NRC RAI 1-1

Indicate groove weld size that can be used interchangeably with fillet welds.

Additional note 3 on Sheet 1 of Drawing 9786 indicates in part that "fillet welds may be replaced with groove welds of equal or greater strength". Provide the size of the groove weld that will be used in place of a fillet weld in these instances since it is unclear how a weld of greater strength will be provided without such information.

This information is needed by the staff to determine compliance with 10 CFR 71.33.

Holtec's response to RAI 1-1

Because the majority of the key welds in the ATB-1T cask are full-penetration welds for which this option is not applicable, the sentence referring to the substitution of weld types has been removed from Note 3, which now states the following:

UNLESS OTHERWISE NOTED, FULL PENETRATION WELDS MAY BE SINGLE-SIDED OR DOUBLE-SIDED. STYLE OF GROOVE MAY ALSO BE MODIFIED AT FABRICATOR'S DISCRETION.

This change eliminates the need to provide the size of the groove welds to replace fillet welds.

<u>NRC RAI 1-2</u>

Clarify the dimensions of lid spacer bars shown in the cask lid sub-assembly and how they are modeled in LS-DYNA.

Sheet 3 of 5 on Drawing 9786 indicates there are 5 evenly spacer bars with undetermined thickness and height and attachment to the closure lid (BOM 8). It is assumed that they are like BOM item 42, which is welded on one side with a *W'* fillet, although BOM 42 has different proportions. Drop and puncture simulations in LS-DYNA treats them as fully integrated into the closure lid (BOM 8). Clarify the dimensions of the lid spacer bars, their connection to the closure lid, and update LS-DYNA drop and puncture simulations for normal conditions of transport (NCT} and hypothetical accident conditions (HAC) as needed based on their actual attachment to the lid.

This information is needed by the staff to determine compliance with 10 CFR 71.33, 71.71(c)(7), 71.73(c)(1), and 71.73(c)(3).

<u>Holtec's Response to RAI 1-2</u>

The lid spacer bars have been re-designed to better meet the structural requirements. The design change is reflected in both Drawing 9786 and the LS-DYNA model. All size, spacing and attachment methods required to support the structural analysis have been included in the revised drawing.

NRC RAI 1-3

Provide additional clarifying information on the drawings of the package in Section 1.3 of the application, as described below.

Drawing 9876, Sheet 1 of 8 states that "all dimensions are in inches." The dimensions do not match up with those described in the application, including Drawing 9786, and therefore appear to be in millimeters. The applicant needs to correct the typographical error stating that these dimensions are in inches.

Drawing 9786 and 9876 contain instances where the designation "TYP." Is used. Clarify what this means and provide minimum dimensions for all components that are credited within the shielding evaluation. Wall thicknesses credited within the shielding evaluations cannot be "typical" and must contain minimum dimensions as these perform a safety function for radiation shielding.

Some drawings are missing dimensions of components used for shielding. Revise the drawings to include minimum dimensions of all components used for shielding, including the thicknesses of the walls of the BFA-tanks and BFA-Tank cassettes. The wall thicknesses for all 4 different BFA-tanks and BFA-Tank Cassettes need to be shown. Table 7.1.2 of the application states "representative wall thickness of the Waste Package," as these are used as radiation shielding the components are considered important to safety and the minimum allowable dimensions must be defined.

Provide additional labeling of the drawings. Since the ATB-1T is a rectangular parallelepiped, 2-D rectangular views should clearly identify which face of the package it represents.

NUREG/CR-5502, "Engineering Drawings for 10 CFR Part 71 Package Approvals," provides guidance for preparing drawings of transportation packages submitted in an application for approval under 10 CFR Part 71. It states that engineering drawings should have tolerances that are consistent with the package evaluation. The staff recognizes that the applicant desires flexibility in the package design by allowing for dimensional variation that does not impact the package's design function (e.g., components fabricated slightly out of manufacturing tolerance). However, this flexibility may be achieved by specifying tolerances in the package design drawings that are large enough to bound reasonable variations in fabrication (see guidance in the staff's ISG-20). The shielding analysis should include the design drawing tolerances, which would, in this scenario, be less restrictive than the manufacturing tolerances.

This information is needed by the staff to determine compliance with 10 CFR 71.33(a).

Holtec's Response to RAI 1-3

For convenience, responses to this RAI have been divided into the following sections:

DEFAULT DIMENSIONS IN DRAWING 9876

In the title block of drawing 9876, the note that "ALL DIMENSIONS ARE IN INCHES" is located beneath the header "UNLESS OTHERWISE NOTED". Additional Note 2 then states that "ALL DIMENSIONS ARE IN MILLIMETERS", which serves as a statement that "otherwise notes" the units that are used for all dimensions. Semantically, Holtec believes this indicates that all dimensions should be interpreted to be stated in millimeters. However, in recognition of the confusion that this verbal juggling may cause, the statement in the title block of drawing 9876 has been modified to "ALL DIMENSIONS ARE IN MILLIMETERS" and Additional Note 2 has been deleted.

EXPLANATION OF USE OF "TYP." IN DRAWINGS 9786 and 9876

The use of the designation TYP., an abbreviation for TYPICAL, is meant to convey that these dimensions or features can be found in more than one location in the drawing. This is done to eliminate repeating callouts that would otherwise clutter the drawing and make it more difficult to read. It is not meant to imply that the indicated dimension and/or tolerance may vary from that stated. For example, in Zone B5 of Drawing 9786 the "TYP." designation has been used to indicate that the 7 ¾" MIN wall dimension is applicable to all four sides of the cask. All four sides, therefore, must meet the minimum overall dimension. Holtec notes that, although the use of the designation "TYP." is standard practice in component drawings, it can sometimes lead to ambiguity as to what it is referring. Therefore, to better clarify the drawings, the following revisions have been made:

<u>Dwg 9786</u>

The following dimension descriptions have been changed (note that design dimensions and tolerances remain the same):

Overall cask thickness: 7 ¾" MIN TYP. ALL FOUR SIDES
Upper containment thickness: 4" ± 1/16" TYP. ALL FOUR SIDES
Dose blocker thickness: 3 ¾" TYP. ALL FOUR SIDES
Lower containment wall thickness: 2" ± 1/16" TYP. ALL FOUR SIDES
Intermediate dose blocker thickness: 2" TYP. ALL FOUR SIDES

<u>Dwg 9876</u>

BFA Tank T-50: Top plate: 40 NOM, 39 MIN
Bottom plate: 30 NOM, 29 MIN
Side plate: 50 NOM, 49 MIN, TYP. ALL FOUR SIDES
Cassette top plate: 10 NOM, 9 MIN
Cassette bottom plate: 50 NOM, 49 MIN

BFA Tank T-100: Top plate: 50 NOM, 49 MIN
Bottom plate: 50 NOM, 49 MIN
Side plate: 100 NOM, 99 MIN, TYP. ALL FOUR SIDES
Cassette top plate: 50 NOM, 49 MIN

Cassette bottom plate: 50 NOM, 49 MIN

BFA Tank T-150: Top plate: 50 NOM, 49 MIN
Bottom plate: 50 NOM, 49 MIN
Side plate: 150 NOM, 148 MIN, TYP. ALL FOUR SIDES
Cassette top plate: 100 NOM, 99 MIN
Cassette bottom plate: 100 NOM, 99 MIN

BFA Tank T-200: Top plate: 100 NOM, 99 MIN
Bottom plate: 50 NOM, 49 MIN
Inner Side plate: 50 NOM, 49 MIN, TYP. ALL FOUR SIDES
Outer side plate: 150 NOM, 148 MIN, TYP. ALL FOUR SIDES
Cassette top plate: 100 NOM, 99 MIN
Cassette bottom plate: 150 NOM, 148 MIN

TOLERANCE ON DIMENSIONS CREDITED FOR SHIELDING

Minimum dimensions (as listed in the changes described above) have been included on Drawing 9876 for Tank and Cassette plates that are credited in the shielding analysis. Tank sides are renamed LONG SIDE and SHORT SIDE as an editorial change to help clarify their locations. All plate thickness that are credited in the shielding analysis for Drawing 9786 are now more clearly indicated as a result of the changes made in addressing the use of designation TYP.

ADDITIONAL LABELING OF THE DRAWINGS

The drawing changes made in addressing the use of designation TYP. on Drawing 9786 dimensions also provide better indication of the faces of the rectangular parallelepiped to which the features apply. An additional exploded view of the cask, with labeled components, is also provided on Sheet 1 of Drawing 9786. Where needed, additional item balloons have been added to Drawing 9876 to better correlate the key dimensional requirements to the plates to which they apply. The additional view and additional labeling should be sufficient to unambiguously represent the package construction.

NRC RAI 2-1

Clarify how strain rate criteria is applied to certain portions of lid and flange only, and how damage in these regions due to free drop will be affected by the thermal test described under HAC.

The last sentence of ASME Section FF-1110 states: *"These strain-based acceptance criteria are not allowed to be used in instances where the resulting deformations could result in a breach of the containment."*

The HI STAR ATB 1T parts have been partitioned arbitrarily into zones (not discussed by ASME) which indicate when certain criteria will apply. Specifically, the application states that Zone A is where ASME strain based criteria (non-mandatory appendices EE and FF) will be applied, while Zone C is where high strains are expected but away from Zone A. The application describes Zone C as one that: *"If a crack were to develop in Zone C as a result of the high deformation levels, it would not pose a threat to the containment boundary for the following reasons. The extended portion of the top flange is not a pressure retaining component, and therefore a thruwall crack in this region of the top flange cannot produce a leak in the containment cavity. For the closure lid, if a crack were to develop in Zone C as the result of a drop event, it would be arrested by the machined slots in the lid for the [closure lid locking system] CLLS before reaching the containment boundary."*

However, Figure 2.1.1 indicates that the flange and lid are part of the pressure retaining boundary. It is unclear how machined slots will arrest any cracks present in the material. Cracks have been known to be arrested by mechanical fasteners such as bolts and rivets due to localized compression, or by drilled holes at crack tips. However, none of these cases are applicable to the HI STAR ATB 1T package. Additionally, there has not been any consideration to a thermal scenario described under HAC, where the pressure in the containment boundary is expected to increase, potentially forcing any cracks in the material located in Zone C post free drop to "open up" and drive them further into Zone A.

Clarify:

a) How the flange is not part of pressure retaining boundary when it is according to Figure 2.1.1 of the application, and Sheet of Licensing Drawing 9786,

b) What criteria are used to specify Zone C and A areas (these zones appear to be arbitrarily assigned), and what maximum strains and/or cracks may exist at this interface,

c) How cracks/strains in Zone C will be affected by an additional increase in pressure due to the fire scenario of HAC.

This information is needed by the staff to determine compliance with 10 CFR 71.73(c)(1) and 71.73(c)(4).

<u>Holtec's Response to RAI 2-1</u>

SAR Figure 2.1.1, showing the containment boundary, is updated to precisely to define the cask containment boundary region. As indicated in Figure 2.1.1, a portion of the lid and the top flange above the CLLS is categorized as energy absorbing region as represented by Zone C. However, it must be demonstrated by analysis that the plastic strain (if present) in underlying Zone A, which is defined as containment boundary region, must be less than the allowable strain limits per ASME Appendix FF.

Further, it is clarified that any material erosion (if present) is limited to the localized energy absorbing regions (so called Zone C) which will not adversely affect the containment boundary or the seal performance.

The clarification is added in section 2.1.

The seals opening (relaxation) subsequent to drop accidents must be shown to be within the useful spring back of the seals.

The above criteria will ensure that the containment boundary is not breached and the seal performance is maintained.

Lastly, cracks/strains in Zone C will not be affected by an additional increase in pressure due to the fire scenario of HAC. This is because (a) the HI-STAR ATB 1T cask has a low operating internal pressure even during a fire event, and (b) the regions of the cask defined as Zone C are not in the direct load path of the containment cavity pressure (i.e,, they are not subject to a pressure differential). Per Table 3.1.3 of the SAR, the maximum pressure inside the containment cavity during a fire accident is only 24.9 psia (or 10.2 psig), which is insignificant in comparison to the loads sustained due to the 9-meter drops under HAC.

NRC RAI 2-2

Clarify the dimensions of the trunnion keeper plate (BOM item 34) and the trunnion (BOM item 19).

Lifting calculations contained in document HI-2177540RO indicate that the trunnion keeper plate length is 0.25in; however, there are no dimensions of this part on the licensing drawings. While the trunnion keeper plate is NITS, it does affect the overall length of the trunnion (ITS) since the axial length of the trunnion is specified relative to the trunnion keeper plate.

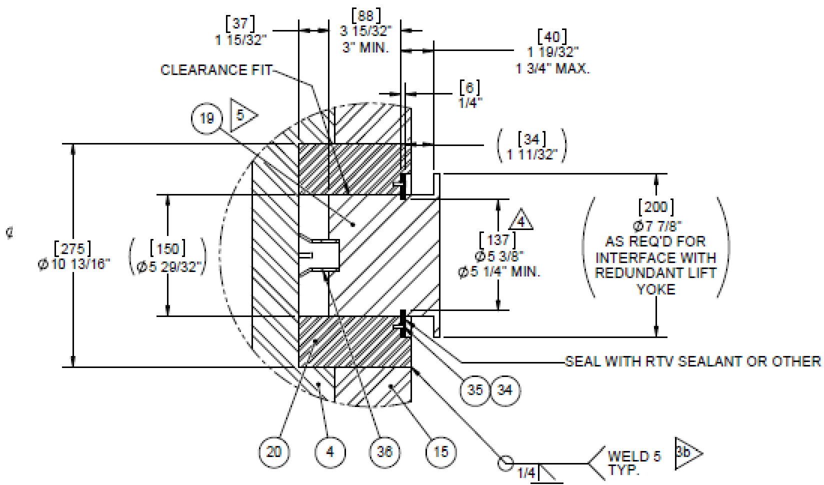
Additionally, lifting calculations do not appear to consider the trunnion keeper plate's protrusion into the trunnion. As drawn, it appears that the entire cross section of the trunnion cannot be used for lifting calculations as relied upon in document HI-2177540R0 due to the trunnions keeper plate location.

Provide the axial length of the trunnion and trunnion keeper plate dimensions on the licensing drawings and revise the lifting calculations, as necessary, for a reduced available cross-section due to the trunnion keeper plate.

This information is needed by the staff to determine compliance with 10 CFR 71.45.

Holtec's Response to RAI 2-2

The trunnion and trunnion keeper plate dimensions are revised, as shown below, to indicate the minimum cross-section of the trunnion, the cantilevered length of the trunnion and the thickness of the keeper plate. The updated licensing drawing is included in Section 1.3 of the SAR.



DETAIL DF
SCALE 1 : 4
(TYPICAL TRUNNION DETAIL)

The lifting calculations have also been updated to reflect the dimensions shown above and to account for the trunnion keeper plate's protrusion into the trunnion. The updated calculations are documented in Calculation No. 1 of Holtec report HI-2177540, and they are also summarized in Section 2.5.1.1 of the HI-STAR ATB 1T SAR.

This RAI has no impact on the LS-DYNA benchmark analysis of the ¼-scale drop tests documented in Holtec report HI-2167517 since the lifting trunnions are not included in the ¼-scale test model.

NRC RAI 2-3

Clarify or revise the number of trunnions used in lifting calculations.

Lifting calculations contained in document HI-2177540R0 indicate that 8 trunnions will be used for lifting in Section 6.2.1. However, the preceding sections of those calculations (Sections 2.5.1.1 and 8.1.3.1 of the application) indicate that only 4 trunnions are actively in use during lifting operations.

Verify and/or revise the lifting calculations as necessary, as it appears that the bearing stress values would be exceeded if only 4 trunnions, rather than 8, were to be used.

This information is needed by the staff to determine compliance with 10 CFR 71.45.

Holtec's Response to RAI 2-3

As discussed in Section 8.1.3 of the SAR, the HI-STAR ATB cask is equipped with eight trunnions (4 pairs) that are used for vertical lifting and handling of the cask. Further, the 4 pairs of trunnions constitute two redundant load paths.

Calculation No. 1 of Holtec report HI-2177540 has been updated so that all associated lifting calculations, including the bearing stress evaluation in Section 6.2.1, only take credit for 4 lifting trunnions (one load path). In order to do so, the construction material for the trunnion hollow shaft (BOM Item 20) has been changed from SA-479 304 to SA-182 FXM-19.

Accordingly, the results is SAR section 2.5 are updated.

This RAI has no impact on the LS-DYNA benchmark analysis of the ¼-scale drop tests documented in Holtec report HI-2167517 since the lifting trunnions are not included in the ¼-scale test model.

NRC RAI 2-4

Clarify the triaxiality values used to predict material failure in LS-DYNA simulations.

Triaxiality values used in material model 224 (Tabulated Johnson-Cook) In LS-DYNA appear to be inputted incorrectly. As specified, failure strains do not occur more readily with increasingly positive triaxiality, while failure strains due to compressive behavior do appear to occur more readily with increasingly negative triaxiality. Both the trend and values of specified triaxiality appear to be incorrect relative to the values and guidance in the non-mandatory appendix of Section EE-1150.

Clarify these values and/or update all LS-DYNA drop and puncture simulations for both normal and accident conditions since element failure can potentially result in breaches in the containment boundary due to material failure.

This information is needed by the staff to determine compliance with 10 CFR 71.71(c)(7), 71.73(c)(1), and 71.73(c)(3).

Holtec's Response to RAI 2-4

The triaxiality factors (TF) used to predict material failure in LS-DYNA are input correctly. The values only appear to be incorrect because the triaxiality factor is defined differently in the ASME Code versus the LS-DYNA User Manual for material model 224. The two definitions are given below.

Per Section EE-150 of the ASME Code, the triaxiality factor is defined as:

$$TF_{ASME} = (\sigma 1 + \sigma 2 + \sigma 3)/SQRT[1/2 \text{ x } \{(\sigma 1 - \sigma 2)^2 + (\sigma 2 - \sigma 3)^2 + (\sigma 3 - \sigma 1)^2\}]$$

Per the LS-DYNA User Manual, the triaxiality factor is defined as:

$$TF_{DYNA} = -1/3 \text{ x } (\sigma 1 + \sigma 2 + \sigma 3)/SQRT[1/2 \text{ x } \{(\sigma 1 - \sigma 2)^2 + (\sigma 2 - \sigma 3)^2 + (\sigma 3 - \sigma 1)^2\}]$$

As noted from the above equations, the triaxiality factors differ between ASME and LS-DYNA by a factor of -1/3. It implies that in the LS-DYNA code:

a. The triaxiality factor (TF) is computed as a negative value if the triaxial stress-state in the element is in tension and vise-versa (see Figure 1 below from LS-DYNA User Manual).

b. The TF magnitude differs between LS-DYNA and ASME by a factor of 1/3.

For example, if the triaxiality factor per ASME is 1, LS-DYNA computes it as -1/3. Likewise, a TF of 2 per ASME relates to -2/3 in LS-DYNA.

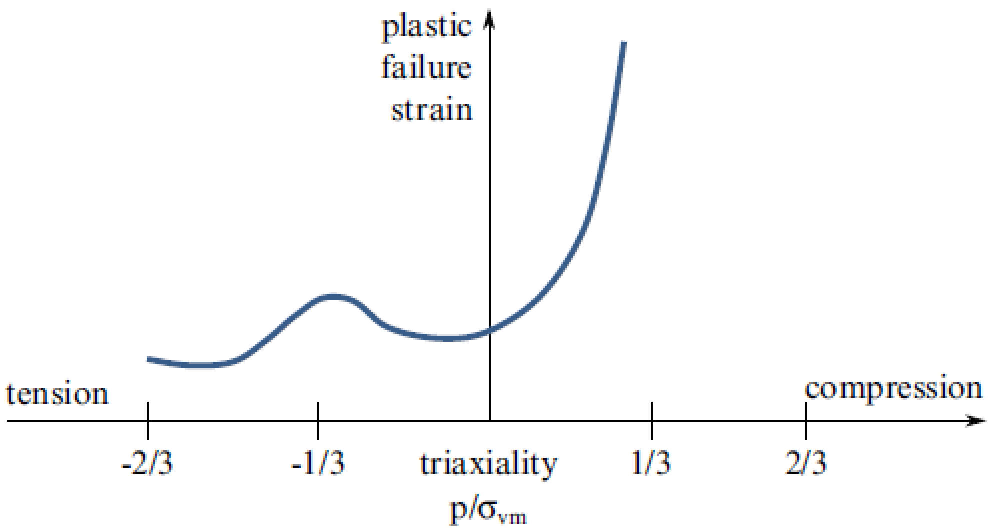


Figure M224-1. Typical failure curve for metal sheet, modeled with shell elements.

A new appendix is added to the calculation HI-2177539 documenting the material behavior.

Since the triaxiality factor is appropriately considered in the LS-DYNA simulations, this RAI has no adverse effect on the ¼-scale drop simulations documented in Holtec report HI-2167517.

NRC RAI 2-5

Justify the dimensions and placement of the puncture bar used for the puncture test for HAC conditions along with the initial state of the package.

Title Code 10 CFR 71.73(a) indicates that the same specimen subjected to the free drop test, is to be subjected to the puncture test. For the LS-DYNA simulation titled "1m- CGOC Puncture", the starting condition of the specimen is one that appears to have been subjected to a 9m drop on its center of gravity over corner (CGOC). However, an "interrogation" of the model indicates that there is no initial plastic strain anywhere in the package prior to the simulated the puncture test. Since the intent of this sequence of drops is to properly account for cumulative damage, it appears that that package could have indeed more damages than observed.

In addition, it appears that the puncture bar is not directed at the most damaged portion of the specimen. That is, the puncture bar should be directed to strike the breached portion of the outer bottom plate (BOM Item 1) where the underlying weld and intermediate shell are exposed. The puncture bar itself should also be shortened to the minimum length of 8 inches as described in the regulations for maximum impact. As modeled, the puncture bar is 30 inches long and is redirecting potential forces and energy away from the package as evidenced by excessive deformation in the puncture bar itself. For the 1m-CGOC puncture simulation, update:

a)The initial starting plastic strains from the previous 9m CGOC drop,
b)Corrected puncture bar placement,
c)Shortened puncture bar length,

and describe the state of the package with respect to containment and dose rates.

This information is needed by the staff to determine compliance with 10 CFR 71.73(c)(1), 71.73(c)(3), and 71.51(a)(2).

Holtec's Response to RAI 2-5

The 1-m CGOC puncture simulation is revised as follows:

1. The elements subject to failure (eroded elements) and cask component stress/strain state from the 30-ft (9-m) bottom CGOC drop (simulation # 9) are preserved and carried into the 1-m CGOC puncture simulation using the restart feature in LS-DYNA.

2. Since the mild steel puncture bar is modeled as an elastic-plastic material with a specified failure strain limit, the shorter length 8-inch bar completely fails in compression before the cask components dissipate their initial kinetic energy associated with the 1-m drop. On the other hand, the longer puncture bar (~ 30 in.) is subject to bending, which redirects the kinetic energy of the package resulting in a non-conservative solution. To avoid these two modeling issues, the length of the puncture bar is now set at 16 inches, and the peripheral nodes of the bar are constrained to move only in vertical direction to maximize the damage to the cask.

3. The puncture bar is now positioned so as to maximize the damage to the containment boundary including the containment corner welds for this specific drop. That is, the puncture bar is directed to strike the breached portion of the outer bottom plate (BOM Item 1) where the underlying weld and intermediate shell are exposed.

4. Since the puncture bar elements are subject to significant erosion (element failure) in this specific drop simulation, the material failure strain and strain rate effects for the mild steel bar are amplified by approximately 30%. The enhanced puncture bar properties minimize the damage to the puncture bar and maximize the damage to the cask.

Revision 1 to Holtec report HI-217754 documents the revised 1-m CGOC puncture simulation implementing the above features.

This RAI has no impact on the LS-DYNA benchmark analysis documented in Holtec report HI-2167517 since the ¼-scale test model was not subjected to a 1-m CGOC puncture drop.

NRC RAI 2-6

Clarify the dimensions and the modeled properties of the cask wedge blocks depicted on licensing drawings used in LS-DYNA simulations for both the prototype and ATB 1T. Sheet 2 of Drawing 9786 of the ATB 1T depicts cask wedge blocks (BOM 11) in relationship to the top flange (BOM 2) under the view "closure lid wedge system". It appears that the cask wedge blocks are tapered 4° and forced against an equally tapered 4° closure lid locking wedge (BOM 9 and 10).

According to Section 2.3 of the application, shims will also be installed against the cask wedge blocks. This similarly applies to the prototype as well, as shims were used at the location of the wedge blocks. Since the cask wedge blocks help maintain a positive closure on the seals of the package:

a) Describe why wedge blocks (BOM 9 and 10) are not modeled with a 4° taper.

b) Provide the compressive stress (sealing force) expected on the seals (BOM 7) and the sealing surface of the flange (BOM 2) when the lid (BOM 8) is fully engaged by closure lid locking wedges (BOM 9 and 10). The expected compressive force (if any) should be incorporated into LS-DYNA simulations, supported by calculation, and tractable with respect to an installation procedure.

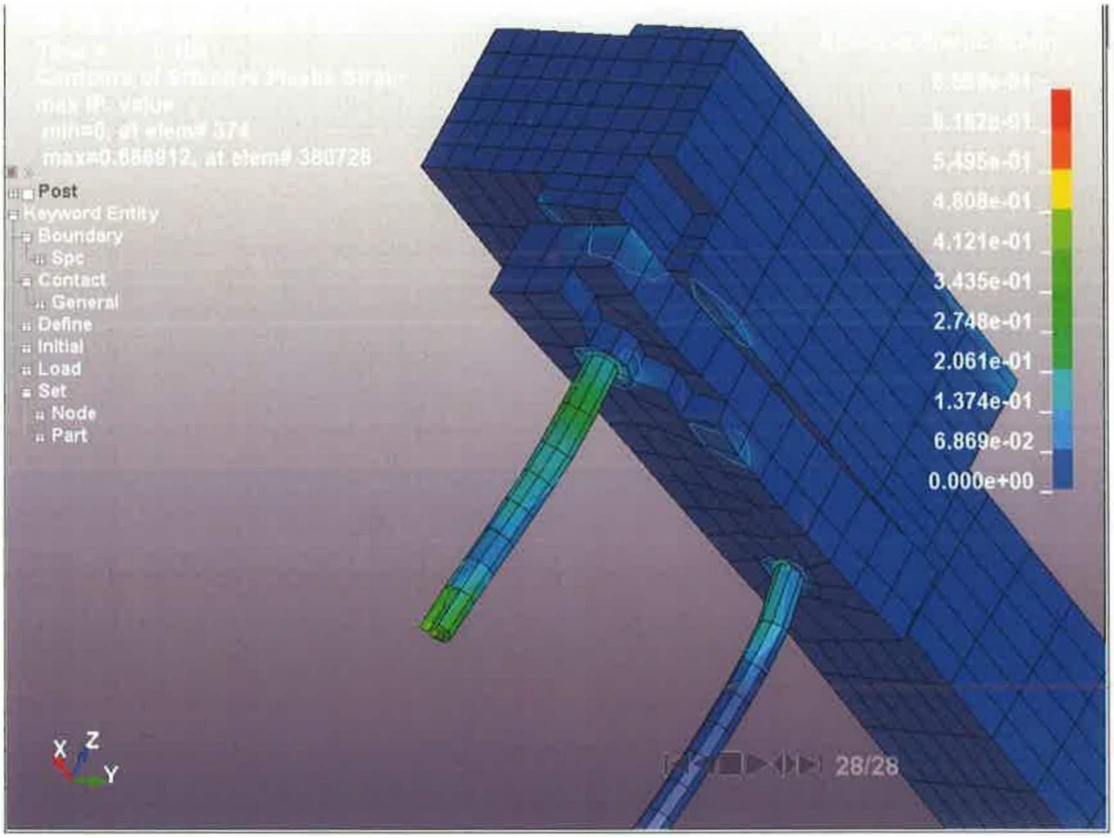
It is noted that the procedure used to ensure this sealing force is key to keeping the containment boundary intact and should be deployed reliably when operating the package.

c) Describe why shims (currently un-dimensioned or not specified material-wise) are not incorporated into the HI-STAR ATB 1T and prototype LS-DYNA models. Shims are key to maintaining closure rather than being incidental to fabrication. Shims and wedge blocks were known to have become loose during prototype drop testing and should be modeled as such for puncture and drop simulations for NCT and HAC.

d) Describe how cask wedge block securing bolts (BOM 12) are connected to the cask wedge blocks and/or the flange (BOM 2). It appears that the wedge blocks are directly attached to the securing bolts rather than just having a surface to surface contact. As modeled, a large, unrealistic tensile force would be needed to dislodge the wedge blocks from the bolts (via bolt failure). The bolts should be modeled per actual installation.

e) Describe why a contact surface such as eroding-surface-to-surface was not specified in LS-DYNA between the flange (BOM 2), closure lid locking wedges (BOM 9 and 10), and the cask wedge blocks. Such a surface currently exists between the cask wedge blocks (BOM 11) and the cask wedge securing bolts (BOM 12).

It was noted that both the wedge blocks (BOM 11), the closure lid locking wedges (BOM 9 and 10), and the wedge block securing bolts (BOM 12) undergo element erosion (material failure) depicted as missing "cubes" in the image below (30ft oblique drop shown).



Update all LS-DYNA simulations for both the prototype and ATB 1T as necessary along with the results in the Safety Analysis Report (SAR) and benchmarking work.

This information is needed by the staff to determine compliance with 10 CFR 71.71(c)(7), 71.73(c)(1), and 71.73(c)(3).

Holtec's Response to RAI 2-6

The response to each query is documented separately, as follows:

a) Describe why wedge blocks (BOM 9 and 10) are not modeled with a 4° taper.

The full simulation model is revised to consider the tapered geometry of the wedge blocks with an approximate 4 degree angle.

b) Provide the compressive stress (sealing force) expected on the seals (BOM 7) and the sealing surface of the flange (BOM 2) when the lid (BOM 8) is fully engaged by closure lid locking wedges (BOM 9 and 10). The expected compressive force (if any) should be incorporated into LS-DYNA simulations, supported by calculation, and tractable with respect to an installation procedure.

It is noted that the procedure used to ensure this sealing force is key to keeping the containment boundary intact and should be deployed reliably when operating the package.

The closure lid locking wedges (BOM 9 and 10) and the cask wedge blocks (BOM 11) interface surfaces will be precisely machined such that any gap between these components will be closed to create a positive closure in the locked position. The positive closure may result in a small compressive stress at the sealing surface. However, the additional interface force (if any) associated with the positive closure is not credited in the analysis. The only sealing force credited in the drop simulations is the dead weight of the closure lid.

The seals themselves sit in precisely machined grooves such that the extent of compression of the seals, and therefore their seating load, is precisely controlled. As discussed in Section 2.2.4 of the SAR, elastomeric seals are characterized by a relatively small compression force to "seat" them in the groove and hence the required seating load is not an important parameter. The size of the O-ring in relation to the size of the groove, on the other hand, is a critical dimension that is based on the gasket supplier's test data.

To ensure a positive sealing of the containment cavity, the interface gap between the top flange seating surface (BOM 2) and the closure lid (BOM 8) is measured subsequent to HAC drop events.

c) Describe why shims (currently un-dimensioned or not specified material-wise) are not incorporated into the HI-STAR ATB 1T and prototype LS-DYNA models. Shims are key to maintaining closure rather than being incidental to fabrication. Shims and wedge blocks were known to have become loose during prototype drop testing and should be modeled as such for puncture and drop simulations for NCT and HAC.

Shims were used in the ¼-scale test model for expediency and ease of fabrication. However, the drop tests revealed that the shims, as configured, were a design weakness. Therefore, in the actual full scale HI-STAR ATB 1T cask design, shims will not be used. The closure lid locking wedges (BOM 9 and 10) and the cask wedge blocks (BOM 11) will be precisely machined to close any gap between these components and create a positive closure without the need for shims.

With respect to the LS-DYNA benchmark simulations of the ¼-scale drop tests, the shims are not explicitly modeled as individual components. Instead the dimensions of the cask wedge blocks (BOM 11) are adjusted in the FE model to achieve a zero gap between the closure lid locking wedges (BOM 9 and 10) and the cask wedge blocks at the start of the simulation. This modeling simplification is considered acceptable since the objective of the benchmark analysis is to numerically predict with reasonable accuracy the global response of the package in terms of its deceleration response, permanent deformations, and strain levels in the containment boundary, which does not require detailed modeling of shims as evident by the simulation results.

d) Describe how cask wedge block securing bolts (BOM 12) are connected to the cask wedge blocks and/or the flange (BOM 2). It appears that the wedge blocks are directly attached to the securing bolts rather than just having a surface to surface contact. As modeled, a large, unrealistic tensile force would be needed to dislodge the wedge blocks from the bolts (via bolt failure). The bolts should be modeled per actual installation.

The cask wedge block securing bolts (BOM 12) connect through the holes provided in the top flange and are threaded into the removable wedge blocks (BOM 11). The removable wedge blocks (BOM 11) form a positive contact interface with the cask closure lid locking wedge (BOM 9 and 10).

The securing bolts, the removal wedge blocks and the closure lid locking wedge blocks are all modeled as per the design. Only the topmost nodes on the securing bolts are connected to the surface nodes on the top flange at the thru hole locations to eliminate any rigid body motion. Below the top surface of the bolts, an eroding contact is defined between the securing bolts and the top flange holes. The tapped holes in the wedge block (BOM 11) and the securing bolts (BOM 12) share common nodes to simulate their threaded connection.

e) Describe why a contact surface such as eroding-surface-to-surface was not specified in LS-DYNA between the flange (BOM 2), closure lid locking wedges (BOM 9 and 10), and the cask wedge blocks. Such a surface currently exists between the cask wedge blocks (BOM 11) and the cask wedge securing bolts (BOM 12).

It was noted that both the wedge blocks (BOM 11), the closure lid locking wedges (BOM 9 and 10), and the wedge block securing bolts (BOM 12) undergo element erosion (material failure) depicted as missing "cubes" in the image below (30ft oblique drop shown).

Eroding contacts are established for the following contact interfaces:

1. Between wedge securing bolts (BOM 12) and removable cask wedge blocks (BOM 11). This contact becomes effective only if the wedge securing bolts fail in this region.
2. Between wedge securing bolts (BOM 12) and top flange (BOM 2) which may involve contact and erosion.

Per the updated drop simulations, the closure lid locking wedges (BOM 9 and 10) and the wedge blocks (BOM 11) experience very limited element erosion and only during the top down CGOC drop. The element erosion is not enough to cause any of the components to dislodge or shift position. Therefore, the use of standard (non-eroding) surface-to-surface contact elements is adequate for the closure lid locking wedges and wedge blocks, and it has no adverse effect on the results.

This comment does not have any bearing on the ¼-scale drop simulations documented in Holtec report HI-2167517. All contacts in the quarter-scale drops are appropriately defined.

NRC RAI 2-7

Clarify why strain rate and triaxiality effects were not considered in modelling the material behavior of those components made with SB637-N07718 with respect to drop and puncture simulations for HAC.

Several ITS components such as the closure lid locking wedges, cask wedge blocks, and locking wedge pins are made with SB637-N07718 material. At least one drop simulation such as the 30ft oblique drop, depicts element erosion (material failure) for both wedge blocks (BOM 11), closure lid locking wedges (BOM 9 and 10), and cask wedge securing bolts (BOM 12) as shown in the image for RAI 11. Without incorporating triaxiality and strain rate effects, additional portions of these parts could be failing, potentially jeopardizing the closure lid's ability to remain secure.

Clarify why these material phenomena were excluded from the model and/or update drop and puncture simulations in LS-DYNA.

This information is needed by the staff to determine compliance with 10 CFR 71.71(c)(7), 71.73(c)(1), and 71.73(c)(3).

Holtec's Response to RAI 2-7

In the updated submittal, all cask components including the welds are modeled using *MAT_224 (*MAT_TABULATED_JOHNSON_COOK), which accounts for material strain rate and triaxiality effects.

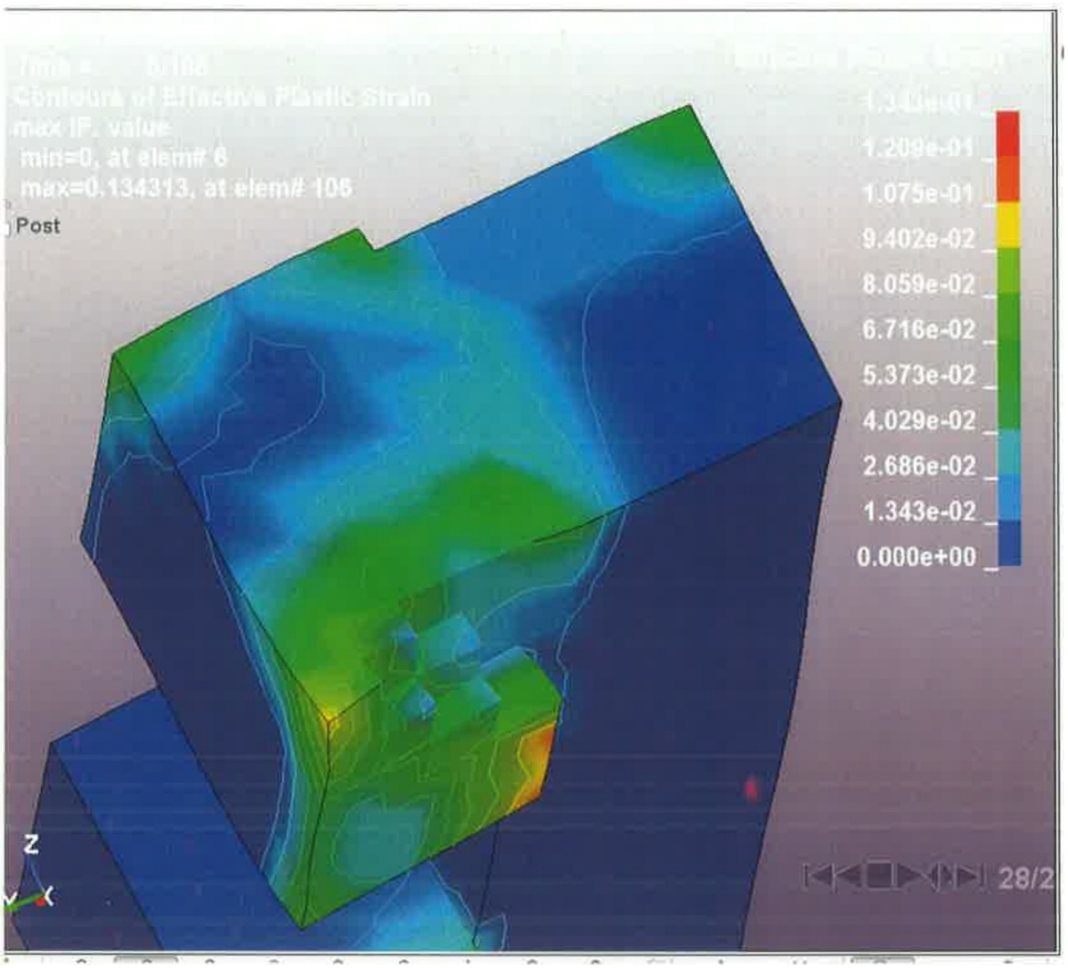
The ASME minimum strength properties along with the area reduction (or elongation) are appropriately considered to derive the material true stress-vs-true strain curve for each material type.

This comment does not have any bearing on the ¼-scale drop simulations documented in HI-2167517. It is to be noted that all cask components in the quarter scale simulation model were appropriately defined using the material erosion (failure) criteria using *Mat_224 material model with exception to the CLLS. Further, neither the actual drop tests performed on the prototype nor the corresponding benchmark simulations show any failure of the CLLS material. Therefore, the material definition for the CLLS in the ¼-scale drop simulations is justified.

<u>NRC RAI 2-8</u>

Clarify and justify the acceptance criteria used for the closure lid locking mechanisms and how this part is modeled in LS-DYNA.

Section 2.1.2.2 of the application states that the acceptance criteria for the closure lid locking mechanism is such that it should not undergo gross yielding. For at least one LS-DYNA simulation, the 30ft oblique drop appears to depict gross yielding of the closure lid locking wedge along with some material failure. The missing material is depicted below:



Gross yielding is assumed here to have occurred because a plane can be passed through the end of CLLS, and encounter effective plastic strain throughout that plane.

Clarify how this acceptance criteria is met in this instance and why the criteria is valid. It could be argued that the CLLS can undergo partial inelastic yielding (not gross) and cause a breach in containment. For instance, one face of the CLLS could suffer uniform material failure allowing the lid to become loose.

This information is needed by the staff to determine compliance with 10 CFR 71.71(c)(7), 71.73(c)(1), and 71.73(c)(3).

Holtec's Response to RAI 2-8

The following acceptance criteria are used for the closure lid locking system (CLLS), which ensure that the cask containment sealing is maintained:

1. No gross (through thickness) plastic deformation of the cask closure lid locking wedge (BOM 9 and 10) and the removable wedges (BOM 11).

2. The clearance gap between the cask top flange sealing surface and the closure lid must remain within its acceptable limit. As established in Chapter 2 of the SAR, the gap subsequent to the most severe HAC drops must remain below the seal useful springback limit of 1.8 mm.

3. The locking wedge locking pin must remain in place subsequent to the drop accident.

Complying with the acceptance criteria established above ensures that the lid will not become loose and the performance of the containment sealing will not be jeopardized.

With minor refinements to the HI-STAR ATB-1T cask design, viz., changing the top flange material (BOM 2) to SA-182 FXM-19 (a.k.a. Nitronic-60), repositioning the crushable bar locations (BOM 42) and adding a gap between the maintenance cover (BOM 27) and the top flange, the CLLS and the closure lid sealing region is protected from any failure (or element erosion). The cask closure lid locking wedges are also demonstrated to remain intact in their locked position.

This RAI does not have any effect on the ¼-scale drop simulations documented in Holtec report HI-2167517. Only limited plastic strain is observed in the CLLS in the quarter scale drop simulations from the oblique drop. The prototype drop tests and the corresponding benchmark simulations further demonstrates the CLLS is very well protected from failure and provide high level confidence against the containment breach.

NRC RAI 2-9

Clarify the parameters used to model concrete in LS-DYNA.

Drop test simulations of the prototype in LS-DYNA use material model 16 (pseudo tensor) for representing the concrete target as part of benchmarking. However, it is unclear how the parameters used in this material model represent the actual concrete properties of the drop test site. Update the benchmarking report as necessary.

This information is needed by the staff to determine compliance with 10 CFR 71.71(c)(7), 71.73(c)(1), and 71.73(c)(3).

Holtec's Response to RAI 2-9

For the benchmark effort, the target properties are chosen so as to reasonably represent the stiffness characteristics used in the prototype tests. The essential characteristics of the target, viz., the concrete thickness, its compressive strength, the top HY Armor 80 steel material and its thickness, are obtained from SNL.

The concrete material model used in the LS-DYNA ¼-scale drop simulations is consistent with the one used for numerous other dry storage applications including HI-STORM FW, HI-STORM 100. Specifically, the concrete pad behavior is characterized using the same LS-DYNA material model (i.e., MAT_PSEUDO_TENSOR or MAT_016) as for the end drop and tipover analyses of the HI-STORM 100 storage cask and the tipover analysis of the HI-STORM FW storage overpack. Note that this ISFSI pad material modeling approach was originally based upon the LS-DYNA benchmark efforts performed by LLNL [2-9-1], where very good agreement was obtained between the analysis results and the physical test results.

Since the essential portion of the impact energy is absorbed by the HI-STAR ATB 1T package, the impact target has a minimal effect on the overall response of the cask. Holtec report HI-2167517 has been revised to include the above explanation.

This RAI pertains directly to the ¼-scale drop simulations documented in Holtec report HI-2167517, and the report has been revised as needed.

[2-9-1] Witte, M., et al., "Evaluation of Low-Velocity Impacts Tests of Solid Steel Billet onto Concrete Pads, and Application to Generic ISFSI Storage Cask for Tipover and Side Drop", Lawrence Livermore National Laboratory, UCRL-ID-126295, Livermore, California, March 1997.

NRC RAI 2-10

Clarify the criteria used to terminate drop test simulations in LS-DYNA.

With the exception of the oblique drop test, all puncture, 0.3 m, and 9 m drop tests simulated in LS-DYNA terminate prior to a secondary impact of the package with the target.

Based on the Sandia test report, the prototype package managed to rebound 20 inches after the primary impact, and caused significant permanent deformation after the 30-ft CGOC drop due to the secondary impact. An examination of the kinetic energy in LS- DYNA for this scenario indicates that around 5% of the initial kinetic energy remains after the first impact of the package. Similar energy ratios can be found for other 30ft drop simulations.

Given that the simulated bottom end drop for the 1-ft NCT drop simulation of the package was enough for the full scale package to experience significant inelastic deformation in the landing around the seals, describe the state of the package post primary impact of the package for NCT and HAC drop test simulations and the criteria under which the package will be judged to have come to rest.

This information is needed by the staff to determine compliance with 10 CFR 71.71(c)(7), 71.73(c)(1), and 71.73(c)(3).

Holtec's Response to RAI 2-10

Secondary impacts are considered where applicable using the LS-DYNA full deck restart option. Since the cask response is essentially elastic (barring some local strains), the energy corresponding to 1 ft. drop (2.96 e+6 lbf-in) is established as the threshold energy to make a determination if a secondary impact is critical for the cask. All 30 ft (9 m) HAC drops wherein the residual energy from the primary impact is greater than the threshold established above, a secondary drop simulation (second load case) is performed using the residual energy from the primary impact as the input.

The following Table summarizes the primary impact energy and the residual energy subsequent to the end of primary impact and determines if the secondary impact (load step) is warranted.

Simulation Number	**Initial Energy (lbf-in)**	**Residual Energy (lbf-in)**	**Ratio of Residual Energy to Initial Energy (%)**	**Second load step is warranted**
# 1	8.95 e+7	1.025 e+6	1.15	No
# 2 (Primary Impact)	8.95 e+7 →	3.91 e+6	4.4	Yes
# 2 (Secondary Impact)	4.59 e6 →	5.3 e +5	0.6 when compared to the initial energy 8.95 e+7	No
# 3	8.95 e+7	1.94 e+6	2.17	No
# 4	8.93 e+7	8.6 e+5	0.96	No
# 5	8.95 e+7	1.49 e+6	1.66	No

# 6	8.95 e+7	2.08 e+6	2.32	No

Note: The arrows indicate the input energy from primary impact to the secondary impact simulation.

When performing a secondary impact simulation (second load step), the element erosion and stress/strain from the primary impact are preserved and the second load step is followed through until the residual energy is less than the threshold energy corresponding to 1 ft (0.3 m) normal drop. This information will be included in the revised Holtec report HI-2177539.

As discussed earlier, with the improvements in the cask design in the closure lid region, the induced strain in the cask sealing region remains below the material elastic limit. Specifically, for the bottom end 1 ft. drop simulation the maximum strain in the sealing region is 0.3% which is limited to the sharp corner of the flange seal seating surface.

This comment does not have any bearing on the ¼-scale drop simulations documented in Holtec report HI-2167517 since both the primary and secondary impacts are captured in the LS-DYNA simulation of the oblique drop. The other drop tests (i.e., 9-meter top down drop, 1-meter puncture drop) did produced only minor significant secondary impacts.

NRC RAI 2-11

Justify the large amounts of hour glassing energy found in parts for the prototype and the HI-STAR ATB 1T package during drop and puncture LS-DYNA simulations.

Typically, it is desired that hour glassing energy be as small as possible (under 10%) relative to internal energy (energy ratio) as large amounts of hour glassing energy lead to inaccurate solutions such as unrealistic deformations and physical behavior. In the case of the closure lid locking mechanism (Part 17 of the prototype), hour glassing energy reaches 200% of the internal energy during the course of the simulation when examined at a part by part basis for the puncture simulation of the prototype. This part also experiences hour glassing energy of 50% of the internal energy for the CGOC 30 ft drop of the prototype. For the 30-ft bottom end drop, the locking pins were found to have as much as 40% energy ratio while the removable wedges were found to have a 15% ratio. This behavior was also exhibited in other simulations and other components such as welds and crush bars for both the prototype and the ATB 1T.

Verify that this behavior is not occurring for both other parts and other LS-DYNA simulations. Update the application and the benchmarking report, as necessary.

This information is needed by the staff to determine compliance with 10 CFR 71.71(c)(7), 71.73(c)(1), and 71.73(c)(3).

Holtec's Response to RAI 2-11

All full scale drop simulations for the HI-STAR ATB-1T cask design are revised to ensure:

1. The total hourglass energy is less than 10% of the peak internal energy.
2. The identical measure for individual parts is also minimized to the extent practical without compromising the overall runtime for the simulations.

To meet the above, some of the key cask components which are prone to hour glassing are switched to use fully integrated S/R solid formation in LS-DYNA. The components are selectively changed to this element formulation based on the drop configuration and the expected deformations. In the end, it is ensured that the hour glassing criteria established above is faithfully met. Specifically, the removable wedges noted in the RAI use fully integrated solid elements thereby totally eliminating the hourglass energy in this component.

This comment also pertains to the ¼-scale drop simulation as discussed in the succeeding paragraph. Since the hourglass energy on a part basis is very small as compared to the total peak internal energy and the initial kinetic energy, this will not influence the overall responses of the cask. However, to be absolutely certain, a ¼-scale puncture drop simulation is revisited and the result comparison is documented in the revised Holtec report HI-2167517.

NRC RAI 2-12

Justify the approach used to model welds for both the HI-STAR ATB 1T package and the prototype in LS-DYNA for free drop and puncture simulations for NCT and HAC.

LS-DYNA simulations of the HI-STAR ATB 1T package and of the prototype for both NCT and HAC drop simulations depict "horizontal welds", such as the one located between the outer bottom dose blocker plate (BOM 13) and the outer long dose blocker plate (BOM 15). This full penetration weld has been modeled as being rectangular in cross section that is 0.86 inches thick. The licensing drawings indicate that a triangular shaped weld would be present at this location and is about 3 %" thick due to plate preparation (45° bevel) not including the heat affected zone. For both the HI-STAR ATB 1T and the prototype, clarify:

a) Why the physical dimensions of the welds modeled are so different than from the licensing drawings,

b) How the heat affected zone is incorporated into the modeling of these welds,

c) Why some horizontal welds, and all "vertical" welds have been excluded from both the prototype and ATB 1T, such as the weld between the outer long dose blocker plate (BOM 15) and the outer short dose blocker plate (BOM 14).

Update the weld modeling as necessary for both the prototype and the HI-STAR ATB 1T with respect to free drop and puncture LS-DYNA simulations. Ensure that both the application and the benchmarking report reflect any such changes.

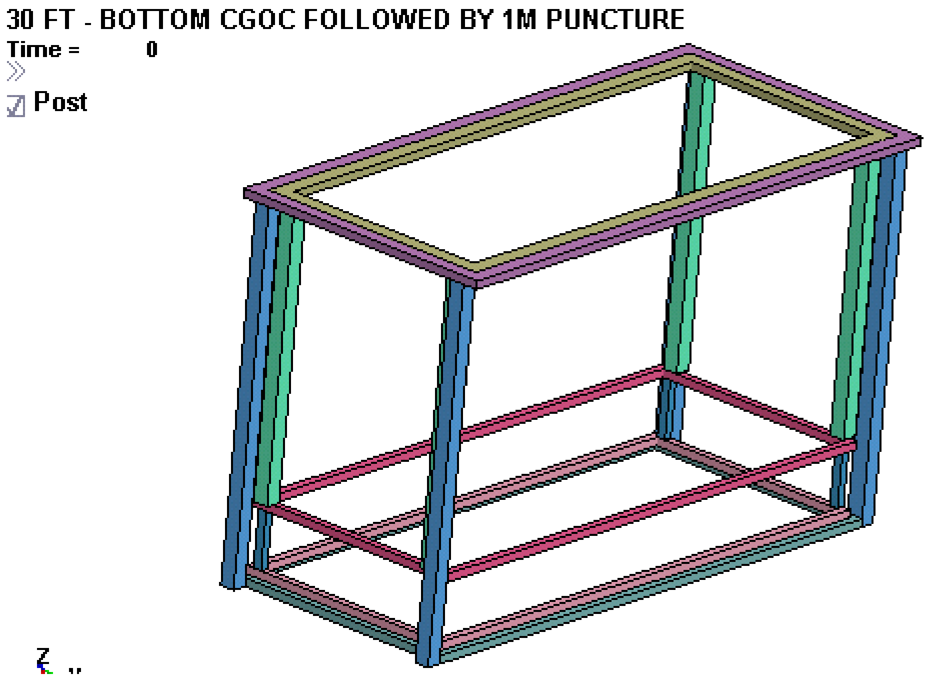
This information is needed by the staff to determine compliance with 10 CFR 71.71(c)(7), 71.73(c)(1), and 71.73(c)(3).

Holtec's Response to RAI 2-12

All cask horizontal and vertical welds are appropriated considered in the FE analysis. The containment shell lower welds between BOM 3 and BOM 4 were not explicitly represented in the base simulations. However, the presence of these welds are considered in the sensitivity simulation for the most governing Bottom CGOC simulations viz. 30 ft Bottom CGOC onto a rigid plate followed by 1-m Bottom CGOC drop onto a puncture bar. The welds are represented by rectangular cross-section with a minimum width and depth equal to the weld size (see figure below).

Weld material true stress-vs-strain curve, strain rate characteristics, triaxiality factor and failure strain reduction are appropriately considered in the updated simulations, and the report is revised accordingly.

The heat affected zones are not differentiated separately from the rest of the base metal material in the LS-DYNA model. Thus, the heat affected zones are assigned the same material properties as the parent base metal.

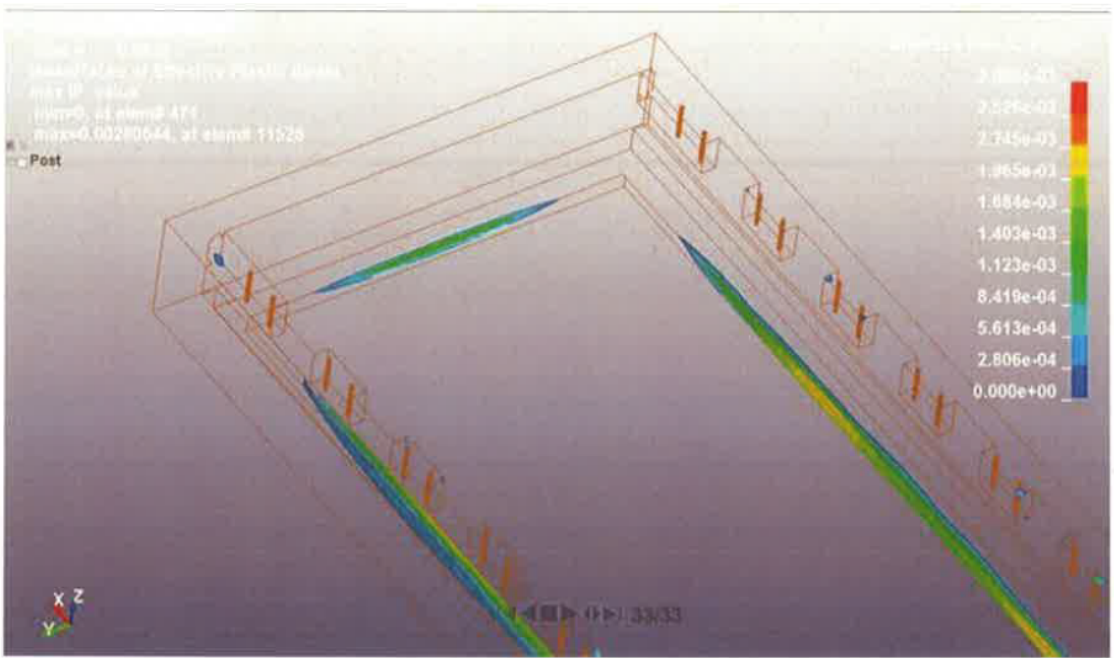


This comment also pertains to the ¼-scale drop simulation. However, since the true-stress-vs-strain curves developed for the base metal and the welds show a very small difference in terms of the total strain energy before material failure, and the fact that no weld failures were observed during the drop test, the overall response of the cask will not change, and a re-analysis of the ¼-scale drop simulations is unwarranted.

NRC RAI 2-13

Verify the modeling of the top flange landing and package contents.

Page 2-8 of the application mentions that strain-based criteria cannot be applied to the landing area of the top flange (BOM 2) and of the closure lid (classified as Zone B). LS- DYNA simulations for both the bottom end 1 ft drop (NCT) and 30 ft bottom end drop (HAC) report inelastic deformations around the flange landing as depicted below (1 ft bottom end drop shown):



The flange landing in LS DYNA has been modeled as 3.125" wide, where in the licensing drawings the landing is depicted as being only 2.5" wide. It is expected that, if a value of 2.5" had been used, higher degrees of inelastic deformation would have been reported by LS-DYNA.

In addition, higher strains may exist for HAC conditions as a result of rigid body assumptions of the contents at the flange. Specifically, the closure lid is unable to fully flex during the simulation due to contact with the contents, resulting in excess forces being transferred through the contents rather than the landing where the seals are located. The applicant shall:

a) Update LS-DYNA puncture and free drop model with regards to flange dimensions,

b) Describe the seal/flange landing performance as a function of rigid body assumptions.

This information is needed by the staff to determine compliance with 10 CFR 71.71(c)(7), 71.73(c)(1), and 71.73(c)(3).

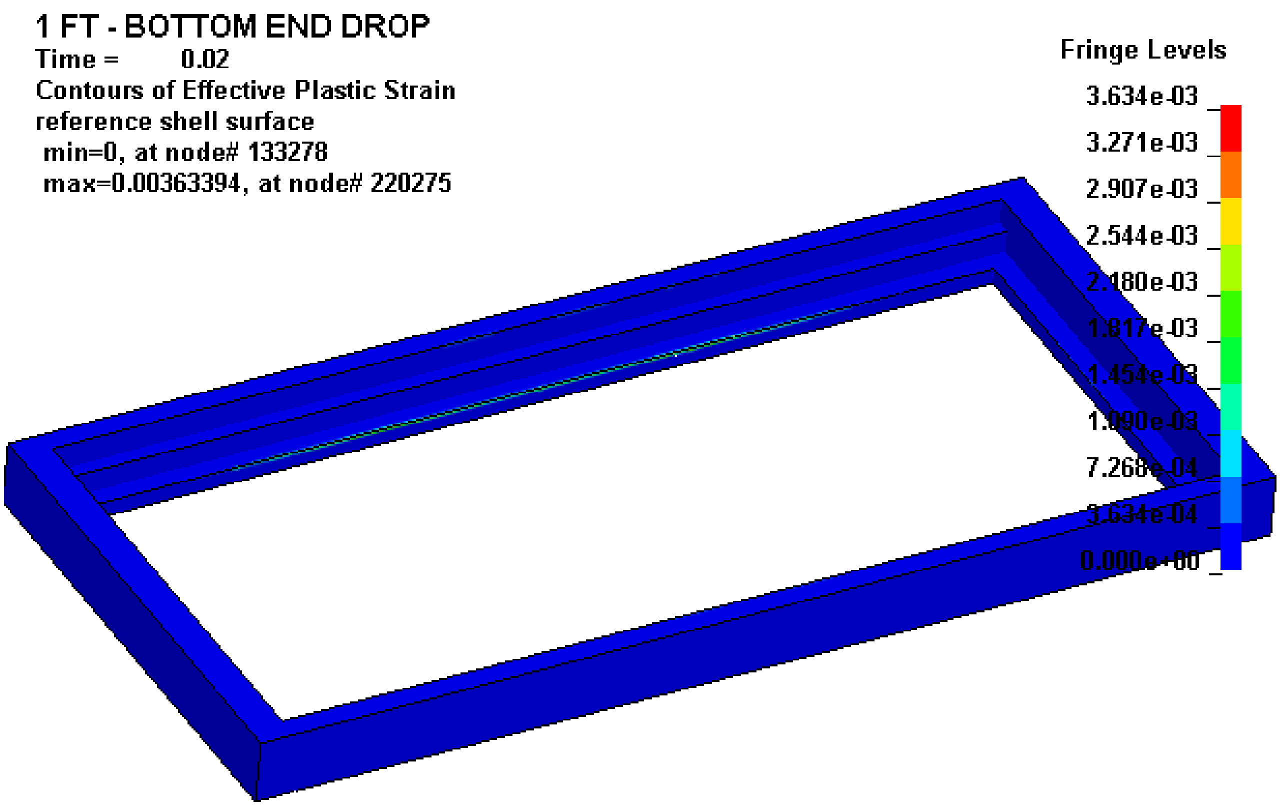
<u>Holtec's Response to RAI 2-13</u>

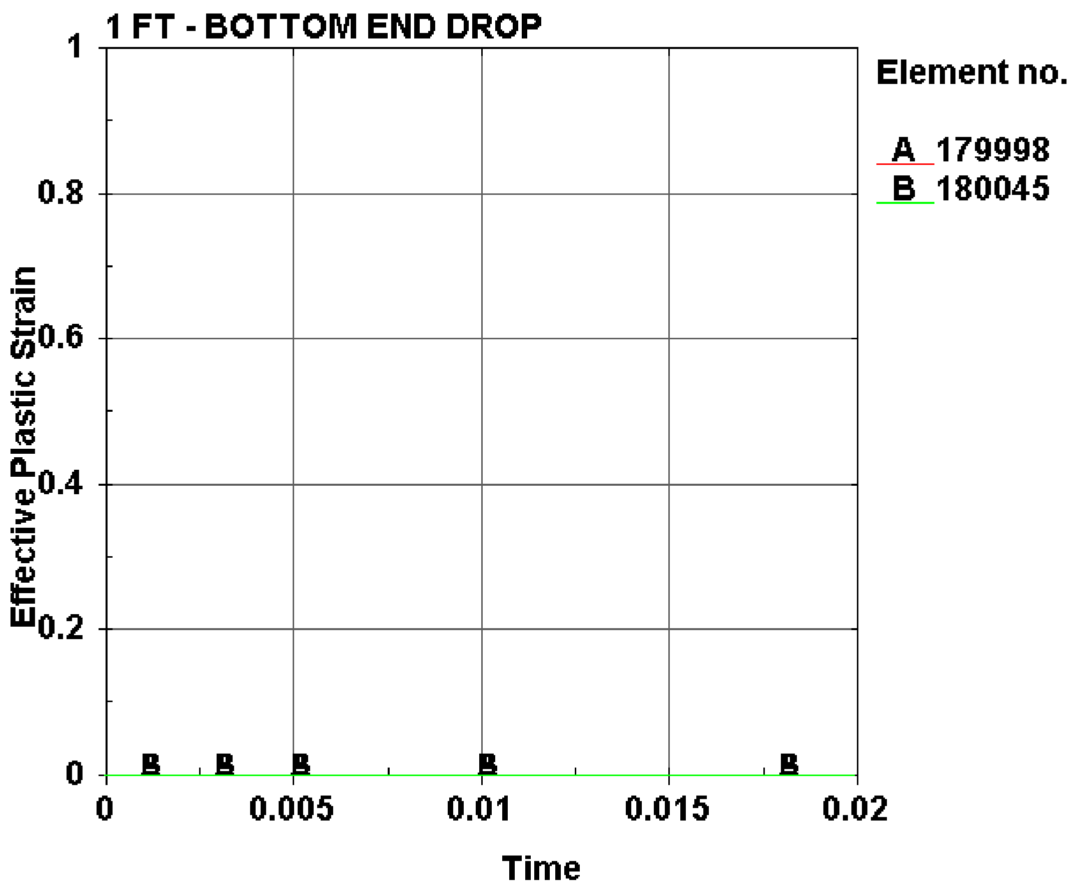
The flange landing width is corrected in the updated simulations.

Also, in the updated simulations the BFA tank enclosing the BFA Tank cassette is represented by an elastic-plastic body allowing the closure lid to deflect fully under the severe drop accidents.

With the enhancements to the cask design in the flange/sealing/closure lid region, the resulting strains in the sealing region, from the updated simulations, are noted to be insignificant (as shown in figures below).

As expected, the maximum strains tend to occur along the free edge of the closure flange seating area. The elastomeric seals are offset approximately 1.25 inches from the free edge, where the inelastic strain is negligibly small.





Strain in the seal seating region on the top flange

This comment has no bearing on the ¼-scale drop simulations documented in Holtec report HI-2167517.

NRC RAI 2-14

Confirm that stress limits within the lid of the ATB 1T do not exceed the values set forth by ASME for the 1-ft bottom end drop simulation for NCT conditions.

Section 2.1.2.2 of the application indicates that stresses within the lid are not to exceed ASME Section Ill NB values for NCT. This criteria implies that stress intensity values should remain elastic.

However, for the LS-DYNA simulation of the 1-ft bottom end drop, the closure lid (BOM 8) undergoes permanent inelastic deformation indicating that material has yielded (stress of 47 ksi according to effective Von-Mises option in LS-DYNA).

Confirm that this, and other containment boundary components, does not exceed stress intensity values according to ASME Section Ill NB for all NCT drop and penetration simulations nor observe plastic strain values.

In addition, clarify how stress values reported by LS-DYNA are used to compute and compare to ASME values as it is not apparent in the application how such values are determined. For instance, Table 2.6.2 of the application reports primary bending stress intensity values, but it is unclear how these values were determined based on LS-DYNA output values.

This information is needed by the staff to determine compliance with 10 CFR 71.71(c)(7),

Holtec's Response to RAI 2-14

Agreed. This is documented in the updated report.

The following Table summarizes the Level-A stress limits for the 304 base metal and the 308 welds, respectively.

SA 240 304 Material (Base Metal)		
Stress Category	**Limit per NB -3220**	**Value MPa (ksi)**
Primary Membrane, P_m	S_m	138 (20.0)
Local Membrane, P_L	$1.5S_m$	207 (30.0)
Membrane plus Primary Bending	$1.5S_m$	207 (30.0)
Primary Membrane plus Primary Bending	$1.5S_m$	207 (30.0)
Membrane plus Primary Bending plus Secondary	$3S_m$	414 (60.0)

308 Material (Welds)		
Weld Stress Allowable	0.3 Su	25 ksi

The minimum yield strength of the SA 240 304 material, per ASME Part II-D, is 27 ksi at applicable temperature of operation (~150 deg. F). As noted from the above Table, material yielding (self-limiting in nature) is permitted in the material except when evaluating the primary stress intensity. Also, ASME section III subsection NB notes that the primary bending stress limit excludes the stress of secondary or peak nature.

The report HI-217754R1 is revised briefing the stress application and classification for the containment boundary parts.

This comment has no bearing on the ¼ scale drop simulations documented in HI-2167517.

NRC RAI 2-15

Clarify how whole parts that are expected to experience inelastic deformations will perform when welded from multiple pieces under NCT and HAC drop and puncture tests.

Flag note 6 on Sheet 1 of 5, Drawing 9786, indicates that whole parts may be comprised of multiple pieces joined by full penetration welds. It is unclear how components made in this fashion will perform for drop and puncture tests at welded areas where material properties are not the same as base materials.

This information is needed by the staff to determine compliance with 10 CFR 71.71(c)(7), 71.73(c)(1), and 71.73(c)(3).

Holtec's Response to RAI 2-15

Flag note 6 on Drawing 9786 has been entirely revised such that the option to fabricate whole parts from multiple pieces joined by full penetration welds is no longer permitted. All parts and connecting welds that form the HI-STAR ATB 1T cask are modeled in LS-DYNA as shown on the drawing, with one exception.

The short and long containment wall plates (BOM 3 & 4) are now shown on Drawing 9786 as solid plates that extend the full height of the cask containment cavity. However, in the LS-DYNA simulation model for the full scale package, each short and long containment wall plate is comprised of two pieces joined by full penetration welds at the location where the plate thickness steps down from 4" to 2". Even though the simulation results for the two-piece construction are acceptable for all NCT and HAC drop and puncture tests, our licensing commitment per the updated drawing is to fabricate the short and long containment wall plates as single piece parts for enhanced safety.

This comment has no bearing on the ¼-scale drop simulations documented in Holtec report HI-2167517 since all parts are modeled in LS-DYNA as fabricated.

NRC RAI 2-16

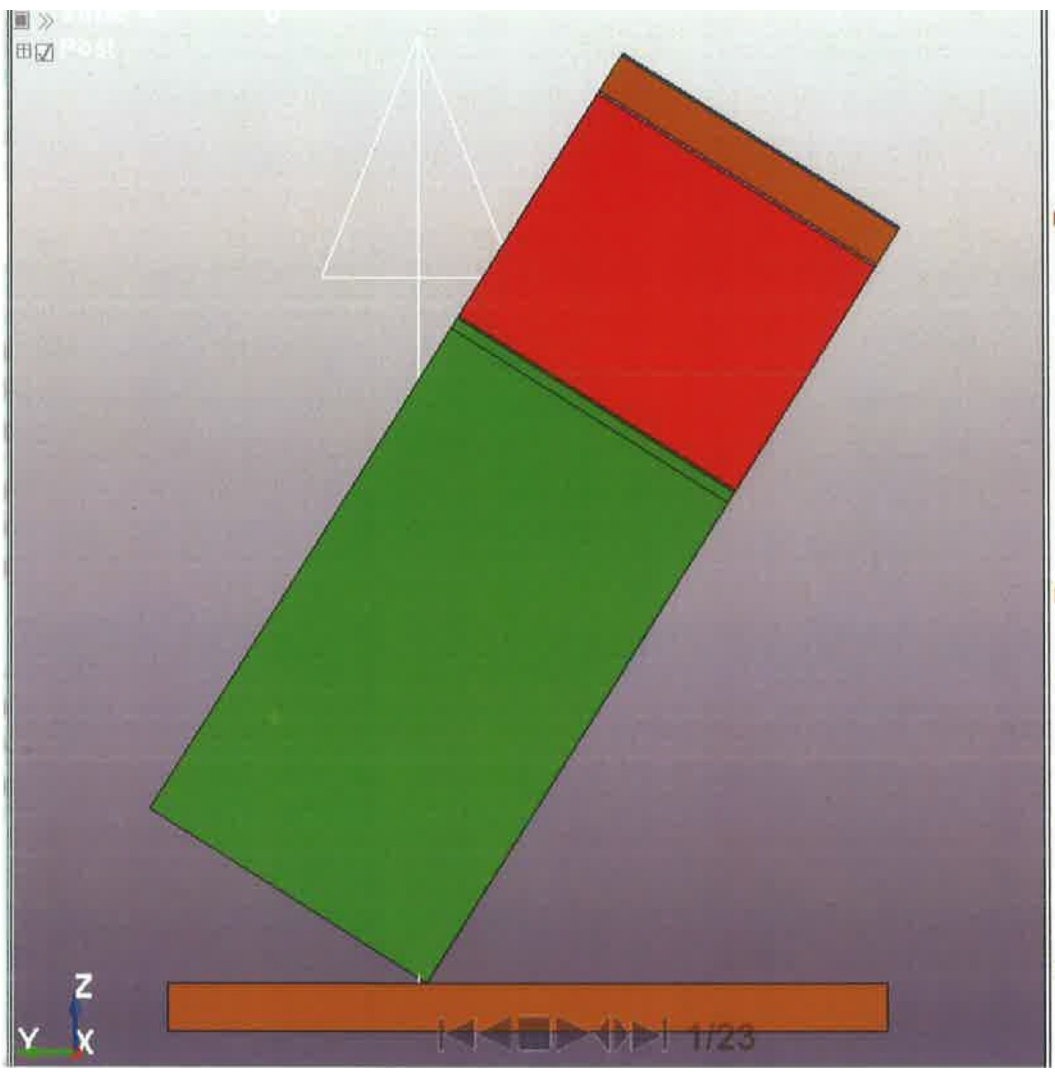
Verify that the HI-STAR ATB 1T orientation was correct when conducting CGOC simulations in LS-DYNA for NCT and HAC.

The HI-STAR ATB 1T center of gravity is located relatively close to its geometric center. An arrow drawn normal to the target and close to the point of impact should pass through the center of gravity. It is expected that this fictitious arrow would pass through the center of gravity and close to the opposing corner of the package.

It appears that this may not be the case according to the picture below where the package is seen to be leaning too far to the right from the arrow.

Verify that the package orientation for the CGOC simulation is correct.

Update all drop/puncture LS-DYNA simulations for the HI-STAR ATB 1T for NCT and HAC conditions as appropriate.



This information is needed by the staff to determine compliance with 10 CFR 71.71 (c)(7), and 71.73 (c)(1).

Holtec's Response to RAI 2-16

The updated simulations reflect the cask orientation correctly.

This comment has no bearing on the ¼-scale drop simulations documented in Holtec report HI-2167517 since the package orientations accurately reflect the drop test measurements.

NRC RAI 2-17

Describe the condition of the HI-STAR ATB 1T as a result of cumulative damage resulting from the drop test and the fire test for HAC conditions.

Section 2.7.3 of the application describes thermal stresses as a result of the fire test. However, this section does not provide details regarding the structural integrity of the containment as a result of increased internal pressure due to the HAC fire test.

Describe the condition of the package in this regard by updating the application, while also noting that the package is initially damaged from a previous drop or puncture test.

This information is needed by the staff to determine compliance with 10 CFR 71.73(a) and 71.73(c)(4).

Holtec's Response to RAI 2-17

The internal pressure due to the fire accident (24.9 psia) is not a significant load for the ATB-1T package as compared to the loads sustained from the accidental drops. Therefore, the fire test will not have any adverse effect on the cask containment boundary including the seal performance.

To demonstrate this, we consider the long containment wall plate (BOM 4) as a simply supported rectangular plate under a uniform pressure load of 24.9 psia (or 10.2 psig), which is the maximum internal pressure due to the fire accident per SAR Table 3.1.3. For conservatism, the bending stress in the plate is calculated based on a uniform thickness of 2" (even though more than half of the plate is 4" thick per Drawing 9786). Based on this set of conservative assumptions, the bending stress at the center of the rectangular plate is only 9.77 ksi, which is well below the yield strength (17.6 ksi) of SA-240 304 material at 700°F. Per SAR Table 3.1.2, the maximum metal temperature of the cask containment wall plates in the wake of the fire accident is 673°F. Therefore, the fire accident will not cause any further plastic deformations to the containment boundary components.

Calculation 7 of HI-2177540 provides details pertaining to the seal performance subsequent to the fire accident.

NRC RAI 2-18

Describe the specific test methods, test conditions, and acceptance criteria that will be used to qualify the containment seal, Item 7, elastomeric, sheet 1 of 5 on drawing 9786 to meet the critical characteristics provided in Table 2.2.2 of the application.

Table 2.1.2 of the application states that the non-code seals and gaskets will be procured with manufacturer's catalog and test data. The staff note that the properties of elastomers can vary, depending on their processing and chemical composition.

The staff require information on the specific qualification tests or standards used, test conditions, and the acceptance criteria for the test results to complete its review of the capability of the seal and gaskets to meet their containment function under normal conditions of transport and hypothetical accident conditions.

This information is needed by the staff to determine compliance with the requirements of 10 CFR 71.31(c).

Holtec's Response to RAI 2-18

The acceptance criteria for the critical characteristics of the seals are shown in Table 2.2.2. The table has been revised to include specific test methods, where applicable, for establishing the critical characteristic. The materials listed in the Table have been pre-qualified as possessing these critical characteristics. Additional testing will be performed for each seal procured for use with the cask to confirm that it is the proper material and has been manufactured to yield the appropriate properties as listed in Table 2.2.2. Testing will be performed in accordance with the Holtec QA program.

In addition, critical characteristics are added to the NITS outer seal. Although this seal is not credited for containment, it is recognized that because it is loaded in parallel with the primary seal, its dimensional and material characteristics are important for determining the distribution of the initial load on the o-rings. Other critical material characteristics (for example, minimum continuous operating temperature and maximum continuous operating temperature) are specified in the table to ensure that the seal remains operationally viable in all conditions and continues to provide redundant sealing during normal conditions of transport.

An additional change to Table 2.2.2 removes "linear thermal expansion" and "minimum elongation" from the critical characteristics of the seals. Due to the relatively low maximum normal operating temperature of the transport cask, linear thermal expansion is not a critical consideration for specifying the seal material. The linear thermal expansion of the specified FFKM and EPDM compounds is in the typical range of other elastomeric seals, and is therefore considered acceptable without establishing specific critical characteristics. Similarly, maximum elongation for both compounds is typical of other elastomeric seal material. Because installation and operation of the seals does not require significant o-ring stretch, this characteristic is also removed from the critical characteristics table.

NRC RAI 2-19

Define what is meant by "non-code" welds performed on the HI-STAR ATB 1T transportation packaging materials/components and define an equivalent weld procedure.

Section 2.2.3 of the application states that all non-Code welds will be made using weld procedures that meet ASME Section IX, AWS D1.1, D.1.2 or equivalent. It's unclear to the staff whether "non-Code welds" refers to the component design, weld procedure, or both. Also, clarify, both in the application and on the licensing drawings, the criteria to determine what could be an equivalent procedure. The criteria should specify the minimum critical characteristics equivalent to that of weld procedures from ASME and/or AWS national standards.

This information is needed by the staff to determine compliance with 10 CFR 71.31(c).

Holtec's Response to RAI 2-19

To bring Section 2.2.3 of the application into alignment with the definition of weld types (which include specific definitions of requirements for weld procedures, NDE, etc.) in the cask licensing drawing (refer to note 5 of drawing 9786), Section 2.2.3 is revised as follows (changes shown in italics). This eliminates references to "non-code" welds which were ambiguous when compared to the weld type descriptions used in the licensing drawings. Reference to "equivalent" weld procedures is also eliminated; all weld procedures must meet all minimum requirements of ASME to be acceptable.

> All weld filler materials utilized in *performing Containment Boundary welds (as defined in the licensing drawings),* will comply with the provisions of the appropriate ASME Code Subsection (e.g., cited paragraphs of Subsection NB and with applicable paragraphs of Section IX). All *Dose Blocker Structure welds (as defined in the licensing drawings)* will be made using weld procedures that meet *the requirements of* ASME Section IX. The minimum tensile strength of the weld wire and filler material (where applicable) will be equal to or greater than the tensile strength of the base metal listed in the ASME Code.

The second paragraph of Section 2.2.3 is deleted to eliminate redundancy with Note 5 of Drawing 9786.

In addition, ADDITIONAL NOTE 2 of Licensing Drawing 9786 is revised as follows to clearly indicate which weld types it is applicable to:

> 2. ALL CONTAINMENT BOUNDARY AND DOSE BLOCKER/STRUCTURAL WELD SIZES ARE MINIMUM VALUES.

NRC RAI 2-20

Clarify, both in the application and on the licensing drawings, the required materials properties of ITS items that have a generic material designation (e.g., steel, aluminum).

Item 19, steel, trunnion solid shaft, ITS, structural, and Item 37, aluminum, lid spacer, ITS, structural, sheet 1 of 5 on drawing 9786 of the application and flag notes/remarks 4 and 5, respectively, provide no or limited mechanical properties. In addition, various items, steel (various descriptions)/bolt(s), ITS, sheet 1 thru 8 of 8 on drawing 9876 of the application and flag note/remark 1 provide examples of standards, limited mechanical properties and none for the bolts.

The materials of construction for all ITS components should be described with sufficient detail to allow the staff to perform a technical review, including the minimum yield strength, tensile strength, and elongation (either by citing a specific material standard/grade or by providing the minimum material properties). The criteria should also describe how material fracture toughness or stress-rupture criteria will be met, if applicable to the product form.

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

Holtec's Response to RAI 2-20

To more specifically define the relevant properties of the materials of construction for all ITS components, the following revisions have been made to the licensing drawings:

Licensing Drawing 9786

MAT SPEC for ITEM 37 in the BOM is changed to SB209-6061.

For structural reasons, the MAT SPEC FOR ITEM 19 in the BOM is changed to NICKEL ALLOY and the minimum yield and ultimate strengths are changed to 144 ksi (992 MPa) and 177 ksi (1224 MPa), RESPECTIVELY, AT TEMPERATURES AT OR BELOW THE MAXIMUM NORMAL OPERATING TEMPERATURE OF THE CASK. These are the only material criteria that are applicable to ITEM 19, the lifting trunnions.

The strength Table 2.2.1C is updated accordingly.

Licensing Drawing 9876

A reference to flag note 1, which indicates the required mechanical properties for the BFA Tank bolts for all four tank designs (T-50 through T-200), is added to the REMARKS column in the parts list for Items 105 (T-50), 205 (T-100), 305 (T-150) and 405 (T-200). These bolts are classified as ITS because their presence is required, along with interfaces with other components, to maintain the general orientation and location of BFA tank walls that are credited for shielding in the assembled waste package. No additional mechanical properties beyond those described in flag note 1 are required for these bolts to perform their safety function.

The above changes to the licensing drawings were made to provide details to allow the staff to perform their technical reviews.

NRC RAI 2-21

Define what "equal" mechanical properties may be substituted for use in the HI-STAR ATB 1T transportation packaging materials/components.

Note E, sheet 1 of 5, drawing 9786 states that the ASME and/or ASTM designation(s) of each material type specified herein is intended to fix its chemical and metallurgical attributes, not its raw material product form (viz. plate or forging, seamless or welded tube, etc.). Alternate product forms having the same chemical designation and equal mechanical properties may be substituted by the manufacturer. Alternate material types shall be tested in accordance with the applicable ASME code requirements for the product type.

Clarify, both in the application and/or on the licensing drawings, the criteria to determine what could be an "equal" material in lieu of those materials grades originally called for in the application. The criteria should specify the minimum yield strength, tensile strength, elongation, reduction of area, fracture toughness, and/or stress-rupture criteria (as applicable to each referenced standard in the drawings).

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

Holtec's Response to RAI 2-21

Holtec has removed Note E from licensing drawing 9786. The limited number of material types used in the cask and the reliance on relatively standard and readily available product types informed Holtec's decision to eliminate this option for substituting materials, which has been a standard practice to ensure manufacturing flexibility in some other transport and storage cask designs. For consistency within the license application, this note is also removed from licensing drawing 9876. Criteria to determine what qualifies as an “equal” material are therefore no longer required.

NRC RAI 3-1

Clarify the bounding heat load distribution for the NCT and HAC thermal analyses so that a review of maximum package temperatures can be performed.

Page 3-19 appears to indicate that maximum temperatures are found for the concentrated heat load distribution. However, page 3-18 states that the uniform heat load distribution is the limiting loading scenario for the license basis model. The thermal analyses should be based on the bounding heat load distribution.

This information is required by the staff to determine compliance with 10 CFR 71.33, 71.35(a).

Holtec's Response to RAI 3-1

The uniform heat distribution model as explained in the following is bounding for licensing basis evaluation. The objective of thermal modeling is two-fold wherein one scenario is defined to maximize computed temperatures of the radioactive source inside the cassette as shown in Figure 3-1.1 and a second scenario defined to maximize cavity temperatures and co-incident containment pressures. Under the first scenario the radioactive source is assumed to be concentrated in a block of solid metal equal to the mass of the source materials and levitating in air as shown in Figure 1. In the second case the source material is assumed uniformly distributed within the cassette space with the objective of maximizing cavity temperatures. To construct a licensing basis model that bounds both scenarios an effective conductivity of the cassette interior space under the second scenario is determined to yield the *same* maximum temperature obtained in the first scenario. This calibrated thermal model defined as "uniform heat distribution" model is adopted for Normal Conditions of Transport (NCT) evaluations.

Under Hypothetical Accident Conditions (HAC) of transport a conservative construct is postulated wherein the BFA-tank and the radioactive contents are assumed to be distributed in the cask cavity to maximize containment pressures. The effective conductivity of the cavity space is calibrated to yield the maximum source temperatures obtained under concentrated heat distribution scenario defined above. In this manner a bounding model is obtained and adopted for HAC evaluation.

In light of the above discussion SAR Section 3.3.10 is suitably revised for clarity.

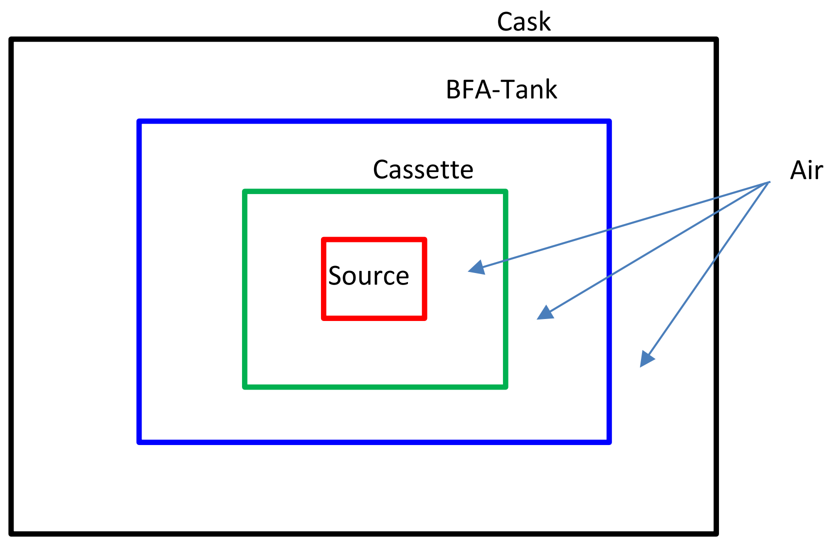


Figure 3-1.1: Schematic of Levitating Cask Configuration

NRC RAI 3-2

Clarify the bounding condition, related to gaps, for the NCT and HAC thermal analyses so that a review of maximum package temperatures can be performed.

Page 3-19 bottom appears to state that temperatures without gaps are higher than a model with gaps. This is inconsistent with Table 3.5.5 which indicates that a package with larger thermal resistances, such as gaps, result in larger temperatures.

This information is required by the staff to determine compliance with 10 CFR 71.33, and 71.35(a).

Holtec's Response to RAI 3-2

Licensing basis evaluation of normal conditions of transport are described in Section 3.3.6 of the SAR. These evaluations assume the dose blocker plates are welded to the containment boundary plates to create gap free interfaces between the adjacent plates. However, realistically interface gaps between adjacent plates may exist locally. In order to assess the impact of such gaps, a sensitivity study was performed and presented in Section 3.3.10 of the SAR. Analysis assumed a conservative gap of 2mm between all adjacent plates of the HI-STAR ATB 1T cask. The results from the sensitivity study are summarized in Table 3.3.5 of the SAR. The results confirm the impact of such an overstated air gap has a second order impact on the peak temperatures.

During hypothetical accident conditions (HAC), the interface gap between adjacent plates will hinder the heat from fire into the cask cavity. Thus, it is conservative to ignore the presence of any such gaps in the thermal model for HAC.

In light of the above discussion SAR Section 3.3.10 is suitably revised for clarity.

NRC RAI 3-3

Provide the .cas and .dat files for the bounding NCT condition and the .cas and .dat files for the post-fire HAC analyses.

Confirm that the .cas and .dat files provided are for the bounding NCT condition (see first thermal RAI above). In addition, it appears that the .cas and .dat files for the post-fire HAC condition were not provided and so a review could not be performed.

This information is required by the staff to determine compliance with 10 CFR 71.33, and 71.35(a).

Holtec's Response to RAI 3-3

All the FLUENT input and output files (.cas and .dat) supporting NCT and HAC analyses are listed in Section 5.0 of Holtec Report HI-2156585 Revision 1 and are provided with the SAR submission. The files are listed below for ready reference.

NCT Files:

07/23/2015	05:16 PM	150,351,975	T200-half-center-1d75kw.cas
07/23/2015	05:17 PM	2,587,879,495	T200-half-center-1d75kw.dat

HAC Files:

Initial Condition

07/27/2015	10:47 AM	150,171,036	T200-half-uniform-cavity-1d75kw-normal.cas
07/27/2015	10:47 AM	2,531,718,227	T200-half-uniform-cavity-1d75kw-normal.dat

Fire Condition

07/27/2015	10:57 AM	140,125,063	T200-half-1d75kw-fire.cas
07/27/2015	10:50 AM	2,339,478,864	T200-half-1d75kw-fire-initial.dat
07/27/2015	02:33 PM	2,377,953,994	T200-half-1d75kw-fire-1-600.dat
07/27/2015	04:01 PM	2,377,954,786	T200-half-1d75kw-fire-1-1200.dat
07/27/2015	05:31 PM	2,377,955,590	T200-half-1d75kw-fire-1-1800.dat

Post-Fire Cooldown Condition

07/27/2015	11:10 AM	140,119,716	T200-half-1d75kw-postfire.cas
07/28/2015	01:07 PM	2,377,889,534	T200-half-1d75kw-postfire-1-2160.dat
07/28/2015	05:18 PM	2,377,922,321	T200-half-1d75kw-postfire-1-3720.dat
07/28/2015	06:08 PM	2,377,887,171	T200-half-1d75kw-postfire-1-4320.dat
07/28/2015	06:28 PM	2,377,930,711	T200-half-1d75kw-postfire-1-4560.dat
07/28/2015	06:48 PM	2,377,902,251	T200-half-1d75kw-postfire-1-4800.dat
07/28/2015	07:39 PM	2,377,939,101	T200-half-1d75kw-postfire-1-5400.dat
07/29/2015	12:56 AM	2,377,903,951	T200-half-1d75kw-postfire-1-6000.dat
07/29/2015	02:36 AM	2,377,905,651	T200-half-1d75kw-postfire-1-7200.dat

07/15/2015 11:42 AM 872 heat-transfer-coeff.c

NRC RAI 3-4

Provide the residuals and energy balances for the NCT and HAC thermal analyses.

The residuals and energy balances for the NCT and HAC thermal analyses were not provided and so a review of the code convergence could not be performed.

This information is required by the staff to determine compliance with 10 CFR 71.33, and 71.35(a).

Holtec's Response to RAI 3-4

FLUENT Version 14.5.7 is used to perform the simulations for NCT and HAC. In FLUENT 14.5.7, the residuals are checked using "Display > Residuals", and the total heat transfer rate from the cask external surface can be obtained using "Reports > Fluxes". The energy balance is confirmed by ensuring decay heat input to cask accords with heat dissipation from cask surfaces. This is illustrated below for normal condition of transport.

Table 3-4.1: Energy Balance

Cask Decay Heat	1750 W
Heat Dissipation (calculated as two times the half symmetric model output shown below)	1758.8 W
Energy Balance	100%

Table 3-4.2: Heat Flux Output from Half-Symmetric Model

```
Total Heat Transfer Rate                (w)
-------------------------------- --------------------
cask-botsurf                  0
cask-outsurf-ls            -575.4896
cask-outsurf-ls:178           -35.315195
cask-outsurf-ls:179           -99.172341
cask-outsurf-ls:180           -7.3608695
cask-outsurf-ss-1          -106.40723
cask-outsurf-ss-1:107         -11.793224
cask-outsurf-ss-1:108         -7.3001144
cask-outsurf-ss-1:109         -20.933632
cask-outsurf-ss-1:110         -1.5604351
cask-outsurf-ss-2          -106.42571
cask-outsurf-ss-2:103         -11.79988
cask-outsurf-ss-2:104         -7.3002504
cask-outsurf-ss-2:105         -20.930783
cask-outsurf-ss-2:106         -1.5593285
cask-topsurf            133.91419
```

```
---------------- --------------------
Net          -879.43441
```

As requested, the residuals are graphed in Figure 3-4.1 for normal conditions of transport.

For the HAC evaluation presented in Section 3.4 of the SAR, a transient simulation is performed. Following the method for NCT above, the residuals and the total heat transfer rate can be checked using FLUENT data files listed in the response to RAI 3-3. It is noted that the physical scenario involves excess energy transfer into the cask during fire and out during post-fire cooling. Heat balance is achieved when the system asymptotically reaches a steady state. It must be noted that the transient simulation is terminated when containment boundary component reach their maximum temperatures as shown in Figure 3.4.1 of the SAR (at time t=120 minutes). At this time, since a steady state condition has not yet been reached, heat dissipation from the cask surfaces is higher than the decay heat from the waste content due to heat input absorbed during fire condition.

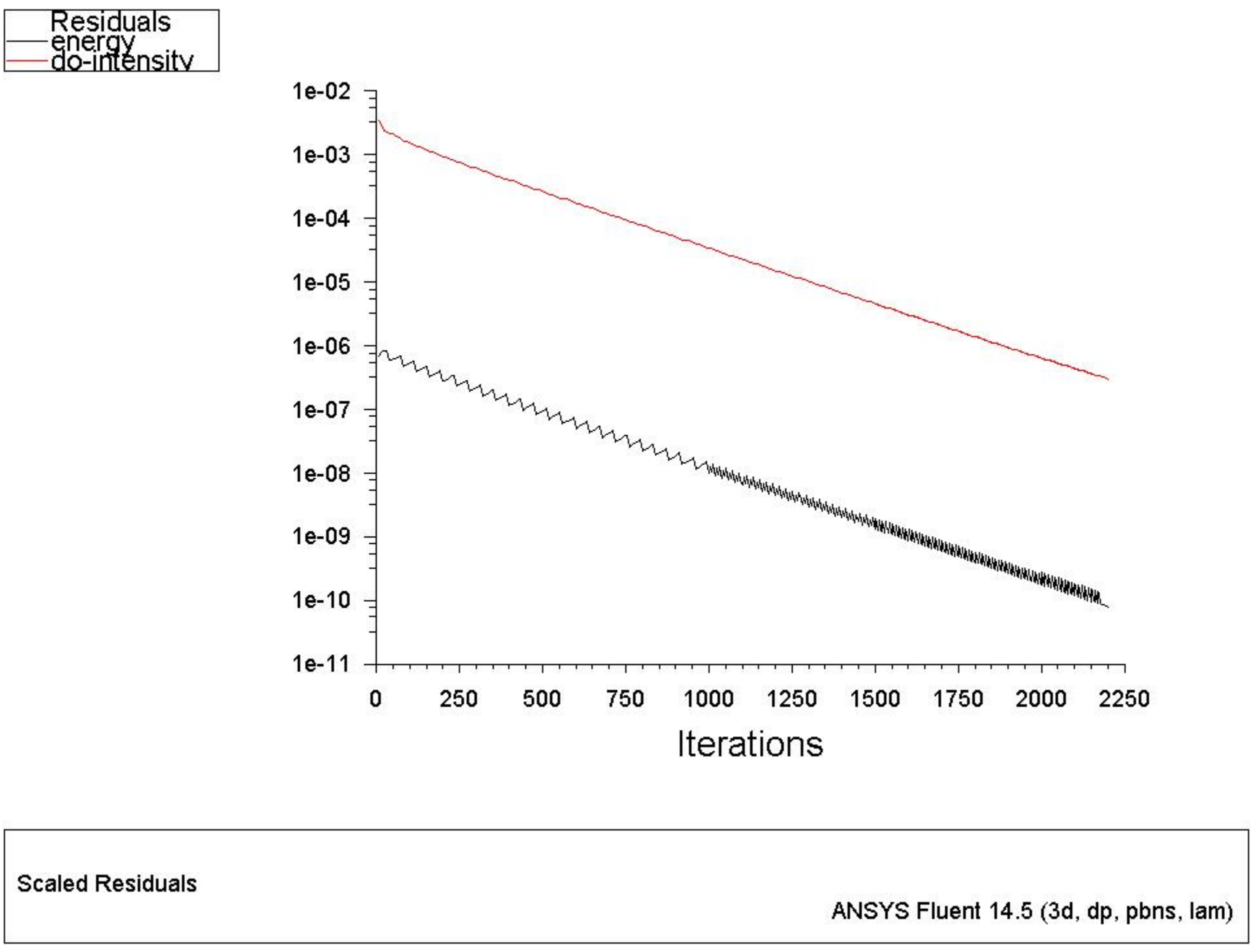


Figure 3-4.1 Residuals for NCT

NRC RAI 3-5

Clarify the 0.6 surface absorptivity value reported in Table 3.4.1, especially during the 30 minute fire.

Section 3.4.2 mentions a "unit absorptivity" during the fire. However, Table 3.4.1 indicates a 0.6 surface absorptivity value during the 30-minute fire, whereas 10 CFR 71.73(c)(4) specifies that the value must be either the value which the package may be expected to possess or 0.8, whichever is greater. There was no justification for the lower absorptivity. In addition, justify the 0.6 value after the fire, considering the potential for soot.

This information is required by the staff to determine compliance with 10 CFR 71.33, and 71.73.

Holtec's Response to RAI 3-5

The surface absorbtivity presented in Table 3.4.1 of the SAR is not the surface absorbtivity for heat absorbed from fire. It is the "Cask Surface Solar Absorbtivity", which is the absorptivity for heat absorbed from solar. As required by 10 CFR 71.73, the HI-STAR ATB 1T Package is evaluated under an all-engulfing fire. The engulfing fire potentially blocks solar due to smoke. In the thermal model, the insolation is conservatively applied on the cask external surface without credit for blocking during both fire and post-fire with surface absorptivity of 0.6, which is conservative. For the heat absorbed from the engulfing fire, the minimum specified emissivity (i.e. 0.9) and unit absorbtivity are adopted during the 30-minute fire, as stated in Section 3.4.2 of the SAR.

NRC RAI 3-6

Clarify the external convection heat transfer that occurs after the 30-minute fire.

There was limited discussion of the heat transfer that occurs after the 30-minute fire and during the 1.5 hour cooldown; thus, a review could not be performed.

This information is required by the staff to determine compliance with 10 CFR 71.33, and 71.73(c)(4).

Holtec's Response to RAI 3-6

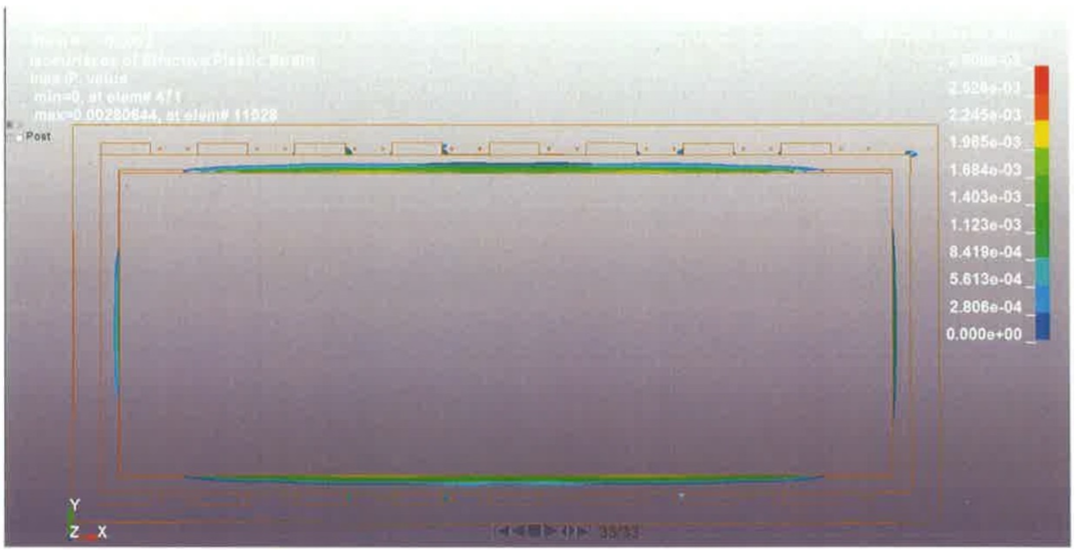
Table 3.4.1 of the SAR provides information on the assumptions made for heat dissipation from the cask external surface during and after 30-minute fire. As described in Section 3.4.2 of the SAR, a forced convection heat transfer tabulated in Table 3.4.2 of the SAR is adopted in thermal evaluations of 30-minute fire. During post-fire cooldown, the cask surface dissipates heat by natural convection and heat radiation. The natural convection heat transfer coefficient is determined using correlations described in SAR Section 3.3.4. This methodology to model the convection heat transfer during and after the 30-minute fire is consistent with that previously approved by NRC in HI-STAR 180 (Docket #71-9325) and HI- STAR 180D (Docket #71-9367).

Section 3.4.2 of the SAR is revised to provide further clarification on external convection heat transfer after 30-minute fire.

NRC RAI 4-1

Demonstrate that the package will maintain containment under NCT and HAC tests.

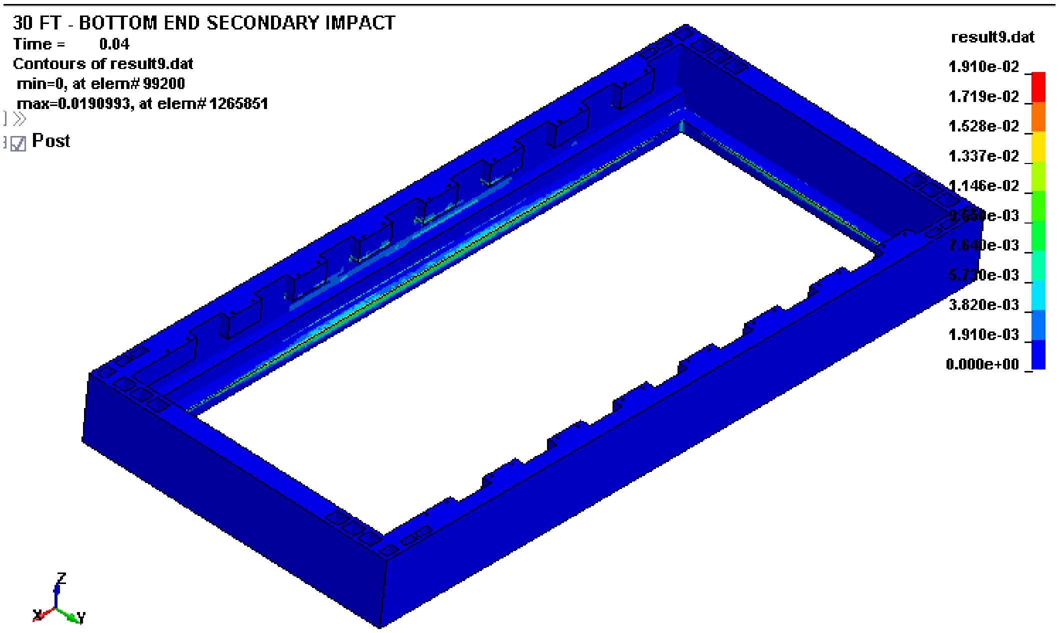
An evaluation of the structural analyses shows inelastic deformation of the landing. There is no demonstration that the seal, which rests on the landing, would maintain containment after undergoing the NCT and HAC tests. The Figure below is at NCT drop; strains are greater for HAC.

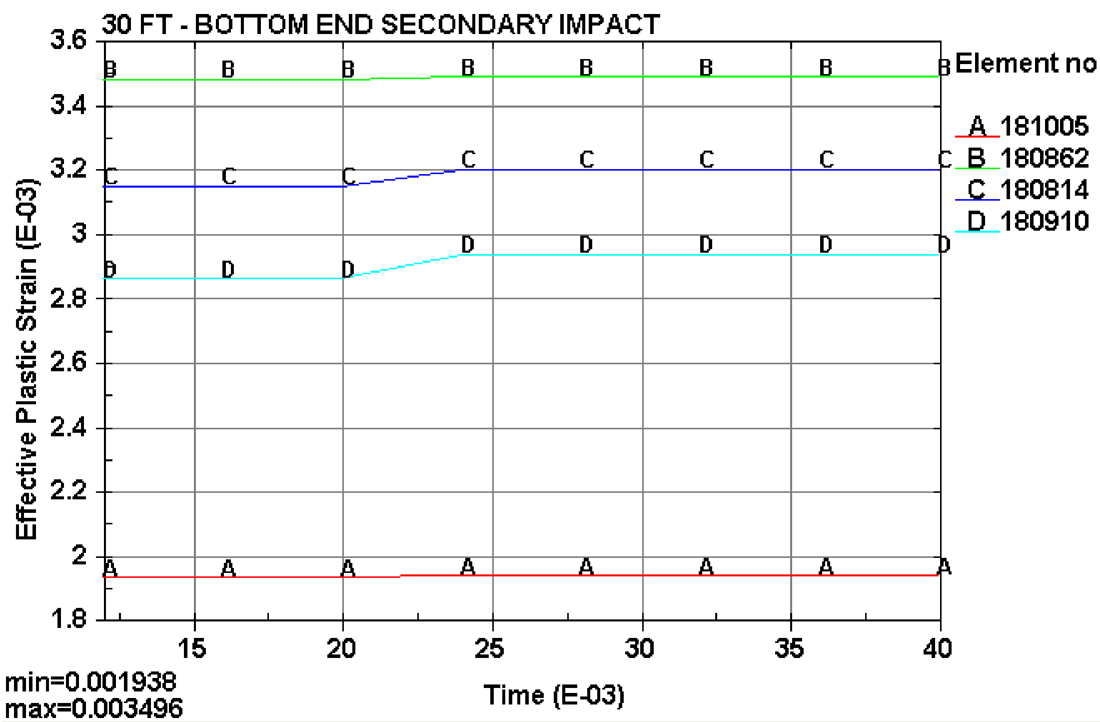


This information is required by the staff to determine compliance with 10 CFR 71.51(a), 71.71(c)(7), 71.73(c)(1).

Holtec's Response to RAI 4-1

With the trivial enhancements to the cask design in the flange/sealing/closure lid region, the resulting strains in the sealing region, from the updated drop simulations are noted to be insignificant (as shown in figures below). The maximum plastic strain in the sealing region are much reduced (less than 0.35%).





Element plastic Strain in Seal Seating Region

In addition, it is demonstrated from the analysis that the opening between the lid and the top flange subsequent to the sever HAC accident conditions is less than the allowable (useful) spring back of the seals. Therefore, it is demonstrated that the containment boundary of the ATB-1T package remains unbreached.

NRC RAI 4-2

Demonstrate the applicability of the FKM fluoroelastomer seal's -26°C to 204°C allowable temperature range and specify the seal's performance at cold conditions, as noted in 10 CFR 71.71(c).

a) A vendor data sheet or document specifying the seals allowable temperature range was not provided and, therefore, an evaluation could not be performed.

b) Page 3-19 does not address that the cold NCT conditions (i.e., -40°C) is beyond the -26°C allowable seal temperature range described in Table 2.2.2.

This information is required by the staff to determine compliance with 10 CFR 71.33(a)(4), 71.71(c).

Holtec's Response to RAI 4-2

To cover the full range of applicable temperature (minimum normal operations to maximum accident conditions), the fluoroelastomer compound is changed to FFKM and the seal design is modified, as reflected in revised Table 2.2.2 and the licensing drawing. Note 1 of Table 2.2.2 has been added to identify Parker FFKM compound FF400-80 as the material that has been identified to meet the required critical characteristics for the primary (inner) containment seal. The attached vendor data sheet and excerpts from the Parker o-ring handbook, along with results from additional testing performed to evaluate the effect of short-term temperature spikes on the material properties, is provided for Parker compound FF400-80. In addition, Parker EPDM compound E0740-75 has been identified as the material for use in the redundant (outer) seal. Although the outer seal is a NITS component, in place to allow leakage testing of the closed package, the compound chosen for this seal is also effective at the specified cold conditions, providing additional assurance that the package will remain leaktight.

To address point (b) of this RAI, the fifth sentence of Section 3.3.8.2 is revised as follows (additions in italics):

The *o-ring seals and* stainless steel material of construction of HI-STAR ATB 1T, as discussed in Chapter 2, will perform satisfactorily in cold environmental conditions.

FF400-80

Low Temperature Parker ULTRA®

Developed for Low Temperature, HPHT and RGD:

Exploration and production technology advancements are creating a new series of challenges for seal materials in the Oil and Gas industry. Seals are now being pushed to perform in temperature and pressure extremes never seen before in the rubber industry. Application pressures exceeding 25k psi and service temperatures ranging from -40°F to 527°F are placing immense amounts of stress on sealing elements. Exposure to aggressive down hole fluids and production wells with elevated levels of hydrogen sulfide (H_2S) require excellent chemical resistance. High pressure gaseous applications with excessive decompression rates can cause elastomers to rupture at a moment's notice. -continued to next page-

Contact Information:

Parker Hannifin Corporation
O-Ring Division
2360 Palumbo Drive
Lexington, KY 40509

phone 859 269 2351
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ordmailbox@parker.com

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Product Features:

- Temperature range -40° to 527° F
- Excellent low temperature
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- RGD resistant per ISO 23936-2 and TOTAL GS EP PVV 142
- H_2S resistant per ISO 23936-2 (10%)
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-continued from front

Parker's FF400-80 compound has been formulated to provide a solution to all of these sealing challenges.

A best in class TR-10 temperature of -22°F gives Parker's FF400-80 low temperature performance never seen before from a perfluoroelastomer (FFKM). The FF400-80 offers low temperature capability approximately 45°F below a standard FFKM compound and has a recommended service temperature range of -40°F to 527°F. This low temperature flexibility can be extremely valuable for surface equipment such as valves which can be exposed to frigid cold in arctic environments.

The FF400-80 offers unprecedented Rapid Gas Decompression (RGD) resistance. This compound has been tested to and passed the ISO 23936-2 and TOTAL GS EP PVV 142 industry standards. These certifications can be supplied for FF400-80, as well as several other compounds, by Parker O-Ring Division.

All of these characteristics combined with excellent resistance to a broad range of media including elevated levels of hydrogen sulfide (H_2S) make the FF400-80 an optimal solution for use in down hole tools, subsea chokes and other critical devices across the oil and gas industry.

Property		FF400-80
Original physical properties	Test Method	Test Results
Hardness, shore A, pts.	ASTM D2240	82
Tensile strength, psi	ASTM D1414	1677
Elongation, %	ASTM D1414	188
Modulus @ 100% elongation, psi	ASTM D1414	879
Specific gravity	ASTM D297	1.85
Low temperature retraction, ASTM D1329		
TR-10, °F (°C)		-22°F (-30°C)
Compression set, ASTM D395 Method B		
70 hrs. @ 392°F (200°C), % original deflection		21
70 hrs. @ 446°F (230°C), %original deflection		27
70 hrs. @ 482°F (250°C),% of original deflection, max		29
Fluid immersion steam, 70 hrs. @232°F (121°C), ASTM D471		
Hardness change, pts.		+2
Tensile strength change, psi		+11
Elongation change, %		+5
Modulus at 100% elongation change, psi		+9
Volume change, %		0
Fluid immersion, ethylene diamine, 70 hrs. @ 194°F (90°C), ASTM D471		
Hardness change, pts.		-10
Volume change, %		+23
Fluid immersion, diesel #2, 70 hrs. @ 212°F (100°C), ASTM D471		
Hardness change, pts.		-5
Tensile change, %		-25
Elongation change, %		+31
Modulus @ 100% elongation change, %		-23
Volume change, %		+5
Fluid immersions, methanol, 70 hrs. @ 75°F (23.9°C), ASTM D471		
Hardness change, pts.		-2
Tensile change, %		-14
Elongation change, %		+23
Modulus @ 200% elongation change, %		-17
Volume change, %		+1
Fluid immersion, zinc bromide, 70 hrs. @ 212°F (100°C), ASTM D471		
Hardness change, pts.		0
Tensile change, %		-2
Elongation change, %		-2
Modulus @ 100% elongation change, %		-4
Volume change, %		+1

Parker Hannifin Corporation
O-Ring Division
2360 Palumbo Drive
Lexington, KY 40509

Office 859 269 2351
Fax 859 268 5128

RESEARCH & DEVELOPMENT LABORATORY REPORT

TITLE

Evaluation of Parker Compound FF400-80

DATE

May 10, 2013

REFERENCE

LTR93341

PREPARED BY: Deric Greger, Lab Tech III

CONCURRENCE: S. Frank Stewart, R&D Manager

Parker

Research & Development Laboratory Report
Evaluation of Parker Compound FF400-80
May 10, 2013

TITLE: Evaluation of Parker Compound FF400-80

OBJECTIVE: Provide basic mechanical properties for new compound FF400-80

METHODS: The following standard ASTM test methods were used to measure the original physical properties, compression set, chemical compatibility, and TR-10 and glass transition. ASTM D1414, ASTM D395, ASTM D471, ASTM E1356, and ASTM D1329

DISCUSSION: Parker compound FF400-80 in the nomenclature described in ASTM D1418 as an FFKM material. The subject compound exhibits very low temperature performance as determined by the TR-10 and the glass transition via differential scanning calorimeter. Additionally, the subject compound has very good compression resistance up to 250 ºC. FF400-80 also exhibits good chemical compatibility in the fluids tested. (Table 1)

CONCLUSIONS: Parker compound FF400-80 is a new low temperature FFKM developed for demanding applications in aggressive chemical environments that require good to excellent low temperature performance. The steam and ethylene di-amine were chosen as the test media due to their aggressive behavior towards FFKM materials, as seen in the data FF400-80 performs very well in steam and reasonably well in ethylene di-amine. In summary FF400-80 offers excellent low temperature performance and very good compression set resistance up to 250 ºC

Parker

Research & Development Laboratory Report
Evaluation of Parker Compound FF400-80
May 10, 2013

Table 1

	Test Method	Test Results
Original Physical Properties		
Hardness, Shore A, pts.	ASTM D2240	82
Tensile Strength, psi	ASTM D1414	1354
Ultimate Elongation, %	ASTM D1414	188
Modulus at 25% Elongation, psi	ASTM D1414	251
Modulus at 50% Elongation, psi	ASTM D1414	414
Modulus at 75% Elongation, psi	ASTM D1414	620
Modulus at 100% Elongation, psi	ASTM D1414	844
Specific Gravity	ASTM D297	1.85
Compression Set		
70 hrs. @ 200°C		
Percent of Original Deflection, max	ASTM D395 Method B	25
Compression Set		
70 hrs. @ 230°C		
Percent of Original Deflection, max	ASTM D395 Method B	27
Compression Set		
70 hrs. @ 250°C		
Percent of Original Deflection, max	ASTM D395 Method B	29
Fluid Immersion		
Steam , 70 hrs @ 121°C	ASTM D471	
Hardness Change, pts.		+2
Tensile Strength change, psi		+11
Ultimate Elongation change, %		+5
Modulus at 25% Elongation change, psi		+4
Modulus at 50% Elongation change, psi		+8
Modulus at 75% Elongation change, psi		+9
Modulus at 100% Elongation change, psi		+9
Volume Change, %		-0.1
Fluid Immersion		
Ethylene Diamine , 70 hrs @ 90°C	ASTM D471	
Hardness Change, pts.		-10
Tensile Strength change, psi		-47
Ultimate Elongation change, %		+38
Modulus at 25% Elongation change, psi		-44
Modulus at 50% Elongation change, psi		-45
Modulus at 75% Elongation change, psi		-53
Modulus at 100% Elongation change, psi		-58
Volume Change, %		+23
Low Temperature		
TR-10, °C	ASTM D1329	-30
Glass Transistion by DSC °C	ASTM E1356	-35

Parker Hannifin Corporation
O-Ring Division
2360 Palumbo Drive
Lexington, KY 40509

Office 859 269 2351
Fax 859 268 5128

RESEARCH & DEVELOPMENT LABORATORY REPORT

TITLE

Effects of Short-Term Temperature Spike on FF400 Compression Set

DATE

September 7, 2016

REFERENCE

LTR 117015

PREPARED BY: Nathanael Reis
Research Chemical Engineer

CONCURRENCE: S. Frank Stewart
R&D Manager

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Research & Development Laboratory Report
Short-Term Temp. Spike on FF400
September 8, 2016

TITLE: Effects of Short-Term Temperature Spike on FF400 Compression Set

OBJECTIVE: Customer Holtec requires a material that can seal effectively after experiencing a fire emergency with a moderately ramping, one-hour increase in temperature above that for which the material is rated for extended-life use. Evaluate the effect that such temperature spikes have on the compression set of FF400.

METHODS: A series of five compression set tests were performed on specimens of FF400 O-rings, size 2-214. A control specimen was tested under the common condition of 70 hrs. at 200 °C. Two additional sets of specimens were also tested identically, except that the test fixtures were placed in separate ovens at 300 °C and 320 °C for the first hour of the test duration in order to replicate the fire emergency conditions. Another pair of specimens were exposed to only the one-hour period to serve as an additional indicator of the effect of the 20-degree difference in spike temperatures. All specimens were compressed to 25% deflection.

DISCUSSION: The results of the testing are displayed in Table 1. A minimal difference in low compression set was observed between the samples exposed to the temperature spikes alone. The material took on a significant increase in set when the spike temperature was increased from 300 °C to 320 °C in the emergency replications, but the compression set values from all test conditions denote functional sealing performance.

CONCLUSIONS: The analysis suggested that an exponential increase in compression set is observed when one-hour temperature spikes (followed by normal application temperatures) are raised past 300 °C. However, the material maintained sealing ability during all test conditions. When the material is exposed to a temperature spike alone, little change in elastomeric rebound is observed by varying the spike temperature across the range of interest.

Research & Development Laboratory Report
Short-Term Temp. Spike on FF400
September 8, 2016

Test	Temp. Spike	70 hr. Exposure	**Result (% set)**
1	None	X	22
2	300 °C	X	24
3	320 °C	X	34
4	300 °C		7
5	320 °C		9

Table 1. Compression Set Results from Temperature Spike Testing

COMPOUND COMPATIBILITY RATING
1 - Satisfactory
2 - Fair (usually OK for static seal)
3 - Doubtful (sometimes OK for static seal)
4 - Unsatisfactory
x - Insufficient Data

	Recommended	Nitrile NBR	Hydrogenated Nitrile HNBR	Ethylene Propylene EPDM	Fluorocarbon FKM	Hifluor FKM	Perfluoroelastomer FFKM	Aflas (TFE/Propylene) FEPM	Neoprene/Chloroprene CR	Styrene-Butadiene SBR	Polyacrylate ACM	Polyurethane AU, EU	Butyl IIR	Butadiene BR	Isoprene IR	Natural Rubber NR	Hypalon CSM	Fluorosilicone FVMQ	Silicone MQ, VMQ, PVMQ
Benzyl Amine	FF500-75	X	X	X	X	1	1	X	X	X	X	X	X	X	X	X	X	X	X
Benzyl Benzoate	V1164-75	4	4	4	1	1	1	2	4	4	4	4	2	4	4	4	4	1	4
Benzyl Bromide	V1164-75	4	4	4	1	1	1	2	4	4	4	4	4	4	4	4	4	1	4
Benzyl Butyl Phthalate	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
Benzyl Chloride	V1164-75	4	4	4	1	1	1	2	4	4	4	4	4	4	4	4	4	1	4
Benzyl Phenol	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Benzyl Salicylate	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Beryllium Chloride	N0674-70	1	1	1	1	1	1	1	3	3	3	3	1	3	3	3	3	3	3
Beryllium Fluoride	N0674-70	1	1	1	1	1	1	1	3	3	3	3	1	3	3	3	3	3	3
Beryllium Oxide	N0674-70	1	1	1	1	1	1	1	3	3	3	3	1	3	3	3	3	3	3
Beryllium Sulfate	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
Bismuth Carbonate	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
Bismuth Nitrate	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
Bismuth Oxychloride	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
Bittern	V3819-75	X	X	X	X	1	1	X	X	X	X	X	X	X	X	X	X	X	X
Black Liquor	E0540-80	2	X	1	1	4	3	1	1	X	X	X	X	X	X	X	X	X	X
Black Point 77	N0674-70	1	1	1	1	1	1	1	3	3	3	3	1	3	3	3	3	3	3
Blast Furnace Gas	S0604-70	4	4	4	1	1	1	2	4	4	4	4	4	4	4	4	4	2	1
Bleach Liquor	E0540-80	3	3	1	1	1	1	1	2	3	4	4	1	2	2	3	1	2	2
Bleach Solutions	E0540-80	X	X	1	1	1	1	X	X	X	X	X	X	X	X	X	X	X	X
Blood	E3609-70	2	0	1	1	1	1	3	1	X	X	X	X	X	X	X	X	X	2
Borax	E0540-80	2	2	1	1	1	1	1	4	2	2	1	1	2	2	2	4	2	2
Borax Solutions	E0540-80	X	X	1	1	1	1	X	X	X	X	X	X	X	X	X	X	X	X
Bordeaux Mixture	E0540-80	2	2	1	1	1	1	1	2	2	4	4	1	2	2	2	1	2	2
Boric Acid	N0674-70	1	1	1	1	1	1	1	1	1	4	1	1	1	1	1	1	1	1
Boric Oxide	E0540-80	3	3	1	3	2	1	X	1	1	4	4	1	1	1	1	1	1	2
Borneol	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Bornyl Acetate	V1164-75	2	2	4	1	2	1	X	4	4	4	3	4	4	4	4	4	2	X
Bornyl Chloride	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Bornyl Formate	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Boron Fluids (HEF)	V1164-75	2	2	4	1	1	1	2	4	4	4	4	4	4	4	4	4	2	4
Boron Hydride	V3819-75	X	X	X	X	1	1	X	X	X	X	X	X	X	X	X	X	X	X
Boron Phosphate	V3819-75	X	X	X	X	1	1	X	X	X	X	X	X	X	X	X	X	X	X
Boron Tribromide	V3819-75	X	X	X	X	1	1	X	X	X	X	X	X	X	X	X	X	X	X
Boron Trichloride	V3819-75	X	X	X	X	1	1	X	X	X	X	X	X	X	X	X	X	X	X
Boron Trifluoride	V3819-75	X	X	X	X	1	1	X	X	X	X	X	X	X	X	X	X	X	X
Boron Trioxide	V3819-75	X	X	X	X	1	1	X	X	X	X	X	X	X	X	X	X	X	X
BP Turbine Oil 2197	VM835-75	4	4	4	3	1	1	2	4	4	4	4	4	4	4	4	4	4	4
Brake Fluid DOT 3 (Glycol Type)	E0667-70	3	3	1	4	1	1	2	2	1	X	4	2	X	X	X	2	4	3
Brake Fluid DOT 4	E0667-70	3	3	1	4	1	1	2	2	1	X	4	2	X	X	X	2	4	3

Approximate Service Temperature Ranges for Commonly Used Basic Polymer Types*

Nitrile (General Service)	-34°C to 121°C (-30°F to 250°F)*	AFLAS	-9°C to 232°C (15°F to 450°F)*
Nitrile (Low Temperature)	-55°C to 107°C (-65°F to 225°F)*	Neoprene	-51°C to 107°C (-60°F to 225°F)*
Hydrogenated Nitrile	-32°C to 149°C (-23°F to 300°F)*	Polyacrylate	-21°C to 177°C (- 5°F to 350°F)*
Ethylene Propylene	-57°C to 121°C (-70°F to 250°F)*	Polyurethane	-40°C to 82°C (-40°F to 180°F)*
Fluorocarbon	-26°C to 205°C (-15°F to 400°F)*	Butyl	-59°C to 120°C (-75°F to 250°F)*
Hifluor	-26°C to 205°C (-15°F to 400°F)*	Fluorosilicone	-73°C to 177°C (-100°F to 350°F)*
Perfluoroelastomer (Parofluor)	-26°C to 320°C (-15°F to 608°F)*	Silicone	-115°C to 232°C (-175°F to 450°F)*

NOTE: *These temperature ranges will apply to the majority of media for which the material is potentially recommended. With some media however, the service temperature range may be significantly different. ALWAYS TEST UNDER ACTUAL SERVICE CONDITIONS.

Parker Hannifin Corporation • O-Ring Division
2360 Palumbo Drive, Lexington, KY 40509
Phone: (859) 269-2351 • Fax: (859) 335-5128
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FROM PARKER O-RING HANDBOOK

COMPOUND COMPATIBILITY RATING
1 - Satisfactory
2 - Fair (usually OK for static seal)
3 - Doubtful (sometimes OK for static seal)
4 - Unsatisfactory
x - Insufficient Data

	Recommended	Nitrile NBR	Hydrogenated Nitrile HNBR	Ethylene Propylene EPDM	Fluorocarbon FKM	Hifluor FKM	Perfluoroelastomer FFKM	Aflas (TFE/Propylene) FEPM	Neoprene/Chloroprene CR	Styrene-Butadiene SBR	Polyacrylate ACM	Polyurethane AU, EU	Butyl IIR	Butadiene BR	Isoprene IR	Natural Rubber NR	Hypalon CSM	Fluorosilicone FVMQ	Silicone MQ, VMQ, PVMQ
Pyridine Sulfate	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
Pyridine Sulfonic Acid	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
Pyrogallol (Pyrogallic Acid)	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Pyrogard 42, 43, 55	E0540-80	4	4	1	1	1	1	2	4	X	X	X	X	X	X	X	X	X	X
Pyrogard 53, Mobil Phosphate Ester	E0540-80	4	4	1	1	1	1	X	4	4	4	4	1	4	4	4	4	4	4
Pyrogard D, Mobil Water-in-Oil Emulsion	N0674-70	1	1	4	4	1	1	X	2	4	X	1	4	4	4	4	1	2	3
Pyroligneous Acid	E0540-80	4	4	2	4	1	1	X	2	4	4	4	2	4	4	4	2	4	X
Pyrolube	V1164-75	4	4	2	1	1	1	X	4	4	4	4	2	4	4	4	4	2	2
Pyrosulfuric Acid	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
Pyrosulfuryl Chloride	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Pyrrole	E0540-80	4	4	4	4	1	1	X	4	2	4	X	4	2	2	2	2	4	2
Pyruvic Acid	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
—Q—																			
Quinidine	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Quinine	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Quinine Bisulfate	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
Quinine Hydrochloride	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
Quinine Sulfate	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
Quinine Tartrate	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
Quinizarin	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Quinoline	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Quinone	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Quintolubric	N0674-70	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Quintolubric 888	V1164-75	1	1	4	1	1	1	1	2	X	X	1	2	X	X	X	X	X	X
— R —																			
Radiation (Gamma, 1.0 E+07 Rads)	E0740-75	3	3	2	4	3	2	X	X	X	X	4	4	X	X	4	X	4	2
Raffinate	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Rapeseed Oil	E0540-80	2	2	1	1	1	1	X	2	4	2	2	1	4	4	4	2	1	4
Red Line 100 Oil	N0674-70	1	1	4	1	1	1	X	2	4	1	1	4	4	4	4	2	1	4
Red Oil (MIL-H-5606)	N0674-70	1	1	4	1	1	1	X	2	4	1	1	4	4	4	4	2	1	4
Resorcinol	E0540-80	3	3	1	3	1	1	X	1	1	4	4	1	1	1	1	1	1	2
Rhodium	V3819-75	X	X	X	X	1	1	X	X	X	X	X	X	X	X	X	X	X	X
Riboflavin	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
Ricinoleic Acid	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
RJ-1 (MIL-F-25558)	N0602-70	1	1	4	1	1	1	X	2	4	1	1	4	4	4	4	2	1	4
RJ-4 (MIL-F-82522)	N0602-70	2	2	4	1	1	1	X	4	4	2	2	4	X	X	4	X	1	4
Rosin	V1164-75	2	2	4	1	1	1	X	4	4	4	3	4	4	4	4	4	2	X
RP-1 (MIL-R-25576)	N0602-70	1	1	4	1	1	1	X	2	4	1	1	4	4	4	4	2	1	4

Approximate Service Temperature Ranges for Commonly Used Basic Polymer Types*

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Hydrogenated Nitrile	-32°C to 149°C (-23°F to 300°F)*	Polyacrylate	-21°C to 177°C (- 5°F to 350°F)*
Ethylene Propylene	-57°C to 121°C (-70°F to 250°F)*	Polyurethane	-40°C to 82°C (-40°F to 180°F)*
Fluorocarbon	-26°C to 205°C (-15°F to 400°F)*	Butyl	-59°C to 120°C (-75°F to 250°F)*
Hifluor	-26°C to 205°C (-15°F to 400°F)*	Fluorosilicone	-73°C to 177°C (-100°F to 350°F)*
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FROM PARKER O-RING HANDBOOK

Seal Design: 0.312” Hollow FFKM Seal

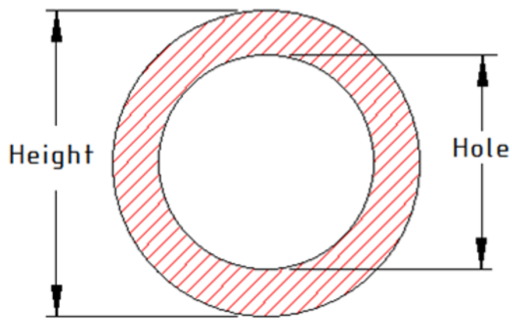
Customer:
Seal Orientation: Face Seal
Cross-Section: Hollow O
Units: in

Mating Components	Nominal	MMC	LMC
Groove Depth	.231 + .003	.231	.234
Groove Width	.233 ± .002	.231	.235
Surface Flatness	.000		
Mating Surface Flatness	.000		

Seal Dimensions	Nominal	MMC	LMC
Seal ID	.000 ± .032	.032	-.032
Seal Height	.312 ± .012	.324	.300
Hole	.192 ± .008	.184	.200

Outputs	Nominal	MMC	LMC	Ideal
Compression (%)	26.0%	28.7%	22.0%	15-50%

Seal profile dimensions:
OD: 0.312 ± 0.012
Hole: 0.192 ± 0.008



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Seal Design: 0.250” Hollow EPDM Seal

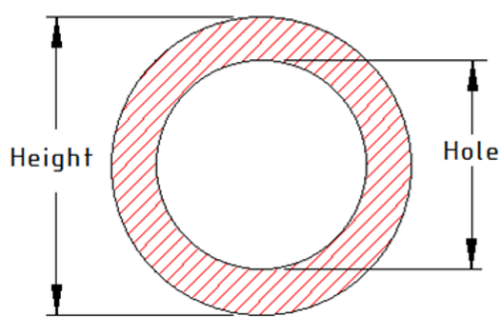
Customer:
Seal Orientation: Face Seal
Cross-Section: Hollow O
Units: in

Mating Components	Nominal	MMC	LMC
Groove Depth	.210 + .003	.210	.213
Groove Width	.213 ± .002	.211	.215
Surface Flatness	.000		
Mating Surface Flatness	.000		

Seal Dimensions	Nominal	MMC	LMC
Seal ID	.000 ± .027	.027	-.027
Seal Height	.250 ± .007	.257	.243
Hole	.125 ± .005	.120	.130

Outputs	Nominal	MMC	LMC	Ideal
Compression (%)	16.0%	18.3%	12.3%	15-50%

Seal profile dimensions:
OD: 0.250 ± 0.007
Hole: 0.125 ± 0.005



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NRC RAI 4-3

Justify the performance of the seals, including the critical characteristics of the cask containment seals specified in Table 2.2.2.

a) The table lists a 20% maximum permissible compression set at 175°C for 70 hours and a minimum useful springback of 1.8 mm. The performance of the seals at different temperatures, such as at cold normal conditions of transport and for the thermal hypothetical accident condition was not provided.

b) Provide the calculation that justifies the 10.5 N/cm minimum force to maintain sealing at hot and cold normal conditions of transport and for the thermal hypothetical accident condition.

c)DWG 9786 sheet 5 of 5 appears to show the inside radius of the seal abutting (or extending beyond) the ledge at the four corners. Demonstrate that there is adequate seal/lid contact and that this design performs at NCT and HAC conditions.

d)Demonstrate that the package's containment boundary seal can withstand the external water pressure of the HAC immersion test. It is not certain from the analysis that the 0-ring groove/gland is designed for external pressure. Likewise, there was no discussion as to whether CLLS components prevent external pressure from reaching the seal (i.e., are watertight).

e) Table 3.1.2 indicates that the cask closure lid seal temperatures of approximately 300°C are greater than the 204°C maximum allowable temperature provided in Table 2.2.2. Provide justification that supports the short term 310°C operating temperature limit and clarify the meaning of the 100°C upper temperature limit.

f) Provide documentation that justifies the helium permeability rates listed in Table 2.2.2.

This information is required by the staff to determine compliance with 10 CFR 71.33, and 71.51(a).

Holtec's Response to RAI 4-3

a) Table 2.2.2 is revised to address compression set and useful springback requirements for the FFKM material that has been specified as part of the overall design changes made to the cask closure lid. For both the inner and outer seal materials, compression set is negligible for normal transport due to the relatively low maximum transport temperature. Compression set at higher temperature, such as that of the hypothetical fire accident condition, will be greater. However, sealing is maintained throughout this static, short-term condition as the loading conditions are maintained and the seal material is compatible with the high temperature conditions.

b) Minimum sealing force is based on minimum cask lid weight of 22,500 pounds and o-

ring length of approximately 375 inches. The cask lid provides the initial compression of the o-ring, which is maintained throughout transport by closure of locking wedge bars. Justification for the assumed minimum sealing force has been added to Table 2.2.2. (As suggested by the comment, there was a typographical error that shifted the decimal point from the intended 105 N/cm to 10.5 N/cm. This error trap has been corrected by listing the force in only English units in Table 2.2.2.)

c) O-ring dimensions of Drawing 9786 are revised to ensure sufficient sealing area is evident. The dimensions are also made reference, as slight deviations from stated dimensions do not affect o-ring sealing performance as long as critical loading characteristics on seal in Table 2.2.2 are met.

d) The o-ring seal is designed for both its stated internal pressure and the external water pressure of Table 2.1.1. Deflection of the seal region due to external water pressure is considered to be bounded by deflection evaluated during all drop accidents. The CLLS components are not designed to prevent external water pressure from reaching the inner seal during all accident conditions, however the redundant outer seal is likewise designed to seal against internal and external pressure, thus preventing loading of the inner seal by external pressure during normal conditions of transport.

e) Table 2.2.2 did not intend to indicate that the maximum allowable temperature of the closure seals is 204°C. The vendor data sheets supplied in response to RAI 4-2 provide the effective operating temperature limits of the seal material. Table 2.2.2 has been revised to refer to Table 3.1.2 for the post-fire seal temperatures. Further, information is added to indicate that the maximum short term temperature is only applicable to the inner FFKM seal.

f) Estimated gas permeability rates at available test temperatures have been assumed based on comparison with nitrile material (Parker compound N0674-70) which is considered to conservatively bound the performance of the FFKM material. The gas permeability rate is considered a second-order characteristic for sealing due to the low pressure differential across the seal during normal transport operations. Primary sealing effectiveness is established by the physical design and springback capability of the o-ring seal, which retains the internal fixed or particulate contamination within the transport cask. Because the gas permeability rate affects only the ability to pass initial and pre-shipment pressure-loss testing of the seals, and then only as a second-order effect, helium permeability has been removed from the critical characteristics table (Table 2.2.2) for the seal.

NRC RAI 4-4

Justify that the surface activity considered in the containment analysis represents, or is bounding, of the content that would be placed within the package.

Section 4.4.1 states that the surface activity considered in the analysis is "representative of typical radioactive inventories expected" and that these were reported in Reference 4.4.1. However, Reference 4.4.1 is a characterization of "typical" surface activities, whereas the analyses should represent actual, or bounding, surface activities to ensure containment criteria are met.

This information is required by the staff to determine compliance with 10 CFR 71.51(a).

Holtec's Response to RAI 4-4

Holtec agrees that in the first assumption in Section 4.4.1, it is stated that surface activities in the containment analysis are "representative of typical radioactive inventories expected". However, please note that in Section 4.4.1 Paragraphs 2a), 2b) and 2c) provide justification that the values used in the containment analysis are indeed conservative and bounding for the waste that is to be transported in the package. The main conservatisms cited in Paragraph 2 are:

- Surface activity density considered in the analyses (140×10^{-6} Ci/cm^2) bounds the activity densities reference BWR station on inner surfaces of reactor vessel and reactor water piping in NUREG/CR-0672.
- The above conservative surface activity density is applied to the surface area of the contaminated solids that is conservatively larger than the upper bound actual surface area of reactor internal components per single load to be transported by the HI-STAR ATB 1T.
- The activity of non-fixed contamination that can be released due to vibrations or an impact in transport of the package is a small fraction of the surface activity considered in the analysis.

The first assumption in Section 4.4.1 is removed for clarification purposes and assumptions 2a) 2b), and 2c) referenced above are changed to 1a), 1b), and 1c).

In addition, to comply with the containment analysis the user will verify that the surface activity of the loose contamination is bounded by the activity value provided in Table 4.4.3 of the SAR. Table 7.1.2: Cask and Waste Package Control Parameters has the following row added:

Table 7.1.2: Cask and Waste Package Control Parameters.

Maximum permissible Co-60 activity of non-fixed surface contamination (Bq)	*2.211E+13*

<u>NRC RAI 4-5</u>

Clarify that the 0-ring dimensions will be sized for the seal groove/gland dimensions provided in drawing 9786 sheet 2 of 5.

The seal groove dimensions were provided in the drawing as a result of RSI 4-2. Recognizing that the 0-ring and the seal groove/gland are, together, an engineered system, it is important to specify in the SAR that the 0-ring is designed for the seal groove provided in the drawings.

This information is required by the staff to determine compliance with 10 CFR 71.33(a)(4).

<u>Holtec's Response to RAI 4-5</u>

Holtec agrees that the o-ring and associated groove act together as an engineered system. To specify this, the description of the "o-ring type" in the seal critical characteristics table (Table 2.2.2) is revised to refer to Note 3, which states:

Refer to licensing drawings per Section 1.3 for seal groove design details. The seal groove design and tolerances are engineered to provide the required useful seal springback when used with a seal that meets the critical o-ring design parameters described in this Table.

NRC RAI 5-1

Clarify if the contents include any other radioactive materials other than activated stainless steel or activated lnconel 718.

The applicant performed source term calculations in Appendix 5.A for activated stainless steel and lnconel 718. The contents description in Section 1.2.2 of the application does not limit the radioactive contents to activated stainless steel and lnconel 718 and includes examples of contents that could consist of other materials. For example, metallic waste filters could have "ceramic mesh screens" and CRUD.

The applicant needs to clarify if it is requesting shipment for other radioactive materials and, if so, specifically (i) state what these contents are, (ii) include appropriate contents specifications, and (iii) provide analyses demonstrating that the HI-STAR ATB-1T package's shielding design is sufficient to meet regulatory dose rate limits for these contents.

This information is needed by the staff to determine compliance with 10 CFR 71.47(b)(1), 71.47(b)(2), 71.47(b)(3), and 71.51(a)(2).

Holtec's Response to RAI 5-1

(i) The details of the radioactive contents of the cask are in Subsection 1.2.2 and generally consist of activated stainless steel, activated inconel, residual contamination from spent fuel pool water, and CRUD. The ceramic mesh screens are not directly activated by the neutron flux in the core. The ceramic mesh screens may have surface contamination present (from contaminated spent fuel pool water), but this is no different from the surface contamination that may be present on other waste content. All content is required to meet the Technical Specification requirements present in Table 7.1.2.

(ii) The stainless steel content specifications remain bounding so no additional content specifications are added. Table 7.1.2 is updated to include activity and specific activity limits for radionuclides other than Cobalt-60, that have gammas greater than 0.45 MeV. For additional information on gamma energy range considered in the shielding analysis, see response to RAI 5-2 (ii).

(iii) Utilizing activated stainless steel as the source material remains bounding in terms of calculated dose rates for the shielding analyses. Inconel 718 is also analyzed and included in the dose rate results in SAR Table 5.4.2 and Table 5.4.3 of the Sensitivity Study.

NRC RAI 5-2

Provide additional information on the neutron flux used to perform the activation analysis.

In Appendix 5.A, the applicant performed an evaluation to calculate the relative amounts of radioisotopes generated by activating stainless steel and lnconel 718. The applicant states that "The calculations are performed by irradiating 1 kg of stainless steel or 1 kg of lnconel 718 using the neutron flux calculated in SAS2H for the fuel assembly described in Reference [5.A.2]."

Reference [5.A.2] is the reference for the Model No. HI-STAR 80 package (Docket No. 71-9374). The HI-STAR 80 application consists of many different fuel assemblies irradiated under many different conditions. The staff requests that the applicant (i) provide additional information on the neutron flux used to activate the lnconel 718 and stainless steel and (ii) justify that it is bounding for determining the radioisotopes generated by neutron activation.

This information is needed by the staff to determine compliance with 10 CFR 71.47(b)(1), 71.47(b)(2), 71.47(b)(3), and 71.51(a)(2).

Holtec's Response to RAI 5-2

(i) The neutron flux in the stainless steel and Inconel 718 SAS2H output files is in the range of 2.7E+13 – 3.8E+13 n/cm^2/sec.

(ii) All radioisotopes that have gammas that could contribute significantly to dose rates on the outside of the HI-STAR ATB 1T are listed in Table 5.A.3 through Table 5.A.6. The following wording has been added to Subsection 5.A.2, "Gammas with energies below 0.45 MeV are too weak to penetrate the overpacks. Further justification of this approach is provided in Appendix 11 of Reference [5.A.3]." Reference [5.A.3] is added. Conclusions regarding the appropriate gamma energy range to consider in shielding calculations as provided in NUREG-1617 is already present in Subsection 5.A.2. The study was not performed to get bounding numbers for activation, but to determine the relative percentage of radioisotopes excluding Cobalt-60 that contribute to external dose rates, i.e. radioisotopes with gammas over 0.45 MeV, and at different cooling times. The specific activity of the activated waste is higher for a burnup of 180,000 MWD/MTU, but the relative percentage of radioisotopes other than Co-60 that contribute to the > 0.45 MeV gamma source is greater for a burnup of 360,000 MWD/MTU.

Added Reference:

[5.A.3] HI-STORM Shielding Design and Analysis for Storage, HI-971608 Rev 16, Holtec International. Appendix 11.

NRC RAI 5-3

State and justify the geometry of the modeled contents, and modify the analyses, as necessary, to account for all possible geometries of the contents within the package.

The applicant does not specify the geometry used to model the contents for external dose rate calculations. Based on staff's estimates, the interior volume of the package is larger than that of the contents specified in Table 7.1.2 of the application at full density stainless steel. Therefore, to specify full density contents would leave space within the cask interior. The applicant needs to state the geometry it assumed for the contents and justify that it is conservative.

For example, contents modeled as shifted towards the side of the container would be more conservative as this minimizes space between the contents and the detector; also, compressing the contents concentrates the source term. In addition, external dose rates could be different if the volume of the source was concentrated at the top, short side, long side or bottom of the package.

The applicant needs to justify that the geometry and location of the source selected within the external dose rate analyses produce bounding external dose rates. The applicant needs to address any differences in the geometry that result from NCT and HAC and address those differences within the analysis model as well as justify that it is appropriate.

This information is needed by the staff to determine compliance with 10 CFR 71.47(b)(1), 71.47(b)(2), 71.47(b)(3), and 71.51(a)(2).

Holtec's Response to RAI 5-3

The MCNP models, when stating "Full Density" or "maximum waste density" assume a stainless steel density of 7.92 g/cc throughout the volume of the interior cavity formed by the walls of the BFA tank and top and bottom plates of the BFA tank-cassette (BTC).

Actual loadings of the HI-STAR ATB 1T will contain a waste package with an interior volume that is taken up by air and activated waste. By assuming the entire BFA-Tank and BTC interior cavity is filled with the maximum specific activity (Bq/kg) stainless steel, this conservatively accounts for any shifting of contents that may occur during normal and off-normal operations and models a significantly higher total activity (Bq) than what is allowed in Table 7.1.2. For instance, for the Waste Package A (BFA-200) maximum density model, a Total Co-60 activity of 6.05 E+16 Bq is modeled for normal conditions, while the Total Co-60 activity allowed in Table 7.1.2 is 3.60 E+15 Bq. As another example, for the Waste Package B (BFA-150) a total Co-60 activity of 9.41 E+15 Bq is modeled, while the total Co-60 activity limit in Table 7.1.2 is 2.16 E+15 Bq. The MCNP shielding models take into account dimensions provided in Drawings 9786 and 9876 (latest revisions).

NRC RAI 5-4

Justify the assumption of uniform source distribution and modify the analyses, as necessary, to account for non-uniform sources.

Section 5.4.1 states: "The ^{60}Co source in the waste content is assumed as uniformly distributed over the appropriate regions." The applicant needs to clarify what is meant by "appropriate regions." The staff finds that uniformly distributing the ^{60}Co over the entire volume of the contents may not necessarily be representative of contents described in Section 1.2.2 of the application as contents may not be activated uniformly.

An activated object may be more activated near the surface and the central portions of the item may not be providing self-shielding. Uniform source distribution also does not account for the possibility of source relocation due to reconfiguration of contents during transport or removable source terms such as CRUD.

The applicant needs to discuss: (i) how it ensures the user loads contents with a ^{60}Co distribution that is bounded by the assumed distribution within the analysis and (ii) include these restrictions within the operating procedures in Chapter 7 of the application. These procedures need to ensure there is no hot spot or areas of very high activity and ensure the distribution of contents is controlled during loading and transport.

This information is needed by the staff to determine compliance with 10 CFR 71.47(b)(1), 71.47(b)(2), 71.47(b)(3), and 71.51(a)(2).

Holtec's Response to RAI 5-4

The MCNP modeling for the HI-STAR ATB 1T assumes that the maximum specific activity of the waste is paired with the maximum stainless steel density possible (all stainless steel, no air, at 7.92 g/cm^3) to create the highest possible dose rates for that particular waste package type. In this configuration, it would not be possible to get more activated stainless steel to "shift" to one side since the waste content is already "packed" as densely as is physically possible in the MCNP model.

Text in Section 5.4.1 is changed to the following, "The ^{60}Co source in the waste content is assumed as uniformly distributed across the interior volume of the waste package (Waste Package Types A, B, C, D, and E)."

A note is added below Table 7.1.2 to state, "The limits for maximum specific activity of contents for each Waste Package Type in Table 7.1.2 have to be met by the most activated portion of any single waste item."

NRC RAI 5-5

Justify the assumption that the contents remain within the BTC and BFA-tanks for the external dose rate analysis under HAC.

For the hypothetical accident analysis, the applicant assumes that the BFA-tank welds fail and that there is a gap between all BFA-tank walls. The applicant assumes that the BTC tie rods fail and that the BTC top and bottom plates would relocate. The applicant states that the bounding case would be the BFA-200 tank since this plate has the largest thickness of all BTC top and bottom plates (150 mm), and the BFA-200 tanks contain waste with the highest activity.

The applicant evaluated a drop on the top of the cask as this would cause the bottom plate to relocate. The applicant assumed the plate would rotate 45 degrees and expose a section of the contents approximately 300 mm wide. The applicant modeled this by ignoring the rotation and creating a 300 mm missing section of the bottom plate. The applicant assumed that the missing area is filled with contents at the maximum specific activity.

The dimensions of the contents are not specified and the integrity of the contents is unknown. CRUD and loose contamination could also relocate during HAC. Therefore, the staff does not have enough information to determine that the contents would not leave the BTC and relocate to the outside of the BTC and BFA-tank shield walls. The applicant needs to justify the assumption that the contents remain within the BTC and BFA-tanks under HAC.

This information is needed by the staff to determine compliance with 10 CFR 71.51(a)(2).

Holtec's Response to RAI 5-5

The following paragraph is added to sub-paragraph 5.3.1.1.2: "Under hypothetical accident conditions it is possible for activated material to enter the gap that could be present if welds of the Waste Package (Types A, B, C, and D) fail. Conservatively, the case shown in Figure 5.3.9 assumes the highest allowable specific activity for Waste Package Type A fills the widest possible gap along the same edge where the BTC lid is assumed to have been dislodged and waste material is present."

Figure 5.3.9 is added to show the new case where source material is present in the gap along the same edge where the BTC lid is assumed to have been dislodged.

Sub-paragraph 5.3.1.1.2 provides the justification for the hypothetical accident conditions modeling, and mentions that due to the arrangement of the individual plates that the BFA tank are made of, a significant relocation of those parts is in fact not possible. Drawing 9876 in the drawing package (Section 1.3) provides exact dimensioning of the BFA tank walls.

Table 5.1.3 and Table 5.4.4 make it clear that the accident condition source (excluding the point source) remains the "maximum specific activity", which is defined for each waste package type in Table 7.1.2.

NRC RAI 5-6

Justify that stainless steel as a self-shielding material is bounding for lnconel 718 or any other contents (see RAI 5-1).

The applicant states in Sections 5.3.1.2.1 and 5.3.1.3 of the application that it modeled the contents as full density stainless steel to represent the self-shielding. The applicant states that the content will be activated stainless steel or lnconel 718. The applicant needs to provide justification that modeling stainless steel is equivalent or more conservative than lnconel 718 or any other contents (see RAI 5-1).

This information is needed by the staff to determine compliance with 10 CFR 71.47(b)(1), 71.47(b)(2), 71.47(b)(3), and 71.51(a)(2).

Holtec's Response to RAI 5-6

The shielding models all use the maximum specific activity (Bq/kg) allowed (Table 7.1.2) in each waste package type. While stainless steel has a density of 7.92 g/cc, Inconel 718 has a density of 8.19 g/cc. An MCNP case where the Inconel 718 material composition and density are used in MCNP, while specific activity (Bq/kg) is constant (total activity is increased for the Inconel 718 case since there is now greater activity per unit volume) is added to the Chapter 5 shielding analysis. The surface and 2 meter dose rate results under normal conditions with Inconel 718 as 100% of the source material in Waste Package A (BFA-200) has been added to Tables 5.4.2 and 5.4.3.

The following text has been added to Sub-paragraph 5.3.1.2.1,

"Inconel 718 (material composition shown in Table 5.A.1), may be loaded into the waste packages within the HI-STAR ATB 1T. As a defense in depth, full density Inconel 718 is modeled in MCNP as source material within in the BFA-200 tank, as a point of comparison to full density stainless steel. The dose rate results in Table 5.4.2 and Table 5.4.3 demonstrate that, assuming the same Co-60 specific activity (Bq/kg), the maximum dose rates outside the HI-STAR ATB 1T are equivalent (no significant difference) using Inconel 718 as a source material as compared to stainless steel."

The following text has been added to Sub-paragraph 5.3.1.3,

"The material composition of Inconel 718 is shown in Table 5.A.1. The density of Inconel 718 used in the MCNP models is shown in Table 5.4.2 and Table 5.4.3."

RAI 5-6 also asks to ensure that stainless steel is bounding for "any other contents". Subsection 1.2.2 describes the allowed contents in detail which may include stainless steel, inconel, residual contamination from spent fuel pool water, and CRUD. Total activity (Bq) and specific activity (Bq/kg) limits in Table 7.1.2 apply to all contents loaded into the HI-STAR ATB 1T package.

NRC RAI 5-7

Provide information on the tallies used to calculate external dose rates, as described below.

The applicant did not provide any information on the tally locations within the application. The applicant provides a cartoon drawing of the tally surfaces in Figure 5.1.1, 5.1.2 and 5.1.3 of the application; however, it is not clear where dose rate evaluations are made especially considering that these sketches are 2-D. External dose rates at every point on every surface needs to be considered.

The applicant needs to provide more specific information discussing the surfaces and locations where external dose rates are calculated and identify the surfaces and locations on the surfaces where the maximum dose rates occur. If every location on every surface is not evaluated, the applicant needs to provide a justification for the selected locations, i.e., if the package and source geometry are symmetrical, then all surfaces may not need to be evaluated.

Under HAC there is streaming where there are gaps in the plates of the secondary containers and contents may not be symmetrical. Therefore, the applicant needs to justify that the tally specification has taken this into consideration.

Section 5.1.3 of the application states: "The dose rates listed in the tables in this subsection are maximum values. This is achieved by specifying a reasonably fine grid of dose locations around the cask, and selecting the highest values." The staff is unable to determine if the grid of dose locations is reasonably fine because the applicant did not provide any information on the tally specifications, including the grid (mesh) size. If the tally grid is too coarse, then maximum dose rates may be reduced when averaged with lower dose rate locations. The staff requests that the applicant provide additional information on the tally grid used to calculate external dose rates.

This information is needed by the staff to determine compliance with 10 CFR 71.47(b)(1), 71.47(b)(2), 71.47(b)(3), and 71.51(a)(2).

Holtec's Response to RAI 5-7

The sentence stating that there is "a reasonably fine grid of dose locations around the cask" and other mentions of a "fine grid" of dose locations are deleted since this was not accurate; the HI-STAR ATB 1T MCNP model uses standalone F4 cell tallies and not a tally grid.

To provide better detail into the tallies surrounding the HI-STAR ATB 1T package, the following text is added to Subsection 5.1.3:

"Further description of tally specifications is provided in Reference [5.1.3]. The source region is geometrically symmetrical in that it fills the shape of the Waste Package Cavity (i.e. fills the volume of a rectangular prism). Under normal conditions, surface and 2 meter tallies are located outside the HI-STAR ATB 1T package aligned with the center of the waste source for

each unique rectangular face of the HI-STAR ATB 1T cask. The through thickness of the waste packages and the HI-STAR ATB 1T are constant, with the exception of the trunnion areas where shielding is slightly reduced to accommodate the collapsible trunnion structural safety feature. Tallies are also present adjacent to the trunnions for both surface and 2 meter dose rates under normal conditions.

Under accident conditions, tallies are located 1 meter from the outside of the HI-STAR ATB 1T package, aligned with the center of the waste source for each unique rectangular face of the HI-STAR ATB 1T cask. Accident conditions tallies are also located 1 meter from the trunnions. Following a drop accident local deformation and material erosion at the edges and/or corners of the cask may take place, but the through thickness of the HI-STAR ATB 1T at these edge and corner locations remains greater than the through thickness at the center of each unique face of the HI-STAR ATB 1T. Accident conditions tallies are present 1 meter from locations with the least shielding thickness present under accident conditions."

MCNP input files, which contain the exact geometric dimensions and locations of the tallies, have also already been made available to the USNRC for review in the shielding calculations package [5.1.3].

The following reference is added:

[5.1.3] HI-STAR ATB 1T Shielding Calculation Package HI-2156583. Holtec International. Latest Revision.

More detailed information on tally specifications are provided in the HI-STAR ATB 1T Shielding Calculation Package HI-2156583R3 in Table 3 and Table 4.

NRC RAI 5-8

Provide an analysis of external dose rates at 1m away from the external surface of the corner that is struck during the bottom center of gravity over corner (BOT-CGOC) 9m free drop simulation.

Section 5.1.3.2 of the application discusses the assumptions used in the model for calculating external dose rates around the package under HAC. This section states: "Chapter 2 shows that the HI-STAR ATB 1T package remains significantly unaltered throughout the hypothetical accident conditions. Localized damage of the cask outer surface could be experienced during the pin puncture, and drop accidents. However, such localized deformations will have a negligible impact on the dose rate at 1 meter from the surface."

Although the staff agrees that the deformation experienced after the pin puncture would likely have a negligible impact on the dose rate at 1 meter given the margin to the limits, the staff finds that there is significant inelastic deformation, in addition to some loss of material (element erosion), that occurs at the corner directly impacted during the bottom 9m CGOC free drop simulation in LS-DYNA. Figures 5-8.1, 5-8.2 and 5-8.3 below illustrate the extent of inelastic deformation by tracking the change in length of the imaginary line between two points on the package as a function of time: the impacted corner, and the corner on the opposing corner of the package. The graph implies that the struck corner deforms as much as 7 inches during the simulation relative to its pre- impact location terminating, with more than 4 inches of permanent deformation (note element erosion at the impact site around node 328835). Note that other measures could also indicate additional information.

The staff finds that this effect significantly decreases the distance from the source to the detector and could create a streaming path; thus, it cannot be neglected without providing additional information.

The applicant needs to provide a dose rate analysis demonstrating that the simulated deformation and material loss would not cause an increase in external dose rates beyond regulatory limits, while concurrently considering the streaming from conditions of the BFA-tanks and BTC (see RAI 5-5).

This information is needed by the staff to determine compliance with 10 CFR 71.51(a)(2) and 10 CFR 71.73(c)(1).

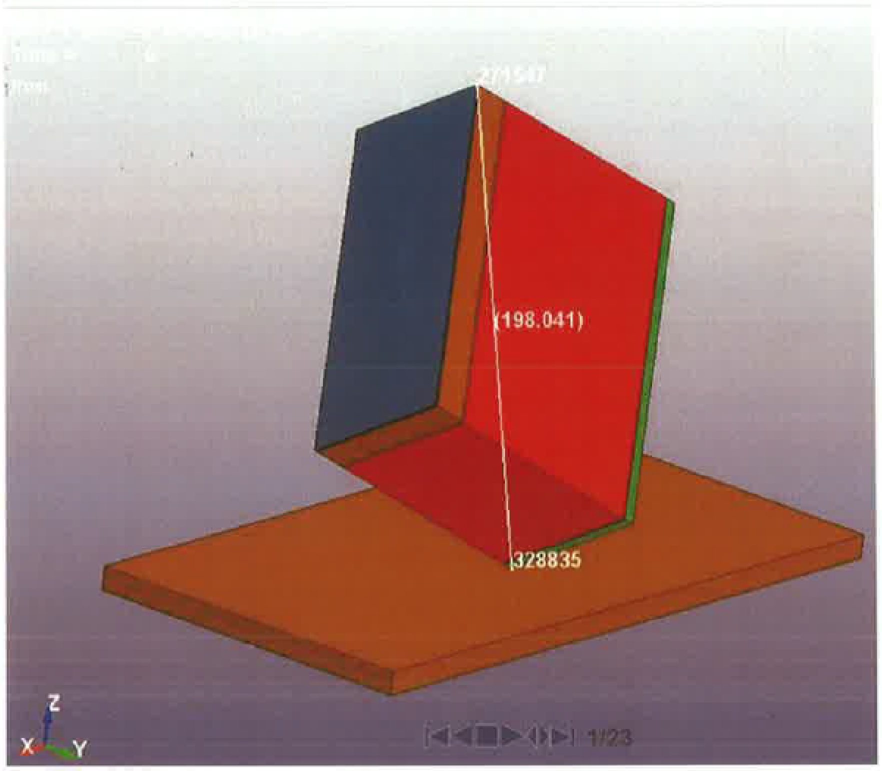


Figure 5-8.1

Figure 5-8.2

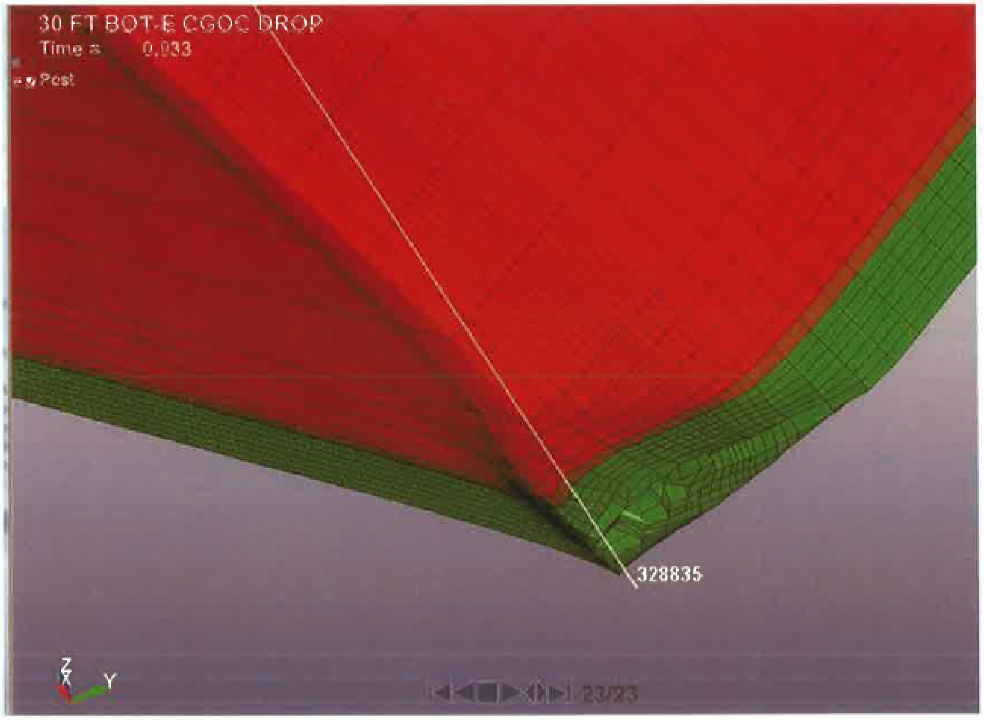


Figure 5-8.3

Holtec's Response to RAI 5-8

The HI-STAR ATB 1T sides are all at least 19.6 cm (rounded down to third decimal place) thick. The through thickness along an edge of the cask is the hypotenuse of a triangle that has two legs of 19.6 cm length or $\sqrt{19.6^2 + 19.6^2}$ = 27.7. The through thickness at the corner of the cask is the diagonal that travels through the center of a cube with sides of length 19.6 cm length or $\sqrt{19.6^2 + 19.6^2 + 19.6^2}$ = 33.9 cm.

This RAI mentions that there could be as much as 4 inches (10.16 cm) material erosion at the corner of the cask. Subtracting 10.16 cm from 33.9 cm is 23.7 cm, which is a greater through thickness at the damaged corner as compared to other locations at the side of the cask. There are many possible geometries for localized material erosion at the corner of the cask.

As a defense in depth, slightly more than 4 inches of material erosion along a bottom long edge of the HI-STAR ATB 1T is considered (See Figure 5.3.9). This is a very conservative model since material erosion is assumed to occur along the entire bottom long edge and not just a single cask corner. In the updated bounding accident case, tallies are placed 1 meter from external surfaces of the cask with the least through thickness between the source region(s) and the outside of the HI-STAR ATB 1T cask including from the surface created by the damaged long bottom corner edge. Updated design basis accident conditions dose rate results are presented for this configuration in Table 5.1.3.

NRC RAI 7-1

Clarify how the BFA-tank cassettes (BTCs) will be lowered into the BFA-Tank when the Docking Protective Cover is still in place over the BFA-Tank.

Section 7.1.1.2 details that a Docking Protective Cover will be placed on the BFA-Tank to prevent water from contaminating the interior of the BFA-Tank during installation of the BTC. It is unclear how the BTC can be docked inside the BFA-Tank with the Docking Protective cover apparently still in place (see Section 7.1.2.1 of the application).

This information is needed by the staff to determine compliance with 10 CFR 71.87(f).

Holtec's Response to RAI 7-1

The Docking Protective Cover is a piece of operational equipment that covers only the gap between the outer edge of the BFA-Tank and the top surfaces of the cask edge. Simply described, it is a rectangular cover with a rectangular hole through it. There is sufficient clearance for placement of the BTC into the BFA-Tank as it passes through the Docking Protective Cover. The intent of specifying this step in the operational procedure is not to fully define the design of the Cover, but to indicate that appropriate equipment is being used to minimize contamination of surfaces. Therefore, the Cover design is not explicitly shown in the licensing application. It is understandable, however, that the use of the word "cover" creates a vague impression of a device that fully spans the cask. To avoid this unnecessary confusion, Step 3 of Section 7.1.1.2 is replaced as follows:

3. A Docking Protective Cover *is installed to close off the gap between the BFA-tank and the inside of the cask to prevent contamination of the BFA-tank exterior and of the cask interior during installation of the BTC.*

NRC RAI 7-2

Clarify in the procedures section when the lifting device that will be used to lift the BFA-Tank will be installed to lift the BFA-Tank for Loading Scenario 2 (LS-2).

Step 7 of Section 7.1.2.2 states: *"The BFA-Tank lifting device is removed from the BFA-Tank."* However, installation of the lifting device itself appears to never have been mentioned in LS-2 loading procedures.

This information is needed by the staff to determine compliance with 10 CFR 71.87(f) and 71.33.

Holtec's Response to RAI 7-2

To correct this oversight, Step 6 of Section 7.1.2.2 is revised (changes in italics) to state:

6. The *BFA-Tank lifting device is installed and the* loaded BFA-Tank is lifted and placed in the prepared HI-STAR ATB 1T Cask.

NRC RAI 7-3

Clarify what actions will be taken when the ATB 1T cask is found to have an impaired physical condition beyond superficial marks and dents when preparing for loading or unloading.

Section 7.1.1.1 and 7.2.1 of the application state that, if there is any indication of damage observed during loading preparations beyond superficial marks and dents, site management would be notified. However, it is unclear (i) if any loading preparations will be stopped, and (ii) if or when any corrective actions/repairs will take place.

This information is needed by the staff to determine compliance with 10 CFR 71.87(b).

Holtec's Response to RAI 7-3

To clarify the actions that will be taken if more than superficial damage, or other impaired conditions, are detected on the Cask, Step 2 of Section 7.1.1.1 is revised (deletions crossed out, additions in italics) as follows:

2. The empty HI-STAR ATB 1T Cask is visually receipt inspected to verify that there are ~~is~~ no *outward visual* indication*s* of ~~an~~ impaired physical condition*s* except for superficial marks and dents. ~~Any indication of damage is brought to the attention of site management.~~ Any road dirt is washed off and any foreign material is removed. *If there are any indications of damage beyond superficial marks and dents, loading preparations will be stopped and site management will be notified. Conditions will be evaluated and repaired in accordance with Section 8.2.4(ii). Loading preparations will resume only after corrective actions and/or repairs have been completed.*

Similarly, Step 1 of Section 7.2.1 is revised as follows:

1. The HI-STAR ATB 1T Package is received from the carrier and inspected to verify that there are no outward visual indications of impaired physical conditions except for superficial marks and dents. ~~Any indication of damage shall be reported to the Owner's management.~~ *If there are any indications of damage beyond superficial marks and dents, unloading preparations will be stopped and the condition will be reported to the Owner's management. Conditions will be evaluated and repaired in accordance with Section 8.2.4(ii). Unloading preparations will resume only after corrective actions and/or repairs have been completed.*

These additional actions clarify that package operations will not proceed until the cask's physical condition has been fully evaluated and/or restored. In addition to the editing made for clarification, minor edits are also made for better agreement in phrasing and sentence structure between these two similar steps.

NRC RAI 7-4

Clarify in the procedures section the minimum width of the lifting device used to lift the ATB 1T package by its trunnions.

Page 24 of document HI-2177540R0 indicates that the minimum plate thickness of the device used to lift the package by its trunnions is 20 mm (anything smaller could damage the trunnions). However, the minimum thickness of the lifting device is not described in the procedure.

This information is needed by the staff to determine compliance with 10 CFR 71.45.

Holtec's Response to RAI 7-4

Because Chapter 7 does not include any other dimensional constraints on the cask, Holtec believes it would be clearer to add this information to the licensing drawing, where the interfacing dimensions of the trunnions are also located. This would provide a single reference document for the dimensions used in the lifting trunnion stress analysis. The following information is therefore added to Licensing Drawing 9786 (flag note 5):

THE MINIMUM THICKNESS OF THE LIFTING LINK THAT ENGAGES THE CASK LIFTING TRUNNION SHALL BE 20 MM.

In addition, the following statement is added to the third paragraph of Section 7.0 (addition shown in italics):

Users shall develop or modify existing programs and procedures to account for the transport operation of the HI-STAR ATB 1T. Written procedures are required and will be developed or modified to account for such items as handling and storage of systems, structures and components identified as important-to-safety, heavy load handling, specialized instrument calibration, special nuclear material accountability, training, equipment and process qualifications. The User shall implement controls to ensure that the lifted weights do not exceed the cask lifting trunnion design limit. *Lifting device interfaces shall meet the requirements of the licensing drawings.* The User shall also implement controls to ensure that the cask cannot be subjected to a fire event in excess of the design limits during loading operations.

NRC RAI 7-5

Modify Chapter 7, "Package Operations," to include specific details of how a user must interpret "specific activity" in Table 7.1.2 of the application.

Table 7.1.2 of the application contains specific activity limits for each of the five configurations. This table states: "Maximum permissible Co-60 specific activity of any single waste item loaded into respective BFA Tank (GBq/Kg)." The staff finds that this could be interpreted in a non-conservative way depending on how a user considers a "single waste item." For example, if this is interpreted as an item with multiple parts, some of these parts could be more activated than others and may possibly relocate during NCT and HAC, thus creating a scenario where areas of greater activity are being separated from areas of less activity that are providing self-shielding.

The applicant needs to (i) provide additional information within the package operations, instructing a user on what exactly is meant by "single waste item" and (ii) ensure this definition is consistent with or bounded by the assumptions within the shielding evaluation in Chapter 5 of the application.

This information is needed by the staff to determine compliance with 10 CFR 71.47(b)(1), 71.47(b)(2), 71.47(b)(3), and 71.51(a)(2).

Holtec's Response to RAI 7-5

(i) *Single waste item* is added to the glossary with the following definition, "**Single Waste Item** means any non-divisible waste item under accident conditions. If an item could potentially break into pieces during an accident, then the maximum permissible specific activity limits in Table 7.1.2 applies to any volume of that waste item that could potentially be fragmented and become a separate single piece."

(ii) This definition for single waste item is bounded by the assumptions within the shielding evaluation in Chapter 5, which used the maximum allowed specific activity of the waste content for each waste package type.

NRC RAI 7-6

Provide the acceptance criteria that ensures the CLLS system has been fully engaged/locked and will provide containment for internal and external pressures.

Section 7.1.3 indicate that Locking Wedge Locking Pins are inserted to ensure the CLLS remains engaged during shipment. However, an acceptance criteria, such as locking pin insertion length or hydraulic pressure for locking, was not provided. The acceptance criteria would be the equivalent of a bolt torque for a typical lid closure.

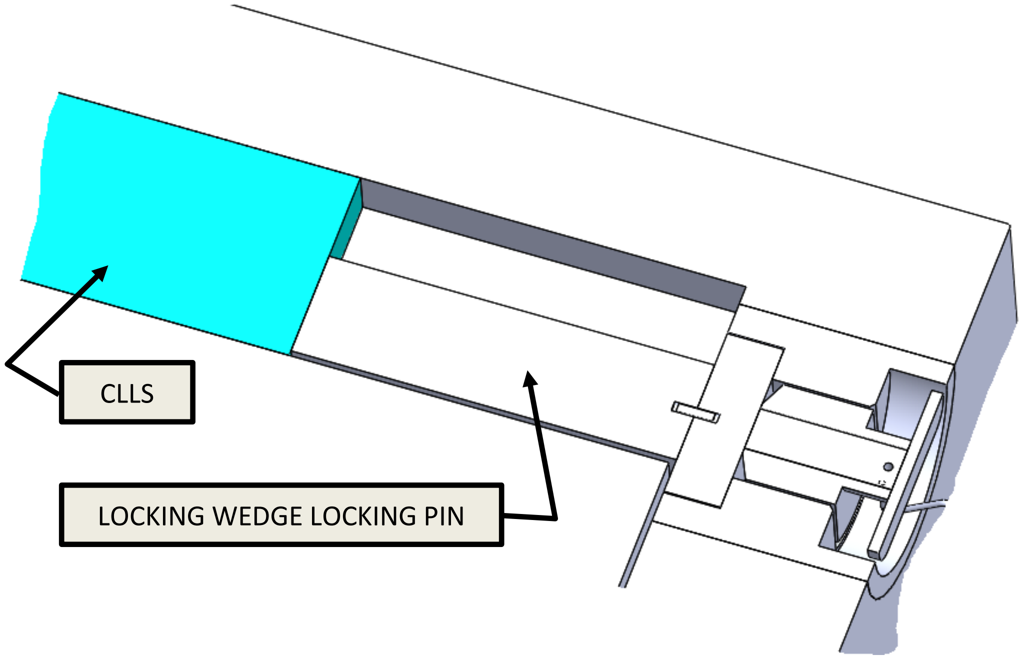
This information is required by the staff to determine compliance with 10 CFR 71.43(c).

Holtec's Response to RAI 7-6

The weight of the Closure Lid provides the only force required for compression of the sealing o-ring, which provides the containment for internal and external pressure. Therefore, maintaining the lid closure relies entirely upon ensuring the CLLS remains sufficiently engaged (i.e., no clearance between Locking Wedges, Wedge Blocks and Closure Lid) after it has been closed using the hydraulic system. To achieve this, the Locking Wedge Locking Pins are sized to provide a near zero-clearance fit against the end of the Locking Wedges (see figure below). The successful installation of the Locking Pins therefore provides the acceptance criteria that ensures the CLLS remains engaged. To clarify this in the operation procedures, Step 3 of Section 7.1.3 is revised as follows:

3. The CLLS is moved to the locked position *and* the Locking Wedge Locking Pins *and Shear Bars* are inserted. ~~to ensure the CLLS remains engaged with the cask body during shipment.~~ *Successful insertion of the Locking Wedge Locking Pins is the only acceptance criteria required to ensure that the CLLS remains fully engaged with the cask body and closure lid during shipment, thus maintaining containment.*

It should be noted that the closure lid Shear Bars also engage with the closure lid, as shown in licensing drawing 9786. The function of the Shear Bars is to provide additional safety assurance by improving the margin of safety against seal leakage (containment breach), as discussed in Section 2.7 of the SAR. The Shear Bars are not relied upon to ensure the CLLS remains fully engaged. However, in addition to adding actions to cover the operational step of inserting the Shear Bars in Step 3 of 7.1.3 (as shown above), similar edits have been made in Step 5 of Section 7.1.1.1, Step 4 of Section 7.2.2 and Step 3 of Section 7.3.1 to include Shear Bar insertion/removal as part of the operations.


CLLS
LOCKING WEDGE LOCKING PIN

NRC RAI 8-1

Clarify the acceptance tests and criteria for determining the shielding is functional post-fabrication, modifying them as needed.

In Section 8.1.6 of the application, the applicant provides information on the acceptance tests performed post-fabrication to ensure that the package shielding is functional and fabricated consistent with the assumptions within the shielding evaluation in Chapter 5 of the application.

The staff does not have enough information to determine that the post-fabrication tests and acceptance criteria are adequate for determining that the package shielding was fabricated consistent with the assumptions in Chapter 5 of the application and the design drawings. Section 8.1.6 states the following: "An inspection using a calibrated radiation detector and a ^{60}Co source will be performed. Acceptance criteria will be defined by comparative measure on mock-up or reference blocks produced using the casting technique used for the as-built cask components and having calibrated defects."

The applicant needs to include additional information on the requirements of the inspection. The applicant needs to provide more specific acceptance criteria and clarify the above language as the staff does not understand what is meant by "reference blocks produced using the casting technique used for the as-built cask components and having calibrated defects." The acceptance criteria should have a clear connection between them and demonstrate that the as-fabricated package meets the minimum design specifications in the design drawings and the assumptions regarding the packaging in the shielding evaluation.

The applicant also needs to specify procedures for determining acceptance of the BFA- Tanks and cassettes as these components are used as shielding and considered important for safety.

This information is needed by the staff to determine compliance with 10 CFR 71.85(a).

Holtec's Response to RAI 8-1

Response to RAI 8-1 to be provided at a later time, as discussed in Holtec Letter 2404007-NRC dated December 8, 2017.

NRC RAI 8-2

Clarify the acceptance tests and criteria for determining that the shielding is functional pre-shipment, modifying them as needed.

In Section 8.1.6 of the application, the applicant provides information on the acceptance tests to be performed prior to the first shipment (pre-shipment after first loading). This section states: "Measurements shall be taken at locations specified by the user's radiation protection program for comparison against the calculated values in this SAR for the specific loaded contents and BFA-Tank/BTC combination (when applicable) to assess the continued effectiveness of the shielding. If the measured dose rates are higher than the calculated values, then the cask shall not be shipped until the root cause is determined, appropriate corrective actions are completed, and the cask is re-tested with acceptable results."

The staff does not find these procedures capable of determining if the package shielding is effective. As the calculated values in the application are design basis, comparing against any non-equivalent source would not provide any information on whether or not the shielding is effective. For example, a user could load a source with strength significantly less (e.g. 5%) than that of the design basis, and if the measurement shows that external dose rates with this source are less than that of the application, e.g., even if it is 95% of the limit, then the package shielding is still considered effective when it is possible that the package shielding is underperforming.

The applicant needs to modify the acceptance criteria to compare the measurement with a calculation using an equivalent source for both the measurement and the calculation.

This information is needed by the staff to determine compliance with 10 CFR 71.85(a).

Holtec's Response to RAI 8-2

The pre-shipment testing requirements in Subsection 8.1.6 of the SAR have been revised to state that "Measurements shall be taken at locations specified by the user's radiation protection program for comparison against **calculated values** for the specific loaded contents and BFA-Tanks/BTC combination (when applicable) to assess the continued effectiveness of the shielding. If the measured dose rates are higher than the calculated values, then the cask shall not be shipped until the root cause is determined, appropriate corrective actions are completed, and cask is re-tested with acceptable results." This revised requirement for pre-shipment testing after first loading of the package, brings Subsection 8.1.6 (shielding acceptance testing) into alignment with Subsection 8.2.4(i) (shielding maintenance testing).

NRC RAI 8-3

Clarify in the SAR that those approving the leakage test procedures and performing the leakage tests are qualified.

Section 8.1.4 indicates that testing shall be performed per written and approved procedures. However, there were no details in the SAR of the qualifications for those approving the procedures and performing the tests. For example, ANSI N14.5-2014 provides information on the qualification and certification of personnel performing leakage rate tests. Likewise, an individual who has obtained certification as an American Society for Nondestructive Testing nondestructive testing Level III in leak testing has the qualification necessary to develop and approve written instruction for conducting leakage rate testing.

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

Holtec's Response to RAI 8-3

Subsection 8.1.4 of the SAR (Proposed Rev. 2A) has been updated to provide details of the qualification for individuals approving and performing leakage tests. Specifically, ANSI N14.5 (2014) is referenced as a replacement for ANSI N14.5 (1997) for leakage testing requirements, including qualifications for those approving and performing the leakage tests for the HI-STAR ATB 1T cask containment seals.

In accordance with ANSI N14.5 (2014), leakage rate testing procedures shall be approved by an American Society for Nondestructive Testing (ASNT) Level III specialist. The written and approved test procedures shall clearly define the test equipment arrangement. Leakage rate testing shall be performed by personnel who are qualified and certified in accordance with the requirements of SNT-TC-1A (2006), which replaces SNT-TC-1A (1992) in Subsection 8.1.4. Leakage rate testing shall be performed in accordance with a written quality assurance program.

Related changes are made to Paragraph 1.2.1.3, Subsection 4.2.2, Sections 4.0, 4.3 and 4.4, Paragraph 4.4.2.6, Table 8.1.1, Subsection 8.2.3 and Chapters 1, 4 and 8 references sections. Certain changes in the referenced sections and tables have been made to mirror the HI-STAR 190 SAR under Docket 71-9373].

NRC RAI 8-4

Justify that the elastomeric seals do not have to be replaced on a yearly basis.

Table 8.2.1 indicates that elastomeric seals do not have to be replaced, remaining part of the containment boundary for an indefinite period unless visual inspection shows that replacement is necessary. This is not consistent with NUREG-1609 (page 8-6) which indicates that elastomeric seals are replaced, at least, on a yearly basis. Details of the material performance justification and qualified acceptance criteria of inspection should be provided to understand the rationale for the indeterminate acceptance period.

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

Holtec's Response to RAI 8-4

Table 8.2.1 and Subsection 8.2.4(v) have been updated to require that in addition to replacing elastomeric seals if they fail to meet the leakage criteria during pre-shipment, periodic and maintenance testing or as recommended by the manufacturer, the following visual inspections may be performed as deemed necessary by the user following disengagement of the Closure Lid Locking System (CLLS):

- Inspection of seal to ensure it remains free of debris
- Inspection of seal to ensure it does not exhibit damage (i.e. no tears or gouges)
- Inspection of seal to ensure it does not exhibit excessive compression set (i.e. the seal projects past the plane of the top seating surface of the seal groove)

Failure to meet the criteria for the above inspections requires seal replacement.

Seals in use for a period which exceeds 12 months shall be replaced when the CLLS is next disengaged and removed.

In addition to these changes to Chapter 8, Paragraph 7.1.1.1 of Chapter 7 has also been revised to provide reference to Table 8.2.1 for maintenance inspection of the cask and trunnions (Step 2 of Paragraph 7.1.1.1) and maintenance inspection and/or replacement of cask lid o-ring seals (Step 6 of Paragraph 7.1.1.1).

NRC RAI 8-5

Remove Note 2 of Table 8.1.1 which states that alternative types of leak rate tests may be used.

An applicant may use various types of leak rate tests to ensure that regulatory release rates are met. However, the leak rate tests are to be specified and described in the SAR so that an evaluation can be performed.

This information is required by the staff to determine compliance with 10 CFR 71.51(a).

Holtec's Response to RAI 8-5

Table 8.1.1 has been revised to include additional permissible ANSI N14.5 leakage rate tests for the HI-STAR ATB 1T package. Specifically, for testing of the Closure Lid Inner Seal, the Gas Filled Envelope (A.5.3) and Evacuated Envelope (A.5.4) tests have been added to Table 8.1.1. Additionally, consistent with HI-STAR 190 SAR under Docket 71-9773, Note 2 of Table 8.1.1 has been revised to provide an alternative pre-shipment leakage rate acceptance criterion that may be employed during pre-shipment testing, in lieu of adherence to the leakage rate acceptance criterion in Table 8.1.1. Note 3 has been added to Table 8.1.1, and states the purpose of the leakage tests in Table 8.1.1 (Fabrication, Pre-Shipment, Maintenance, Periodic).