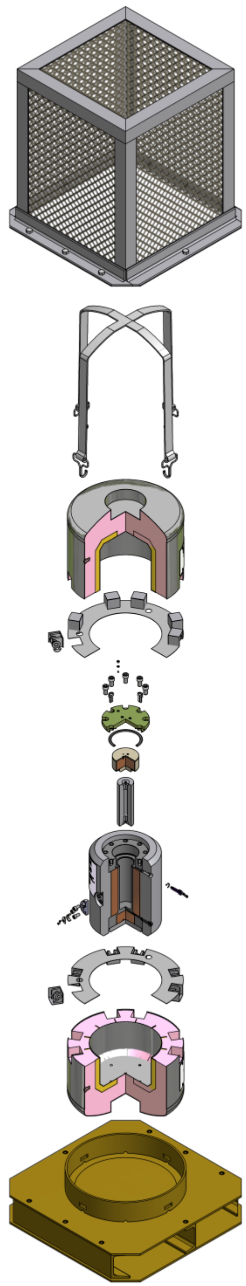
Alpha-Omega Services, Inc.

AOS CASK SAR RAI's

May 3, 2011



Introduction

RAI Action Plan:

- NRC March 2011 RAI responses
- The projected completion Schedule to complete the RAI response/approach

AOS

Request for Additional Information

RAI 2-1:

Correct the cylinder radius and the calculated buckling critical force in Table No. 2-2, and correct the Young modulus values in note (b) to Table No. 2-2. This RAI is a follow up to AOS response to RAI No. 2.1, dated December 24, 2009.

The cylinder radii reported for the Model Nos. AOS-050 and AOS-100 packages are erroneous, and should be 7.0 in. and 14.0 in., respectively. This correction results in a corrected critical buckling force of 2.184 10^6, which is lower than the 2.78 10^6 reported. Furthermore, there is a factor of 10 error in the Young modulus values provided in note (b) to Table No. 2-2.

AOS

Request for Additional Information

RAI 2-1 Response:

Equation 2-1 the buckling formula used to develop Table 2-2 is,

$$F_{cr} = 0.182 * E * t / r$$

In Table 2-2 the radius values used for models 100 and 050 are correct, but the value for model 025 should be 2.75 rather than 3.5. Therefore the buckling stress value of $2.78 * 10^6$ psi, is based on average radii and is correct. However, the result for the AOS-025 is incorrect and will be corrected in the updated SAR.

AOS

Request for Additional Information

RAI 2-2:

Make the following corrections in the application, and assess the impact of these changes on any analyses that may be affected, if any:

Page No. 2-36: change "21mm" to "21 microns" to match the notes in the certificate drawings.

Page No. 2-37: delete "per hour" in the statement "when subjected to a maximum cumulative dose of $2x10^8$ rads per hour."

Page No. 2-39 in Table No. 2-17: drawing number 105E9712G001 does not exist: replace with drawing number 105E9712.

Request for Additional Information

RAI 2-2 (Continued):

Section No. 2.6.2: "Low-temperature service does not affect the AOS Transport Packaging System, because all containment and non-containment structural components are fabricated of SS300, a material that does not undergo ductile-to-brittle transition in the temperature range of interest, down to -40°C (-40°F). Therefore, it is safe from brittle fracture." Modify this statement to take into account (1) the lid attachment bolts made of nickel alloy N07718, and (2) the impact limiters containing FR-3700 series foam. Both the lid attachment bolts and the impact limiters are structural components.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.33, 71.51(a)(1) and 71.51(a)(2).

Request for Additional Information

RAI 2-2 Response:

The above corrections will be done in the next revision of the SAR. In reference to the comment on Table No. 2-17, drawing number 105E9712G001 refers to group G001 in drawing 105E9712; however the requested change is made. Furthermore, Subsection 2.6.2 Cold is revised to address the comment as follows:

"Low-temperature service does not affect the AOS Transport Packaging System, because the majority of structural components are fabricated of SS300, a material that does not undergo ductile to brittle transition in the temperature range of interest, down to -40°C (-40°F). For the lid bolts material, Ni-alloy SB637, brittle failure is not a consideration per ASME Code, Section III, Division 3, paragraph WB-2311 (a) (7) and the foam material GPMC FR-3700 series has a operating temperature range down to -54°C (-65°F)."

Request for Additional Information

RAI 2-3:

Clarify in Table No. 2-8 and justify in the application the codes and standards which are applicable for the design, fabrication and testing of the AOS Transport Packaging System.

RAI 2-3 Response:

The ASME Code selection give in Table 2-8 is based on the recommendation of NUREG/CR-3854, "Fabrication Criteria for Shipping Containers," with the following exceptions:

Selection of B&PV Section III, Division 3 for the containment system, which is based on recommendation from *NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel," Section 2.7. "REFERENCES."*

Selection of B&PV Section III, Division 1, Subsection NG for the cask outer shell, lid plug and cask end plate that was upgraded from the NUREG/CR-3854 recommendation of Subsection NF because GEH's engineering judgment concluded that those components require a higher level of requirement than those prescribe in Subsection NF.

In addition Table 2-8 is revised to provide the component names in the columns heading rather than the functional component names and the column for the "Heat Transfer Jacket" is deleted because it is not applicable to the designs of the AOS-025, AOS-050 and AOS-100.

Request for Additional Information

RAI 2-3 (Continued):

For components of the “other safety” group, the referenced B&PV code section is Section III, Division 1, Subsection NG, but several NF code subsections are then referenced below in the same Table. Clarify and justify the use of either NF or NG code subsections.

RAI 2-3 Response (Continued):

The codes used are those suggested by RegGuide/CR-3854.
For gamma shielding tungsten, a non-ASME code material, was used. Therefore, we proposed the Straight Beam Method per subsection NG.
For the shell, lid plug and cask end plate the more restrictive NG subsection was applied because our engineering judgment was that the more restrictive code should be applied. The B&PV Code Section line will be updated to reflect the use of both NF and NG subsections.

AOS

Request for Additional Information

RAI 2-3 (Continued):

For components of the "containment" group, the referenced B&PV code section is Section III, Division 3, Subsection WB. Section III, Division 1, Subsection NB is the normally accepted code section for the design, fabrication and testing of the containment. Justify the use of Subsection WB instead of Subsection NB: describe any differences between these two code sections, and the implications for the design, fabrication and testing of the containment.

RAI 2-3 Response (Continued):

WB is the correct section to be used because it is based on B&PV Section III, Division 3 for the containment system, which is based on recommendation from *NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel," Section 2.7. "REFERENCES."*

Request for Additional Information

RAI 2-3 (continued):

For the acceptance testing of the Gamma Shielding, ASME Section V, Article 5, paragraph T-544 does not exist in the 2010 B&PV code. Provide an alternate standard for the acceptance testing of the Gamma Shielding.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.33 and 71.37(a).

RAI 2-3 Response (Continued):

For gamma shielding tungsten, a non-ASME code material, was used. The previous SAR had an error and will be updated to propose the Straight Beam Method per subsection NG-2532.1, Section III, Division 1, 2001 Edition with 2003 Addendum.

Request for Additional Information

RAI 2-4:

Specify the exact type of foam used in the impact limiters for the Model No. AOS-165 package drop tests.

Provide the density, mechanical, and thermal properties of the foam used in the Model No. AOS-165 test package and compare these properties with those of the foams used for the other package sizes in the AOS Transport Packaging System application.

The staff needs this information to assess the validity of the structural and thermal models and analyses described in the application.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.51(a)(1) and 71.51(a)(2).

Request for Additional Information

RAI 2-4 Response:

A copy of the Certificate of Conformance provided by the foam manufacturer, General Plastics Manufacturing Company will be added as an Appendix in Chapter 2 of the SAR. As shown in the COC the foam density of the AOS-165 is 20 lbs/cuft which is the same foam density as the AOS-025. Refer to Table 2-14 for the mechanical properties in question.

Request for Additional Information

RAI 2-5:

Provide a complete description of the copper alloy used to fabricate the port plug seals and the conical seals on the AOS Transport Packaging System. Provide mechanical and thermal properties for the copper alloy used to make the seals. This RAI is a follow up to the AOS response to RAI No. 2.4, dated December 24, 2009.

The copper alloy C10100 is referenced in Section No. 2.2.2 of the application. A national consensus standard should be provided for this material, as well as the corresponding material properties (mechanical and thermal). The material specifications should be consistent with those specified in the licensing drawings.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.43(d), 71.51(a)(1), and 71.51(a)(2).

Request for Additional Information

RAI 2-5 Response:

The copper seals manufacturer, Alcoa Fastening Systems, identifies the material as UNS C10100, Chemical composition per ASTM B152 and Mechanical Property per AMS 4500. This information will be added to pertinent Certification Drawings.

Request for Additional Information

RAI 2-6:

Modify Table No. 2-14 to provide the mechanical properties of the different grades of LAST-A-FOAM FR-3700 foams used for the AOS Transport Packaging System as a function of temperature for temperatures ranging from -40°F to 279°F (the component temperature range specified in Table No. 3-3). For the Model No. AOS-050 package, justify the use of the FR-3710 foam at temperatures within 3°F of the glass transition temperature of 279°F. This RAI is a follow up to AOS's response to RAI No. 2.21, dated December 24, 2009.

Based on the manufacturer data found at http://www.generalplastics.com/products/idatasheets.php?pfoamname=FR-3700& the properties of FR-3710, FR-3712, and FR-3720 change by more than a factor of two between -75°F and 250°F. These changes in material properties as a function of temperature must be taken into account in the structural models of the impact limiters.

AOS

Request for Additional Information

RAI 2-6 (continued):

For the Model No. AOS-050 package, the maximum temperature of the foam for the impact limiter is 276°F, while the glass transition temperature of FR-3710 is 279°F (maximum operating temperature range). It is expected that the mechanical properties of FR-3700 series foams will decrease rapidly above the glass transition temperature. The 3°F temperature margin is very small, and should be justified.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.51(a)(1) and 71.51(a)(2).

Request for Additional Information

RAI 2-6 Response: Additional data will be obtained from the manufacturer and provided in the SAR. The analysis performed at 75°F is conservative for higher temperatures because the foam material becomes less dense with temperature reducing impact forces and accelerations. In addition there is sufficient foam present to keep the foam from bottoming out. The area with temperature near the glass transition point is small and does not significantly impact the results.

AOS

Request for Additional Information

RAI 2-7:

Justify the use of the mean coefficient of thermal expansion instead of the instantaneous coefficient of thermal expansion in Table Nos. 2-9, 2-10, and 2-12 of the application.

Table TE-1 in ASME Code Section II, Part D, provides three different values for the thermal expansion coefficient for each material group: instantaneous, mean, and linear (columns A, B, and C respectively). Justify the use of the mean instead of the instantaneous coefficient of thermal expansion.

If the thermal expansion coefficients are changed, assess the impact of these changes on the analyses and calculations presented in the application. Update these analyses and calculations as required, and address any inconsistencies in the application as a result of these changes.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.51(a)(1) and 71.51(a)(2).

AOS

Request for Additional Information

RAI 2-7 Response:

The mean coefficient of thermal expansion is applied to evaluate thermal effects over a range of temperatures, whereas the instantaneous coefficient is applied to evaluate thermal effects at a specific temperature

All SAR applications of thermal expansion coefficients involve ranges of temperature, consequently, the mean coefficient of thermal expansion is appropriate.

Request for Additional Information

RAI 2-8:

Correct Table No. 2-10 to show the mechanical properties of the N07718 nickel alloy. This RAI is a follow up to AOS's response to RAI No. 2.3, dated December 24, 2009.

RAI 2-8 Response:

Table 2-10 has been corrected to the mechanical properties of N07718 nickel alloy.

RAI 2-8:

The Young modulus shown in Table No. 2-11 is that of the incorrect material (Material Group B Nickel Steel). The Young modulus must be provided for N07718 Nickel alloy (Table TM-4 in Section II, Part D, of the ASME code). The design stress intensity is also incorrect by a factor of about 2, and should be corrected to show the correct design stress intensity for the N07718 Nickel alloy.

RAI 2-8 Response:

Design stress intensity should reference the NUREG/CR-6007. The NUREG uses a value of 2/3 yield at temperature.

Request for Additional Information

RAI 2-8 (Continued):

Assess the impact of these corrections on the analyses and calculations presented in the application, update the analyses and calculations as required, and address any inconsistencies in the application as a result of these corrections.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.51(a)(1) and 71.51(a)(2).

RAI 2-8 Response (Continued):

The corrections that were made to Table 2-10 were reviewed with respect to analysis to assure that safety margins remain sufficient. No changes were necessary to other parts of the SAR.

AOS

Request for Additional Information

RAI 2-9:

Provide temperature dependent properties for the tungsten alloy mechanical properties in Table No. 2-11. This RAI is a follow up to AOS response to RAI No. 3.1, dated December 24, 2009.

Table No. 2-11 should resemble Table Nos. 2-9, 2-10 and 2-12. Assess the impact of these changes on the analyses and calculations presented in the application. Update these analyses and calculations as required, and address any inconsistencies in the application as a result of these changes.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.51(a)(1) and 71.51(a)(2).

RAI 2-9 Response:

Tungsten material is used only as shielding, and not as structural components. Those properties reported in 2-11 are the ones used in the analysis.

AOS

Request for Additional Information

RAI 2-10:

Provide the basis by which the three different grades of the polyurethane foam LAST-A-FOAM 3700 were selected for use in each of the three package sizes of the AOS Transport Packaging System family (FR-3720, FR-3710, and FR-3712, for the Model Nos. AOS-025, AOS-050, and AOS-100, respectively).

The basis and rationale for the selection of the different foams in each of the different package sizes is not clear, particularly since the mechanical and thermal properties of each of the FR-3700 foams are different. There is no explanation of the engineering reasons behind the choice of different foams, especially in view of the fact that the packages are geometrically similar.

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

Request for Additional Information

RAI 2-10 Response:

Three parameters were used in the foam selection and optimization process, impact force, size, and maximum foam strain. While the models 025, 050 and 100 scale linearly, the factors to be optimized do not and an iterative process was used. For models 050 and 100, impact force and maximum foam strain were controlling in the selection where as for the model 025 size and maximum foam strain controlled the selection.

AOS

Request for Additional Information

RAI 2-11:

Revise the second and third paragraphs of Section No. 2.4.3 "Positive Closure" of the application.

The closures referred to in 10 CFR 71.43 (c) refer to containment closures. The impact limiters and personnel barrier are not part of the containment boundary, but they do provide added assurance that the containment boundary will not be unintentionally breached.

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

Response:

Subsection 2.4.3, "Positive Closure" is revised to describe only the containment system positive closure.

AOS

Request for Additional Information

RAI 2-12:

Correct the discrepancies in the classification of components listed in the application and in the drawings.

Table No. 2-8 of the application lists major components and classifications according to NUREG/CR-6407 "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety". All components are classified either A or B. However, in the drawings, apparently contradictory classifications are listed. For example, drawing 105E9711 lists the shipping tie-down assembly and turnbuckles as "C," when according to the application (and, by reference, NUREG/CR-6407) they should be "B." There are also several other "C" classifications in the rest of the drawings which do not conform to NUREG/CR-6407.

This information is required by the staff to determine compliance with 10 CFR 71.111.

Request for Additional Information

RAI 2-12 Response:

Table No. 2-8 and the package certification drawings were revised to show the proper safety classification of "B" for all tie-down components within the load path.

AOS

Request for Additional Information

RAI 2-13:

Explain the potential errors in the load combinations discussed below.

Staff has identified several potential errors in the loading combinations presented in the application. For example, per Table No. 2-6, Load Combination 103, "Increased External Pressure," contains load cases 103, 201, and 211 (-20°F Ambient, Zero Decay Heat, Zero Insolation, Internal Design Pressure, Fabrication Stress). There is no external pressure load in this load combination, which appears to be an error. The analysis input file, cmb_loads.in, indicates that this potential error was also introduced into the analyses. Load Combination 231 (4-ft drop) only includes "Hot" initial conditions (without considering insolation); there is no "Cold" condition load combination. Similarly, Load Combinations 221, 222, and 223 ("Vibration"), do not have "Cold" initial conditions.

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

AOS

Request for Additional Information

RAI 2-13 Response:

Load Combination 103 will be changed, and we will add the Load Combinations 224, 225, 226, and 233 in accordance with the following table.

Load Combination	Description	Load Cases
103	Increased external pressure	103,202,211
224	forward vibration @ cold temperature	221,103,211
225	lateral vibration @ cold temperature	222,103,211
226	vertical vibration @ cold temperature	223,103,211
233	3/4 ft drop @ cold temperature	231,103,211

AOS

Request for Additional Information

RAI 2-14:

Explain the discrepancy between the stated type of analysis and the actual analysis performed for the NCT 4-ft drop. Explain the similarity in stress results for the 4-ft and 30-ft drop cases.

The input files for NCT drop indicate that a linear static analysis was performed. However, this conflicts with the statement on page No. 2-70 of the application that "The Drop condition evaluation consists of a direct integration dynamic analysis."

The 4-ft drop stress results, as listed in various tables of Section No. 2.12.2 for the different models, are roughly half of the stress results of the 30-ft drop cases. These results need to be discussed in view of the more than sevenfold increase in potential energy of the 30-ft drop case when compared to the 4-ft. drop.

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

Request for Additional Information

RAI 2-14 Response:

The statement on pg. 2-70 is incorrect. The 4-ft drop analyses are based on the energy-displacement curves developed for the 30-ft drop analyses.

The 4-ft drops develop nearly half the foam stress as the 30-ft drops because the impact limiter foams are selected for 30-ft drops. Less dense foams producing lower stress levels would be optimum for 4-ft drop conditions, but would "bottom-out" under the 30-ft drops producing very high stress levels.

The 4-ft drop analyses will also be updated. The new analysis will include the entire package.

Request for Additional Information

RAI 2-15:

Demonstrate compliance with 10 CFR 71.73(c)(1).

In previous communications, NRC staff indicated to the applicant the concern about the adequacy of the methodology employed to model the HAC 30-ft drops.

The issue lies with the constraints of the foam model, which are fixed at the "top" surface (as presented in Figure No. 2-29 of the application for the Model No. AOS-100 package, and also as seen on the applicant's response to the structural issue (ADAMS ML110620226)). These constraints do not allow the realistic, two-sided deformations that occurred in the Model No. AOS-165 package test to occur in the finite element model. The staff does not agree with the applicant's explanation of Figure No. 2-32 regarding the deformation of the foam model versus the test deformation. In the model, the boundary conditions do not allow the "top" part to move; therefore, the deformation is artificially concentrated at the "bottom." The time-lapse high speed photography presented on page No. 2-797 only shows the outside of the package ("bottom") deformations. This cannot illustrate the "top" deformations, explained previously.

AOS

Request for Additional Information

RAI 2-15 (continued):

The impact limiter finite element model, used to determine the applied force and foam internal strain energy as a function of displacement, must, as a minimum, reasonably reflect the deformation results from the actual test. Figure No. 2-37 shows that the impact limiter displacement necessary to absorb the energy from a 30-foot drop is approximately 6.2 inches. Figure No. 31 on page No. 2-799 (Image 5) shows a displacement at the "bottom" (ground impact location) of only 2.416 inches, which is not sufficient to absorb the total energy from a 30-foot drop. Figure No. 2-32 from the actual test shows considerable crushing of the foam on the "top" side of the impact limiter, which would account for the additional displacement of between 3 to 4 inches necessary to absorb the total energy. In contrast, the finite element model causes crushing only on the "bottom" and no crushing on the "top." This is completely inconsistent with the test results.

Furthermore, the pressure film photographs indicate that the contact between the package and the impact limiter was concentrated on the impact limiter strengthening ribs, which does not correspond well with the applicant's approach of applying an evenly distributed load in the finite element models.

Request for Additional Information

RAI 2-15 (continued):

To enable staff to make a safety finding, staff requests the following:

a) revised Figure No. 31 (for page No. 2-799) that shows both "top" and "bottom" for the impact limiter profile,

RAI 2-15 Response:

No data taken at time test because no deformation of the area in question was noted. Metrology data reading was compiled by East Coast Metrology at time of test. There is no data at cask-form interface. SAR Figure 2-32 shows this interface.

Request for Additional Information

RAI 2-15 (continued):

b) a computational component study which shows equal load-displacement characteristics, deformations and external forces when the foam is modeled by fixing one of the boundaries and loading on the other side, and when both sides are loaded and allowed to deform, and

RAI 2-15 Response (Continued):

b) The attachment "Comparison of Libra Static and Dynamic Impact Analyses" presents a comparison study of the SAR static analyses method and a dynamic analysis of the model 165 rib-on drop test. In the static analysis, as in the SAR, a 180°, 3D foam model with fixed boundary conditions at the cask is used to find the strain energy and impact force corresponding to a 30-ft. drop. In the dynamic analysis, the 30-ft. drop impact velocity is applied as an initial condition, and cask response determined by a dynamic, direct integration solution. An axisymmetric, 2D model of the foam and cask is used.

AOS

Request for Additional Information

RAI 2-15 Response (Continued):

The cask is modeled as a solid steel cylinder, with density adjusted to give a total cask and foam weight of 40k lbs. A bi-linear foam constitutive model and von Mises yield criteria is used Both foam-ground and foam-cask interfaces are modeled by gapped, compression-only, spring elements. The displacements and forces determined in the static and dynamic analyses are shown to be in very good agreement. In addition, the deformation patterns given by the two solutions are also in very good agreement.

AOS

Request for Additional Information

RAI 2-15 (continued):

c) a computational study which shows minimal difference in the effects upon the package when applying loads in the evenly distributed fashion, and when applying loads of equal magnitude in a concentrated fashion as the impact limiter ribs would transmit.

Alternatively, the applicant may present a fully dynamic analysis of the model, appropriately benchmarked per Interim Staff Guidance 21 (ISG-21).

This information is required by the staff to determine compliance with 10 CFR 71.73(a).

AOS

Request for Additional Information

RAI 2-15 Response (Continued):

c) The attachment "Effect of Ribs on Stress at Foam-Cask Interface" presents a study of the steel ribs attached to the foam cladding on the cask stress. In this study, a section of foam impact limiter, steel cask, and steel rib, simplified by removing curvature, is analyzed for foam compression. The changes in stress distributions in the cask due to the rib are shown to be highly localized to within an inch of the rib location, and in accordance with Saint-Venant's Principle* these perturbations do not have a significant effect on cask stress at critical locations which are removed from the rib locations.

* see Timoshenko, Theory of Elasticity, 2nd Ed., pg. 33.

AOS

Request for Additional Information

RAI 2-16:

Include the leak test results in the application.

The applicant's response to RAI No. 2.25, dated December 24, 2009, provides the requested leak test results, but these results have not been incorporated into the application.

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

RAI 2-16 Response:

The drop test leak test report is added to Chapter 2 in a new Appendix 2.12.6.2, "Drop Test Leak Test Report."

AOS

Request for Additional Information

RAI 2-17

Correct the text in Section No. 2.7.1.1.3 "Correlation of Head-on Drop Analysis and Test," and clarify Section No. 2.7.1.2.5 “Correlation of Slap-Down Drop Analysis and Test.”

Section No. 2.7.1.1.3 states "In the Cg/Corner test, the cask was oriented with one end offset 25.4 cm (10 in.) above the other." This was a Slap-Down test not a Cg/Corner test. In order to be a Cg/Corner test, the offset would have to be approximately 47 in.

Section No. 2.7.1.2.5 states "The dimensional analysis results are used to correlate Cg/Corner test and analysis results. Again, a Cg/Corner test was never performed. Also the caption in Table No. 2-35 refers to a "Cg/Corner Drop Analysis and Test," which is not correct.

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

Request for Additional Information

RAI 2-17 Response:

The textural errors and incorrect references to the cg/corner test will be corrected.

AOS

Request for Additional Information

RAI 2-18:

Evaluate the effects of HAC on the impact limiter connectors.

The thermal analyses for HAC fire assume that the impact limiters will stay attached to the package. There is no evaluation presented to assure that the connectors and their components will not fail under the HAC 30-ft. drop. Such an event was already observed in the AOS-165 test report.

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

RAI 2-18 Response:

Analyses of the impact limiter connectors will be included in the SAR.

Request for Additional Information

RAI 2-19:

Clarify the statement in Section No. 2.7.3 Puncture "The puncture analysis was conducted at the nominal weight of 8,600 lbs. for the Model AOS-100. The analysis was not re-conducted at the maximum weight of 9,510 lbs, due to the minimum Margin of Safety of 0.39 at worst-case conditions."

This statement implies that a worse condition is being ignored, since a heavier package would more than likely receive worse damage. Without sufficient justification the staff would have to restrict the maximum package weight to the analyzed weight of 8,600 lbs.

This information is required by the staff to determine compliance with 10 CFR 71.73(c)(3).

RAI 2-19 Response:

The puncture analysis will be changed to account for maximum weight.

AOS

Request for Additional Information

RAI 2-20:

Provide the input and output (results) file listings from the Fortran program, described in Appendix 4.5.2, that was used to perform the analysis of the lid attachment bolts and that formed the basis for the results shown in Table No. 4-2 “Bolt Evaluation.”

The note at the bottom of Table No. 4-2 states that "A detailed analysis of the bolt evaluation is presented in Appendix 4.5.2." Contrary to this statement, no such detailed analysis exists in Appendix 4.5.2, only a listing of the Fortran program.

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

RAI 2-20 Response:

The requested information will be provided.

Request for Additional Information

RAI 2-21:

For each package, provide the methodology and calculations used to develop the Dynamic Load Factor (DLF) of 1.15 shown in Table No. 4-1 for the analysis of the lid attachment bolts.

In the absence of a gap between the lid and contents, the impact of the package contents into a typical closure lid during the HAC drop test results in a maximum DLF of 2.0. This is discussed in NUREG-6007 "Stress Analysis of Closure Bolts for Shipping Casks." The use of a DLF less than 2.0 requires justification.

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

AOS

Request for Additional Information

RAI 2-21 Response:

The attachment "Analysis of Content-Lid Impact" presents a study of the content-lid impact accelerations due to 30-ft. head-on package drops. In this attachment, the equations of motion of the lid and contents are developed and applied to determine the impact acceleration due to an initial gap between the lid and contents. In addition, cask impact accelerations determined in head-on, 30-ft drop analyses are amplified by a 1.15 factor and used when greater than values given by equations of motion. For all three casks the amplified, 30-ft drop acceleration values govern.

A DLF of 2 is sometimes applied to static loadings to account for vibration. Under dynamic loading structures oscillate about a position of static equilibrium, resulting in maximum amplitude twice the static value. The procedure of equating strain energy to maximum kinetic energy used in the SAR for 30-ft drops gives the maximum dynamic loading, and does not require a DLF. Nevertheless, in the bolting analyses a DLF of 1.15 is applied for conservatism.

Request for Additional Information

RAI 2-22:

Determine the maximum gap that can exist between the closure lid and lid plug, and the lid plug and contents for each package. Provide an analysis of the effect of these gaps on the calculation of the DLF. The resulting DLF should be used in the analysis of the lid attachment bolts under HAC.

The effect of gaps on the impact response of the lid attachment bolts under HAC can be significant and must be incorporated into the evaluation of the lid attachment bolts.

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

Request for Additional Information

RAI 2-22 Response:

In the write-up Analysis of Content-Lid Impact the methodology for evaluating Content-Lid gaps is presented. The methodology developed in the write-up is programmed in the Fortran program ContentAcc listed in the write-up. In the AOS casks the inner container is immobilized so there is no gap between content and lid other than manufacturing tolerance, evaluated as 0.033 in. This tolerance also applies to lid plugs. In the lid bolting analyses both plug and content accelerations are the larger of the ContentAcc value or 1.15x drop analysis value. In all cases, due to the small gaps, the drop analysis acceleration governs.

AOS

Request for Additional Information

RAI 2-23:

Provide the following information:

The basis for the factors (in footnote d of Table No. 4-1) that are used to convert impact accelerations at 100°F to impact accelerations at -40°F, and

The weight of the cask lid and lid plug for each of the three packages.

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

Request for Additional Information

RAI 2-23 Response:

The impact limiter drop analyses used to determine maximum impact accelerations are generated for both 75°F and -40°F. At the time of generating foam impact analyses, -40°F temperature stress-strain data was available only for model 100, 12 lb foam. In conjunction with the manufacturer, examination of 12 lb foam properties at 75°F and -40°F showed that properties at -40°F could be conservatively enveloped by applying a factor of 1.4 to properties at 75°F. As a result, 10 lb and 20 lb foam stress-strain data at -40°F was taken as 1.4x data at 75°F.

The lid and plug weights applied in the bolting analyses are listed below and in Table 4.1.

AOS Model	Lid Wgt. (lb)	Plug Wgt. (lb)
025	2.0	4.0
050	12.0	35.0
100	99.0	278.0

AOS

Request for Additional Information

RAI 2-24:

Demonstrate compliance with 10 CFR 71.45(a).

10 CFR 71.45(a) requires lifting attachments "be designed so that failure of any lifting device under excessive load would not impair the ability of the package to meet other requirements of this subpart." No analysis of the consequences of a lifting device failure is included in the application.

This information is required by the staff to determine compliance with 10 CFR 71.45(a).

RAI 2-24 Response: The package as presented for transport has no exposed lifting devices aside from the pallet fork lift pockets. Chapter 2 will be updated to reflect this.

Request for Additional Information

RAI 2-25:

Demonstrate compliance with 10 CFR 71.45(b).

Clarify what system of tie-downs is being evaluated in Section No. 2.5.2 "Tie-Down Devices."

Provide calculations demonstrating that the trunnions and impact limiter turnbuckles for the Model Nos. AOS-050 and AOS-100 packages satisfy the requirements of 10 CFR 71.45(b).

Demonstrate compliance with 10 CFR 71.45(b)(3), which requires that "each tie-down device that is a structural part of a package must be designed so that failure of the device under excessive load would not impair the ability of the package to meet other requirements of this part." No analysis of the consequences of tie-down failure is included in the application.

This information is required by the staff to determine compliance with 10 CFR 71.45(b).

Request for Additional Information

AOS RAI 2-25 Response:

The current package configuration includes the cask assembly and personnel barrier. The reconfigured personnel barrier for the AOS-025, -050, and -100 no longer includes tiedown devices that are integral to the design. Tiedown is accomplished with standard chains and straps. Therefore, the requirements of 10 CFR 71.45 are satisfied. The attachment of the cask to the pallet is evaluated for loads experienced during normal conditions.

Request for Additional Information

RAI 2-26:

Clarify whether the personnel barrier is part of the package design and revise the application to prove compliance with regulations accordingly.

Table No. 5.5 "Activation Product Maximum Radiation Level Summary for Normal Conditions of Transport – All Models," footnote (a) states: "For this analysis, the package surface is considered to be the personnel barrier."

Information Notice 80-32 ""Clarification of Certain Requirements for Exclusive Use Shipments of Radioactive Materials" states the following, referring to package coverings used as exterior surfaces in terms of "closed transport vehicles": "The personnel barrier essentially becomes an integral part of the transport vehicle in such a case and may not be considered to be a component of the package."

However, the AOS packages are not specified to be exclusive-use, nor is there any justification for use of the package's Personnel Barrier as a part of a closed transport vehicle under exclusive use.

This information is required by the staff to determine compliance with 10 CFR 71.71(7), 10 CFR 71.45, and 10 CFR 71.47(a).

AOS

Request for Additional Information

AOS RAI 2-26 Response: The personnel barrier is always in place in NCT, and therefore is used as the position to measure dose. The package will not necessarily be sent exclusive use.

Chapter 1
General Information

Request for Additional Information

RAI 1-2:

Provide the detailed chemical characteristics, physical characteristics, location, and configuration of the contents of the AOS Transport Packaging System, and indicate whether the contents will be Special Form or Normal Form. This RAI is a follow up to AOS response to RAI Nos. 1.2 and 2.8, dated December 24, 2009.

The chemical and physical form shall include density and moisture content. The location and configuration of the contents within the packaging shall include secondary containers, wrapping, shoring, and other materials not defined as part of the packaging.

The staff needs to know precisely what the content materials consist of (as listed above) in order to determine if the 1000°F temperature limit is bounding for all contents that will be transported in the AOS Transport Packaging System, and to determine if any materials will be subject to chemical, galvanic, or other reactions, including the generation of combustible gases.

Request for Additional Information

RAI 1-2 (Continued):

Section No. 2-10 of the application indicates that "Special Form material does not apply for the AOS Transport Packaging System," but Section No. 1.2.2 and Table No. 1-3 of the application indicate that the package can be used for transporting solid radioactive material in Normal or Special Forms. If Special Form is a content of the AOS Transport Packaging System, a note indicating "current Certificate of Compliance, as Special Form, required" must be added to Table No. 1-3.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.33(b)(3) and 71.4.

Request for Additional Information

AOS RAI 1-2 Response:

Carbon, sodium, phosphorus and selenium will be removed from allowable contents.

All materials with melting point less than 1000 deg. F will be required to be in special form.

Shoring will be material with melting point above 1000 deg. F.

Certificate of Compliance will be required for all *Special Form* material

Section 2-10 will be modified to be consistent with section 1.2.2

Radioactive material may be in any location in the package and unconstrained within the inner containers. However, the inner containers must be immobilized by the shoring.

The SAR will be updated to reflect these points.

AOS

Chapter 3
Thermal Evaluation

AOS

Request for Additional Information

RAI 3-3:

Provide a clear reference for the seal temperature limit of 572°F that appears in Table Nos. 3-3 and 3-4 for the silver jacketed HELICOFLEX seal. This RAI is a follow-up to AOS response to RAI No. 3-8, dated December 24, 2009.

The origin of the 572°F rated seal temperature should be clearly stated in the application.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.33(a)(2).

Response:

We obtained the information from the manufacturer. We are obtaining additional information to support this reference. This will support the determination of 572 as the control temperature. A reference note will be added to Tables 3.3 and 3.4 to identify that the information came from the Manufacture of the seal.

Request for Additional Information

RAI 3-11:

Address the temperatures of the contents, basket, and shielding liners/plates that have not been modeled due to the assumption of uniform decay heat in Section 3.5.6 of the application. This RAI is a follow-up to AOS response to RAI No. 3-31, dated December 24, 2009.

Regarding the response to RAI No. 3-31, the applicant has chosen to not perform a thermal analytical model containing the radioactive contents, basket, or removable shielding, but has instead chosen to continue to apply a uniform decay heat to the cavity walls. The applicant has therefore not predicted temperatures for the radioactive contents, basket, or removable shielding. The staff believes that the cask cavity predicted temperatures using an applied uniform decay heat, underestimates the temperature of the contents in the cask cavity (radioactive contents, basket, and removable shielding). This was demonstrated in the physical test where higher temperatures were observed in thermocouples 1 and 2 which were located inside the cask cavity during the physical test. The applicant stated in the RAI response that this was due to the fact that the heat was applied to the center of the cavity.

Request for Additional Information

RAI 3-11 (Continued):

All types of contents in each package need not be modeled; instead the applicant should evaluate the most bounding contents and determine that the performance of the package is acceptable with those contents. This should include an evaluation of predicted temperatures, MNOP, and HAC cavity pressures.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.71 and 71.73.

Response:

SAR does not limit particular configurations. The decay heat distribution is applied in a manner that produces maximum stress at critical locations. The SAR limits the types of materials that will be used in shoring to those that remain solid at 1000 F.

AOS

Request for Additional Information

RAI 3-14:

Revise Table No. 2-18 of the application, so that the thermal design test description is in agreement with Section No. 8.1.7 of the application.

The thermal design test description in Table No. 2-18 of the application appears to be related to the thermal test performed on the Model No. AOS-165 package, that is now in Section Nos. 3.5.7 and 3.5.8 of the application, but was in Section No. 8.1.7 in prior revisions of the application.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.107.

Response: The description of the Thermal Test in Table 2-18 is revised to give a more general description that is agreement with Section No. 8.1.7.

Chapter 5
Shielding Evaluation

Request for Additional Information

RAI 5-1:

Update Chapter No. 5 of the application to provide additional information demonstrating that the package meets the dose rate requirements in 10 CFR 71.51(a)(1) under the tests specified in 10 CFR 71.71.

The current revision of the application (Rev. D, 9/2010) uses the personnel barrier as a reference surface for performing dose rate calculations. For non-exclusive use packages, the dose rate requirements in 10 CFR 71.47 and 71.51 are for the "external surface of the package" therefore the staff must interpret the personnel barrier as part of the package. However, as noted in RAI 2-26, the structural adequacy of this surface has not been demonstrated. RAI 2-26 also requests that the applicant provide a definition of the surface of the package. As a result of RAI 2-26, the staff believes that the applicant will submit information supporting one of two possible cases: (1) the applicant demonstrates the structural performance of the personnel barrier to the extent that would limit the doses at the personnel barrier up to the allowable regulatory level under normal conditions of transport (e.g., 4-foot drop) and hypothetical accident conditions or (2) the applicant defines the package surface as the impact limiter.

Request for Additional Information

RAI 5-1 (Continued):

For whichever surface is defined as the package surface in response to RAI 2-26 (either the personnel barrier or the impact limiter), the applicant should demonstrate compliance with 10 CFR 71.51(a)(1) which requires that there be no significant increase in external surface radiation levels as a result of the tests specified in 10 CFR 71.71. Paragraph 646 of IAEA regulations (TS-R-1, 2009 edition) quantifies this as a 20% increase in the maximum radiation level at the surface of the package.

In the case (2) where the surface of the package is redefined as the impact limiter, the applicant should also recalculate all dose rates at the surface of the impact limiter and 1 meter from the impact limiter to demonstrate compliance with 10 CFR 71.47. In addition, moving the dose point location closer to the source (without altering contents) will reduce the current safety margin for certain contents (as currently specified) within certain packages. For cases in which the margin is significantly reduced the staff expects that the analysis will include additional uncertainty evaluations with respect to package design tolerances, content definition and measurements, shielding code, etc.

AOS

Request for Additional Information

RAI 5-1 (Continued):

This question is a follow-up to Observation 3 submitted with the Request for Supplemental Information (RSI) dated July 31, 2009, and RAI Nos. 5.6 and 2.7 submitted with the RAI letter dated December 24, 2009.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.47 and 71.51.

AOS RAI 5-1 Response:

The current plan is to modify the personnel barrier then perform analysis that demonstrates the deformed position of the personnel barrier NTC is equal to or further from the cask surface than the analysis points in Chapter 5. Therefore, the dose rate analysis in Chapter 5 is conservative to the current design.

Response Schedule

Complete analysis and verifications TBD

Update SAR document 4 weeks later

Submit updated SAR to NRC 1 week later

BACKUPS

Chapter 1
General Information

Request for Additional Information

RAI 1-1:

Clarify the Ci/Watt values for Co-60 and Sr/Y-90 in Table No. 1.2 of the application. Also clarify the activity values for Sr/Y-90. This RAI is a follow-up to AOS's response to RAI No. 3-6, dated December 24, 2009.

The Ci/Watt values for Co-60 and Sr/Y-90 have changed from Rev. C to Rev. D of the application. The activity values in Ci and TBq for Sr/Y-90 do not appear to be equivalent.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.33(b).

Response:

The values for Co-60 and Sr/Y-90 were rounded to 1 significant figure in Table 1-2. The SAR will be revised to have 3 significant figures to be consistent with the other isotopes.

AOS

Request for Additional Information

RAI 1-3:

Correct the inconsistency in gross weight values on the nameplates and Note 3 in Licensing Drawing No. 166D8142, sheet 2, and No. 166D8143, sheet 2. Similar inconsistencies also appear to exist for the Model Nos. AOS-50 and AOS-100 packages. This RAI is a follow-up to AOS response to RAI No. 1-12, dated December 24, 2009.

The weight listed on any nameplate should be the package weight (packaging, contents, and impact limiters). It appears that Licensing Drawing No. 166D8142, sheet 2 lists the Model No. AOS-25 package weight as 168 pounds (packaging, contents, and impact limiters) on the nameplate and note 3, while Licensing Drawing No. 166D8143, sheet 2 lists the Model No. AOS-25 package weight as 140 pounds (packaging without impact limiters, and contents). While Licensing Drawing No. 166D8143 does not show the impact limiters, the weight on the nameplate should include the impact limiters and note 3 should be consistent with the nameplate.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.33(a)(2).

Request for Additional Information

RAI 1-3 Response:

The name plate is to be used for information on the cask. It is not intended to meet marking requirements for the package. The weight is the proper weight for the cask and contents (excluding the impact limiter), and is intended to assure that personnel have proper values for lifting and rigging of a cask. The nameplates will be removed from the certification drawing.

AOS

Request for Additional Information

RAI 1-4:

Make the following corrections and changes to the licensing drawings (see tables below), and modify Table No. 2-17 of the application to precisely match the information in the drawings.

All components with safety classification A or B must have at least one material specified by a national consensus standard and the corresponding material grade or type. For example, "300 series stainless steel" is not an acceptable material designation, but ASME SA-240/ASTM A240 Type 304 is acceptable.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.51(a)(1) and 71.51(a)(2).

Response:

These changes will be made and safety classifications added where appropriate.

AOS

Chapter 3
Thermal Evaluation

Request for Additional Information

RAI 3-1:

Ensure that the following are in agreement with the licensing drawings, Chapters Nos. 3 and 4 of the application:

a. Quality category for each of the containment boundary seals.
b. Temperatures for all containment boundary seals.
c. Locations, in the thermal models, for all containment boundary seals.

In addition, clarify if the copper alloy seals that are mentioned in Section No. 3.2.2 of the application are containment boundary seals. This RAI is a follow-up to AOS responses to RAI Nos. 1-1 and 4-2, dated December 24, 2009.

For example, in Drawing 105E9712, for the Model No. AOS-100 package, item numbers 30 and 31 are Category A copper seals, while item numbers 19 and 29 are silicone and Category B. From the Figure No. 4-1 of the application, it appears to the staff that the applicant is stating that item numbers 19 and 29 are the containment boundary seals, which is in contrast to the Category B quality category given in drawing 105E9712.

Request for Additional Information

RAI 3-1 (Continued):

Looking further at the vent port in the thermal chapter, it appears that the applicant is pulling a temperature from detail X in the lid area of drawing 105E9712 sheet 3. This also does not appear to be in agreement with Figure No. 4-1 of the application. It also appears that the applicant has switched the labeling of the vent port and test port in the thermal chapter and on the licensing drawings, which may be the case for all AOS models, not only the Model No. AOS-100 package. Finally, if the copper alloy seals are not part of the containment boundary, they should be removed from Section No. 3.2.2. On the contrary, if there are containment boundary seals that are not mentioned in Section No. 3.2.2, these should be mentioned in that section and their peak temperatures should be provided in Table Nos. 3-3 and 3-4. The drawings quality category and seal location for the containment boundary seals, the seal temperatures provided in Chapter No. 3, the seal temperature locations from the thermal model, and the containment boundary seals in Chapter No. 4 of the application should all be in agreement. The applicant needs to present a clear understanding of the containment boundary location and of its components throughout the entire application.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71,33(a)(4), 71.51, 71.71, and 71.73.

Request for Additional Information

AOS Response 3-1:

We will review the temperatures and assure they are properly used in Chapter 4. Safety classifications of the containment components are correct. In the case of item numbers 19 and 29 these items are seals for the port cover which is not required for containment. The containment boundary is maintained by Items 20 and 28 (pipe plug). The containment boundary has been clarified on Figure No. 4-1.

Request for Additional Information

RAI 3-2:

Confirm that the correct temperatures per Regulatory Guide 7.8 for load case 111 in Table No. 2-4 of the application are being used. Also confirm that the temperatures from the latest thermal models as reported in the application have been used when required for all stress analysis load combinations.

Because there are two thermal load cases with the designation number 111 for each AOS model (for example lc111-t1-mf.025 and lc111-t2-mf.025 for the Model No. AOS-025 package), a confirmation that the temperatures from the lc111-t2-mf.XYZ thermal model at the end of the thirty minute fire are being used in the subsequent load combination 350 is required. It appears that some of the thermal input files were created after the stress analysis was run. It seems that the AOS-25 thermal input files were created on 9/14/2010 and the AOS-50 thermal input files were created on 6/27/2010, while the stress analysis output files appear to have been created between 6/3/2010 and 6/6/2010. Confirmation is needed to determine if the latest thermal models have been used when required for the stress analysis. If confirmation cannot be provided, the stress analysis should be rerun with temperatures from the latest thermal models.

AOS

Request for Additional Information

RAI 3-2 (Continued):

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.107.

Response:

The analyses were performed in the proper order. During review and verification some files had comments updated which changes the creation date. Therefore, it appears that thermal files were created prior to the stress files. We will review and confirm that only comments, not data, were changed in the files that appear to be out of order.

Request for Additional Information

RAI 3-4:

Justify the validity of the simplified approximation of increasing the impact limiter foam density and thermal conductivity based on reduced impact limiter volume due to HAC deformation without actual foam crush data. This RAI is a follow-up to AOS response to RAI No. 3-24, dated December 24, 2009.

The applicant made simplified assumptions on the density and thermal conductivity of the impact limiter foam based on the reduced volume of the impact limiter due to the HAC deformation. These assumptions must be justified with a demonstration that the approximation is bounding for the actual behavior of the foam when it is crushed.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.73.

Request for Additional Information

AOS Response 3-4:

When the material is crushed the density increases. Because information is not available at every density, interpretations are made between available data points. This method was suggested by the manufacturer and is a reasonable engineering solution. To further analyze the results we will perform sensitivity calculations around the values used to assure the results do not challenge limits.

An analysis of the AOS-100A model will be performed with uncrushed geometry. The properties are design values for a 12 pcf foam. This study will demonstrate that maximum cask component temperatures are not significantly affected by changes in foam properties.

Request for Additional Information

RAI 3-5:

Revise the heat flux shown in Table No. 3-12 of the application for the Model No. AOS-25 package.

In Table No. 3-12, the decay heat divided by the cavity area is not equal to the heat flux that is provided in Table No. 3-12 for the Model No. AOS-25 package.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.33(b)(7).

Response:

In Table 3-12, the heat flux for model AOS-025 is listed as1.51 BTU/hr-in^2. The correct value is 1.15 BTU/hr-in^2. A correction to Table 3-12 will be made.

AOS

Request for Additional Information

RAI 3-6:

Describe and justify how the current thermal models capture the thermal performance of the impact limiters, specifically with respect to the inside ribs that appear in the engineering drawings and their effect on peak temperatures of components such as containment boundary seals.

The thermal models of the impact limiters for the Model Nos. AOS-25, AOS-50, and AOS-100 packages appear to only consist of the impact limiter foam and the stainless steel outer shell of the impact limiters. In the engineering drawings there is a significant number of stainless steel inside ribs that have not been thermally modeled. Describe the affect of the impact limiter ribs on peak temperatures of components such as containment boundary seals. This may be best addressed by determining the AOS model where the impact limiter ribs would have the largest effect on seal temperatures and then modifying that thermal model to include the inside ribs as part of a sensitivity study.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.71 and 71.73.

Request for Additional Information

AOS Response 3-6:

The ribs add small conductivity reducing temperatures except, possibly, for fire condition. In addition, leaving the ribs out is conservative in the stress calculations. We will run NCT and HAC cases with rib conductivity for comparison.

Request for Additional Information

RAI 3-7:

Provide an explanation for the decrease in temperature of the lid plug and the cavity shell peak temperatures during the first 5 to 20 minutes of the fire that can be seen in Figure Nos. 3-18, 3-45, 3-72, and 3-97 of the application.

This is a phenomenon that is somewhat unexpected considering the boundary temperature has increased from 100°F to 1475°F. Noting that the air gaps within the package have been closed during the fire makes the phenomenon more realistic. Justification of the behavior should be provided in Section No. 3.4.6 of the application.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.73

Request for Additional Information

AOS Response 3-7:

The phenomenon caused by increased conductivity due to gap closures for fire condition. The closed gap is a conservative assumption during the fire period to increase heat flow. There is a brief period following gap closure when conductivity is increased and the fire heat has not reached plug. During this brief period the plug cools.

Request for Additional Information

RAI 3-8:

Provide a single thermal analysis of the worst-case post-accident condition of the package. The post-fire orientation and boundary conditions should be realistic based on the drop event. In addition, clarify if the "Side crush" that appears in Figure Nos. 3-124 through 3-126 is referring to side drop damage of the package. The thermal analysis should also include any crush and puncture damage which has been requested to be addressed in RAI 2-19 of this package. This RAI is a follow-up to AOS response to RAI No. 3-25, dated December 24, 2009.

Figure Nos. 3-124 through 3-126 of the application show all drop effects modeled simultaneously. The applicant should justify the one HAC drop that results in highest component temperatures and only model the effects of that drop. The worst case orientations (post-fire) should also be justified (i.e., vertical or horizontal) and boundary conditions should be realistic based on the drop event. Section 3.5.4.2.5 provides a sensitivity study for 50% drop deformation versus 100% drop deformation. The consideration of 50% drop deformation is not consistent with providing a single thermal analysis of the worst-case post-accident condition of the package.

Request for Additional Information

RAI 3-8 (Continued):

The staff recommends removing Section 3.5.4.2.5 and applying 100% deformation for the one HAC drop that results in the highest component temperatures and only model the effects of that drop. Crush and puncture damage, if present, should also be included in the thermal models which have been requested to be addressed in RAI 2-19 of this package. Finally, the staff notes the outside shell maximum temperature in Table No. 3-90 of the application does not match the maximum post-fire temperature presented in Table No. 3-4 of the application for the Model No. AOS-100A package.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.73

Response:

A thermal HAC fire analysis for all models will be performed with head-on drop deformed geometry. that include only the head-on drop deformations. Also, in the RAI #6 response, a thermal HAC fire condition will be evaluated for an uncrushed model AOS-100A configuration.

AOS

Request for Additional Information

RAI 3-9:

Justify the use of the equation for equivalent convection due to radiation in Section Nos. 3.5.4.4.1 and 3.5.4.4.2 of the application for air gap No. 5 for all thermal models. This RAI is a follow-up to AOS response to RAI No. 3-16, dated December 24, 2009.

*The equation given in Section Nos. 3.5.4.4.1 and 3.5.4.4.2 is hr = S*F*4*T3 which makes the approximation that the temperature on both sides of the air gap is the same. The air gap No. 5 in all thermal models has a rather large temperature difference across the air gap, up to 242.2°F during the AOS-25 post-fire as is seen in Table No. 3-97. If the use of the equation cannot be justified, an alternative method for modeling the radiative heat transfer across the air gap should be provided and the thermal models, temperature plots, peak temperatures should be updated accordingly.*

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.71 and 71.73.

Response:

Additional calculations will be provided that demonstrate the radiation approximation used in SAR is both appropriate and conservative for these temperature differences.

Request for Additional Information

RAI 3-10:

Correct the equation for Tf in Section No. 3.5.4.6 of the application.

The equation in Section No. 3.5.4.6 of the application should be Tf = (Tw – Tb) / 2 + Tb. The staff notes that the values for Tf in Table No. 3-121 of the application are from this equation and the values are correct.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.35.

Response:

The equation in Section 3.5.4.6 should be $T_f = (T_w + T_b) / 2$
Correction will be made in the SAR.

AOS

Request for Additional Information

RAI 3-12:

Clarify how the five rows of "Temperature change" values were arrived upon. Also address why an ambient temperature of 1475°F was not included in the table. If any changes to Table No. 4-1 of the application potentially results in changes to the lid attachment bolt analysis, the analysis and results should be updated.

It is not clear how the five rows of temperature change values were arrived upon; the values do not appear to match up with thermal model temperature changes across surfaces or temperatures of surfaces. The staff also notes that if the values are temperature changes, a delta T of 80°C is not equal to a delta T of 176°F. It is also not clear to the staff why an ambient temperature of 1475°F was not included in the table.

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

AOS

Request for Additional Information

AOS Response 3-12:

The cask bolting evaluation is based on the temperature measured from stress free conditions, and is performed for five cask locations in accordance with Reg Guide NUREG/CR-6007. The stress free temperature is 70^{o} F. Both a sketch and a list of the nodal temperature values used for each of the five cask locations will be included into the SAR.

The HAC ambient temperature of 1475^{o} F is a fire and cool down transient condition following a 30 foot drop accident event. There are no impact accelerations associated with cool down, and results of stress evaluations for the cool down show that bolting loads are not significant.

Table 4-1 will be updated to correct all temperature conversion errors.

AOS

Request for Additional Information

RAI 3-13:

Justify how the thermal analysis parameters for the LAST-A-FOAM provide bounding peak temperatures when the material tests described in Table No. 8.5 allow for +/- 15% or 20% tolerance from thermal parameter nominal values. Table No. 8.5 also shows only one nominal value for LAST-A-FOAM density and thermal conductivity, clarify if the material test will be performed for each density and respective thermal conductivity of LAST-A-FOAM used.

Table No. 8.5 shows that the material testing of LAST-A-FOAM allows for +/- !5% tolerance from the nominal density value, +/- 15% tolerance from the nominal thermal conductivity value, and +/- 20% from the nominal specific heat value. The LAST-A-FOAM density and thermal conductivity values used in the NCT analysis are nominal values or are based on nominal values for the HAC analysis which may not be providing the maximum temperatures based on the allowable tolerance for the LAST-A-FOAM material tests. This should be addressed in Section No. 3.3.1 of the application.

AOS

Request for Additional Information

RAI 3-13 (Continued):

If it cannot be justified, the NCT and HAC models should be rerun with the bounding LAST-A-FOAM parameters and peak temperatures should be updated. The staff also notes that only one nominal value for LAST-A-FOAM density and thermal conductivity was provided in Table No. 8-5.

The staff needs clarification if the material test will be performed for each density and respective thermal conductivity of LAST-A-FOAM shown on the engineering drawings. This should be addressed in Table No. 8-5 of the application.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.71 and 71.73.

Request for Additional Information

AOS Response 3-13:

Thermal properties values used in the analyses were the nominal's values given in the manufacture's (General Plastic) literature. The properties values variation given in Table 8.5 represents the degree of accuracy of the test procedure employed in determine the properties values. However, a sensitivity study was performed to determine the effect of these variations have in the temperature field analysis results. This study identified that a ±15% variation on these properties change the temperature field in some areas by a fraction of a degree.

AOS

Chapter 4
Containment

Request for Additional Information

RAI 4-1:

Provide manufacturer data for the design operating range of the lid seals Helicoflex H-309854, H-309852, and H-309850. Provide a complete description of the silver and Alloy 90 materials used in the seals, and correct the Model No. AOS-100 package licensing drawings and Bill of Materials to accurately indicate the lid seal materials. This RAI is a follow up to AOS response to RAI No. 4.1, dated December 24, 2009.

The lid seal references provided could not be found on the manufacturer's website; thus, no information regarding the operating range of the seals was found. The materials composing the lid seal are not adequately defined: a complete description of the materials including composition and temperature dependent thermal and mechanical properties must be provided for the entire design temperature range.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.51(a)(1) and 10 CFR 71.51(a)(2).

AOS

Request for Additional Information

AOS Response 4-1:

The thermal and mechanical properties for the construction materials of the Helicoflex seals were not available for the entire packaging design temperature range; hence, thermal test were performed to address the performance of the seal construction materials.

In addition, the seal manufacturer, Garlock Helicoflex, has revised the seal drawing to provide more specific detail on the material specification of the components either by providing the United Nations, UN, or ASTM reference.

Request for Additional Information

RAI 4-2:

Provide a revised description, in Section No. 4.1.1, and a correct illustration, in Figure No. 4-1, of the containment boundary for the AOS series of packages.

The description of the containment boundary is not clear, nor is the illustration in the current Figure No. 4.1 correct. The staff considers the containment boundary of the package to be the actual physical boundary including cavity walls, ports, and O-rings along (or against) which a particle might travel if attempting to escape from the package. This includes any boundaries that the particle might encounter preventing it from being released. Lid bolts which are used to attach the lid to the cask cavity are not generally considered part of the containment boundary. The actual boundary should be highlighted. An "outline" of the boundary is not acceptable.

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

Response:

Figure No. 4-1 has bend revised to highlight the actual containment boundary.

Request for Additional Information

RAI 4-3:

Define the terms "Primary Vessel" and "Structural Shell" and revise Table No. 2-8 of the application to clearly indicate the relation of the components listed in the table to the components and features of the AOS series of packages.

In Table No. 2-8, the terms "Primary Vessel" and "Structural Shell" are used in the "Containment" and "Other Safety" categories, respectively. These terms appear nowhere else in the entire application. It is not clear what components of the AOS transportation packages these terms apply to. This must be clarified in order for the reviewers to determine what components the underlying codes mentioned in Table No. 2-8 apply to.

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

AOS

Request for Additional Information

AOS RAI 4-3 Response:

The terms in the header were directly copied from the Regulatory Guide without changing the nomenclature to be consistent with the SAR. The table will be updated to be consistent with the rest of the SAR.

Request for Additional Information

RAI 4-4:

Provide clarification of Section No. 4.4, which states that the section "describes the leakage test used to demonstrate that the AOS transport packages meet the containment requirements of 10 CFR 71.51" and yet does not provide this description.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.51.

AOS RAI 4-4 Response:

Application will be revised such that Section 4.4 properly referenced the corresponding subsection 8.2.2, Leakage Tests in Chapter 8 - Maintenance, will be updated to provide more details on the leak tests to be performed on these packages.

Chapter 7
Package Operations

Request for Additional Information

RAI 7-1:

Ensure every package for shipment undergoes a temperature survey to verify that limits specified in 71.43(g) are not exceeded. This RAI is a follow-up to AOS response to RAI No. 7-3, dated December 24, 2009.

Based on NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material," Section 7.5.1.3, every package for shipment undergoes a temperature survey to verify the limits specified in 71.43(g) are not exceeded. Section No. 7.1.3.4 of the application states: "Note: step k does not need to be performed for routine shipments of the same payload, after three (3) initial thermal surveys are conducted. From then on, step k should be conducted every 10 shipments. Step k must always be conducted for shipments in which the content decay heat value is equal to or greater than 80% of the maximum authorized decay heat value."

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

AOS

Request for Additional Information

AOS RAI 7-1 Response:

The SAR will be updated to require measurements of every package.
Note: Step k has been deleted.

Request for Additional Information

RAI 7-2:

Modify the following sections of Chapter No. 7 “Package Operations” per the descriptions provided below:

- *Section No. 7.1.1.1.d. (and following) – the term “Job Supervisor” is not a widely used nor understood term, and may not apply to all users of the AOS transport system. Provide a definition of this term, or use a more applicable generic term.*

AOS RAI 7-2 Response:

The following definition will be added the paragraph 7.1.1.1.d “The Job Supervisor is the person responsible for direct oversight of people who are actually performing the work.”

Request for Additional Information

RAI 7-2 (Continued):

- *Section No. 7.1.3 – the sequence of the placement and securing of the cask lid, especially when the cask is loaded underwater, is not clear. Specifically, it is not clear if the lid is placed on the unit and secured (lid bolts tightened) while it is still submerged or if this is done after the unit is removed from the water. It is also unclear what steps are taken to remove water from the threaded holes in the cask lid flange.*

AOS RAI 7-2 Response (Continued):

Paragraph 7.1.3.2.b will be reviewed as follows to provide additional details. “If the cask was loaded under water, place the lid underwater, remove cask from pool, placing at least 5 bolts to held the lid as the cask break the water surface, drain the cask, by removing the drain and vent ports cover and threaded plug and dry the bolts threaded holes including those bolts holes where the bolts were installed prior to removing the cask out of the water. To displace any remaining water within the cavity.”

Request for Additional Information

RAI 7-2 (Continued):

- *Figure No. 7-4 – State whether this figure represents the actual vacuum drying system that is expected to be used for the AOS transportation system. It is not clear what a "Typical Vacuum Drying System" means in this case. In addition, this figure is of poor quality and difficult to read.*

AOS RAI 7-2 Response (Continued):

Figure 7-4 illustrates a typical vacuum drying system which draws vacuum and measures pressure conditions. The equipment consists of ultra fine vacuum pump, vacuum pressure gauge, cryogenic water trap, vacuum connectors and valve. The subject figure, the schematic of vacuum drying system equipment currently in used, will be revised to improve legibility.

AOS

Request for Additional Information

RAI 7-2 (Continued):

- *Section No. 7.1.3.3 – This section is titled "Assembly Verification Leak Testing," however, it describes a pre-shipment leak test. This does not coincide with the term used in Table No. 8-1 "Acceptance Test Matrix," which lists a "Containment at assembly" verification test. Clarification of the terminology is requested. In addition, the section does not provide acceptance criteria for the pre-shipment leak test. This should be added.*

AOS RAI 7-2 Response (Continued):

Paragraph 7.1.3.3 leading sentence will be revised as follows: "To verify that the containment system of the package is properly assembled for shipment the following Pre-shipment leak test is performed:" The information given in Table 8-1, under "Containment at assembly refers fabrication leak test requires under clause 7.3 of ANSI N14.5, "Leakage Tests on Package for Shipment."

Request for Additional Information

RAI 7-2 (Continued):

- *Section No. 7.1.3.3.a. – Provide a justification for the use of a thermal conductivity sensing instrument for leak testing. Leak testing using a "thermal conductivity sensing instrument" is not a standard industry practice. It is not clear that this method is appropriate for the pre-shipment testing of the package to the required sensitivity.*

AOS RAI 7-2 Response (Continued):

Clause 8.4, "Sensitivity," ANSI N14.5 requires that the Preshipment Leakage Rate need not to be more sensitive than 1 x 10-3 ref cm3/s. Leak detection instrument based on thermal conductivity changes in the tracer gases is sensitive up to 1 x 10-5 ref.cm3/s. The portability and adequacy of these instruments made the instrument ideal for this application as demonstrated in their used since 1993 in the GE Model 2000 Package.

AOS

Request for Additional Information

RAI 7-2 (Continued):

- *Section No. 7.2.2.a. – The "site's Safeguard organization" is not a widely used nor understood term, and may not apply to all users of the AOS transport system. Provide a definition of this term, or use a more applicable generic term.*

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

AOS RAI 7-2 Response (Continued):

Paragraph, 7.2.2.b will be revised as follows: "Break the tamper-indicating device(s), if applied. In the event that the device is broken, indicating tampering, isolate the cask and immediately notify the site's Safeguard organization, then wait for their instructions. "Safeguards organization" refers to the organization or person at the facility responsible for maintaining an inventory of radioactive material."

Chapter 8
Acceptance Tests and Maintenance Program

AOS

Request for Additional Information

RAI 8-1:

Justify how the first fabricated packages used in the thermal test, as shown in Figure No. 8-1 of the application, will demonstrate the heat transfer capability of the packages as shown in the engineering drawings. Clarify if new thermal analytical models will be created to compare the predicted temperatures to the thermal test temperatures. This RAI is a follow-up to AOS response to RAI No. 8-3, dated December 24, 2009.

The purpose of the thermal test is to demonstrate the heat transfer capability of the packaging and that the heat transfer performance determined in the evaluation is achieved in the fabrication process. There are clearly some differences between the AOS models shown in the engineering drawings and the thermal test model shown in Section No. 8.1.7 (no impact limiters or lid plug). The applicant should address that the majority of fabrication gaps have been captured by the thermal test model as shown in Figure No. 8-1 and in conjunction with the material tests for the impact limiter foam, the heat transfer performance of the packages will be demonstrated.

Request for Additional Information

RAI 8-1 (Continued):

Clarify in Section No. 8.1.7 if new thermal analytical models will be created to compare temperature predictions with the results of the thermal tests.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.85(a) and 71.87(b).

AOS RAI 8-1 Response

- Post fabrication of each AOS Model, a thermal test will be conducted (reference Subsection 3.5.7). The test configuration of the packaging will be modeled using finite analysis techniques and results compared against the analytical results, documented in Appendix 3.5.7 of the SAR.

Request for Additional Information

AOS RAI 8-1 Response (Continued):

- The objective of the test reported in Appendix 3.5.7 "Thermal Test," is to evaluate the analytical model used to demonstrate compliance with the thermal regulatory requirements. By this we mean "is the model capable to predict with good accuracy the temperature within the cask having the heat content fairly distributed in the cask cavity." It is our engineering judgment that the modeling of the cask is more difficult to perform that the modeling of the impact limiters. This is so because the dissimilar materials used in the design and the several gaps among components produced by the manufacturing and assemblies processes. And if we were to model the entire package (cask, content and impact limiters) still the cask structure and content would greatly influence the analytical outcome. Therefore, we concentrated our effort in getting the cask/content model as accurate as possible. The exclusion of the lid plug component was needed to have room to introduce the electric and thermocouple wires into the cask cavity and it was our assessment this will no impact on the test objective as long as model and test object have the same dimensions and geometry.

AOS

Request for Additional Information

AOS RAI 8-1 Response (Continued):

- The following sentence will be added at the end of the first paragraph of Subsection 8.1.7, “Thermal Tests:” The analytical model developed for this test must has the same component arrangement that those of the test prototype to allow a direct comparison of results.

Request for Additional Information

RAI 8-2:

Justify the use of SA-193 Grade B8RA and SA-564 Type 630-H1100 as bolting materials (Table 8-3). If these materials are to be used, provide all corresponding temperature dependent mechanical and thermal material properties.

SA-193 Grade B8RA and SA-564 Type 630-H1100 are not mentioned anywhere either in the drawings or the application, except in Table No. 8-3. Explain this discrepancy.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.43(d), 71.51(a)(1), and 71.51(a)(2).

AOS RAI 8-2 Response:

These bolts were not used in the final package therefore, reference to alloys SA-193 Grade B8RA and SA-564 Type 630-H1100 in Table 8-3 will be deleted from the Table.

AOS

Request for Additional Information

RAI 8-3:

Clarify statements made in Section No. 8.1.4 “Leak Tests,” regarding the leak test procedures meeting the ANSI N14.5-1997 standard.

The statement “The leak test procedure meets the ANSI N14.5-1997 standard” is made followed by a general description of the leak tests conducted before first use, after its third use, and every 12 months thereafter, on the AOS series of packages. The statement cannot be verified, given that detailed leak-test procedures are not provided nor is a description of the how the proposed “leak test procedure” specifically meets ANSI N14.5.

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

Request for Additional Information

AOS RAI 8-3 Response:

The SAR will be updated to be clear that a requirement of Chapter 8 is that the site specific leak test procedure must meet the requirements of ANSI N14.5-1997. In particular, the site specific procedure shall conform to the acceptance limits and testing methodology required in the standard.

Request for Additional Information

RAI 8-4:

Define a "Routine" leak test and compare it to a "pre-shipment" leak test in Section No. 8.2.2. "Leakage Tests." Clearly state that this test is conducted prior to each shipment of a package.

It is not clear from the description provided in Section No. 8.2.2.a that the test described is conducted prior to each shipment of any of the AOS series of packages.

This information is required by the staff to determine compliance with the requirements of 10 CFR 71.87.

Request for Additional Information

AOS RAI 8-4 Response:

In the SAR, pre-shipment and routine are synonyms. The SAR will be updated to only use the term pre-shipment.

Paragraph 8.2.2.a will be revised to read:

Preshipment Leak Testing (Conduct for Normal Form content only)

Leak testing of the cask closure seal and vent and drain threaded pipe plugs is conducted with a tracer gas (Helium) sniffer detector prior to each shipment of Normal form type materials. Pressurize to one (1) atm pressure differential across the boundary to be tested (verified with a double pressure gauge), sniff the seal test port and the outside of the threaded plug area of the drain and vent ports with the instrument, to determine whether helium is present. The instrument to be used must be calibrated to a sensitivity of 1×10^{-5} atm cm^3/sec (helium) or greater. If leakage greater than 1×10^{-3} atm cm^3/sec is detected, repair or replace the suspect component(s), then retest for leakage.

AOS