Holtec International Revised Responses to NRC RSIs on HI-STAR 190

Chapter 1 – General Information

1.1 Provide the "Metamic-HT Qualification Sourcebook" (Reference 1.2.3), and ensure it includes the materials properties used in support of the analyses in Section 2.1.2.2 (ii) Fuel Basket.

Reference 1.2.3 in the application, "Metamic-HT Qualification Sourcebook," Holtec Report N. HI-2084122, Latest Revision, (Holtec Proprietary), is cited several times in the application. The staff requires the referenced document to review the material properties used in the analyses of the Model No. HI-STAR 190.

This information is required to determine compliance with 10 CFR 71.31(c).

Holtec Response:

Holtec has provided the most recent revision of HI-2084122 as Enclosure 5 to letter 5024003 (ADAMS No. ML15300A320) in the initial response to the HI-STAR 190 RSIs. This report is considered Holtec Proprietary Information.

Licensing Drawings

1-2 Revise Drawing No. 9841 and Figure 2.3.4, as appropriate, to delineate the location and the design details of the lower trunnion support structure of the package.

Figure 2.3.4, "Lower Trunnion Support Structure" indicates that, along the neutron shield rib, the lower trunnion support structure is aligned, in the cask axial direction, with the upper trunnion support structure. As such, there appears to be no consideration for introducing an offset for placement of the lower trunnion support from the cask symmetry plane to facilitate the cask down-ending operations. Also, the design details for the lower support structure should be presented on the drawing.

This information is required to determine compliance with 10 CFR 71.33(a)(5)(iii) and 10 CFR 71.45(a).

Holtec Response:

We regrettably agree that the statement in Section 1.2.1.7 describing the bottom trunnions as off-center is incorrect. The error has been removed, therefore, Figure 2.3.4 is correct as shown, and has not been revised.

The top and bottom trunnion support structures are identical in design. Section CU-CU on drawing no. 9841, sheet 4 of 5, shows the details of the trunnion support structure. These details are shown as "typical," because they are identical for both the upper and lower trunnions.

Similarly the parts list on sheet 1 of 5 has no separate identifiers for the upper and lower trunnion support components, as they are identical.

1-3 Revise note No. 28 of Drawing Nos. 6505 and 6512, on the cited Subsection 3.4.3.2 of the application for which the 8X 1-3/4 5UNC threaded holes are provided for the single-failure-proof MPC loading operations as depicted in Figure 1.2.5.

The erroneously cited subsection appears to be that associated with the MPC-37 and MPC-89 storage configurations. On this note, a review of the Drawing No. 6512, Rev. 4, of Docket No. 72-1032 for HI-STORM FW storage suggests that only four (4), in lieu of eight (8), threaded holes, are available for lifting the loaded MPCs.

This information is required to determine compliance with 10 CFR 71.33(a)(5)(iii).

Holtec Response:

Drawings 6505 and 6512 are the licensing drawings of MPC 37 and MPC 89 enclosure vessels, respectively, and they are included in both the HI-STORM FW FSAR and in the HI-STAR 190 SAR. MPC 37 and MPC 89 are the only two types of MPCs allowed to be loaded into the HI-STORM FW storage cask and the HI-STAR 190 transport cask. Both drawings show 8 threaded holes on the lid. Subsection 3.4.3.2 of the HI-STORM FW FSAR states: “The MPC lid has 8 TALs as shown on the drawings in Section 1.5, as stated in Section 3.4.3.1, only four tapped holes in the MPC lid are credited to carry the weight.” Further details on the MPC lid tapped holes, including engagement depth is discussed in the response to RSI 2-6.

For clarity, the drawing note has been revised to point to Subsection 3.4.3.2 of the HI-STORM FW FSAR.

1-4 Provide tolerances in the package drawings on dimensions of components relied on for shielding.

The package drawings should include tolerances on those package components that are included in the shielding analysis. Package tolerances are necessary to understand the package design and ensure the analysis is appropriate for the package design. Tolerances can have a significant impact on the shielding analysis.

This information is required to determine compliance with 10 CFR 71.47 and 71.51

Holtec Response:

The Holtite-B material used for the neutron shield is required to have a minimum hydrogen areal density, given in Table 8.1.9 of the application. This areal density is based on bulk density of the material, weight fraction of hydrogen, and thickness of the Holtite-B material in the cask. The as-built HI-STAR 190 cask will need to comply with this areal density to maintain shielding performance. Therefore, only a nominal value is shown on the drawing, and Note 8 references the additional critical characteristics defined in the SAR.

The lead material used for the gamma shield is evaluated in the shielding analysis. To ensure that the shielding analysis is appropriate, a minimum value has been added to the lead thickness on sheet 5 of 5, drawing number 9841.

Chapter 2 – Structural and Materials Evaluation

2-1 *Revise the misrepresented description of the upper lifting trunnions to recognize that the trunnions are not attached to the containment vessel flange as noted in the HI-STAR 190 application, Section 1.2.1.7, "Lifting and Tie-down Devices." Revise, as appropriate, the statement, "[T]he bottom trunnions may be slightly off-center to facilitate the rotation direction of the cask," or Drawing No. 5024 which does not display the off-center location for the lower trunnion support structure.*

Contrary to the statement, "Lifting trunnions are attached to the containment vessel flange," both Figure 2.3.4 and Drawing No. 5024 show that the upper trunnions are attached to the vertical neutron shield ribs instead. Also, it appears there is no design provision to allow an off-center alignment between the upper and lower trunnion support structures.

This information is required to determine compliance with 10 CFR 71.33(a)(5)(iii) and 71.45(a).

Holtec Response:

We regrettably agree that Section 1.2.1.7 contains an incorrect description of the cask lifting trunnion location. The trunnions are attached to the vertical neutron shield ribs as depicted in Figure 2.3.4 and Drawing No. 9841. Section 1.2.1.7 of the HI-STAR 190 SAR has been revised to correct the error and the alignment of the trunnions is described in RSI 1-2.

Lastly, to avoid confusion it is noted that the drawing number (5024) referenced in RSI 2-1 is incorrect. The correct drawing number is 9841. The number 5024, which appears in the title block of the drawing, is the Holtec project number.

2-2 *Revise the application to define the bounding oxide thickness and hydride rim values used to calculate the effective thickness for the high-burnup fuel cladding. Provide valid references for these values, as described in ISG-11, Rev. 3.*

Section 2.11 of the application states: "… the high burn-up fuel (i.e., fuel with burnups generally exceeding 45 GWd/MTU) may have cladding walls that have become relatively thin from in-reactor formation of oxides or zirconium hydride. The analysis thus considers the effective cladding thickness, per the guidance from ISG-11, to account for any loss of thickness from oxidation."

ISG-11, Rev. 3, further states: "For design basis accidents, where the structural integrity of the cladding is evaluated, the applicant should specify the maximum cladding oxide thickness and the expected thickness of the hydride layer (or rim). Cladding stress calculations should use an effective cladding thickness that is reduced by those amounts. The reviewer should verify that the applicant has used a value of cladding *oxide thickness that is justified by the use of oxide thickness measurements, computer codes validated using experimentally measured oxide thickness data, or other means that the staff finds appropriate. Note that oxidation may not be of a uniform thickness along the axial length of the fuel rods."*

Table 2.6.8 identifies a "cladding thickness considering thinning due to in-reactor oxidation" but does not identify the bounding oxide thickness and hydride rim values used to calculate this value. The application also does not provide valid references for the assumed values, per the guidance in ISG-11, Rev. 3.

This information is required to determine compliance with 10 CFR 71.85(a).

Holtec Response:

The cladding thickness listed in Table 2.6.8 has been derived based on the allowable contents for the HI-STAR 190, the oxidation corrosion data reproduced in Figure 4.A.12 of the HI-STORM 100 FSAR Rev. 2, and the guidance from the PNNL paper by Lanning and Beyer[1]. In short, the limiting fuel rod geometry is identified as the Westinghouse 14x14 OFA PWR fuel assembly based on its critical buckling load. This assembly type has a nominal cladding thickness of 0.0243". From Figure 4.A.12 of the HI-STORM 100 FSAR Rev. 2, the oxide corrosion based on a maximum burnup of 68.2 GWD/t is estimated to be 100 μm (3.94×10^{-3} in). Finally, per the PNNL paper by Lanning and Beyer, the wall reduction corresponding to a given oxide layer is determined based on the ratio (1.56) of the metal density to the oxide density. The resulting cladding thickness considering thinning due to in-reactor oxidation is 0.0218" [0.0243" – (0.00394"/1.56) = 0.0218"]. This calculation of the minimum cladding thickness is documented in Attachment 16A to Holtec Calculation Package No. HI-2146413.

A footnote has been added to Table 2.6.8 to provide the basis for the fuel cladding thickness.

It should be noted that the radioactive contents are not part of the HI-STAR 190 Packaging. Therefore, the condition of the fuel cladding has no bearing on the effectiveness of the packaging, and therefore compliance with 10 CFR 71.85(a) is ensured.

2-3 Revise the discussion in Section 2.11 to:

1. *Clearly define the specific zirconium cladding alloys in the proposed contents (e.g., Zircaloy-2 or Zircaloy-4, or both).*
2. *Clarify that Zirlo™ and M5® are not cladding alloys in the allowed contents.*
3. *Address the following when determining bounding mechanical property data for all cladding alloys in the proposed contents:*

    a. *maximum hydrogen in the cladding and distribution (for burnups 45-68.2 GWD/MTU),*
    b. *radial hydride fraction (for "load-and-go" and post-storage scenarios),*

[1] Lanning, D. D. and Beyer, C. E., "Estimated Maximum Cladding Stresses for Bounding PWR Fuel Rods During Short Term Operations for Dry Cask Storage", Pacific Northwest National Laboratory, January 2004.

c. fabrication process (recrystallized annealed, cold work stress relieved annealed), and,
d. thermal history (accounting for annealing of dislocation loops/hydrogen traps during an initial storage period prior to transport).

Revise the assumed bounding yield stress and elastic moduli, as appropriate, upon consideration of the above variables.

Section 2.11 of the application states that the fuel cladding for the HI-STAR 190 design bases fuel is "zircaloy," similar to that analyzed in Reference 2.11.4, and therefore concludes that the mechanical properties used in that study are adequate. However, Reference 2.11.4 states that "the material properties used in the analyses were based on expert judgment and included uncertainties. Ongoing experimental programs will reduce the uncertainties." Therefore, the use of these mechanical properties should be adequately justified in the application.

Section 2.11 further states that Reference 2.11.8 ("PNNL Stress/Strain Correlation for Zircaloy", PNNL-17700) shows a minimum elastic modulus of 9.61×10^6 psi and a minimum yield strength of 76,870 psi for the high burnup fuel cladding. These minimum cladding properties were determined from Figure 22 in Reference 2.11.8 for a bounding temperature of 673K (400°C) with a fast fluence of 11.7×10^{25} n/m^2, nominal hydrogen concentration of 360 ppm and 50% cold worked. Reference 2.11.8 states that the models described in that reference apply only to cladding with circumferential hydrides and do not apply to cladding with radial hydrides or significant hydride blisters or spalling.

The applicant states (Section 2.11) that the referenced EPRI Report 1015048 considered the interaction between radial and circumferential hydrides in that it "essentially predicts the minimum properties described above." The application does not reference any figure or specific data or discussion on this report that would serve as confirmation that the data in Figure 22 in Reference 2.11.8 is indeed bounding for all claddings in the allowed contents. The data in Figure 22 is based on cladding with a nominal hydrogen concentration of 360 ppm, which are not representative for the requested maximum burnup (68.2 GWd/MTU). Hydrogen concentrations exceeding 600 ppm are observed for discharge burnups in the range of 60-65 GWd/MTU. The radial hydride fractions for Zircaloy-2 and Zircaloy-4 are also expected to be different, as Zircaloy-4 is generally cold work stress relieved annealed (elongated grains and a high density of dislocations) whereas Zircaloy-2 may be recrystallized annealed (more susceptible to radial hydride formation) and may contain an alloyed or pure Zr liner affecting hydride precipitation over long-term storage. The thermal history of the fuel is also expected to affect the resultant radial hydride fraction and the available hydrogen to precipitate, therefore the mechanical properties will be dependent on when the fuel is transferred following an initial storage period. The application needs to address all these variables prior to assuming bounding a given set of values for elastic moduli and yield strength.

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

Holtec Response:

In the HI-STAR 190, the type and condition of the fuel cladding material does not impact the containment capability and the shielding effectiveness of the packaging. This is because the HI-STAR 190 cask has been designed to meet the leaktight requirements per ANSI N14.5. In addition, containment boundary integrity is maintained under a hypothetical 100% fuel rod rupture with coincident hypothetical fire accident consistent with RG 7.6.

The fuel rod integrity analysis summarized in Section 2.11 of the HI-STAR 190 SAR is part of the multi-layered approach used to demonstrate compliance with 10 CFR 71.55 and qualify high burnup fuel (HBF) for safe transport in the HI-STAR 190 cask. As discussed in detail in Appendix 1.A and summarized in Table 1.2.4 of the SAR, the fuel rod integrity analysis is just one component of the defense-in-depth safety case. The primary safety case for safe transport of HBF under accident conditions is based on moderator exclusion.

For normal conditions of transport, as described in Table 1.2.4 of the SAR, the best estimate structural assessment of HBF integrity, based on available fuel cladding data for Zircaloy indicates that there will be no rod break or permanent lateral deformation of lattice. However, due to the lack of availability of material data, the HI-STAR 190 application follows the strategy outlined in the NRC's Draft Regulatory Issue Summary, "Considerations in Licensing High Burnup Spent Fuel in Dry Storage and Transportation," for transporting fuel that has been in dry storage. Since detailed materials data is not available for all fuel cladding types, safety analyses have been performed assuming a minimum of 3% fuel failure. These analyses as summarized in Table 1.2.4, show that the package maintains its effectiveness under normal conditions of transport. Table 1.2.4 has been updated to clarify these analyses.

In summary, the primary safety case for normal conditions of transport is based on 3% failed fuel, and the primary safety case for hypothetical accident conditions is based on moderator exclusion as described in Appendix 1.A. Since the fuel rod integrity analysis is not the main approach used to demonstrate compliance with 10 CFR 71.55, Holtec believes that the analysis as performed is sufficient and provides the additional assurance expected from a defense-in-depth evaluation.

2-4 *Revise the application to clarify if Carboguard 890 will be used as a coating for interior or for exterior surfaces. Clarify if the Carboguard 890 and Carboline 890 coatings are equivalent. Clarify if any of the Carboline® coatings (Thermaline® 450 or equivalent, and Carboline 890 or equivalent) used to coat the interior/exterior steel surfaces of the HI-STAR 190 package are important to safety. Clarify if any of the other proposed surface passivation coatings in Section 2.2.1.2.5 (aluminum oxide or alternate) are important to safety. If the coatings are important to safety, revise Section 8.2.3.3 "Components and Materials Tests," to ensure these coatings are properly maintained.*

Section 2.2.1.2.4 states that: "The HI-STAR 190 cask's internal surfaces are coated with a conventional surface preservative such as Carboguard® 890 (see www.carboline.com for product data sheet) and/or equivalent surface preservative." However, notes 13 and 9 of drawings 9841 and 9848, respectively, state: "All carbon steel external surfaces (except for threaded holes or sealing surfaces) to be coated with Carboline 890 or *equivalent." It is unclear if Section 2.2.1.2.4 should be referring to external surfaces instead of internal surfaces.*

In addition, Sections 2.2.1.2.4, 2.2.1.2.5 and Drawing Nos. 9841 and 9848 do not identify if the Carboline® coatings used for coating the interior/interior surfaces of the cask are important to safety. Section 2.2.1.2.5 further does not define the alternate surface passivation coatings (aluminum oxide or equivalent) as important to safety. Therefore, the staff cannot verify if the acceptance criteria in Section 8.2.3.3 for "Component and Materials Tests" is adequate.

This information is required to determine compliance with 10 CFR 71.31(c).

Holtec Response:

The exterior steel surfaces of the cask will be coated with a conventional surface preservative such as Carboguard® 890, which is equivalent to Carboline® 890. The interior surface of the cask may be coated with Thermaline® 450, or protected by other surface preservation methods as discussed in Section 2.2.1.2.5. The first sentence in Section 2.2.1.2.4 has been corrected and the titles of Sections 2.2.1.2.4 and 2.2.1.2.5 have been revised to avoid confusion. The proposed cask interior and exterior surface coatings, i.e., Thermaline® 450, Carboline® 890/ Carboguard® 890, as well as other surface preservation methods mentioned in Subsection 2.2.1.2.5, are not important to safety (NITS), since their failure would not reduce the package shielding effectiveness and would not adversely affect public health and safety. The NITS designation has been explicitly documented in the above referenced SAR subsections.

Observations

2-5 Provide clarification, as appropriate, on how the fuel deceleration attenuator (FDA) is implemented in the package design for closure of the gap between the stored fuel assemblies and the closure lid.

The staff is unable to locate the subject hardware in the drawings.

This information is required to determine compliance with 10 CFR 71.33(a)(5)(iii).

Holtec Response:
The FDA is not used in the design of HI-STAR 190, which, unlike bare fuel transport casks (e.g., HI-STAR 180) with two closure lids, is an MPC based transport cask with only one closure lid. The HI-STAR 190 package design ensures that the cask closure lid is directly buttressed by the impact limiter backbone structure in the governing top end 30 ft drop event so that the closure lid seals remain safely compressed under the impact from the loaded MPC. Holtec has removed the definition of FDA from the glossary to avoid confusion.

2-6 Provide an evaluation of the engagement depth for the threaded holes for the MPC lifting operations.

A review of Drawing No. 6512, Rev. 4, for the HI-STORM FW application suggests that only four (4), in lieu of eight (8), threaded holes, are available for lifting the loaded MPCs.

This information is required to determine compliance with 10 CFR 71.33(a)(5)(iii).

Holtec Response:

Drawings 6505 and 6512 are the licensing drawings of MPC 37 and MPC 89 enclosure vessels, respectively, and they are included in both the HI-STORM FW FSAR and in the HI-STAR 190 SAR. MPC 37 and MPC 89 are the only two types of MPCs allowed to be loaded into the HI-STORM FW storage cask and the HI-STAR 190 transport cask. Beginning with Revision 5 of both drawings, which were issued in September 2012, the number of threaded lifting holes on the MPC lid was increased from four to eight. This design change was first reflected in HI-STORM FW FSAR Revision 2 by including Revision 7 of Drawing 6512 and Revision 6 of Drawing 6505. In addition, Subsection 3.4.3.2 of the HI-STORM FW FSAR was revised to state: “The MPC lid has 8 TALs as shown on the drawings in Section 1.5, but as stated in Subsection 3.4.3.1, only four tapped holes in the MPC lid are credited to carry the weight.” All MPC 37 and MPC 89 fabrication has been based on HI-STORM FW FSAR Revision 2 or a later revision, which means that all fabricated MPC lids are equipped with 8 threaded holes.

The engagement depth for the threaded holes was evaluated previously to support the HI-STORM FW application (see Subsection 3.4.3.2 of the HI-STORM FW FSAR) by demonstrating that the threaded holes maintain a minimum safety factor of 3 based on material yield strength (per RG 3.61) and a minimum safety factor 10 based on material ultimate strength (per NUREG-0612). Note that the threaded holes on the MPC lid are interfacing lift points and therefore are only required to maintain a minimum safety factor of 10 based on material ultimate strength per NUREG-0612. Therefore, the existing structural evaluation of the threaded lifting holes on the MPC lid performed in the HI-STORM FW FSAR effectively satisfies all applicable stress requirements of NUREG 1617, 10CFR§71.45(a) and NUREG-0612 for lifting attachments or interfacing lift points associated with a transport package. The existing evaluation in the HI-STORM FW FSAR is directly referenced in Subsection 2.5.4 of the revised HI-STAR 190 SAR.

2-7 Provide an evaluation of the closure lid-to-flange joint configuration with respect to the interface clearance between the closure lid and the containment top flange.

The applicant should demonstrate that closure lid bolts need not to be evaluated for the average shear and tension plus shear stresses, per ASME Section III, Appendix F, for the 30-ft free-drop accidents. On the basis of the evaluation results, revise, accordingly, Table 2.1.3, “Stress Limits for Lid Closure Bolts (Elastic Analysis per NB-3230),” as appropriate.

Table 2.1.3 does not provide the basis for not considering stress other than the average bolt tensile stress for bolt stress evaluation. The staff notes that the Drawing No. 9841 provides no closure lid design details, including the difference in diameters between the lid and the containment closure flange, in which the lid appears to be in close proximity *to the flange, which would allow the former, and thus the lid bolts, to be subject to shear force during a side drop accident.*

This information is required to determine compliance with 10 CFR 71.33(a)(5)(iii) and 10 CFR 71.73(c)(1).

Holtec Response:

The cask closure lid bolt joint is sufficiently preloaded (3.035×10^6 lbf per Table 2.2.10 of the HI-STAR 190 SAR) to be qualified as a friction type connection per NF-3324.1, since the friction force (based on a conservatively assumed static friction coefficient of 0.5) at the lid-to-flange interface can prevent the 13,000 lb lid from sliding as long as the lid's deceleration is less than 117 g's. Per Table 2.7.2 of the SAR, the maximum lid deceleration in all analyzed 30 ft drop events is 89.0 g's. Therefore, the closure lid bolts are exempt from shear stress evaluation per ASME Section III, F-1135.2 and NF-3324.6. A note has been added in Table 2.1.3 of the HI-STAR 190 SAR for clarification along with the above justification. Because the closure lid bolt joint is indeed a friction type connection, more details with respect to the closure lid design (including the lid-to-flange interface clearance) are not shown on the licensing drawing of the cask.

2-8 *Ascertain that the containment shell stress intensity results are consistently reported and evaluated.*

The maximum stresses based on the fringe plots are seen different from those noted in the captions of Figures 2.7.12 and 2.7.15. For instance, in Figure 2.7.12, a maximum shear stress of 20.16 ksi, which is different from that of 25.04 ksi displayed in the fringe plot, is used for calculating the maximum primary stress intensity of 40.32 ksi (20.16 x 2 = 40.32). It appears that the stress intensity should have been calculated as 50.08 ksi (25.04 x 2 = 50.08) instead.

This information is required to determine compliance with 10 CFR 71.33(a)(5)(iii) and 71.73(c)(1).

Holtec Response:

For the Level-D accident conditions analyzed in Section 2.7, only the primary stress intensity value of the analyzed structure is required to be evaluated per ASME B&PV code, Section III, Division 1, Subsection NB and Appendix F. The peak stress value shown in the fringe plot is typically the maximum secondary stress at a local structural discontinuity or directly at the point of impact. All the reported primary stress intensity values were carefully taken from the areas away from the secondary stress locations and they represent the bounding primary stresses based on the results shown in the fringe plots.

2-9 Provide the following references:

(i) "Development and Discussion of Design Code for Baskets Made of Aluminum Alloys and Borated Aluminum Alloys for Transport/Storage Packagings," by M. Hirose, T. Saegusa, K. Miyata, T. Nakatani, H. Akamatsu, and T. Yamamoto, Proceedings of the 15th International Symposium on the Packaging and Transportation of Radioactive Materials. PATRAM 2007, Miami, Florida.

(ii) Source for S_y, S_u, E, and % Elongation values in "Properties of Aluminum Alloys, Tensile, Creep, and Fatigue Data at High and Low Temperatures, ASM International, November 2006," page 82.

This information is required to determine compliance with 10 CFR 71.31(c).

Holtec Response:

Holtec previously provided a copy of the first reference as Enclosure 6 to Letter 5024003 (ADAMS No. ML15300A320). The relevant pages of the second reference, a book from which that material property data listed in Table 2.2.7 was taken, were also provided as Enclosure 6 to Letter 5024003.

Chapter 5 – Shielding Evaluation

5-1 Provide the following information regarding the assembly hardware and non-fuel hardware shielding analysis:

(i) Cobalt impurity level assumed for assembly hardware and non-fuel hardware, both for the steel and Inconel components, and provide the basis for the assumed impurity level.

(ii) AgInCd gamma source spectrum for axial power shaping rods, as in Table 5.2.13.

This information is an important part of the analysis of the contributions to dose rates from the assembly hardware and the non-fuel hardware.

This information is required to determine compliance with 10 CFR 71.47 and 71.51.

Holtec Response:

(i) Discussion about cobalt impurity level is added to Subsections 5.2.1 and Paragraph 5.2.3.1.

(ii) As discussed in Paragraph 5.2.3.2, "*there are two types of B&W stainless steel clad APSRs: gray and black. According to reference [5.0.4], the black APSRs have 36 inches of AgInCd as the absorber while the gray ones use 63 inches of inconel as the absorber. Because of the cobalt-60 source from the activation of inconel, the gray APSRs produce a higher source term than the black APSRs and therefore are the bounding APSR.*" As a result, the AgInCd axial power shaping rods have not been explicitly analyzed.

It is acknowledged that the misunderstanding has happened to due to typos in last two columns' headers in Table 5.2.12. The correct Table 5.2.12 is:

Axial Dimensions Relative to Bottom of Active Fuel			**Flux Weighting Factor**	**Mass of Cladding (kg Steel)**	**Mass of Absorber (kg Inconel)**
Start (in.)	**Finish (in.)**	**Length (in.)**			
Configuration 1 - 10% Inserted					
0.0	15.0	15.0	1.0	1.26	5.93
15.0	18.8125	3.8125	0.2	0.32	1.51
18.8125	28.25	9.4375	0.1	0.79	3.73

Additionally, the term "from Inconel" will be removed from the last column's header of Table 5.2.13.

It should be noted that Table 5.2.12 and Table 5.2.13 are the same as Table 5.2.33 and Table 5.2.35 of HI-STORM 100 FSAR (HI-2002444R12), for 10% inserted APSR.

5-2 Provide the following specifications for the proposed contents in Appendix 7.C.

(a) Maximum uranium loading in MTU per assembly,

(b) Clear specifications for maximum irradiation exposures, in terms of MWd/MTU, and minimum decay times for the different types of proposed non-fuel hardware contents,

(c) Material specifications for guide and instrument tubes, water rods, and BWR channels.

These specifications appear to be missing from the application's description of the proposed contents given in Appendix 7.C of the application. Thus, the description is not adequate to explain the package contents or to evaluate the adequacy of the shielding analysis in addressing the proposed package contents.

This information is required to determine compliance with 10 CFR 71.33(b), 71.47, and 71.51.

Holtec Response:

(a)
Maximum uranium weight is added to Table 7.C.1 for PWR ($\leq$ 0.495 MTU) and BWR ($\leq$ 0.198 MTU) fuel. The weights are based on bounding 15x15 and 7x7 assemblies, respectively. These

maximum initial uranium loadings are based on the same values cited in the HI-STORM 100 CoC (Docket Number 72-1014).

(b)
Table 7.C.13 is added to Appendix 7.C. This table provides non-fuel hardware burnup and cooling time limits, and is based on Table 2.1-8 of HI-STORM 100 CoC (Docket Number 72-1014). Minor editorial changes are made to Appendix 7.C to accommodate Table 7.C.13.

(c)
Material specification for guide tubes, instrument tubes, water rods and BWR channels is "Zr" based alloy. This information is added to Table 7.C.1. Definition of "Zr" is provided in glossary of terms in Chapter 1.

5-3 Include a shielding analysis to address transportation of damaged fuel and fuel debris for both PWR and BWR spent fuel contents.

Appendix 7.C, Table 7.C.1, indicates that the proposed contents include damaged fuel and fuel debris. However, the shielding analysis appears to only address undamaged fuel for spent fuel at burnups less than 45 GWd/MTU. The staff recognizes that specific reconfiguration cases have been analyzed for spent fuel with burnups greater than 45 GWd/MTU (i.e., high burnup fuel, or HBF). However, these reconfiguration cases do not address the proposed HBF contents that are loaded as damaged fuel or fuel debris. Damaged fuel and fuel debris will be in a degraded condition for both NCT and HAC and will not necessarily fit the specific reconfiguration cases considered in the shielding analysis.

This information is required to determine compliance with 10 CFR 71.47 and 71.51.

Holtec Response:

Discussion about shielding analysis of debris and damaged fuel assemblies is added to Sections 5.0 and Subsection 5.4.10, by referring to previous shielding analyses of debris and damaged fuel for the 100-ton HI-TRAC and HI-STAR 100 [5.0.4].

5-4 Provide the basis for the amount of reconfiguration assumed in NCT (and HAC) shielding analyses.

Holtec Response:

NCT Reconfiguration: For the NCT it was assumed that ALL rods break and that as a result the active region collapses by 10%, i.e. to a height of 90% of the initial active region. This is considered to be more conservative than the condition recommended in [1], where it is suggested to consider 3% of fuel rods to be broken, but without any specific recommendations with respect to the resulting configuration broken rods. To show that the approach taken here is acceptable, two additional configurations have been analyzed, using the 3% value from [1] as the amount of broken rods, and, as an extremely conservative assumption, assume that all fuel from those rods collects at the bottom of the cask. All results are summarized in the revised Table 5.4.3 of the SAR.

The results show that the dose rates for the three configurations with broken rods (one configuration with 10% and two with 3%) are comparable to each other, comparable to the reference condition without any broken rods, and are all below the regulatory limit.

It should be noted that for MPC-37 loading patterns, the maximum burnup in HI-STAR 190 SAR is 68,200 MWd/mtU. Conservatively, in shielding analyses the burnup of 70,000 MWd/mtU is used instead of 68,200 MWd/mtU for the same enrichment and cooling times. Besides, an additional burnup of 75,000 MWd/mtU (with an initial enrichment of 4.6 wt%) is also considered. For two new analyzed NCT reconfiguration scenarios, the maximum burnup is limited to 70,000 MWd/mtU, which is still conservative.

HAC Reconfiguration: For the HAC it was assumed that all rods break and that as a result the active region collapses by 50%, i.e. to a height of 50% of the initial active region. This is considered very conservative, since the tight package of rods in an intact assembly, together with the presence of the support structure components such guide tubes and grid straps, is not expected to allow a fuel assembly to collapse to such an extent. Note that the same approach was taken for the HI-STAR 180 [3] and HI-STAR 180D [4].

5-5 Clarify how the shielding analysis addresses MPCs of different lengths; the analysis should include the MPC/package configuration that results in maximum dose rates.

Holtec Response:

Table 7.C.8(a) is updated to include PWR fuel assemblies with longer active fuel lengths.

For these fuel assemblies, the minimum cooling times are increased in a manner so that the neutron and gamma source terms (neutrons/s and photons/s) of the longer fuel assemblies are less than those of the design basis assembly (considering both evaluated Westinghouse 17x17 and B&W 15x15 fuel assemblies). Since the minimum cooling times for these longer fuel assemblies are longer than those of design basis fuel assembly, the design basis fuel assembly will have a higher cobalt source term as well. It is concluded that the MPC/package configuration for the design basis fuel assembly results in maximum dose rates, considering fuel specifications provided in Appendix 7.C.

Since, currently, only BWR assemblies with one active fuel assembly range (which is ≤150 inches) are authorized to be loaded to HI-STAR 190, no similar table for BWR fuel assemblies with longer active fuel length is needed.

A new Subsection 5.4.12 is added to clarify the fuel assemblies with longer active fuel length, and Appendix 7.C is updated accordingly.

5-6 Demonstrate that analysis conservatisms adequately compensate for analysis uncertainties (from using source term code above validated range, assumptions/simplifications in the models, etc.).

Holtec Response:

To show that the shielding analysis conservatisms adequately compensate for analysis uncertainties, a comparison has been added between the design basis calculations and a set of calculations with reduced conservatisms ("best estimate") and added uncertainties. Results are presented in revised Subsection 5.4.6 of the SAR, and show that in fact the conservatism sufficiently compensate for the uncertainties. Note that the approach is similar to that used for the HI-STAR 180 [3, Subsection 5.4.6].

5-7 Provide the design basis source terms for both PWR and BWR spent fuel contents, including for other fuel types evaluated (i.e., W 17x17, GE 10x10, B&W 15x15, and GE 7x7 assembly types).

Holtec Response:

Due to the large range of burnups, enrichments and cooling times, and hence large range of source terms, that are shown to be acceptable for loading in the HI-STAR 190, only a small set of representative source terms is presented in Chapter 5 of the SAR (Tables 5.2.3, 5.2.5 and 5.2.6). Other source terms are documented in Holtec Report HI-2146423 provided with the SAR.

5-8 Describe whether the proposed TPD and NSA contents include TPD and NSA types that have absorber rodlets and how the shielding analysis addresses these types of TPDs and NSAs.

Holtec Response:

The proposed TPD and NSA contents include TPD and NSA types that have absorber rodlets, and notes have been added to Appendix 7.C in that respect.

The shielding analysis as presented already bounds such configurations, as can be shown from the results presented in Table 5.4.7 considering the specific configurations of those devices: The TPD/NSA and the absorber rods (BPRA rods) have activated material in slightly different locations, and hence dose rates in different locations around the cask:

- TPDs/NSAs have activated material predominantly near the top of the assembly. The main dose rate impact is therefore at the top of the cask. This can be seen from the surface dose rates near the top (Dose Location 3) listed in Table 5.4.7, which shows a more pronounced increase for the TPDs compared to the BPRAs, although the values are still far below the limit.
- BPRA has also some activated material near the top of the assembly, but then the main activated material from those rodlets is along the active region, based on the assumed steel cladding of the absorber. This can also be seen from the results

presented in Table 5.4.7, where the maximum dose rate at 2 m distance from the cask is increased for the presence of the BPRAs, but not for the presence of the TPDs. (Note that surface dose location 2 is not useful for the comparison here, since the maximum surface dose rate is found near the bottom of the cask which is neither affected by TPDs or BPRAs).

It should also be noted that the maximum allowable burnup for TPDs with burnable rodlets is limited in Appendix 7.C to maximum allowable burnup for BPRAs.

In summary, since TPDs/NSAs and BPRAs affect different areas around the cask, and since the impact of the TPDs/NSAs is very small, any addition of absorber rodlets to TPDs is bounded by the current analyses and acceptable. Subsections 5.2.3 and 5.2.4, and Appendix 7.C of the SAR have been updated to clarify this.

5-9 Describe how the shielding analysis supports the distinct specifications for 8x8F assemblies in Table 7.C.1 versus the other BWR assemblies in the proposed contents.

Holtec Response:

The distinct specifications for 8x8F assemblies in Table 7.C.1 versus the other BWR assemblies in the proposed contents is based on potential differences in the thermal performance of this assembly type, and not related to shielding. From a shielding perspective, the design basis analyses bound this assembly, since they consider a higher fuel mass than that assembly, and more limiting burnup and cooling time combinations.

5-10 Clarify whether the proposed contents include assemblies with axial blankets and how the shielding analysis includes assemblies with axial blankets.

Holtec Response:

For a given assembly average burnup, the local burnup at the top and bottom of the active region will be lower due to the lower enrichment, and in the center of the assembly the burnup will be somewhat higher, compared to an assembly with a constant axial enrichment. Consequently, dose rates near the assembly ends will be lower, while the dose rate in the center of the fuel will be slightly higher. For the side surface of the HI-STAR 190 cask, the maximum dose rate is in front of the bottom trunnions, not at the center of the cask. Thus, the use of axial blankets will not result in increasing maximum side surface dose rates. At 2 m, the effect on dose rates will be reduced since the increase will be partially offset by the reduced contribution from the end section of the fuel. Overall, the effect of axial blankets is therefore not expected to be significant, and hence fuel assemblies with axial blankets are considered acceptable.

Subsection 5.4.11 is added to clarify the loading of fuel assemblies with axial blankets, and Appendix 7.C is updated accordingly.

Chapter 5 RSI References:

1. NRC Draft Regulatory Issue Summary 2015-XX Considerations in Licensing High Burnup Spent Fuel in Dry Storage and Transportation, ML14175A203.
2. HI-STORM 100 FSAR (Docket 72-1014), HI-2002444, Revision 12.
3. HI-STAR 180 SAR (Docket No. 71-9325), HI-2073681, Revision 6.
4. HI-STAR 180D SAR (Docket No. 71-9367), HI-2125175, Revision 3.
5. Recommendations for Shielding Evaluations for Transport and Storage Packages, NUREG/CR-6802, ORNL/TM-2002/31.

Chapter 6 – Criticality Evaluation

6-1 Revise the application to specify the minimum required 10B areal density in the Metamic HT neutron absorber panels for the MPC-37 and MPC-89 canisters.

The minimum 10B areal density for the Metamic HT absorber panels does not appear to be specified on the HI-STAR 190 licensing drawings, or in the criticality safety chapter of the application.

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

Holtec Response:

The reference on the minimum B_4C loading in Metamic-HT material is shown in Note 18 in the licensing drawings 6506 and 6507 for MPC-37 and MPC-89, respectively. Also, the minimum B_4C content is presented as the acceptance criterion for the Metamic-HT panel in Table 8.1.4 of HI-STAR 190 SAR. Nevertheless, it is additionally provided in Subsection 6.3.2 of HI-STAR 190 SAR.

6-2 Revise the application to consider preferential flooding of the damaged fuel cans in configurations where they are present.

Section 6.3.4.4 addresses preferential flooding, and concludes that an explicit analysis is not required, as the basket is designed with drain holes at the top and bottom of the neutron absorber panels, and the damaged fuel cans have mesh screens at the top and bottom for water drainage. However, for damaged fuel can configurations, the drain rate (or fill rate, in the case of reflooding) of the damaged fuel cans will be lower than that of the rest of the canister, and could potentially be much lower if fuel debris were to partially block the lower screen. Therefore, the canister could exist for some time with different water levels in the damaged fuel cans than is in the rest of the canister, during draining or reflooding.

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

Holtec Response:

[Withheld in Accordance with 10 CFR 2.390]

Observations

6-3 Appendix 7.D, for Method A of burnup verification, states: "For each assembly in the F-37 where burnup credit is required, the minimum burnup is determined from the burnup requirement applicable to the configuration chosen for the cask (see Table 7.D.6)." Table 7.D.6 does not appear to be part of the application. Provide this table or revise the text to reference the appropriate existing table in the application.

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

Holtec Response:

All instances of reference on Table 7.D.6 in Appendix 7.D are replaced with the references on Table 7.C.4 (a).

Chapter 7 – Criticality Evaluation

7-1 Provide package operations descriptions in Chapter 7, "Package Operations," for loading spent fuel contents into the MPCs for 'load and go' transport.

Operations for 'load and go' transport do not fall under the jurisdiction of 10 CFR Part 72 operations since the MPC is not stored for any duration of time at a 10 CFR Part 72 independent spent fuel storage installation.

The loading operations in this scenario are to directly transport the spent fuel from the spent fuel pool to some off-site location. Thus, these loading operations are under the jurisdiction of 10 CFR Part 71 and the essential elements of these operations should be described in the package operations part of the application to ensure that the package is operated in a manner consistent with the analyses submitted in the application.

This information is required to determine compliance with 10 CFR 71.87.

Holtec Response:

While the majority of MPCs planned for loading into the HI-STAR 190 are MPCs that have been stored under storage dockets 72-1032 and 72-1040, MPCs may also be used in the "load and go" configuration. The essential operational elements of the "load and go" process have been added to the HI-STAR 190 SAR, under Subsection 7.1.6.

Chapter 8 – Maintenance Procedures

8-1 Provide the minimum B_4C content specifications for the neutron shielding material in Chapter 8 of the application (in Table 8.1.9) and an acceptance test for ensuring material compliance with this specification.

The B_4C content is an important component of the neutron shield material that is part of the shielding analysis. Without this specification, the description of the critical characteristics of the package's neutron shielding is not complete, and it is unclear that the shielding analysis uses the appropriate material information.

This information is required to determine compliance with 10 CFR 71.47 and 71.51.

Holtec Response:

Chapter 8 of the SAR has been revised to specify the minimum B_4C content for the neutron shielding material (Holtite-B) and to provide an acceptance test for ensuring material compliance with this specification.

The following clarifications have been made to the application.

- **Chapter 1, Table 1.5.3:** Deleted "nominal" from the property "Boron Carbide Content".
- **Chapter 8, Paragraph 8.1.5.4:** Added spectrochemical and/or gravimetric analysis as the acceptance test for the boron carbide content of Holtite-B for each manufactured lot.
- **Chapter 8, Table 8.1.9:** Added the "Minimum Boron Carbide Content" specification for Holtite-B.

8-2 Revise the application to describe procedures and acceptance criteria for pre-transport inspections for ensuring that MPCs loaded during their initial storage period or during a renewed period will be free of corrosion pits, partial through-wall cracks, uncontrolled voids or other defects that could significantly reduce the effectiveness of the packaging, and compromise compliance with the proposed approach consistent with ISG-19. The proposed acceptance criteria should be justified by ensuring the MPC configuration analyzed in the application is valid for all shipments.

Section 8.2.2 states: "A pre-shipment leakage rate test of cask containment seals and MPC containment boundary (See Appendix 8.A for applicability) is performed following fuel loading per Subsection 8.1.4. This pre-shipment leakage rate test is valid for 1 year. If the pre-shipment leakage rate test expires, a periodic leakage rate test of the containment seals must be performed prior to transport. This periodic leakage rate test is valid for 1 year."

Section 8.2.1 further states: "The MPC maintenance program under the aegis of the HI-STORM FW FSAR (Docket # 72-1032) or the HI-STORM UMAX FSAR (Docket # 72-1040) shall include an aging management program (applicable to storage durations longer than the initial storage license life) that ensures continued radiological safety of the MPC and verifies that the MPC pressure and/or containment boundary (as applicable) is free of cracks, pinholes, uncontrolled voids or other defects that could significantly reduce the effectiveness of the packaging."

Section 1.A.2 further states: "The MPC is already designed, manufactured and field-welded to be completely leak-tight. However, since a leak test directly after loading the MPC is not feasible, the MPCs are not formally leak-tight per ANSI 14.5, they are simply described as a system where leakage is not credible. The leakage test of the MPC after loading it into the HI-STAR 190 will serve now as the formal proof that the MPC is leak-tight in compliance with the ANSI standard."

The statement in Section 8.2.2 appears to be only applicable to the "load-and-go" configuration, as defined in page 1.0-1 of the application. The statement in Section 8.2.1 suggests that the licensee would rely on the aging management program for verifying the confinement of the MPC has not been breached. However, it is unclear if an additional acceptance inspection will be performed prior to transport of an MPC during its renewed storage period (i.e., >20 years).

Moreover, it is unclear if MPCs in their initial storage period (i.e., <20 years) will be subject to any pre-transport acceptance inspection, since these canisters would not be subject to an aging management program. Table 8.A.1 and the statement in Section 1.A.2 suggest that such pre-transport inspections are not a requirement. If so, the application should address the procedures and acceptance criteria to determine that the pressure and/or containment boundary is free of corrosion pits, partial through-wall cracks, uncontrolled voids, or other defects due to age-related degradation (e.g., stress corrosion cracking) that could reduce the effectiveness of the package and compromise compliance with the proposed approach consistent with ISG-19.

The staff notes that, although aging management programs start at year 20, age-related degradation starts at the time the MPC is placed on the pad. The acceptance criteria for the pre-transport inspections should be properly justified in the discussions by providing reasonable assurance that the configuration analyzed in the application is valid for all shipments.

This information is required to determine compliance with 10 CFR 71.85(a).

Holtec Response:

The application requires <u>all</u> MPCs containing high burnup fuel to undergo pre-transport leakage rate testing of its containment boundary in accordance with ANSI N14.5 and to the leak-tight criteria of ANSI N14.5 regardless of whether or not the MPC entered a period of interim storage and regardless of applicability of an aging management program. This leakage rate test is performed with the sealed MPC placed in the HI-STAR 190 Overpack. The overpack is used as a test vessel to facilitate the leakage rate testing of the MPC containment boundary.

The leakage rate testing of all MPCs containing high burnup fuel is consistent with Section 1.A.2 and Table 8.A.1 of the application. Table 8.A.1 "MPC Transportability Checklist" of the application provides a listing of all MPC requirements under various categories such as acceptance tests and inspections, design criteria, design features, fabrication inspection, license-of-origin, aging management program and maintenance program. More specifically, Table 8.A.1 requirement titled "Containment Boundary Leakage Tests" is applicable to "MPCs loaded with HBF" and refers to application Subsection 8.1.4 titled "Leakage Tests". The "Containment Boundary Leakage Tests" requirement is not listed under the category of "Aging Management Program" because it is a separate stand-alone requirement regardless of the period of interim storage, if any at all. Pre-shipment leakage rate test of the MPC containment boundary (applicable to MPCs containing HBF) is also listed in the schedule provided in Table 8.2.1 of the application (a requirement consistent with Subsection 7.1.4, Step 2). In Table 8.2.1 of the application, the pre-shipment leakage rate test of the cask containment boundary is purposely listed separately since it is required regardless of whether the MPC contains high burnup fuel or moderate burnup fuel (a requirement consistent with Subsection 7.1.5, Step 1). An aging management program applies to MPCs loaded with either MBF or HBF as delineated in Table 8.A.1.

The following clarifications have been made to the application:

- **Chapter 8, Subsection 8.2.2:** The following statement has been revised as indicated by red-line markup. "A pre-shipment leakage rate test of cask containment seals and MPC containment boundary (See Appendix 8.A for applicability) is performed per Subsection 8.1.4 following ~~fuel~~ loading of the sealed MPC in the HI-STAR 190 Overpack ~~per Subsection 8.1.4~~."
- **Chapter 8, Table 8.2.1:** The requirement for pre-shipment and periodic leakage rate tests of MPCs prior to transport has been further clarified to directly state that is applies only to MPCs containing HBF.
- **Chapter 7, Subsection 7.1.4 Step 2:** The step has been revised to 1) clearly indicate that all MPCs containing HBF are leakage tested in the HI-STAR 190 Overpack regardless of whether or not the MPC entered a period of interim storage and 2) clarify that the leakage rate testing of the HI-STAR 190 overpack containment boundary is described in Subsection 7.1.5, Step 1 and applies regardless of whether or not the MPC contains high burnup fuel.
- **Chapter 1, Appendix 1.A, Section 1.A.2:** The following statement has been revised as indicated by red-line markup. "The MPC is already designed, manufactured and field-welded to be completely leak-tight. However, since a leak test directly after loading the MPC in a HI-TRAC transfer cask is not feasible, the MPCs are not formally leak-tight per ANSI 14.5, they are simply described as a system where leakage is not credible. The leakage test of the MPC after loading it into the HI-STAR 190 will serve now as the formal proof that the MPC is leak-tight in compliance with the ANSI standard."

The above changes are provided with this response.

See Holtec response to Observation 8-3 for discussion on "Load-and-go" scenario.

Observations

8-*3* *Modify the Chapter 8 acceptance tests and maintenance program information to address MPCs which are used in a 'load and go' fashion (i.e., not stored at a Part 72 ISFSI prior* *to transport under Part 71); such MPCs are subject only to Part 71 requirements and the Part 71 CoC conditions and not to Part 72 CoC or license.*

This information is required to determine compliance with 10 CFR 71.47, 71.51, and 71.85.

Holtec Response: Chapter 8 has been modified to specify the acceptance tests and maintenance program for all MPCs as stand-alone "Part 71" requirements (irrespective of "load and go" scenario).

The following clarifications have been made to the application.

- **Chapter 8, Section 8.0:** The second paragraph in this section has been modified to clarify that although acceptance tests and maintenance program shall have been performed under part 72 dockets, the MPC acceptance tests and maintenance program are specified in an independent and complete manner in this application. Except for Section 8.0, all other references to part 72 dockets have been removed from Chapter 8.
- **Chapter 8, Subsection 8.1.2:** MPC weld examination details have been addressed.
- **Chapter 8, Subsection 8.1.3:** MPC structural and pressure test requirements have been addressed.
- **Chapter 8, Paragraph 8.1.3.2:** MPC pressure testing details have been addressed.
- **Chapter 8, Paragraph 8.1.5.5, Table 8.1.4A and Table 8.1.4B:** MPC neutron absorber production testing requirements have been addressed. Table 8.1.4 has been replaced by Table 8.1.4A. New Table 8.1.4B has been added.
- **Chapter 8, Table 8.1.5 and Table 8.1.6:** MPC ASME Code Requirements and Alternatives have been addressed.
- **Chapter 8, Subsection 8.2.5:** The subsection has been revised to state no additional miscellaneous tests are required for HI-STAR 190 packaging.
- **Chapter 8, Section 8.3:** ASME Code reference [8.1.1] has been revised to specify the code edition application to MPCs and the code edition applicable to FSW. Reference [8.1.10] has been added in support of the changes to Paragraph 8.1.5.5.
- **Chapter 8, Appendix 8.A:** The title and statements have been revised consistent with the proposed changes in Section 8.0 and Subsection 8.2.5.