Structural RAIs

RAI 3-1:

Provide the structural evaluation and/or analysis for the Type 5 basket in Appendix 3.9.2, "EOS-37PTH AND EOS-89BTH BASKET STRUCTURAL ANALYSIS."

The applicant has proposed to add a new basket type (Type 5), which is comparable in geometry to existing Type 1, 2 and 3 baskets, but with a low conductivity poison and the low emissivity option of the Type 4 basket, with the ability to be stored in either the EOS-HSM or the new NUHOMS MATRIX design. The applicant, however, did not provide a structural evaluation and/or analysis for the proposed Type 5 basket.

This information is needed so that the NRC staff may determine compliance with the regulations in 10 CFR 72.236(b), (g) and (l).

RESPONSE TO RAI 3-1:

The EOS-37PTH Type 5 basket is identical to Types 1/2/3, the only difference being the low emissivity coating steel plates and low conductivity poison plates, and the coating and poison plate are not credited for in structural evaluations. Furthermore, the heat load of the Type 5 basket is limited to keeping the existing temperature bounding. Therefore, the structural evaluation presented in UFSAR Sections 3.9.2.1 and 3.9.2.3 remains valid for EOS-37PTH Type 5 basket. Section 3.9.2.3B has been added to UFSAR Section 3.9.2.3 to provide a structural evaluation of the Type 5 basket.

Application Impact:

UFSAR Section 3.9.2.3B has been added as described in the response.

RAI 3-2:

Discuss whether the HSM-MX will overturn and slide as a result of the design basis earthquake. Provide justification for the conclusions provided in the discussion.

The applicant provided the results of the structural analysis for the HSM-MX subjected to the seismic load in Table A3.9. 7-5 "Static analysis, Overturning and Sliding of the HSM-MX" in Amendment 1. From the table, the NRC staff found that the calculated factors of safety (FSs) for the HSM-MX with the concrete density of 160 pcf, with respect to the overturning and sliding, are 0.70 and 0.44, respectively. From Table 3-3 "Load Combinations for Steel and Reinforced Concrete Non-Confinement Structures" in NUREG-1536, Rev. 1, it states, *"Capacity/demand ≥1.00 for structure to be satisfied for both overturning and sliding,"* where a capacity/demand is defined as a factor of safety (FS).

This information is needed so that the NRC staff may determine compliance with the regulations in 10 CFR 72.236(l).

RESPONSE TO RAI 3-2:

As discussed in UFSAR Section A.3.9.7.2.3.1, the results summarized in Table A.3.9.7-5 "Static analysis, Overturning and Sliding of the HSM-MX" show that the safety factors are less than 1 for both overturning and sliding, which are based on conservative static analyses.

Because the hand calculations are conservative, the amount of lifting and sliding are calculated using non-linear dynamic analyses (UFSAR Section A.3.9.7.2.3.2). For each of the seven seismic input time histories, three different coefficients of friction (0.4, 0.6, and 0.8) are considered for a total of 21 computer runs. The maximum values over time for sliding and rocking movements from the seven time histories are used to derive the "computed" response as the median value plus 1 standard deviation, for each friction coefficient value. As shown in UFSAR Table A.3.9.7-6, the resulting estimations by the non-linear dynamic analysis are a maximum sliding displacement of 12.5 inches and an uplift displacement of 0.13 inches. These displacements are provided in lieu of safety factors.

Application Impact:

No changes as a result of this RAI.

<u>Thermal RAIs</u>

RAI 4-1:

Provide justification for removing the following from Technical Specification 3.1.3: a. The maximum heat load for each DSC model in LCO 3.1.3 and, b. "[...]after the completion of LCO 3.1.2 actions or[...]," in SR 3.1.3.

Technical Specification 3.1.3 describes the time limit for completion of DSC transfer. In the technical specifications for NUHOMS EOS Amd. 0 (ADAMS Accession No. ML 16242A022) the maximum heat load for each DSC model was provided. In addition, in the technical specifications for NUHOMS EOS Amd. 0, the surveillance requirement 3.1.3, to verify that the time limit for completion of DSC transfer is met, was initiated after the completion of LCO 3.1.2 actions for the DSC helium backfill pressure. Justification should be provided for removing these parameters from Technical Specification 3.1.3.

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

RESPONSE TO RAI 4-1:

The maximum heat load for each dry shielded canister (DSC) model in Limiting Conditions of Operation (LCO) 3.1.3 was removed to simplify the Technical Specifications (TS), since the specification of the heat load zone configuration (HLZC) number along with the maximum heat load is redundant. The maximum allowable heat loads for each HLZC are already shown in Figure 1A to Figure 2 in the TS, and remain applicable to this LCO.

The text "[...]after the completion of LCO 3.1.2 actions or[...]," in Surveillance Requirement (SR) 3.1.3 was removed to clarify the TS. While SR 3.1.3 will always be performed after completion of LCO 3.1.2 once drainage of the water in the transfer cask (TC)/DSC annulus is initiated, it is not necessary to perform SR 3.1.3 after completion of LCO 3.1.2, as long as water is maintained in the TC/DSC annulus. SR 3.1.3 is only applicable after the initiation of draining of the water in the TC/DSC annulus.

Application Impact:

No changes as a result of this RAI.

Proprietary Information on Pages 4 through 18
Withheld Pursuant to 10 CFR 2.390

Editorial RAI:

Page 4.9.6-19 of the application states, "Time limits for transfer operations of the EOS-37PTH DSC with HLZCs 7, 8, and 9 are listed in Table 4.9.6-7." Table 4.9.6-7 should be Table 4.9.6-11.

RESPONSE TO EDITORIAL RAI:

UFSAR Page 4.9.6-19 is part of UFSAR Section 4.9.6.2, and has shifted in this revision. The typographical error that was previously on page 4.9.6-19, has been updated in UFSAR Section 4.9.6.2 to reflect the correct table, Table 4.9.6-11.

Application Impact:

UFSAR Section 4.9.6.2 has been revised as described in the response.

Shielding RAIs

RAI 6-1:

Verify the accuracy of the fuel assembly design data presented in Tables 2-2 and 2-4 of Revision 1 of the SAR and revise all the safety analyses as necessary.

Tables 2-2 and 2-4 of Revision 10f the SAR for the NUHOMS EOS system provides the design parameters of the spent fuel assemblies to be stored in the NUHOMS EOS dry cask storage system. However, the staff notes that there may be some errors in these data. For example, the cladding inner diameter (0.364") of the WE14x14 FA is smaller than the pellet diameter (0.368"). The same *is* true for the WE17x17 (ENRESA ASCO) FA design, which has pellet diameter of 0.322" and clad inner diameter of 0.315". Also, the staff notes that the number of guide tubes (control guide tubes+ instrument tube) for some of the fuel assembly designs, e.g., the WE17x17/BW, 17x17 Mark C fuel, and the Fort Calhoun CE14x14, and CE 15x15 Palisades, seems to be incorrect; the sum of the number of fuel rods and guide tubes do not add up to the total size of the lattices. All or part of the safety analyses may be based on incorrect data for the requested amendments which include shorted cooling time and failed fuel.

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.124(a), 72.124(b), and 72.236(d).

RESPONSE TO RAI 6-1:

UFSAR Tables 2-2, 2-3, and 2-4 have been reviewed and modified accordingly for the WE14x14, WE17x17 (ENRESA ASCO), BW17x17 Mark C, CE14x14, CE15x15 fuels and other PWR and BWR allowable fuels.

The criticality and shielding analyses are consistent with the updated tables and therefore are not affected by these modifications.

Application Impact:

UFSAR Tables 2-2, 2-3, and 2-4 have been revised as described in the response.

RAI 6-2:

Provide a definition and specification for the "reloaded assemblies" with respect to the requested new contents.

In Section 2.2 of Amendment 1 Revision 2 of the SAR for the NUHOMS EOS system, the applicant states: *"The NUHOMS® EOS System is designed to accommodate pressurized water reactor (PWR) (14x14, 15x15, 16x16 and 17x17 array designs) and boiling water reactor (BWR) (7x7, 8x8, 9x9 and 10x10 array designs) fuel types and reload assemblies that are available for storage."* However, the applicant provides no definition for the term "reload assemblies."

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.234(a) and 72.236(a).

RESPONSE TO RAI 6-2:

The phrase "and reload assemblies" has been deleted for clarity from UFSAR Section 2.2. The initial intent of the phrase was to state that equivalent fuel assemblies manufactured by other vendors are also acceptable. A clarification has been added to UFSAR Section 2.2.

Application Impact:

UFSAR Section 2.2 has been revised as described in the response.

RAI 6-3:

Revise the first paragraph from Section 6 Amendment 1 Revision 0 of the SAR to clearly state that the allowable content includes damaged fuel and failed fuel in rod storage basket (RSB).

In the first sentence in Section 6 Amendment 1 Revision 0 of the SAR for the NUHOMS EOS system, the applicant states: *"The EOS system is designed to store **intact** pressurized water reactor (PWR) and boiling water reactor (BWR) fuel assemblies (FAs) within the EOS-37PTH dry shielded canister (DSC) and EOS-89BTH DSC, respectively. The transfer casks (TCs) EOS-TC108 and EOS-TC125/135 are used to transfer the EOS-DSC to the EOS horizontal storage module (EOS-HSM). Normal and off-normal condition, near-field dose rates are presented in this chapter for the EOS-TC and EOS-HSM."* This is inconsistent with the additional content requested in the amendment application. The Shielding Evaluation Chapter should clearly reflect the proposed new contents.

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.236(a) and 72.236(d).

RESPONSE TO RAI 6-3:

The first paragraph of UFSAR Chapter 6 has been modified to reflect the new PWR contents for CoC 1042 Amendment 1.

Application Impact:

UFSAR Chapter 6 has been revised as described in the response.

RAI 6-4:

Provide drawings with dimensions and allowable manufacturing tolerances in all drawings for the new (Type 4/5) basket designs.

The amendment incorporates two new basket designs (Type 4 and Type 5) to allow for storage of damaged and failed fuel compartments. The applicant provided drawings for the new basket types, however, these drawings do not include dimensions for the basket cells that are designated to hold damaged or failed fuel cans with end caps. Also, none of the drawings includes allowable manufacturing tolerances. Because the dimensions and associated tolerances are critical parameters for shielding analyses, the applicant needs to revise the drawings to include these data.

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.236(d).

RESPONSE TO RAI 6-4:

On Sheet 3 of Drawing EOS01-1010-SAR Revision 2C, the minimum basket cell dimensions are given as a square dimension of 8.80 inches minimum; these basket cells are used to store intact as well as damaged and failed fuel with the use of end-caps and failed fuel canisters, respectively. This is specified on the drawing by Note 21:

"Damaged or failed fuel may be stored in the DSC, but shall not be loaded in the same DSC. Damaged Fuel shall require end caps (items 52, 53, 56, and 57). Failed fuel shall require a failed fuel canister (items 58 through 65)."

Additionally, Note 18 on UFSAR Drawing EOS01-1010-SAR, Revision 2C states:

"The top and bottom end caps shall be installed in the fuel cells, and a maximum total gap of .12 verified all around (assuming lid shifting), between inside surface of the fuel compartment and end caps body (items 53 and 57). The assembled end caps shall slide freely inside the fuel compartment."

This means that each end-cap is manufactured for its specific cell to comply with the 0.12-inch maximum gap requirement, after the basket is fabricated based on the as-built cell dimensions.

Fuel compartment width variation was analyzed in UFSAR Section 7A Part 2: "Determination of Most Reactive Configuration – Fuel Assembly Width Variation." The results described in Table 7-14 show k_{eff} values for 8.76 and 8.96 inches and demonstrate that a compartment width of 8.76 inches results in a higher k_{eff}. The most reactive configuration was determined to be 8.76 inches. Even with the effects of manufacturing tolerances, the basket cell dimension does not go below the bounded analyzed value 8.76 inches.

Furthermore, Note 8 on EOS01-1010-SAR Revision 2C states: "Inspect fuel compartments to verify minimum inside dimension. Inspection may be performed prior to assembly." This note ensures that the effects of plate stack-up at the current plate width does not result in any individual basket cell having dimensions smaller than the square dimension of 8.80 inches minimum. Therefore, regardless of the manufacturing tolerances, the inspected dimension will be greater than the design requirement.

For the shielding analysis, nominal values for slot thickness are justified in the analysis because of the built-in conservatism. Metal-matrix composite (MMC) poison plates (aluminum with boron carbide (B_4C) particulates) are used for criticality control in both the EOS-37PTH and EOS-89BTH DSCs. There are various levels of effective B-10 content for the baskets, which is adjusted for the fuel type. To provide for a bounding analysis, all MMC in both EOS DSCs is treated as pure aluminum at a slightly reduced density. This allows for full credit of the mass of aluminum to be taken for gamma shielding while maximizing the neutron dose rate external to the HSM. The description of this built-in conservatism in the model can be found in UFSAR Sections 6.3 and A.6.3.

There are various aluminum plate thicknesses in the basket. For the EOS-89BTH DSC, aluminum plates are not modeled. Aluminum plates are primarily located towards the inner fuel compartments in the EOS-89BTH DSC basket. This is conservative for both EOS DSCs, as it reduces the overall basket mass. Therefore, slight variations resulting from manufacturing tolerances are bounded by the overall conservatisms described above.

Additionally, UFSAR Chapter 6 (Shielding Evaluation) and Chapter 7 (Criticality Evaluation) also clearly indicate that no credit is taken for the failed fuel canister or any secondary containers. Therefore, the level of detail of the dimensions provided in UFSAR Drawing EOS01-1010-SAR, Revision 2C for the basket components is adequate for the shielding and criticality analysis.

Application Impact:

No changes as a result of this RAI.

RAI 6-5:

Revise the drawings to include dimensions and manufacturing tolerances for the NUHOMS® MATRIX design.

The applicant provided drawings for the NUHOMS® MATRIX design. However, these drawings do not include the width of the vent covers and there is no information on the manufacturing tolerances for any of the components. In particular, the dimensions and allowable manufacturing tolerances of the vent covers are important to shielding analyses.

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.236(d).

RESPONSE TO RAI 6-5:

Unless noted otherwise, fabrication tolerances required for proper fit-up and assembly of the components shall be based on generally accepted industry practice and guidelines, including ACI-117 (Reference 1), or as specified by the TN Americas specification. This note has been added to Drawing MX01-5000-SAR. Tolerances on other critical features, such as the front wall and the overall height, has been added as well.

The full dimensions of the outer vent cover are given on Sheet 14 of UFSAR Drawing MX01-5000-SAR Rev 0A, with supplemental information provided in Detail H-H, including the width. The dimensions of the inlet and outlets are given on Sheets 9 and 12 of the same drawing. The covers, including the bird screen, that go over the inlets and outlets are not modeled as part of the shielding analysis. As such, these do not have an effect on the shielding analysis.

The shielding analysis uses nominal dimensions because of the built-in conservatism of the calculation. The analysis does not take credit for embedments, front and rear steel supports, or installation hardware. The minimum specified concrete density of 140 pcf is used in the analysis model, which is less than the nominal concrete density of 150 pcf. Additionally, that lower density does not account for the increased shielding performance provided by the steel rebar. The absence of rebar yields conservative surface-averaged dose rates because the system is gamma-dominated.

References:

1. American Concrete Institute, “Specification for Tolerances for Concrete Construction and Materials (ACI 117-10) and Commentary,” ACI Standard, June 2010.

Application Impact:

UFSAR Drawing MX01-5000-SAR has been revised as described in the response.

RAI 6-6:

Provide the definition for the term “reasonably bounding” used in the shielding analyses for the new content.

In Section 6 of Amendment 1 Revision 0 of the SAR for the NUHOMS EOS system, the applicant states: *“The methodology, source terms, and dose rates presented in this chapter are developed to be reasonably bounding for general licensee implementation of the EOS System.”* This statement appears to indicate that the shielding analyses do not envelope all of the proposed contents.

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.236(d).

RESPONSE TO RAI 6-6:

A new UFSAR Section 6.2.8, Justification for the Reasonably Bounding Source Term Methodology, has been added. Refer to Section 6.2.8 for a detailed discussion.

“Reasonably bounding” refers to the minimum enrichments defined in UFSAR Table 6-7. Because a limited number of fuel assemblies in a DSC may have minimum enrichment values below UFSAR Table 6-7, the neutron-dominated EOS-TC accident dose rates have been conservatively doubled prior to the exposure evaluation to account for the potential increase of neutron sources at lower enrichments. The EOS-TC accident exposure has been modified in UFSAR Sections 6.1, 6.4.3, and 12.3.1. EOS-HSM, HSM-MX, and site dose rates are gamma dominated and thus are not affected.

Application Impact:

UFSAR Section 6.2.8 has been added as described in the response.

UFSAR Sections 6.1, 6.4.3, and 12.3.1 have been modified as described in the response.

RAI 6-7:

Provide the burnup, initial enrichment, and cooling time (BECT) combination for the proposed spent fuel contents that represent the bounding source terms used to determine radiation dose rates. Alternatively, provide a list of BECTs to demonstrate that the source terms from these new contents to be authorized under Amendment 1 result in radiation dose rates that are within the design limits.

Paragraph 234(a) of 10 CFR Part 72 requires that the design of a spent fuel storage system meets the regulatory requirements of 10 CFR 72.236. For radiation protection, 72.236(d) states: "Radiation shielding and confinement features must be provided sufficient to meet the requirements in §§ 72.104 and 72.106." The applicant performed a shielding analyses based on source terms listed in Tables 6-14 to 6-19 of Amendment 1, Revision 1 of the Safety Analysis Report (SAR) for selected BECT combinations. In Section 6.2 of the SAR, the applicant states: "The bounding HLZCs are used for dose rate analysis" and that the source terms are developed to be "reasonably bounding consistent with the limits on fuel qualification." However, the maximum burnup and minimum cooling time parameters provided in the proposed Technical Specifications (TS) Table 2.1 does not include an associated minimal enrichment value and does not mirror the fuel parameters used in the calculation of the design basis radiation sources as shown in Tables 6-14 to 6-19 of Amendment 1, Revision 1 of the SAR. Without the associated minimal enrichment, the source terms for a fuel assembly with a given burnup and cooling time are not defined. Although the applicant provides the decay heat limits for the various loading patterns in the TS, there is no information provided on the specific relationship between the decay heat and the radiological source terms. A fuel assembly with a given decay heat can produce a wide variation of radiological source terms.

It is important to note that the recommendations published in NUREG/CR-6716, "Recommendations on Fuel Parameters for Standard Technical Specifications for Spent Fuel Storage Casks" are based on a balanced evaluation of parameters important to safety while alleviating limitations in the TS to provide the certificate of compliance holders flexibility to make design changes under the provisions in 10 CFR 72.48.

The staff requests this information to determine if the NUHOMS® EOS spent fuel dry cask storage system design with the requested new contents meets the regulatory requirements of 10 CFR 72.236(d).

RESPONSE TO RAI 6-7:

RAI 6-7 is similar to RAI 6-6. As part of the RAI 6-6 response, it is demonstrated that:

1. The design basis source terms utilized are bounding for the new contents in Amendment 1 when following the burnup/enrichment curve in UFSAR Table 6-7. This is demonstrated by considering ~1700 burnup/enrichment combinations per zone.

2. The number of "outlier" fuel assemblies (fuel assemblies outside the burnup/enrichment combinations considered when developing design basis source terms) is a very small fraction of the spent fuel population (<0.5%). Outlier fuel assemblies primarily affect the neutron source.

3. Outlier fuel assemblies have essentially no effect on normal condition storage dose rates (72.104) or accident condition storage dose rates (72.106) because the storage system is gamma dominated. In any case, the site dose analysis used to demonstrate compliance with Technical Specifications (TS) 5.1.2 and 72.104 limits must consider outlier fuel assemblies, if present.

4. While outlier fuel assemblies are not expected to have an effect on transfer cask accident (72.106) dose rates due to their limited number, because the transfer cask accident dose rates are neutron dominated, the transfer cask accident dose rates are conservatively doubled to address this scenario. Exposure at the site boundary is <1% of the 72.106 dose limit.

The shielding analysis provided in the UFSAR is comprehensive. It is based on the bounding HLZC and every location in the basket is filled with the hottest allowed fuel. A range of BECT combinations is examined to determine limiting BECT combinations. Minimum enrichments are determined based on a review of domestic spent fuel discharged over the past 40 years and encompasses >99.5% of the domestic spent fuel population. The UFSAR analysis is used to determine the TS dose rate limits specified in TS 5.1.2(c).

Fuel qualification is addressed in the analysis performed to demonstrate compliance with TS 5.1.2(a). A fuel qualification methodology has been explicitly added to TS 5.1.2(a) to make clear to all potential users how fuel for the system is to be qualified.

The analysis required in TS 5.1.2(a) and the dose rate requirements of TS 5.1.2(c) provide a balanced evaluation of parameters recommended by NUREG/CR-6716. The dose rate analysis required prior to loading, and dose rate measurements required after loading, ensures virtually no risk to the public. Because dose rates are measured as the ISFSI is loaded, it is not credible that multiple adverse events could occur that would affect the site boundary dose rate, as the site boundary dose rate is the aggregate of dozens of individual HSMs. Per TS 5.1.2(c), if the measured dose rates exceed the TS 5.1.2(b) or TS 5.1.2(c) limits, the NRC must be notified within 30 days. A gross "dose rate misload event" that would affect a site boundary dose rate is not credible due to the TS dose rate restrictions on each HSM, the comprehensive analysis in the UFSAR, and the comprehensive analysis required in TS 5.1.2(a).

The linkage between decay heat and source terms is complex and does not exist in a simple closed-form solution. This linkage is not required in the TS. When the site-specific analysis is performed, the decay heat and source terms are computed for every fuel assembly to be stored (see TS 5.1.2(a)). The relationship between decay heat and source terms is linked through the input parameters used in the ORIGEN-ARP input files, primarily specific power (40 MW/MTU). A specific power of 40 MW/MTU over the entire fuel assembly irradiation is a reasonably conservative value for PWR fuel analysis based on a review of publicly available data for commercial PWRs. When the fuel population is evaluated for a site-specific dose rate analysis, the specific power appropriate for the site-specific spent fuel population is employed when developing source terms.

BECT combinations of concern to the NRC, such as high burnup, low cooling time combinations are not credible because the decay heat of such fuel assemblies is too large. The analysis in the UFSAR is sufficient to demonstrate that such BECT combinations are not credible. Clearly, a PWR fuel assembly with a burnup of 62 MWd/MTU and cooling time of 2 years would result in storage dose rates significantly higher than those currently calculated in the UFSAR. However, there is currently no HLZC that could accept such a fuel assembly because the decay heat would be > 2.4 kW. Such a fuel assembly would screen out when the decay heats are calculated per TS 5.1.2(a). Any fuel assembly that meets the decay heat requirement is evaluated for source terms. Therefore, the proposed methodology ensures compliance with 72.104 dose rate limits for any arbitrary fuel population that meets the TS requirements on decay heat, maximum burnup (62 GWd/MTU) and minimum cooling time (2 years for new contents).

The methodology used to qualify fuel for loading has been added to TS 5.1.2(a).

Application Impact:

TS Section 5.1.2(a) has been revised as described in the response.

RAI 6-8:

Provide justification for why the average rather than the peak side surface dose rate was used as a means to identify the bounding loading patterns.

On Page 6-9 of Amendment 1 Revision 2 of the SAR for the NUHOMS EOS system, the applicant states: "The bounding HLZCs are used for dose rate analysis." On the same page, the applicant further states: "Based on MCNP scoping calculations, HLZC 4 bounds HLZC 1, and HLZC 4 and HLZC 5 result in similar peak dose rates for the EOS-TC1251135 and EOSHSM. However, HLZC 4 results in larger average dose rates on the EOS-TC125/135 side surface compared to HLZC 5 because HLZC 4 has the largest heat load in the peripheral zone. Therefore, HLZC 4 is used in design basis PWR calculations for the EOS-TC125/135 and EOSHSM. Source terms for HLZC 4 are derived for 1.0 kW/FA in Zone 1and1.625 kW/FA in Zones 2 and 3 for a total DSC heat load of 52. 0 kW. This bounds the maximum DSC heat load of 50. 0 kW." The staff reviewed the heat load zone configurations HLZCs 4 and 5 and notes: (1) the fuel assemblies in HLZC 5, zone 3 are much hotter (3.4 kW) than those in zone 3 of HLZC 4, (2) the fuel assemblies in HLZC 5, zone 3 are not shielded by any fuel assemblies, and (3) HLZC 5 has an asymmetric loading pattern in terms of heat load. Therefore, HLZC 5 may have much higher dose rate at the some spots at the side where fuel with 2.4 kW decay heat is allowed. Also, the staff could not determine if the average dose rate can correctly identify the bounding loading pattern for dose rate calculations because of the asymmetric loading of HLZC 5. The SAR does not provide information on how the peak dose rate was calculated.

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.236(d).

RESPONSE TO RAI 6-8:

The transfer cask dose rates are input to the exposure analysis provided in Chapter 11 of the UFSAR. The exposure analysis is based on average EOS-TC dose rates because operations are performed at various locations around the EOS-TC. For this reason, the HLZC with the highest average EOS-TC side dose rate will result in the maximum exposure and is considered the design basis. Because HLZC 4 results in larger average dose rates on the side of the EOS-TC125/135 compared to HLZC 5, HLZC 4 results in a larger exposure than HLZC 5. For the EOS-HSM, the design basis HLZC is selected to maximize vent dose rates.

In response to this RAI, source terms are developed for HLZC 5, and a dose rate analysis is performed for HLZC 5 to allow direct dose rate comparisons with HLZC 4 dose rates. It is demonstrated that HLZC 4 dose rates bound HLZC 5 dose rates in the EOS-TC125/135. For the EOS-HSM, HLZC 4 and HLZC 5 result in similar vent dose rates. However, the design basis HLZC for EOS-HSM analysis is the EOS-89BTH DSC HLZC 1, which bounds PWR HLZC 5.

UFSAR Chapter 6 has been revised to include HLZC 5 source terms and dose rates, primarily in Sections 6.2.2, 6.4.3, and 6.4.4. EOS-TC125/135 source terms are provided in Table 6-16d through Table 6-16g, and dose rates have been added to Table 6-53. EOS-HSM source terms are provided in Tables 6-19a through 6-19d, and vent dose rates are provided in Section 6.4.4.

Application Impact:

UFSAR Sections 6.2.2, 6.4.3, and 6.4.4 have been revised as described in the response.

UFSAR Tables 6-16d through 6-16g, 6-19a through 6-19d, and 6-53 have been added as described in the response

RAI 6-9:

Demonstrate that it is appropriate to treat the entire axial fuel region of the fuel assembly as one segment in determining the source terms for high burnup and low cooling time fuel.

Tables 6-14, 6-15, 6-16, 6-16a, 6-16b, 6-16c, 6-17, 6-18, and 6-19 of Amendment 1 Revision 1Of the SAR provide the source terms for various axial radiation source distributions. From the data shown in these tables, it appears that the sources for the fuel region in a fuel assembly are averaged over the entire region. It is not clear whether this approximation can correctly represent the source distributions in the shielding models because it is well understood that the gamma source from spent fuel is linearly proportional to the fuel burnup and the neutron source is proportional to fourth power of the fuel burnup based on NUREG/CG-6700. As such, it is expected that the neutron and gamma sources in the high burnup part of the fuel region will peak and produce peak dose rate at the side of the dry canister or the transfer casks. Using the sources averaged over the fuel region in the shielding models may not capture the high radiation/dose rate spot(s).

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.236(d).

RESPONSE TO RAI 6-9:

Axial distributions are considered in the analyses reported in the UFSAR. The pressurized water reactor (PWR) and boiling water reactor (BWR) axial source distributions are discussed in UFSAR Section 6.2.3 and provided in Tables 6-30 and 6-31.

The source term is computed using ORIGEN-ARP for the entire fuel region for the average fuel assembly burnup, and the axial source distribution is applied to this source term. Because of the non-linear nature of the neutron source variation with burnup, the neutron source magnitude computed by ORIGEN-ARP is scaled by 1.215 and 1.232 for PWR and BWR fuels, respectively, to account for the burnup profile. See UFSAR Section 6.2.3 for a more comprehensive discussion.

Application Impact:

No changes as a result of this RAI.

RAI 6-10:

Provide information on how the ORIGEN-ARP data libraries were collapsed from ENDF/B-VII 238-group cross section library or correct the statement and clearly state how the ORIGEN/ARP data are generated.

In Section 6.2.3 of Revision 1 of the SAR for the NUHOMS EOS system, the applicant states *"Prior to using OR/GEN-ARP, detailed two-dimensional models of the design basis PWR and BWR FAs are developed in TRITON using the FA design data in Chapter 2. TRITON is used to generate OR/GEN-ARP data libraries as a function of burnup and enrichment. These libraries are collapsed from the ENDFIB-VII 238-group cross section library and are used by ORIGENARP to compute the source terms."* However, the staff cannot find the ENDF/B-VII-238 cross section library from the National Nuclear Data Center. The staff's understanding is that the ORIGEN-ARP data libraries are just lookup tables generated by TRITON or SAS2H (in the earlier versions). The ORIGEN/ARP data library contains spent fuel related data and is not the cross section collapsed from ENDF/B-VII 238-group cross section library as stated in the SAR. Also, the staff's understanding is that the ORIGEN/ARP data library is assembly type and cooling time dependent.

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.236(d).

RESPONSE TO RAI 6-10:

The ORIGEN-ARP data libraries are generated using the standard method described in the SCALE6 user's manual. The ENDF/B-VII cross section library is included with the SCALE6 package ("v7-238" is the library name in the manual). UFSAR Section 6.2.1 has been modified to clarify that the ENDF/B-VII 238 group cross section library is used in the TRITON inputs. The ORIGEN-ARP data libraries are generated by TRITON, although it is not correct to say that these data libraries are simply "collapsed" from the ENDF/B-VII 238 group cross section library. Section 6.2.1 has been modified to state that the ENDF/B-VII 238 group cross section library (v7-238) is used in the TRITON inputs and the ORIGEN-ARP libraries are generated by TRITON.

Application Impact:

UFSAR Section 6.2.1 has been revised as described in the response.

Proprietary Information on Pages 34 and 35
Withheld Pursuant to 10 CFR 2.390

RAI 6-12:

Justify that the method used to develop source terms of the intact fuel is appropriate for developing source terms of failed fuel.

On Page 6-9 of Amendment 1 Revision 2 of the SAR, the applicant states: *"The methodology for developing damaged/failed fuel source terms is the same as used for developing intact fuel source terms."* However, it is not clear why the method used for developing source terms for intact fuel can be used to develop source terms for intact fuel. While the failed fuel might be irradiated at the same irradiation conditions as intact fuel in the reactor, it has lost its geometry after failure and so do the source terms. The geometry change of the source terms will make the source distributions in the cask very different from that of the intact fuel. As such, it is not clear why the method used for determining the source terms for intact fuel, specifically the geometric form, can be used for developing source terms of failed fuel.

The staff needs this information to determine if the NUHOMS EOS dry cask storage system design meets the regulatory requirement of 10 CFR 72.236(d).

RESPONSE TO RAI 6-12:

The source terms (gammas/s and neutron/s) are developed in UFSAR Section 6.2.2, PWR and BWR Source Terms. Section 6.2.2 is only concerned with generation of the source terms using ORIGEN-ARP. The fuel is undamaged while in the reactor. Reconfiguration of damaged or failed fuel is addressed in UFSAR Section 6.3.2, MCNP Model Geometry for the EOS-TC. When fuel reconfigures, the total undamaged fuel source term (gammas/s and neutron/s) remains the same.

UFSAR Section 6.2.2 has been modified to clarify that the ORIGEN-ARP methodology is the same for intact, damaged, and failed fuel.

Justification of the geometric form considered for damaged and failed fuel is addressed as part of the RAI 6-14 response.

Application Impact:

UFSAR Section 6.2.2 has been revised as described in the response.

Proprietary Information on Pages 37 through 41
Withheld Pursuant to 10 CFR 2.390

RAI 6-16:

Explain in detail how an HLZC (heat load zone configuration) is determined to be bounding for the EOS-TC (EOS Transfer Cask) dose rate.

On Page 6-9 of Amendment 1 Revision 2 of the SAR for the NUHOMS EOS system, the applicant states: *"The bounding HLZCs are used for dose rate analysis. Dose rates are generally larger for higher heat loads, and radial dose rates are dominated by fuel in the peripheral regions. For BWR fuel, it is determined by inspection that HLZC 1 is bounding for the EOS-TC1251135 and HLZC 2 is bounding for the EOS-TC108. For PWR fuel, it is also determined by inspection that HLZC 2 is bounding for the EOS-TC108."* The SAR provides no specific information on how the "inspection" is done.

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.236(d).

RESPONSE TO RAI 6-16:

A detailed discussion has been added to UFSAR Section 6.2.2 to explain how the bounding HLZCs were selected.

Application Impact:

UFSAR Section 6.2.2 has been revised as described in the response.

Proprietary Information on Pages 43 through 46
Withheld Pursuant to 10 CFR 2.390

Criticality RAIs

RAI 7-1:

Clarify Table 4 of the proposed Technical Specifications (TS) to clearly state which basket types are used for damaged/failed fuel.

Table 4 of the TS shows fuel loading parameters for damaged/failed fuel for all basket types. This is contradictory with the statements in the SAR and analyses in the SAR that state that damaged/failed fuel is only allowed for Basket Type 4. The applicant needs to provide justification to support the proposed TS Table 4 or clarify and revise the proposed TS if necessary to clearly state the basket types where damaged/failed fuel is allowed consistent with the SAR.

This information is needed in conjunction with 10 CFR 72.236(a).

RESPONSE TO RAI 7-1:

Basket types A and B are changed to A4L and B4L, respectively, in Table 4 of the TS and in UFSAR Table 7-51 because damaged/failed fuels are only allowed in the basket type 4L. Moreover, a note is added on Page 7-1 of Chapter 7 to clarify that damaged and failed fuels can only be loaded in basket types A4L and B4L. These changes do not affect the enrichment results for the EOS-37PTH DSC damaged/failed fuels but ensure consistency with the system configurations for the EOS-HSM and HSM-MX systems shown in Table 1-2 of Chapter 1.

Note (2) in Table 7-51 has been changed to (1) as an editorial correction.

Application Impact:

UFSAR Chapter 7, Section 7 and Table 7-51 have been revised as described in the response.

TS Table 4 has been revised as described in the response.

RAI 7-2:

Confirm that the cross sections used with the KENO V.a code for evaluating criticality safety are the 44-group ENDF/B-V.

The changed pages of the SAR do not state which cross sections were used with the KENO V.a code when performing damaged/failed fuel and fuel debris analyses. The staff requests that the applicant confirm the cross sections used are the same as that used for performing the benchmarking evaluation, 44-group ENDF/B-V.

The staff needs to review the references so that it may determine compliance with the criticality safety regulations in 10 CFR 72.124 and 72.236(c).

RESPONSE TO RAI 7-2:

The 44-group cross section library built into the SCALE 6.0 system and based on the ENDF/B-V data is used for the EOS-37PTH DSC damaged/failed fuels analyses. This library is the same as that used for the EOS-37PTH DSC intact fuels analyses and benchmarking evaluation in Chapter 7.

Application Impact:

No changes as a result of this RAI.

Proprietary Information on Pages 49 through 51
Withheld Pursuant to 10 CFR 2.390

RAI 7-5:

Provide justification for changing the action to "remove all fuel assemblies from DSC" to "24 hours" when LCO 3.2.1 on soluble boron concentration cannot be met.

The minimum soluble boron concentration is used to ensure the EOS-37PTH is subcritical when loading within the spent fuel pool. LCO 3.2.10f the proposed Amendment 1 Revision 2 Technical Specifications provides actions for the licensee to take when the minimum soluble boron concentration cannot be met. One of these actions is to remove all fuel assemblies from the DSC. The current LCO states that this must be done immediately. The applicant has proposed to change this to 24 hours. The staff requests that the applicant justify the amount of time it has selected to complete this action.

The staff needs to review the references so that it may determine compliance with the criticality safety regulations in 10 CFR 72.124 and 72.236(c).

RESPONSE TO RAI 7-5:

The intent was not to change the immediacy of removing the fuel assemblies from the DSC in case the soluble boron concentration limit is not met, but to put a realistic completion time for the removing. However, because it is a matter of fact that all the fuel assemblies cannot be removed at the same time, the "24 hours" are changed back to "immediately" to insist on the urgency of action.

Application Impact:

TS Section 3.2.1 has been revised as described in the response.

Material RAIs

RAI 8-1:

Provide additional information that defines the functional characteristics that determines whether control components that are not listed in the updated final safety analysis report (UFSAR) Section 2.2.1 are authorized for storage in the EOS-37PTH DSC.

UFSAR Section 2.2.1 of the application includes a paragraph that states:

> *Control components not explicitly listed herein, but that meet the definition provided above and have similar functional characteristics as those listed above, are also authorized within the DSC.*

UFSAR Section 2.2.1 provides a detailed description of the specifically listed control components that includes materials of construction. These materials in the specifically listed control components are consistent with the description in NUREG 1536 Revision 1 Section 8.4.8.2 which were found to be satisfactory for the evaluation of galvanic/corrosive reactions. It is not clear from the description in UFSAR Section 2.2.1 if the "functional characteristics" includes consideration of the potential for galvanic or corrosive reactions during dry storage loading operations.

This information is needed to determine compliance with 10 CFR 72.236(a) and (g).

RESPONSE TO RAI 8-1:

The paragraph from UFSAR Section 2.2.1 cited in the RAI has been revised completely for clarity. The intention is that the limiting characteristics are:

1. Materials exposed to the pool water are limited to zirconium alloys, nickel alloys, and stainless steels.

2. Radiological and thermal limits are not exceeded.

As a result of this change, the Technical Specifications (TS) Section 1.1 definition for "Control Components" has been modified to include these limiting characteristics.

Weight limits and dimensional limits of the DSC are not exceeded

Application Impact:

UFSAR Section 2.2.1 and TS Section 1.1 have been revised as described in the response.

Proprietary Information on Pages 54 through 63
Withheld Pursuant to 10 CFR 2.390

RAI 8-3:

Clarify the maximum normal and off-normal cladding temperature limits for damaged fuel assemblies. UFSAR Section 4.2 states:

> *For intact fuel assemblies, a maximum fuel cladding temperature limit of 400 °C (752 °F) has been established for normal conditions of storage and for short-term storage operations such as transfer and vacuum drying [4-1]. During off-normal storage and accident conditions, the fuel cladding temperature limit is 570 °C (1058 °F) [4-1].*

Also, UFSAR Section 2.2.1 states:

> *The structural analysis for damaged fuel cladding described in Chapter 3 demonstrates that the cladding does not undergo additional degradation under normal and off-normal conditions of storage.*

The staff note that UFSAR Sections, 2.2.1, 3.9.6.7 and 4.2 do not include or reference the maximum cladding temperature for damaged fuel. Because the analysis in the USFAR relies on no additional degradation for damaged fuel under normal and off-normal conditions, the damaged fuel cladding temperature limits are necessary.

This information is needed to determine compliance with 10 CFR 72.236(b), (g) and (h).

RESPONSE TO RAI 8-3:

The phrase "For intact fuel assemblies" was incorrectly added to the second bullet of UFSAR Section 4.2. All other locations in the UFSAR refer only to "fuel cladding temperature limits" without further qualification. The intention is that the same temperature limits are applied to damaged and intact fuel cladding.

The added phrase has been deleted.

Application Impact:

UFSAR Section 4.2 has been revised as described in the response.

Proprietary Information on Pages 65 and 66
Withheld Pursuant to 10 CFR 2.390

RAI 8-5:

Provide the ASTM Standard number for reference A.8-9 ASTM International, "Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel," Latest Edition. It appears from the context of the reference and the title of Table A.8-2 that this should be ASTM A572.

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

RESPONSE TO RAI 8-5:

Reference A.8-9 in the UFSAR Section A.8.7 has been modified to indicate the ASTM Standard number as ASTM A572/A572M.

Application Impact:

UFSAR Section A.8.7 has been revised as described in the response.

RAI 8-6:

Provide the following additional information for UFSAR Tables A.8-2, A.8-3 and A.8-4 which apply to ASTM A572 Grade 50, ASTM A992 Grade 50, and ASTM A588 steels respectively:

1. Justify the methodology used to estimate the mechanical properties of these steels atelevated temperatures.

   There are several established methodologies used to estimate the elevated temperature mechanical properties of structural steel. Sief et al., (2016) reviewed elevated temperature properties for structural steels and compared the estimated values from several models to actual data for the elastic modulus, yield strength and tensile strength (NIST Technical Note 1907 Figures 2-3, 2-4 and 2-6 respectively). Sief et al., (2016) showed significant variations in the mechanical properties of structural steels as well as variations in the predicted values of models used to estimate the mechanical properties at elevated temperatures.

   Aziz and Kodur (2016) also showed significant differences between predicted values and actual measured values of yield strength and elastic modulus for ASTM A572 Grade 50 at elevated temperatures.

2. Provide allowable stress values for these materials as a function of temperature, a technical basis for the determination of the allowable stresses and an analysis showing that the actual stresses do not exceed the allowable stresses.

   Tables A.8-2, A.8-3 and A.8-4 for ASTM A572 Grade 50, ASTM A992 Grade 50, and ASTM A588 steels, respectively, contain information on the predicted values of yield and tensile stresses and elastic modulus. Allowable stresses for these materials are not provided and the analyses conducted do not include an assessment of the actual stresses compared to the allowable stresses as a function of temperature.

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

RESPONSE TO RAI 8-6:

Response to Part 1

As shown in UFSAR Table A.8-1, ASTM A572 Grade 50, ASTM A992 Grade 50, and ASTM A588 steels are used for the HSM-MX DSC support pedestal/stop plate, DSC support pedestal, and axial retainer rod, respectively. As indicated in the notes for UFSAR Tables A.8-2 and A.8-3, the mechanical properties at elevated temperatures for ASTM A572 Grade 50 and ASTM A992 Grade 50 steels are calculated using the rate of reduction provided in UFSAR Reference A.8-8 [1]. The rate of reduction was applied to the room temperature values of the yield and ultimate strength provided in the respective ASTM specification for ASTM A572 Grade 50 and ASTM A992 Grade 50. Similarly, the rate of reduction was applied to the modulus of elasticity at room temperature provided in the ASME BPVC, Section II, Part D [5]. The notes for UFSAR Table A.8-4 indicate that the temperature-dependent properties for the yield and ultimate strength for ASTM A588 steel are based on the rate of reduction for ASTM A36 steel, using the room temperature properties at 70 °F provided in ASTM A588 as the basis. The modulus of elasticity for ASTM A588 is taken from ASME BPVC, Section II, Part D [5] for carbon steels with $C \leq 0.3\%$.

Figures RAI 8-6-1, RAI 8-6-2, and RAI 8-6-3 show the temperature-dependent reduction factors (for temperatures up to 400 °F) of the following four materials for the elastic modulus (E), yield strength (F_y), and tensile strength (F_u), respectively:

- Temperature-dependent reduction factors for ASTM A572 Grade 50 and ASTM A992 Grade 50 (based on UFSAR Reference A.8-8 [1]),
- Temperature-dependent reduction factors for ASTM A588 (based on ASTM A36 steel),
- Proposed temperature-dependent reduction factors from NIST Technical Note 1907 (Equations 2.2, 2.4, and 2.14 of [2] for E, F_y, and F_u, respectively), and
- Proposed temperature-dependent reduction factors by Aziz and Kodur [3] (Equations 1, 2, and 3 of [3] for F_y, F_u, and E, respectively).

Figure RAI 8-6-1 shows that the temperature-dependent values of modulus of elasticity used in the UFSAR for A572/A992 and A588 steels are in very good agreement with those from NIST Technical Note 1907 [2], but greater than those from Aziz and Kodur [3] throughout the entire temperature range. Figure RAI 8-6-2 shows that the temperature-dependent values of yield strength used in the UFSAR for A572/A992 and A588 steels are slightly less than those from NIST [2] and Aziz and Kodur [3] for the entire temperature range, with the exception that the UFSAR properties for A588 are slightly greater than those from NIST [2] for a low temperature range (< 120 °F). Figure RAI 8-6-3 shows that the temperature-dependent values of tensile strength used in the UFSAR for A572/A992 and A588 steels are in good agreement with those from NIST [2] and Aziz and Kodur [3] for the entire temperature range.

Structural evaluations of the HSM-MX DSC support pedestal/stop plate and axial retainer rod use the tensile, compressive, and shear strengths of the materials. The material properties are evaluated at 250 °F, which is the bounding temperature for the HSM-MX DSC support pedestal/stop plate and axial retainer rod, for the normal and off-normal conditions.

The tensile and shear strengths rely on the yield strength. As shown in Figure RAI 8-6-2, the yield strengths of the A572/A992 and A588 steels used in the UFSAR are less than those proposed by NIST [2] and Aziz and Kodur [3], except for the temperature range below 120 °F, where the yield strength of the A588 steel used in the UFSAR is greater. However, this exceedance does not affect the structural evaluation, because the yield strengths proposed by NIST [2] and Aziz and Kodur [3] in this low temperature range are higher than the UFSAR yield strength at 250 °F. Therefore, the mechanical property values used in the UFSAR for the tensile and shear strengths are conservative.

The compressive strength relies on both the yield strength and the modulus of elasticity. According to the AISC Manual of Steel Construction [4], the critical stress F_{cr} for compressive strength is:

$$F_{cr} = \left[0.658^{\frac{F_y}{F_e}}\right] F_y$$

where $F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$ and $\frac{KL}{r}$ is the effective slenderness ratio. As shown in Figure RAI 8-6-4, the critical stress of the A572/A992 steel (for E = 29,000 ksi at 70 °F) for $\frac{KL}{r}$ of 34.4, which was used in the evaluation of the HSM-MX DSC support pedestal, is less than those proposed by NIST [2] and Aziz and Kodur [3] for the entire temperature range. Also, as shown in Figure RAI 8-6-5, the critical stress of the A588 steel for $\frac{KL}{r}$ of 36.7, which was used in the evaluation of the HSM-MX axial retainer rod, is less than those proposed by NIST [2] and Aziz and Kodur [3] for the entire temperature range, except for the temperature range below 120 °F, where the critical stress of the A588 steel used to derive the compressive strength in UFSAR Section A.3.9.4.10.4 is greater. However, this exceedance does not affect the structural evaluation because the critical stresses proposed by NIST [2] and Aziz and Kodur [3] in this low temperature range are higher than the UFSAR critical stress at 250 °F. Therefore, the mechanical property values used in the UFSAR for the compressive strength are conservative.

The discussion presented above demonstrates that the mechanical properties for the ASTM A572 Grade 50, ASTM A992 Grade 50, and ASTM A588 steels presented in UFSAR Tables A.8-2, A.8-3, and A.8-4 are conservative when compared with the properties proposed in the recent publications ([2] and [3]). Therefore, the methodologies used to estimate these properties are appropriate.

Response to Part 2

Figure RAI 8-6-6 shows the temperature-dependent allowable tensile stress, allowable compressive stress, and allowable shear stress for A572/A992 steels, where nominal allowable stresses (F_y for tensile, F_{cr} for compressive (for E = 29,000 ksi at 70 °F and $\frac{KL}{r}$ of 34.4), and $0.6F_y$ for shear) without safety factors are presented. Figure RAI 8-6-7 shows the same temperature-dependent allowable stresses for the A588 steel (F_y for tensile, F_{cr} for compressive (for E = 29,400 ksi at 70 °F and $\frac{KL}{r}$ of 36.7), and $0.6F_y$ for shear). Since the allowable tensile stresses and allowable shear stresses are directly related to the yield strength, their temperature-dependent variations shown in Figures RAI 8-6-6 and RAI 8-6-7 are exactly the same as in UFSAR Tables A.8-2 through A.8-4. As demonstrated in the response to Part 1 of this RAI, these properties are based on conservative estimations of the mechanical properties for the A572/A992 and A588 steels at elevated temperatures.

Structural evaluation of the DSC support pedestal/stop plate (A572/A992): The maximum load in the DSC longitudinal direction and the maximum compressive load on the DSC support are 135.3 kips and 156.5 kips, respectively. The evaluations shown below for the DSC support Option A bound the Option B evaluations.

- Shear of the rear DSC support stop plate: The shear strength based on the yield strength of 45 ksi at 250 °F is 249.0 kips > 135.3 kips. (Therefore, this is acceptable.)

- Connection between the stop plate and top flange of the W-beam: The connection strength based on the yield strength of 45 ksi at 250 °F is 164.5 kips > 135.3 kips. (Therefore, this is acceptable.)

- Web shear in the W-beam: The shear strength based on the yield strength of 45 ksi at 250 °F is 157.3 kips > 135.3 kips. (Therefore, this is acceptable.)

- Compression of the W-beam: The compressive strength based on the yield strength of 45 ksi and modulus of elasticity of 28,112 ksi is 156.9 kips > 156.5 kips. (Therefore, this is acceptable.)

Structural evaluation of the axial retainer rod (A588): The maximum load in the DSC longitudinal direction is 270.5 kips.

- Compression of the axial retainer rod: The compressive strength based on the yield strength of 45 ksi and modulus of elasticity of 28,550 ksi is 280.3 kips > 270.5 kips. (Therefore, this is acceptable.)

References:

1. Mark Fintel, "Handbook of Concrete Engineering," Second Edition, September 1985.

2. NIST Technical Note 1907, "Temperature-Dependent Material Modeling for Structural Steels: Formulation and Application."

3. E. M. Aziz and V. K. Kodur, "Effect of temperature and cooling regime on mechanical properties of high-strength low-alloy steel," Fire and Materials, Volume 40, pp. 926-939, 2016.

4. American Institute of Steel Construction, "AISC Manual of Steel Construction," 13th Edition or later.

5. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, 2010 Edition with 2011 Addenda.

Application Impact:

No changes as a result of this RAI.

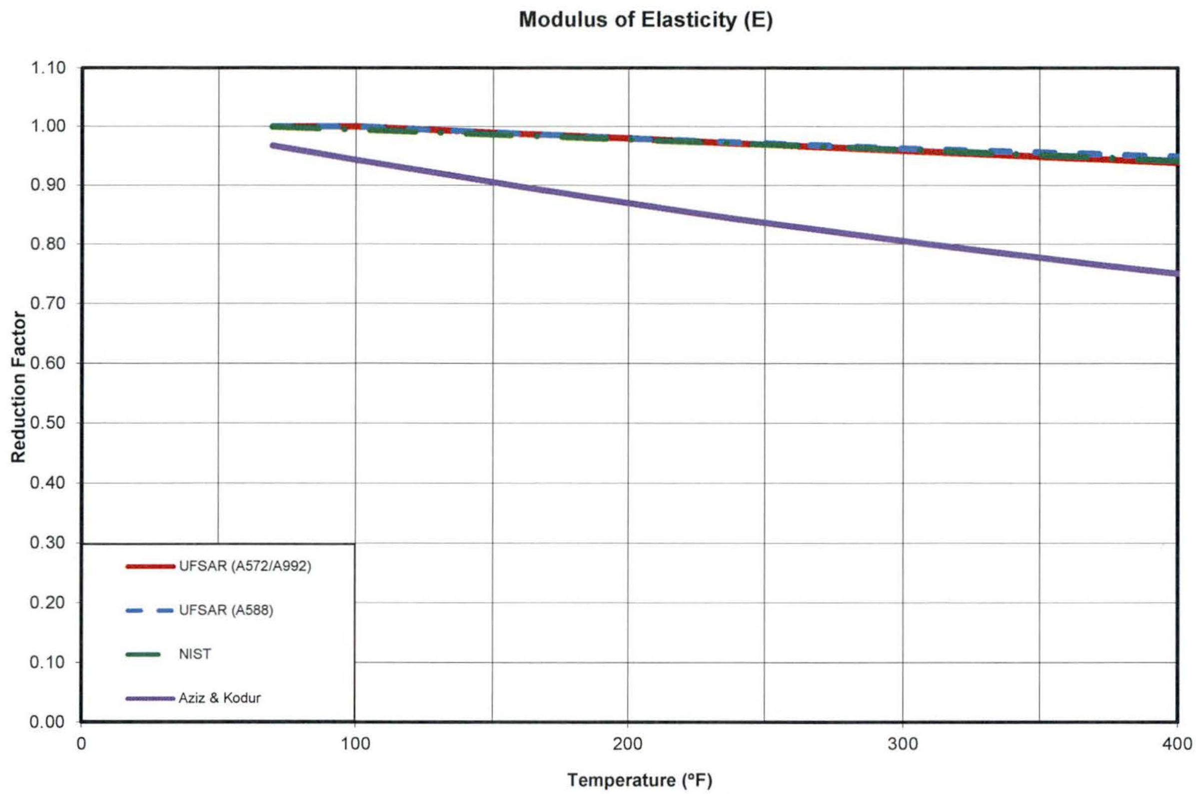

Figure RAI 8-6-1
Reduction factors for modulus of elasticity at elevated temperatures

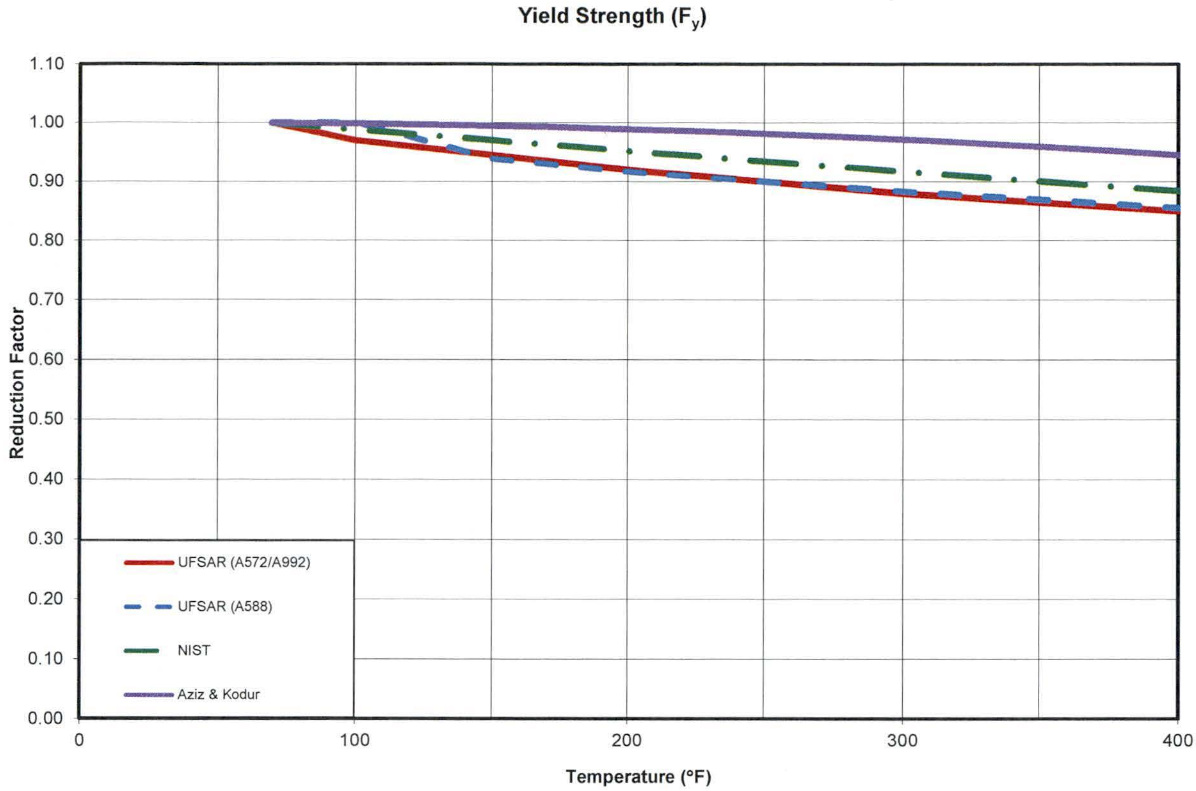

Figure RAI 8-6-2
Reduction factors for yield strength at elevated temperatures

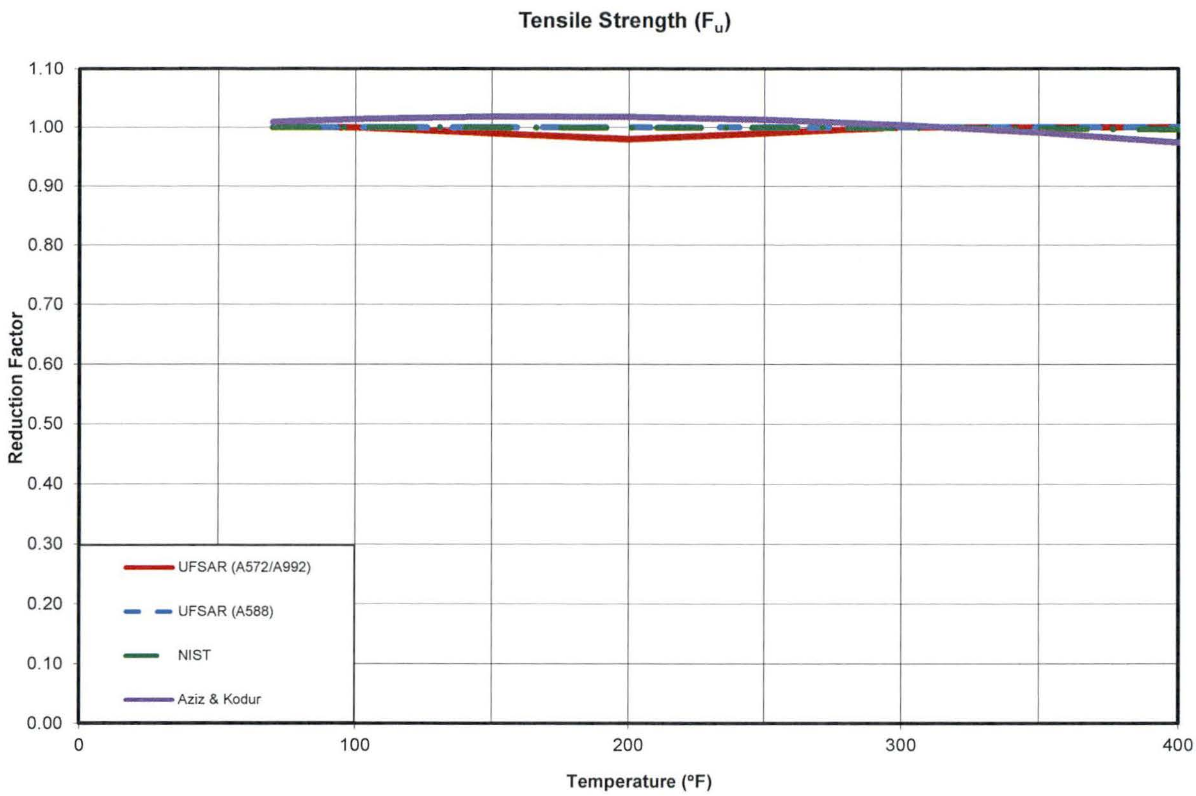

Figure RAI 8-6-3
Reduction factors for tensile strength at elevated temperatures

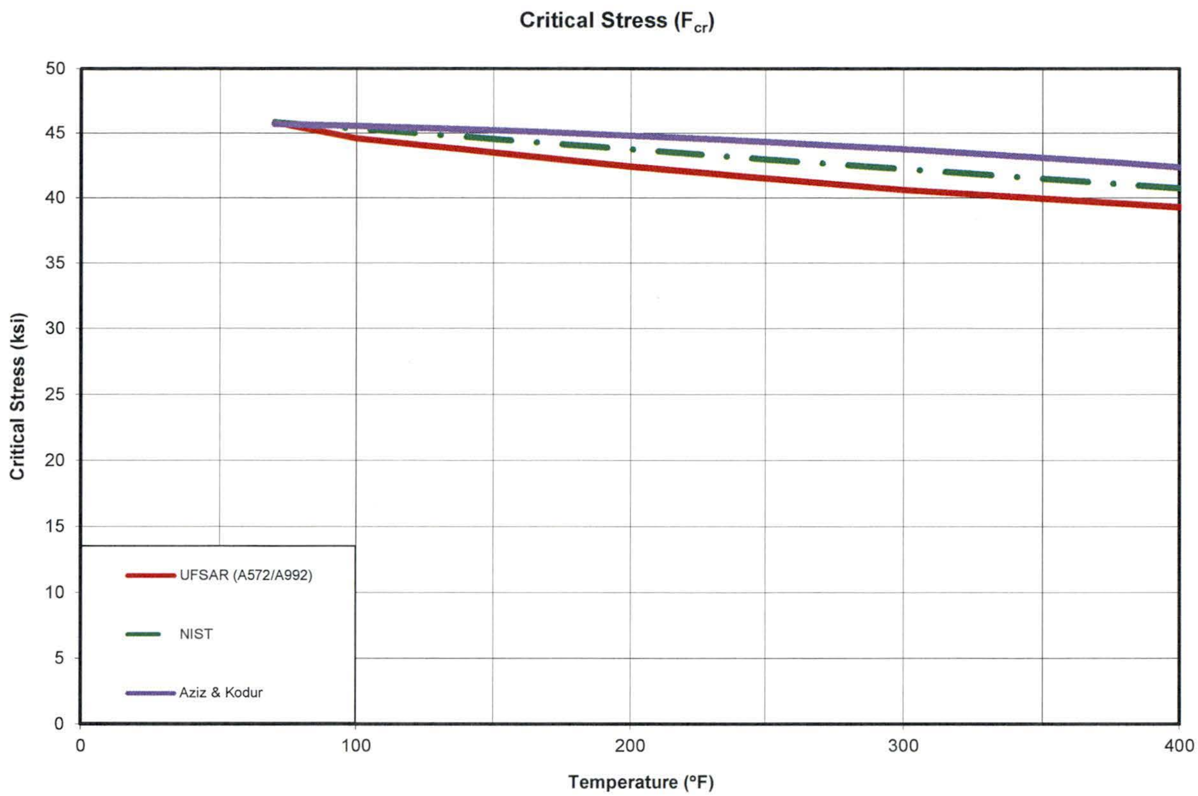

Figure RAI 8-6-4
Critical stress at elevated temperatures (A572/A992)

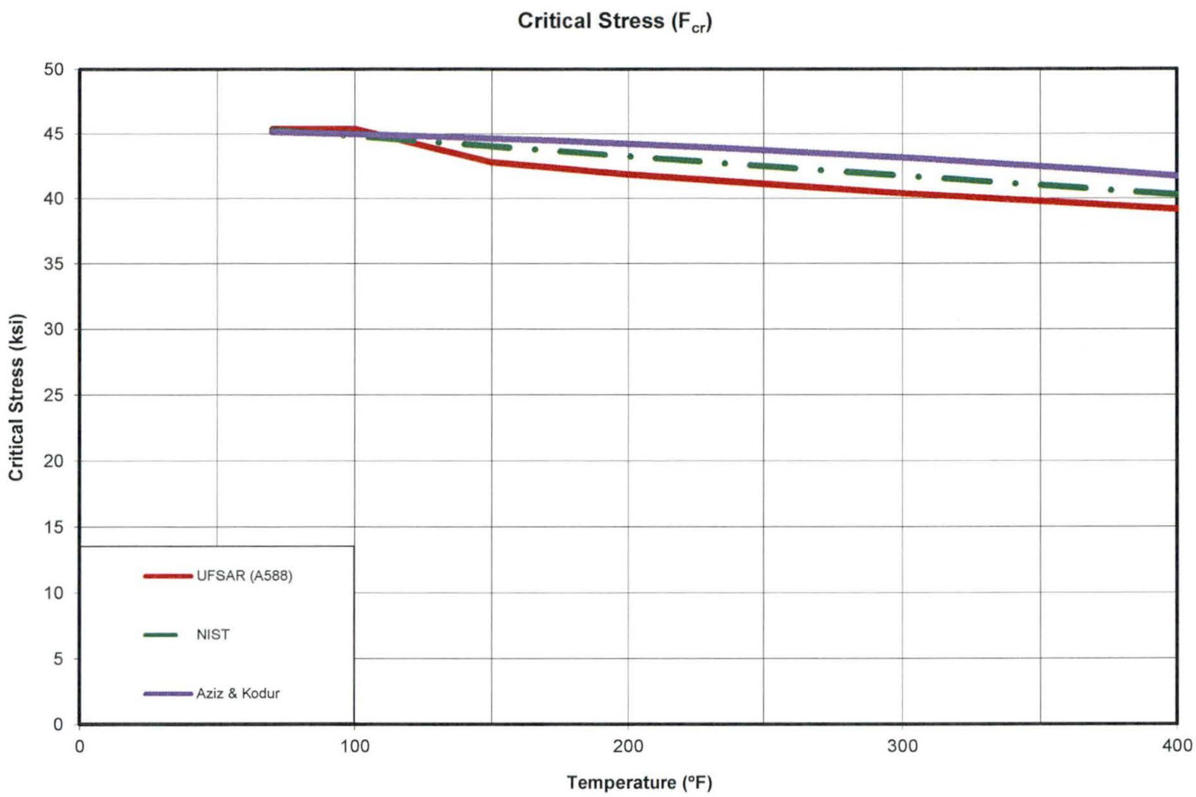

Figure RAI 8-6-5
Critical stress at elevated temperatures (A588)

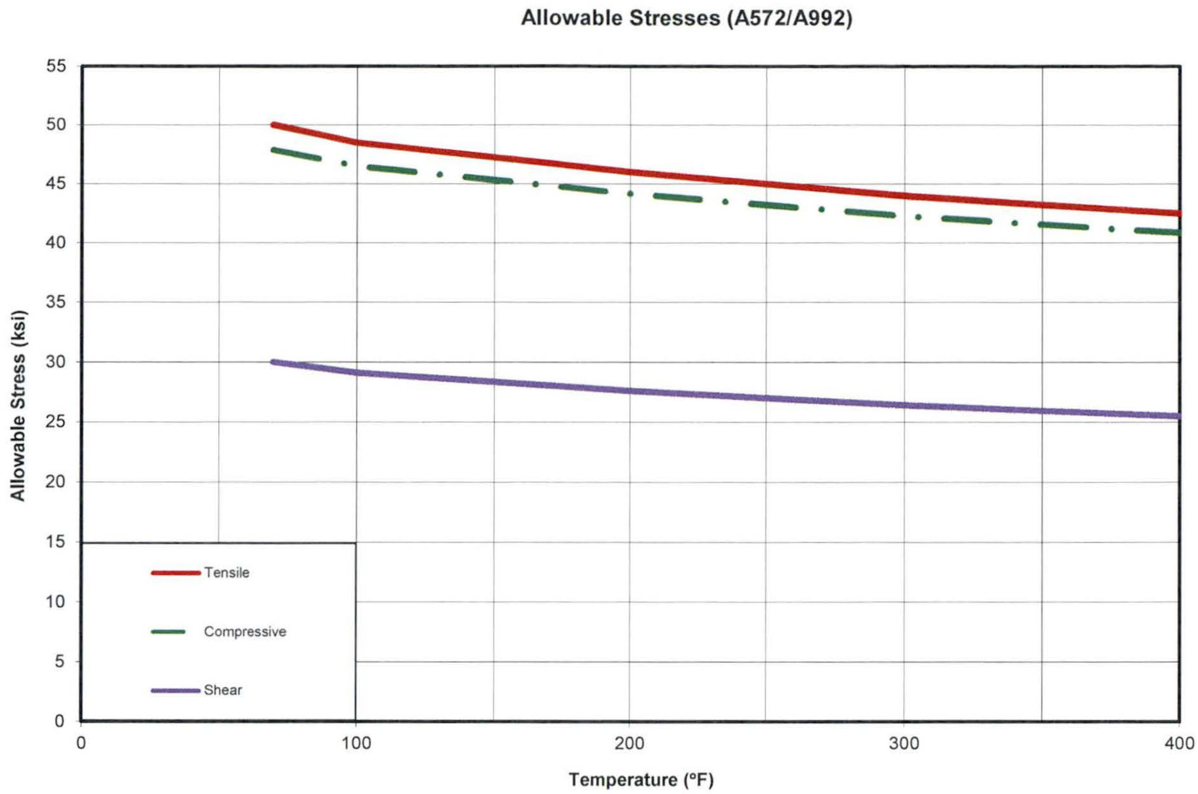

Figure RAI 8-6-6
Tensile, compressive, and shear allowable stresses at elevated temperatures (A572/A992)

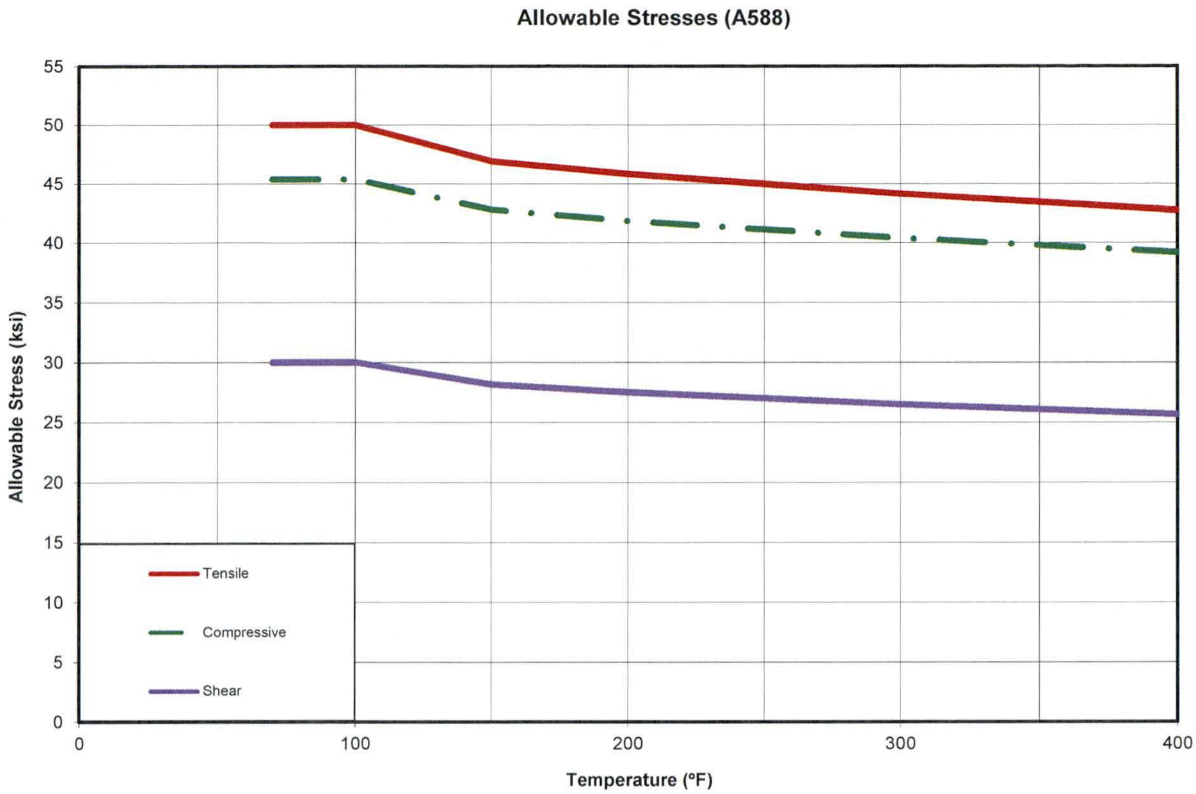

Figure RAI 8-6-7
Tensile, compressive, and shear allowable stresses at elevated temperatures (A588)

RAI 8-7:

Provide allowable stress values for ASTM A829 Gr 4130, AMS 6345 SAE 4130 and other HSLA steels as a function of temperature, a technical basis for the determination of the allowable stresses and an analysis showing that the actual stresses do not exceed the allowable stresses. ASTM A829 Gr 4130 or AMS 6345 SAE 4130 and other HSLA steels are identified in UFSAR Section 10.1.7. UFSAR Table 8-10 contains information on the predicted values of yield and tensile stresses and elastic modulus. Allowable stresses for these materials are not provided and the analyses conducted do not include an assessment of the actual stresses compared to the allowable stresses as a function of temperature.

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

RESPONSE TO RAI 8-7:

UFSAR Table 8-10 provides the allowable stress values for ASTM A829 Gr 4130, AMS 6345 SAE 4130 and other HSLA steels as a function of temperature based on the initial scoping analysis, which provides a yield stress (S_y) value of 80 ksi @ 500 °F that would provide sufficient margin when evaluating the design as described in Appendix.3.9.2. Based on the yield stress value of 80 ksi @ 500 °F, the rate of reduction provided in Figure 2.3.1.1.2 of military handbook reference document, MIL-HDBK-5J, "Metallic Materials and Elements for Aerospace Vehicle Structures," U.S. Department of Defense Handbook, 31 January 2003, was utilized to derive temperature-dependent properties for the yield stress.

Similarly for Modulus of Elasticity (E), the value of 29.0 E +06 @ 70 °F is taken from Table 2.3.1 of military handbook reference document, MIL-HDBK-5J, "Metallic Materials and Elements for Aerospace Vehicle Structures," U.S. Department of Defense Handbook, 31 January 2003. The rate of reduction from Figure 2.3.1.1.4 was utilized to derive the temperature-dependent properties for the Modulus of Elasticity.

The values for ultimate stress (S_u) are calculated conservatively to be low, assuming 1.05 * yield stress (S_y).

To validate the values provided in UFSAR Table 8-10, material testing was performed to meet or exceed the allowable limits as provided in reference Document No. 51-9230070, "Evaluating Optimum Tempering Temperature for AISI 4130 to achieve desired strength and toughness properties." A copy of this proprietary document is provided as Enclosure 14.

Reference Document No. 51-9230070, Table 5-1 provides the mean and lower bound yield stress values and Table 5-2 provide the mean and lower bound tensile stress values. Based on the material qualification as described in this document, ASTM A829 Gr 4130 or AMS 6345 SAE 4130, the lower bound yield and ultimate values (tested @ 70 °F) are 103.6 ksi and 123.1 ksi, respectively, as discussed in UFSAR Section 10.1.7. These test values exceed the design basis allowable values of yield and ultimate stress of 96.4 ksi and 101.2 ksi @ 70 °F, respectively, as provided in Table 8-10.

The structural analyses were performed in Appendix 3.9.2 based on the material properties provided in UFSAR Table 8-10 and results show that the calculated stresses meet these material allowable limits. To additionally ensure that these values are met, the material procured to fabricate the basket shall meet or exceed the allowable limits of 103.6 ksi and 123.1 ksi as discussed in in UFSAR Section 10.1.7.

Application Impact:

No changes as a result of this RAI.

Enclosure 14 has been provided as described in the response.

Operating Procedures RAIs

RAI 9-1:

Provide an estimate for the required time to complete each of the steps for loading and unloading as described in the operating procedures.

Chapter 9 of Amendment 1 Revisions of the SAR provides revised operating procedures for loading and unloading the EOS-HSM ISFSI for the new contents (failed fuel, fuel with reduced cooling time, and new loading patterns) and canister designs (i.e., Type 4/5). However, the operating procedures do not include the estimated time for completing each.of the operations. The estimated time to complete each operation is necessary for estimating the exposure to the occupational workers and developing plan for implementation of the ALARA principle.

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.236(d).

RESPONSE TO RAI 9-1:

An evaluation of the occupational exposure is provided in Chapter 11, Table 11-4 for transfer operations for loading the EOS-HSM with the EOS-TC125/135 for the EOS-37PTH DSCs storing the new contents. The occupational exposure dose rates were revised in CoC 1042 Amendment 1, Revision 0 based on the new HLZCs, two-year cooled fuel, and damaged/failed fuel, and changes to Table 11-4 are indicated as such.

Application Impact:

No change as a result of this RAI.

RAI 9-2:

Provide the following information on the fuel spacers identified in UFSAR Amendment 1 Revision 0 Section 9.1.1 Steps 1.b. and 9.b.:

1. Clarify whether the evaluation for adverse impact of the fuel spacers is related to Part 72 activities or Part 71.

   Section 9.1.1 Step 1.b of Amendment 1 Revision 0 of the NUHOMS EOS System UFSAR, states, in part, " ... There are no requirements for fuel spacers under Part 72. Fuel spacers, if used, may be placed below the assembly, above the assembly, or both, and shall be evaluated for any adverse impact." It is unclear whether the adverse impact is in reference to storage or transportation operations.

2. Clarify the use of the term "requirements" in the above mentioned statement in UFSAR Section 9.1.1 Step 1.b and the term "required" in the description provided in UFSAR Section 9.1.1 Step 9.b. Section 9.1.1 Step 9.b of Amendment 1 Revision 0 of the UFSAR states, in part,

   "... verify that the bottom fuel assembly spacers, if required, are present in the fuel cells." It is unclear if the fuel spacers identified on UFSAR pages 9-3 and 9-4 are the same component or if the term "fuel spacers", that may be required, on page 9-4 refers to a different component than the item identified on USFAR page 9-3.

3. Provide drawings with dimensions, allowable manufacturing tolerances, material specifications, quality category and code criteria for the fuel spacers identified in UFSAR Chapter 9 Section 9.1.1.

   The application contains two changes to UFSAR Section 9.1.1 which identify the use of fuel spacers in step 1.b. and step 9.b. Based on the context of the changes in UFSAR Section 9.1.1, it appears that there is more than one type of spacer that may be used in the EOS DSCs. The drawings provided by the applicant do not appear to include specific information on the fuel spacers identified in Section 9.1.1 Steps 1.b. and 9.b.

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.236(a), (b), (c), (d), (f) and (h).

RESPONSE TO RAI 9-2:

Response to Part 1:

The EOS DSCs are designed to be variable in length as to minimize the need for fuel spacers. However, the need for fuel spacers arises when various types of control components are stored, such that even within a DSC, not all fuel assemblies are the same length. For the EOS-89BTH, the DSC is sized such that fuel spacers are not needed.

The fuel spacers replace the void at the top or bottom of a fuel assembly to reduce the gap between the fuel assembly and the DSC cavity to mitigate the effect of impact for the drop accidents for transportation under 10 CFR Part 71. Their purpose is to maintain a minimum nominal gap requirement between the fuel and the transport closure lid to avoid adverse effects, including damage to the fuel assembly, rods, or cladding, due to a secondary impact under transport accident conditions. The transport cask is licensed under the 10 CFR Part 71.

Response to Part 2

The clarification provided in the response to RAI 9-2 Part 1, above, has been added to UFSAR Section 9.1.1, Step 1.b.

The fuel spacers referenced in Section 9.1., Step 1.a are the same fuel spacers referenced in Section 9.1.1, Step 9.b. Fuel spacers may be placed below the assembly, above the assembly or both depending on the length of fuel assemblies to be loaded. For consistency, the term "bottom fuel assembly spacers" is revised to state "fuel spacers."

Response to Part 3

There are no requirements for fuel spacers under 10 CFR Part 72. Structural, confinement, thermal, shielding and criticality functions are attributed to the dry shielded canister (DSC) in the UFSAR. The spacers are located inside of the confinement boundary and are variably-sized depending on the site- specific fuel assembly length, control components, cavity length, and accounting for thermal expansion as to not affect the confinement function provided by the DSC shell assembly. Since the spacers provide an improved conduction path and add material for increased shielding at the top or bottom of the fuel assemblies, they do not have any adverse effect on the thermal or shielding functions of the DSC and are consistent with the design basis. Fuel spacers do not perform any structural design functions. They replace the void at the top and bottom of the fuel assembly to reduce the axial gap between the fuel assembly and DSC cavity.

No particular function is attributed to the fuel spacers in the UFSAR; therefore, the drawings for the fuel spacers are not provided in the UFSAR as they are not part of the licensing basis.

Application Impact:

UFSAR Section 9.1.1 has been revised as described in the response.

Radiation Protection RAIs

RAI 11-1:

Revise Chapter 11 of the SAR to provide new annual dose assessments for the general public and occupational workers or provide analyses to demonstrate that there are no changes to the expected radiation exposure to the occupational workers and the real individual at beyond the controlled area boundary with the hotter fuel.

Chapter 11 of Revision 0 of the SAR provides dose assessments for occupational workers and general public. However, there is no revision to these assessments in the Amendment 1 revised SAR pages for the requested new contents (failed fuel, reduced cooling time, new basket designs, new loading patterns, etc.).

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.236(d).

RESPONSE TO RAI 11-1:

The EOS-TC125/135 with EOS-37PTH DSC exposure calculation consistent with intact fuel in HLZC 4 is provided in CoC 1042 Amendment 1, Revision 0, page 11-4, and is shown in detail in Table 11-4. HLZC 4 is new in Amendment 1, and includes the reduced cooling time. The new basket designs have no effect on shielding performance.

The exposure analysis has not been updated in the revised Amendment 1 UFSARs (Revisions 1 and 2) for damaged or failed fuel because the damaged or failed fuel are allowed only in HLZC 6 or 8 in the EOS-TC125/135, and the EOS-TC125/135 with EOS-37PTH DSC exposure calculation is performed for the intact fuel in HLZC 4. A dose rate comparison between the intact fuel in HLZC 4 and the damaged or failed fuel in HLZC 6 or 8 is provided in the revised Amendment 1 UFSARs (Revisions 1 and 2), Section 6.4.3 and Table 6-53a. It is demonstrated that the damaged or failed fuel in HLZC 6 or 8 would result in approximately the same exposure as the intact fuel in HLZC 4.

The offsite dose calculations in SAR Chapter 11 are performed only for the EOS-89BTH DSC. The EOS-89BTH DSC bounds the EOS-37PTH DSC for offsite dose rates. This is stated in Section 11.3.1, and is discussed in more detail as part of the response to RAI 11-2.

Application Impact:

No changes as a result of this RAI.

RAI 11-2:

Provide a revised dose rate versus distance curve or table for the revised NUHOMS EOS storage system design or demonstrate that there is no change in the curve with the new contents and ISFSI configuration.

Chapter 11 of Revision 1 of the SAR provides the dose rate as a function of distance from the ISFSI pad to the controlled area of design basis ISFSI. There are no changes made to Chapter 11 in the Amendment 1 revised SAR pages. Because the amendment requests new contents (failed fuel and reduced cooling time) and new basket designs (Type 4/5) the dose rates around the transfer cask and the HSM module may have changed. Therefore, it is expected that the dose rate versus distance curve would change accordingly.

The staff needs this information to determine if the NUHOMS EOS spent fuel dry cask storage system design meets the regulatory requirement of 10 CFR 72.236(d).

RESPONSE TO RAI 11-2:

The offsite dose calculations in SAR Revision 1 Chapter 11 are performed only for the EOS-89BTH DSC. The EOS-89BTH DSC bounds the EOS-37PTH DSC for offsite dose rates. This is stated in Section 11.3.1. The EOS-89BTH DSC source term has not changed in Amendment 1.

The offsite dose rates computed in the offsite dose calculations are primarily from radiation streaming from the inlet and outlet vents. Inlet and outlet vent dose rates for the EOS-HSM are provided in SAR Revision 1 Section 6.4.4 for the EOS-89BTH DSC and EOS-37PTH DSC (HLZC 4). The inlet vent dose rate is 712 mrem/hr for the EOS-89BTH DSC and only 493 mrem/hr for the EOS-37PTH DSC. Likewise, the outlet vent dose rate is 1903 mrem/hr for the EOS-89BTH DSC and only 1,270 mrem/hr for the EOS-37PTH DSC. Therefore, EOS-89BTH DSC offsite dose rates bound EOS-37PTH DSC offsite dose rates, and offsite dose rates for the EOS-37PTH DSC are not explicitly computed or provided.

Also, as stated in UFSAR Revision 1 Section 6.4.4, the EOS-HSM with the EOS-37PTH DSC with damaged or failed fuel in HLZC 6 would have lower vent dose rates than the analyzed HLZC 4. Therefore, the EOS-89BTH DSC bounds the EOS-37PTH DSC for offsite dose rates, including damaged or failed PWR fuel in HLZC 6.

Application Impact:

No change as a result of this RAI.