Request for Additional Information
Docket No. 72-1042
Model No. NUHOMS® EOS System

By application dated June 16, 2015, as supplemented July 30, 2015, AREVA submitted an application for approval of a spent fuel storage cask design, developed by AREVA and designated the NUHOMS EOS System. This request for additional information (RAI) identifies information needed by the U.S. Nuclear Regulatory Commission staff (the staff) in connection with its review of the application. The requested information is listed by chapter number and title in the applicant's safety analysis report (SAR). NUREG-1536, "Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility — Final Report," was used by the staff in its review of the application.

Each question describes information needed by the staff for it to complete its review of the application and to determine whether the applicant has demonstrated compliance with regulatory requirements.

Chapter 3 – Structural Evaluation

1. Revise the Section 2.3.4 of the SAR and Technical Specification (TS) descriptions of seismic input to the HSM to recognize that the earthquake motions considered at the base of the Horizontal Storage Module (HSM) for structural valuation may be different from those associated with the Regulatory Guide (RG) 1.60 free-field motions.

   The Section 2.3.4 language appears to suggest that the 0.5 g and 0.33 g zero period accelerations (ZPAs), per RG 1.60, are associated with the free-field horizontal and vertical component motions, respectively, for a power reactor site. The staff notes that the earthquake motion acceleration level and frequency content defined at the base of the HSM could be markedly different from those of the free-field or control motion for a power reactor site. As such, it's unclear how the modal properties of the HSM are used for determining the in-structure response spectra for a free-standing HSM. Furthermore, the staff notes that, as one of the analyzed site parameters for configuration control for the cask deployment, the earthquake acceleration levels must also be defined in the TS to facilitate the 72.212 (b)(5)(ii) site evaluations by the cask users.

   This information is needed to determine compliance with10 CFR 72.236(b).

2. Provide the results of the seismic stability of the EOS-HSM (sliding, overturning and Dry Shielded Canister (DSC) stability on the support structure).

   In Section 3.9.7.1.3 of the SAR, the EOS is evaluated for seismic stability against sliding and overturning as well as the stability of the DSC on the support rails. The evaluation includes the equations for determining the overturning moment, the stabilizing moment, sliding force, etc. The statement is then made that "From the evaluation performed, it is concluded that the EOS-HSM is stable for seismic loads up to 0.5g horizontal and 0.33g vertical." The SAR contains no qualification for this statement in the form of the actual moments and forces along with the factors of safety.

   This information is needed to determine compliance with10 CFR 72.236(l).

Enclosure

3. Verify the reference in Table 3-1, "Summary of Stress Criteria for Subsection NB Pressure Boundary Components Shells and Cover Plates," of the SAR to the ASME B&PV Code stress acceptance criteria, "$F_{p} < 1.0S_y$ or $1.5\ S_y$," for the DSC stress evaluation.

   F_p is not an ASME B&PV Code recognizable stress category and the staff is unclear how it is to be considered in the DSC stress evaluation.

   This information is needed to determine compliance with10 CFR 72.236(b).

4. Identify the structural entities and corresponding basis for which the stress criterion, "$\sigma_1 + \sigma_2 + \sigma_3 \leq 4S_{m,}$" as cited in Table 3-1, "Summary of Stress Criteria for Subsection NB Pressure Boundary Components Shells and Cover Plates," is used for the DSC stress evaluation.

   Section 3.9.1.1.1 of the SAR, which cites the subject table does not appear to have identified a technical basis for which the subject criterion can be considered for stress evaluation.

   This information is needed to determine compliance with10 CFR 72.236(b).

5. Clarify the SAR basis of considering the "last converged solution" for the Inner Top Cover Plate (ITCP)-to-shell partial penetration weld by the <u>Limit Load Analysis</u> of Section 3.9.1.2.6, "Stress Categorization Sensitivity Studies." With modified collapse loads, revise the Section 3.9.1.6 discussion on "<u>Limit Load Criteria</u>" by recognizing that collapse loads much lower than the cited 282 psig and 217 g could result.

   ASME B&PV Code Division III, Section 1, Paragraph NB-3228-1 provides, "[W]hen two-thirds of the lower bound collapse load is used the effects of plastic strain concentrations…must be considered." With respect to the load-displacement curves of Figures 3.9.1-24 and -25, the staff notes that, when subjected to a 20 psig internal pressure, the 3/16-inch ITCP-to-shell partial penetration weld would be seen to have undergone no more than a deformation of ¼ inch for an average tensile strain of, say, 100% (3/16 x 100% ≤ ¼). This suggests that a major weld fracture could have occurred. As such, it's unclear how a finite element analysis can allow more than one order of magnitude higher than the 100% strain to develop in the weld to result in a plate displacement of 16 inches shown in Figure 3.9.1-24 of the SAR.

   This information is needed to determine compliance with10 CFR 72.236(b),(l)

6. Revise the strain based criteria description in Section 3.9.1.2.6 of the SAR to recognize that both the average and maximum equivalent plastic strain criteria shall be satisfied for the top cover plate lid-to-shell partial penetration welds.

   The last sentence of the first paragraph under "<u>Strain Criteria Analysis</u>" suggests that Section FF-1142 of Appendix FF is used for the subject weld evaluation. As such, the second paragraph of the SAR description of considering only the "maximum" equivalent plastic strain for evaluation is incomplete for proper application of the subject strain based acceptance criteria.

This information is needed to determine compliance with10 CFR 72.236(b).

7. Clarify whether the applicable strain based acceptance criteria, per ASME B&PV Code Section III, Appendix FF, Paragraph FF-1142, are considered for evaluating and reporting factors of safety of the top cover plate lid-to-shell partial penetration welds. Revise, as appropriate, the SAR description on page 3.9.1-11, which states, "The maximum factor of safety is 2.6. The results are shown in Table 3.9.1-15."

   Contrary to what is suggested by the caption of Table 3.9.1-15, "Summary of Maximum Strain for Side Drop (Strain Criteria)," for the "maximum" equivalent plastic strain evaluation, the listed factors of safety indicate that only "average" equivalent plastic strains are evaluated for the welds. The staff notes that, for the baseline 75-g load case, the average equivalent plastic strain criterion, per FF-1144(a), in lieu of the FF-1144(b) maximum equivalent plastic strain criterion, is used in calculating the factor of safety of 2.6 (0.17/ 0.065 = 2.6). The applicant should include both the maximum and average equivalent plastic strains in the evaluation.

   This information is needed to determine compliance with10 CFR 72.236(b),(l).

8. Provide necessary sketches or computer plots in the SAR page 3.9.2-1, Section 3.9.2.3, "EOS-37PTH Basket Structural Evaluation for On-Site Accident Drop Loads," to delineate sufficiently the finite element model attributes for calculating the DSC shell side-drop deformations.

   The SAR states that "a simplified, half-length model of the DSC shell was used to get more realistic cylindrical shell side drop deformation for gap calculations." However, it's unclear how the "simplified" model is configured. A sufficiently detailed SAR sketch of model attributes will aid in evaluating the adequacy of the half-length model of the DSC for providing an estimate of the fuel basket boundary conditions, which could have significant effects on the analyzed fuel basket structural performance.

   This information is needed to determine compliance with10 CFR 72.236(l).

9. Clarify the use of nomenclature "Von Mises Plastic Strain" in Tables 3.9.2-6, -7, -10, and -11, "Basket Grid Plate Strain Summary," of the SAR by identifying the relevant material failure theory associated with the calculated strains for the basket grid plates undergoing the DSC side drop accident.

   Although the Von Mises stress is commonly calculated in the finite element analysis, it is unclear how the Von Mises strain is defined in open literature and implemented in a finite element analysis to calculate strains for evaluation against appropriate materials failure theories.

   This information is needed to determine compliance with10 CFR 72.236(b),(l).

10. Revise the bulletized list of conservatisms and assumptions in Section 3.9.3.3.1, "Conservatism and Assumptions," of the SAR by removing those not applicable to the

drop analysis of the loaded transfer cask. Revise the table on materials property data located on page 3.9.3-3 of the SAR by removing the entries, including temperatures and material yield/ultimate strengths, which might not have been used for constructing the transfer cask drop analysis finite element model.

The staff notes that extraneous description of the finite element modeling attributes could result in misrepresentation of an otherwise properly configured and sufficiently delineated finite element analysis model. Examples on the seemly extraneous information include fuel assemblies (FAs) stiffness, weld categorization, and materials yield/ultimate strengths.

This information is needed to determine compliance with10 CFR 72.236(b),(l).

11. Revise the design criteria presented in Section 3.9.3.3.2, "Design Criteria," of the SAR by removing and relocating those not associated with the transfer cask drop analysis.

    The staff notes that the section includes the fuel basket crack propagation and growth evaluation criteria, which should have be presented in other SAR section(s).

    This information is needed to determine compliance with10 CFR 72.236(b).

12. Clarify the second paragraph description of Section 3.9.4.6.4, "Finite Element Model for Structural Analysis of Heat Shield Panels and Connection Studs," of the SAR which states, "[M]odal time-history analysis of the EOS-HSM is performed…to determine the ISRS at the nodes at which the studies are supported," by providing the applicable time-histories and modal properties such as modal participation factors required of a "modal time-history analysis, for the staff to perform a safety review.

    A review of the SAR statement and the related description in Section 3.9.4.9.2, "Earthquake (Seismic) Load (E) Analysis," of the SAR does not appear to suggest that any spectrum-compatible time-histories have been used for calculating the time-history response of either the single- or multiple-segment of the EOS-HSM. As such, it's unclear how a modal "time-history" analysis is implemented for evaluating the heat shield panel assembly seismic capabilities. Also, the staff notes that the modal properties of the panel-stud assemblies need to be generated and presented in the SAR, for the subject seismic response analysis by mode superposition of the assemblies.

    This information is needed to determine compliance with10 CFR 72.236(e).

13. Justify the absence of a fatigue evaluation on the Transfer Cask (TC) and the TC trunnions.

    The SAR includes an analysis on the DSC in accordance with ASME B&PV, Division III Subsection NB-3222.4 that determines that fatigue effects need not be met for the DSC; however, the applicant does not perform the same analysis in accordance with the criteria of ASME B&PV Code Section III Div. 1 NC–3219.2 for the TC which is subject to cyclic thermal loading. Additionally, fatigue is not considered for the trunnions which are subject to several force reversals during the loading and transfer process.

    This information is needed to determine compliance with10 CFR 72.236(b).

14. Clarify the tornado wind design requirements and the tornado missile design requirements.

Two different tornado wind design requirements for the HSM and the TC are used in the SAR. For the HSM, the region I intensities from RG 1.76 revision 0 are used which specifies a maximum wind speed of 360 mph. For the TC, the Region I intensities from Regulatory Guide (RG) 1.76, Revision 1, “Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants,” are used, which specifies a maximum wind speed of 230 mph. The staff notes that both RG revisions are valid references, and that the older reference is conservative, but believes that consistent environmental design requirements should be specified for the same storage system to avoid confusion on the part of the potential user. Additionally, the tornado maximum wind speed listed in Section 4.5.3 of the TS is 290 mph which is less than the design criteria for the transfer cask.

In the same respect, inconsistent tornado missile requirements are used for the HSM and the TC. For the HSM, the tornado missiles of NUREG 0800, Revision 2, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants,” Section 3.5.1.4 are used which include a 35’ utility pole, an armor piercing artillery shell, a 15’ schedule 40 steel pipe, a 4000 lb. automobile and a small diameter solid sphere. For the TC, the tornado missiles of NUREG 0800, Revision 3, Section 3.5.1.4 are used which only require the 15’ utility pole, the 15’ schedule 40 pipe and the 4,000 lb. automobile. Again, the staff notes that both NUREG revisions are valid references, and that the older reference is conservative, but believes that consistent environmental design requirements should be specified for the same storage system to avoid confusion on the part of the potential user.

This information is needed to determine compliance with10 CFR 72.236(b).

15. Justify the absence of a seismic stability analysis for the EOS transfer casks.

Section 12.3.2 of the SAR indicates that a seismic accident analysis was conducted and is located in Appendices 3.9.4 and 3.9.7 of the SAR. The staff notes that the seismic loads are bounded by the drop loads for the transfer EOS-TC components with respect to a stress analysis; however, Appendix 3.9.7 involves stability. Appendix 3.9.7 includes a tornado wind and tornado missile stability analysis for the transfer casks, but does not include a seismic stability analysis.

This information is needed to determine compliance with10 CFR 72.236(b),(l).

16. Clarify the loading combination for the tornado stability analysis on the EOS transfer casks.

In Appendix 3.9.7, a stability analysis is conducted on the transfer casks for tornado winds and tornado missile accidents, but the two loads are not combined in accordance with NUREG-0800 Section 3.9.7.1.6 which states $W_t = W_w + 0.5W_p = W_m$, where W_t is the total tornado load, W_w is the tornado wind load, W_p is the tornado pressure load and

W_m is the tornado missile load. This load combination is used to analyze the EOS-HSM for stability against tornado loads in Appendix 3.9.7, but not the transfer cask.

This information is needed to determine compliance with10 CFR 72.236(b).

17. Provide the results of the stability analysis for the EOS TC in Appendix 3.9.7 against tornado loads in Appendix 3.9.7 of the SAR.

    Appendix 3.9.7 of the SAR walks through the conservation of momentum and conservation of energy equations that are used to determine the maximum angle achieved by the transfer cask as a result of a massive missile impact (see RAI regarding tornado load combination), but does not indicate the results of the analysis. All that is stated is that $\square_{tip}$ = 27.42° and that $\square_{tip}$ >> $\square$, but $\square$ is never determined.

    This information is needed to determine compliance with10 CFR 72.236(b),(l).

18. Clarify the design pressure for the EOS DSCs.

    The table in Section 10.1.1.1 of the SAR lists the design pressures for the EOS37PTH DSC and the EOS89BTH DSC to be 15 psig. Section 4.2 of the SAR states, "The maximum DSC internal pressure during normal and off-normal conditions must be below the design pressures of 15 psig and 20 psig, respectively." Table 2-5 uses 20 psig for normal and off-normal load combinations. There appears to be some contradictions as to what the actual design pressure is. Additionally, Section 9.1.3 Step 19 of the SAR states, "Pressurize the DSC with helium to more than 34 psig, but do not exceed 37 psig and hold for 10 minutes." This step represents the pneumatic test procedure described by ASME B&PV Code, Section III, Division 1, NB-6321 and NB-6323, which indicates a design pressure of 30 psig.

    This information is needed to determine compliance with10 CFR 72.236(b),(l).

19. Explain how the structural properties of the DSC support rail were determined.

    In the finite element model description of the EOS-HSM, Section 3.9.6.1 of the SAR states that the DSC main support beam (W12x136) and the brace (C3x5) are modeled using BEAM4 ANSYS beam elements with the appropriate section properties. Section 3.9.4.6.3 of the SAR then states that the web of the DSC main support beam has triangular opening resulting in vertical and diagonal web elements. Because of the openings in the web, the standard structural properties (cross sectional area, moment of inertia, section modulus, etc.) of the W12x136 are no longer valid.

    This information is needed to determine compliance with10 CFR 72.236(b),(l).

20. Clarify the use of the wind load in Load Case C2 for the EOS-HSM.

    The wind load is discussed in Section 3.9.4.7.5 of the SAR under the main heading of Normal Operational Structural Analysis; however, the load case that includes wind (C2) is an off-normal event. Furthermore, Section 3.9.4.7.5 states that the concrete structure forces and moments due to the design basis wind load are bounded by the results of the tornado generated wind load and that no separate analysis is performed for this case. The staff is unsure if load case C2 is even considered.

This information is needed to determine compliance with10 CFR 72.236(b),(l).

Chapter 4 – Thermal Evaluation

1. Explain the inconsistency between the air inlet temperature and the ambient temperature for load cases #1a and #3 with the EOS-37PTH DSC in EOS-HSM.

   The applicant described Table 4-5 of the SAR that load case #1a and load case #3 have the ambient temperatures of 100^{o}F and 117^{o}F, respectively, for the thermal analyses for normal storage and off-normal storage of EOS-37PTH DSC in EOS-HSM. However, Table 4-9 of the SAR shows that the inlet temperatures of load case #1a and load case #3 are 90^{o}F and 103^{o}F were used in the thermal model to predict the air temperature rise between inlet and outlet for EOS-37PTH DSC in EOS-HSM.

   The staff questioned that using an inlet temperature different from the ambient temperature may affect the thermal parameters (e.g., heat transfer coefficient) and the shell temperature, and therefore under-predict the air temperature rise through EOS-HSM. Hence, the applicant needs to explain why the inlet temperature is different from the ambient temperature used in the thermal analysis for each of the load cases #1a and #3.

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

2. Provide an explanation of how the porosity values used for security bar and support beam in the CFD model were generated.

   The applicant stated in Section 4.4.2.3.5 of the SAR that a porosity of 86.7% is used for security bar and also showed in Figure 4-8 (page 4-49) of the SAR that the porosities of 44.0%, 52.7%, and 44.0% are used for porous-1, porous-2 and porous-3 regions, respectively, of the EOS-HSM support beam (page 4-158) in the CFD model. Because the porosity value is related to the calculations of pressure drop and flow pattern of the cooling air entering into the EOS-HSM. The applicant needs to explain how these porosities were generated.

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

3. Characterize the flow regime for the air circulation within the TC/DSC annulus.

   The applicant stated in Section 4.5.2.2.1 of the SAR that ANSYS FLUENT uses the Reliable k-ε model to simulate the air flow through the TC/DSC annulus. The applicant needs to characterize the flow regime by calculating the Reynolds number (Re) and Raleigh number (Ra). The staff needs this information to assure that the Reliable k-ε model is adequate for simulating the air circulation within TC/DSC annulus.

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

4. Evaluate the impact of low-speed wind (from three different directions) on the cask heat removal capability of NUHOMS EOS-HSM system.

   The applicant stated in SAR 4.3 that EOS-HSM has the inlet and outlet vents separated by about 16 ft. (192 inches) and the larger separation between inlet vent and outlet vent causes no impact of the wind on the mixing of the airflows of the inlet and the outlet of the EOS-HSM.

   However, the staff notes that the wind speed may have a negative effect on the cask performance, as compared to quiescent conditions. For the EOS-HSM with the inlet vent on the front and the outlet vent at the top of the cask, the applicant needs to perform a wind effect analysis with wind directions: frontal, backward and side, and with wind speed in a range of 0 to 15 mph. Sustained wind speeds as high as 8 mph have been reported (NOAA) to prevail for enough duration for the decay heat removal system to reach a new steady state. This may affect the predicted peak cladding temperatures.

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

5. Provide an explanation of how the flow loss coefficient of the screens and the porosities of dose reduction hardware were generated at EOS-HSM inlet and outlet.

   The applicant stated in Section 4.4.2.3.4 (page 4-46) of the SAR that a flow loss coefficient of 0.58 is specified to the screens located at EOS-HSM inlet and outlet, per Table CR6-1 in Reference 4-13 <u>ASHARE Handbook.</u> The value of 0.58 is based on cross-sectional area ratio of screen to duct A1/A0 = 1 and free area ratio of screen n = 0.7. The Handbook is listed in Reference, but not provided in the application. The applicant also needs to explain why the free ratio of screen is determined as 0.7 when the cross-sectional area ratio of screen to duct is 1.0.

   In addition, as described in Section 4.4.2.3.3 (page 4-45) of the SAR, the dose reduction hardware, also located at EOS-HSM inlet and outlet, has porosities of 93.4% at inlet and 87.1% at outlet.

   The applicant needs to provide an explanation of both how the flow loss coefficient of the screens (0.58) and the porosities of the dose reduction hardware (93.4% and 87.1%) in the SAR were generated. The information helps the staff understand the flow resistance at the EOS-HSM inlet and outlet.

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

6. Explain why the porous media parameters (as described in items (a) and (b) below) for nitronic rail are conservative for the thermal analysis and provide an explanation of how the inertial resistance factor was calculated for the pressure drop across the holes within the nitronic rail.

   The applicant displayed the equation of the pressure drop across the holes within the nitronic rail in Section 4.9.2.3.4.1 of the SAR <u>Porous Media Parameters for Nitronic Rail</u>

and referenced to a loss coefficient of 18.19 in Table 4-21 of the NUHOMS HD FSAR. The applicant stated in Section 4.9.2.3.4.1 that (a) the viscous resistance for the flow through the slotted bar is zero, and (b) the inertial resistance factor is modified to account for 100% open cells of the porous medium and the length of the porous medium in the direction of the flow, and (c) the inertial resistance factor accounting for 100% opening is 3176.314 1/m.

The applicant needs to explain why the items (a) and (b) above, used in calculating the pressure drop for the flow through the slotted bar, will be conservative in the thermal analysis. The applicant needs to verify that the loss coefficient of 18.19 cited from the NUHOMS HD FSAR is adequate for the NUHOMS-EOS system and show how the inertial resistance factor of 3176.314 1/m is calculated in the SAR of the NUHOMS-EOS system.

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

7. Identify the maximum temperature of the neutron shield in the design load case #5 with the EOS-37PTH DSC inside the EOS-TC125.

The applicant listed the maximum temperatures of the EOS-TC125 loaded with the EOS-37PTH DSC at 50 kW, accident conditions with loss of the neutron shield and loss of the air circulation (the design load case #5 for the EOS-TC125) in Tables 4-28 and 4-29 of the SAR. The applicant provided a temperature of 296°F for the neutron shield outer skin in Table 4-28 and a temperature of 327°F of the neutron shield in Table 4-29.

The applicant needs to explain the inconsistency in the temperatures of the neutron shield for the design load case #5 subject to <u>loss of the neutron shield</u> and loss of the air circulation.

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

8. Compare the maximum fuel cladding temperatures between the load case #1 and the load case #3, as well as between the load case #8 and the load case #10 at steady conditions for EOS-TC125 loaded with EOS-37PTH DSC. Explain the inconsistency of the maximum fuel cladding temperatures in the load cases #1, #3, #8 and #10.

Table 4-24 of the SAR shows that the load case #1 (ambient 120°F and no solar heat) has the maximum cladding temperature of 648°F. This is <u>4°F below</u> the maximum cladding temperature of 652°F for the load case #3 (ambient 117°F and solar heat) at <u>steady-state initial</u> for EOS-TC125 loaded with EOS-37PTH DSC at 50 kW and no air circulation.

However, Table 4-25 of the SAR shows that the load case #8 (as the load case #1) has a maximum cladding temperature of 732°F. This is <u>18°F above</u> the maximum cladding temperature of 714°F for the load case #10 (as the load case #3) at <u>steady-state condition</u> for EOS-TC125 loaded with EOS-37PTH DSC at 36.35 kW and no air circulation.

The applicant needs to explain why the load case #1 has a peak cladding temperature (PCT) lower than that of the load case #3, while the load case #8 has a PCT greater than that of the load case #10. The applicant should explain inconsistency in the PCTs of the load cases #1, #3, #8 and #10.

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

9. Clarify the time limits of the transfer operations for the design load case #2 and provide the time limit Tables 4-31 and 4-35 of the SAR.

The applicant stated in the Section 4.5.1 of the SAR that for transfer of both EOS-37PTH DSC inside EOS-TC125 and EOS-89BTH DSC inside EOS-TC125, the design load case #3 bounds the design load case #2 due to higher ambient temperature. The transfer of EOS-37PTH DSC and EOS-89BTH DSC in the load case #3 is limited to 12 hours, as shown in Table 4-31 of the SAR for the EOS-37PTH DSC and Table 4-35 of the SAR for the EOS-89BTH DSC. The applicant needs to clarify whether there are time limits for the design load case #2 for both EOS-37PTH DSC and EOS-89BTH DSC when transported within EOS-TC125. The applicant needs to provide the time limits of transfer operations for both EOS-37PTH DSC and 89BTH DSC for the design load case #2 in the Table 4-31 of the SAR.

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

10. Provide the analyses of the design load case #7 for the EOS-TC125 loaded with EOS-37PTH DSC and EOS-89BTH DSC, respectively. The analyses should start with the blower or the air circulation failed immediately after exceeding the 6-hour transfer time limit.

The applicant noted in Table 4-27 of the SAR that the time limit of 6 hours is chosen for the conditions in the load case #7 (off-normal, 50 kW, hot, outdoor, transient, ambient 117°F, and <u>air circulation is turned off after initiation</u>), for transfer operations of the EOS-TC 125 loaded with EOS-37PTH DSC and EOS-89BTH DSC, respectively.

The staff noted that the load case #7 starts wherein the steady-state conditions are established with the air circulation in operation (after exceeding the 6-hr transfer time limit) and, subsequently the air circulation is lost during transfer operation. The staff is not convinced that the failure of the forced air circulation from a steady-state condition (after exceeding the 6-hr limit) is the bounding case. The bounding case for the design load case #7 would be at the point where the time limit applicable to the TC/DSC transfer has been exceeded, and the blower or the air circulation fails immediately after just being initiated as a corrective action. The PCT at this point in the transient would be expected to be much higher than the steady-state PCT with forced air circulation active.

The applicant needs to provide analyses for the design load case #7 with the blower or the air circulation failed immediately after exceeding the 6-hr transfer time limit.

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

11. Provide an explanation of how the contact resistance of 0.008 between the DSC outer shell and the support structure is calculated in the thermal evaluation.

The applicant specified a contact resistance of 0.008 m between the DSC outer shell and the support structure for the thermal evaluation. The staff needs to know how this contact resistance is calculated and why this number adequately captures heat transfer in this region.

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

12. Explain differences of the thermal properties for the neutron shield between the 37PTH DSC and the 89BTH DSC in thermal analysis and evaluate the impact of the differences to the heat removal capability of the DSCs.

The applicant stated in Section 4.2.2 of the SAR that the EOS-37PTH and EOS-89BTH DSC designs allow for use of the various neutron absorber materials such as MMC and BORALR composite panel. Single neutron absorber plates with thickness of 0.164 inch and 0.175 inch are used in the evaluation of the EOS-37PTH and EOS-89BTH DSCs, respectively. The applicant listed the EOS-TC125 effective neutron shield properties for normal/off-normal horizontal transfer and the calculated effective conductivities for liquid neutron shielding in Section 4.2.1 (pages 4-22-4-25) of the SAR.

The staff reviewed the proposed Certificate of Compliance (CoC) No. 1042 and found that the EOS-37PTH DSC has the poison plates containing a borated metal matrix composite (MMC) at different B-10 concentrations and the EOS-89BTH DSC has the poison plates containing the borated MMC or Boral and the concentration of B-10. The materials used for the poison plates of the 37PTH DSC seems to be different from those for the 89BTH DSC.

The staff is not sure whether the material properties of the poison plates in the EOS-37PTH DSC (MMC at different B-10 concentrations) and the EOS-89BTH DSC (Boral at B-10 concentration) are different or identical. If different, explain how the difference is reflected in the thermal properties as shown in pages 4-22~4-25. This information is needed for the staff to assure that the thermal analysis of the 37PTH DSC can be used to bound the thermal analysis of the 89BTH DSC.

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

13. Identify the maximum heat loads for the shorter fuels and perform the thermal evaluations for the bounding Heat Load Zone Configurations (HLZCs) in EOS-37PTH and EOS-89BTH DSCs, respectively.

The applicant stated in Section 4.9.1.3 of the SAR that for FA with active fuel length shorter than 144 inches, there is possibility that the concentration of the heat generation in a smaller volume might result in a non-conservative temperature distribution. To ensure that the temperature distribution remains bounding, scaling factors for short FAs were used in the thermal model for EOS37PTH DSC and EOS-89BTH DSC (with the equation shown in page 4.9.1-5 of the SAR).

Instead of just using a scale factor, the applicant needs to identify the maximum heat loads for the shorter fuels and perform the thermal evaluations for the bounding HLZCs in EOS-37PTH DSC (50 kW) and EOS-89BTH DSC (43.6 kW), respectively.

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

14. Analyze meshing sensitivity and spatial discretization error with the GCI method described in NUREG-2152 "Computational Fluid Dynamics Best Practice Guidelines for Dry Cask Applications" and provide the GCI calculations in details (with numbers and units in each step) for review.

    The applicant described the methodology of the grid convergence study and the steps to determine the discretization error in SAR 4.9.3.1.1. The applicant's calculation came out a Grid Convergence Index (GCI) (11.88°F) of less than 2% of the max fuel cladding temperature for the fine Grid #2.

    Given that the EOS-37PTH basket assembly, the EOS-TC125 and the EOS-HSM are separately meshed in the CAD model and are imported into ANSYS FLUENT with (a) EOS-37PTH DSC and EOS-TC125 merged together and (b) EOS-37PTH DSC and EOS-HSM merged together, the applicant should analyze the spatial discretization error directly for the cases (a) and (b) with the GCI method which is described in NUREG-2152.

    When using the GCI method to estimate the discretization error, the following criteria should be met:

- The solution from the different grids used display monotonic convergence.
- The solution from the different grids used should be in the asymptotic range

    Instead of equations in Section 4.9.3.1.1 of the SAR, the applicant should use the GCI method in NUREG-2152 and provide the GCI calculations step by step, with numbers and units in each step. The calculations could be included in a separate calculation package and the obtained results should be fully explained. An explanation on how the above criteria are met should be provided.

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

15. Revise the statements in Section 4.5.11 and Section 8.3.2 of the SAR for better explanation on thermal phenomena which eliminate the thermal cycling in the vacuum drying operations.

    The applicant stated in Section 4.5.11 of the SAR that the vacuum drying operation does not reduce the pressure sufficiently to reduce the thermal conductivity of the helium in the DSC cavity and Section 8.3.2 of the SAR that the subsequent vacuum drying eliminates the thermal cycling of the fuel cladding during helium backfilling of the EOS-37PTH and EOS-89BTH DSC subsequent to vacuum drying and it eliminates the need for a time limit on the vacuum drying operation, since the thermal conductivity of helium does not change with pressure during vacuum drying operations.

    The staff reviewed the pressure requirement in TS Limiting Condition for Operation (LCO) 3.1.1 which states "the DSC vacuum drying shall be sustained at or below 3 Torr (3 mmHg) absolute for a period of at least 30 minutes following evacuation". The staff views that (a) a pressure down to less than 3 Torr described in TS LCO 3.1.1 is not consistent with the statement in Section 4.5.11 of the SAR (underlined above) and (b) elimination of the need for a time limit on the vacuum drying is mainly due to the boundary conditions (cooling water existing in the TC/DSC annulus to cool the DSC shell), instead of no change in the thermal conductivity of helium with the pressure during vacuum drying, as described in Section 8.3.2 of the SAR (underline above).

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

16. Verify that the correlations used to model the convection heat transfer to the environment are adequately applied for similar conditions where the correlations were obtained. The applicant used the empirical correlations to calculate the heat transfer coefficient from the outside surface of the HSM. These empirical correlations are only valid when an average surface temperature is used. However, the applicant developed the CFD thermal model using the correlation to calculate the local heat transfer coefficient based on the local temperature. Either the applicant should use these correlations based on the average surface temperature or use other applicable correlations developed for the local temperatures.

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

17. Explain how the coefficients (inertial resistance coefficient, permeability, etc.) for the porous media, porous jump as well as inlet and outlet vents are obtained. Provide details of the calculations and justify the applicability of the calculated values.

    The applicant's thermal model used porous media and porous jump model to simplify the geometry at different regions of the flow domain. However, details of the calculations and adequacy of the obtained values are not provided in the SAR.

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

18. Verify that the inertial resistance coefficient for the porous media of the inlet vent is correctly specified, according to the flow direction which predominates for this type of flow.

    The applicant's CFD thermal model uses porous media to represent the inlet vent. However, the coefficient does not appear to be correctly specified in the thermal model.

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

19. Verify that the mesh complies with the required characteristics for the turbulence model applied in the air region.

    The applicant's CFD thermal model uses the low Reynolds k-epsilon model to represent turbulent flow. However, a detailed review and post-processing of the results reveals that flow characteristics such as the y-plus values don't seem to adequately follow the guidance for the applicability of this model for some parts of the flow domain.

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

20. Clarify why the porous media zones used to represent the inlet and outlet vents in the CFD thermal model do not account for frictional (viscous) pressure losses.

The applicant's CFD thermal model uses porous media to represent the inlet and outlet vents. The porous media model of the ANSYS/FLUENT CFD code needs that both frictional (viscous) loss and inertial loss terms be specified so the pressure drop is properly calculated. However, the frictional losses are equal to zero in the applicant's thermal model. This would underestimate the pressure drop in these regions.

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

21. Explain why a first-order spatial discretization will provide accurate predictions of the peak cladding temperature for this storage system.

    The staff checked the applicant's computer files (Fluent CFD files E-40553, December 2014 and ANSYS Finite Element files E-41436, March 2015) and found that the applicant's CFD thermal model uses first-order upwind spatial discretization for all equations solved (e.g., density, momentum, energy, turbulence kinetic energy, turbulent dissipation and discrete-ordinate radiation model). However, due to the small margin in predicted results, the staff needs to have assurance that the discretization order used by the applicant will be sufficient to provide accurate results. The applicant needs to demonstrate this by performing a sensitivity calculation using a higher order solution scheme.

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

    <u>Technical Specifications</u>

22. Explain the required actions under TS LCO 3.1.2 "DSC Helium Backfill Pressure" of NUHOMS EOS.

    The applicant listed the required actions in TS LCO 3.1.2 of the NUHOMS EOS if the required backfill pressure cannot be obtained or stabilized during loading operations. To assure that the required actions for NUHOMS EOS are appropriate and acceptable, the staff refers to TS LCO 3.1.2 of <u>Standardized NUHOMS</u> and assured that Action A.1.3 required by TS LCO 3.1.2 of Standardized NUHOMS (see below) is removed from TS LCO 3.1.2 of NUHOMS EOS.

    TS LCO 3.1.2 (A.1.3) of Standardized NUHOMS states: "check and repair as necessary the seal weld between the inner top cover plate/top shield plug assembly and the DSC shell."

    The applicant needs to clarify why removal of the action required by TS LCO 3.1.2 of Standardized NUHOMS from NUHOMS EOS will not cause any safety issue during loading operations.

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

23. Explain the surveillance requirements (SR) under TS SR 3.1.3 "Time Limit for Completion of DSC Transfer" of NUHOMS EOS.

To verify that the time limit for completion of the DSC transfer is met, the applicant noted the frequency indicated in TS SR 3.1.3 of NUHOMS EOS as “Once per DSC at the initiation of draining of TC/DSC annulus water.”

To assure that the frequency shown in SR 3.1.3 of NUHOMS EOS is appropriate and acceptable, the staff refers to the frequency indicated in TS SR 3.1.3 of Standardized NUHOMS as “Once per DSC, <u>after the completion of LCO 3.1.2 actions or</u> after the initiation of draining of TC/DSC annulus water” and verified the statement underlined above is removed from TS SR 3.1.3 of NUHOMS EOS.

The applicant needs to explain why the statement (underlined above) is removed from TS SR 3.1.3 of NUHOMS EOS (when compared to Standardized NUHOMS) with no negative impact to the DSC transfer operations.

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

24. Provide additional justification as to how action A.3 can be completed within 2 hours when compared to action A.1, as listed in TS LCO 3.1.3 of NUHOMS EOS, if the required time limit for completion of a DSC transfer is not met.

    The applicant listed completion time of 2 hours under action A.1 if the DSC/TC is in the cask handling area in a vertical orientation and same completion time of 2 hours under action A.3 to return the DSC/TC to the cask handling area and follow action A.1.

    For action A.3 with DSC and TC in horizontal orientation on the transfer skid, the applicant needs to move the DSC/TC back to the handling area, change DSC/TC from horizontal to vertical, and then follow action A.1. The staff is not sure that action A.3 can be completed within 2 hours when compared to action A.1. The applicant needs to provide additional justification (based on typical completion times for each of the actions needed to put the canister in a safe configuration) that action A.3 can be completed within 2 hours when compared to action A.1.

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

25. Revise the note for TS LCO 3.1.3 to assure that the calculated transfer time limit for the heat load less than 50 kW is appropriate and acceptable.

    The applicant listed the time limits in TS LCO 3.1.3 Time Limit for Completion of DSC Transfer (page 3-7) and noted that “if the maximum heat load of a DSC is less than 50 kW, time limits for transfer operation can be determined to provide additional time for transfer operations. The calculated time limits shall not be less than 12 hours.”

    To assure that the statement is complete and the requirements are met, the note should be revised to “if the maximum heat load of a DSC is less than 50 kW, time limits for transfer operation can be determined to provide additional time for transfer operations. The calculated time limits shall not be less than 12 hours. <u>*The calculation should be performed using the same methodology documented in SAR*</u>.”

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

26. Perform a transient thermal analysis for a total of 20 hours (with air circulation off), including 12-hour DSC transfer, 2-hour action A.2 in TS LCO 3.1.3 and additional 6-hour time period to complete the DSC transfer.

    The applicant stated in TS LCO 3.1.3 (page 3-8) that "if the required time limit to complete the DSC transfer is not met and the TC is in a horizontal orientation on transfer skid, initiate air circulation in TC/DSC annulus by starting one of the blowers provided on the transfer skid within 2 hours. After the blowers are turned off, the time limit for completion of DSC transfer is 6 hours."

    It is not clear to the staff how the 6-hour time limit was determined for completion of DSC transfer. The applicant needs to perform the thermal transient analysis for a total 20 hours, including 12-hour DSC transfer (no air circulation), 2-hour action A.2 in TS LCO 3.1.3 (page 3-8) with no air circulation due to failure of the blower, and additional 6-hour time frame (TS LCO 3.1.1, page 3-8) with no air circulation to complete the transfer.

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

27. Provide additional information and justification that air circulation will be maintained during transport and is reliable for recovery action.

    The staff reviewed the TS 3.1.3 and found that it lacks sufficient detail to assure that the air circulation (a type of forced cooling) is always operable during transport or air circulation would be quickly recoverable in the event of failure. Therefore, the staff needs additional information to assure the air circulation will be operable during transport or justify why the air circulation could be quickly recoverable in the event of a failure, or the staff requests that TS 3.1.3 be modified to incorporate appropriate actions to be taken in the event that the air circulation cannot be maintained.

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

28. Provide verification that the cask's heat removal capability will be maintained for EOS-37PTH and 89BTH DSCS in EOS-HSM.

    The applicant summarized the air temperatures at inlet and outlet in Table 4-9 for EOS-37PTH DSC in EOS-HSM and in Table 4-21 for EOS-89BTH DSC in EOS-HSM of the SAR.

    The applicant should add an LCO in the TS to limit the air temperature rise between inlet and outlet of the EOS-HSM. The added LCO is needed to assure the surveillance method is technically acceptable based on the SAR thermal evaluations.

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

Chapter 5 – Confinement Evaluation

1. Clarify the acceptance test requirements for the DSC in Section 10.1.1.1 of the SAR.

    The unlabeled table in Section 10.1.1.1 of the SAR provides normal and off-normal conditions calculated pressure values for both the EOS37PTH and EOS89BTH which are inconsistent with the pressure values presented in Chapter 4, Tables 4-45 and 4-46 of the SAR. This inconsistency needs to be clarified.

In addition, Section 10.1.1.1 states, “The test pressure is 1.1 times the design pressure which bounds the normal and off-normal pressures calculated in Chapter 4.” The table in Section 10.1.1.1 does not provide the design pressure for the off-normal condition which is listed as 20 psig in Tables 4-45 and 4-46. Based on this off-normal design pressure, the applicant needs to clarify how a test pressure of 16.5 psig bounds the off-normal condition design pressure, and needs to revise Section 10.1.1.1 accordingly.

This information is needed to determine compliance with10 CFR 72.236(l).

Chapter 8 – Materials Evaluation

1. Provide a justification for using the American Society for Testing and Materials (ASTM) specifications for the components described below.

   Drawings EOS01-1000-SAR, and EOS01-1001-SAR (37PTH), as well as EOS01-1005-SAR and EOS01-1006-SAR (89BTH) list ASME SA240 as the material specification for the confinement boundary materials and ASTM A240 for the outer top cover plate, outer bottom cover plate, grapple ring support, grapple ring, lifting lug, lifting lug plate and test port plug.

   This information is necessary to assure compliance with 10 CFR 72.236(b).

2. Provide specific information to identify duplex stainless steels used in the construction for the DSC shells for marine environments and the consensus codes and standards, including ASME and ASME code cases that support the use of these materials.

   Section 8.2.1.1 of the CoC application states that the EOS-37PTH DSC and the EOS-89BTH DSC are constructed in accordance with the ASME Boiler and Pressure Vessel Code Section III Division I Subsection NB and the Alternatives to the ASME code described in Section 4.4.4 of the TS. The CoC application cites ASME Code Case N-635-1, endorsed by RG 1.84 as the bases for including duplex stainless steels in SA-240 including UNS S31803 and Type 2205. The staff notes that ASME Code Case N-635-1 is specific to UNS S31803 and that both ASME SA-240 and ASTM A182 identify Type 2205 duplex stainless steel as UNS S32205, which is not included in the ASME Code Case N-635-1.

   This information is necessary to assure compliance with 10 CFR 72.236(b).

3. Clarify or correct the carbon content of austenitic stainless steel materials.

   Section 8.2.3 states, “As noted above, austenitic stainless steels for the DSC shell are procured with a maximum 0.3% carbon for reduced sensitization of the heat affected zones.” Section 8.2.1.1 of the CoC application specifies a maximum carbon content of 0.03%. The value of 0.3% in Section 8.2.3 appears to be incorrect. In order to be considered low carbon steel meeting the specification of UNS 30403 or UNS 31603 the carbon content should be a maximum of 0.03%.

This information is necessary to assure compliance with 10 CFR 72.236(b).

4. Section 8.2.3 of the CoC application states; "Duplex stainless steels can be substituted as alternate materials when superior resistance to atmospheric chloride induced stress corrosion cracking is required." Provide additional information to support the material properties for DSCs constructed from duplex stainless steel, including the fracture toughness and the corrosion resistance of the fabrication and closure welds. Information provided in the CoC application does not acknowledge that the microstructural stability of duplex stainless steels are sensitive to a number of factors, nor does it describe processes, controls and testing to ensure the corrosion resistance and mechanical properties will not be significantly altered by fabrication and welding.

   Alteration of the microstructure in UNS S31803 and Type 2205 duplex stainless steels, particularly as a result of fabrication and welding processes, may result in reductions in corrosion resistance and mechanical properties (ASTM, 2014). The staff notes that duplex stainless steels are not immune from stress corrosion cracking (SCC) in marine environments. Operational experience has shown that SCC of welds in UNS S31803 can be susceptible to SCC at temperatures less than 100°C [212°F] (Leonard, 2003). A number of factors have been shown to affect the microstructure of welds in duplex stainless steels. Liou et al. (2002) showed that cooling rate and nitrogen content had a marked effect on the austenite to ferrite content. Fast cooling rates decreased the austenite content and a weld microstructure with 70 percent ferrite was cited by Leonard (2003) as one of the factors that contributed to SCC of UNS S31803 in marine environments. Liou et al. (2002) also showed increased chloride SCC susceptibility when the austenite content decreased below 30 percent. Sieurin and Sandstrom (2007) compared time temperature transformation curves and critical cooling temperature curves for Type 2205 duplex stainless steels and concluded that, in order to avoid sigma precipitation and at the same time obtain a sufficient ferrite–austenite phase balance, the cooling rate should approximately be in the range 0.25–50K/second. In addition, Sieurin and Sandstrom (2007) stated that in order to avoid more than 1% σ (sigma) phase, the cooling rate from the solution treatment temperature should exceed 0.23K/second and the aging time at the most critical temperature 865°C [1590°F] must not exceed 134 seconds. Chen et al. (2002) showed significant decreases in impact energy for Type 2205 duplex stainless steel exposed to temperatures in the range of 800 to 950°C [1472 to 1742°F] for periods of 10 min or less corresponding to 5% σ (sigma) phase. Momeni and Dehghani (2010) showed that hot working strain rates can have a significant effect on σ (sigma) phase formation in Type 2205 duplex stainless steel. The staff is aware of the January 26, 2010, response to RAI on TRUPACT-IH, Docket No. 71-9305, TAC No. L24403 (ML100491406) and the previously cited work by Weng et al. (2003).

   This information is necessary to assure compliance with 10 CFR 72.236(b) and 10 CFR 72.158.

5. Clarify and completely describe the materials used in the EOS transfer cask.

   Drawing EOS01-2000-SAR Sheet 1 of 5 indicates the TC top cover plate may be 2 in. nominal ASTM B209 Alloy 6061-T6 or ASME SA-516 Grade 70. The description in Section 8.2.1.2 of the SAR does not mention the Al lid option.

This information is necessary to assure compliance with 10 CFR 72.236(b).

6. Clarify or correct information in Section 8.2.1.2 of the SAR which states, “The trunnions are ASTM high strength low-alloy steel.”

   Drawing EOS-2001-SAR indicated that the trunnion is ASTM A182 Grade F6NM which is a martensitic stainless steel has greater than 5% alloying elements so it does not qualify as a low alloy steel.

   This information is necessary to assure compliance with 10 CFR 72.236(b).

7. Justify the use of the testing in accordance with RG 7.11 Table 4 for the Type 2205 and UNS S30103 Duplex Stainless Steels used for the DSC cited in TS Section 4.4.4.

   RG 7.11 Table 4 - Category I fracture toughness requirements and criteria for ferritic steels with yield strength no greater than 100 ksi, was not developed for Type 2205 and UNS S31803 which are duplex stainless steels.

   This information is necessary to assure compliance with 10 CFR 72.236(b).

8. Correct callouts to ASME code sections in Section 8.2.13.2 of the SAR. This section has at least 2 errors where ASME code sections are identified as ASTM.

   a. The SA-516 Gr 70 material and the procedures for all welds in the load path are subject to Charpy impact testing at 0 °F in accordance with <u>ASTM</u> Code Section III, Article NF-2300 for Class 1 supports.
   b. The trunnion materials, a martensitic stainless steel, are subject to drop weight testing at -40 °F per ANSI N14.6 or to Charpy impact testing at 0 °F in accordance with <u>ASTM</u> Code Section III, Article NF- 2300 for Class 1 supports.

   This information is necessary to assure compliance with 10 CFR 72.236(b).

9. Provide additional information on the use, fabrication and qualification of the SA-350 LF3 material in the transfer cask. Specifically identify whether the weld procedures used to join the SA-350 LF3 and the SA 516 Grade 70 will be evaluated using impact testing.

   This information is necessary to assure compliance with 10 CFR 72.236(b) and 10 CFR 72.158.

10. Section 8.2.2.2 of the SAR. Provide complete callout to tables with structural properties and thermal conductivity. The CoC application has these tables called out as “8-“ (i.e., the table callout is incomplete)

    This information is necessary to assure compliance with 10 CFR 72.236(b)

11. Clarify whether the duplex stainless steel base metal and welds will be evaluated using ASTM A923-14 or another test method to assure that the corrosion resistance and mechanical properties are adequate.

    This information is necessary to assure compliance with 10 CFR 72.236(b)

12. Clarify and or correct the non-destructive examination (NDE) method used for the EOS-TC108 removable neutron shield.

    Drawing EOS01-2003-SAR indicates that welds in the ASTMB209 Alloy 6061-T6 will be examined using magnetic particle testing (MT). Because Al 6061 is not a ferromagnetic material, MT is not a valid NDE method.

    This information is necessary to assure compliance with 10 CFR 72.158.

13. Provide updated information on coatings used in the AREVA NUHOMS EOS system.

    There are several varieties of Carboline Carboguard 890 http://www.carboline.com/markets-we-serve/power-nuclear/product-details.aspx?market=Power%20-%20Nuclear&product=0986. The Keeler and Long coatings identified for the Transfer Cask have been reported as discontinued products.

    This information is necessary to assure compliance with 10 CFR 72.236(b).

14. Provide the following additional information on coatings used in the AREEVA NUHOMS EOS system including (1) the coatings used on the exterior and interior carbon steel surfaces of the EOS-TC that is described as being suitable for spent fuel pool immersion and withstanding long-term exposure to the elevated temperatures of the TC, (2) the exterior of the removable aluminum alloy neutron shield for the NUHOMS-EOS TC 108, and (3) the DSC support structure in the HSM.

a. Indicate whether the coating is Important to Safety or Not Important to Safety

b. For Not Important to Safety coatings, indicate the purpose of the coating and whether the coating is necessary to prevent degradation of an important to safety SSC or SSC subcomponent.

c. Provide information on the chemistry of the coatings including solids additions that may result in a conductive coating (i.e. coating containing zinc or aluminum as metal solids). This information may be provided in product Material Data Safety Sheets (MSDS)

    This information is necessary to assure compliance with 10 CFR 72.236(b).

15. Section 8.2.5.2 of the SAR addresses both Austenitic Stainless Steels and Duplex Stainless Steels. Retitle this section appropriately. Provide additional information to assess the behavior of stainless steels in Pressurized Water Reactor (PWR) water with Boric Acid.

    Section 8.2.5.2 of the SAR only addresses corrosion in a deionized water environment; it does not provide an evaluation of the potential impact of boric acid.

    This information is necessary to assure compliance with 10 CFR 72.236(b).

16. Provide an assessment of the corrosion and galvanic corrosion behavior of the A506 Grade 4130 steels in PWR water with Boric Acid

    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.

This information is necessary to assure compliance with 10 CFR 72.236(b)

17. Provide additional information to support the statement that the graphite lubricants have no adverse effects on the DSC materials.

    It is well known that graphite is noble with respect to stainless steel and will be preferentially cathodic in a stainless steel graphite galvanic couple which could accelerate the corrosion rate of the stainless material. Note that, for the 72-1004 renewal application a similar RAI was issued to request additional information cited to support the lack of galvanic corrosion between stainless steels and graphite lubricants. The information provided in the 72-1004 CoC renewal application did not clearly identify examples of where graphite lubricants are used in contact with stainless steels in operating reactors, or if these operating experiences are under similar environmental conditions compared to the operating environment for the DSC. Note that valve packing material using graphite typically includes either zinc (low temperatures only, to avoid molten zinc and liquid metal embrittlement), or phosphorous, as corrosion inhibitors. Although austenitic and duplex stainless steels are noted to be less susceptible than martensitic stainless steels often used in valve components, austenitic and duplex stainless steels will still be preferentially anodic when coupled to graphite.

    This information is necessary to assure compliance with 10 CFR 72.236(b).

18. (**NOTE: this is the same in its entirety as DSC-RAI-20 for the round 1 RAIs for the 72-1004 application. The Applicant has referenced material in the Appendix of the 72-1004 application**) Provide justification for the selection of data used for the assessment of the Chloride-Induced Stress Corrosion Cracking (CISCC) growth rates and indicate how the Aging Management Review documented in renewal application Appendix 5B support the DSC External Surfaces Aging Management Program and the DSC Aging Management Program for the effects of CISCC in Appendix 6A. Specifically, describe how the results of the Aging Management Review in Appendix 5B are used to determine parameters for the Aging Management Program elements including the Scope of the Program, Parameters Monitored or Inspected, Detection of Aging Effects, Monitoring and Trending, Acceptance Criteria, and Corrective Actions. In addition state how the additional and forthcoming information will be assessed and evaluated in Operating Experience DSC Aging Management Programs:

- Crack growth rate data cited by the CoC holder in the evaluation of CISCC rates included reports from Central Research Institute of Electric Power Industry of Japan (CRIEPI). CRIEI sponsored work Shirai et al., 2011 [5B.6.4]; and Tani et al., 2009 [5B.6.5]. The CoC holder reported that Shirai et al., 2011 observed a two stage crack growth rate behavior with 304 stainless steels in tests conducted with synthetic sea salt at 80°C and a relative humidity of 35 percent. Initial crack growth rates reported by Shirai et al., 2011 were 4.4×10^{-10} m/s (13.9 mm/yr) for the initial 1300 hours of growth. After the initial growth period, the crack growth rate decreased to 1.6×10^{-11} m/s (0.5 mm/yr). However, no such decrease in crack growth rate was observed with tests conducted in $MgCl_2$ salt. The CoC holder also cited the work by Tani et al., (2009) who reported crack growth rates for 316 stainless steel under identical conditions. Tani et al., 2009 reported initial crack growth rates of 3.14×10^{-10} m/s (9.9 mm/yr). The CoC holder examined the data by Tani et al., 2009 and stated that after testing for more than 800 hours the crack growth rate appeared to decrease to approximately 3.8×10^{-11} m/s (1.2 mm/yr).

- The crack growth rate data is very limited and the CoC holder has selectively used one set of data obtained at conditions that are not relevant for atmospheric exposures that show a lower crack growth rate (0.5 mm/yr for Shirai et al. 2011 vs 1.2 mm/yr for Tani et al. 2009). In addition, the nuclear power plant operating experience summarized in Table 5B-6 is also not used because, according to CoC renewal application Section 5B.3.3, the Relative Humidity (RH) for these events is greater than 80 percent and under those conditions the deliquescence of NaCl will occur and accelerate the crack growth rate. In addition the stated conditions for the St. Lucie operating experience reported in Table 5B-6 incorrectly indicates an operating temperature of 49°C. The temperature of the emergency core cooling systems (ECCS) suction piping is listed as outside ambient according to the Pressurized Water Reactors Owners Group (PWROG) summary of outer diameter SCC (ODSCC) events (Nowinnowski, 2010). The apparent crack growth rate for the St. Lucie operating experience is 0.4 mm/yr assuming initiation at the time of initial plant operation (CoC renewal application Table 5B-6). Using Shirai et al., (2011) data obtained at 80°C and an activation energy (Ea) of 30.5 kJ/mol (Hayashibara et al., 2008) the predicted crack growth rate at 30°C is 0.09 mm/yr, less than 25% of the apparent crack growth rate obtained from the St. Lucie operating experience. Using the Tani et al. 2009 data obtained at 80°C and an Ea of 30.5 kJ/mol, the predicted crack growth rate at 49°C is 0.44 mm/yr.
- The selection of data to determine crack growth rates does not agree with operational experience. In contrast to the assessment in CoC renewal application Section 5B, the operational experience at operating power plants appears to be relevant for DSC operational environments. Whether or not the environmental conditions summarized in Appendix 5B are determined to be relevant to the conditions expected on DSCs, the operating conditions for CISCC to occur (tensile stresses, susceptible material, and a corrosive environment) are the same and the assessment of possible CISCC growth rates for the DSCs should be benchmarked to operational experience where CISCC has been identified as the degradation mechanism.

This information is necessary to assure compliance with 10 CFR 72.236(b)

19. Provide additional information to support the statement that the coating system for the DSC support structure is more than adequate for the 20-year initially licensed storage period.

    The cited references are for Oconee and Calvert Cliffs renewal applications. The NUHOMS systems at Both Oconee and Calvert Cliffs have lower heat loads and did not have high burnup fuel. The justification for the coating lasting for 20 years should also include an assessment of the differences in the operating conditions and provide data to support the assertion that the coating will perform satisfactorily when exposed to the expected time-temperature conditions.

    This information is necessary to assure compliance with 10 CFR 72.236(b).

20. Provide the technical basis for using a 1/16 inch loss of material for the stress analysis of the DSC support structure.

    This information is necessary to assure compliance with 10 CFR 72.236(b).

21. Provide a definition of “intact” fuel assemblies in the TS that clarifies the presence or absence of cladding breaches and other fuel damage (e.g., displaced or missing structural components).

Neither the TS nor the SAR includes a definition for “intact.”

This information is necessary to assure compliance with 10 CFR 72.236(a).

22. Justify that the use of an aluminum top cover plate on the transfer cask will not create excessive tensile loading of the associated steel bolting, given the differences in thermal expansion between these two materials.

Table 8-3 of the SAR includes an option to use an aluminum top cover plate for the transfer cask. The bolts that fasten this cover plate are constructed of alloy steel. The staff noted that the differential thermal expansion between the aluminum cover and steel bolts could subject the bolts to high tensile stresses as the cover heats up after closure of the transfer cask.

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

23. Justify that the high-density polyethylene neutron shielding (Quadrant Borotron®) is capable of fulfilling its shielding function at temperatures that exceed the manufacturer’s stated maximum continuous service temperature.

Table 8-29 of the SAR and the Quadrant data sheet on Borotron HD050 Borated PE state that the maximum continuous service temperature of this neutron shield is 180°F. In addition, the Borotron HDPE materials safety data sheet describes this material’s melting point/freezing point as 219.2-280.4°F and states “no data available” on decomposition temperature.

Given that Sections 4.5 and 4.6 of the SAR describe loading cases where the polyethylene shielding exceeds 180°F and can reach up to 257°F, it’s not clear to the staff that this material is capable of maintaining its shielding function under the design conditions. The staff requires additional information that supports the use of Borotron at these elevated temperatures.

This information is required to demonstrate compliance with 10 CFR 72.236(d).

24. Revise the design drawings for the transfer cask to include the requirements for impact and drop weight testing of the ferritic steels described in Section 8.2.13.2 of the SAR.

Section 8.2.13.2 of the SAR describes Charpy impact testing at 0°F and drop weight testing at -40°F for ferritic steels in the transfer cask. This testing references ASME Code Section III, Article NF-2300 for Class 1 supports (Charpy testing) and ANSI N14.6 (drop weight). The design drawings for the transfer cask do not include this testing requirement, in contrast to the DSC basket drawings, which include the requirement for dynamic tear testing of ferritic steels.

ASME Code Division 1, Section III, Article NF-2300 states that design specifications shall state the designated impact test temperature, when required.

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

25. Clarify whether inspections of the external surfaces of the HSM are required. If so, state the inspection frequency.

Section 8.6.1 of the safety analysis report states that the system only requires periodic inspection of the air inlets and outlets to ensure no blockage has occurred. In contrast, Section 10.2.1.2 of the SAR states the HSM exterior is visually inspected for concrete damage and settling. The discussion of these HSM exterior inspections does not cite a frequency or reference any codes or standards.

This information is required to demonstrate compliance with 10 CFR 72.144(c)(4).

26. In SAR Section 8.2, provide the technical basis for the cladding material properties used in the structural analyses.

SAR Tables 8-25 and 8-26 cite reference 8-21 ("PNNL Stress/Strain Correlation for Zircaloy," PNNL-17700) as the source of the cladding materials properties. However, the SAR does not reference any specific equation or figure from this report, nor does it include a discussion of how the materials properties were derived.

The staff requires an understanding of how the cladding properties were derived, including, but not necessarily limited to, the consideration of the:

- specific equation/figure in the PNNL report relevant to the cladding properties
- cladding fabrication process (e.g., recrystallized annealed, cold work stress relieved)
- assumed hydrogen concentration, and distribution and type of hydride precipitates
- applicable burnup range of the spent nuclear fuel
- uncertainties (scatter) in the PNNL report data

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

27. In SAR Section 9.1, provide clarifying information on the dye penetrant (PT) examinations that are to be performed on the DSC confinement boundary field welds.

Section 8.6 of the SAR and TS Section 4.4.4 states that:

- the confinement boundary field welds (with the exception of the weld associated with the outer top cover) are to be examined by PT of the root and final weld passes
- the weld between the DSC shell and outer top cover is to receive a multi-level PT examination in accordance with the guidance in NUREG-1536, Revision 1

The operating procedures in Section 9 of the SAR do not reference the above TS requirements for the multi-layer PT examinations.

This information is required to demonstrate compliance with 10 CFR 72.234(f).

<u>Materials RAI References</u>

ASTM A923-14, "Standard Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels, West Conshohocken, PA: ASTM International, 2014.

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A. Momeni and K. Dehghani, “Effect of Hot Working on Secondary Phase Formation in 2205 Duplex Stainless Steel,” Journal of Material Science Technology, Vol. 26(9), pp. 851-857, 2010.

H-Y. Liou, R-I. Hsieh, W-T. Tsai, “Microstructure and stress corrosion cracking in simulated heat-affected zones of duplex stainless steels,” Corrosion Science, Vol 44, pp. 2841–2856, 2002.

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