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HI-STAR ATB 1T
TYPE B(U) TRANSPORTATION PACKAGE LICENSE APPLICATION

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Proposed Responses to Second Request for Additional Information

August 24, 2018

Holtec International

Agenda

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- Evolution of the Application
- Proposed RAI responses
  - Overview
  - General Information (Drawing)
  - Structural and Materials Evaluation
  - Thermal Evaluation
  - Containment Evaluation
  - Shielding Evaluation
  - Acceptance Tests and Maintenance Program Evaluation
- Package Contents
- Schedule

Long Evolution of the HI-STAR ATB 1T Application

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- Initial submittal of application – September 23, 2015
- Request for Supplemental Information (RSI) Issued – November 10, 2015
- Holtec commits to perform 1/4 scale model physical drop test – December 7, 2015
- Resubmittal of application to NRC – February 6, 2017
- RSI issued to Holtec – March 21, 2017
- RSI responses submitted to NRC – April 14, 2017
- 1st Round of RAIs issued to Holtec – August 9, 2017
- RAIs responses submitted to NRC – December 8, 2017/April 2, 2018
- 2nd Round of RAIs issued to Holtec – May 29, 2018

Proposed RAIs Responses - Overview

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- Critical RAIs are related to containment (sealing surface plastic deformation and gaskets tests program) and structural qualification of package using LS-DYNA (strain-based acceptance criteria)
- Most challenging is the removal of the sealing surface plastic deformation, given the absence of impact limiters and the restrictions on size and weight of the package
  - The removal of the sealing surface plastic deformation is achieved with a combination of changes to some materials and minor design changes
- The following slides address every RAI, briefly state the main focus of each request, and then characterize the planned response

Proposed RAIs Responses

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- **RAI 1-1 (Drawing)**
  - Clarify location of elastomeric seals in the package
  - Seals location on flange is critical and should be depicted on cask drawing (Drawing No. 9876)
- Holtec's Proposed Response
  - Drawing 9786 to be updated to include dimensions depicting seals locations on flange

Proposed RAIs Responses

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- **RAI 2-1 (Structural)**
  - Clarify how the components in the containment boundary will not exceed ASME Section III NB values for normal conditions of transport (NCT). Specifically, there is inelastic strain 3 inches away from the edge of the inner base plate on the surface for the 1-ft NCT Bottom CG over corner drop.
- Holtec's Proposed Response
  - The inelastic strains, noted in the RAI, occur at locations of gross structural discontinuity viz. the junction of the inner containment shell and the inner base plate. Following the guidance from ASME Section III Subsection NB, these stresses are classified as secondary stresses, which are allowed to exceed the material yield strength.
  - In response to this RAI, Holtec will present a sensitivity run for 1-foot NCT Bottom CGOC drop with a fully elastic model (no strain rate effects) to demonstrate compliance with secondary stress intensity limit per ASME Section III NB.

Proposed RAIs Responses (Continued)

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- **RAI 2-2 (Structural)**
  - Explain and justify the parameters used to model concrete in LS-DYNA for the ¼ scale prototype.
  - Holtec has not demonstrated that this modeling approach is applicable to the site conditions found at Sandia National Laboratories (SNL).
- Holtec's Proposed Response
  - Critical input parameters such as concrete thickness, concrete compressive strength, and the material specification for the steel top plate have been provided by SNL.
  - The material characteristics and the material model (**MAT_PSEUDO_TENSOR)* used for the target in the LS-DYNA benchmark analysis demonstrate excellent agreement between the physical tests and the computer simulations.
  - Moreover, since the target pad at SNL is designed to be an unyielding impact surface, the cask dynamic response is essentially controlled by the cask geometry and component materials.

Proposed RAIs Responses (Continued)

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- **RAI 2-3 (Structural)**
  - Clarify inconsistent yield strength properties for SA-240 304 material (at 150^{o}F) in Tables 2.2.1A and 2.2.1B of the application.
- Holtec's Proposed Response
  - The yield strength values reported in Table 2.2.1A, which applies to the Cask Closure Lid, correspond to the ASME minimum properties for the SA-240 304 material.
  - Table 2.2.1B applies to the Cask Containment Shell and Containment Base Plate, for which Holtec has specified a slightly higher yield strength (above the ASME minimum requirement), as indicated in Flag Note 8 per Licensing Drawing 9786 (as well as Note 2 to Table 2.2.1B).
    - The Certified Material Test Report (CMTR) for these specific components must meet the minimum yield strength requirement per the Licensing Drawing.

Proposed RAIs Responses (Continued)

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- **RAI 2-4 (Structural)**
  - Clarify the material properties used for the trunnions on the drawings.
  - Clarify the safety factors in Table 2.5.1, as they are not based on the minimum material properties specified on the licensing drawings.
- Holtec's Proposed Response
  - The cask trunnion material shall have minimum yield and ultimate strengths equal to 144 ksi and 177 ksi, respectively, per Flag Note 5 of Licensing Drawing 9786 Rev. 4. These values correspond to the ASME minimum strength properties for SB-637 N07718.
  - The analysis documented in HI-2177540, which is summarized in Table 2.5.1, uses the above listed values.
  - The BOM will be updated to change the material specification for the trunnion solid shaft from "NICKEL ALLOY" to "SB-637 N07718 OR BETTER".

Proposed RAIs Responses (Continued)

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- **RAI 2-5 (Structural)**
  - Clarify the effective plastic strain reported for the top end puncture simulation. Analysis report indicates lid maximum strain of 14.13%, but data files submitted indicate maximum plastic strain as high as 22.9%.
- Holtec's Proposed Response
  - Very high local stresses/strains are to be expected where the puncture bar makes contact with Cask Closure Lid. These local impact stresses are typically ignored for transport casks qualified using stress-based acceptance criteria.
  - In a similar vein, the Closure Lid top layer extending 1-inch deep from the top surface is designated as a sacrificial zone (Zone C) for which the strain limits are not applied, as noted in Figure 2.1.1B of the SAR. The safety analysis results presented later on in Section 2.7 of the ATB-1T SAR exclude the sacrificial region (Zone C) when evaluating the induced strain in the Closure Lid.

Proposed RAIs Responses (Continued)

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- **RAI 2-6 (Structural)**
  - Clarify the effective plastic strain reported for the containment base plate and containment weld for the CG over corner followed by puncture simulation for hypothetical accident conditions (HAC). Inconsistencies between values provided in calculation package and submitted data files.
- Holtec's Proposed Response
  - The peak strains in the baseplate (~ 67.8%), as noted in this RAI, are limited to a few elements at the interior corner of the containment cavity where the containment shells and baseplate intersect. The high strains in the corner region are attributed to numerical singularities. ASME Appendix EE and FF acknowledges numerical singularities and permits excluding the hot spots (points of numerical singularity) when reporting the strains.
  - High strains noted in the localized regions, attributed to the sharp corner, will only cause a local redistribution of the stresses.

Proposed RAIs Responses (Continued)

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- **RAI 2-7 (Structural)**
  - Clarify location of effective peak plastic strains and related numerical singularities reported in the application. Clarify which elements are specifically being used for the peak effective plastic strains being reported and the ensuing through thickness effective plastic strains.
- Holtec's Proposed Response
  - The numerical singularities at the sharp re-entrant corners (viz. shell to baseplate juncture), point loads applied on any solid (viz. point load effects from the CGOC impacts), and the constraint effects at the structural discontinuities will result in exceedingly high stresses and strains in localized regions of the structure. These high peak stresses and strains resulting from numerical artifacts, which are also influenced by the mesh density, are considered as unrealistic.
  - Relevant discussion will be added to the calculation package regarding the local high strained regions due to numerical singularities in the solution.

Proposed RAIs Responses (Continued)

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- **RAI 2-8 (Structural)**
  - Verify that close of the package is maintained during drop simulations by justifying the statement: “element erosion is not enough to cause any of the components to dislodge or shift position.” It is unclear how standard non-eroding surface-to-surface contact elements are justified.
- Holtec’s Proposed Response
  - Only very few elements in one corner of the CLLS were eroded, specifically limited to the Top CGOC drop (simulation 6).
  - Since the standard surface to surface contact exists over the majority of the CLLS length, absence of contact in the small eroded region of the CLLS does not affect the current safety results or conclusion. This has been verified by re-performing the analysis with eroding surface_to_surface contact.

Proposed RAIs Responses (Continued)

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- **RAI 2-9 (Structural)**
  - Clarify the values used to model identical materials in the LS-DYNA drop simulation files. Justify use of two materials in the model representing Nitronic 50.
- Holtec's Proposed Response
  - Both MID 2 and 3 have the identical stress strain curves and triaxiality factors. The strain rate amplifier used for MID 2 is slightly over-estimated for the strain rates between 0 and 0.1 (as shown in figure below) resulting in slightly higher stress prediction at low strain rates. However, the strain rates for ATB-1T cask components, subject to 10CFR71 drops, are as high as 100 in/in/sec. Therefore, the cask response and the corresponding results are unaffected by this minor discrepancy. However, this inconsistency in the material models will be corrected.

Proposed RAIs Responses (Continued)

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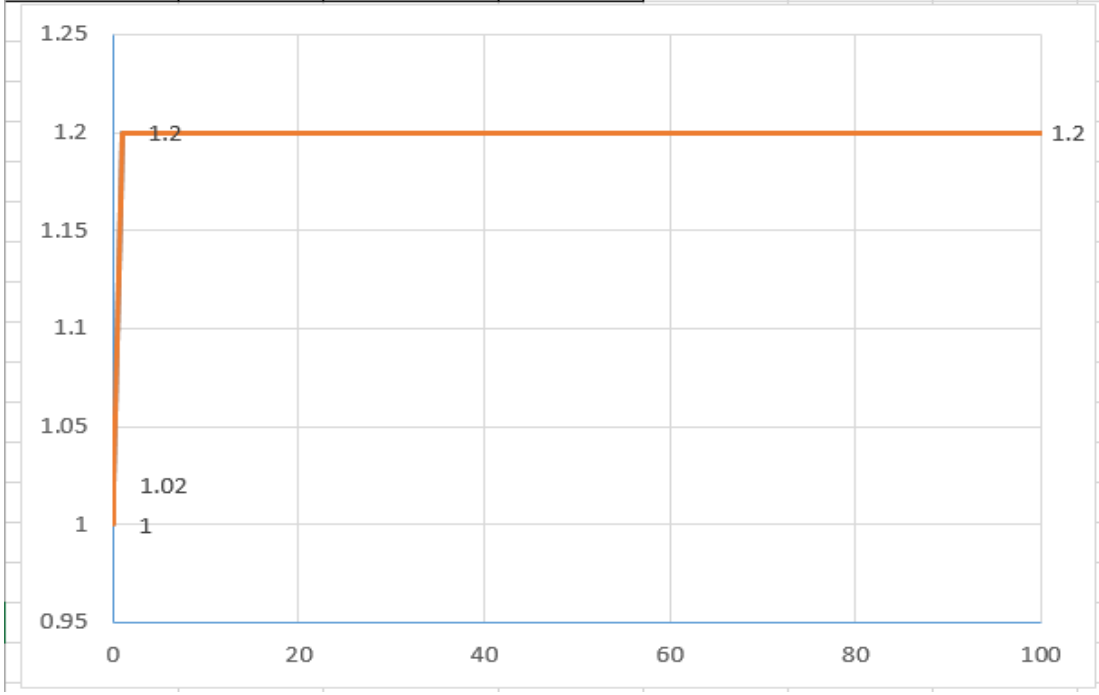
- **RAI 2-9 (Structural) (Continued)**

Strain Rate	Amplifier	Strain Rate	Amplifier
0	1	0	1
0.1	1.02	0.01	1.02
1	1.2	1	1.2
100	1.2	100	1.2



Proposed RAIs Responses (Continued)

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- **RAI 2-10 (Structural)**
  - Clarify the stress limit values used to describe Nitronic 50 material (SB637-N07718). Inconsistencies between stress limits values and source for the calculation package and impact on SAR.
- Holtec's Proposed Response
  - The ASME material specification for Nitronic 50 is SA-182 FXM-19.
  - The stress limits for the Nitronic 50 material (SA-182 FXM-19), listed in Tables 2.1.5, are correct, as they are obtained from Part D mandatory Appendix 2 of the ASME Code.
  - The bending stress limit for the CLLS (SB-637 N07718) in Table 2.1.4 of the SAR will be updated, as well as the calculation package HI-2177439. This has no effect on the overall conclusions.

Proposed RAIs Responses (Continued)

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- **RAI 2-11 (Structural)**
  - Confirm that the secondary packaging coatings, adhesives and lubricants are non-flammable or provide auto-ignition temperatures.
- Holtec's Proposed Response
  - Specifications for coatings, adhesives and lubricants for secondary packaging to be updated in SAR to address flammability as requested.
    - Only trace amount of lubricants with temperature resistance potentially as low as 200 °C
    - Remaining coatings, adhesives and lubricants have temperature resistance above 400 °C
    - Details will be provided

Proposed RAIs Responses (Continued)

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- **RAI 2-12 (Structural)**
  - Clarify and/or provide additional material property data for SA-182, Grade FXM-19 (Nitronic 50) material and update any related LS-DYNA drop simulations as necessary.
- Holtec's Proposed Response
  - The following table lists the properties of SA-182 FXM-19 (Nitronic-50) at the normal operating temperature of 150^{o}F, which are all obtained from ASME Section II, Part D and Part A.

Property	Value
Yield Strength - ksi	49.8
Ultimate Strength - ksi	99.7
Stress Intensity - ksi	33.2
Area Reduction - ksi	55
Elastic modulus - psi	2.79 x 10^{7}

Proposed RAIs Responses (Continued)

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- **RAI 2-12 (Structural) (Continued)**
  - The approach used in deriving the material stress-strain curve for the Nitronic 50, to be used in the FE analysis, is identical to the approach used for the S/S 304 curves.
  - Based on the chemical composition and its mechanical behavior, several publications have concluded that Nitronic 50 is nitrogen-strengthened austenitic steel which offers much higher strength resistance while preserving the material ductility that is typical of other grades of austenitic S/S.
  - Therefore, the material strain rate curves, specified in ASME Appendices EE and FF for austenitic stainless steel, are considered reasonable and are used in the SAR for Nitronic 50 material with a penalty factor (~10%) on the strain rate amplification curve.

Proposed RAIs Responses (Continued)

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- **RAI 3-1 (Thermal)**
  - Specify seals' maximum continuous allowable operating temperature and maximum short term allowable operating temperature. Clarify that during vacuum drying the seal will not exceed the continuous allowable operating temperature.
- Holtec's Proposed Response
  - Holtec revisiting seal temperatures to address allowable limits under continuous and short term conditions. To this end seal manufacturer technical literature is under evaluation for inclusion in revised SAR.
  - Confirming seal temperatures not challenged under vacuum drying as cask closure lid and its associated seals not installed during vacuum drying operations.

Proposed RAIs Responses (Continued)

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- **RAI 3-2 (Thermal)**
  - Provide the HAC thermal model results that consider the effect of a puncture test at the seal location, non-uniform decay heat positioned at the seal and the change in the package closure lid locker so that a bounding condition at the seals can be analyzed.
- Holtec's Proposed Response
  - Holtec revisiting HAC analysis to address cumulative damage due to 30 foot top-down CGOC drop followed by 1 foot puncture accidents, potential heat source relocation and closure lid locker.
- **RAI 3-3 (Thermal)**
  - Clarify boundary conditions used for the thermal model during the hypothetical accident conditions 30 minute fire. Inconsistency between FLUENT model emissivity and response to first round RAI 3-5.
- Holtec's Proposed Response
  - Fire accident radiation boundary conditions applied to FLUENT model meet or exceed 10CFR71 specifications. An abosrbtivity of 1 is assumed during 30 minute fire to maximize heat input into the cask.

Proposed RAIs Responses (Continued)

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- **RAI 4-1 (Containment)**
  - Provide evidence that demonstrates the package will meet regulatory release limits during normal conditions and hypothetical accident conditions (plastic deformation at seal and closure region during NCT and HAC).
- Holtec's Proposed Response
  - Holtec has considered few design and analytical modifications to eliminate the inelastic strain in the sealing surfaces. The key changes are summarized below:
    - Add high strength Incoloy cladding on the seal seating surface on the top flange and the closure lid.
    - Add softer crush material such as Al 6061 on the top corners of the closure flange extending beyond the cask top flange (see figure on next page).
    - The crush material will be connected to the existing top flange using weak links and will not interfere with the lid placement. Further details will be captured in the final licensing dwg.
    - Explicitly model the seal grooves and the seals to capture the behavior of the joint more accurately (see figures on following pages).

Packaging Design Changes

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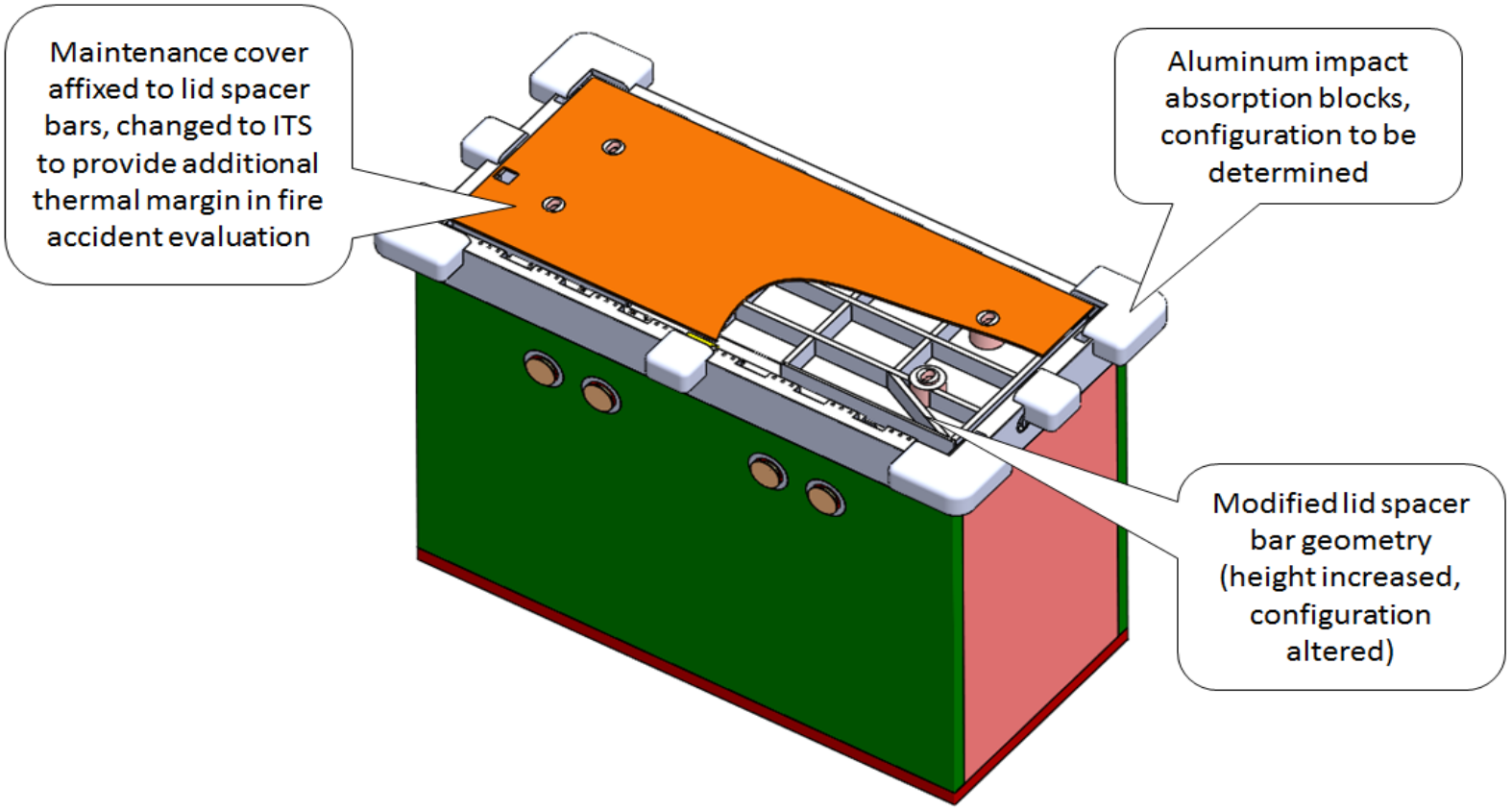

Packaging Design Changes (Continued)

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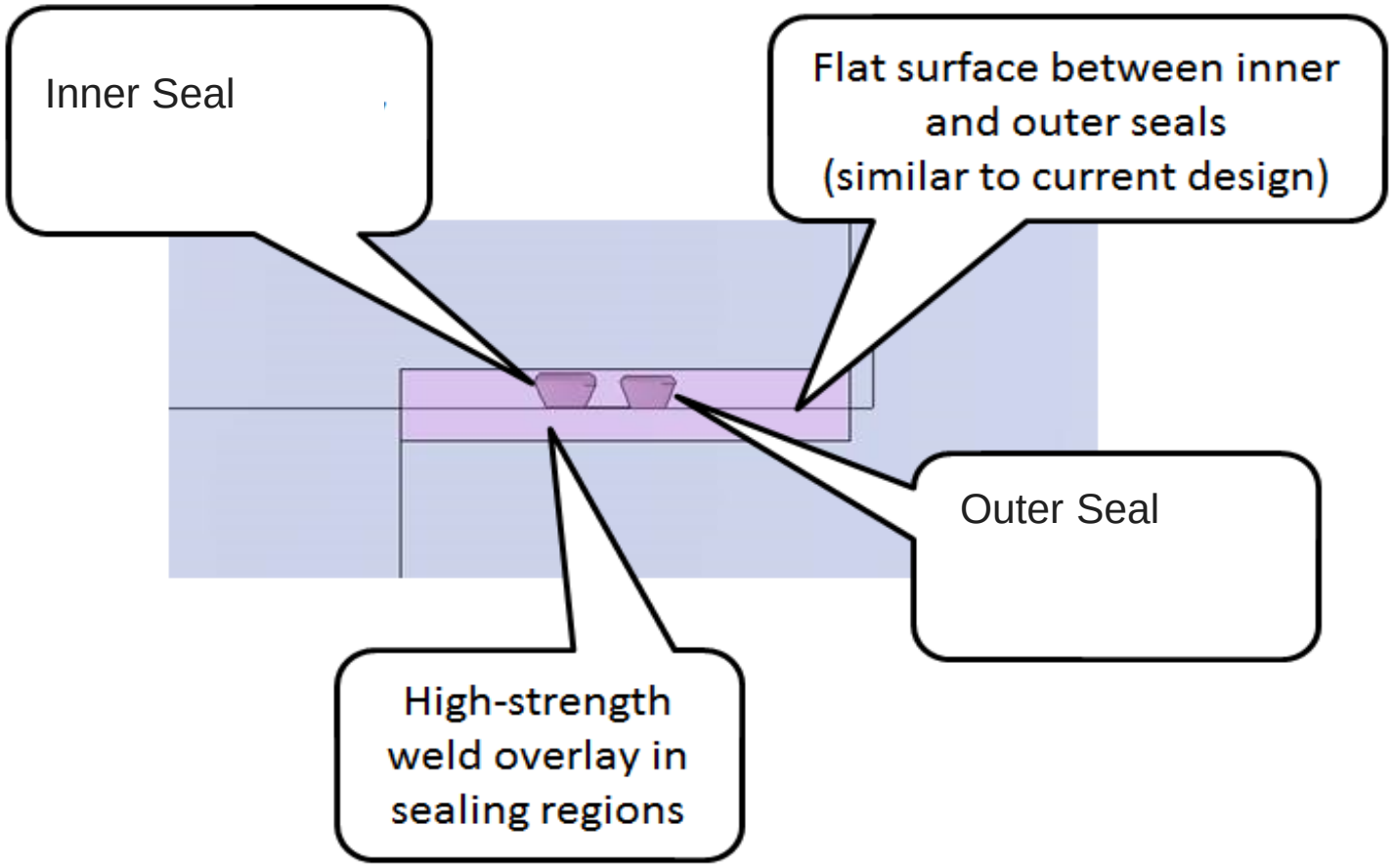
- Proposed Closure Lid Seal Region Design (Option 1)



Packaging Design Changes (Continued)

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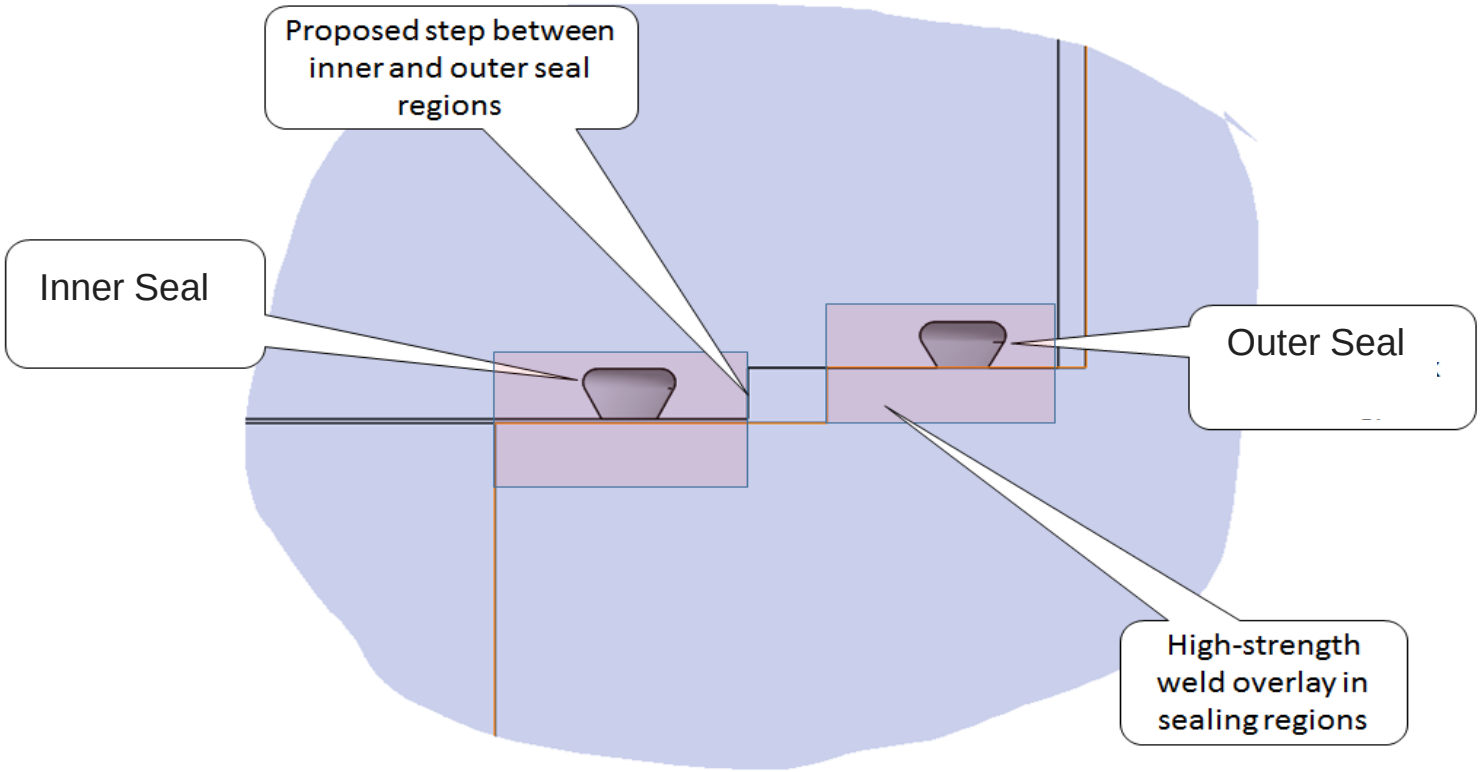
- Proposed Closure Lid Seal Region Design (Option 2)



Proposed RAIs Responses (Continued)

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- **RAI 4-2 (Containment)**
  - Provide additional discussion on the seal short term temperature tests so that a review of the results can be performed. Seal manufacturer (Parker) report should provide additional information on test samples temperatures, durations, and compression sets.
- Holtec's Proposed Response
  - To provide more application-specific data on the compression set of the FF400 material, additional testing is being performed for Holtec by the vendor. The results of this testing will be more indicative of seal performance.

Proposed RAIs Responses (Continued)

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- **RAI 5-1 (Shielding Evaluation)**
  - Justify package containing fixed surface contamination or CRUD meet the regulatory dose rate limits. Include additional information on CRUD modeling, description of allowable contents, discussion of specific activity evaluation for fixed surface contamination and CRUD, and neutron emitting material.
- Holtec's Proposed Response
  - Content specification (Table 7.1.2) is clarified to include CRUD. A maximum allowable neutron source per unit mass is added, including supporting calculations to demonstrate that this maximum allowable neutron source does not contribute significantly to dose rates.
- **RAI 5-2 (Shielding Evaluation)**
  - Provide more specific instructions that show the user how to determine the "most activated portion of any single waste item."
- Holtec's Proposed Response
  - Footnotes on Table 7.1.2 are revised to better clarify the requirements.

Proposed RAIs Responses (Continued)

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- **RAI 5-3 (Shielding Evaluation)**
  - Evaluate HAC dose rates using a bounding model of the bottom BTC (BFA-Tank Cassette) plate or restrict contents so that source cannot relocate outside the BTC plates.
- Holtec's Proposed Response
  - Model is modified and now assumes the Bottom BTC plate is replaced with waste. Additional steel is added to the bottom surface of the HI-STAR ATB 1T cask to ensure accident dose limits are met.

Packaging Design Changes (Continued)

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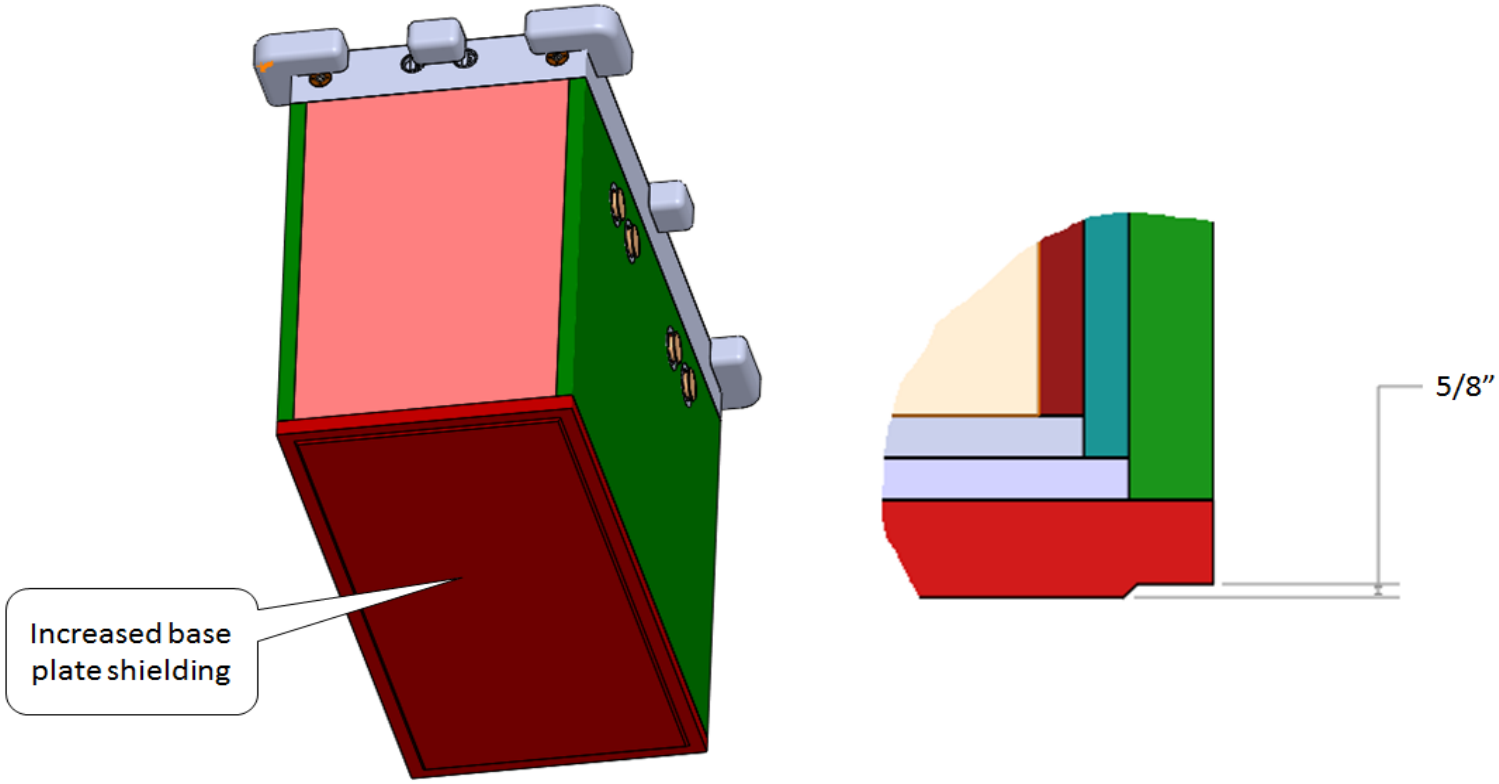

Proposed RAIs Responses (Continued)

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- **RAI 8-1 (Acceptance Tests and Maintenance Program Evaluation)**
  - Visual inspection to ensure that the seal "projects past the plane of the top seating surface of the seal groove" may not be sufficient because O-ring performance is dependent on having sufficient size and flexibility to deform within the groove when pressurized. Update acceptance criteria to ensure seals do not have excessive compression set that could affect seal performance.
- Holtec's Proposed Response
  - Seal visual inspection acceptance criteria for compression set will be revised to state "no evidence of closure seal compression set, such as flattening of the visible seal surface." Notwithstanding, seal visual inspection may be considered defense-in-depth, since CLLS "go" or "no-go" indicator is pre-shipment leakage rate test.

Proposed RAIs Responses (Continued)

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- **RAI 8-2 (Acceptance Tests and Maintenance Program Evaluation)**
  - Clarify rationale for Table 8.1.1 Note 2b ("i.e. the prequalified gasket was not replaced") for pre-shipment alternative leakage test acceptance criterion per ANSI N14.5.
- Holtec's Proposed Response
  - Note 2 of Table 8.1.1 to be revised for clarification: ANSI N14.5 includes pre-shipment leakage test option for testing to sensitivity of at least 10^{-3} ref-cm^3/s for no leakage, and requirement that replaced reusable seals shall demonstrate leakage rate according to reference air leakage rate criterion. Therefore optional testing to 10^{-3} ref-cm^3/s for no leakage is applicable only to reusable prequalified gaskets that are not replaced.

Proposed RAIs Responses (Continued)

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- **RAI 8-3 (Acceptance Tests and Maintenance Program Evaluation)**
  - Clarify that the Level III Specialist described in Section 8.1.4 is trained for the leak testing examination method.
- Holtec's Proposed Response
  - Section 8.1.4 of the SAR to be revised in accordance with ANSI N14.5 (2014) to state that Level III Specialist approving leak testing procedures shall be qualified and certified in the nondestructive examination method of leakage testing for which procedures are written.
- **RAIs 8-4 through 8-10 (Acceptance Tests and Maintenance Program Evaluation)**
  - BFA-Tanks and BFA-Tanks Cassettes QA Program
- Holtec's Proposed Response
  - CoC Condition that NRC-approved QA program is required for BFA-Tanks and BFA-Tanks Cassettes to be used in the United States.

Package Contents

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- No changes to package contents
- Contents specifications (i.e. description, modeling, etc.) is revised based on the responses.

Schedule

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- Proposed Date for Responses
  - October/November 2018