August 2024

Revision 24B

Volunteer® Package

SAFETY ANALYSIS REPORT

RSI Responses

NON-PROPRIETARY VERSION

Docket No. 71-9403

NAC INTERNATIONAL

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Enclosure 1

RSI Responses

Volunteer Package SAR, Revision 24B

Docket No. 71-9403

August 2024

SECTION A

NAC INTERNATIONAL
PROPRIETARY RESPONSES TO THE NUCLEAR REGULATORY COMMISSION

JULY 16, 2024

REQUEST FOR SUPPLEMENTAL INFORMATION FOR REVIEW OF THE NAC INTERNATIONAL VOLUNTEER PACKAGE

August 2024

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NAC INTERNATIONAL RESPONSE
TO
REQUEST FOR SUPPLEMENTAL INFORMATION

CHAPTER 2 - STRUCTURAL AND MATERIALS EVALUATION

2-1 Provide the following supporting or reference documents:

(1) NAC Calculation EA790-2233, Revision 0, “Reduction of Redwood and Balsa Test Data Prepared by Navy Warfare Center”, NAC International, Atlanta, Georgia
(2) STC-CY Test report, “NAC International STC Impact Tests”, Sandia National Laboratories, November 13, 2001
(3) CY-STC Quarter Scale Model Drawings:
  a. 423-352, Revision 0, Balsa Impact Limiter, Upper, 1/4 Scale, NAC-STC Cask
  b. 423-353, Revision 0, Balsa Impact Limiter, Lower, 1/4 Scale, NAC-STC Cask
  c. 423-354, Revision 2, Drop Test Assembly, 1/4 Scale, NAC-STC Cask
  d. 423-355, Revision 2, Cask Body-Scale Model 2nd Generation, NAC-STC Cask

The safety analysis report (SAR) section 2.13.1.2.1 and Calculation 70000.38-2201, Revision 0 describe benchmarking of the LS-DYNA code for the dynamic drop analysis of the Volunteer package by comparing the results of LS-DYNA computer simulations to the measured response from ¼-scale-model physical drop tests of the CY-STC package. The applicant submitted the SAR and supporting structural analyses calculations with the application. However, some of the information in the safety and/or supporting analyses rely on or reference information contained in the above listed documents that were not available with the application.

The staff needs to review these documents to verify their relevance in determining that the benchmarking approach is sufficiently robust and capable of producing analytical results for the proposed impact limiter that would be consistent with results produced in a physical test.

This information is required to determine compliance with Title 10 of the *Code of Federal Regulations* (10 CFR) Section 71.73.

NAC International Response to RAI 2-1:

[redacted]

NAC INTERNATIONAL RESPONSE
TO
REQUEST FOR SUPPLEMENTAL INFORMATION

CHAPTER 2 - STRUCTURAL AND MATERIALS EVALUATION

OBSERVATION 2-2

Clarify the relevance of using LS-DYNA crushable foam material model for the drop analysis of the cask with Balsa wood as impact material. If not relevant, update the affected licensing documents as necessary.

The SAR, Revision 24A, section 2.13.2 on top of the page 2.13-7 states that the impact limiter balsa wood end and side cores are modeled using the LS-DYNA crushable foam material model. Also, the SAR section 7.4.4 first two paragraphs refers to LS-DYNA crushable foam material model. The calculation 70000.38-2201, Revision 0, “LS-DYNA Drop Analysis of Volunteer Balsa Wood Impact Limiter,” section 4.7 refers to LS-DYNA crushable foam material model and list acceleration values for LS-DYNA prediction with new and standard foam material in Figure G3-1.

It is unclear to the staff that there is any relevance of an LS-DYNA crushable foam material model with the SAR section 2.13.1.2.1, which describes the benchmark analysis of the LS-DYNA code for the dynamic drop analysis of the Volunteer package by comparing the results of LS-DYNA computer simulations to the measured response from ¼-scale-model physical drop tests of the CY-STC package.

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

NAC International Response to RAI 2-2

[redacted]

[redacted]

NAC INTERNATIONAL RESPONSE
TO
REQUEST FOR SUPPLEMENTAL INFORMATION

CHAPTER 2 - STRUCTURAL AND MATERIALS EVALUATION

OBSERVATION 2-3

Provide details of how the stiffness of the crushable impact limiter material properties were derived for the Volunteer and ¼ scale model of the CY-STC packages.

Table 2.13.-1 of the SAR provides comparison of the Volunteer and CY-STC Impact Limiter Design Parameters, which includes Side Wood Stiffness and End Core Stiffness. This table documents Side Wood Stiffness derivation formula as (B × C × E) and End Core Stiffness formula as (~H2 × L).

The variables in these formulas are not defined anywhere, and their values are not provided either. The staff needs this information to confirm that the properties of the impact limiter are appropriately captured in the LS-DYNA numerical model for impact simulation.

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

<u>NAC International Response to RAI 2-3</u>

[redacted]

[redacted]

NAC INTERNATIONAL RESPONSE
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CHAPTER 3 - THERMAL EVALUATION

3-1 Provide additional details on the methodology use to numerically connect dissimilar meshes between the impact limiters and the cask top and bottom, and numerically connect the inner surfaces of the cask and the outer diameter of the helium gap, as well as the top and the bottom regions between the loaded basket and the inner surfaces of the cask.

Section 3.3 of the SAR states that constraint equations are used to numerically connect the dissimilar meshes between the impact limiters and the cask top and bottom. Section 3.3 of the SAR also states that constraint equations are used to numerically connect the Inner surfaces of the cask and the outer diameter of the helium gap, as well as the top and the bottom regions between the loaded basket and the inner surfaces of the cask.

However, details of the approach are not provided in the application. The approach needs to be clearly explained. Also, justification on the adequacy of the approach needs to be provided as how this would result in realistic or conservative results.

The staff needs this information to have assurance predicted temperatures remain below allowable limits during NCT and HAC conditions.

This information is required to determine compliance with 10 CFR 71. 71 and 71.73.

<u>NAC International Response to RAI 3-1</u>:

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

NAC INTERNATIONAL RESPONSE
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CHAPTER 4 - CONTAINMENT EVALUATION

OBSERVATION 4-1

Provide the specifications on the licensing drawing Nos. L115 Rev. 0P, note 3 and L130 Rev. 0P note 5 for, “Or equivalent,” for the containment boundary elastomeric O-rings.

Licensing drawing Nos. L115 Rev. 0P, note 3 and L130 Rev. 0P note 5 describe the selected containment boundary elastomeric O-rings (port cover and lid respectively), but also includes the words “or equivalent”.

The containment boundary component specifications for, “or equivalent,” which are important to safety, category A, have not been provided. Staff suggests removing, “or equivalent,” from the licensing drawings.

This information is required to determine compliance with 10 CFR 71.33(a)(4) and 71.51(a)(1) and (2).

NAC International Response to RAI 4-1:

[redacted]

Attachment 1

RSI Response 2-1, Supporting or Reference Documents

Volunteer Package SAR, Revision 24B

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Supporting or Reference Documents

[redacted]

THESE DOCUMENTS ARE PROPRIETARY AND
WITHHELD IN THEIR ENTIRETY PER 10 CFR 2.390

Enclosure 2

Supporting Calculation

Volunteer Package SAR, Revision 24B

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List of Calculations

1. 12414-2202, Revision 2

CACLULATIONS ARE PROPRIETARY AND
WITHHELD IN THEIR ENTIRETY PER 10 CFR 2.390

Enclosure 3

List of Drawing Changes

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Drawing 70000.38-L115, PORT COVER ASSEMBLY, VOLUNTEER, Rev. 1P

[redacted]

Drawing 70000.38-L130, CASK LID ASSEMBLY, VOLUNTEER, Rev. 1P

[redacted]

Drawing 70000.38-L130, CASK LID ASSEMBLY, VOLUNTEER, Rev. 2P

[redacted]

Enclosure 4

List of SAR Changes

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List of Changes, Volunteer Package SAR, Revision 24B

Note: Changes were made to the List of Effective Pages to reflect the changes listed below; no changes to Chapter Tables of Contents, including the List of Figures and the List of Tables, were required.

Chapter 1

- Page 1.1-1, modified text in the last paragraph on the page where indicated.
- Page 1.6-3, updated drawing revision numbers where indicated.

Chapter 2

- Page 2.13-2, added text to paragraph one of Section 2.13.1.2.1 where indicated.
- Page 2.13-3, editorial change where indicated.
- Pages 2.13-4 thru 2.13-7, text flow changes.
- Page 2.13-8, modified text in the first paragraph on the page where indicated.
- Pages 2.13-9 thru 2.13-47, text flow changes.

Chapter 3 – no changes

Chapter 4 – no changes

Chapter 5 – no changes

Chapter 6 – no changes

Chapter 7 – no changes

Chapter 8 – no changes

Chapter 9 – no changes

Enclosure 5

LOEP and SAR Changed Pages

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Volunteer® Package

SAFETY ANALYSIS REPORT

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13 drawings (see Section 1.6.2)

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Page 2.8-1	Revision 24A
Page 2.9-1	Revision 24A
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Page 2.11-1	Revision 24A
Page 2.12-1 thru 2.12-2	Revision 24A
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Chapter 6

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Page 9.2-1 thru 9.2-7	Revision 24A
Page 9.3-1	Revision 24A

1.1 Introduction

The Volunteer transportation package provides a safe means of transporting a wide range of non-fissile or fissile-exempt radioactive materials contents, as described in Section 1.2.2. The Volunteer packaging has long, standard, and short configurations, designated as Configurations 1, 2, and 3, respectively. Each configuration accommodates various contents as designated by the configuration IDs summarized in Table 1-1 and shown on Drawing No. 70000.38-L100 in Appendix 1.6.2. Package configurations 1A (long), 2A (standard), and 3A (short) are all for irradiated steel contents described in Section 1.2.2.1. Configurations 1B (long) and 3B (short) are for vitrified Level Waste (HLW) in canisters described in Section 1.2.2.2. Configuration 2B (standard) is for TPBAR contents described in Section 1.2.2.3. Furthermore, Configuration 2B has two options designated Configurations 2B-1 and 2B-2, that use different configurations for the internal support structures, as shown on Drawing No. 70000.38-L100 in Appendix 1.6.2.

Because Volunteer is not a fissile package, the CSI is not applicable. Finally, as discussed in Chapter 3, the Maximum Normal Operating Pressure (MNOP) of the package for irradiated steel and vitrified HLW contents is less than 100 psig, and therefore it is designated Type B(U)-96 for these contents in accordance with 10 CFR 71.4 [1-3]. However, the MNOP for TPBAR contents is greater than 100 psig, and therefore it is designated Type B(M)-96 for TPBAR contents in accordance with 10 CFR 71.4 [1-3].

The primary mode of transportation for the Volunteer package is by road, although rail or sea transport modes are also allowed. The Volunteer package, shown in Figure 1-1, consists of a cask assembly that is equipped with upper and lower impact limiters, and containing a payload, with associated internal support structures and dunnage/shoring, as required. The package is required to be transported under exclusive-use controls. Furthermore, it is transported in a horizontal orientation, secured to a shipping skid by the cask trunnions, and covered by a personnel barrier or in an enclosure, as shown in Figure 1-2. The personnel barrier consists of a metallic frame covered with a porous metallic skin (e.g., expanded or perforated sheet metal) that allows air movement across the skin but prevents personnel from contacting the cask outer surface), whereas the enclosure cover consists of a metallic frame covered by a solid sheet metal skin that protects the package from direct exposure to weather, road grime, and diesel particulate. All contents except for TPBAR CCs must be configured for transport with a personnel barrier. TPBAR contents may be configured for transport either in an enclosure or personnel barrier. More detailed descriptions of the packaging, contents, and operational features are provided in Section 1.2.

1.6.2 Packaging General Arrangement Drawings

The following drawings show the general arrangement and design features of the Volunteer packaging in accordance with NUREG/CR-5502 [1-7]. The drawings refer to material specifications, welding requirements, inspection and test requirements, and dimensions as necessary to support the safety analyses. In addition, the drawings include the quality category (Q CAT) for each packaging component, with important to safety (ITS) designations of A, B, and C for not important to safety (NITS).

Drawing No.	Title	Rev.
70000.38-L100	Packaging Assembly, Volunteer	0NP
70000.38-L110	Cask Assembly, Volunteer	0NP
70000.38-L115	Port Cover Assembly, Volunteer	0NP
70000.38-L116	Port Cover Assembly, Metal Seal, Volunteer	0NP
70000.38-L120	Cask Body Weldment, Volunteer	0NP
70000.38-L130	Cask Lid Assembly, Volunteer	0NP
70000.38-L131	Cask Lid Assembly, Metal Seal, Volunteer	0NP
70000.38-L141	Impact Limiter, Volunteer	0NP
70000.38-L150	Shield Liner Assembly, Volunteer	0NP
70000.38-L160	TPBAR Basket Assembly, Volunteer	0NP
70000.38-L165	TPBAR Spacer, Volunteer	0NP
70000.38-L166	TPBAR Bearing Plate, Volunteer	0NP
70000.38-L167	Basket Extension Assembly, TPBAR, Volunteer	0NP

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objects impacting hard surfaces at high velocities. Its accuracy has been benchmarked through correlation with experimental data. LS-DYNA features include the ability to handle large deformations, finite rotation, sophisticated material models (for steel and aluminum, foams and plastics), complex contact conditions among multiple components, and short-duration impact dynamics.

[redacted]

2.13.1.2.1 Benchmark Analysis of LS-DYNA Drop Model

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Figure 2.13-1 - Benchmark Comparison of CY-STC Drop Analysis and Test Results

2.13.2 Free Drop Loads Analysis

This section describes the drop loads analysis of the package is evaluated for the NCT and HAC free drop test requirements of 10CFR71.71 and 10CFR71.73. Drop loads analyses are performed using the LS-DYNA explicit dynamic finite element computer program described in Section 2.13.1.2. Three separate models, shown in Figure 2.13-2, are used to evaluate the long, standard, and short cask configurations for a range of free drop orientations and thermal conditions, as discussed below.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Table 2.13-2 - NCT Free Drop Analysis Results Summary

[redacted]

Table 2.13-3 - HAC Free Drop Analysis Results Summary

[redacted]

Table 2.13-4 - HAC Puncture Drop Analysis Results Summary

[redacted]

[redacted]

Figure 2.13-2 - Volunteer Package LS-DYNA Models

[redacted]

Figure 2.13-3 - LS-DYNA Model - Cask Assembly and Impact Limiter Interface Details

[redacted]

Figure 2.13-4 - LS-DYNA Model - Impact Limiter Details

[redacted]

Figure 2.13-5 - LS-DYNA Model for HAC Puncture End Impact

[redacted]

Figure 2.13-6 - LS-DYNA Model for HAC Puncture Corner Impact

[redacted]

Figure 2.13-8 - NCT Short/Cold Side Drop Acceleration Time History

[redacted]

Figure 2.13-9 - NCT Short/Cold Corner Drop Acceleration Time History

[redacted]

Figure 2.13-11 - HAC Long/Hot End Drop Damage

[redacted]

Figure 2.13-13 - HAC Standard/Cold Side Drop Acceleration Time History

[redacted]

Figure 2.13-14 - HAC Long/Hot Side Drop Damage

[redacted]

Figure 2.13-16 - HAC Long/Hot Corner Drop Damage

[redacted]

Figure 2.13-18 - HAC Long/Hot Oblique Drop 10° Primary Impact Damage

[redacted]

Figure 2.13-20 - HAC Long/Hot Puncture End Drop Damage

[redacted]

Figure 2.13-22 - HAC Long/Hot Puncture Corner Drop Damage

2.13.3 Equivalent Static Accelerations

[redacted]

[redacted]

[redacted]

Table 2.13-6 - HAC Free Drop DLFs and Equivalent Static Accelerations

[redacted]

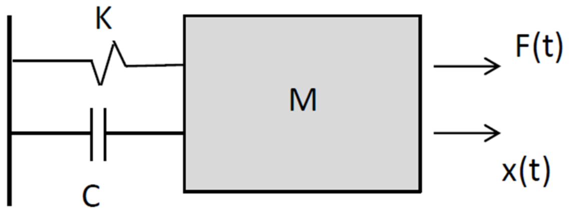

Figure 2.13-23 - ANSYS Single Degree of Freedom Transient Model

2.13.4 ANSYS Model Descriptions

This section provides descriptions of the different finite element models that are used for the stress analysis of the cask assembly. The finite element models used for the structural evaluation of the various cask assembly configurations are described in Section 2.13.4.1. A separate finite element model used for the structural evaluation of the port cover and port cover bolts is described in Section 2.13.4.2.

2.13.4.1 Cask Assembly Models

This section describe the ¼-symmetry and ½-symmetry finite element models that are used for most of the stress analysis of the long, standard, and short configurations of the cask assembly. Section 2.13.4.2 describes a separate finite element model that is used for the structural evaluation of the port cover and port cover bolts.

[redacted]

Model Geometry

[redacted]

NAC PROPRIETARY INFORMATION REMOVED

[redacted]

Element Types

[redacted]

Material Properties

[redacted]

2.13.4.2 Port Cover Model

The port cover stress analysis is performed using the ANSYS 1/6th-symmetry finite element model shown in Figure 2.13-26. The following subheadings describe the model geometry, element types, and material properties of the port cover finite element model. The applied loads and boundary conditions for each condition are discussed in the respective sections of this chapter.

Model Geometry

The model includes the port cover housing (i.e., representing the vent port in the cask lid or the drain port in the bolt flange), the port cover, and the port cover bolt. The port cover and port cover bolt are modeled using the nominal dimensions from the drawings in Appendix 1.6.2. The port cover housing is modeled as a ∅13.26-inch × 9.0-inch thick cylinder with recess for the port cover and a ∅0.75-ing thru-hole. The port cover bolt holes in the port cover housing are modeled as smooth cylindrical holes with diameters matching those of the nominal bolt shaft diameter, neglecting the threads. The port cover bolts are modeled using solid brick elements to represent the bolt shaft and head, as shown in Figure 2.13-26. The bolt shafts are modeled as smooth cylinders with the nominal shaft diameter, neglecting the threads. The bolt heads are modeled as right-circular cylinders with diameters equal to that socket head cap screw (SHCS). Bonded contacts are used to connect the threads of the closure bolt to the corresponding bolt hole and general surface contact elements are modeled between the closure bolt head and the mating surface of the housing.

Element Types

[redacted]

Material Properties

[redacted]

[redacted]

Figure 2.13-24 - ¼-Symmetry Finite Element Model (Long Config. Shown)

[redacted]

Figure 2.13-25 - ½-Symmetry Finite Element Model (Long Config. Shown)

[redacted]

Figure 2.13-26 - Port Cover 1/6th-Symmetry Finite Element Model

2.13.5 Closure Bolt Preload Evaluation

This section describes the structural evaluation of the cask lid bolts and port cover bolts for preload, demonstrating compliance with the applicable allowable Service Level A stress design criteria of ASME Subsection NB [2.5]. The cask lid bolt and port cover bolt evaluations are presented in Sections 2.13.5.1 and 2.13.5.2, respectively. The preload structural evaluations of the bolts determine the average tensile stress in the bolt and average shear stress in the threads of the bolt, insert, and bolt hole resulting from the maximum bolt torques specified on the drawings in Appendix 1.6.2. In addition, the seating loads resulting from the minimum bolt torques specified on the drawings in Appendix 1.6.2 are evaluated to establish the maximum required seating load of the containment seals. In accordance with good bolting design practices, the results show that the threaded connections provide much higher factors of safety than those for bolt tensile stress.

2.13.5.1 Cask Lid Bolts

The cask lid is attached to the cask body weldment by twenty-four (24) 1 ½-12 UNF × 6 inch long socket head cap screws that are lubricated and tightened to a torque of 600 ± 30 ft-lb, as shown in Drawing No. 70000.38-L110 in Appendix 1.6.2. The threaded holes for the lid bolts in

[redacted]

2.13.5.1.1 Bolt Tensile Stress

The tensile force developed in the lid closure bolt from the maximum torque values of 630 ft-lb (7.56 in-kip) is:

$$F_{pl} = T/kD = 31.9 \text{ kip}$$

Where;

k = 0.158, Nut factor for never-seez lubricant ([2.21], Appendix J)

D = 1.5 in., Nominal bolt shaft diameter

The average tensile stress in the lid closure bolt due to the maximum preload force of 30.9 kip is:

$$\sigma_{ab} = F_{pl}/A_t = 20.2 \text{ ksi}$$

Where;

A_t = $0.7854(D - 0.9743/n)^2 = 1.581 \text{ in}^2$, Tensile area at threads for steels up to 100 ksi ultimate tensile strength ([2.22], pg. 1490, Eq. 2a)

D = 1.5 in (from above)

n = 12, number of threads per inch

In accordance with NB-3232 [2.5], the average tensile stress across the bolt cross section shall not exceed $2S_m$, where the value of S_m for the SA-193, Grade B8S material at 300°F is 11.0 ksi (Chapter 7, Table 7-7). Therefore, the allowable average tensile stress across the bolt cross section is 22.0 ksi and the minimum factor of safety against average tensile stress in the bolt for maximum preload is 1.09 (= 22.0/20.2).

2.13.5.1.2 Bolt Thread Shear Stress

The average shear stress in the bolt threads due to the maximum lid closure bolt preload of 31.9 kip is:

$$\sigma_{vt} = F_{pl}/A_s = 5.4 \text{ ksi}$$

Where the shear area, A_s, of the bolt (external) threads is ([2.22], p.1491, Eq. 5):

$$A_s = 3.1416 n L_e K_{nmax}\left[\frac{1}{2n} + 0.57735(E_{smin} - K_{nmax})\right] = 5.95 \text{ in}^2$$

n = threads per inch = 12,

L_e = Minimum thread engagement length (assuming top thread of insert and bottom thread of bolt are ineffective).
= $L_{bp} - L_{ti} - 2 \times P$
= 2.34 in.

L_{bp} = Length of bolt penetration
= 6.0” – 3.37” (Appendix 1.6.2, Drawing No. 70000.38-L130).
= 2.63 in.

L_{ti} = 1.5P, Distance from seal surface to top of insert ([2.23], pg. 16, Hole Preparation)
= 0.125 in.

P = $1/n = 0.0833$ inch/thread

K_{nmax} = 1.428 in., max. minor diameter of 1 ½-12 UNF-2B internal thread [2.22]

E_{smin} = 1.4376 in., min. pitch diameter of 1 ½-12 UNF-2A external thread [2.22]

In accordance with NB-3227.2 [2.5], the average primary shear stress across a section loaded in pure shear is limited to $0.6S_m$, or 6.6 ksi from above.

2.13.5.1.3 Thread Insert Shear Stress

The average shear stress in the helical insert threads due to the maximum bolt preload of 31.9 kip is:

$$\sigma_{vt} = F_{pl}/A_n = 4.0 \text{ ksi}$$

The shear area, A_n, of the threaded hole (e.g., internal threads of helical insert) is ([2.22], p.1491, Eq. 6):

$$A_n = 3.1416 n L_e D_{smin}\left[\frac{1}{2n} + 0.57735(D_{smin} - E_{nmax})\right] = 7.93 \text{ in}^2$$

Where;

n = threads per inch = 12,

L_e = 2.34 in., minimum thread engagement length (from above)

D_{smin} = 1.4867 in., min. major diameter of the 1 ½-12 UNF-2A bolt thread [2.22]

E_{nmax} = 1.4542 in., max. pitch diameter of 1 ½-12 UNF-2B hole thread [2.22]

[redacted]

lid closure bolt material. Therefore, since the shear stress in the insert is lower than that in the lid closure bolt threads and the insert material is stronger than the closure bolt material, the factor of safety in for shear stress in the thread insert is higher than that in the bolt threads.

2.13.5.1.4 Bolt Hole Thread Shear Stress

The average shear stress in the internal threads of the bolt flange due to the maximum bolt preload of 31.9 kip is:

$$\sigma_{vt} = F_{pl}/A_n = 3.2 \text{ ksi}$$

The shear area, A_n, of the threaded hole is ([2.22], p.1491, Eq. 6):

$$A_n = 3.1416 n L_e D_{smin}\left[\frac{1}{2n} + 0.57735(D_{smin} - E_{nmin})\right] = 10.1 \text{ in}^2$$

Where;

n = threads per inch = 12,

L_e = 2.34 in., minimum thread engagement length (from above)

D_{smin} = 1.6126 in., min. major diameter of the tap for the 1 1/2-12 UNF thread insert ([2.23], Table VII)

E_{nmax} = 1.5615 in., max. pitch diameter of 1 1/2-12 UNF-2B hole thread [2.22]

In accordance with NB-3227.2 [2.5], the average primary shear stress across a section loaded in pure shear is limited to $0.6S_m$, where the value of S_m for the SA-182, Type F304 material at 300°F is 20.0 ksi (Chapter 7, Table 7-1). Therefore, the allowable shear stress in the hole threads is 12.0 ksi and the minimum factor of safety against thread shear stress is or in the hole threads is limited to for NCT is 3.75 (= 12.0/3.2).

2.13.5.1.5 Containment Seal Seating Force

The minimum tensile force developed in the lid closure bolt from the minimum torque value of 570 ft-lb (6.84 in-kip) is:

F_{pl} = T/kD = 29.9 kip

Where;

k = 0.158, Nut factor for never-seez lubricant ([2.21], Appendix J)

D = 1.5 in., Nominal bolt shaft diameter

Therefore, the maximum required seating load of the cask lid seals shall not exceed 717.6 kips (i.e., 29.9 kip/bolt × 24 bolts).

2.13.5.2 Port Cover Bolts

The vent and drain port covers, which are identical designs, are both attached to the cask body weldment by three (3) 7/8-9 UNC × 2¼ inch long socket head cap screws that are lubricated and tightened to a torque of 100 ± 10 ft-lb, as shown in general arrangement drawings 70000.38-L110, -L130 and -L131 in Appendix 1.6.2. The threaded holes for the port cover bolts in the

[redacted]

2.13.5.2.1 Bolt Tensile Stress

The tensile force developed in the lid closure bolt from the maximum torque values of 110 ft-lb (1.32 in-kip) is:

F_{pl} = T/kD = 9.5 kip

Where;

k = 0.158, Nut factor for Never-Seez lubricant ([2.21], Appendix J)

D = 0.875 in., Nominal bolt shaft diameter

The average tensile stress in the port cover bolt due to the maximum preload force of 9.5 kip is:

σ_{ab} = F_{pl}/A_t = 20.6 ksi

Where;

A_t = $0.7854(D - 0.9743/n)^2 = 0.462$ in^2, Tensile area at threads for steels up to 100 ksi ultimate tensile strength ([2.22], pg. 1490,. Eq. 2a)

D = 0.875 in (from above)

n = 9, number of threads per inch

In accordance with NB-3232 [2.5], the average tensile stress across the bolt cross section shall [redacted] (Chapter 7, Table 7-7). Therefore, the allowable average tensile stress across the bolt cross section is 22.0 ksi and the minimum factor of safety against average tensile stress in the port cover bolt for maximum preload is 1.07 (= 22.0/20.6).

2.13.5.2.2 Bolt Thread Shear Stress

The average shear stress in the port cover bolt threads due to the maximum bolt preload of 9.5 kip is:

σ_{vt} = F_{pl}/A_s = 4.4 ksi

Where the shear area, A_s, of the bolt (external) threads is ([2.22], p.1491, Eq. 5):

A_s = $3.1416 n L_e K_{nmax}\left[\frac{1}{2n} + 0.57735(E_{smin} - K_{nmax})\right] = 2.14\ in^2$

n = threads per inch = 9,

L_e = Minimum thread engagement length (assuming top thread of insert and bottom thread of bolt are ineffective).
= $L_{bp} - L_{ti} - 2 \times P$
= 1.49 in., thread engagement length (from above)

L_{bp} = Length of bolt penetration
= 2.25” – 0.37” (Appendix 1.6.2, Drawing No. 70000.38-L115)
= 1.88 inches

L_{ti} = 1.5P, Distance from seal surface to top of insert ([2.23], pg. 16, Hole Preparation)
= 0.167 in.

P = 1/n = 0.111 inch/thread

K_{nmax} = 0.778 in., max. minor diameter of 7/8-9 UNC-2B internal thread [2.22]

E_{smin} = 0.7946 in., min. pitch diameter of 7/8-9 UNC-2A external thread [2.22]

In accordance with NB-3227.2 [2.5], the average primary shear stress across a section loaded in [redacted] 300°F is 11.0 ksi (Chapter 7, Table 7-7). Therefore, the allowable shear stress in the bolt threads is 6.6 ksi and the minimum factor of safety against thread shear stress in the port cover bolt threads is 1.50 (= 6.6/4.4).

2.13.5.2.3 Thread Insert Shear Stress

The average shear stress in the helical insert threads due to the maximum bolt preload of 9.5 kip is:

σ_{vt} = F_{pl}/A_n = 3.3 ksi

The shear area, A_n, of the threaded hole (e.g., internal threads of helical insert) is ([2.22], p.1491, Eq. 6):

$$A_n = 3.1416nL_eD_{smin}\left[\frac{1}{2n} + 0.57735(D_{smin} - E_{nmax})\right] = 2.85\ in^2$$

Where;

n = threads per inch = 9,

L_e = 1.49 in., minimum thread engagement length (from above)

D_{smin} = 0.8523 in., min. major diameter of the 7/8-9 UNC-2A bolt thread [2.22]

E_{nmax} = 0.8110 in., max. pitch diameter of 7/8-9 UNC-2B hole thread [2.22]

[redacted]

lid closure bolt material. Therefore, since the shear stress in the insert is lower than that in the lid closure bolt threads and the insert material is stronger than the closure bolt material, the factor of safety in for shear stress in the thread insert is higher than that in the bolt threads.

2.13.5.2.4 Bolt Hole Thread Shear Stress

The average shear stress in the internal threads of the tapped holes for the port cover bolt thread inserts due to the maximum port cover bolt preload of 9.5 kip is:

$\sigma_{vt} = F_{pl}/A_n = 2.3$ ksi

The shear area, A_n, of the threaded hole is ([2.22], p.1491, Eq. 6):

$$A_n = 3.1416 n L_e D_{smin}\left[\frac{1}{2n} + 0.57735(D_{smin} - E_{nmax})\right] = 4.15\ in^2$$

Where;

n = threads per inch = 9,

L_e = 1.49 in., minimum thread engagement length (from above)

D_{smin} = 1.0247 in., min. major diameter of the tap for the 7/8-9 UNC thread insert ([2.23], Table VII)

E_{nmax} = 0.9543 in., max. pitch diameter of 7/8-9 UNC-2B hole thread [2.22]

In accordance with NB-3227.2 [2.5], the average primary shear stress across a section loaded in pure shear is limited to $0.6S_m$, where the value of S_m for the SA-182, Type F304 material at 300°F is 20.0 ksi (Chapter 7, Table 7-1). Therefore, the allowable shear stress in the hole threads is 12.0 ksi and the minimum factor of safety against thread shear stress is or in the hole threads is limited to for NCT is 5.22 (= 12.0/2.3).

2.13.5.2.5 Containment Seal Seating Force

The minimum tensile force developed in the port cover closure bolt from the minimum torque value of 90 ft-lb (1.08 in-kip) is:

$F_{pl} = T/kD = 7.8$ kip

Where;

k = 0.158, Nut factor for Never-Seez lubricant (Ref. [2.21], Appendix J)

D = 0.875 in., Nominal port cover bolt shaft diameter

Therefore, the maximum required seating load for the port cover metal seals shall not exceed 23.4 kips per bolt (i.e., 7.8 kips/bolt × 3 bolts).