Request for Additional Information
Holtec International
Docket No. 71-9373
HI-STAR 190 Transportation Package

By letter dated August 7, 2015, Holtec International (Holtec) submitted an application for Certificate of Compliance No. 9373, Revision No. 0, for the Model No. HI-STAR 190 package. By letter dated October 15, 2015, Holtec responded to a request for supplemental information (RSI) letter dated October 1, 2015. Revised responses were then submitted on December 18, 2015.

This request for additional information (RAI) identifies information needed by the U.S. Nuclear Regulatory Commission staff (the staff) in connection with its review of the HI-STAR 190 package application to confirm whether the applicant has demonstrated compliance with regulatory requirements.

The requested information is listed by chapter number and title in the package application. NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel," was used for this review.

Chapter 1 – General Information

Licensing Drawings

1-1 Revise licensing drawing No. 9841, "HI-STAR 190 Cask Assembly' to reflect the approaches defined in Section 2.2.1.2.5(b, c) of the application, or clarify the basis for exclusion from the drawing.

Note 13 of licensing drawing No. 9841 identifies the approach defined in Section 2.2.1.2.5(a) of the application, which states that the HI-STAR 190 cask interior steel surfaces may be coated with conventional surface preservatives such as Carboline Thermaline® 450 or equivalent surface preservative.

However, the application allows for alternative use of aluminum oxide and other surface passivation methods that provide suitable corrosion resistance [per the acceptance criteria in the table in Section 2.2.1.2.5(a)] along with the heat transfer characteristics used in the thermal analysis. These alternative approaches are not reflected in the licensing drawing for the cask assembly.

The staff recognizes that these coatings are non-important to safety; however, the acceptance criteria for these coatings/liners, as defined in Section 2.2.1.2.5(a) of the application, are necessary to ensure that the safety analyses for the package remain valid.

This information is required to determine compliance with 10 CFR 71.43(d), 71.71 and 71.73.

1-2 Revise Drawings 6505 and 6512 to include the thickness and tolerances of the MPC canister.

From the information in Chapter 5 of the application, it appears as though the shielding analysis is crediting the presence of steel within the MPC canisters for shielding. The staff cannot locate the information on the thickness of the radial shell of the MPC canister in Drawing 6505 for the MPC-37 or 6512 for the MPC-89.

The staff also cannot locate the tolerances of the thickness of the top and bottom plates of the MPCs. The applicant needs to update these drawings to include these dimensions and tolerances for the MPC-37 and MPC-89 canisters.

This information is required to determine compliance with 10 CFR 71.47 and 71.51(a)(2).

Chapter 2 – Structural and Materials Evaluation

2-1 Clarify the maximum design load of the Model No. HI-STAR 190 package.

Section 2.5.1 of the application states that "D" denotes the package dead weight and that it must be taken as the bounding value of the dead load being lifted. Throughout the application and the docketed information referenced in the application, there are several discrepancies regarding the design/maximum weight of the package or the components that comprise the package. The table below illustrates some of these discrepancies.

Rows 3 and 4 show the weight of the package used for strength calculations of the upper trunnions and lower trunnion pockets as compared to the calculated weight (Row 2) and reported weight in the application (Row 1). The weight used to calculate the strength of the upper trunnions (Row 3) does not bound those calculated or reported. Rows 5 and 6 indicate that the MPC weight used to calculate the maximum weight of the package (Row 6) does not bound the weight reported for the same MPC in the storage application (Row 5).

Row	Reference	Component	Design Weight (lbs)
1	Table 2.1.11 of SAR	Version XL Transport Package Loaded with Longest MPC-37	414,269
2	Calculation 5 of Reference 2.1.12 of SAR	Version XL Transport Package Loaded with Longest MPC-37	435,800
3	Section 6.1.1 of Calculation 1 of Reference 2.1.12 of SAR (upper trunnions)	Bounding Cask Weight (Maximum Design load on trunnions)	400,000
4	Section 7.1.1 of Calculation 1 of Reference 2.1.12 of SAR (lower trunnion pockets)	Bounding Package Weight	450,000
5	Table 3.2.8 of Reference 2.1.13 of the SAR	Maximum possible weight of a loaded MPC	116,400
6	Table 2.1.11 of SAR	Loaded MPC-37 – longest	109,900

This information is required to determine compliance with10 CFR 71.45(a).

2-2 Clarify how the upper lifting trunnions will be rendered inoperable as a tie-down device for transportation or provide an analysis to verify that the trunnions meet the requirements of 10 CFR 71.45(b)(1).

Section 2.5.2 of the application states that there are no tie-down devices that are a structural part of the package; however, the upper lifting trunnions could be used for tie-down if not rendered inoperable. Step 6 of Section 7.1.5 of the application states, "If required, the cask lifting appurtenance is removed." The staff assumes this means remove the upper trunnions, but, based on detail DC of Drawing No. 9841, is uncertain how this is accomplished.

This information is required to determine compliance with 10 CFR 71.45(b)(2).

2-3 Provide benchmarking results for the LS-DYNA stress analysis.

Section 2.1 of Holtec Report No. HI-2146321 states that the stresses of critical HI-STAR 190 cask components experienced in the analyzed impact events are directly obtained from LS-DYNA simulations. It further states that it was demonstrated in the HI-STAR 180 application that the cask component stress results obtained from the LS-DYNA finite element analysis (FEA) are comparable with and generally more conservative than those obtained from the corresponding ANSYS static analysis.

The methodology approved for the Model No. HI-STAR 180 package consists of two phases in which LS-DYNA is used to determine deceleration values for the various drop orientations (phase 1) which are then used in an ANSYS quasi static analysis to calculate relevant stress and deformation results (phase 2). This two-phased approach was initially approved for use to qualify the Model No. HI-STAR 100 package based on actual scale model drop tests and component static crush testing of the impact limiter.

While the HI-STAR 180 Safety Evaluation Report (SER) acknowledges the comparison of the ANSY and LS-DYNA stress results, it does not acknowledge, let alone approve, this comparison as a valid benchmarking of LS-DYNA for use in a single phase stress analysis.

A valid benchmarking effort involves the comparison of predicted parameters from an FEA model with parameters that can be physically measured (i.e. strain, deformation, acceleration) in an actual test prototype.

This information is required to determine compliance with 10 CFR 71.41(a).

2-4 Explain why the discrepancies between the drawings and the LS-DYNA model will have no effect on other aspects of the HI-STAR 190 simulation results.

There are at least three discrepancies between the drawings in Chapter 1 of the application and the LS-DYNA model:

a. There are 48 closure bolts depicted in the drawings and 68 closure bolts used in the LS-DYNA model.
b. The impact limiter bolts in the drawings are 1.5 inches in diameter and the bolts in the model are 1 inch in diameter.
c. The closure bolt material in the drawings is SA-750/654 630 (H1025 condition) or SB-637 N07718 material and the bolt material in the LS-DYNA model is SA-193 B7 (MID 11 assigned to PID 11).

For the first discrepancy, Holtec Report No. HI-2146321states that 68 bolts were explicitly modeled although the final cask design only has 48 bolts, and that the difference is fully compensated by scaling the bolt preload and the elastic modulus in the bolt material by a ratio of 48/68. For the second discrepancy, the stress-strain curve and Young's modulus were scaled up by a factor of 2.318 for the SA-197 B8S material used for the impact limiter bolts. This was done, to capture the change in axial stiffness and axial strength due to the difference between the diameters of the bolts modeled versus those depicted in the drawings.

Section 2.5.4.1 of NUREG-1617 provides guidance on the evaluation by analysis. NUREG-1617 states that the analysis model should adequately represent the geometry, boundary conditions, loading, material properties and structural behavior of the package analyzed. The additional closure lid bolts affect the boundary conditions between the closure lid and the cask, and the staff is not convinced that scaling the bolt preload and Young's Modulus will capture the difference between the two configurations in that the gap between bolts is over 1.5 inches larger for the 48 bolt configuration.

Additionally, altering material properties to account for differences in geometry is not a good practice and could lead to unintended anomalies in other results. While the change in the stress-strain curve and Young's Modulus of the impact limiter bolts may satisfy the axial behavior, it will also affect the bending and shear behavior. The staff believes that the model should be accurate and free from "work arounds" that force a desired behavior of the model.

In addition to the material discrepancy in the closure bolts (the third discrepancy), the staff also notes an error in the scaling of Young's Modulus for the closure lid bolts. Based on Table 2.2.2a of the application, Young's Modulus for SA-193 Grade B7 material at 250°F should be 28.75 ksi. When scaled by a factor of 48/68, the result is 20.29 ksi. The value listed for Young's Modulus in the LS-DYNA material model (MID 11) is 22.09 ksi.

This information is required to determine compliance with10 CFR 71.41(a).

2-5 Provide information on how the number of torqueing cycles for the closure bolts and the closure flange threads will be tracked.

Section 2.6.1.3.2 of the application determines and "sets" the number of permitted loadings for a "set of closure lid bolts," as well as the number of cycles in the service life of the containment closure flange bolt threads. Step 8 of Section 7.1.1 (Preparation of the Overpack for Loading) states, "The closure lid bolts are inspected for distortion and damaged threads and any suspect bolts are replaced."

The staff is unsure how the number of cycles for a set of closure bolts, or the containment closure flange is tracked to ensure that the number of allowed cycles is not exceeded. Additionally, if a bolt within a set of closure bolts is replaced, the staff is unsure how the total number of loadings on each bolt is tracked.

This information is required to determine compliance with 10 CFR 71.51(a)(1).

2-6 Provide additional information on how the lead slump was evaluated.

Table 2.7.3 of the application reports the maximum axial and radial lead slump as a result of the HAC drop scenarios (9 meter vertical drop and 9 meter slapdown respectively). The staff was unable to determine how the slump was calculated, because no information was provided in the application on the fabrication process. If the lead is poured, there will be shrinkage as the lead cools from the molten state to the solid state and eventually to ambient temperature. The applicant needs to provide a detailed lead slump calculation for both the radial and bottom lead shields.

This information is required to determine compliance with 10 CFR 71.47 and 51(a)(2).

2-7 Revise the application to clarify that Zircaloy-2, Zircaloy-4 and ZIRLO™ are the only cladding type contents allowed for transport in the HI-STAR 190 package, or revise it, as appropriate, to account for the mechanical properties of M5®.

In the initial response to RSI 2-3 (Holtec Letter 5024003, Enclosure 1), the applicant stated that the glossary and Table 7.C.1 in the application states that any zirconium-based fuel cladding material authorized for use in a commercial nuclear power plant reactor is allowable for transport in the HI-STAR 190. This statement and conclusion is inconsistent with the cladding mechanical properties used in the Structural Calculation Package (Holtec Report No. HI-2146413). Section 2.0 of this Calculation Package states: “The fuel cladding material for the HI-STAR 190 Design Basis Fuel is Zircaloy.” Further, Table 5.2.1 of the application, “Description of Design Basis Fuel Assembly”, only defines Zircaloy-2 and Zircaloy-4 as the design-basis fuel assemblies.

The staff confirmed that the cladding mechanical properties used in the LS-DYNA structural evaluation correspond to models developed based on a database of mechanical properties of stress-relief annealed Zircaloy-4 with a smaller amount of Zircaloy-2 (Geelhood, et al., PNNL-17700). PNNL-17700 includes an independent assessment using additional data on ZIRLO™ ring tensile tests, which verified consistency with the Zircaloy models. However, PNNL-17700 does not include an assessment of the adequacy of the models for M5® cladding type. Therefore, the structural evaluation has not accounted for the M5® cladding type.

As stated in the revised RSI 2-3 response, the primary safety case for normal conditions of transport (NCT) is based on minimum 3% failed fuel, and the primary safety case for hypothetical accident conditions (HAC) is based on moderator exclusion (with a defense-in-depth). The applicant stated that the minimum fuel failure was chosen to be consistent with the draft Regulatory Information Summary (RIS) for high-burnup fuel (ML14175A203).

The staff clarifies that the use of a 3% failed fuel criterion is only consistent with the draft RIS if the cladding mechanical properties used in the package design correspond to the specific cladding-type for the proposed contents. The 3% failed fuel criterion was devised to allow for defense-in-depth analyses that account for degradation of the mechanical properties due to radial hydrides for a given cladding type. The 3% failed fuel criterion was not devised to account for variability in mechanical properties from one cladding type to another. The structural evaluation in the application must still contain bounding as-irradiated mechanical properties for all cladding types of the package contents.

This information is required to determine compliance with 10 CFR 71.43(f), and 71.51(a).

2-8 Regarding MPCs previously in dry storage under a 10 CFR Part 72 license:

1. Revise the application to provide acceptance criteria for the MPC enclosure vessel integrity, which clearly defines allowable degraded conditions prior to transport. The acceptance criteria should demonstrate MPC containment integrity during hypothetical accident conditions.

2. Discuss methods (e.g. transport inspections) used to ensure that the MPC meets the proposed acceptance criteria.

The application (Section 8.2.1, "Structural and Pressure Tests") states that the MPC maintenance program shall include an Aging Management Program (AMP) (under a 10 CFR Part 72 license) that verifies that the MPC pressure and/or containment boundary is free of cracks, pinholes, uncontrolled voids or other defects that could significantly reduce the effectiveness of the packaging. However, the application does not define acceptance criteria for other credible degraded conditions (e.g. loss of material due to localized corrosion pits, etching, crevice corrosion; presence of corrosion products) that ensures that cracks will not develop during transport, which could compromise the validity of the leak-tightness criterion during transport.

The structural evaluation of the HI-STAR 190 package does not consider potential degraded conditions of the MPC during dry storage under a Part 72 license. Therefore, the application should describe the methods used to ensure that the acceptance criteria for the MPC enclosure vessel integrity are met. This could include pre- and post-transport inspections that ensure that the safety analyses remain valid and the MPC is free of cracks, pinholes, uncontrolled voids, or other defects that could compromise the enclosure vessel integrity.

The staff notes that sole reliance on a Part 72 AMP is an overly-simplistic and inadequate approach, as the AMP may identify certain aging effects that the Part 72 licensee deems acceptable for continued storage following review under its corrective action program (CAP), but which could potentially compromise the MPC containment integrity during hypothetical accident conditions (HAC). For example, the acceptance criteria in the AMP for localized corrosion and stress corrosion cracking included in Appendix B of draft NUREG-1927, Rev. 1 (ML15180A011) states that any indications of localized corrosion pits, etching, crevice corrosion, stress corrosion cracking, red-orange colored corrosion products require additional examination and disposition under the Part 72 licensee's CAP.

During the CAP review, the Part 72 licensee may use data from non-destructive examination and other analyses to support the conclusion that a given aging effect (e.g. loss of material due to localized corrosion pits, etching, crevice corrosion; presence of corrosion products) will not compromise the confinement function of the MPC for the expected loads during normal, off-normal and accident conditions of storage. Those loads, however, are not expected to be commensurate with HAC transport loads.

Therefore, reliance on a 10 CFR Part 72 AMP to assure compliance with the HI-STAR 190 structural safety analyses is inadequate.

This information is required to determine compliance with 10 CFR 71.55(e), 71.73 and 71.85(a).

2-9 Justify that both the hydrogen content and fast neutron fluence used to determine the cladding mechanical properties used for the structural evaluation are commensurate to the design-basis fuel burnup (68.2 GWd/MTU), or revise the mechanical properties, as appropriate.

The application defines cladding mechanical properties assuming hydrogen contents that are not representative of the requested content. For burnups above 45 GWd/MTU and up to 62 GWd/MTU, the total hydrogen content is expected to be in the range of 200–1,200 wppm for Zircaloy-4 (Mardon et al., 2010; Thomazet et al., 2005; King et al., 2002; Bossis et al., 2007; Hanson, 2016) and up to 550± 300 wppm for ZIRLO™ (Billone et al., 2013, Billone et al., 2015). The hydrogen contents for recrystallized annealed alloys (Zircaloy-2 and M5®) is expected to be bounded by stress-relieved annealed cladding types (Zircaloy-4 and ZIRLO™). Therefore, the use of mechanical properties corresponding to a considerably lower hydrogen content should be justified, or the materials properties should be revised to ensure them adequate for all proposed alloy-contents.

The staff notes that the range of applicability of the referenced mechanical property models includes excess hydrogen concentrations up to 650 ppm (refer to Table 2 in Geelhood, et al., PNNL-17700). The application should also justify that the assumed neutron fluence is adequate for the burnups and history of the rods to be loaded in the HI-STAR 190 package.

This information is required to determine compliance with 10 CFR 71.33(b)(3).

2-10 Revise Section 2.2.3, “Effects of Radiation on Materials”, of the application to address the technical basis supporting the adequate performance of the elastomeric seals used in the closure lid and port cover.

The discussion on radiation effects does not address performance of the elastomeric seals of the closure lid and port cover under bounding radiation doses.

This information is required to determine compliance with 10 CFR 71.43(d).

2-11 Clarify the method and justify the approach used to derive yield strength (S_y) and tensile strength (S_u) of impact limiter attachment bolts, as noted in Table 2.2.6 of the application. Clarify the room temperature value assumed in Table 2.2.6.

The yield strength (S_y) and tensile strength (S_u) values at the high temperature in Table 2.2.6 were derived using an unclear approach, in which the room temperature values of S_y and S_u were multiplied by the ratio of the design stress intensities at the elevated temperature (165.6 °C) to the “at room” temperature (the staff assumed 40 °C since a value is not provided in the Table 2.2.6).

The staff reviewed the design stress intensity values in Table 4 of ASME B&PV Code, Section II, Part D, and was unable to reproduce the S_y and S_u values at the elevated temperature. In addition, the S_y value at room temperature listed in Table 2.2.6 is

inconsistent with that listed in Table Y-1 of ASME B&PV Code, Section II, Part D. Table 2.2.6 also should define a specific value for “room temperature”.

This information is required to determine compliance with 10 CFR 71.71 and 71.73.

2-12 Revise Table 8.A.1 to clarify that an Aging Management Program is also required for MPCs loaded with high-burnup fuel for confirming the integrity of the enclosure vessel.

Table 8.A.1 is inconsistent with response to RSI 8-2, which states: “An Aging Management Program (AMP) applies to MPCs loaded with either moderate-burnup or high-burnup fuel as delineated in Table 8.A.1.” The integrity of the MPC enclosure vessel (for both moderate and high burnup fuel) is an integral part of ensuring that the conditions of ISG-11, Rev. 3 are maintained, which provide reasonable assurance that the spent fuel remains in the as-analyzed configuration.

Therefore, Table 8.A.1 should reflect that the transportability of MPCs loaded with either moderate and high burnup fuel is dependent on an 10 CFR Part 72 AMP being in place, which ensures that aging effects that could compromise the enclosure vessel integrity during dry storage are appropriately dispositioned under the Corrective Action Program of the Part 72 general licensee. The staff recognizes that the requirement for an aging management program is only applicable to MPCs in dry storage during an extended period of operation, per the requirements of 10 CFR 72.42(a) and 72.240(c).

This information is required to determine compliance with 10 CFR 71.71, 71.73 and 71.85(a).

2-13 With respect to Table 8.1.4A, “Metamic-HT Production Testing Requirements”, and 8.1.4B, “Tier System for Metamic-HT Production Coupon Testing”:

a. Clarify and justify the number of coupons to be tested for mechanical properties, per extrusion.

b. Justify the adequacy of the proposed Tier No. 4 in Table 8.1.4B, i.e. justify that testing 1% of the extrusions in a given lot, provides reasonable assurance that non-conforming extrusions will be adequately identified (consistent with the CoC holder’s Quality Assurance requirements).

c. Justify the adequacy of the statement in Note 1 on Table 8.1.4B, i.e. provide a basis for the sampling plan used to define the extent of condition.

d. Clarify Note 2 in Table 8.1.4B. The note states: “Testing shall be moved up to the next tier if any MGV property fails in two consecutive lots.” The statement is inconsistent with the Tier numbering. In the event that the MGV property fails, the correct action would be to increase the sampling size, i.e. step down to a lower tier.

This information is required to determine compliance with 10 CFR 71.131 and 71.133.

2-14 Clarify the basis for the mechanical properties of lead provided in Table 2.2.9 of the application.

The application states that lead is not considered as a structural member of the HI-STAR 190 Package. However, it is included in the dynamic simulation models for Normal Conditions of Transport and Hypothetical Accident Conditions; therefore, the corresponding mechanical properties were included in Table 2.2.9 of the application.

The staff is unclear the specific data, figure or models used to define the values in Table 2.2.9 from the cited reference (J.H. Evans, "Structural Analysis of Shipping Casks, Volume 8, Experimental Study of Stress-Strain Properties of Lead Under Specified Impact Conditions", ORNL/TM-1312, Vol. 8, ORNL, Oak Ridge, TN, August, 1970).

This information is required to determine compliance with 10 CFR 71.71 and 71.73.

2-15 Revise Table 3.2.1 to identify the reference for the emissivity values for the aluminum basket shims.

Table 3.2.1, "Summary of HI-STAR Packaging Materials Thermal Property References", does not identify the reference for the emissivity values for the aluminum basket shims. The respective entry cites "Note 1", which relates to Metamic-HT.

This information is required to determine compliance with 10 CFR 71.71 and 71.73.

2-16 Justify the use of elastomeric seals past their recommended design-life, and provide acceptance criteria and test methods used to ensure their acceptability for use.

The application (Section 8.2.3.6, "Closure Seals") defines general procedures for use and inspection of the elastomeric seals, and states that closure seals are specified for long-term use and do not require in-service maintenance if not disturbed elastomeric seals may be reused. This Section further states that reused elastomeric seals are subject to replacement based on seal design life as recommended by the seal manufacturer, but they may still be used beyond their recommended design life with proper inspection and engineering justification.

The application does not provide details on what is a "proper inspection" or the test methods/acceptance criteria used to ensure that the seals will perform consistent with the safety analyses in Section 2.6.1.3.4 of the application.

This information is required to determine compliance with 10 CFR 71.55(e), 71.71, and 71.73.

RAI REFERENCES:

Billone, M.C., T.A. Burtseva, Z. Han, and Y.Y. Liu, "Embrittlement and DBTT of High-Burnup PWR Fuel Cladding Alloys," FCR-UFD-2013-000401, ANL-13/16, Argonne National Laboratory, Lemont, Illinois, 2013.

Billone, M.C., T.A. Burtseva, and Y.Y. Liu. "Characterization and Effects of Hydrides in High-Burnup PWR cladding Alloys." Proceedings of the International High-Level Radioactive Waste Management Conference, Charleston, South Carolina. Paper No. 12617. American Nuclear Society. April 12–16, 2015.

Bossis, P., B. Verhaeghe, S. Doriot, D. Gilbon, V. Chabretou, A. Dalmais, J.P. Mardon, M. Blat and A. Miquet. "In PWR Comprehensive Study of High Burn-up Corrosion and Growth Behaviour of M5 and Recrystallised Low-Tin Zircaloy-4." 15th ASTM International Symposium: Zirconium in the Nuclear Industry–Sun River, Oregon. ASTM International. June 20, 2007.

King, S., R. Kesterson, K. Yueh, R. Comstock, W. Herwig, and S. Ferguson. "Impact of Hydrogen on the Dimensional Stability of ZIRLO Fuel Assemblies." ASTM STP 1423. West Conshohocken, Pennsylvania: ASTM International. 2002.

Mardon, J.P., G.L. Garner, and P.B. Hoffmann. "M5® a Breakthrough in Zr Alloy." Proceedings of 2010 LWR Fuel Performance/TopFuel/WRFPM, September 26–29, 2010. Orlando, Florida: American Nuclear Society. 2010.

PNNL-17700, "PNNL Stress/Strain Correlation for Zircaloy", July 2008.

Thomaz J. et al., "The Corrosion of the Alloy M5™: An Overview." IAEA Technical Committee Meeting on Behavior of High Corrosion Zr-Based Alloys. Buenos Aires, Argentina: October 24–28, 2005.

Chapter 3 – Thermal Evaluation

3-1 Clarify if thin solid shim plates are necessary to keep the maximum temperatures below allowable limits.

Page 3.1-2 of the application states that thin solid shim plates may be inserted between the basket and extruded basket shims to ensure a good heat transfer path between the basket and extruded shims. It appears that the thin solid shim plates are optional. The staff needs to know if these plates are part of the thermal design and if they are necessary to keep the maximum temperatures below allowable limits.

This information is required to determine compliance with 10 CFR 71.71 and 71.73.

3-2 Demonstrate that the uncertainty in the maximum NCT pressure for the MPC-37 and MPC-89 is sufficiently evaluated such that the very small reported margin of safety is a reliable means of evaluating reasonable assurance of safety. .

Table 3.1.2 of the application provides the calculated HI-STAR 190 cask maximum operating pressures during NCT. However, the calculated pressures are very close to the allowable limit thereby having a very small margin of safety. The staff needs to have assurance the containment system will be maintained to transport safely the contents of the package.

This information is required to determine compliance with 10 CFR 71.71.

3-3 Provide material thermal properties which will assure that the full expected range of temperatures will be adequately covered.

Tables 3.2.2, 3.2.4, and 3.2.7 of the application provide thermal conductivity and specific heat of HI-STAR 190 cask materials. However, some materials have properties limited to a maximum value which does not seem to cover the entire range. Provide additional

values to cover the expected range or provide adequate justification that these values are realistic or conservative in terms of predicted maximum temperatures.

This information is required to determine compliance with 10 CFR 71.71 and 71.73.

3-4 Clarify that the fuel cladding thermal conductivity values provided in the application bounds all fuel cladding materials that are included in the allowed contents.

Table 3.2.3 of the application provides the thermal conductivity of fuel assembly materials (including fuel cladding). However, the application does not provide a justification for these values. The staff needs to have assurance the used values will bound all allowable contents.

This information is required to determine compliance with 10 CFR 71.71 and 71.73.

3-5 Provide time-to-boil calculations and results for loading operations under the "load and-go" scenario.

Section 3.3.4 of the application provides the thermal evaluation for loading operations under the "load-and-go" scenario. However, the application does not provide the time-to-boils calculations to avoid water boiling in the MPCs in preparation for vacuum drying operations.

This information is required to determine compliance with 10 CFR 71.71.

3-6 Explain why NCT fuel reconfiguration is not considered given the uncertainties with adequate material properties which would provide assurance spent fuel will remain intact.

The application does not provide evaluation assuming fuel reconfiguration as defense-in-depth due to uncertainty of material properties, as compared to the HI-STAR 180D transport package. The staff needs to have assurance fuel cladding will remain intact during the entire transport period or an adequate evaluation for fuel reconfiguration is provided and justified.

This information is required to determine compliance with 10 CFR 71.71.

3-7 Provide adequate operating procedures and/or inspections that could be utilized to ensure spent fuel will remain intact during NCT.

The application states that spent fuel will not degrade or reconfigure during the entire transport period but it does not include any procedures for inspecting the fuel after the transport period to assure fuel remain intact (for example, surface temperature and/or dose measurements, etc.). The staff needs to have assurance fuel cladding will remain intact during the entire transport period.

This information is required to determine compliance with 10 CFR 71.71.

3-8 Provide adequate results which include modeling and application uncertainty of the predicted maximum cladding temperatures during vacuum drying for the "load-and-go" scenarios.

Tables 3.3.11 and 3.3.12 provide maximum temperatures for both MPC-37 and MPC-89 during vacuum drying conditions. The applicant predicted values have small margin. Therefore, the applicant need to either include calculations which will include modeling and application uncertainty (validation) or reduce the total allowable decay heat so adequate margin is assured during vacuum drying conditions.

This information is required to determine compliance with 10 CFR 71.71.

3-9 Explain in greater detail why the HI-STAR 190 thermal performance during HAC is not affected by the drop or puncture events.

Page 3.4-1 of the application states:

"…during drop events, material in the impact limiter is locally crushed. However, the impact limiters survive the drop events without structural collapse and remain attached to the cask during and after the event. During a puncture event the cask's exterior shell may be locally pierced but with no gross damage to the cask or its internals. Because of these reasons the global thermal performance of the HI-STAR 190 cask is unaffected by the drop events."

It is not clear to the staff why crushing of the impact limiters and puncturing the cask will not have any effect on the cask thermal performance.

This information is required to determine compliance with 10 CFR 71.73.

3-10 Perform an explicit analysis of the HI-STAR 190 cask with MPC-89 during HAC fire event to provide adequate maximum temperatures during this event.

Page 3.4-3 of the application states:

> *"…the hypothetical fire accident for an MPC-89 placed in HI-STAR 190 overpack is also evaluated since some containment boundary cask component temperatures are bounding for MPC-89 compared to MPC-37 under normal conditions of Transport. The fuel, MPC-89 and cask component temperatures reported in Section 3.1 of the application are calculated by adding the component temperature difference between MPC-37 and MPC-89 under normal conditions to the predicted fire accident temperatures for MPC-37."*

This approach does not appear to be consistent because results of two different canisters are mixed and an explicit modeling of the fire conditions is not performed. The staff needs to have assurance that adequate modeling is provided in the application so the results can be properly evaluated against the allowable limit.

This information is required to determine compliance with 10 CFR 71.73.

3-11 Clarify why during the HAC fire accident insolation is applied to exposed external surfaces.

Table 3.4.1 of the application states that during the 30-minute fire insolation is applied. It is not clear to the staff why insolation is applied and the staff is also not clear if the HAC

results include insolation during the 30-minute fire so an evaluation of the results can be assessed.

This information is required to determine compliance with 10 CFR 71.73.

3-12 Obtain the analysis discretization error by calculating the grid convergence index (GCI) following the procedure described in American Society of Mechanical Engineers Verification and Validation 20-2009 (ASME V&V 20-2009), “Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer”.

Appendix D of Holtec Report HI-2146286 provides the HI-STAR 190 cask GCI calculations. However, after reviewing these calculations the staff identified the following issues with the procedures and obtained values:

1) The applicant calculated the discretization error using Mesh 4 which is finer than the mesh used in the application (i.e. Mesh 3). The applicant should update the results provided in the application using the results obtained from Mesh 4. The finest mesh (Mesh 4) should be used to perform all calculations presented in the application.

2) If Mesh 4 is used for the application, only the following grid combinations can be used to perform the GCI calculations.

    - Mesh 4, Mesh 3, and Mesh 2
    - Mesh 4, Mesh 3, and Mesh 1
    - Mesh 4, Mesh 2, and Mesh 1

   Grid combination based on Mesh 3, Mesh 2, and Mesh 1 is not applicable for performing GCI calculations since the finest mesh (Mesh 4) will be used in the application. ASME V&V 20-2009 GCI calculation procedures show the GCI is the extrapolated error for the finest mesh (which is Mesh 4 for the HI-STAR 190 Cask).

3) Using the procedures described in ASME V&V 20-2009 the applicant should demonstrate that the calculated peak cladding temperatures are in the asymptotic region for the simulation series.

4) A Factor of Safety (Fs) = 1.25 has not been thoroughly evaluated for unstructured refinement. Scatter in the observed order of accuracy (p), as shown by the applicant in Holtec Report HI-2146286, is to be expected because the grid refinement factor (r) is well defined only for geometrically similar grids. It is generally recommended (see V&V 20-2009) that the more conservative value of Fs = 3 be used to obtain the GCI for unstructured grid refinement. Also, as the grid refinement is not totally systematic an Fs = 3 should be used to obtain the GCI.

5) As the calculated order of accuracy is higher than what is used in the solver, an order of accuracy (p) = 1 should be used to obtain the GCI.

This information is required to determine compliance with 10 CFR 71.73.

Chapter 4 Containment Evaluation

4-1 Explain in more detail why the analysis in Chapter 3 of the application shows that the containment boundary will not leak under the one-foot free drop event.

Table 4.8.1 Item 3 of the application states that the analysis of Chapter 3 of the application shows that the containment boundary will not leak under the one-foot free drop event. However, details on how this analysis shows containment boundary will not leak under these conditions are not provided. The staff needs to have assurance that, under those conditions, containment of the radioactive material is maintained.

This information is required to determine compliance with 10 CFR 71.71.

4-2 Explain in more detail why the bolted joint in the containment boundary maintains its leak-tightness under reduced environmental pressure (3.5 psia) or elevated environmental pressure (20 psia).

Table 4.8.1 Item 4 of the application states that containment boundary maintains its leak-tightness under reduced environmental pressure (3.5 psia) or elevated environmental pressure (20 psia). However, no details are provided on the reasons why leak-tightness is achieved. The staff needs to have a clear explanation and basis for this statement to evaluate the performance of the containment system.

This information is required to determine compliance with 10 CFR 71.71.

4-3 Define more clearly the inner containment system boundary for the HI-STAR 190 transport package.

Page 4.9-1 of the application states that the inner containment system boundary for the HI-STAR 190 packaging consists of the shell; baseplate; top lid; and welded joints, seams, and penetrations. However, no definition is provided for the listed items. The staff needs to have a clear definition of the inner containment boundary and its components so an adequate evaluation of the inner containment boundary is performed.

This information is required to determine compliance with 10 CFR 71.31 and 71.33.

Chapter 5 Shielding Evaluation

5-1 Justify that the tolerances of components credited in the shielding analyses are adequately accounted for in determining compliance with external dose rate regulations.

This RAI is a follow up to RSI 1-4. In RSI 1-4, the staff requested that the applicant include tolerances on components used for shielding. In response to this RSI, the applicant stated that it has added minimum dimensions of the lead thickness and provided the "minimum hydrogen areal density" of the Holtite neutron shield in Table 8.1.9 of the application and that the HI-STAR 190 needs to comply with this density to maintain shielding performance. However, the RSI was more concerned with the tolerances of the components important to shielding and the variations of material properties of these components. The responses to the RSI are not closely related to the questions. The staff requests that the applicant provide the following additional information to address this RSI:

a) The applicant did not provide any discussion on tolerances for any other component used for shielding other than the lead gamma shield and the Holtite neutron shield. Although the Holtite neutron shield and the lead gamma shield are the primary shielding components, other components credited in the shielding analyses also provide radiation attenuation and not accounting for tolerances of these package components is non-conservative. The staff requests that the applicant provide tolerances of all materials credited in the shielding analyses and include an estimate of the potential increase in dose rates to the Section 5.4.6 discussion of best estimate dose rates.

b) Although the staff found the thickness of the lead gamma shield in drawing 9841 Sheet 5 of 5, the staff does not see how this value is differentiated as a minimum and not a nominal value. The staff requests that the applicant clarify how these drawings specify the difference between minimum and nominal values.

c) The staff does not understand how specifying "minimum hydrogen areal density" is equivalent to specifying dimension tolerances of this material. The specification in Table 8.1.9 of the SAR includes this minimum hydrogen areal density. The footnotes of the table says: *The minimum hydrogen areal density may be verified by the product of bulk density, weight fraction of hydrogen and thickness of the main neutron shield.* The staff requires additional clarifying information to fully understand how this is done. Alternatively the staff requests that the applicant discuss the tolerances of this component.

    (1) The staff requests that the applicant discuss how the use of minimum hydrogen areal density (in lieu of dimensional tolerances) is an appropriate means of characterizing the neutron shield for its effectiveness in radiation attenuation as the hydrogen also acts as a moderator for boron absorption.

    (2) Using the information from Chapter 5 of the application, the product of the bulk density (0.95 g/cm^3 from Table 8.1.9 of the application), weight fraction of hydrogen (0.1081 from Table 5.3.2 of the application) and thickness of the main neutron shield (9.84cm = 3 7/8" from page 5 of 5 from Drawing 9841) only gives a hydrogen areal density of 1.01, whereas the minimum from Table 8.1.9 of the application is 1.69. It appears that one of the parameters in this product would need to change significantly to achieve this value. The applicant needs to discuss the range of parameters that would likely be increased and how that effects the package safety.

    (3) It appears that the units used for "bulk density" and "areal density" in Table 8.1.9 of the SAR are in error. Clarify these units and/or correct them as necessary.

This information is required to determine compliance with 10 CFR 71.47 and 71.51(a)(2).

5-2 Discuss how all possible loading configurations (burnup/enrichment/cooling time) were analyzed to meet external dose rate limits.

The applicant states in Section 5.1.2 of the application: *"The burnup and cooling time combinations specified in Appendix 7.C were determined strictly based on the shielding*

analysis in this chapter. Each combination was independently analyzed and it was verified that the calculated dose rates were less than the regulatory limits." The staff requests that the applicant provide additional information discussing how each combination was independently analyzed.

Given the vast number of burnup/enrichment/cooling time combinations from Tables 7.C.8(a), 7.C.8(b), and 7.C.10 that are suitable for loading per Tables 7.C.7 and 7.C.9, the staff requests that the applicant provide information describing how each loading pattern and all allowable fuel burnup/enrichment/cooling time combinations were determined to meet regulatory dose rate limits for NCT and HAC. The applicant needs to justify that this was done in a bounding way.

This information is required to determine compliance with 10 CFR 71.47 and 71.51(a)(2).

5-3 Provide additional information justifying the relationship between decay heat and cooling time.

Tables 7.C.7 and 7.C.9 of the application show the burnup, enrichment and cooling time requirements for assemblies meeting the decay heat limits. Holtec calculation file HI-2146423 indicates that there was a "decay heat curve" used to correlate the decay heat to the cooling time. The staff requests that the applicant provide more information on the decay heat curve used and justify that it is appropriately or conservatively used for all fuel specified in Appendix 7.C including high burnup fuel and both PWR and BWR fuel.

This information is required to determine compliance with 10 CFR 71.47 and 71.51(a)(2).

5-4 Justify the uncertainty of the SAS2H code for evaluating source terms for PWR and BWR fuel up to 68.2 and 65 GWD/MTU, respectively.

In discussing the uncertainty from the SAS2H/ORIGEN-S the applicant references the HI-STAR 180 application. However, the staff was unable to locate appropriate information justifying the use of this code for the HI-STAR 190, particularly for the uncertainty related to source term and decay heat evaluations for high burnup fuel (burnup > 45 GWd/MTU). The staff requests that the applicant provide additional information justifying the use of this code for all of the fuel specified in Appendix 7.C including high burnup PWR and BWR fuel in generating source terms.

a) The staff notes that ORNL no longer supports SAS2H development and has not validated this code up to 68.2 and 65 GWD/MTU and therefore the applicant would need to perform this validation and/or propose and justify an appropriate penalty to account for this uncertainty.

b) The staff requests that the applicant state the cross section library used in the source term calculations and discuss the validation information that covers this cross section set and group structure.

c) The staff requests that the applicant discuss and justify the uncertainty values reported in Table 5.4.18 of the application in the calculation of source term (neutron, gamma, and hardware for both BWR and PWR) for fuel burned up to 68.2 and 65 GWD/MTU for PWR and BWR fuel, respectively.

d) The staff requests that the applicant discuss and justify the uncertainty in the evaluation of decay heat, and discuss if/how this was incorporated into the decay heat limits.

This information is required to determine compliance with 10 CFR 71.47 and 71.51(a)(2).

5-5 Justify the uncertainty in source term as calculated by SAS2H/ORIGEN-S due to variations in depletion parameters.

In discussing the uncertainty of the SAS2H/ORIGEN-S source term and decay heat calculations due to the reactor input (depletion) parameters for the HI-STAR 190, the applicant references the HI-STAR 180 application. However the staff was unable to locate appropriate information justifying this uncertainty for the HI-STAR 190. The HI-STAR 180 application describes a method that is based on Appendix B of NUREG/CR-6802.

a) The staff requests that the applicant justify the applicability of this method for fuel burnup up to 68.2 and 65 GWD/MTU for PWR and BWR fuel as well as for parameters outside of the range of Table B.1 of NUREG/CR-6802 (enrichment and possibly boron loadings).

b) The staff requests that the applicant discuss and justify how it calculated the uncertainty values for "depletion input uncertainty" reported in Table 5.4.18 of the application.

c) The staff requests that the applicant state the cross sections and group structure used in the HI-STAR 190 depletion calculations and if different from those used in NUREG/CR-6802 Appendix B, justify the use of the method.

e) The staff requests that the applicant discuss and justify the uncertainty in the evaluation of decay heat related to the depletion inputs, and discuss if/how this was incorporated into the decay heat limits.

This information is required to determine compliance with 10 CFR 71.47 and 71.51(a)(2).

5-6 Clarify the lead slump assumptions in the dose rate evaluation.

Page 5.3-2 of the SAR says: *"To model the lead slump of the lead in the base plate (Bottom Forging Gamma Shield), it is conservatively assumed that 12.7 cm (5 inches) radially from the outer part of the lead are replaced with a void. To model the lead slump of the lead in the annular space around the Containment Shell (Gamma Shield), it is conservatively assumed that 5.08 cm (2 inches) of the lead in the top and bottom areas are replaced with void. The lead slump assumption is conservative since in reality no lead would be removed."*

a) To clarify the above statements, the applicant needs to include details on where the slump was applied for each location where they evaluated the external dose rate (side, top and bottom) and justify these assumptions are appropriate or conservative. For example, for a drop on the cask's side, a reduction in the radial thickness of the radial shield on one side is conceivable and the reduction of lead shield would increase HAC dose rates in the radial direction. It appears that the applicant has

chosen to reduce the radial thickness of the bottom plate, equally on either side. Therefore this physical phenomenon should be applied to one side as it creates a streaming path at the bottom and dose rates are evaluated near this streaming path, however the staff does not have enough information to determine how this was done nor if it is conservative.

b) In addition, the lead slump information in Section 5.3.1.1 does not correspond to that in Chapter 2 (Structural Evaluation). Table 2.7.3 of the application states that the lead slump assumed in the shielding evaluation is 10 inches in the axial direction and 2 inches in the radial direction. With the calculated value being 6.9 inches in the axial and 0.9 inches radially. The staff requests that the applicant clarify this discrepancy and discuss if these values are applicable to the radial shield or base plate.

This information is required to determine compliance with 10 CFR 71.51(a)(2).

5-7 Provide additional information on the dose rate analyses assuming reconfiguration for HBF under NCT.

The applicant discusses the dose rate analyses performed assuming reconfiguration for HBF under NCT in Section 5.4.5 of the application. The staff needs additional information to evaluate these analyses assumptions.

a) Specifically the staff requests the applicant to provide more details and justifications on if/how it assumed the axial source distribution (i.e. did the applicant assume that fuel from the top relocated to the bottom, or hotter fuel from the center relocated to the bottom).

b) Additionally the staff requests that the applicant provide details and justify where the dose rates were evaluated. Section 5.4.4 of the application states that the dose locations identified in Table 5.4.3 of the application do not correspond to single dose rate locations but the highest value as chosen from multiple axial and azimuthal segments. The applicant needs to show the location of the highest dose rate and if this was the same for all the fuel relocation evaluations. For example, there might be an increase in Dose Location 1 from Figure 5.1.1 of the application, as this appears to be the location outside the neutron shield. The staff requests that the applicant discuss if they evaluated the dose rate at this location for the NCT reconfiguration analyses.

This information is required to determine compliance with 10 CFR 71.47.

5-8 Justify the fuel parameters and loading pattern selection for HBF reconfiguration analyses.

The staff requests that the applicant clarifies, with detailed justifications, how the source terms produced from various burnup/enrichment/cooling time combinations were used in the HBF reconfiguration analyses.

Tables 5.4.2 and 5.4.3 of the application show results for a nominal reference case. The staff requests that the applicant discuss the fuel enrichment/cooling time/burnup chosen for this case and how it was chosen as representative or bounding for all possible fuel

loadings per Appendix 7.C of the application (including BWR fuel). For example fuel that produces the highest neutron source may be more bounding for HAC but not necessarily for NCT.

This information is required to determine compliance with 10 CFR 71.47 and 71.51(a)(2).

5-9 Provide additional information on the axial burnup profile assumed for both PWR and BWR fuel.

The applicant cites references to various other dockets in Section 5.4.1 of the application in discussing the method used to model the axial burnup profile. However the staff did not locate enough information to evaluate the burnup profile for the HI-STAR 190 with respect to the following subject areas.

a) The staff requests that the applicant provide additional information on the shape of the profile used in modeling the active fuel region for both BWR and PWR fuel for the HI-STAR 190 and justify that it/they are conservative for all allowable burnups (specifically for low burnup fuel) and possible features such as control rod insertions, axial power shaping rods, axial blankets and part-length rods that are allowed from Appendix 7.C of the SAR.

b) The staff requests that the applicant justify that the peak relative burnup of 1.15 is representative or bounding for BWR fuel up to the allowable burnup.

c) The staff requests that the applicant justify the relationship to neutron source to the 4.2 power with burnup to implement the axial burnup profile considering that any nodes with relative normalized burnup less than 1 would be significantly reduced in an area where there could be streaming outside the neutron shield. The applicant should provide a comparison of this method as it is implemented in the HI-STAR 190 to that of a source term with axial distribution produced by depleting each axial node to the appropriate burnup to demonstrate it is equivalent or conservative. Alternatively the applicant could provide a specific reference where this has been approved from a previous docket and discuss how it is applicable to the HI-STAR 190. The staff could not find this information in any of the referenced dockets. Any uncertainties in the axial burnup profile should be included in the best estimate evaluation in Section 5.4.6 of the application.

This information is required to determine compliance with the regulations limiting external dose rates in 10 CFR 71.47 and 71.51(a)(2).

5-10 Verify the units of mSv/hr in Table 5.4.18.

It appears that the units of mSv/hr in the table are incorrect and may be in reality mRem/hr.

This information is required to determine compliance with 10 CFR 71.47 and 71.51(a)(2).

5-11 Justify the uncertainty in the selection of the design basis fuel, Westinghouse 17x17 for PWR and the GE 10x10 for BWR.

In justifying the fuel assembly selections as appropriate for all of the analyses, the applicant compared it to fuel assemblies with a higher UO_2 mass, the B&W 15x15 for PWR and the GE 7x7 for BWR.

a) For the PWR assemblies, the applicant shows the differences in the surface dose rate for various locations around the package in Table 5.4.4(a) of the application. These results show that the design basis fuel (Westinghouse 17x17) produces higher surface dose rates for all locations around the package except the top. However, since the fuel burnup is specified as per MTU and the B&W 15x15 fuel has higher fuel load per assembly, it is expected that for the same burnup per MTU, the heavier fuel assembly will produce higher source. It was not clear why the WE 17x17 would give higher dose rates. The staff requests that the applicant discuss the differences between the assemblies and analyses parameters (such as burnup profile) that could produce these results.

b) As shown in Tables 5.4.5(a) and (b) of the application, both the B&W 15x15 and the GE 7x7 have higher dose rates at the limiting 2 meter location at the side of the package than the design basis fuel. The applicant has considered that these are "relatively equivalent." The staff is concerned about any non-conservative analysis assumption because the margins to the regulatory dose rate limit at 2 meters as shown by Table 5.1.3 and 5.1.4 of the application are small for this package. The staff requests that the applicant quantify this uncertainty and include it in the best estimate evaluation in Section 5.4.6 for both BWR and PWR fuel respectively. In doing so the applicant should determine a maximum uncertainty that covers all possible burnup values of the fuel as the difference in source term between the limiting and representative assemblies could be higher at higher burnups.

This information is required to determine compliance with 10 CFR 71.47 and 71.51(a)(2).

5-12 Clarify the best estimate calculation to evaluate uncertainty.

In lieu of evaluating the uncertainty in the calculated dose rates, the applicant has performed a best estimate evaluation to show that the conservatisms in the analysis parameters would compensates for any calculation uncertainty. This evaluation is presented in Section 5.4.6 of the application.

a) This section only includes a best estimate evaluation of the PWR design basis fuel. The staff requests that the applicant justify only evaluating PWR fuel or include a best estimate evaluation of uncertainties when considering BWR fuel.

b) The staff also requests that the applicant justify the conditions used to determine the uncertainties for the best estimate evaluation. For example, the uncertainty in the isotope inventory would be higher at higher burn-up. This may be particularly true for actinides that produce neutron and fission gamma sources.

This information is required to determine compliance with 10 CFR 71.47 and 71.51(a)(2).

Chapter 6 Criticality Evaluation

6-1 Revise Drawings 6506 and 6507 to include the minimum required ^{10}B in the Metamic-HT neutron absorber sheets for the MPC-37 and MPC-89 baskets, respectively.

Note 18 on both Drawing 6506 for the MPC-37 basket and 6507 for the MPC-89 basket include a reference to Table 1.2.2 of the application for the minimum required ^{10}B content of the Metamic-HT neutron absorber panels. Table 1.2.2 of the application does not contain minimum ^{10}B requirements for neutron absorber panels.

This information is required to determine compliance with 10 CFR 71.33.

6-2 Revise the application to demonstrate that the 15x15B, 16x16A, and 10x10A are appropriate to bound all PWR and BWR fuel assemblies, or provide a reference to where this has been demonstrated previously.

Throughout the criticality analysis in Chapter 6 of the application, the 15x15B fuel assembly class is used to bound all 15x15 and 17x17 fuel assembly classes, the 16x16 fuel assembly class is used to bound all 16x16 fuel assembly classes, and the 10x10A is used to bound all BWR fuel assembly classes. However, the application does not appear to include an analysis to support that these are in fact bounding fuel assembly classes. The application should be revised to include such an analysis, or to provide a reference to where this analysis has been previously performed. Note that analyses performed to demonstrate most reactive fuel assembly classes for PWR fuel in storage may not be applicable, as those analyses have been performed for fresh fuel in borated water, and the HI-STAR 190 analyses are performed for spent fuel compositions in fresh water.

This is necessary in order to demonstrate that the applicant has identified the most reactive credible configuration consistent with the chemical and physical form of the material.

This information is required to determine compliance with 10 CFR 71.55(b).

6-3 Revise the application to clarify the burnup assumed for PWR high burnup fuel for the defense-in-depth analysis in Section 6.6, and to clarify the maximum k_{eff} for this analysis.

Table 1.2.3 of the application states that the burnup assumed for potentially reconfigured PWR fuel for the defense-in-depth analysis performed in Section 6.6 is 45 GWd/MTU. However, Table 6.6.2 of the application states that the assumed burnup for this analysis is 45.29 GWd/MTU. Additionally, Table 1.2.3 of the application states that the k_{eff} limit for high burnup fuel with major reconfiguration for the defense-in-depth analysis is 0.95, while the k_{eff}s reported for PWR high burnup fuel in Table 6.6.2 are in excess of this value. The application should be revised to correct these apparent discrepancies.

This information is required to determine compliance with 10 CFR 71.59.

6-4 Revise Appendix 6.B of the application to demonstrate that the potential effects of integral burnable absorbers are bounded by the assumed irradiation conditions of the PWR fuel for the burnup credit analysis.

Section 6.B.2.2 contains a discussion of integral burnable absorbers, and summarizes NUREG/CR-6760, “Study of the Effect of Integral Burnable Absorbers for PWR Burnup Credit.” This study shows a positive effect of integral burnable absorbers that do not cover the ends of the fuel rods in a PWR fuel assembly. Section 6.B.2 of the SAR does

not address integral burnable absorbers further. NUREG/CR-6760 recommends that PWR burnup credit analyses include either: 1) a small reactivity bias to bound the effect of integral burnable absorber, or 2) demonstration that the effects of integral burnable absorbers are bounded by the effects of other modeling assumptions (e.g., BPR exposure).

This is necessary in order to demonstrate that the applicant has identified the most reactive credible configuration consistent with the chemical and physical form of the material.

This information is required to determine compliance with 10 CFR 71.55(b).

6-5 Revise the isotopic bias determination in Section 6.B.3.1.3 to correct the least squares fit and to evaluate trends in the bias as a function of burnup.

This section of the application states that the least squares fit of calculated versus measured reactivity differences in Figures 6.B.1 and 6.B.2 was calculated to intercept 0 delta-k at 0 burnup. This may not be appropriate, as the bias will be non-linear as it nears zero burnup (i.e., will potentially jump significantly from zero burnup to a burnup value that requires isotopic depletion calculations). Additionally, Section 6.B.3.1.3 states that the slope of the fit can be shown to be statistically insignificant, but no such demonstration is provided. The bias appears to vary as much as 0.01 over the burnup range from 10 to 60 GWd/MTU, which is significant from a criticality safety perspective.

This information is required to demonstrate compliance with 10 CFR 71.55 and 71.59.

6-6 Revise Section 6.B.5 of the application to clarify the establishment of loading curves for MPC-37 loading Configuration 3.

Section 6.B.5 of the application states that "the minimum burnup requirement is first determined for the spent fuel assemblies in the Configuration 3 with the fuel enrichment of 5.0 wt% ^{235}U. The damaged fuel assembly with 5.0 wt% ^{235}U enrichment and this minimum required burnup is used with the other spent undamaged fuel assemblies with lower enrichments to ensure that the derived loading curve is acceptable for any combination of undamaged and damaged fuel assemblies." This appears to conflict with the definition of Configuration 3 in Table 7.C.5, which states that the minimum burnup applies to all assemblies. Section 6.B.5 should be revised to clarify which initial enrichment and assembly average burnup assumptions were used to generate the loading curve for Configuration 3.

This information is required to determine compliance with 10 CFR 71.55 and 71.59.

6-7 Revise Section 6.B.5.1 to clarify the use of a combined loading curve for cooling times greater than three years to be used with 16x16A class fuel assemblies.

This section of the application states that the three and seven year cooling time loading curves for 16x16A class fuel assemblies are combined into a single loading curve for a regionalized basket loading applicable for fuel cooled three years or more.

However, the loading curves shown in Table 7.C.4(a) still show separate 16x16A loading curves for three and seven years cooling time. The applicant should revise Section

6.B.5.1, and Table 7.C.4(a), as necessary, to clarify the use of loading curves for regionalized loading configurations of 16x16A class fuel assemblies in the MPC-37 basket.

This information is required to determine compliance with 10 CFR 71.55 and 71.59.

6-8 Revise Appendix 6.C of the application to clarify which axial burnup profile is used for the BWR potential high burnup fuel reconfiguration analysis.

Section 6.C.3 of the application states that a bounding axial burnup profile is used in estimating margin and is applied to a calculation performed with 27 actinide and fission product isotopes and 45 GWd/MTU burnup.

However, this section does not state what axial burnup profile is used for the partial burnup credit approach for BWR fuel at 15 GWd/MTU burnup. Section 6.C.3 should be revised to include this information.

This information is required to determine compliance with 10 CFR 71.55 and 71.59.

Chapter 8 Acceptance Tests and Maintenance Program Evaluation

8-1 Provide additional information (including performance tests) which demonstrate that the package service conditions (temperature and pressure) will not challenge the capabilities of the seals.

Page 8.1-5 of the application states that cask closure seals are specified in the drawing package referenced in the CoC to provide a high degree of assurance of leak tightness under normal and accident conditions of transport. It also states that seal tests under the most severe package service conditions including performance at pressure under high and low temperatures will not challenge the capabilities of these seals and thus are not required.

However, the application did not provide any data to demonstrate seal performance under these conditions. The staff needs to have assurance seals will perform at these conditions to provide containment of the contents.

This information is required to determine compliance with 10 CFR 71.71 and 71.73.

8-2 Clarify what pre-specified threshold temperature during transportation is required for the fuel cladding temperature so protective measure are not required for extremely low temperatures.

Page 8.1-10 of the application states that for MPCs with HBF, protective measures from extremely low fuel cladding temperatures that may cause brittle fracture during transportation shall be in place if required by Chapter 7 of this SAR. It also states that protective measures are not required if fuel cladding temperatures are evaluated to remain above a pre-specified threshold temperature during transportation.

However, a pre-specified threshold temperature is not specified in the application. The staff needs to have assurance fuel cladding will remain above these temperature so the fuel cladding remains intact during the entire transport period.

This information is required to determine compliance with 10 CFR 71.71.

8-3 Clarify what the criteria are to determine that a maintenance leakage rate test of the HI-STAR 190 cask's seals prior to the pre-shipment leakage rate test is optional.

Page 8.2-3 of the application states that a maintenance leakage rate test of the HI-STAR 190 cask's seals prior to the pre-shipment leakage rate test is optional. However, the application does not provide any criteria to determine when a maintenance leakage rate is necessary. The staff needs to have assurance all tests are performed per maintenance program so containment of the contents is demonstrated.

This information is required to determine compliance with 10 CFR 71.71.

8-4 Explain what criteria are applicable to perform a proper inspection on the HI-STAR 190 cask's seals, to determine they can be used beyond recommended design life.

Page 8.2-3 of the application states that use of elastomeric seals beyond recommended design life may be acceptable with proper inspection and engineering justification. However, the application does not provide any acceptable criteria to determine this. The staff needs to have assurance seals will perform their function so containment of the contents is demonstrated.

This information is required to determine compliance with 10 CFR 71.71 and 71.73.

8-5 Explain how the in-service test verifies a continued adequate rate of heat dissipation from the cask to the environment. Provide monitored parameters and/or variables that are measured to demonstrate this along with adequate procedures to perform the in-service test.

Page 8.2-4 of the application states that a periodic thermal performance test shall be performed at least once within the 5 years prior to shipment to demonstrate that the thermal capabilities of the cask remain within its design basis. This test may be performed immediately after a HI-STAR 190 is loaded with approved contents. The in-service test is performed to verify a continued adequate rate of heat dissipation from the cask to the environment.

However, the application does not provide any details on how the in-service test is performed. The staff needs to have assurance that an in-service test will provide meaningful measured parameters that will correlate with adequate rate of heat dissipation and predicted fuel cladding temperatures.

This information is required to determine compliance with 10 CFR 71.71 and 71.73.

8-6 Clarify why enclosure vessel pressure vessel integrity confirmation is not applicable to MPCs loaded with HBF.

Table 8.A.1 (MPC Aging Management Program) of the application states that enclosure vessel pressure vessel integrity confirmation is not applicable to MPCs loaded with HBF. It appears that this confirmation would apply to HBF as well. Since the HI-STAR 190

cask features double containment barrier, the staff needs to have assurance pressure vessel integrity confirmation is demonstrated for HBF.

This information is required to determine compliance with 10 CFR 1.71 and 71.73.