 2500 ppm Boron, to 0.4 mm/y at 60 °C (140 °F) in 2500 ppm boron to ~3 mm/yr at 100 °C (212 °F) in 4000 ppm Boron. At temperatures above boiling, a significant decrease in corrosion rates were observed in aerated solutions. Thus, the use of long term corrosion rates at temperatures above boiling may underestimate the corrosion rates observed in spent fuel loading operations.

This information is needed to demonstrate compliance with 10 CFR 72.236(b).

RESPONSE TO RAI 8-1

As noted by the staff, EPRI-1000975, Boric Acid Corrosion Guidebook, Revision 1 observes that the test results obtained from the Moscow Power Institute (1970) vary as a function of test duration in such a way that the average corrosion rate is higher for short test durations.

The TC and DSC are only kept in the spent fuel pool for a short period of time, typically less than 24 hours (see Safety Analysis Report (SAR) Section 8.1.2). Therefore, selecting an average corrosion rate of 0.008 mm/y resulting from a 1000-hour test may not have been conservative in the previous evaluation presented in SAR Section 8.2.5.3.

Safety Analysis Report Section 8.2.5.3 has been revised to provide an updated assessment of the corrosion based on the relevant conditions for use of the system and the data provided in EPRI -1000975, Boric Acid Corrosion Guidebook, Revision 1. Table 8-36 has been added to provide the relevant corrosion rates taken from EPRI-1000975. Safety Analysis Report Section 8.7 has also been revised to replace NUREG/CR-6875 with EPRI-1000975 for reference 8-42. The updated corrosion assessment concludes again that the thickness reduction due to corrosion does not impact the structural performance.

Application Impact:

SAR Sections 8.2.5.3 and 8.7 have been revised as described in the response.

SAR Table 8-36 has been added as described in the response.

Proprietary Information on Pages 11 through 22
Withheld Pursuant to 10 CFR 2.390