**Responses to Request for Additional Information**
**Certificate of Compliance No. 1032**
**Docket No. 72-1032**
**HI-STORM FW Storage System**
**Amendment No. 6**

## Structural Evaluation

### RAI-3-1

Provide the following information:

a) an evaluation of a drop accident in all credible bounding orientations (e.g., a side drop or corner drop orientation) for assessing the handling accident conditions for the HI-STORM FW cask and the HI-TRAC VW transfer cask, and a justification of why the analyzed orientations are bounding; or

b) a justification for how other drop orientations are bounded by the existing end drop analysis.

As discussed in NUREG-2215, "Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities," the review of a safety analysis report (SAR) should ensure that an applicant evaluated all credible potential orientations of the cask during cask transfer and handling drops. It is not clear to the staff how the vertical end drop analyzed in Holtec Report HI-2200647, "Analysis of the Postulated Drop and Missile Impact Events for the Loaded HI-STORM FW, Version E, Cask and the Loaded HI-TRAC VW System," considers all credible potential orientations of the cask for a handling accident.

This information is needed to determine compliance with the regulatory requirements in 10 CFR 72.236 (b), (c), and (l).

### Holtec Response

1. When performing the lifting operations, the loaded HI-STORM FW overpack is lifted and handled in the vertical orientation at all times. And the maximum lift height of the HI-STORM is limited to 11 inches above the ground. Since the lifted height of the HI-STORM above the ground is very small relative to the cask overall dimensions (i.e., the cask height and the base diameter), it mitigates the HI-STORM from significant angular rotation with respect to the horizontal ground (or target) in the event of a lifting equipment failure. For a small drop height of 11 in., in case of an end slapdown condition, the maximum cask base angle w.r.t the ground is computed as 4.5°. This angle is very small and will not have any safety related consequence when compared to the vertical drop by 11 in. Moreover, these drops are not credible given that the cask lifting/handling device and the cask interface parts are qualified to meet the increased allowable limits per NUREG-0612.

2. Based on the evaluations from Holtec Report HI-2200647, HI-STORM FW FSAR, and the HI-STORM 100 FSAR, it is understood that the fuel rod loading is more critical under axial buckling than the lateral loading. Understandably, the buckling of the fuel rod assembly will be more pronounced in a pure vertical end drop orientation as compared to any other drop orientation. The initial trajectory and the long axis of the fuel assembly aligned in the vertical orientation is conservative since the kinetic energy

of dropped fuel will be focused on the minimized fuel impact area. This assumption is also reasonable because it is consistent with the configuration of the fuel assembly while it is being moved

3. The HI-STORM FW angular drops, although not credible, if postulated may result in local deformation of the target (i.e., the concrete pad) and the HI-STORM outer shell and baseplate localized in the vicinity of direct impact. Moreover, the HI-STORM cask angular drop through appreciably small height (as noted in # 1 above) will be bounded by the non-mechanistic tip-over analysis of the HI-STORM cask documented in Holtec Report HI-2200647. Due to the small drop height (< 11 in.) in conjunction with localized (limited) area participation in impact, the cask deceleration “g” load on the cask and its internals from the angular drops is expected to be significantly lower than those realized from pure vertical drop and non-mechanistic tipover event. The safety results for the MPC confinement boundary and the critical HI-STORM cask components will therefore be bounded by the HI-STORM cask vertical drop and the non-mechanistic tipover event.

Therefore, the HI-STORM cask drop is postulated in the most limiting vertical orientation as documented in Holtec Report HI-2200647.

**RAI-3-2**

Provide an evaluation of the fuel basket, including deflections, to determine if the fuel basket maintains the spent nuclear fuel in a subcritical arrangement under handling accident conditions (considering all credible bounding orientations), and include such evaluation in the design criteria for the handling accident condition.

The structural evaluation of the handling accident condition detailed in Holtec Report HI-2200647 provides a structural analysis of the plastic strains of the fuel basket. However, the evaluation in Holtec Report HI-2200647 does not consider all the design criteria defined for the spent fuel basket defined in Chapter 2 of the SAR (e.g., the maximum deflection defined in the structural design criteria for the fuel basket listed in Table 2.2.11 of the SAR). Additionally, the acceptance criteria for the handling accident condition described in Section 2.2.3(a) of the SAR does not include any criteria for the fuel basket or subcritical arrangement of the spent nuclear fuel.

This information is needed to determine compliance with the regulatory requirements in 10 CFR 72.236(b) and (c).

**Holtec Response**

1. This fuel basket panel is primarily challenged when the cask is oriented horizontally, and the fuel basket panels are subject to significant inertial loading from the fuel during the lateral drop events such as the non-mechanistic tipover event. The fuel basket panel deformation criterion is discussed in Chapter 2 Section 2.2.8 as 0.5% of the basket panel width. Stated differently, the acceptance criteria is defined as the ratio of maximum total basket panel lateral deflection over its width which must be less than 0.005 as specified in Table 2.2.11.

2. The criticality analysis, in Chapter 6 Subsection 6.3.1 of the FSAR, conservatively assumes that 2 adjacent cell walls in each cell are deflected to the maximum extent possible over their entire length and width (i.e., that the cell ID is increased or reduced by 0.5% of the cell width). Similarly, it is assumed for all flux traps that their thickness is reduced by 0.5 mm, or 0.045" for the MPC-37 cells and 0.030" for the MPC-89 cells. For completeness, a reference to Chapter 6 Section 6.3.1 will be added for the panel deflection acceptance criteria noted in Chapter 2.

3. The fuel basket inside the overpack is evaluated in HI-2200647 for the vertical drop orientation. In the vertical drop orientation, it shall be noted that the fuel baskets are subject to inertial (or dynamic) loading from self-weight independent from the stored fuel assemblies. In other words, the fuel baskets are not subject to significant loading from the fuel assemblies during the HI-STORM cask pure vertical end drop. Since there is no lateral loading on the fuel baskets, and the inertial load from the self-weight being insignificant as compared to the weight of the stored fuel assemblies, the basket panel is not subject to lateral deflection under the cask free vertical end drop. Moreover, the HI-STORM vertical end drop analysis documented in HI-2200647 concluded that the fuel basket experiences negligible plastic strain (< 0.0041) which is localized in the bottom elements of the fuel basket (well below the fuel active region). Figure 3.4.54 and Figure 3.4.61 in the FSAR are updated to show the regions of maximum plastic strain. The Figures 7 and 16 in the calculation package HI-2200647 are also updated.

4. Conversely, during the cask non-mechanistic tipover drop event the fuel baskets are subject to increased lateral loading from the fuel assemblies. The HI-STORM FW FSAR establishes the lateral plastic deformation limit for the basket panels in the active fuel region in Table 2.2.11 of the FSAR. And it is demonstrated from the HI-STORM cask tipover analysis, documented in HI-2200647, that the fuel basket plastic deformation is limited in couple of peripheral cells near the top of the basket and beyond the active fuel region. Furthermore, the fuel baskets are considered to be structurally safe since the baskets maintain appropriate spacing between fuel assemblies after the HI-STORM cask tipover event thereby substantiating no criticality consequence subsequent to the HI-STORM cask tipover event.

**RAI-3-3**

Provide the following information:

a) mechanical property data based on physical testing for the materials evaluated using a strain-based approach for the drop accident conditions presented in Holtec Report HI-2200647;

b) failure strains and material flow curves based on this physical testing that consider strain-rate effects, uniform elongation, and triaxiality effects for use in the finite element analysis and structural evaluation of the drop accident conditions presented in Holtec Report HI-2200647; and

c) an updated finite element analysis and structural evaluation of the drop accident conditions presented in Holtec Report HI-2200647 using failure strains and material flow curves based on mechanical property data obtained from physical testing.

Holtec Report HI-2200647 includes a description of the structural evaluation of HI-STORM FW components from the drop accident conditions. This evaluation used a strain-based methodology with strain-based acceptance criteria to determine the structural integrity of important to safety (ITS) components subjected to an 11-inch drop. The applicant calculated true-stress-true-strain data in Appendix B to Holtec Report HI-2200647 and used this data in the analysis of the drop accident for the following materials:

- Metamic,
- Alloy X,
- SA350-LF2,
- SA193-B7,
- SA53,
- SA516-70,
- 304 type stainless steel,
- SA350-LF3,
- SB-637,
- SA-336 f 11,
- SA-240 304 type stainless steel, and
- SA106 grade C.

The methodology used in Appendix B to Holtec Report HI-2200647 to compute material flow curves for the finite element structural analysis and strain-based evaluations follows the Holtec Position Paper DS-307, "Construction of True-Stress-True-Strain Curves for LS-DYNA Simulations." The staff notes that the use of the methodology outlined in this position paper has previously been found inadequate to provide material data for strain-based evaluations, in particular for an evaluation of the ATB 1T transportation package. Specifically, constants used to develop material flow curves have been determined analytically (e.g., constants "K" and "n") without the support of material testing. As discussed in the summary of the November 13, 2018, meeting with Holtec International (ADAMS Accession No. ML18331A184), the staff's position is that these constants should be based on mean test values obtained from material testing. In addition, the applicant needs to supply material flow curves that consider strain-rate effects, uniform elongation, and triaxiality effects if the material is challenged beyond the uniform elongation limit.

The staff notes that strain-based acceptance criteria are specified in the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Non-mandatory Appendices EE and FF. The criteria specified by the applicant is not based on an industry code or standard, but rather a reference that was used in the development of Non-mandatory Appendices EE and FF. In addition, Non-mandatory Appendices EE and FF provide some of the physical data that the applicant needs to provide for 304 type stainless steel.

As the mechanical property data is essential to the validity of the structural analysis of the drop accident condition, the staff requests that the material models used in the LS-DYNA simulations described in Holtec Report HI-2200647 be based on sufficient physical testing and any results be updated.

This information is needed to determine compliance with the regulatory requirements in 10 CFR 72.236(l).

**Holtec Response**

Since the LS-DYNA computer program considers the reduction in the area of the finite elements in the computation of stress during the execution of the analysis, a true stress strain curve is expected to be input for the material properties.

The following simple power law relation is often used to represent the flow curve of all metals in the region of uniform plastic deformation.

$$\boldsymbol{\sigma = K\varepsilon_t^{\,n}} \qquad (1)$$

where n is the strain-hardening exponent and K is the strength coefficient. A log-log plot of the true stress and true strain up to the maximum load (i.e., immediately before necking) will result in a straight line for the flow curve represented by Equation (1). Note that n = 0 and n = 1 represent the two extreme cases, i.e., perfectly plastic and elastic, respectively. It shall be noted that the stress state in the specimen changes from uniaxial tensile stress to complicated triaxial stresses as the necking develops.

To characterize the true-stress after necking, Equation (1) and a linear stress-strain relationship are used as lower bound and upper bound, respectively in [Ref-1] to predict the actual true-stress-true-strain curve after necking using the finite element method in conjunction with test data. For simplicity, we conservatively extend the use of Equation (1) to the entire flow curve and determine n and K based on material properties obtained from regular tensile tests.

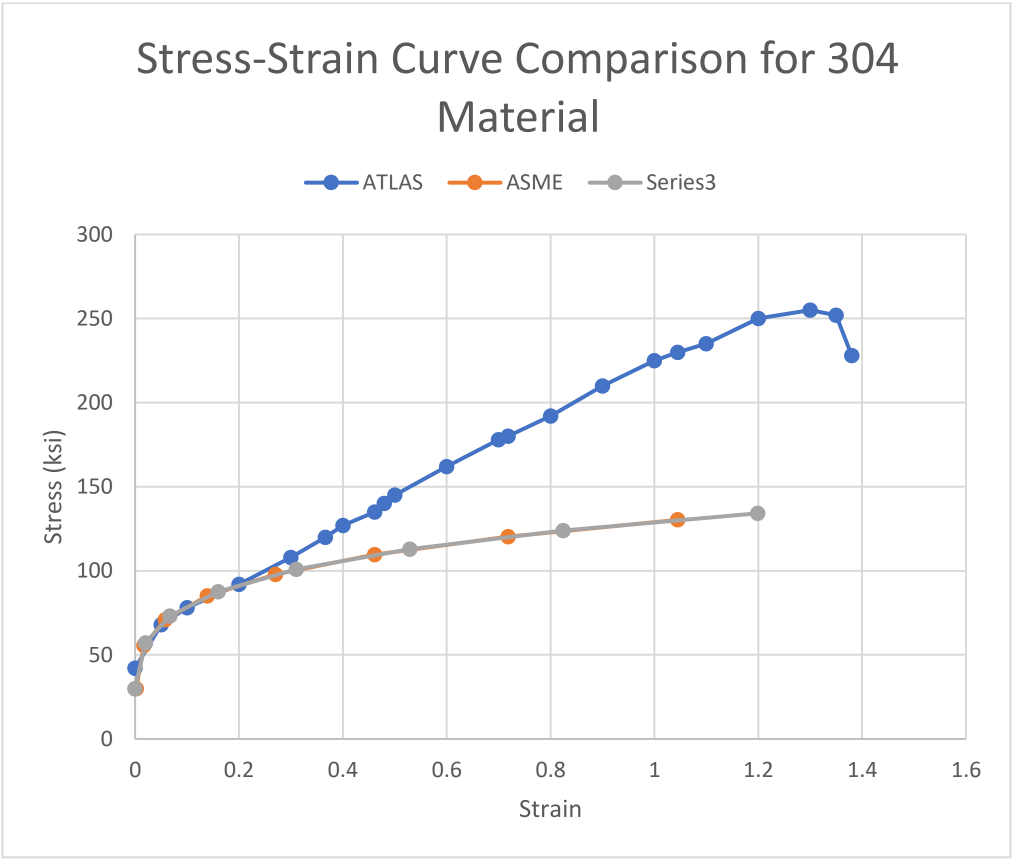
The constants used to develop material flow curves (e.g., constants "K" and "n") are not arbitrary "guessed" values. The values of K and n are computed using an iterative solution method implemented in Mathcad to find the converged solution, which requires an <u>initial</u> guess value. The final converged values of K and n are mathematically accurate and consistent with the underlying material properties (i.e., Sy, Su, elongation, % reduction of area). See the response to RAI 5-21 from HI-STORE application (Docket # 72-1051) for more detailed information (which was recently submitted on November 20, 2020).

Accordingly, the HI-STORM drop simulation performed in support of this amendment use the minimum ASME material properties to develop the true-stress-vs-true strain curves. The actual test properties (Certified Mill test Report) generally show the material strength properties to be higher by approximately 15%. This is substantiated in the following paragraph.

The following figure show the comparison between the material flow curves for a typical stainless-steel 304 material using 2 distinct approaches, as follows:

a. ASME minimum strength properties
b. Atlas-stress and strain curves [Ref-2]

It is clearly noted that the curve developed using the ASME minimum properties, which is the basis for the licensing analysis in support of this amendment, is lower than the curve obtained from the other two sources.




Using the minimum material strength properties from ASME Section II, therefore, yields conservative results for the HI-STORM cask and the MPC confinement when subject to impacts. This is attributed to the fact that the increased material strength and the percentage area reduction results in higher material flow curves (true-stress-vs-strain curves) as compared to the true-stress-vs-strain curves developed using the ASME minimum properties. Consequently, it increases the potential for more energy absorption by the cask components which directly participate in the impact thereby protecting the confinement boundary (i.e., the MPC and the stored fuel inside MPC). Distinctly stated, the plastic region the true stress developed using the ASME minimum properties is always lower than the true stress values using the actual testing [Ref-2]. Thus, at any given deformation level the total energy absorbed by the MPC will be underestimated. This results in a conservative response because it overestimates the total deformation (strain) for the components influenced by the impact loading.

[Ref-1] K.S. Zhang and Z.H. Li, "Numerical Analysis of the Stress-Strain Curve and Fracture Initiation for Ductile Metal," Engineering Fracture Mechanics, 49, 235-241, 1994.
[Ref-2] Atlas of Stress-Strain Curves," Second Edition, ASM International.

**RAI-3-4**

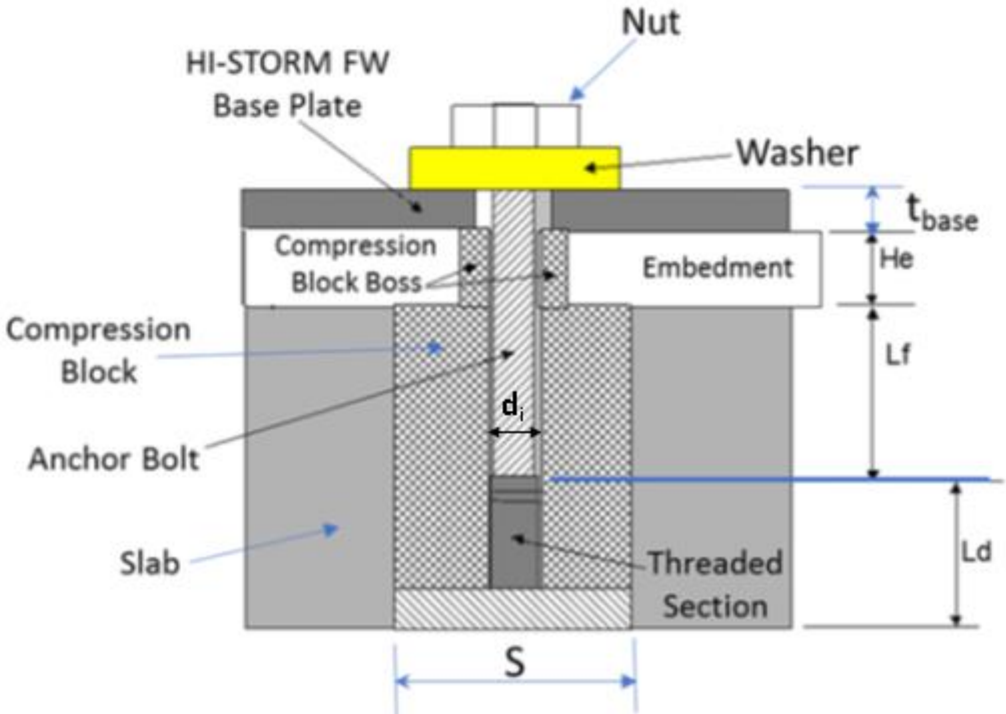
Clarify the discrepancy between the depictions of the anchorage for the HI-STORM FW, Version E, in Drawing No. 11695, “HI-STORM FW Version E Anchored Cask,” and Holtec Report HI-2188720, “Structural Calculation Package for HI-STORM FW Anchor System” and revise the SAR, drawings, and calculations as necessary.

The structural evaluation of the anchored HI-STORM FW system relies on finite element analysis and hand calculations presented in Holtec Report HI-2188720. However, the anchorage configuration evaluated in Holtec Report HI-2188720 differs from the anchorage configuration depicted in the drawings and SAR description of the HI-STORM FW anchorage. Specifically, the anchorage evaluated in Holtec Report HI-2188720 is comprised of several anchorage components that are not depicted in the SAR Drawings, such as an embedment plate, compression block, and anchor rod. As this anchorage hardware is designated as ITS and relied on to resist accident loads (e.g., loads associated with the earthquake and tornado accident conditions), the staff requests clarification of the components and configuration of the anchorage hardware and that the SAR, drawings, and calculations be updated as necessary.

This information is needed to determine compliance with the regulatory requirements in 10 CFR 72.236(b) and (l).

**Holtec Response**

The details of the anchorage system are added in the FSAR, Section 3.1. A figure depicting the typical anchorage system of the HI-STORM FW, Version E is also added in Section 3.1 of the FSAR. The same figure is reproduced below. All the critical dimensions of the anchorage system critical components are also presented in Table 3.1.15 of the FSAR. The embedment details are provided in the Figure 3.1.1 and Table 3.1.15 of the SAR. Any site-specific modifications or deviations from this concept will be evaluated as deemed appropriate for determining the safety consequence.




Cross-Section of Anchorage at Location of Anchor Stud

**RAI-3-5**

Provide structural qualification for the components and welds comprising the anchorage housing and the welds connecting the radially extended baseplate to the cask for the HI-STORM FW, Version E, anchored variant.

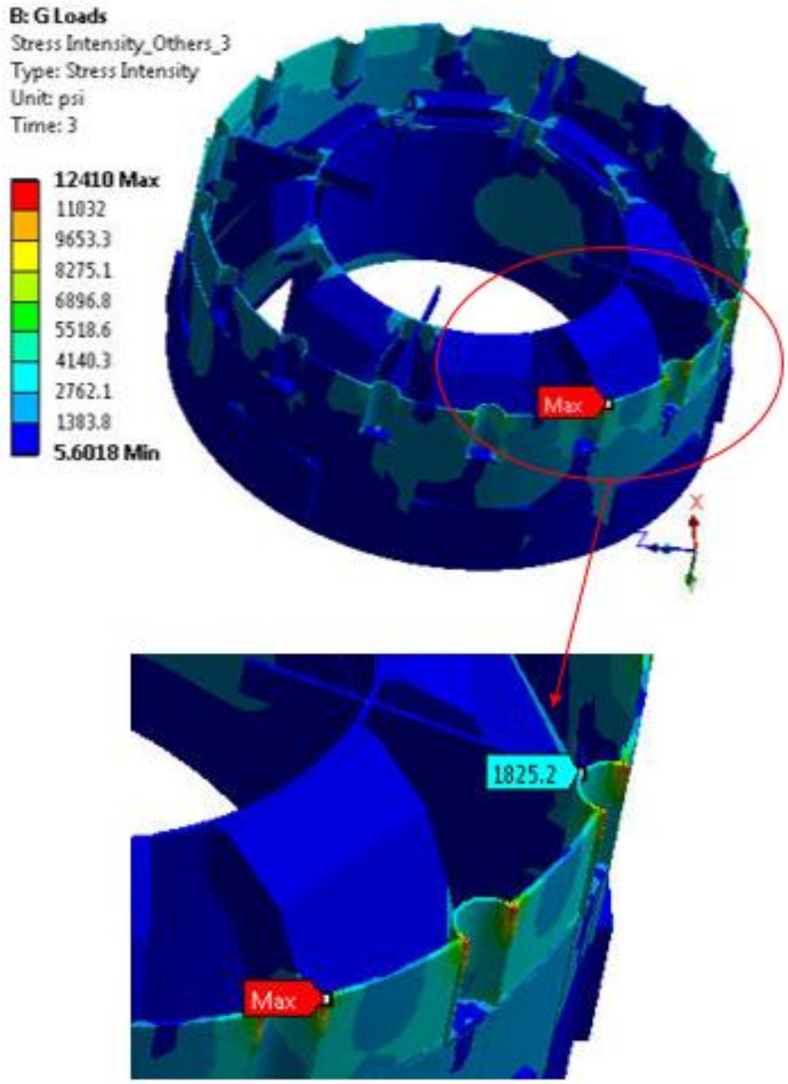
Drawing No. 11695 depicts the components of the anchored HI-STORM FW cask. The drawing includes Item No. 2 described as “Plate, Anchor Housing” and is categorized as ITS; Item No. 5 described as “Plate, Radial Bottom” and is categorized as ITS; and three welds connecting these components and the cask baseplate to the body of the cask. It appears that these components and welds are a part of the structural load path resisting certain loads (e.g., loads associated with the earthquake and tornado accident conditions) on the cask and, therefore, require structural evaluation. However, the structural analyses for the earthquake and tornado accident conditions detailed in Holtec Report HI-2188720 and Holtec Report HI-2200647, respectively, do not appear to contain structural evaluations of these components or welds.

This information is needed to determine compliance with regulatory requirements in 10 CFR 72.236(b) and (l).

**Holtec Response**

Report HI-2188720 presents an extensive analysis of the Anchorage system. Figure C.5.2.3 of the report HI-2188720 shows the induced stress intensity in the anchorage system. The induced stress levels (maximum stress intensity = 12,410 psi, conservatively peak stresses are not ignored) in the components are well below the allowable stress limit (allowable tensile stress = 40,300 psi); including those at the weld locations with allowable stress limit as 21,000 psi (0.3x70 ksi). This implies that the actual stresses induced in the welds will also be below the allowable stress limits.

The report HI-2188720 has been updated to show the maximum stress regions for the item#2 and item#5 interfaces as shown in the figure below.


B: G Loads
Stress Intensity_Others_3
Type: Stress Intensity
Unit: psi
Time: 3
12410 Max
11032
9653.3
8275.1
6896.8
5518.6
4140.3
2762.1
1383.8
5.6018 Min
Max
1825.2
Max

**RAI-3-6**

Specify the preload or pre-tension required of the anchor studs for the HI-STORM FW Version E anchored variant.

As discussed throughout Holtec Report HI-2188720, the structural evaluation of the anchored HI-STORM FW system relies on the friction contact between the top surface of the independent spent fuel storage installation (ISFSI) pad embedded plate and the bottom surface of the baseplate of the anchored cask. An important step of the seismic evaluation described in HI-2188720 is determining that the friction force is greater than the seismic lateral force, and thus, the seismic lateral force on the cask does not impart shear loading directly on the anchorage in the ISFSI pad. The system maintains this friction contact partially by the preload of the anchor studs. As the preloading of the anchor studs is necessary to validate the seismic analysis, the staff requests that the preload of the anchor studs be specified and that the SAR be updated as needed.

This information is needed to determine compliance with the regulatory requirements in 10 CFR 72.236(b).

**Holtec Response**

The preload range is specified in Table 3.1.15 of the revised FSAR (Proposed FSAR revision 7.B). Holtec Report HI-2188720 uses pre-tension in the range of 46-56 ksi on the anchor studs. For Level A service conditions, upper bound pre-tension of 56 ksi yields higher stresses in the studs and the compression block. Lower bound pre-tension of 46 ksi yield lower slip resistance for Level D service conditions. Hence, for Level A, upper bound 56 ksi pre-tension is used; whereas for Level D, lower bound pre-tension of 46 ksi is used.

Appendix A of report HI-2188720 is updated with this range of pretension used therein. Subsequently, the Finite Element analysis presented in Appendix C of the report is also updated for the lower bound pretension value of 46 ksi for Level D conditions.

**RAI-3-7**

Provide an evaluation of the effects of differential thermal expansion and thermal fatigue on the anchorage components and required preload of anchor studs for the HI-STORM FW system.

Holtec Report HI-2188720 presents the structural evaluation of the components of the HI-STORM FW anchorage and the consideration of the effects of the preload in the seismic analysis. The analysis does not contain a discussion or evaluation of the differential thermal expansion of the anchorage components. The staff recognizes the potential for changing temperatures of the anchorage components to result in differential expansion. This differential thermal expansion could affect the stresses of the anchorage components evaluated in the report and the necessary preload evaluated in the report. The significance of the preload of the anchor studs is discussed in RAI-3-5. As the stresses and anchor stud preload evaluated in the report are necessary for ensuring structural integrity of the anchorage, the staff requests that the applicant provides an evaluation of the effects of differential thermal expansion on the anchorage components and the preload of the anchor studs.

Holtec Report HI-2188720 also presents an evaluation of the effects of mechanical fatigue from the earthquake accident condition on the HI-STORM FW anchorage. The staff recognizes the potential for changing temperatures to result in cyclic thermal expansion and thermal fatigue of the anchorage components. As the analysis of fatigue in the anchorage is necessary for ensuring structural integrity, the staff requests that an evaluation of thermal fatigue be provided.

This information is needed to determine compliance with the regulatory requirements in 10 CFR 72.236(b) and (l).

**Holtec Response**

The anchor bolts are typically tensioned using a hydraulic bolt tensioner mechanism. As this procedure takes some time to set up and tension the bolts, the anchor studs and surrounding materials will be in contact with the HI-STORM baseplate for some time and will reach thermal equilibrium prior to full tensioning of the anchors. The HI-STORM baseplate along with the embedment and the stud are assumed at a temperature of 150 deg F. There will not be any relative thermal expansion between the HI-STORM baseplate, embedment, and the anchor studs for the following reasons:

- As the hydraulic bolt pretensioner takes time to pretension the bolts, this allows the components to achieve a thermal equilibrium; thereby resulting in identical temperatures in all the components.
- The coefficient of expansion for the baseplate and the anchor stud is identical for both the stud and the baseplate material.

Thermal Fatigue: Paragraph ASME, Subsection NB-3222.4 (d), provides criteria that are strictly material and design condition dependent to determine whether a component can be exempted from a detailed fatigue evaluation. The same criterion is used in Appendix D of report HI-2188720 R1 to evaluate the maximum temperature difference between the anchorage system components and through calculations, it is concluded that thermal fatigue evaluation of the anchorage system components is unwarranted.

The effects of thermal loading (including fatigue) are addressed in the revised Appendix A of report HI-2188720.

**RAI-3-8**

Demonstrate that the HI-STORM FW design will maintain a safe configuration under the following conditions:

a. the earthquake accident conditions for the proposed anchored HI-STORM FW configuration, and

b. the drop accident conditions for the proposed changed to the technical specification to allow non-single failure proof lifting equipment.

As part of your response, provide the input and output files of the finite element analysis models used to perform structural evaluations of the drop and earthquake accident conditions for the HI-STORM FW storage system.

The applicant is seeking approval of an anchored configuration for the HI-STORM FW for use in high seismic regions and adding to the technical specifications the option to use non-single failure proof lifting equipment when handling the storage system up to a specified maximum height, among a few other changes. To support these changes, the applicant provided Holtec Report Nos. HI-2188720 and HI-2200647 to describe the finite element analyses and structural evaluations for the anchored HI-STORM FW earthquake accident condition and the HI-STORM FW drop accident condition, respectively. The evaluations presented in these reports rely on analyses from finite element modeling to determine the adequacy of certain ITS components to maintain confinement integrity and perform a shielding function.

Given that the models may be complex (i.e., highly non-linear), the staff needs to verify the modeling conditions of the ITS confinement and shielding components such as:

- material model assignment,
- material density,
- overall model weight,
- post yield material behavior,
- element erosion,
- dimensions,
- element type and function,
- overall model behavior (animation files),
- hour glassing effects,
- lock-up effects,
- boundary conditions,
- contacts,
- velocity assignment,
- processor output specification,
- stress distribution, and
- effective plastic strain distribution, among others.

The staff needs the input and output files to efficiently verify the validity and accuracy of the finite element models used by the applicant to conclude that the cask maintains the integrity of the confinement boundary and its shielding function under earthquake and drop accident conditions.

This information is needed to determine compliance with the regulatory requirements in 10 CFR 72.236(d) and (l).

**Holtec Response**

Seismic Analysis:

- Seismic Analysis is performed to quantify the structural adequacy of the pre-tensioned anchor studs connecting the cask at baseplate to the compression block of the anchorage system. An extensive Finite Element (FE) analysis of the loaded HI-STORM held to the slab is performed by a set of long anchor studs (rods).
- The FE analysis employs a three-dimensional model that incorporates contact between the cask baseplate and the ground to simulate the anchoring system. The stiffness of all the structural members is captured by assigning proper material properties. The weight of the loaded HI-STORM is simulated by using mass element.
- The analysis is performed in 3 stages: Pretension analysis, modal analysis, and seismic analysis. Governing inertial accelerations corresponding to the cask response frequency are applied based on the applicable response spectra.
- The stresses induced in the components in the load path are compared to their respective allowable stress limits and the structural adequacy of the anchorage system is established.

Drop Analysis:

- The LS-DYNA finite element model is developed in this calculation to simulate the postulated drop event of the HI-STORM FW Version E storage cask with loaded MPC-37. A similar drop analysis is also performed for the HI-TRAC VW with loaded MPC-37.
- The LS-DYNA finite element models are developed according to the dimensions specified in the respective design drawings. Because of geometric and loading symmetries, a half model of the loaded cask and the impact target is considered in the individual analysis.
- The impact target (ISFSI concrete pad) is characterized using MAT_PSEUDO_TENSOR LS-DYNA material model. The subgrade is also conservatively modelled as an elastic material.
- To assess the potential damage of the cask caused by the drop accident, an LS-DYNA non-linear material model with strain rate effect is used to model the response of the HI-STROM and HI-TRAC structural members.
- A drop height of 11 inches is used to estimate the maximum drop velocity of the cask prior to the impact with the ISFSI pad.
- The structural adequacy of the structural components is established by comparing the maximum local true plastic strain in the structural components to their respective material failure strain.

All the input and output FE files related to these analyses are archived on the Holtec network and will be shared with the staff for their review.

**Thermal Evaluation**

**RAI-4-1**

Specify the allowable temperature limits are for normal or short term conditions in the HI-STORM FW, Amendment No. 6, Appendix A, Technical Specification (TS), Limiting Condition for Operation (LCO) 3.1.2, "SFSC Heat Removal System," required action C.2.3, and in the associated bases B 3.1.2, "SFSC Heat Removal System," for action C.2.3, on page 13.A-21 of the application, that are applicable to all components and contents.

In the HI-STORM FW, Amendment No. 6, Appendix A, Technical Specification 3.1.2, required action C.2.3, the applicant describes that an engineering evaluation shall be performed using the models and methods in the HI-STORM FW final safety analysis report (FSAR) to demonstrate, through this analysis, that all components and contents remain below allowable temperature limits and that the completion time is 24 hours. The allowable temperature limits for normal or short-term conditions for the associated completion time have not been specified.

The bases B 3.1.2, action C.2.2, on page 13.A-20, of the application describes that the completion time of 24 hours reflects the completion time from required action C.2.1 to ensure that component temperatures remain below their short-term temperature limits for the respective decay heat loads. However, the bases B 3.1.2, action C.2.3, on page 13.A-21, of the application describes the following:

1) an engineering evaluation may be performed to demonstrate that all component and content temperatures remain below temperatures that would prevent the component from performing its design function; and

2) if none of the components (and not described, the contents) exceed the temperatures determined above, the MPC can remain in the overpack.

Therefore, it is not clear in the HI-STORM FW, Appendix A, TS 3.1.2, required action C.2.3, or in the bases B 3.1.2, action C.2.3 of the application, if the temperature limits and the temperatures which would prevent it from performing its design function are short-term.

These clarifications are necessary to provide reasonable assurance that the HI-STORM FW spent fuel storage cask reasonably maintains the following:

1) adequate heat removal capacity without active cooling systems for clearly described temperature limits,

2) intact fuel cladding, and

3) the confinement of radioactive material under normal, off-normal, and credible accident conditions.

This information is necessary to determine compliance with 10 CFR 72.236(f) and 72.236(l).

**Holtec Response:**

Required Action C.2.3 of LCO 3.1.2 is applicable when 50% or more of each vent is blocked. Consistent with the HI-STORM FW FSAR, this is an accident condition. Accident conditions are subject to accident condition pressure and temperature limits, which are provided in HI-STORM FW FSAR Tables 2.2.1 and 2.2.3. Required Action C.2.3 is modified to state "… all component and content temperatures remain below allowable accident condition temperature limits and the MPC internal pressure remains below the accident condition pressure limit." In HI-STORM FW FSAR Chapter 13, B3.1.2, the first sentence of Action C.2.3 is modified to state "… all component and content temperatures remain below accident condition temperature limits in Table 2.2.3 and the MPC internal pressure remains below the accident condition pressure limits in Table 2.2.1."

**RAI-4-2**

Provide the following regarding HI-STORM FW, Amendment No. 6, Appendix A, TS 3.1.2, required action C.2.3 of LCO 3.1.2:

a) Summarize the technical bases to demonstrate that a completion time of 24 hours is acceptable to perform an engineering evaluation.

b) Explain how an engineering evaluation is performed to demonstrate that component temperatures are within allowable limits.

c) Describe what type of engineering evaluation is needed to demonstrate that component temperatures are within allowable limits.

The HI-STORM FW, Amendment No. 6, Appendix A, TS 3.1.2, required action C.2.3 of LCO 3.1.2 notes that one option to return the system to operable condition would be to perform an engineering evaluation within 24 hours. It is not clear to the staff how an engineering evaluation, and what type of engineering evaluation that includes analysis and results, could be realistically performed in 24 hours (especially due to the complexity of the thermal model, if it is used in the evaluation).

The staff needs assurance that no safety limit would be exceeded during normal, short-term, off-normal, or accident conditions. See the response provided to RAI 4-1 in ADAMS Accession No. ML19311C517 and the associated page changes in ADAMS Accession No. ML19311C519.

This information is necessary to determine compliance with 10 CFR 72.236(b) and 72.236(f).

**Holtec Response**

a) The 100% vent blockage evaluation in Subsection 4.6.2.4 of the HI-STORM FW FSAR demonstrates that up to 32 hours of complete vent blockage is an acceptable duration. The completion time for Required Action C.2.3 of LCO 3.1.2 is determined to be 24 hours by subtracting the completion time for Action B.1 of LCO 3.1.2 (8 hours) from 32 hours, so the total duration of the two actions is equal to the duration evaluated in the FSAR. As for realistically performing the required analysis in 24 hours, the evaluation may be performed ahead of time using actual loaded cask decay heat loads and actual site ambient temperatures. It is expected that the option to perform an evaluation will be used mostly by sites subject to large snowfall where more than 32 hours may be needed to safely clear a large snowfall.

b) The evaluation would be performed either (1) by using the cask thermal model described in Chapter 4 of the HI-STORM FW FSAR or (2) by comparison to a previously-evaluated similar condition (i.e., a previously evaluated bounding blockage event). If performing a new evaluation (Option 1 above) the model inputs would be modified to reflect actual or bounding expected site conditions including bounding expected amount of blockage, actual decay heat load and actual or expected ambient temperature. This discussion is added to HI-STORM FW FSAR Chapter 13, B3.1.2.

c) Accident condition pressure and temperature limits from HI-STORM FW FSAR Tables 2.2.1 and 2.2.3 apply (see response to RAI 4-1 above).

**Materials Evaluation**

**RAI-4-1**

Clarify the standards used for the construction of the Independent Spent Fuel Storage Installation (ISFSI) pad.

The staff wanted to confirm the standards applicable to the design of the concrete structures and their ability to withstand outdoor conditions. The applicant noted the following:

1) Section 2 of the application includes information regarding the applicability of the code.

2) ACI 318-05 is used for the strength analysis of the ISFSI pad.

3) the analysis considers concrete behavior due to outdoor exposure.

4) the maximum concrete compression is assumed to be 7,000 psi.

For the pad, the assumptions and analyses allow to construct the pad in any place in the U.S.

The staff pointed out that the question was mainly about the fabrication requirements of the storage system. The staff noted that the safety analysis report does not contain specific requirements for the pad to be designed and constructed in accordance with ACI durability requirements to account for outdoor exposures. The applicant noted that the applicable code was ACI-318 for fabrication and that it intended to follow the durability requirements in that code. The applicant will be adding information in the safety analysis report (SAR) to clarify the applicable code for outdoor durability considerations.

This information is needed to determine compliance with the regulatory requirements in 10 CFR 72.236(b).

**Holtec Response**

As described in FSAR Section 2.0.4.2, ACI 318-05 is used in the design, evaluation, and construction of the concrete ISFSI pad. Chapter 4, Durability Requirements, of ACI 318-05 lists the design requirements for various environmental conditions. It also discusses the minimum concrete compressive strength for special exposure conditions. These exposure conditions require a minimum concrete compressive strength ranging from 4000 psi to 5000 psi dependent on conditions. The FW ISFSI pad data in Table 2.2.9 lists a maximum compressive strength of 7000 psi, which is greater than the highest minimum compressive strength required due to exposure conditions. All components used during construction of the ISFSI pad are subject to the durability requirements Chapter 4 of ACI 318-05. Section 2.0.4.1 of the FSAR has been clarified to state that Chapter 4 of ACI 318-05 applies.