4 CONTAINMENT

This chapter identifies the AOS Transport Packaging System containment systems and describes how the Packages comply with the containment requirements of *10 CFR 71* **[4.1]**, under Normal Accident conditions of transport (NCT) and Hypothetical Accident conditions (HAC) of transport, as well as *49 CFR 173* **[4.2]**, and the *International Atomic Energy Agency Safety Standards Series No. TS-R-1 (IAEA TS-R-1)* **[4.3]**.

4.1 DESCRIPTION OF THE CONTAINMENT SYSTEM

This section identifies and describes the AOS Transport Package containment systems, including the welds, seals, lids, cover plates, and closure devices. The AOS Transport Packaging System is designed to meet the "leak-tight" criteria specified the American National Standards Institute, *ANSI N14.5-1997* **[4.4]**, for the transportation of activated material in *Normal* and *Special form*.

4.1.1 Containment Boundary

The AOS transport package containment boundary (located within the cask of the transport package) is composed of the following:

- Cask cavity shell
- Containment penetrations or port plug sub-assemblies
- Cask lid elastomeric and metallic seal components of the AOS Transport Packaging System cask

The containment boundary loops along the cask cavity shell walls and port plug walls, across the port opening, between its pipe plug and plug cover, through the cask lid material and across the cask lid seal joint between the two (2) retainer rings (elastomeric seal) or "C" cross-sections (metallic seal). The dashed lines in Figure 4-1 illustrate the containment boundary (located within the cask unit of the transport package).

The cask unit is constructed of 300 series stainless steel (SS300) material. Tungsten alloy or carbon steel material is embedded within the cask body and cask lid plug, to enhance the assembled cask shielding capability. Shielding material options are variable within the AOS Transport Packaging System models. There are two (2) penetrations into the cavity region of the cask – the cask drain port and cask vent port. These ports are comprised of a lower seal, a threaded pipe plug, a silicone material O-Ring, and a port cap, as discussed in Section 4.1.2.

The cask lid seals use either a pair of elastomeric O-Rings captured within one (1) or two (2) SS300 series flat rings, or a metallic double "C" cross-section arrangement, as discussed in Section 4.1.3. Figure 4-1 illustrates the general arrangement of these systems. The cask lid seals used on the AOS Transport Packaging System models are included in Appendix 4.5.1.

Proprietary Information

Figure Withheld Under 10 CFR 2.390

Model AOS-100A

Proprietary Information

Figure Withheld Under 10 CFR 2.390

Model AOS-100A-S

Figure 4-1. Containment Boundary (Cask Lid Metallic Seal Shown)

Note: *In Figure 4-1, the Model AOS-100A containment boundary illustration is a typical representation of the Model AOS-025A, AOS-050A, and AOS-100B containment boundaries.*

To protect the cask lid/cask lid seal joint, which is part of the containment boundary, during transport, the lid(s) is (are) recessed within the wall of the cask external body. The analytical results, presented throughout this SAR, indicate that the containment boundary (including the cask lid/cask lid seal joint) does not suffer any deformation that can impair its ability to contain the radioactive material content, as detailed in Chapter 2, "Structural Evaluation." These results were validated by a series of Free-Drop tests performed on the AOS-165A prototype packaging. The Free-Drop test results are presented in Appendix 2.12.6, "Impact (Free-Drop) Test Report."

The materials of construction used on the AOS containment boundary meet ASME Code **[4.5]** requirements, except for the cask lid seal materials. All AOS Transport Packaging System materials are listed in the applicable certification drawings, and documented in Section 2.3, "Fabrication and Examination."

A structural weld closes the containment boundary encasing the shielding material cylinders within the cask cavity shell and cask outer shell. The Model AOS-025, AOS-050, and AOS-100 transport packages use an ASME Code corner weld (Type C) joint design for this purpose. Figure 4-2 provides a typical illustration of a corner weld joint on the cask cavity shell.

Proprietary Information

Figure Withheld Under 10 CFR 2.390

Figure 4-2. Typical Corner Cask Cavity Shell Weld Joint Configuration – All Models

4.1.2 Containment Penetrations (Port Plugs)

The AOS transport packages have two (2) containment penetrations:

- Two (2) penetration ports – the cask drain port and cask vent port. These ports consist of three (3) diametrical steps studded with a threaded end at the smaller diameter. Each of these port plugs connect to the cask cavity shell.

  In addition, there is one (1) penetration into the cask lid seal region, on top of the cask lid.
- One (1) penetration – leak testing port. The cask lid has a port that intersects the channel in the upper surface of the cask lid seal groove, which is provided to detect Helium in the gas stream.

For illustration purposes, Figure 4-3 shows the port plug for the Model AOS-100. A socket head pipe plug (which is located within the containment boundary), followed by a cap, close each penetration. An elastomeric O-Ring (Parker O-Ring Division, S1224-70 compound), attached to the cap, provides a redundant seal to these penetrations. In addition, there is a conduit that is used to verify the integrity of the port plug joint between the port plug and the cask body shells, which is covered by a threaded pipe plug.

Two components within the port assembly close the cask cavity chamber – (1) 3/8-18NPT pipe plug, which provides the primary containment for the drain and vent passages; and (2) 37° conical seal, which isolates the cask cavity from the shield material chamber. Both components have a secondary component. The pipe plug's secondary component is the port cover/O-Ring component. The 37° conical seal's secondary component is the 1/8-27NPT pipe plug. In addition to this isolation function, this pipe plug opening is used for leak testing verification of the 37° conical seal during the annual inspection.

The seal replacement schedule is as follows:

- **Metallic Seal** – Single use only.
- **Elastomeric Seal** – Once every twelve uses or every twelve (12) months, whichever comes first, or if damaged.
- **37° Conical Seal** – Only when damaged. This seal is expected to last a long time; however, it must be monitored during the periodic inspection. Replacement of this seal entails machining of the weld that secures the port plug in place, as well as removal of the port plug and its re-installation and testing, per original requirements. It is important to note that the port plug design was dropped three (3) times, without failure, during the 165 prototype's Drop Test. Therefore, it can be expected that Normal conditions of transport will have minimum impact on this seal.

Proprietary Information

Figure Withheld Under 10 CFR 2.390

Figure 4-3. Typical Port Plug Configuration

Note: *All dimensions are in inches for the Model AOS-100.*

4.1.3 Cask Lid Seal

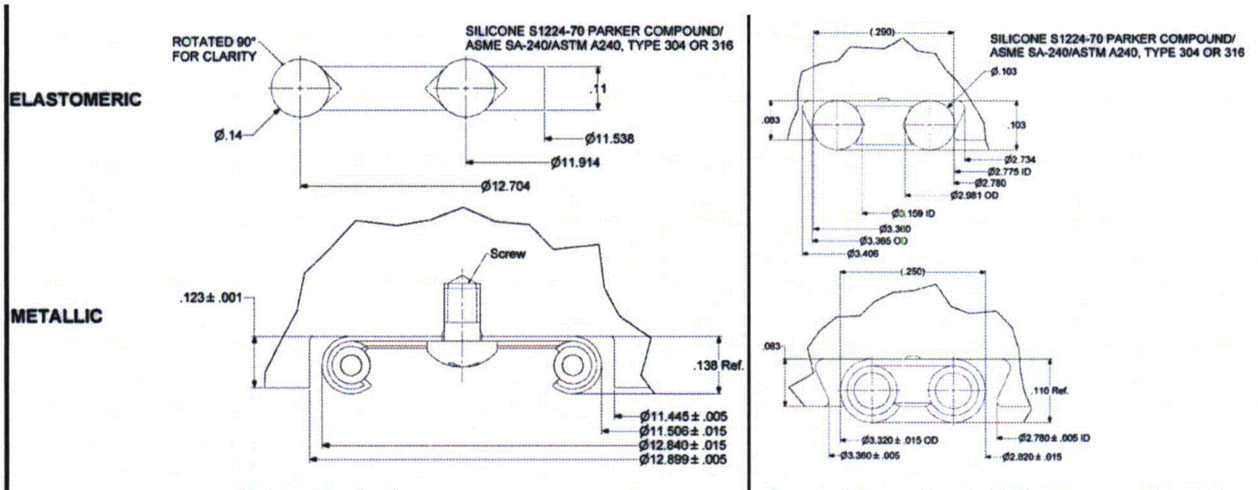
The AOS Transport Packaging System provides two (2) cask lid seal designs for the Model AOS-025A and AOS-050A, and all variations of the Model AOS-100:

- Pair of elastomeric O-Rings captured within either one (1) or two (2) flat metal retainer rings to form a unit, –or–
- Helicoflex metallic (silver, nickel-chromium alloy, and stainless steel) cask lid seal joint design, which includes a seal between the cask lid and cask cavity body

The Model AOS-025A and AOS-050A's cask lid metallic seals are of the same standard configuration as the other models. However, their elastomeric seal consists of two (2) O-Rings separated by a metal ring, which is captured within the dove-tailed groove that is machined onto the cask lid bottom surface.

The sealing principle of these seal options is based upon the deformation of the elastomeric O-Rings or, in the case of the metallic seal, of the jacket of greater ductility than the flange materials. This occurs between the sealing faces of the lid/cask body and O-Rings, for the elastomeric seal; and the elastic core comprised of a close-wound helical spring for the metallic seal. The spring has a specific compression resistance that prevents the seal from being crushed. During compression, the resulting specific pressure forces the jacket to yield and fill the flange surface imperfections, while ensuring positive contact with the flange sealing faces. Each helical spring coil functions independently, and allows the seal to conform to irregularities on the flange surface. The spring's compression resistance maintains the contact between the seal surface and the two (2) sealing surfaces.

Figure 4-4 illustrates the cask lid elastomeric and metallic seals. Appendix 4.5.1 contains manufacturer drawings of the AOS Transport Packaging System cask lid seals, by model.



Cask Lid Seals, Typical
(Dimensions shown are those of the Model AOS-100A)

Cask Lid Seals, Models AOS-025A and AOS-050A
(Dimensions shown are those of the Model AOS-025A)

Figure 4-4. Cask Lid Elastomeric and Metallic Seals

Notes: *The compression resistance of the elastomeric O-Ring or metallic double "C" cross-section's spring maintains the contact between the seal surface and surfaces being sealed.*

The dimensions (in inches) are those of the Model AOS-025A and AOS-100A transport packages.

The Model AOS-100's cask lid elastomeric seal, or the cask lid metallic seal for all models, is attached to the cask lid, inside its groove, by four (4) seal attachment screws. The screws are sized and installed in such a way as to prevent the screws from interfering with the deformation of the elastomeric O-Rings or metallic double "C" cross-sections when the cask lid attachment bolts are being tightened. The Model AOS-025 and AOS-050's cask lid elastomeric seal is captured within the seal groove by dove-tail profile, on the groove's side wall.

Figure 4-5 illustrates how the cask lid metallic seal is attached to the cask lid by four (4) small seal attachment screws. A callout for the hole used for leak testing is included in Figure 4-5, to differentiate it from the screws in the photograph.

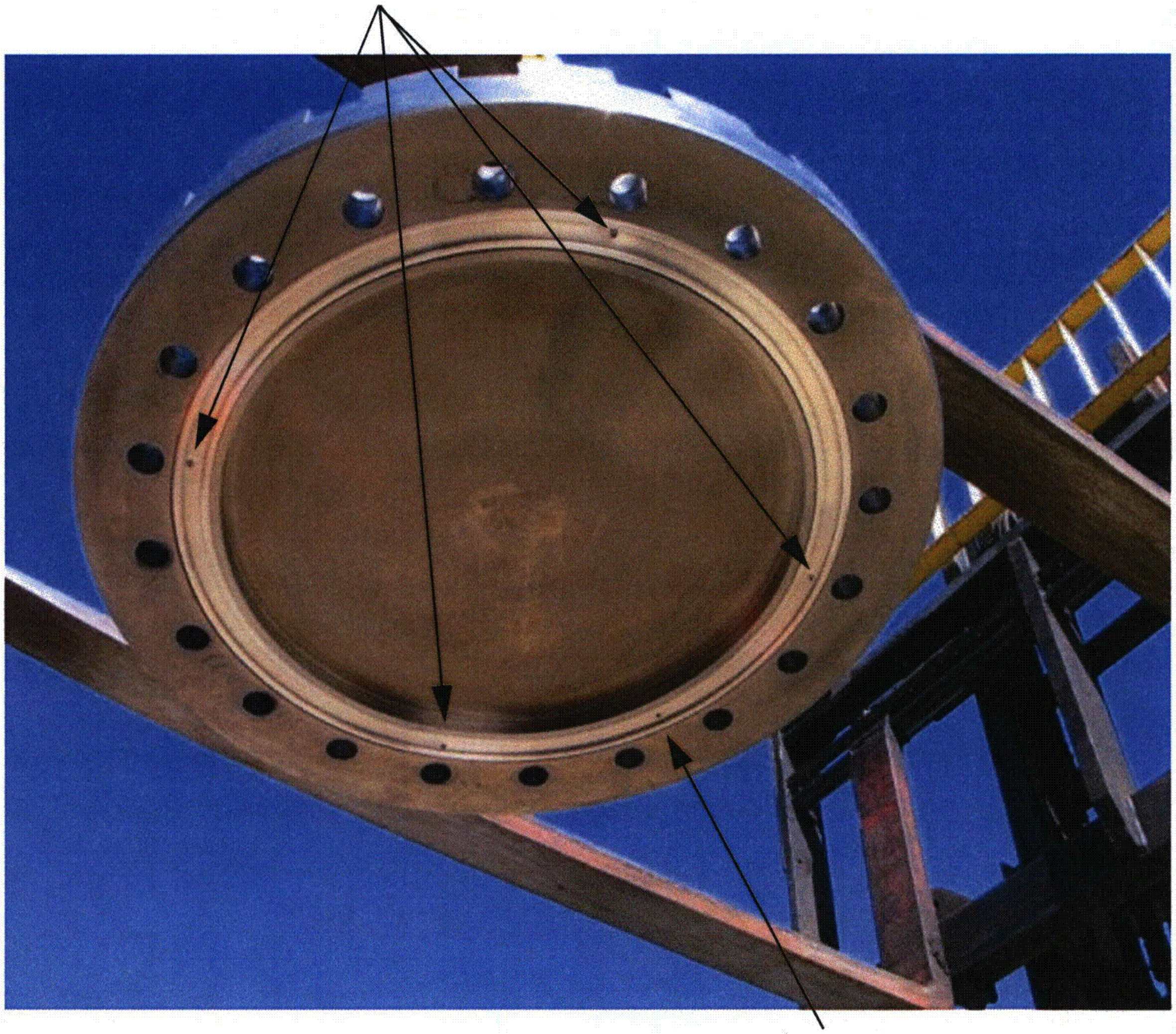


Figure 4-5. Cask Lid Showing the Cask Lid Metallic Seal Installed – Attachment by way of Four (4) Screws, and Leak-Testing Hole

4.1.4 Closure

A set of cask lid attachment bolts, ASME SB-637, UNS N07718, attaches the cask lid to the cask lidmetallic seal (all models), or to the cask lid elastomeric seal (Model AOS-100, all variations). For Models AOS-025 and AOS-050, the cask lid elastomeric seal is captured within the dove-tailed groove that is machined onto the cask lid bottom surface. The cask lid bolted joint is recessed within the cask body, to protect the joint from transportation loads. The cask lid attachment bolt stress analysis followed the methodology and acceptance criteria specified in *NUREG/CR-6007* (Reference **[4.6]**), and a Fortran program (Appendix 4.5.2) was coded to facilitate the required calculations. The input information required by the program is listed in Table 4-1. The program's output (results) are summarized in Table 4-2. The actual input and output files used in conjunction with the program are provided in Appendix 4.5.3.

A bolting analysis is performed for Normal and Hypothetical Accident conditions of transport. Ambient conditions of 38°C (100°F) and -40°C (-40°F) are considered. The cask lid and cask lid attachment bolt head are protected in the cask lid design. Cask loadings for pressure, temperature, impact, and vibration are considered in this evaluation. Design conditions for minimum gasket loads and bolt preload are also considered. The Hypothetical Accident conditions of transport ambient temperature of 800°C (1,475°F) is a combination of fire and cool-down transient conditions, following a 30-ft. drop accident event. There are no impact accelerations associated with cool-down, and the evaluation results show that bolting loads are not significant.

Temperatures within the cask lid, cask lid attachment bolts, and cask are used to perform the evaluation, at the locations indicated in Figure 4-6.

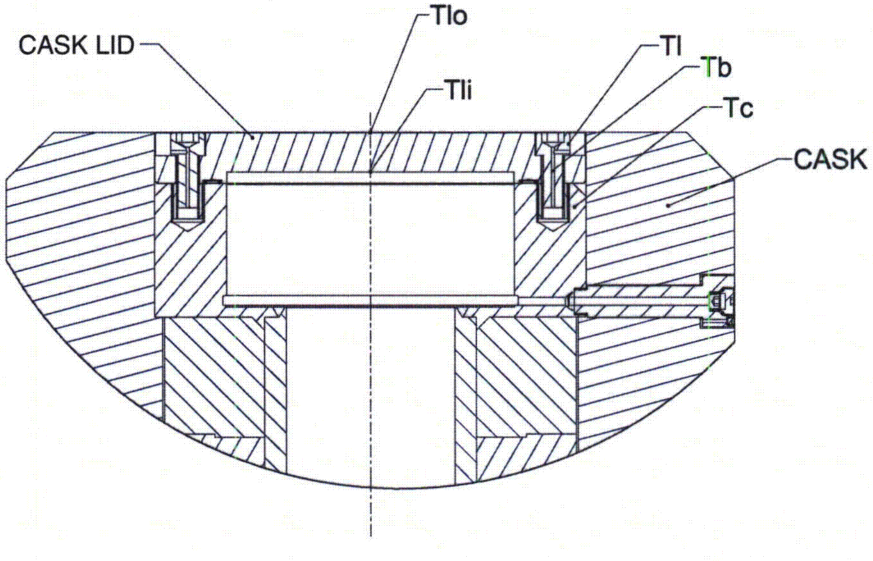


Figure 4-6. Cask Lid, Cask Lid Attachment Bolt, and Cask Temperature Evaluation Nodes

Note: *In Figure 4-6, the cask lid plug is removed for clarity.*

where:

Tb	=	Temperature of cask lid attachment bolt, node 4995
Tc	=	Temperature of cask wall, node 4995
Tl	=	Temperature of cask lid, node 3557
Tlo	=	Temperature of outside surface of cask lid, node 3309
Tli	=	Temperature of inside surface of cask lid, node 3233

Note: *All temperature changes are measured from the stress-free temperature (70°F).*

Normal Conditions of Transport, Maximum Stress Analysis

The following stress limits must be met, per *NUREG/CR-6007* (Reference [4.6]):

- Tension
  - Average stress < S_m (Allowable stress)
- Shear
  - Average stress < 0.6 S_m (Allowable stress)
- Tension plus shear
  - Stress ratio = Computed average stress/allowable average stress
  - Rt = Stress ratio for average tensile stress
  - Rs = Stress ratio for average shear stress
  - $Rt^2 + Rs^2 \leq 1.0$
- Tension plus shear plus bending plus residual torsion
  - For bolts having minimum tensile strength (S_u) greater than 100 ksi
  - Maximum stress intensity < 1.35 S_m

where:

S_m = Basic allowable stress limit for the bolt material, equal to 2/3 of S_y at the room temperature –or– 2/3 of S_y at the operating temperature, whichever is less

S_y = Minimum yield stress or strength of the bolt material

Normal Conditions of Transport, Fatigue Stress Analysis

The following stress limits must be met, per *NUREG/CR-6007* (Reference [4.6]):

- Maximum cumulative usage factor (U) due to alternating stress intensity < 1.0
- For bolts with minimum yield strength greater than 100 ksi
  - Use ASME Code, Section III (Reference [4.5]), Appendix I, fatigue curves I-9-4

Hypothetical Accident Conditions of Transport, Maximum Stress Analysis

The following stress limits must be met, per *NUREG/CR-6007* (Reference **[4.6]**):

- Tension
  - Average stress < The smaller of 0.7 S_u or S_y at temperature (Allowable stress)
- Shear
  - Average stress < The smaller of 0.42 S_u or 0.6 S_y at temperature (Allowable stress)
- Tension plus shear
  - Stress ratio = Computed average stress/allowable average stress
  - Rt = Stress ratio for average tensile stress
  - Rs = Stress ratio for average shear stress
  - $Rt^2 + Rs^2 \leq 1.0$

where:

S_u = Minimum ultimate stress or strength of the bolt material

Table 4-1. Cask Lid Attachment Bolt Features and Properties Used for Fortran Program Input – All Models[a]

Item	Model and Ambient Temperatures, by Condition[b, c]					
	AOS-025		AOS-050		AOS-100	
	38°C (100°F)	-40°C (-40°F)	38°C (100°F)	-40°C (-40°F)	38°C (100°F)	-40°C (-40°F)
Geometry Definitions						
Seal Type (Cask Lid)[d]	Metallic	Metallic	Metallic	Metallic	Metallic	Metallic
Quantity of Bolts	8	8	10	10	14	14
Cask Lid Diameter at Bolt Line (in.)	3.9	3.9	7.414	7.414	14.064	14.064
Arc Length per Bolt (in.)	1.53	1.53	2.33	2.33	3.16	3.16
Cask Lid Diameter at Gasket (in.)	3.07	3.07	6.09	6.09	12.172	12.172
Bolt Diameter (in.)	0.375	0.375	0.5	0.5	0.875	0.875
Cask Lid Diameter – Inside (in.)	2.63	2.63	5.53	5.53	11.04	11.04
Cask Lid Diameter – Outside (in.)	4.65	4.65	8.90	8.90	16.59	16.59
Cask Lid Thickness (in.)	0.37	0.37	0.75	0.75	1.51	1.51
Cask Lid Flange Thickness (in.)	0.48	0.48	0.97	0.97	1.94	1.94
Cask Wall Thickness (in.)	1.03	1.03	1.705	1.705	2.805	2.805
Bolt Length (in.)	0.15	0.15	0.41	0.41	1.06	1.06
Bolt Momentum of Inertia (in^4)	0.001	0.001	0.003	0.003	0.02	0.02

Table 4-1. Cask Lid Attachment Bolt Features and Properties Used for Fortran Program Input – All Models[a] (Continued)

Item	Model and Ambient Temperatures, by Condition[b, c]					
	AOS-025		AOS-050		AOS-100	
	38°C (100°F)	-40°C (-40°F)	38°C (100°F)	-40°C (-40°F)	38°C (100°F)	-40°C (-40°F)
Material Properties (Provided at the component temperature resulting from the specified Thermal Condition)						
Young Modulus – Cask Lid (psi)	27.3E+06	28.3E+06	27.1E+06	28.3E+06	27.1E+06	28.3E+06
Young Modulus – Flange (psi)	27.3E+06	28.3E+06	27.1E+06	28.3E+06	27.1E+06	28.3E+06
Young Modulus – Cask (psi)	27.3E+06	28.3E+06	27.1E+06	28.3E+06	27.1E+06	28.3E+06
Young Modulus – Bolt (psi)	28.0E+06	29.1E+06	27.9E+06	28.9E+06	27.9E+06	28.9E+06
Poisson's Ratio – Cask Lid	0.3	0.3	0.3	0.3	0.3	0.3
Poisson's Ratio – Cask	0.3	0.3	0.3	0.3	0.3	0.3
Cask Lid – CTE, in/in/°F	9.0E-06	8.6E-06	9.0E-06	8.6E-06	9.1E-06	8.6E-06
Bolt – CTE, in/in/°F	7.2E-06	7.0E-06	7.3E-06	7.0E-06	7.3E-06	7.0E-06
Cask Wall – CTE, in/in/°F	9.0E-06	8.6E-06	9.0E-06	8.6E-06	9.1E-06	8.6E-06
Flange Coefficient Friction[e]	0.9	0.9	0.9	0.9	0.9	0.9
S_m (ksi)	95	100	94	100	94	100
S_y (ksi)	142	150	141	150	141	150
S_u (ksi)	175	185	174	185	174	185
Code Evaluation Options (Select 1 or 2)[f]	1/2	1/2	1/2	1/2	1/2	1/2

Table 4-1. Cask Lid Attachment Bolt Features and Properties Used for Fortran Program Input – All Models[a] (Continued)

Item	Model and Ambient Temperatures, by Condition[b, c]					
	AOS-025		AOS-050		AOS-100	
	38°C (100°F)	-40°C (-40°F)	38°C (100°F)	-40°C (-40°F)	38°C (100°F)	-40°C (-40°F)
Mechanical Loads						
Inside Pressure at Cask Lid (psia)	30	30	60	60	280	280
Outside Pressure at Cask Lid (psia)	15	15	15	15	15	15
Inside Pressure at Wall (psia)	30	30	60	60	280	280
Outside Pressure at Cask Wall (psia)	15	15	15	15	15	15
Temperature Change across Cask Lid	103°C (185°F)	-19°C (-34°F)	120°C (216°F)	8°C (15°F)	124°C (223°F)	9°C (15°F)
Temperature Change across Bolt	103°C (185°F)	-19°C (-34°F)	120°C (216°F)	8°C (15°F)	124°C (223°F)	9°C (15°F)
Temperature Change across Cask Wall	103°C (185°F)	-19°C (-34°F)	120°C (216°F)	8°C (15°F)	124°C (223°F)	9°C (15°F)
Temperature Change at outside of Cask Lid	103°C (185°F)	-19°C (-34°F)	120°C (216°F)	8°C (15°F)	124°C (224°F)	9°C (16°F)
Temperature Change at inside of Cask Lid	103°C (185°F)	-19°C (-34°F)	120°C (216°F)	9°C (16°F)	124°C (224°F)	9°C (16°F)
Weight of Cask Contents + (Plug Weight) (lbs.)	10 + 4 = 14	10 + 4 = 14	60 + 35 = 95	60 + 35 = 95	500 + 278 = 778	500 + 278 = 778
Weight of Cask Lid (lbs.)	2	2	12	12	99	99

Table 4-1. Cask Lid Attachment Bolt Features and Properties Used for Fortran Program Input – All Models[a] (Continued)

Item	Model and Ambient Temperatures, by Condition[b, c]					
	AOS-025		AOS-050		AOS-100	
	38°C (100°F)	-40°C (-40°F)	38°C (100°F)	-40°C (-40°F)	38°C (100°F)	-40°C (-40°F)
Mechanical Loads (Continued)						
Head-On Drop						
Drop Angle of Impact (Degrees)	90	90	90	90	90	90
Impact Acceleration (g)[g]	883	1,237	314	439	156	218
Side Drop						
Drop Angle of Impact (Degrees)	0	0	0	0	0	0
Impact Acceleration (g)[g]	1,286	1,798	335	469	171	240
Cg/Corner Drop						
Drop Angle of Impact (Degrees)	45	45	45	45	45	45
Impact Acceleration (g)[g]	799	1,125	176	247	88	124
Dynamic Load Factor	1.15	1.15	1.15	1.15	1.15	1.15
Puncture Load	0	0	0	0	0	0
Puncture Angle of Impact (Degrees)	0	0	0	0	0	0
Axial Vibration Acceleration (g)[h]	10	10	10	10	10	10
Transverse Vibration Acceleration (g)	5	5	5	5	5	5
Vibration Transmissibility	1.0	1.0	1.0	1.0	1.0	1.0
Preload Torque (ft-lb)[i]	35	35	62.5	62.5	500	500
Nut Factor for Preload Torque	0.15	0.15	0.15	0.15	0.15	0.15
Gasket Seating Width (in.)	1.0	1.0	1.0	1.0	1.0	1.0
Gasket Seating Stress (psi)	3,000	3,000	3,000	3,000	3,000	3,000
Gasket Factor[j]	9.53	9.53	3.18	3.18	0.54	0.54

Table 4-1. Cask Lid Attachment Bolt Features and Properties Used for Fortran Program Input – All Models[a] (Continued)

Item	Model and Ambient Temperatures, by Condition[b, c]					
	AOS-025		AOS-050		AOS-100	
	38°C (100°F)	-40°C (-40°F)	38°C (100°F)	-40°C (-40°F)	38°C (100°F)	-40°C (-40°F)
Geometry Loads						
Fatigue Stress for Normal Operation (ksi)	142	150	141	150	141	150
Fatigue Stress for Vibration (ksi)	13	13	13	13	13	13
Number of Threads per Inch	16	16	13	13	9	9

a. *The actual files used as input to the Fortran program are provided in Appendix 4.5.3.1.*

b. *The conditions are defined in Table 3-1, "Transport Package Thermal Environment Conditions – All Models."*

c. *Temperature changes are measured from the stress-free temperature of 70°F.*

d. *Garlock Helicoflex drawing numbers H-309854 (Model AOS-025), H-309852 (Model AOS-050), and H309850 (Model AOS-100). Only the cask lid metallic seal was considered in this analysis, because it requires a higher gasket factor than the cask lid elastomeric seal.*

e. *Used in bolt flange friction force computation.*

f. *Code evaluation options are as follows – 1 = Normal, 2 = Hypothetical Accident.*

g. *Accelerations are obtained from the impact forces defined in the drop analysis results provided in Paragraph 2.7.1.5.2.1, "Impact Load Tables."*

h. *Normal conditions of transport accelerations, g, are:*

Axial 10

Lateral 5

i. *Recommended bolt torque:*

7/8"-9 500 ft-lb

1/2"-13 62.5 ft-lb

3/8"-16 35 ft-lb

j. *Helicoflex spring seal (cask lid metallic seal), per Helicoflex calculations, for gasket factor, m:*

Model AOS-025 cask $m = Y1 / (2 * DP) = 286 / (2 * (30 - 15)) = 9.53$

Model AOS-050 cask $m = Y1 / (2 * DP) = 286 / (2 * (60 - 15)) = 3.18$

Model AOS-100 cask $m = Y1 / (2 * DP) = 286 / (2 * (280 - 15)) = 0.54$

where:

Y1 = Linear load on the seal, to maintain sealing in service at low pressure

DP = Pressure inside the cask cavity

Table 4-2. Cask Lid Attachment Bolt Fortran Program Results Summary – All Models[a, b]

Item	Model and Ambient Temperatures, by Condition[c]					
	AOS-025		AOS-050		AOS-100	
	38°C (100°F)	-40°C (-40°F)	38°C (100°F)	-40°C (-40°F)	38°C (100°F)	-40°C (-40°F)
Bolt size (in.)	3/8		1/2		7/8	
Number of threads per in.	16		13		9	
Number of Bolts	8		10		14	
Torque, ft-lb	35		62.5		500	
Normal Conditions of Transport						
Axial Stress / S_m	0.09	0.08	0.18	0.14	0.41	0.36
Shear Stress / 0.6 S_m	0.30	0.29	0.22	0.21	0.30	0.28
$Rt^2 + Rs^2$	0.10	0.09	0.08	0.06	0.26	0.21
Se / 1.35 S_m	0.55	0.52	0.47	0.42	0.90	0.82
Accumulated Fatigue Usage	0.10	0.09	0.24	0.19	0.66	0.60
Hypothetical Accident Conditions of Transport						
Head-On Drop						
Axial Stress / 0.7 S_u	0.68	0.87	0.71	0.86	0.81	0.92
Shear Stress / 0.42 S_u	0.23	0.22	0.17	0.16	0.23	0.22
$Rt^2 + Rs^2$	0.52	0.80	0.53	0.77	0.71	0.89
Side Drop						
Axial Stress / 0.7 S_u	0.07	0.06	0.13	0.11	0.32	0.27
Shear Stress / 0.42 S_u	0.23	0.22	0.17	0.16	0.23	0.22
$Rt^2 + Rs^2$	0.06	0.05	0.05	0.04	0.15	0.12
Cg/Corner Drop						
Axial Stress / 0.7 S_u	0.46	0.58	0.36	0.41	0.51	0.53
Shear Stress / 0.42 S_u	0.23	0.22	0.17	0.16	0.23	0.22
$Rt^2 + Rs^2$	0.27	0.38	0.16	0.19	0.32	0.33

a. *The Fortran program used to analyze the cask lid attachment bolts, in accordance with NUREG/CR-6007 (Reference* [4.6]*) is provided in Appendix 4.5.2.*

b. *The actual files generated as output from the Fortran program are provided in Appendix 4.5.3.*

c. *The conditions are defined in Table 3-1, "Transport Package Thermal Environment Conditions – All Models."*

4.1.5 Keensert Device Evaluation

This subsection documents the evaluation of the Keensert devices used in the cask lid component, for each AOS Transport Packaging System model. The methodology used in the evaluation was taken from References [4.7] and [4.8]. The insert material is Type 303 or 303SE.

The critical areas of stress to the mating screw threads are as follows:

a. Effective cross-sectional area;
b. Shear area of the external thread; and
c. Shear area of the internal thread.

If failure should occur, it is preferable for the screw to break, rather than to have the external or internal thread strip. To prevent stripping of the external thread, the length of engagement should be not less than:

$$L_e = 2 * A_t / \{3.1416 * K_n max * [1/2 + 0.57735 * n * (E_s min - K_n max)]\}$$

The tensile area, A_t, is given by:

- For steels of up to 100,000 psi ultimate tensile strength:

$$A_t = 0.7854 * (D - 0.9743 / n)^2$$

- For steels of more than 100,000 psi ultimate tensile strength:

$$A_t = 3.1416 * (E_s min / 2 - 0.16238 / n)^2$$

If the internal thread is made of material of a lower strength than the external thread, it is necessary to determine whether stripping of the internal thread occurs before the screw breaks. The relative strength of the external and internal threads is represented as the factor J, and is defined as:

$$J = A_s * S_u ext / (A_n * S_u int)$$

where:

$$A_s = 3.1416 * n * L_e * K_n max * [1 / (2 * n) + 0.57735 * (E_s min - K_n max)]$$

$$A_n = 3.1416 * n * L_e * D_s min * [1 / (2 * n) + 0.57735 * (D_s min - E_n max)]$$

If J is less than or equal to 1, the length of engagement, L_e, is adequate to prevent stripping of the internal thread. If J is greater than 1, the required length of engagement, Q, that is needed to prevent stripping of the internal thread is:

$$Q = J * L_e$$

To compute the pull-out strength in any parent material, use the following formula:

$$F_{po} = SEA * S_{upm}$$

The parameters used above are defined as:

A_n	=	Shear area of the internal thread
A_s	=	Shear area of the external thread
A_t	=	Tensile stress area of the screw thread
D	=	Basic major diameter of the thread
$D_s min$	=	Minimum major diameter of the external thread
$E_n max$	=	Maximum pitch diameter of the internal thread
$E_s min$	=	Minimum pitch diameter of the external thread
F_{po}	=	Pull-out strength
J	=	Relative strength of the external-to-internal thread
$K_n max$	=	Maximum minor diameter of the internal thread
L_e	=	Minimum engagement length to prevent stripping of the external thread
n	=	Number of threads, per inch
Q	=	Required length of engagement to prevent stripping of the internal thread
SEA	=	Shear engagement area
$S_u ext$	=	Tensile strength of the external thread material
$S_u int$	=	Tensile strength of the internal thread material
S_{upm}	=	Ultimate shear strength of the parent material

4.1.5.1 Keensert Evaluation – Model AOS-025

Table 4-3. Keensert Evaluation – Model AOS-025

Parameter	3/8-in. Φ UNC
Number of threads, per inch	16
External thread class	3A
Internal thread class	3B
D (in.)	0.3750
$D_s$min (in.)	0.3656
$E_n$max (in.)	0.3387
$E_s$min (in.)	0.3311
$K_n$max (in.)	0.3182
SEA (in^2)	0.4975
$S_u$ext (ksi)	185.0
$S_u$int (ksi)	90.0
S_{upm} (ksi)	40.6

4.1.5.1.1 Internal Thread Check – Model AOS-025

L_e = (2) (0.0759) / {(3.1416) (0.3182) [1/2 + (0.57735) (16) (0.3311 - 0.3182)]}

= 0.245 in.

Where external thread $S_u$ext > 100 ksi:

A_t = $(3.1416)\ (0.3311 / 2 - 0.16238 / 16)^2 = 0.0759\ in^2$

Relative strength check:

J = (0.152) (185) / (0.211) (90.0)

= 1.481

where:

A_s = (3.1416) (16) (0.245) (0.3182) [1 / (2 (16)) + (0.57735) (0.3311 - 0.3182)]

= $0.152\ in^2$

A_n = (3.1416) (16) (0.245) (0.3656) [1 / (2 (16)) + (0.57735) (0.3656 - 0.3387)]

= $0.211\ in^2$

J is greater than 1.0; therefore, the internal thread may strip.

The minimum internal thread engagement is:

Q = (1.481) (0.245) = 0.363 in. (required minimum engagement)

The Keensert 3/8-inch bolt is catalog number KNH616J. The length of the insert is 0.50 inches. Therefore, the thread design is acceptable.

4.1.5.1.2 Pull-Out Strength – Model AOS-025

The 3/8-inch bolt's insert pull-out strength is:

$$F_{po} = SEA * S_{upm}$$

$$= 0.4975 * 40.6 = 20.20 \text{ k}$$

The bolt tensile strength is:

$$F_b = S_u * A_t$$

$$= 185 * 0.0759 = 14.04 \text{ k} < 20.20 \text{ k}$$

where:

S_u = Ultimate strength of the bolt

A_t = Tensile stress area of the bolt

The joint is acceptable.

4.1.5.2 Keensert Evaluation – Model AOS-050

Table 4-4. Keensert Evaluation – Model AOS-050

Parameter	1/2-in. Φ UNC
Number of threads, per inch	13
External thread class	3A
Internal thread class	3B
D (in.)	0.5000
$D_s min$ (in.)	0.4891
$E_n max$ (in.)	0.4548
$E_s min$ (in.)	0.4463
$K_n max$ (in.)	0.4284
SEA (in^2)	0.8884
$S_u ext$ (ksi)	185.0
$S_u int$ (ksi)	90.0
S_{upm} (ksi)	40.6

4.1.5.2.1 Internal Thread Check – Model AOS-050

$$L_e = (2)(0.139) / \{(3.1416)(0.4284)[1/2 + (0.57735)(13)(0.4463 - 0.4284)]\}$$

$$= 0.326 \text{ in.}$$

Where external thread $S_u ext > 100$ ksi:

$$A_t = (3.1416)(0.4463/2 - 0.16238/13)^2 = 0.139 \text{ in}^2$$

Relative strength check:

$$J = (0.278)(185) / (0.379)(90.0)$$

$$= 1.508$$

where:

$$A_s = (3.1416)(13)(0.326)(0.4284)[1/(2(13)) + (0.57735)(0.4463 - 0.4284)]$$

$$= 0.278 \text{ in}^2$$

$$A_n = (3.1416)(13)(0.326)(0.4891)[1/(2(13)) + (0.57735)(0.4891 - 0.4548)]$$

$$= 0.379 \text{ in}^2$$

J is greater than 1.0; therefore, the internal thread may strip.

The minimum internal thread engagement is:

$$Q = (1.508)(0.326) = 0.492 \text{ in. (required minimum engagement)}$$

The Keensert 1/2-inch bolt is catalog number KNH813J. The length of the insert is 0.66 inches. Therefore, the thread design is acceptable.

4.1.5.2.2 Pull-Out Strength – Model AOS-050

The 1/2-inch bolt's insert pull-out strength is:

$$F_{po} = SEA * S_{upm}$$

$$= 0.8884 * 40.6 = 36.07 \text{ k}$$

The bolt tensile strength is:

$$F_b = S_u * A_t$$

$$= 185 * 0.139 = 25.72 \text{ k} < 36.07 \text{ k}$$

where:

S_u = Ultimate strength of the bolt

A_t = Tensile stress area of the bolt

The joint is acceptable.

4.1.5.3 Keensert Evaluation – Model AOS-100

Table 4-5. Keensert Evaluation – Model AOS-100

Parameter	7/8-in. Φ UNC
Number of threads, per inch	9
External thread class	3A
Internal thread class	3B
D (in.)	0.8750
$D_s$min (in.)	0.8611
$E_n$max (in.)	0.8089
$E_s$min (in.)	0.7981
$K_n$max (in.)	0.7681
SEA (in^2)	3.137
$S_u$ext (ksi)	185.0
$S_u$int (ksi)	90.0
S_{upm} (ksi)	40.6

4.1.5.3.1 Internal Thread Check – Model AOS-100

$$L_e = (2)(0.4561) / \{(3.1416)(0.7681)[1/2 + (0.57735)(9)(0.7981 - 0.7681)]\}$$

$$= 0.576 \text{ in.}$$

Where external thread $S_u ext > 100$ ksi:

$$A_t = (3.1416)(0.7981/2 - 0.16238/9)^2 = 0.4561 \text{ in}^2$$

Relative strength check:

$$J = (0.912)(185) / (1.202)(90.0)$$

$$= 1.560$$

where:

$$A_s = (3.1416)(9)(0.576)(0.7681)[1/(2(9)) + (0.57735)(0.7981 - 0.7681)]$$

$$= 0.912 \text{ in}^2$$

$$A_n = (3.1416)(9)(0.576)(0.8611)[1/(2(9)) + (0.57735)(0.8611 - 0.8089)]$$

$$= 1.202 \text{ in}^2$$

J is greater than 1.0; therefore, internal thread may strip.

The minimum internal thread engagement is:

$$Q = (1.560)(0.576) = 0.899 \text{ in. (required minimum engagement)}$$

The Keensert 7/8-inch bolt is catalog number KNH1409J. The length of the insert is 1.25 inches. Therefore, the thread design is acceptable.

4.1.5.3.2 Pull-Out Strength – Model AOS-100

The 7/8-inch bolt's insert pull-out strength is:

$$F_{po} = SEA * S_{upm}$$

$$= 3.137 * 40.6 = 127.36 \text{ k}$$

The bolt tensile strength is:

$$F_b = S_u * A_t$$

$$= 185 * 0.4561 = 84.38 \text{ k} < 127.36 \text{ k}$$

where:

S_u = Ultimate strength of the bolt

A_t = Tensile stress area of the bolt

The joint is acceptable.

4.2 CONTAINMENT UNDER NORMAL CONDITIONS OF TRANSPORT

This section presents the evaluation of the AOS containment system under Normal Conditions of Transport for the chemical and physical forms of the approved contents, documented in Subsection 1.2.2, "Contents," and evaluated in Subsection 3.3.2, "Maximum Normal Operating Pressure."

4.2.1 Containment of Radioactive Material

The AOS Transport Packaging System containment is designed so that no release, loss, or dispersal of radioactive materials can occur under all conditions of transport, nor will there be any significant increase in external radiation or reduction in package effectiveness. This conclusion is supported by the analyses and various component qualification tests presented throughout this SAR.

4.2.2 Pressurization of Containment Boundary

The AOS transport packages have been designed to withstand pressures and temperatures in excess of those encountered during Normal conditions of transport. The maximum Normal conditions of transport pressures encountered are well within the Design Pressure of each transport package, documented in Subsection 3.3.2, "Maximum Normal Operating Pressure."

The only mechanism for pressurization of the cask cavity is that due to temperature change. There are no other mechanisms of gas generation from the approved contents, or from interaction with the environment in the cask's cavity. None of the approved contents undergo alpha decay in any appreciable amount, nor is there helium generation from boron captures, because there are no neutron emitters nor boron in the system.

The structural evaluation provided in Subsection 2.6.11, "Structural Evaluation Results Summary and Minimum Margins of Safety under Normal Conditions of Transport," shows low stress values throughout the cask structure, especially in the cask lid seal area, under Normal conditions of transport. In addition, the maximum temperatures shown in Table 3-3, "Maximum Temperature Summary, Normal Conditions of Transport – All Models," are lower than the corresponding limits of the containment boundary materials; therefore, they do not pose a threat to containment integrity.

Table 4-6. Maximum Cask Cavity Pressure Due to Normal Conditions of Transport – All Models

Model	Temperature (T)		Pressure (P)[a]			Design Pressure[b]	
	°C	°F	kPa	psia		kPa	psia
AOS-025A	125	257	135	20	<	207	30
AOS-050A	147	296	142	21	<	414	60
AOS-100A AOS-100A-S	155	312	145	21	<	1,930	280
AOS-100B	156	312	145	21	<	1,930	280

a. *Pressure calculation is based upon the ideal gas law:*

$$\frac{P_1 \cancel{V_1}}{T_1} = \frac{P_2 \cancel{V_2}}{T_2} \Rightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Initial Condition

$P_1 = 14.7$ psia

$T_1 = 78°F$

Final Condition

$P_2 = ?$

$T_2 = 257°F$

$$P_2 = \frac{(257 + 460)}{(78 + 460)} * 14.7 = 19.59 \text{ psia}$$

b. ***Model AOS-100 transport package*** *– Pressure value is based upon projected operating conditions.*

Table 4-7. Maximum Cask Cavity Pressure Due to Fire Condition – All Models

Model	Temperature[a]		Pressure[b]			Design Pressure[c]	
	°C	°F	kPa	psia		kPa	psia
AOS-025A	136	277	139	20	<	207	30
AOS-050A	259	499	181	26	<	414	60
AOS-100A AOS-100A-S	246	476	177	26	<	1,930	280
AOS-100B	241	467	175	25	<	1,930	280

a. *Temperature listed is the maximum value obtained throughout the Fire event.*

b. *Pressure calculation is based upon the ideal gas law illustrated in Table 4-6, footnote a.*

c. ***Model AOS-100 transport package*** *– Pressure value is based upon projected operating conditions.*

4.2.3 Containment Criterion

The AOS Transport Packaging System containments are designed, and verified by Leak test, to meet the "leak-tight" criteria established in Reference **[4.4]**, for the transportation of activated material in *Normal form.*

4.3 CONTAINMENT UNDER HYPOTHETICAL ACCIDENT CONDITIONS

This section presents the evaluations performed on the AOS Transport Package containment system under Hypothetical Accident conditions of transport and documents that the Package design meets the containment requirements of *10 CFR 71.51(a)(2)* **[4.1]** under Hypothetical Accident conditions of transport, specifically, the structural performance of the containment system, including the cask lid seal, cask lid attachment bolts, cask cavity shell, and penetrations. These results are documented in Subsection 2.7.8, "Summary of Damages." Temperature distributions under these conditions are listed in Table 3-4, "Maximum Temperature Summary, Hypothetical Accident Conditions of Transport (Condition 3) – All Models."

Under Hypothetical Accident conditions of transport, the pressure within the AOS Transport Packaging System models' cask cavity is well below the design pressures listed in Table 4-7. Temperatures at the cask lid elastomeric or metallic seal and port cover seal are also below the temperature criteria for the applicable seal material listed in Table 3-4, "Maximum Temperature Summary, Hypothetical Accident Conditions of Transport (Condition 3) – All Models."

Table 4-7 summarizes the maximum temperatures obtained during the Fire Transient evaluation, for each transport package model. The analytical evaluations under Hypothetical Accident conditions of transport, presented in Chapter 2, "Structural Evaluation," show that the stresses throughout the cask structure are below the material's failure criteria. This is also demonstrated by the results of the AOS-165A prototype Free-Drop test, presented in Appendix 2.12.6, "Impact (Free-Drop) Test Report." During the test, the cask structure did not suffer any measurable deformation on its entire surface and the cask leak tightness was maintained, despite the fact that the cask was dropped three (3) times.

4.3.1 Containment of Radioactive Material

The results of the structural and thermal analyses presented in Chapter 2, "Structural Evaluation," and Chapter 3, "Thermal Evaluation," respectively, and the Free-Drop test results presented in Appendix 2.12.6.2, "Free-Drop Test Activity Record – Pre- and Post-Leak Test," verify that the AOS transport packages are capable of withstanding the Hypothetical Accident conditions of transport that meet the containment criteria specified in Reference **[4.4]**.

4.3.2 Containment Criterion

The AOS Transport Packaging System containments are designed, and verified by Leak test, to meet the "leak-tight" criteria established in Reference **[4.4]**, for the transportation of activated material in *Normal form.*

4.3.3 Fission Gas Products

Not applicable. The authorized content of the AOS Transport Packaging System does not include any fission product gases, nor materials that can produce them, during transport.

4.4 LEAKAGE RATE TESTS FOR TYPE B PACKAGES

Pre-shipment and periodic Leakage tests, meeting the requirements of Reference **[4.4]**, are used to demonstrate that the AOS transport packages meet the containment requirements of *10 CFR 71.51* **[4.1]** are delineated in Subsection 8.2.2, "Leakage Tests [8.4]."

4.5 APPENDIX

This appendix includes a lists of references, applicable pages from referenced documents, supporting information and analysis, test results, and other supplemental information:

- Garlock Helicoflex Cask Lid Metallic Seal and AOS Cask Lid Elastomeric Seal Drawings
- Fortran Program Used to Analyze Cask Lid Attachment Bolts (Reference [4.6])
- Cask Lid Attachment Bolt Fortran Program Input/Output Files

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4.5.1 Garlock Helicoflex Cask Lid Metallic Seal and AOS Cask Lid Elastomeric Seal Drawings

Note: *As used throughout this SAR, "Garlock Helicoflex" and/or "Helicoflex" are also referred to as "Technetics Group – Columbia".*

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Garlock Helicoflex Drawing No. H-309854, Rev. 0

Model AOS-025 Cask Lid Metallic Seal

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Proprietary Information withheld from public disclosure per 10 CFR 2.390(a)(4).

Garlock Helicoflex Drawing No. H-309852, Rev. 0

Model AOS-050 Cask Lid Metallic Seal

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Proprietary Information withheld from public disclosure per 10 CFR 2.390(a)(4).

Garlock Helicoflex Drawing No. H-309850, Rev. 0

Model AOS-100 Cask Lid Metallic Seal

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Proprietary Information withheld from public disclosure per 10 CFR 2.390(a)(4).

AOS Drawing No. 183C8478Goo2, Rev. A

Model AOS-025A Lid Seal, Elastomeric

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Proprietary Information withheld from public disclosure per 10 CFR 2.390(a)(4).

AOS Drawing No. 183C8470Goo2, Rev. D

Model AOS-050A Lid Seal, Elastomeric

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Proprietary Information withheld from public disclosure per 10 CFR 2.390(a)(4).

AOS Drawing No. 183C8460Goo2, Rev. B

Models AOS-100A / AOS-100B / AOS-100A-S Lid Seal, Elastomeric

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Proprietary Information withheld from public disclosure per 10 CFR 2.390(a)(4).

4.5.2 Fortran Program Used to Analyze Cask Lid Attachment Bolts (Reference [4.6])

Note: *The actual files used as input to, and output from, the Fortran program are provided in Appendix 4.5.3.*

```
 PROGRAM MAIN
C
C     ANALYSIS OF LID ATTACHMENT BOLTS BY NUREG/CR-6007
C
C
C
C          ********* DEFINITION OF VARIABLES *********
C
C     AB      - COEFFICIENT OF THERMAL EXPANSION FOR BOLT
C     AC      - COEFFICIENT OF THERMAL EXPANSION FOR CASK WALL
C     ACCI    - IMPACT ACCELERATION DUE TO CG/CORNER DROP
C     AL      - COEFFICIENT OF THERMAL EXPANSION FOR LID
C     AVA     - AXIAL VIBRATION ACCELERATION
C     AVT     - TRANSVERSE VIBRATION ACCELERATION
C     ACCI    - IMPACT ACCELERATION DUE TO CG/CORNER DROP
C     BCF     - BOLT CLAMPING FORCE
C     BD      - BOLT DISPLACEMENT
C     BL      - BOLT LENGTH - BETWEEN TOP AND BOTTOM SURFACES OF LID
                AT BOLT CIRCLE
C     BXA     - BOLT X-SECTION AREA
C     CET     - CODE EVALUATION TYPE: 1-NORMAL, 2-ACCIDENT
C     DB      - NOMINAL BOLT DIAMETER
C     DLB     - LID DIAMETER AT BOLT CIRCLE
C     DLI     - LID DIAMETER AT INNER EDGE
C     DLO     - LID DIAMETER AT OUTER EDGE
C     DPNB    - DOUBLE PRECISION VALUE OF NB
C     DYLF    - DYNAMIC LOAD FACTOR (1.0-1.5)
C     DLG     - LID DIAMETER AT GASSKET
C     EB      - YOUNG'S MODULUS FOR BOLT
C     EC      - YOUNG'S MODULUS FOR CASK
C     EL      - YOUNG'S MODULUS FOR LID
C     ELF     - YOUNG'S MODULUS FOR LID FLANGE
C     FA_i    - BOLT TENSILE FORCE
C     FCF     - FLANGE COEFICIENT OF FRICTION
C     FF_i    - LID EDGE FORCE
C     FS_i    - BOLT SHEAR FORCE
C     FSO     - FATIGUE STRESS FOR OPERATING CONDITIONS
C     FSV     - FATIGUE STRESS FOR VIBRATIONS
C     GB      - GASKET SEATING WIDTH  (ASME BPV CODE, SECT III, APP E)
C     GM      - GASKET FACTOR         (ASME BPV CODE, SECT III, APP E)
C     GY      - GASKET SEATING STRESS (ASME BPV CODE, SECT III, APP E)
C     MF_i    - LID EDGE MOMENT
C     NB      - NUMBER OF BOLTS
C     NTI     - NUMBER OF BOLT THREADS / IN
C     PCI     - INSIDE PRESSURE AT CASK WALL
C     PCO     - OUTSIDE PRESSURE AT CASK WALL
C     PLI     - INSIDE PRESSURE AT LID
C     PLO     - OUTSIDE PRESSURE AT LID
```

```
C      PUNC     - PUNCTURE LOAD
C      Q        - PRELOAD TORQUE
C      QK       - NUT FACTOR FOR PRELOAD TORQUE
C      SM       - Sm STRESS
C      SY       - Sy STRESS
C      Su       - Su STRESS
C      TC       - THICKNESS OF CASK WALL
C      TEMPB    - TEMPERATURE CHANGE ACROSS BOLT
C      TEMPC    - TEMPERATURE CHANGE ACROSS CASK WALL
C      TEMPL    - TEMPERATURE CHANGE ACROSS LID
C      TEMPLI   - TEMPERATURE AT INSIDE OF LID
C      TEMPLO   - TEMPERATURE AT OUTSIDE OF LID
C      TL       - THICKNESS OF LID
C      TLF      - THICKNESS OF LID FLANGE
C      TM_i     - BOLT TORSIONAL MOMENT
C      VTR      - VIBRATION TRANSMISSIBILITY FACTOR BETWWEN SUPPORT & CASK
C      WC       - WEIGHT OF CASK CONTENTS
C      WCK      - TOTAL WEIGHT OF CASK
C      WL       - WEIGHT OF CASK LID
C      XIB      - BOLTS AREA MOMENT OF INERTIA / CIRCUMFERENCE OF BOLT CIRCLE
C      XI_DROP  - ANGLE OF IMPACT (DEGREES) FOR DROP
C      XI_PUNC  - ANGLE OF IMPACT (DEGREES) FOR PUNCTURE
C      XNUC     - POISSON'S RATIO FOR CASK
C      XNUL     - POISSON'S RATION FOR LID
C
C
       IMPLICIT REAL*8(A-H,O-Z)
       CHARACTER*80 TITLE
C
C
C      OPEN INPUT/OUTPUT FILES
C
       OPEN(5,FILE='CASKBOLT.DAT')
       OPEN(6,FILE='CASKBOLT.OUT')
       OPEN(1,FILE='TEMP.DAT')
C
C
C      READ & ECHO DATA
C
       READ(5,'(A)') TITLE
       WRITE(6,'(/,A,//)') TITLE
       WRITE(6,'(//,44H *************** INPUT DATA ****************)')
C
       CALL DATA(DPNB)
       NB=INT(DPNB)
       CALL DATA(DLB )
       CALL DATA(DLG )
       CALL DATA(DB  )
       CALL DATA(DLI )
       CALL DATA(DLO )
       CALL DATA(TL  )
       CALL DATA(TLF )
       CALL DATA(TC  )
       CALL DATA(BL  )
```

```
      CALL DATA(XIB )
C
      WRITE(6,'(1H )')
      WRITE(6,10) NB,DLB,DLG,DB,DLI,DLO,TL,TLF,TC,BL,XIB
   10 FORMAT(43H NUMBER OF BOLTS .......................(NB),I12   ,/,
     .       43H LID DIAMETER AT BOLT CIRCLE .........(DLB),E12.5,/,
     .       43H LID DIAMETER AT GASKET  .............(DLG),E12.5,/,
     .       43H NOMINAL BOLT DIAMETER ................(DB),E12.5,/,
     .       43H LID DIAMETER AT INNER EDGE ..........(DLI),E12.5,/,
     .       43H LID DIAMETER AT OUTER EDGE ..........(DLO),E12.5,/,
     .       43H THICKNESS OF LID ....................(TL),E12.5,/,
     .       43H THICKNESS OF LID FLANGE .............(TLF),E12.5,/,
     .       43H THICKNESS OF CASK WALL ...............(TC),E12.5,/,
     .       43H BOLT LENGTH ..........................(BL),E12.5,/,
     .       43H BOLT MOMENT OF INERTIA / CIR ........(XIB),E12.5    )
C
      CALL DATA(EL  )
      CALL DATA(ELF )
      CALL DATA(EC  )
      CALL DATA(EB  )
      CALL DATA(XNUL)
      CALL DATA(XNUC)
      CALL DATA(AL  )
      CALL DATA(AB  )
      CALL DATA(AC  )
      CALL DATA(FCF )
C
      WRITE(6,'(1H )')
      WRITE(6,20) EL,ELF,EC,EB,XNUL,XNUC,AL,AB,AC,FCF
   20 FORMAT(43H YOUNG'S MODULUS FOR LID ..............(EL),E12.5,/,
     .       43H YOUNG'S MODULUS FOR LID FLANGE ......(ELF),E12.5,/,
     .       43H YOUNG'S MODULUS FOR CASK .............(EC),E12.5,/,
     .       43H YOUNG'S MODULUS FOR BOLT .............(EB),E12.5,/,
     .       43H POISSON'S RATIO FOR LID ............(XNUL),E12.5,/,
     .       43H POISSON'S RATIO FOR CASK ...........(XNUC),E12.5,/,
     .       43H LID THERMAL EXPANSION COEFF ..........(AL),E12.5,/,
     .       43H BOLT THERMAL EXPANSION COEFF .........(AB),E12.5,/,
     .       43H WALL THERMAL EXPANSION COEFF .........(AC),E12.5,/,
     .       43H FLANGE COEFFICIENT OF FRICTION ......(FCF),E12.5    )
C
      CALL DATA(PLI)
      CALL DATA(PLO)
      CALL DATA(PCI)
      CALL DATA(PCO)
C
      WRITE(6,'(1H )')
      WRITE(6,40) PLI,PLO,PCI,PCO
   40 FORMAT(43H INSIDE PRESSURE AT LID ..............(PLI),E12.5,/,
     .       43H OUTSIDE PRESSURE AT LID .............(PLO),E12.5,/,
     .       43H INSIDE PRESSURE AT CASK WALL ........(PCI),E12.5,/,
     .       43H OUTSIDE PRESSURE AT CASK WALL .......(PCO),E12.5    )
C
      CALL DATA(TEMPL )
      CALL DATA(TEMPB )
```

```
      CALL DATA(TEMPC )
      CALL DATA(TEMPLO)
      CALL DATA(TEMPLI)
C
      WRITE(6,'(1H )')
      WRITE(6,50) TEMPL,TEMPB,TEMPC,TEMPLO,TEMPLI
   50 FORMAT(43H TEMPERATURE CHG ACROSS LID ........(TEMPL),E12.5,/,
     .       43H TEMPERATURE CHG ACROSS BOLT .......(TEMPB),E12.5,/,
     .       43H TEMPERATURE CHG ACROSS WALL .......(TEMPC),E12.5,/,
     .       43H TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO),E12.5,/,
     .       43H TEMPERATURE AT INSIDE OF LID .....(TEMPLI),E12.5   )
C
      CALL DATA(WC     )
      CALL DATA(WL     )
      CALL DATA(XI_DROP)
      CALL DATA(ACCI   )
      CALL DATA(DYLF   )
C
      WRITE(6,'(1H )')
      WRITE(6,60) WC,WL,XI_DROP,ACCI,DYLF
   60 FORMAT(43H WEIGHT OF CASK CONTENTS ..............(WC),E12.5,/,
     .       43H WEIGHT OF CASK LID ...................(WL),E12.5,/,
     .       43H DROP ANGLE OF IMPACT, deg .......(XI_DROP),E12.5,/,
     .       43H CG/CORNER IMPACT ACCEL, g ..........(ACCI),E12.5,/,
     .       43H DYNAMIC LOAD FACTOR ................(DYLF),E12.5   )
C
      CALL DATA(PUNC   )
      CALL DATA(XI_PUNC)
C
      WRITE(6,'(1H )')
      WRITE(6,70) PUNC,XI_PUNC
   70 FORMAT(43H PUNCTURE LOAD .......................(PUNC),E12.5,/,
     .       43H PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC),E12.5   )
C
      CALL DATA(AVA)
      CALL DATA(AVT)
      CALL DATA(VTR)
C
      WRITE(6,'(1H )')
      WRITE(6,80) AVA,AVT,VTR
   80 FORMAT(43H AXIAL VIBRATION ACCELERATION ........(AVA),E12.5,/,
     .       43H TRANSVERSE VIBRATION ACCELERATION ...(AVT),E12.5,/,
     .       43H VIBRATION TRANSMISSIBILITY FACTOR ...(VTR),E12.5   )
C
      CALL DATA(Q )
      CALL DATA(QK)
      CALL DATA(GB)
      CALL DATA(GY)
      CALL DATA(GM)
C
      WRITE(6,'(1H )')
      WRITE(6,90) Q,QK,GB,GY,GM
   90 FORMAT(43H PRELOAD TORQUE ...........................(Q),E12.5,/,
     .       43H NUT FACTOR FOR PRELOAD TORQUE ........(QK),E12.5,/,
```

```
     .       43H GASKET SEATING WIDTH ................(GB),E12.5,/,
     .       43H GASKET SEATING STRESS ...............(GY),E12.5,/,
     .       43H GASKET FACTOR .......................(GM),E12.5   )
C
      CALL DATA(SM )
      CALL DATA(SY )
      CALL DATA(SU )
      CALL DATA(CET)
      ICET=INT(CET)
C
      WRITE(6,'(1H )')
      WRITE(6,93) SM,SY,SU,ICET
   93 FORMAT(43H Sm STRESS ...........................(SM),E12.5,/,
     .       43H Sy STRESS ...........................(SY),E12.5,/,
     .       43H Su STRESS ...........................(SU),E12.5,/,
     .       43H CODE EVALUATION TYPE.................(CET),I12     )
C
      CALL DATA(FSO)
      CALL DATA(FSV)
      CALL DATA(XTI)
      NTI=INT(XTI)
C
      WRITE(6,'(1H )')
      WRITE(6,92) FSO,FSV,NTI
   92 FORMAT(43H OPERATING FATGIGUE STRESS (ksi) .....(FSO),E12.5,/,
     .       43H VIBRATION FATIGUE STRESS (ksi) ......(FSV),E12.5,/,
     .       43H NUMBER OF BOLT THREADS / INCH .......(NTI),I12     )
      N=0
C
  100 CONTINUE
      IF(N.NE.0) THEN
      WRITE(*,110) N
  110 FORMAT(///,' ERROR IN INPUT DATA LINE',I3,//)
      STOP
      ENDIF
C
C
C     FORCES & MOMENT DUE TO PRESSURE (TABLE 4.3)
C
      PIE  = 3.141592654
      FA_1 = PIE*DLG**2*(PLI-PLO)/(4*DPNB)
      FS_1 = PIE*EL*TL*(PCI-PCO)*DLB**2/(2*DPNB*EC*TC*(1.0-XNUL))
      FF_1 = DLB*(PLI-PLO)/4.0
      FM_1 = (PLI-PLO)*DLB**2/32.0
C
      WRITE(6,'(/////,41H ******** BOLT LOADS & STRESSES *********)')
      WRITE(6,'(//)')
      WRITE(6,'(43H BOLT FORCES DUE TO PRESSURE, TABLE 4.3    )')
      WRITE(6,120)
  120 FORMAT(52H ---------------------------------------------------)
      WRITE(6,'(37H AXIAL LOAD DUE TO PRESSURE..........,E15.5)') FA_1
      WRITE(6,'(37H SHEAR LOAD DUE TO PRESSURE..........,E15.5)') FS_1
      WRITE(6,'(37H EDGE LOAD DUE TO PRESSURE...........,E15.5)') FF_1
      WRITE(6,'(37H EDGE MOMENT DUE TO PRESSURE.........,E15.5)') FM_1
```

```
C
C
C     FORCES & MOMENT DUE TO TEMPERATURE (TABLE 4.4)
C
      FA_2 = 0.25*PIE*DB**2*EB*(AL*TEMPL-AB*TEMPB)
      FS_2 = PIE*EL*TL*DLB*(AL*TEMPL-AC*TEMPC)/(DPNB*(1.0-XNUL))
      FF_2 = 0.0
      FM_2 = EL*AL*TL**2*(TEMPLO-TEMPLI)/(12.0*(1.0-XNUL))
C
      WRITE(6,'(//)')
      WRITE(6,'(43H BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4 )')
      WRITE(6,120)
      WRITE(6,'(37H AXIAL LOAD DUE TO TEMPERATURE.......,E15.5)') FA_2
      WRITE(6,'(37H SHEAR LOAD DUE TO TEMPERATURE.......,E15.5)') FS_2
      WRITE(6,'(37H EDGE LOAD DUE TO TEMPERATURE........,E15.5)') FF_2
      WRITE(6,'(37H EDGE MOMENT DUE TEMPERATURE.........,E15.5)') FM_2
C
C
C     FORCES & MOMENT DUE TO CG/CORNER IMPACT (TABLE 4.5)
C
      XI   = XI_DROP*PIE/180.0
      FA_3 = 1.34*DSIN(XI)*DYLF*ACCI*(WL+WC)/DPNB
      FS_3 = DCOS(XI)*ACCI*WL/DPNB
      FF_3 = 1.34*DSIN(XI)*DYLF*ACCI*(WL+WC)/(PIE*DLB)
      FM_3 = 1.34*DSIN(XI)*DYLF*ACCI*(WL+WC)/(8.0*PIE)
C
      WRITE(6,'(//)')
      WRITE(6,'(43H BOLT FORCES DUE TO IMPACT, TABLE 4.5       )')
      WRITE(6,120)
      WRITE(6,'(37H AXIAL LOAD DUE TO IMPACT............,E15.5)') FA_3
      WRITE(6,'(37H SHEAR LOAD DUE TO IMPACT............,E15.5)') FS_3
      WRITE(6,'(37H EDGE LOAD DUE TO IMPACT.............,E15.5)') FF_3
      WRITE(6,'(37H EDGE MOMENT DUE IMPACT..............,E15.5)') FM_3
C
C
C     FORCES & MOMENT DUE TO PUNCTURE LOAD (TABLE 4.7)
C
      XI   = XI_PUNC*PIE/180.0
      FA_4 =-DSIN(XI)*PUNC/DPNB
      FS_4 = DCOS(XI)*PUNC/DPNB
      FF_4 =-DSIN(XI)*PUNC/(PIE*DLB)
      FM_4 =-DSIN(XI)*PUNC/(4.0*PIE)
C
      WRITE(6,'(//)')
      WRITE(6,'(43H BOLT FORCES DUE TO PUNCTURE, TABLE 4.7     )')
      WRITE(6,120)
      WRITE(6,'(37H AXIAL LOAD DUE TO PUNCTURE..........,E15.5)') FA_4
      WRITE(6,'(37H SHEAR LOAD DUE TO PUNCTURE..........,E15.5)') FS_4
      WRITE(6,'(37H EDGE LOAD DUE TO PUNCTURE...........,E15.5)') FF_4
      WRITE(6,'(37H EDGE MOMENT DUE PUNCTURE............,E15.5)') FM_4
C
C
C     FORCES & MOMENT DUE TO VIBRATION LOAD (TABLE 4.8)
C
```

```
      FA_5 = VTR*AVA*WL/DPNB
      FS_5 = VTR*AVT*WL/DPNB
      FF_5 = VTR*AVA*WL/(PIE*DLB)
      FM_5 = VTR*AVA*WL/(8.0*PIE)
C
      WRITE(6,'(//)')
      WRITE(6,'(43H BOLT FORCES DUE TO VIBRATION, TABLE 4.8    )')
      WRITE(6,120)
      WRITE(6,'(37H AXIAL LOAD DUE TO VIBRATION.........,E15.5)') FA_5
      WRITE(6,'(37H SHEAR LOAD DUE TO VIBRATION.........,E15.5)') FS_5
      WRITE(6,'(37H EDGE LOAD DUE TO VIBRATION..........,E15.5)') FF_5
      WRITE(6,'(37H EDGE MOMENT DUE VIBRATION...........,E15.5)') FM_5
C
C
C     FORCES & TORQUES DUE TO PRELOAD TORQING (TABLES 4.1 & 4.2)
C
      FA_6 = Q/(QK*DB)
      TM_6 = 0.5*Q
      FA_7 = PIE*DLG*GB*GY/DPNB
      TM_7 = 0.5*PIE*QK*DB*DLG*GB*GY/DPNB
      FA_8 = 2.0*PIE*DLG*GB*GM*(PLI-PLO)/DPNB
C
      WRITE(6,'(//)')
      WRITE(6,'(43H BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2)')
      WRITE(6,120)
      WRITE(6,'(37H AXIAL LOAD DUE TO PRELOAD...........,E15.5)') FA_6
      WRITE(6,'(37H AXIAL LOAD DUE TO GASKET SEATING....,E15.5)') FA_7
      WRITE(6,'(37H AXIAL LOAD DUE TO GASKET OPERATION..,E15.5)') FA_8
      WRITE(6,'(37H TORQUE DUE TO PRELOAD...............,E15.5)') TM_6
      WRITE(6,'(37H TORQUE DUE TO GASKET ...............,E15.5)') TM_7
C
C
C     TENSILE BOLT FORCE (TABLE 4.9)
C
      FA    = FA_1 + FA_2 + FA_3 + FA_4 + FA_5 + FA_6 + FA_8
      FA_PT = FA_2 + FA_6
      FA_AL = FA_1 + FA_3 + FA_4 + FA_5 + FA_8
C
      WRITE(6,'(//)')
      WRITE(6,'(43H TOTAL NON-PRYING BOLT FORCES, TABLE 4.9    )')
      WRITE(6,120)
      WRITE(6,'(37H TOTAL NON-PRYING AXIAL LOAD.........,E15.5)') FA
      WRITE(6,'(37H TEMP & PRELOAD NON-PRYING AXIAL LD..,E15.5)') FA_PT
      WRITE(6,'(37H AXIAL LOAD LESS TEMP & PRELOAD......,E15.5)') FA_AL
C
      IF(FA_PT .GE. FA_AL) THEN
      FA_C  = FA_PT
      ELSE
      FA_C  = FA_AL
      ENDIF
      IF(FA_C .LT. 0.0) FA_C=0.0
C
      FF_C = FF_1 + FF_2 + FF_3 + FF_4 + FF_5
      FM_C = FM_1 + FM_2 + FM_3 + FM_4 + FM_5
```

```
C
      WRITE(6,'(37H TOTAL EDGE LOAD.....................,E15.5)') FF_C
      WRITE(6,'(37H TOTAL EDGE MOMENT...................,E15.5)') FM_C
C
C
C     PRYING TENSILE BOLT FORCE (TABLES 2.1 & 2.2)
C
      C1 = 1.0
      C2 = (  8.0/(3.0*(DLO-DLB)**2) )
     .    *(  EL*TL**3/(1.0-XNUL) + (DLO-DLI)*ELF*TLF**3/DLB )
     .    *(  BL/( DPNB*DB**2*EB ) )
C
      S = DPNB/(PIE*DLB)
      P = S*FA_PT
C
      B = P
      IF(FF_C .GT. P)  B = FF_C
C
C
      FAP_C = (PIE*DLB/DPNB)
     .  *( 2.0*FM_C/(DLO-DLB) - C1*(B - FF_C) - C2*(B - P) )
     .  /(C1 + C2)
C
      XKB = (DPNB/BL)*(EB/DLB)*(DB**4/64.0)
      XKI = EL*TL**3/
     . ( 3.0*DLB*( (1.0-XNUL**2) + (1.0-XNUL)**2*(DLB/DLO)**2 ) )
C
      BMB = (PIE*DLB/DPNB)*(XKB/(XKB+XKI))*FM_C
C
      WRITE(6,'(//)')
      WRITE(6,'(43H PRYING ACTION FORCES, TABLE 2.1 & 2.2      )')
      WRITE(6,120)
      WRITE(6,'(37H AXIAL LOAD DUE TO PRYING............,E15.5)') FAP_C
      WRITE(6,'(37H BENDING MOMENT DUE TO PRYING........,E15.5)') BMB
C
C
C     TOTAL BOLT LOADS
C
C     FAT - TOTAL BOLT AXIAL LOAD
C     FST - TOTAL BOLT SHEAR LOAD
C     BMT - TOTAL BOLT BENDING MOMENT
C     BTT - TOTAL BOLT TORSIONAL MOMENT
C
      FAT = FA_C + FAP_C
      FST = FS_1 + FS_2 + FS_3 + FS_4 + FS_5
      BMT = FM_C + BMB
      BTT = TM_6
C
      WRITE(6,'(//)')
      WRITE(6,'(43H TOTAL BOLT FORCES                          )')
      WRITE(6,120)
      WRITE(6,'(37H TOTAL BOLT AXIAL LOAD...............,E15.5)') FAT
      WRITE(6,'(37H TOTAL BOLT SHEAR LOAD...............,E15.5)') FST
```

```
      WRITE(6,'(37H TOTAL BOLT BENDING MOMENT...........,E15.5)') BMT
      WRITE(6,'(37H TOTAL BOLT TORSIONAL MOMENT.........,E15.5)') BTT
C
C
C     BOLT STRESSES
C
      DBA=DB-0.9743/DBLE(NTI)
      BXA=PIE*(DBA/2)**2
      XI=PIE*DBA**3/32
      XJ=PIE*DBA**3/16
      SIG_A0=FAT/BXA
      SIG_A1=SIG_A0+BMT/XI
      SIG_A2=SIG_A0-BMT/XI
      SIG_A=SIG_A1
      IF(SIG_A2 .GT. SIG_A) SIG_A=SIG_A2
C********
C      SIG_S =DABS(FST/BXA)+DABS(BTT/XJ)
C      SIG_S0=DABS(FST/BXA)+DABS(BTT/XJ)/2

      SIG_S =DABS(BTT/XJ)
      SIG_S0=DABS(BTT/XJ)/2
C
      WRITE(6,'(//)')
      WRITE(6,'(43H TOTAL BOLT STRESSES                       )')
      WRITE(6,120)
      WRITE(6,'(37H TOTAL BOLT DIRECT STRESS (+MC/I) ...,E15.5)') SIG_A1
      WRITE(6,'(37H TOTAL BOLT DIRECT STRESS (-MC/I) ...,E15.5)') SIG_A2
      WRITE(6,'(37H AVE BOLT DIRECT STRESS .............,E15.5)') SIG_A0
      WRITE(6,'(37H TOTAL BOLT SHEAR STRESS ............,E15.5)') SIG_S
      WRITE(6,'(37H AVE BOLT SHEAR STRESS ..............,E15.5)') SIG_S0
C
C
C     CODE STRESS EVALUATION FOR NORMAL CONDITION (TABLE 6.1)
C
      IF(CET.EQ.1) THEN
      SM=1000.0*SM
      RT=SIG_A0/SM
      RS=SIG_S0/(0.6*SM)
      RC=RT**2 + RS**2
      RB=SIG_A/(1.5*SM)
      SE=DSQRT(SIG_A**2+4.0*SIG_S**2)
      RV=SE/(1.35*SM)
C
      WRITE(6,'(//)')
      WRITE(6,'(43H CODE EVALUATION FOR NORMAL COND, TABLE 6.1)')
      WRITE(6,120)
      WRITE(6,'(37H Rt (AXIAL_STRESS/Sm) ...............,E15.5)') RT
      WRITE(6,'(37H Rs (SHEAR_STRESS/0.6Sm) ............,E15.5)') RS
      WRITE(6,'(37H Rtý+Rsý ............................,E15.5)') RC
      WRITE(6,'(37H VON MISES EQUIVALENT STRESS (Se) ...,E15.5)') SE
      WRITE(6,'(37H Se/1.35Sm ..........................,E15.5)') RV
      ENDIF
C
C
```

```
C     CODE STRESS EVALUATION FOR ACCIDENT CONDITION (TABLE 6.3)
C
      IF(CET.EQ.2) THEN
      SU1=700.0*SU
      SY1=1000.0*SY
      SA=SU1
      IF(SA.GT.SY1) SA=SY1
      SU1=420*SU
      SY1=600*SY
      TA=SU1
      IF(TA.GT.SY1) TA=SY1
      RT=SIG_A0/SA
      RS=SIG_S0/TA
      RC=RT**2 + RS**2
C
      WRITE(6,'(//)')
      WRITE(6,'(43H CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3)')
      WRITE(6,120)
      WRITE(6,'(37H ALLOWABLE TENSILE STRESS (Sa) ......,E15.5)') SA
      WRITE(6,'(37H ALLOWABLE SHEAR STRESS (Ta) ........,E15.5)') TA
      WRITE(6,'(37H Rt (AVE AXIAL STRESS/Sa) ...........,E15.5)') RT
      WRITE(6,'(37H Rs (AVE SHEAR_STRESS/Ta) ...........,E15.5)') RS
      WRITE(6,'(37H Rtý+Rsý ............................,E15.5)') RC
      ENDIF
C
C
C     BOLT CLAMPING FORCE =   FA_AL (APPLIED LOADS LESS TEMP LOAD & PRE LOAD)
C                           + FAP_C (LOAD DUE TO PRYING ACTION)
C                           - FA_PT (PRE LOAD & TEMP LOAD)
C
      BCF = DABS(FA_AL) + DABS(FAP_C) - DABS(FA_PT)
      BD  = BCF*BL/(BXA*EB)
      BDA = 0.003
      FF  = FCF*BCF
C
      WRITE(6,'(//)')
      WRITE(6,'(43H FLANGE SEPARATION EVALUATION              )')
      WRITE(6,120)
      WRITE(6,'(37H BOLT CLAMPING FORCE ................,E15.5)') BCF
      WRITE(6,'(37H DISPLACEMENT ACROSS BOLT ...........,E15.5)') BD
      WRITE(6,'(37H ALLOWABLE FLANGE SEPARATION ........,E15.5)') BDA
      WRITE(6,'(37H FLANGE FRICTION FORCE ..............,E15.5)') FF
      WRITE(6,'(37H TOTAL BOLT SHEAR FORCE .............,E15.5)') FST
C
C
C     FATIGUE ANALYSIS
C
      IF(CET.EQ.1) THEN
      IF(FSO.GT.0.0 .OR. FSV.GT.0.0) THEN
      R1 = SIG_A/(1000.0*FSO)
      R2 = (FA_5/BXA)/(1000.0*FSV)
      R3 = R1+R2
```

```
C
      WRITE(6,'(//)')
      WRITE(6,'(43H FATIGUE EVALUATION                         )')
      WRITE(6,120)
      WRITE(6,'(37H USEAGE FOR NORMAL OPERATION ........,E15.5)') R1
      WRITE(6,'(37H USEAGE FOR VIBRATION  ..............,E15.5)') R2
      WRITE(6,'(37H ACCUMULATIVE FATIGUE USEAGE ........,E15.5)') R3
      ENDIF
      ENDIF
C
C
      END
      SUBROUTINE DATA(X)
C
C     READ NEXT DATA ITEM ON INPUT FILE
C
      REAL*8 X
      CHARACTER*80 BUFFER
C
  100 CONTINUE
      READ(5,'(A)',ERR=200,END=200) BUFFER
      IF(BUFFER(1:1).EQ.'*') GOTO 100
      BUFFER(1:43)=CHAR(32)
      REWIND 1
      WRITE(1,'(A)') BUFFER
      REWIND 1
      READ(1,*,ERR=100,END=200) X
      RETURN
  200 CONTINUE
      WRITE(6,210)
      STOP
  210 FORMAT(//' ERROR READING INPUT DATA FILE')
C
      RETURN
      END
```

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4.5.3 Cask Lid Attachment Bolt Fortran Program Input/Output Files

Note: *The Fortran program used in conjunction with these input and output files, is provided in Appendix 4.5.2.*

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4.5.3.1 Cask Lid Attachment Bolt Fortran Program Input Files

This appendix provides the following input files, that are used to build the content in Table 4-1:

- Cask Lid Attachment Bolt Fortran Program Input Files – Model AOS-025
- Cask Lid Attachment Bolt Fortran Program Input Files – Model AOS-050
- Cask Lid Attachment Bolt Fortran Program Input Files – Model AOS-100

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4.5.3.1.1 Cask Lid Attachment Bolt Fortran Program Input Files – Model AOS-025

This appendix provides the following input files, that are used to build the content in Table 4-1:

- Input, Normal Conditions of Transport, 30-Ft. Drop, 38°C (100°F) Ambient – Model AOS-025
- Input, Normal Conditions of Transport, 30-Ft. Drop, -40°C (-40°F) Ambient – Model AOS-025
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, 38°C (100°F) Ambient – Model AOS-025
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, -40°C (-40°F) Ambient – Model AOS-025
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, 38°C (100°F) Ambient – Model AOS-025
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, -40°C (-40°F) Ambient – Model AOS-025
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, 38°C (100°F) Ambient – Model AOS-025
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, -40°C (-40°F) Ambient – Model AOS-025

4.5.3.1.1.1 Input, Normal Conditions of Transport, 30-Ft. Drop, 38°C (100°F) Ambient – Model AOS-025

```
NORMAL CONDITION - AXIAL=10g,LATERAL=5g, AOS-025, 100F AMBIENT
*
NUMBER OF BOLTS .....................(NB)    8
LID DIAMETER AT BOLT CIRCLE .........(DLB)   3.90
LID DIAMETER AT GASKET .............(DLG)    3.07
NOMINAL BOLT DIAMETER ................(DB)   .375
LID DIAMETER AT INNER EDGE ..........(DLI)   2.63
LID DIAMETER AT OUTER EDGE ..........(DLO)   4.65
THICKNESS OF LID ....................(TL)    .37
THICKNESS OF LID FLANGE .............(TLF)   .48
THICKNESS OF CASK WALL ..............(TC)    1.03
BOLT LENGTH .........................(BL)    .15
BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .001
*
YOUNG'S MODULUS FOR LID ..............(EL)   27.3E6
YOUNG'S MODULUS FOR LID FLANGE .......(EL)   27.3E6
YOUNG'S MODULUS FOR CASK .............(EC)   27.3E6
YOUNG'S MODULUS FOR BOLT .............(EB)   28.0E6
POISSON'S RATIO FOR LID ............(XNUL)   0.3
POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
LID THERMAL EXPANSION COEFF ..........(AL)   9.0E-6
BOLT THERMAL EXPANSION COEFF .........(AB)   7.2E-6
WALL THERMAL EXPANSION COEFF .........(AC)   9.0E-6
FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
INSIDE PRESSURE AT LID ..............(PLI)   30.0
OUTSIDE PRESSURE AT LID .............(PLO)   15.0
INSIDE PRESSURE AT CASK WALL ........(PCI)   30.0
OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
TEMPERATURE CHG ACROSS LID ........(TEMPL)   185.
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   185.
TEMPERATURE CHG ACROSS WALL .......(TEMPC)   185.
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   185.
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   185.
*
WEIGHT OF CASK CONTENTS ..............(WC)   14.
WEIGHT OF CASK LID ...................(WL)   2.
DROP ANGLE OF IMPACT, deg .......(XI_DROP)   0.0
CG/CORNER IMPACT ACCEL, g ..........(ACCI)   0.
DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
PUNCTURE LOAD ......................(PUNC)   0.0
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
AXIAL VIBRATION ACCELERATION (g) ....(AVA)   10.0
TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   5.0
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
PRELOAD TORQUE .......................(Q)    420.0
```

```
NUT FACTOR FOR PRELOAD TORQUE ........(QK)    0.15
GASKET SEATING WIDTH .................(GB)    1.0
GASKET SEATING STRESS ................(GY)    3000.0
GASKET FACTOR ........................(GM)    9.53
*
Sm (ksi) .............................(SM)    95.
Sy (ksi) .............................(SY)    142.
Su (ksi) .............................(SU)    175.0
CODE EVALUATION TYPE ................(CET)    1
*
FATIGUE STRESS FOR NORMAL OPERATION .(FSO)     142.
FATIGUE STRESS FOR VIBRATION ........(FSV)     13.0
NUMBER OF BOLT THREADS INCH .........(NTI)     16
```

4.5.3.1.1.2 Input, Normal Conditions of Transport, 30-Ft. Drop, -40°C (-40°F) Ambient – Model AOS-025

```
NORMAL CONDITION - AXIAL=10g,LATERAL=5g, AOS-025, -40F AMBIENT
*
NUMBER OF BOLTS ......................(NB)   8
LID DIAMETER AT BOLT CIRCLE .........(DLB)   3.90
LID DIAMETER AT GASKET .............(DLG)    3.07
NOMINAL BOLT DIAMETER ................(DB)   .375
LID DIAMETER AT INNER EDGE ..........(DLI)   2.63
LID DIAMETER AT OUTER EDGE ..........(DLO)   4.65
THICKNESS OF LID .....................(TL)   .37
THICKNESS OF LID FLANGE .............(TLF)   .48
THICKNESS OF CASK WALL ...............(TC)   1.03
BOLT LENGTH ..........................(BL)   .15
BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .001
*
YOUNG'S MODULUS FOR LID ..............(EL)   28.3E6
YOUNG'S MODULUS FOR LID FLANGE .......(EL)   28.3E6
YOUNG'S MODULUS FOR CASK .............(EC)   28.3E6
YOUNG'S MODULUS FOR BOLT .............(EB)   29.1E6
POISSON'S RATIO FOR LID ............(XNUL)   0.3
POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
LID THERMAL EXPANSION COEFF ..........(AL)   8.6E-6
BOLT THERMAL EXPANSION COEFF .........(AB)   7.0E-6
WALL THERMAL EXPANSION COEFF .........(AC)   8.6E-6
FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
INSIDE PRESSURE AT LID ..............(PLI)   30.0
OUTSIDE PRESSURE AT LID .............(PLO)   15.0
INSIDE PRESSURE AT CASK WALL ........(PCI)   30.0
OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
TEMPERATURE CHG ACROSS LID ........(TEMPL)   -34.
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   -34.
TEMPERATURE CHG ACROSS WALL .......(TEMPC)   -34.
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   -34.
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   -34.
*
WEIGHT OF CASK CONTENTS ..............(WC)   14.
WEIGHT OF CASK LID ...................(WL)   2.
DROP ANGLE OF IMPACT, deg .......(XI_DROP)   0.0
CG/CORNER IMPACT ACCEL, g ..........(ACCI)   0.
DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
PUNCTURE LOAD ......................(PUNC)   0.0
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
AXIAL VIBRATION ACCELERATION (g) ....(AVA)   10.0
TRANSVERSE VIBRATION ACCELER (g) ....(AVT)   5.0
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
PRELOAD TORQUE ........................(Q)   420.0
```

```
 NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
 GASKET SEATING WIDTH .................(GB)   1.0
 GASKET SEATING STRESS ................(GY)   3000.0
 GASKET FACTOR ........................(GM)   9.53
*
 Sm (ksi) .............................(SM)   100.
 Sy (ksi) .............................(SY)   150.0
 Su (ksi) .............................(SU)   185.0
 CODE EVALUATION TYPE ................(CET)   1
*
 FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    150.0
 FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
 NUMBER OF BOLT THREADS INCH .........(NTI)    16
```

4.5.3.1.1.3 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, 38°C (100°F) Ambient – Model AOS-025

```
 30 FT DROP - HEAD ON, AOS-025, 100F AMBIENT
*
 NUMBER OF BOLTS .....................(NB)    8
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   3.90
 LID DIAMETER AT GASKET .............(DLG)    3.07
 NOMINAL BOLT DIAMETER ................(DB)   .375
 LID DIAMETER AT INNER EDGE ..........(DLI)   2.63
 LID DIAMETER AT OUTER EDGE ..........(DLO)   4.65
 THICKNESS OF LID ....................(TL)    .37
 THICKNESS OF LID FLANGE .............(TLF)   .48
 THICKNESS OF CASK WALL ...............(TC)   1.03
 BOLT LENGTH ..........................(BL)   .15
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .001
*
 YOUNG'S MODULUS FOR LID ..............(EL)   27.3E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   27.3E6
 YOUNG'S MODULUS FOR CASK .............(EC)   27.3E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   28.0E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   9.0E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.2E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   9.0E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID .............(PLI)    30.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   30.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   185.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   185.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   185.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   185.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   185.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   14.
 WEIGHT OF CASK LID ...................(WL)   2.
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   90.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   883.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD .....................(PUNC)    0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE .......................(Q)    420.0
```

```
NUT FACTOR FOR PRELOAD TORQUE ........(QK)    0.15
GASKET SEATING WIDTH .................(GB)    1.0
GASKET SEATING STRESS ................(GY)    3000.0
GASKET FACTOR ........................(GM)    9.53
*
Sm (ksi) .............................(SM)    95.
Sy (ksi) .............................(SY)    142.
Su (ksi) .............................(SU)    175.0
CODE EVALUATION TYPE .................(CET)   2
*
FATIGUE STRESS FOR NORMAL OPERATION .(FSO)     142.
FATIGUE STRESS FOR VIBRATION ........(FSV)     13.0
NUMBER OF BOLT THREADS INCH .........(NTI)     16
```

4.5.3.1.1.4 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, -40°C (-40°F) Ambient – Model AOS-025

```
 30 FT DROP - HEAD ON, AOS-025, -40F AMBIENT
*
 NUMBER OF BOLTS ......................(NB)   8
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   3.90
 LID DIAMETER AT GASKET .............(DLG)    3.07
 NOMINAL BOLT DIAMETER ................(DB)   .375
 LID DIAMETER AT INNER EDGE ..........(DLI)   2.63
 LID DIAMETER AT OUTER EDGE ..........(DLO)   4.65
 THICKNESS OF LID .....................(TL)   .37
 THICKNESS OF LID FLANGE .............(TLF)   .48
 THICKNESS OF CASK WALL ...............(TC)   1.03
 BOLT LENGTH ..........................(BL)   .15
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .001
*
 YOUNG'S MODULUS FOR LID ..............(EL)   28.3E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   28.3E6
 YOUNG'S MODULUS FOR CASK .............(EC)   28.3E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   29.1E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   8.6E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.0E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   8.6E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   30.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   30.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   -34.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   -34.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   -34.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   -34.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   -34.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   14.
 WEIGHT OF CASK LID ...................(WL)   2.
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   90.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   1237.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)   420.0
```

```
NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
GASKET SEATING WIDTH .................(GB)   1.0
GASKET SEATING STRESS ................(GY)   3000.0
GASKET FACTOR ........................(GM)   9.53
*
Sm (ksi) .............................(SM)   100.
Sy (ksi) .............................(SY)   150.0
Su (ksi) .............................(SU)   185.0
CODE EVALUATION TYPE ................(CET)   2
*
FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    150.0
FATIGUE STRESS FOR VIBRATION.........(FSV)    13.0
NUMBER OF BOLT THREADS INCH .........(NTI)    16
```

4.5.3.1.1.5 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, 38°C (100°F) Ambient – Model AOS-025

```
 30 FT DROP - SIDE ORIENTATION, AOS-025, 100F AMBIENT
*
 NUMBER OF BOLTS ......................(NB)    8
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   3.90
 LID DIAMETER AT GASKET .............(DLG)    3.07
 NOMINAL BOLT DIAMETER ................(DB)   .375
 LID DIAMETER AT INNER EDGE ..........(DLI)   2.63
 LID DIAMETER AT OUTER EDGE ..........(DLO)   4.65
 THICKNESS OF LID .....................(TL)   .37
 THICKNESS OF LID FLANGE .............(TLF)   .48
 THICKNESS OF CASK WALL ...............(TC)   1.03
 BOLT LENGTH ..........................(BL)   .15
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .001
*
 YOUNG'S MODULUS FOR LID ..............(EL)   27.3E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   27.3E6
 YOUNG'S MODULUS FOR CASK .............(EC)   27.3E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   28.0E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   9.0E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.2E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   9.0E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   30.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   30.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   185.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   185.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   185.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   185.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   185.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   14.
 WEIGHT OF CASK LID ...................(WL)   2.
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   0.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   1286.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)   420.0
```

```
NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
GASKET SEATING WIDTH .................(GB)   1.0
GASKET SEATING STRESS ................(GY)   3000.0
GASKET FACTOR ........................(GM)   9.53
*
Sm (ksi) .............................(SM)   95.
Sy (ksi) .............................(SY)   142.
Su (ksi) .............................(SU)   175.0
CODE EVALUATION TYPE ................(CET)   2
*
FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    142.
FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
NUMBER OF BOLT THREADS INCH .........(NTI)    16
```

4.5.3.1.1.6 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, -40°C (-40°F) Ambient – Model AOS-025

```
 30 FT DROP - SIDE ORIENTATION, AOS-025, -40F AMBIENT
*
 NUMBER OF BOLTS ......................(NB)    8
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   3.90
 LID DIAMETER AT GASKET .............(DLG)    3.07
 NOMINAL BOLT DIAMETER ................(DB)   .375
 LID DIAMETER AT INNER EDGE ..........(DLI)   2.63
 LID DIAMETER AT OUTER EDGE ..........(DLO)   4.65
 THICKNESS OF LID .....................(TL)   .37
 THICKNESS OF LID FLANGE .............(TLF)   .48
 THICKNESS OF CASK WALL ...............(TC)   1.03
 BOLT LENGTH ..........................(BL)   .15
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .001
*
 YOUNG'S MODULUS FOR LID ..............(EL)   28.3E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   28.3E6
 YOUNG'S MODULUS FOR CASK .............(EC)   28.3E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   29.1E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   8.6E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.0E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   8.6E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   30.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   30.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   -34.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   -34.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   -34.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   -34.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   -34.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   14.
 WEIGHT OF CASK LID ...................(WL)   2.
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   0.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   1798.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)   420.0
```

```
NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
GASKET SEATING WIDTH .................(GB)   1.0
GASKET SEATING STRESS ................(GY)   3000.0
GASKET FACTOR ........................(GM)   9.53
*
Sm (ksi) .............................(SM)   100.
Sy (ksi) .............................(SY)   150.0
Su (ksi) .............................(SU)   185.0
CODE EVALUATION TYPE ................(CET)   2
*
FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    150.0
FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
NUMBER OF BOLT THREADS INCH .........(NTI)    16
```

4.5.3.1.1.7 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, 38°C (100°F) Ambient – Model AOS-025

```
 30FT DROP @ 45 DEG, AOS-025, 100F AMBIENT
*
 NUMBER OF BOLTS ......................(NB)    8
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   3.90
 LID DIAMETER AT GASKET .............(DLG)    3.07
 NOMINAL BOLT DIAMETER ................(DB)   .375
 LID DIAMETER AT INNER EDGE ..........(DLI)   2.63
 LID DIAMETER AT OUTER EDGE ..........(DLO)   4.65
 THICKNESS OF LID .....................(TL)   .37
 THICKNESS OF LID FLANGE .............(TLF)   .48
 THICKNESS OF CASK WALL ...............(TC)   1.03
 BOLT LENGTH ..........................(BL)   .15
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .001
*
 YOUNG'S MODULUS FOR LID ..............(EL)   27.3E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   27.3E6
 YOUNG'S MODULUS FOR CASK .............(EC)   27.3E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   28.0E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   9.0E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.2E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   9.0E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   30.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   30.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   185.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   185.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   185.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   185.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   185.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   14.
 WEIGHT OF CASK LID ...................(WL)   2.
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   45.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   799.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)   420.0
```

```
 NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
 GASKET SEATING WIDTH .................(GB)   1.0
 GASKET SEATING STRESS ................(GY)   3000.0
 GASKET FACTOR ........................(GM)   9.53
*
 Sm (ksi) .............................(SM)   95.
 Sy (ksi) .............................(SY)   142.
 Su (ksi) .............................(SU)   175.0
 CODE EVALUATION TYPE ................(CET)   2
*
 FATIGUE STRESS FOR NORMAL OPERATION .(FSO)     142.
 FATIGUE STRESS FOR VIBRATION ........(FSV)     13.0
 NUMBER OF BOLT THREADS INCH .........(NTI)     16
```

4.5.3.1.1.8 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, -40°C (-40°F) Ambient – Model AOS-025

```
 30FT DROP @ 45 DEG, AOS-025, -40F AMBIENT
*
 NUMBER OF BOLTS ......................(NB)   8
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   3.90
 LID DIAMETER AT GASKET .............(DLG)    3.07
 NOMINAL BOLT DIAMETER ................(DB)   .375
 LID DIAMETER AT INNER EDGE ..........(DLI)   2.63
 LID DIAMETER AT OUTER EDGE ..........(DLO)   4.65
 THICKNESS OF LID .....................(TL)   .37
 THICKNESS OF LID FLANGE .............(TLF)   .48
 THICKNESS OF CASK WALL ...............(TC)   1.03
 BOLT LENGTH ..........................(BL)   .15
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .001
*
 YOUNG'S MODULUS FOR LID ..............(EL)   28.3E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   28.3E6
 YOUNG'S MODULUS FOR CASK .............(EC)   28.3E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   29.1E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   8.6E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.0E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   8.6E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   30.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   30.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID .......(TEMPL)   -34.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   -34.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   -34.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   -34.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   -34.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   14.
 WEIGHT OF CASK LID ...................(WL)   2.
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   45.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   1125.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)   420.0
```

```
NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
GASKET SEATING WIDTH .................(GB)   1.0
GASKET SEATING STRESS ................(GY)   3000.0
GASKET FACTOR ........................(GM)   9.53
*
Sm (ksi) .............................(SM)   100.
Sy (ksi) .............................(SY)   150.0
Su (ksi) .............................(SU)   185.0
CODE EVALUATION TYPE ................(CET)   2
*
FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    150.0
FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
NUMBER OF BOLT THREADS INCH .........(NTI)    16
```

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4.5.3.1.2 Cask Lid Attachment Bolt Fortran Program Input Files – Model AOS-050

This appendix provides the following input files, that are used to build the content in Table 4-1:

- Input, Normal Conditions of Transport, 30-Ft. Drop, 38°C (100°F) Ambient – Model AOS-050
- Input, Normal Conditions of Transport, 30-Ft. Drop, -40°C (-40°F) Ambient – Model AOS-050
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, 38°C (100°F) Ambient – Model AOS-050
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, -40°C (-40°F) Ambient – Model AOS-050
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, 38°C (100°F) Ambient – Model AOS-050
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, -40°C (-40°F) Ambient – Model AOS-050
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, 38°C (100°F) Ambient – Model AOS-050
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, -40°C (-40°F) Ambient – Model AOS-050

4.5.3.1.2.1 Input, Normal Conditions of Transport, 30-Ft. Drop, 38°C (100°F) Ambient – Model AOS-050

```
 30FT DROP @ 45 DEG, AOS-025, -40F AMBIENT
*
 NUMBER OF BOLTS ......................(NB)    8
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   3.90
 LID DIAMETER AT GASKET .............(DLG)    3.07
 NOMINAL BOLT DIAMETER ................(DB)   .375
 LID DIAMETER AT INNER EDGE ..........(DLI)   2.63
 LID DIAMETER AT OUTER EDGE ..........(DLO)   4.65
 THICKNESS OF LID .....................(TL)   .37
 THICKNESS OF LID FLANGE .............(TLF)   .48
 THICKNESS OF CASK WALL ...............(TC)   1.03
 BOLT LENGTH ..........................(BL)   .15
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .001
*
 YOUNG'S MODULUS FOR LID ..............(EL)   28.3E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   28.3E6
 YOUNG'S MODULUS FOR CASK .............(EC)   28.3E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   29.1E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   8.6E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.0E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   8.6E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   30.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   30.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   -34.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   -34.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   -34.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   -34.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   -34.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   14.
 WEIGHT OF CASK LID ...................(WL)   2.
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   45.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   1125.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)   420.0
```

```
NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
GASKET SEATING WIDTH .................(GB)   1.0
GASKET SEATING STRESS ................(GY)   3000.0
GASKET FACTOR ........................(GM)   9.53
*
Sm (ksi) .............................(SM)   100.
Sy (ksi) .............................(SY)   150.0
Su (ksi) .............................(SU)   185.0
CODE EVALUATION TYPE ................(CET)   2
*
FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    150.0
FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
NUMBER OF BOLT THREADS INCH .........(NTI)    16
```

4.5.3.1.2.2 Input, Normal Conditions of Transport, 30-Ft. Drop, -40°C (-40°F) Ambient – Model AOS-050

```
 NORMAL CONDITION - AXIAL=10g,LATERAL=5g AOS-050, -40F AMBIENT
*
 NUMBER OF BOLTS ......................(NB)   10
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   7.414
 LID DIAMETER AT GASKET .............(DLG)    6.09
 NOMINAL BOLT DIAMETER ................(DB)   .50
 LID DIAMETER AT INNER EDGE ..........(DLI)   5.53
 LID DIAMETER AT OUTER EDGE ..........(DLO)   8.90
 THICKNESS OF LID .....................(TL)   .75
 THICKNESS OF LID FLANGE .............(TLF)   .97
 THICKNESS OF CASK WALL ...............(TC)   1.705
 BOLT LENGTH ..........................(BL)   .41
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .003
*
 YOUNG'S MODULUS FOR LID ..............(EL)   28.3E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   28.3E6
 YOUNG'S MODULUS FOR CASK .............(EC)   28.3E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   28.9E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   8.6E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.0E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   8.6E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   60.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   60.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   15.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   15.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   15.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   15.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   16.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   95.
 WEIGHT OF CASK LID ...................(WL)   14.
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   0.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   0.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   10.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   5.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)   750.0
```

```
NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
GASKET SEATING WIDTH ................(GB)   1.0
GASKET SEATING STRESS ...............(GY)   3000.0
GASKET FACTOR .......................(GM)   3.18
*
Sm (ksi) ............................(SM)   100.
Sy (ksi) ............................(SY)   150.0
Su (ksi) ............................(SU)   185.0
CODE EVALUATION TYPE ................(CET)  1
*
FATIGUE STRESS FOR NORMAL OPERATION .(FSO)   150.0
FATIGUE STRESS FOR VIBRATION ........(FSV)   13.0
NUMBER OF BOLT THREADS INCH .........(NTI)   13
```

4.5.3.1.2.3 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, 38°C (100°F) Ambient – Model AOS-050

```
 30-FT DROP HEAD ON AOS-050 CONFIGURATION, 100F AMBIENT
*
 NUMBER OF BOLTS ......................(NB)    10
 LID DIAMETER AT BOLT CIRCLE .........(DLB)    7.414
 LID DIAMETER AT GASKET .............(DLG)     6.09
 NOMINAL BOLT DIAMETER ................(DB)    .50
 LID DIAMETER AT INNER EDGE ..........(DLI)    5.53
 LID DIAMETER AT OUTER EDGE ..........(DLO)    8.90
 THICKNESS OF LID .....................(TL)    .75
 THICKNESS OF LID FLANGE .............(TLF)    .97
 THICKNESS OF CASK WALL ...............(TC)    1.705
 BOLT LENGTH ..........................(BL)    .41
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)    .003
*
 YOUNG'S MODULUS FOR LID ..............(EL)    27.1E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)    27.1E6
 YOUNG'S MODULUS FOR CASK .............(EC)    27.1E6
 YOUNG'S MODULUS FOR BOLT .............(EB)    27.9E6
 POISSON'S RATIO FOR LID ............(XNUL)    0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)    0.3
 LID THERMAL EXPANSION COEFF ..........(AL)    9.0E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)    7.3E-6
 WALL THERMAL EXPANSION COEFF .........(AC)    9.0E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)    0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)    60.0
 OUTSIDE PRESSURE AT LID .............(PLO)    15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)    60.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)    15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)    216.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)    216.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)    216.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)    216.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)    216.
*
 WEIGHT OF CASK CONTENTS ..............(WC)    95.
 WEIGHT OF CASK LID ...................(WL)    14.
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)    90.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)    314.
 DYNAMIC LOAD FACTOR ................(DYLF)    1.15
*
 PUNCTURE LOAD ......................(PUNC)    0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)    45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)    0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)    0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)    1.0
*
 PRELOAD TORQUE ........................(Q)    750.0
```

```
NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
GASKET SEATING WIDTH .................(GB)   1.0
GASKET SEATING STRESS ................(GY)   3000.0
GASKET FACTOR ........................(GM)   3.18
*
Sm (ksi) .............................(SM)   94.
Sy (ksi) .............................(SY)   141.0
Su (ksi) .............................(SU)   174.0
CODE EVALUATION TYPE ................(CET)   2
*
FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    141.0
FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
NUMBER OF BOLT THREADS INCH .........(NTI)    13
```

4.5.3.1.2.4 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, -40°C (-40°F) Ambient – Model AOS-050

```
30-FT DROP HEAD ON AOS-050 CONFIGURATION, -40F AMBIENT
*
NUMBER OF BOLTS ......................(NB)    10
LID DIAMETER AT BOLT CIRCLE .........(DLB)   7.414
LID DIAMETER AT GASKET .............(DLG)    6.09
NOMINAL BOLT DIAMETER ................(DB)    .50
LID DIAMETER AT INNER EDGE ..........(DLI)   5.53
LID DIAMETER AT OUTER EDGE ..........(DLO)   8.90
THICKNESS OF LID .....................(TL)    .75
THICKNESS OF LID FLANGE .............(TLF)   .97
THICKNESS OF CASK WALL ...............(TC)   1.705
BOLT LENGTH ..........................(BL)   .41
BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .003
*
YOUNG'S MODULUS FOR LID ..............(EL)   28.3E6
YOUNG'S MODULUS FOR LID FLANGE .......(EL)   28.3E6
YOUNG'S MODULUS FOR CASK .............(EC)   28.3E6
YOUNG'S MODULUS FOR BOLT .............(EB)   28.9E6
POISSON'S RATIO FOR LID ............(XNUL)   0.3
POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
LID THERMAL EXPANSION COEFF ..........(AL)   8.6E-6
BOLT THERMAL EXPANSION COEFF .........(AB)   7.0E-6
WALL THERMAL EXPANSION COEFF .........(AC)   8.6E-6
FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
INSIDE PRESSURE AT LID ..............(PLI)   60.0
OUTSIDE PRESSURE AT LID .............(PLO)   15.0
INSIDE PRESSURE AT CASK WALL ........(PCI)   60.0
OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
TEMPERATURE CHG ACROSS LID ........(TEMPL)   15.
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   15.
TEMPERATURE CHG ACROSS WALL .......(TEMPC)   15.
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   15.
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   16.
*
WEIGHT OF CASK CONTENTS ..............(WC)   95.
WEIGHT OF CASK LID ...................(WL)   14.
DROP ANGLE OF IMPACT, deg .......(XI_DROP)   90.0
CG/CORNER IMPACT ACCEL, g ..........(ACCI)   439.
DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
PUNCTURE LOAD ......................(PUNC)    0.0
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
PRELOAD TORQUE ........................(Q)    750.0
```

```
 NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
 GASKET SEATING WIDTH .................(GB)   1.0
 GASKET SEATING STRESS ................(GY)   3000.0
 GASKET FACTOR ........................(GM)   3.18
*
 Sm (ksi) .............................(SM)   100.
 Sy (ksi) .............................(SY)   150.
 Su (ksi) .............................(SU)   185.0
 CODE EVALUATION TYPE ................(CET)   2
*
 FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    150.
 FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
 NUMBER OF BOLT THREADS INCH .........(NTI)    13
```

4.5.3.1.2.5 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, 38°C (100°F) Ambient – Model AOS-050

```
 30-FT DROP SIDE ORIENTATION AOS-050 , 100F AMBIENT
*
 NUMBER OF BOLTS ......................(NB)   10
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   7.414
 LID DIAMETER AT GASKET .............(DLG)    6.09
 NOMINAL BOLT DIAMETER ................(DB)   .50
 LID DIAMETER AT INNER EDGE ..........(DLI)   5.53
 LID DIAMETER AT OUTER EDGE ..........(DLO)   8.90
 THICKNESS OF LID .....................(TL)   .75
 THICKNESS OF LID FLANGE .............(TLF)   .97
 THICKNESS OF CASK WALL ...............(TC)   1.705
 BOLT LENGTH ..........................(BL)   .41
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .003
*
 YOUNG'S MODULUS FOR LID ..............(EL)   27.1E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   27.1E6
 YOUNG'S MODULUS FOR CASK .............(EC)   27.1E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   27.9E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   9.0E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.3E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   9.0E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   60.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   60.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   216.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   216.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   216.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   216.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   216.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   95.
 WEIGHT OF CASK LID ...................(WL)   14.
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   0.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   335.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)   750.0
```

```
NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
GASKET SEATING WIDTH .................(GB)   1.0
GASKET SEATING STRESS ................(GY)   3000.0
GASKET FACTOR ........................(GM)   3.18
*
Sm (ksi) .............................(SM)   94.
Sy (ksi) .............................(SY)   141.0
Su (ksi) .............................(SU)   174.0
CODE EVALUATION TYPE ................(CET)   2
*
FATIGUE STRESS FOR NORMAL OPERATION .(FSO)     141.0
FATIGUE STRESS FOR VIBRATION ........(FSV)     13.0
NUMBER OF BOLT THREADS INCH .........(NTI)     13
```

4.5.3.1.2.6 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, -40°C (-40°F) Ambient – Model AOS-050

```
 30-FT DROP SIDE ORIENTATION AOS-050, -40F AMBIENT
*
 NUMBER OF BOLTS ......................(NB)    10
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   7.414
 LID DIAMETER AT GASKET .............(DLG)    6.09
 NOMINAL BOLT DIAMETER ................(DB)    .50
 LID DIAMETER AT INNER EDGE ..........(DLI)   5.53
 LID DIAMETER AT OUTER EDGE ..........(DLO)   8.90
 THICKNESS OF LID .....................(TL)    .75
 THICKNESS OF LID FLANGE .............(TLF)   .97
 THICKNESS OF CASK WALL ...............(TC)    1.705
 BOLT LENGTH ..........................(BL)    .41
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .003
*
 YOUNG'S MODULUS FOR LID ..............(EL)    28.3E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)    28.3E6
 YOUNG'S MODULUS FOR CASK .............(EC)    28.3E6
 YOUNG'S MODULUS FOR BOLT .............(EB)    28.9E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)    8.6E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)    7.0E-6
 WALL THERMAL EXPANSION COEFF .........(AC)    8.6E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   60.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   60.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   15.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   15.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   15.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   15.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   16.
*
 WEIGHT OF CASK CONTENTS ..............(WC)    95.
 WEIGHT OF CASK LID ...................(WL)    14.
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   0.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   469.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)    750.0
```

```
NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
GASKET SEATING WIDTH .................(GB)   1.0
GASKET SEATING STRESS ................(GY)   3000.0
GASKET FACTOR ........................(GM)   3.18
*
Sm (ksi) .............................(SM)   100.
Sy (ksi) .............................(SY)   150.
Su (ksi) .............................(SU)   185.0
CODE EVALUATION TYPE ................(CET)   2
*
FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    150.
FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
NUMBER OF BOLT THREADS INCH .........(NTI)    13
```

4.5.3.1.2.7 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, 38°C (100°F) Ambient – Model AOS-050

```
30-FT @ 45 DEG CORNER AOS-050 CONFIGURATION, 100F AMBIENT
*
NUMBER OF BOLTS .....................(NB)    10
LID DIAMETER AT BOLT CIRCLE .........(DLB)   7.414
LID DIAMETER AT GASKET .............(DLG)    6.09
NOMINAL BOLT DIAMETER ................(DB)   .50
LID DIAMETER AT INNER EDGE ..........(DLI)   5.53
LID DIAMETER AT OUTER EDGE ..........(DLO)   8.9
THICKNESS OF LID ....................(TL)    .75
THICKNESS OF LID FLANGE .............(TLF)   .97
THICKNESS OF CASK WALL ...............(TC)   1.705
BOLT LENGTH .........................(BL)    .41
BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .003
*
YOUNG'S MODULUS FOR LID ..............(EL)   27.1E6
YOUNG'S MODULUS FOR LID FLANGE .......(EL)   27.1E6
YOUNG'S MODULUS FOR CASK .............(EC)   27.1E6
YOUNG'S MODULUS FOR BOLT .............(EB)   27.9E6
POISSON'S RATIO FOR LID ............(XNUL)   0.3
POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
LID THERMAL EXPANSION COEFF ..........(AL)   9.0E-6
BOLT THERMAL EXPANSION COEFF .........(AB)   7.3E-6
WALL THERMAL EXPANSION COEFF .........(AC)   9.0E-6
FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
INSIDE PRESSURE AT LID ..............(PLI)   60.0
OUTSIDE PRESSURE AT LID .............(PLO)   15.0
INSIDE PRESSURE AT CASK WALL ........(PCI)   60.0
OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
TEMPERATURE CHG ACROSS LID ........(TEMPL)   216.
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   216.
TEMPERATURE CHG ACROSS WALL .......(TEMPC)   216.
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   216.
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   216.
*
WEIGHT OF CASK CONTENTS ..............(WC)   95.
WEIGHT OF CASK LID ...................(WL)   14.
DROP ANGLE OF IMPACT, deg .......(XI_DROP)   45.
CG/CORNER IMPACT ACCEL, g ..........(ACCI)   176.
DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
PUNCTURE LOAD ......................(PUNC)   0.0
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
PRELOAD TORQUE ........................(Q)   750.0
```

```
 NUT.FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
 GASKET SEATING WIDTH .................(GB)   1.0
 GASKET SEATING STRESS ................(GY)   3000.
 GASKET FACTOR ........................(GM)   3.18
*
 Sm (ksi) .............................(SM)   94.
 Sy (ksi) .............................(SY)   141.0
 Su (ksi) .............................(SU)   174.0
 CODE EVALUATION TYPE ................(CET)   2
*
 FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    141.0
 FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
 NUMBER OF BOLT THREADS INCH .........(NTI)    13
```

4.5.3.1.2.8 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, -40°C (-40°F) Ambient – Model AOS-050

```
30-FT @ 45 DEG CORNER AOS-050 CONFIGURATION, -40F AMBIENT
*
NUMBER OF BOLTS ......................(NB)     10
LID DIAMETER AT BOLT CIRCLE .........(DLB)    7.414
LID DIAMETER AT GASKET .............(DLG)     6.09
NOMINAL BOLT DIAMETER ................(DB)    .50
LID DIAMETER AT INNER EDGE ..........(DLI)    5.53
LID DIAMETER AT OUTER EDGE ..........(DLO)    8.9
THICKNESS OF LID .....................(TL)    .75
THICKNESS OF LID FLANGE .............(TLF)    .97
THICKNESS OF CASK WALL ...............(TC)    1.705
BOLT LENGTH ..........................(BL)    .41
BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)    .003
*
YOUNG'S MODULUS FOR LID ..............(EL)    28.3E6
YOUNG'S MODULUS FOR LID FLANGE .......(EL)    28.3E6
YOUNG'S MODULUS FOR CASK .............(EC)    28.3E6
YOUNG'S MODULUS FOR BOLT .............(EB)    28.9E6
POISSON'S RATIO FOR LID ............(XNUL)    0.3
POISSON'S RATIO FOR CASK ...........(XNUC)    0.3
LID THERMAL EXPANSION COEFF ..........(AL)    8.6E-6
BOLT THERMAL EXPANSION COEFF .........(AB)    7.0E-6
WALL THERMAL EXPANSION COEFF .........(AC)    8.6E-6
FLANGE COEFFICIENT OF FRICTION ......(FCF)    0.9
*
INSIDE PRESSURE AT LID ..............(PLI)    60.0
OUTSIDE PRESSURE AT LID .............(PLO)    15.0
INSIDE PRESSURE AT CASK WALL ........(PCI)    60.0
OUTSIDE PRESSURE AT CASK WALL .......(PCO)    15.0
*
TEMPERATURE CHG ACROSS LID ........(TEMPL)    15.
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)    15.
TEMPERATURE CHG ACROSS WALL .......(TEMPC)    15.
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)    15.
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)    16.
*
WEIGHT OF CASK CONTENTS ..............(WC)    95.
WEIGHT OF CASK LID ...................(WL)    14.
DROP ANGLE OF IMPACT, deg .......(XI_DROP)    45.
CG/CORNER IMPACT ACCEL, g ..........(ACCI)    247.
DYNAMIC LOAD FACTOR ................(DYLF)    1.15
*
PUNCTURE LOAD ......................(PUNC)    0.0
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)    45.0
*
AXIAL VIBRATION ACCELERATION (g) ....(AVA)    0.0
TRANSVERSE VIBRATION ACCELER (g). ...(AVT)    0.0
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)    1.0
*
PRELOAD TORQUE ........................(Q)    750.0
```

```
NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
GASKET SEATING WIDTH .................(GB)   1.0
GASKET SEATING STRESS ................(GY)   3000.
GASKET FACTOR ........................(GM)   3.18
*
Sm (ksi) .............................(SM)   100.
Sy (ksi) .............................(SY)   150.
Su (ksi) .............................(SU)   185.0
CODE EVALUATION TYPE ................(CET)   2
*
FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    150.
FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
NUMBER OF BOLT THREADS INCH .........(NTI)    13
```

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4.5.3.1.3 Cask Lid Attachment Bolt Fortran Program Input Files – Model AOS-100

This appendix provides the following input files, that are used to build the content in Table 4-1:

- Input, Normal Conditions of Transport, 30-Ft. Drop, 38°C (100°F) Ambient – Model AOS-100
- Input, Normal Conditions of Transport, 30-Ft. Drop, -40°C (-40°F) Ambient – Model AOS-100
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, 38°C (100°F) Ambient – Model AOS-100
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, -40°C (-40°F) Ambient – Model AOS-100
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, 38°C (100°F) Ambient – Model AOS-100
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, -40°C (-40°F) Ambient – Model AOS-100
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, 38°C (100°F) Ambient – Model AOS-100
- Input, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, -40°C (-40°F) Ambient – Model AOS-100

4.5.3.1.3.1 Input, Normal Conditions of Transport, 30-Ft. Drop, 38°C (100°F) Ambient – Model AOS-100

```
 NORMAL CONDITION - AXIAL=10g,LATERAL=5g AOS-100, 100F AMBIENT
*
 NUMBER OF BOLTS ......................(NB)    14
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   14.064
 LID DIAMETER AT GASKET .............(DLG)    12.172
 NOMINAL BOLT DIAMETER ................(DB)   .875
 LID DIAMETER AT INNER EDGE ..........(DLI)   11.04
 LID DIAMETER AT OUTER EDGE ..........(DLO)   16.59
 THICKNESS OF LID .....................(TL)   1.51
 THICKNESS OF LID FLANGE .............(TLF)   1.94
 THICKNESS OF CASK WALL ...............(TC)   2.805
 BOLT LENGTH ..........................(BL)   1.06
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .029
*
 YOUNG'S MODULUS FOR LID ..............(EL)   27.1E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   27.1E6
 YOUNG'S MODULUS FOR CASK .............(EC)   27.1E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   27.9E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   9.1E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.3E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   9.1E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   280.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   280.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   223.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   223.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   223.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   224.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   224.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   786.0
 WEIGHT OF CASK LID ...................(WL)   96.0
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   0.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   0.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   10.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   5.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)   6000.0
```

```
 NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
 GASKET SEATING WIDTH .................(GB)   1.0
 GASKET SEATING STRESS ................(GY)   3000.0
 GASKET FACTOR ........................(GM)   .54
*
 Sm (ksi) .............................(SM)   94.
 Sy (ksi) .............................(SY)   141.
 Su (ksi) .............................(SU)   174.0
 CODE EVALUATION TYPE .................(CET)  1
*
 FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    141.
 FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
 NUMBER OF BOLT THREADS INCH .........(NTI)    9
```

4.5.3.1.3.2 Input, Normal Conditions of Transport, 30-Ft. Drop, -40°C (-40°F) Ambient – Model AOS-100

```
 NORMAL CONDITION - AXIAL=10g,LATERAL=5g AOS-100, -40F Ambient
*
 NUMBER OF BOLTS ......................(NB)    14
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   14.064
 LID DIAMETER AT GASKET .............(DLG)    12.172
 NOMINAL BOLT DIAMETER ................(DB)    .875
 LID DIAMETER AT INNER EDGE ..........(DLI)   11.04
 LID DIAMETER AT OUTER EDGE ..........(DLO)   16.59
 THICKNESS OF LID .....................(TL)   1.51
 THICKNESS OF LID FLANGE .............(TLF)   1.94
 THICKNESS OF CASK WALL ...............(TC)   2.805
 BOLT LENGTH ..........................(BL)   1.06
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .029
*
 YOUNG'S MODULUS FOR LID ..............(EL)   28.3E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   28.3E6
 YOUNG'S MODULUS FOR CASK .............(EC)   28.3E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   28.9E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   8.6E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.0E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   8.6E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   280.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   280.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   15.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   15.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   15.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   16.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   16.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   786.0
 WEIGHT OF CASK LID ...................(WL)   96.0
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   0.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   0.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   10.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   5.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)   6000.0
```

```
NUT FACTOR FOR PRELOAD TORQUE ........(QK)    0.15
GASKET SEATING WIDTH .................(GB)    1.0
GASKET SEATING STRESS ................(GY)    3000.0
GASKET FACTOR ........................(GM)    .54
*
Sm (ksi) .............................(SM)    100.
Sy (ksi) .............................(SY)    150.0
Su (ksi) .............................(SU)    185.0
CODE EVALUATION TYPE ................(CET)    1
*
FATIGUE STRESS FOR NORMAL OPERATION .(FSO)     150.0
FATIGUE STRESS FOR VIBRATION ........(FSV)     13.0
NUMBER OF BOLT THREADS INCH .........(NTI)     9
```

4.5.3.1.3.3 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, 38°C (100°F) Ambient – Model AOS-100

```
30-FT DROP - Head-on  AOS-100, 100F Ambient
*
 NUMBER OF BOLTS ......................(NB)   14
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   14.064
 LID DIAMETER AT GASKET .............(DLG)    12.172
 NOMINAL BOLT DIAMETER ................(DB)   .875
 LID DIAMETER AT INNER EDGE ..........(DLI)   11.04
 LID DIAMETER AT OUTER EDGE ..........(DLO)   16.59
 THICKNESS OF LID .....................(TL)   1.51
 THICKNESS OF LID FLANGE .............(TLF)   1.94
 THICKNESS OF CASK WALL ...............(TC)   2.805
 BOLT LENGTH ..........................(BL)   1.06
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .029
*
 YOUNG'S MODULUS FOR LID ..............(EL)   27.1E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   27.1E6
 YOUNG'S MODULUS FOR CASK .............(EC)   27.1E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   27.9E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   9.1E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.3E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   9.1E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   280.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   280.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   223.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   223.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   223.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   224.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   224.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   786.0
 WEIGHT OF CASK LID ...................(WL)   96.0
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   90.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   156.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE .........................(Q)   6000.0
```

```
 NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
 GASKET SEATING WIDTH .................(GB)   1.0
 GASKET SEATING STRESS ................(GY)   3000.0
 GASKET FACTOR ........................(GM)   .54
*
 Sm (ksi) .............................(SM)   94.0
 Sy (ksi) .............................(SY)   141.0
 Su (ksi) .............................(SU)   174.0
 CODE EVALUATION TYPE ................(CET)   2
*
 FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    141.0
 FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
 NUMBER OF BOLT THREADS INCH .........(NTI)    9
```

4.5.3.1.3.4 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, -40°C (-40°F) Ambient – Model AOS-100

```
 30-FT DROP - Head-on  AOS-100, -40F Ambient
*
 NUMBER OF BOLTS ......................(NB)   14
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   14.064
 LID DIAMETER AT GASKET .............(DLG)    12.172
 NOMINAL BOLT DIAMETER ................(DB)   .875
 LID DIAMETER AT INNER EDGE ..........(DLI)   11.04
 LID DIAMETER AT OUTER EDGE ..........(DLO)   16.59
 THICKNESS OF LID .....................(TL)   1.51
 THICKNESS OF LID FLANGE .............(TLF)   1.94
 THICKNESS OF CASK WALL ...............(TC)   2.805
 BOLT LENGTH ..........................(BL)   1.06
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .029
*
 YOUNG'S MODULUS FOR LID ..............(EL)   28.3E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   28.3E6
 YOUNG'S MODULUS FOR CASK .............(EC)   28.3E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   28.9E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   8.6E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.0E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   8.6E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   280.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   280.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   15.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   15.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   15.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   16.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   16.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   786.0
 WEIGHT OF CASK LID ...................(WL)   96.0
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   90.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   218.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)   6000.0
```

```
 NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
 GASKET SEATING WIDTH .................(GB)   1.0
 GASKET SEATING STRESS ................(GY)   3000.0
 GASKET FACTOR ........................(GM)   .54
*
 Sm (ksi) .............................(SM)   100.
 Sy (ksi) .............................(SY)   150.0
 Su (ksi) .............................(SU)   185.0
 CODE EVALUATION TYPE ................(CET)   2
*
 FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    150.0
 FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
 NUMBER OF BOLT THREADS INCH .........(NTI)    9
```

4.5.3.1.3.5 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, 38°C (100°F) Ambient – Model AOS-100

```
30-FT DROP - Side  AOS-100, 100F Ambient
*
 NUMBER OF BOLTS ......................(NB)    14
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   14.064
 LID DIAMETER AT GASKET .............(DLG)    12.172
 NOMINAL BOLT DIAMETER ................(DB)   .875
 LID DIAMETER AT INNER EDGE ..........(DLI)   11.04
 LID DIAMETER AT OUTER EDGE ..........(DLO)   16.59
 THICKNESS OF LID .....................(TL)   1.51
 THICKNESS OF LID FLANGE .............(TLF)   1.94
 THICKNESS OF CASK WALL ...............(TC)   2.805
 BOLT LENGTH ..........................(BL)   1.06
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .029
*
 YOUNG'S MODULUS FOR LID ..............(EL)   27.1E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   27.1E6
 YOUNG'S MODULUS FOR CASK .............(EC)   27.1E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   27.9E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   9.1E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.3E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   9.1E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   280.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   280.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   223.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   223.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   223.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   224.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   224.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   786.0
 WEIGHT OF CASK LID ...................(WL)   96.0
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   0.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   171.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)   0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)   6000.0
```

```
 NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
 GASKET SEATING WIDTH .................(GB)   1.0
 GASKET SEATING STRESS ................(GY)   3000.0
 GASKET FACTOR ........................(GM)   .54
*
 Sm (ksi) .............................(SM)   94.
 Sy (ksi) .............................(SY)   141.
 Su (ksi) .............................(SU)   174.0
 CODE EVALUATION TYPE ................(CET)   2
*
 FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    141.
 FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
 NUMBER OF BOLT THREADS INCH .........(NTI)    9
```

4.5.3.1.3.6 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, -40°C (-40°F) Ambient – Model AOS-100

```
30-FT DROP - Side  AOS-100, -40F Ambient
*
NUMBER OF BOLTS .......................(NB)   14
LID DIAMETER AT BOLT CIRCLE .........(DLB)   14.064
LID DIAMETER AT GASKET .............(DLG)    12.172
NOMINAL BOLT DIAMETER ................(DB)   .875
LID DIAMETER AT INNER EDGE ..........(DLI)   11.04
LID DIAMETER AT OUTER EDGE ..........(DLO)   16.59
THICKNESS OF LID .....................(TL)   1.51
THICKNESS OF LID FLANGE .............(TLF)   1.94
THICKNESS OF CASK WALL ...............(TC)   2.805
BOLT LENGTH ..........................(BL)   1.06
BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .029
*
YOUNG'S MODULUS FOR LID ..............(EL)   28.3E6
YOUNG'S MODULUS FOR LID FLANGE .......(EL)   28.3E6
YOUNG'S MODULUS FOR CASK .............(EC)   28.3E6
YOUNG'S MODULUS FOR BOLT .............(EB)   28.9E6
POISSON'S RATIO FOR LID ............(XNUL)   0.3
POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
LID THERMAL EXPANSION COEFF ..........(AL)   8.6E-6
BOLT THERMAL EXPANSION COEFF .........(AB)   7.0E-6
WALL THERMAL EXPANSION COEFF .........(AC)   8.6E-6
FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
INSIDE PRESSURE AT LID ..............(PLI)   280.0
OUTSIDE PRESSURE AT LID .............(PLO)   15.0
INSIDE PRESSURE AT CASK WALL ........(PCI)   280.0
OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
TEMPERATURE CHG ACROSS LID ........(TEMPL)   15.
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   15.
TEMPERATURE CHG ACROSS WALL .......(TEMPC)   15.
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   16.
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   16.
*
WEIGHT OF CASK CONTENTS ..............(WC)   786.0
WEIGHT OF CASK LID ...................(WL)   96.0
DROP ANGLE OF IMPACT, deg .......(XI_DROP)   0.0
CG/CORNER IMPACT ACCEL, g ..........(ACCI)   240.
DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
PUNCTURE LOAD ......................(PUNC)   0.0
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
PRELOAD TORQUE ........................(Q)   6000.0
```

```
 NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
 GASKET SEATING WIDTH .................(GB)   1.0
 GASKET SEATING STRESS ................(GY)   3000.0
 GASKET FACTOR ........................(GM)   .54
*
 Sm (ksi) .............................(SM)   100.
 Sy (ksi) .............................(SY)   150.0
 Su (ksi) .............................(SU)   185.0
 CODE EVALUATION TYPE ................(CET)   2
*
 FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    150.0
 FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
 NUMBER OF BOLT THREADS INCH .........(NTI)    9
```

4.5.3.1.3.7 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, 38°C (100°F) Ambient – Model AOS-100

```
 30-FT DROP - @ 45 DEG CORNER AOS-100, 100F AMBIENT
*
 NUMBER OF BOLTS ......................(NB)    14
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   14.064
 LID DIAMETER AT GASKET .............(DLG)    12.172
 NOMINAL BOLT DIAMETER ................(DB)   .875
 LID DIAMETER AT INNER EDGE ..........(DLI)   11.04
 LID DIAMETER AT OUTER EDGE ..........(DLO)   16.59
 THICKNESS OF LID .....................(TL)   1.51
 THICKNESS OF LID FLANGE .............(TLF)   1.94
 THICKNESS OF CASK WALL ...............(TC)   2.805
 BOLT LENGTH ..........................(BL)   1.06
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .029
*
 YOUNG'S MODULUS FOR LID ..............(EL)   27.1E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   27.1E6
 YOUNG'S MODULUS FOR CASK .............(EC)   27.1E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   27.9E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   9.1E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.3E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   9.1E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   280.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   280.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   223.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   223.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   223.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   224.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   224.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   786.0
 WEIGHT OF CASK LID ...................(WL)   96.0
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   45.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   88.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)    0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE ........................(Q)   6000.0
```

```
 NUT FACTOR FOR PRELOAD TORQUE ........(QK)   0.15
 GASKET SEATING WIDTH .................(GB)   1.0
 GASKET SEATING STRESS ................(GY)   3000.0
 GASKET FACTOR ........................(GM)   .54
*
 Sm (ksi) .............................(SM)   94.0
 Sy (ksi) .............................(SY)   141.0
 Su (ksi) .............................(SU)   174.0
 CODE EVALUATION TYPE ................(CET)   2
*
 FATIGUE STRESS FOR NORMAL OPERATION .(FSO)    141.0
 FATIGUE STRESS FOR VIBRATION ........(FSV)    13.0
 NUMBER OF BOLT THREADS INCH .........(NTI)    9
```

4.5.3.1.3.8 Input, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, -40°C (-40°F) Ambient – Model AOS-100

```
 30-FT DROP - @ 45 DEG CORNER AOS-100, -40F AMBIENT
*
 NUMBER OF BOLTS ......................(NB)    14
 LID DIAMETER AT BOLT CIRCLE .........(DLB)   14.064
 LID DIAMETER AT GASKET .............(DLG)    12.172
 NOMINAL BOLT DIAMETER ................(DB)   .875
 LID DIAMETER AT INNER EDGE ..........(DLI)   11.04
 LID DIAMETER AT OUTER EDGE ..........(DLO)   16.59
 THICKNESS OF LID .....................(TL)   1.51
 THICKNESS OF LID FLANGE .............(TLF)   1.94
 THICKNESS OF CASK WALL ...............(TC)   2.805
 BOLT LENGTH ..........................(BL)   1.06
 BOLT MOMENT OF INERTIA / CIRUMFER....(XIB)   .029
*
 YOUNG'S MODULUS FOR LID ..............(EL)   28.3E6
 YOUNG'S MODULUS FOR LID FLANGE .......(EL)   28.3E6
 YOUNG'S MODULUS FOR CASK .............(EC)   28.3E6
 YOUNG'S MODULUS FOR BOLT .............(EB)   28.9E6
 POISSON'S RATIO FOR LID ............(XNUL)   0.3
 POISSON'S RATIO FOR CASK ...........(XNUC)   0.3
 LID THERMAL EXPANSION COEFF ..........(AL)   8.6E-6
 BOLT THERMAL EXPANSION COEFF .........(AB)   7.0E-6
 WALL THERMAL EXPANSION COEFF .........(AC)   8.6E-6
 FLANGE COEFFICIENT OF FRICTION ......(FCF)   0.9
*
 INSIDE PRESSURE AT LID ..............(PLI)   280.0
 OUTSIDE PRESSURE AT LID .............(PLO)   15.0
 INSIDE PRESSURE AT CASK WALL ........(PCI)   280.0
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)   15.0
*
 TEMPERATURE CHG ACROSS LID ........(TEMPL)   15.
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)   15.
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)   15.
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)   16.
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)   16.
*
 WEIGHT OF CASK CONTENTS ..............(WC)   786.0
 WEIGHT OF CASK LID ...................(WL)   96.0
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)   45.0
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)   124.
 DYNAMIC LOAD FACTOR ................(DYLF)   1.15
*
 PUNCTURE LOAD ......................(PUNC)    0.0
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)   45.0
*
 AXIAL VIBRATION ACCELERATION (g) ....(AVA)   0.0
 TRANSVERSE VIBRATION ACCELER (g). ...(AVT)   0.0
 VIBRATION TRANSMISSIBILITY FACTOR ...(VTR)   1.0
*
 PRELOAD TORQUE .......................(Q)    6000.0
```

```
 NUT FACTOR FOR PRELOAD TORQUE ........(QK)    0.15
 GASKET SEATING WIDTH .................(GB)    1.0
 GASKET SEATING STRESS ................(GY)    3000.0
 GASKET FACTOR ........................(GM)    .54
*
 Sm (ksi) .............................(SM)    100.
 Sy (ksi) .............................(SY)    150.0
 Su (ksi) .............................(SU)    185.0
 CODE EVALUATION TYPE ................(CET)    2
*
 FATIGUE STRESS FOR NORMAL OPERATION .(FSO)     150.0
 FATIGUE STRESS FOR VIBRATION ........(FSV)     13.0
 NUMBER OF BOLT THREADS INCH .........(NTI)     9
```

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4.5.3.2 Output Files from Cask Lid Attachment Bolt Fortran Program

This appendix provides the following output files, that are used to build the content in Table 4-2:

- Cask Lid Attachment Bolt Fortran Program Output Files – Model AOS-025
- Cask Lid Attachment Bolt Fortran Program Output Files – Model AOS-050
- Cask Lid Attachment Bolt Fortran Program Output Files – Model AOS-100

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4.5.3.2.1 Cask Lid Attachment Bolt Fortran Program Output Files – Model AOS-025

This appendix provides the following output files, that are used to build the content in Table 4-2:

- Output, Normal Conditions of Transport, 30-Ft. Drop, 38°C (100°F) Ambient – Model AOS-025
- Output, Normal Conditions of Transport, 30-Ft. Drop, -40°C (-40°F) Ambient – Model AOS-025
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, 38°C (100°F) Ambient – Model AOS-025
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, -40°C (-40°F) Ambient – Model AOS-025
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, 38°C (100°F) Ambient – Model AOS-025
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, -40°C (-40°F) Ambient – Model AOS-025
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, 38°C (100°F) Ambient – Model AOS-025
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, -40°C (-40°F) Ambient – Model AOS-025

4.5.3.2.1.1 Output, Normal Conditions of Transport, 30-Ft. Drop, 38°C (100°F) Ambient – Model AOS-025

```
NORMAL CONDITION - AXIAL=10g,LATERAL=5g, AOS-025, 100F AMBIENT


*************** INPUT DATA ****************

NUMBER OF BOLTS .....................(NB)            8
LID DIAMETER AT BOLT CIRCLE .........(DLB)  0.39000E+01
LID DIAMETER AT GASKET  .............(DLG)  0.30700E+01
NOMINAL BOLT DIAMETER ................(DB)  0.37500E+00
LID DIAMETER AT INNER EDGE ..........(DLI)  0.26300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO)  0.46500E+01
THICKNESS OF LID .....................(TL)  0.37000E+00
THICKNESS OF LID FLANGE .............(TLF)  0.48000E+00
THICKNESS OF CASK WALL ...............(TC)  0.10300E+01
BOLT LENGTH ..........................(BL)  0.15000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB)  0.10000E-02

YOUNG'S MODULUS FOR LID ..............(EL)  0.27300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF)  0.27300E+08
YOUNG'S MODULUS FOR CASK .............(EC)  0.27300E+08
YOUNG'S MODULUS FOR BOLT .............(EB)  0.28000E+08
POISSON'S RATIO FOR LID ............(XNUL)  0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC)  0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL)  0.90000E-05
BOLT THERMAL EXPANSION COEFF .........(AB)  0.72000E-05
WALL THERMAL EXPANSION COEFF .........(AC)  0.90000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF)  0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI)  0.30000E+02
OUTSIDE PRESSURE AT LID .............(PLO)  0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI)  0.30000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO)  0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL)  0.18500E+03
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)  0.18500E+03
TEMPERATURE CHG ACROSS WALL .......(TEMPC)  0.18500E+03
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)  0.18500E+03
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)  0.18500E+03

WEIGHT OF CASK CONTENTS ..............(WC)  0.14000E+02
WEIGHT OF CASK LID ...................(WL)  0.20000E+01
DROP ANGLE OF IMPACT, deg .......(XI_DROP)  0.00000E+00
CG/CORNER IMPACT ACCEL, g ..........(ACCI)  0.00000E+00
DYNAMIC LOAD FACTOR ................(DYLF)  0.11500E+01

PUNCTURE LOAD ......................(PUNC)  0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)  0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.10000E+02
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.50000E+01
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE ......................(Q) 0.42000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.95300E+01

Sm STRESS ............................(SM) 0.95000E+02
Sy STRESS ............................(SY) 0.14200E+03
Su STRESS ............................(SU) 0.17500E+03
CODE EVALUATION TYPE.................(CET)           1

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.14200E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          16


******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
-------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.13879E+02
SHEAR LOAD DUE TO PRESSURE..........    0.22989E+02
EDGE LOAD DUE TO PRESSURE...........    0.14625E+02
EDGE MOMENT DUE TO PRESSURE.........    0.71297E+01


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
-------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.10298E+04
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........    0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
-------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.00000E+00
SHEAR LOAD DUE TO IMPACT............    0.00000E+00
EDGE LOAD DUE TO IMPACT.............    0.00000E+00
EDGE MOMENT DUE IMPACT..............    0.00000E+00
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
----------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
----------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.25000E+01
SHEAR LOAD DUE TO VIBRATION.........    0.12500E+01
EDGE LOAD DUE TO VIBRATION..........    0.16324E+01
EDGE MOMENT DUE VIBRATION...........    0.79577E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
----------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.74667E+04
AXIAL LOAD DUE TO GASKET SEATING....    0.36168E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.34468E+03
TORQUE DUE TO PRELOAD...............    0.21000E+03
TORQUE DUE TO GASKET ...............    0.10172E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
----------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.88575E+04
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.84965E+04
AXIAL LOAD LESS TEMP & PRELOAD......    0.36106E+03
TOTAL EDGE LOAD.....................    0.16257E+02
TOTAL EDGE MOMENT...................    0.79255E+01


PRYING ACTION FORCES, TABLE 2.1 & 2.2
----------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.78148E+04
BENDING MOMENT DUE TO PRYING........    0.67577E+01


TOTAL BOLT FORCES
----------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.68166E+03
TOTAL BOLT SHEAR LOAD...............    0.24239E+02
TOTAL BOLT BENDING MOMENT...........    0.14683E+02
TOTAL BOLT TORSIONAL MOMENT.........    0.21000E+03
```

```
TOTAL BOLT STRESSES
---------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.13623E+05
TOTAL BOLT DIRECT STRESS (-MC/I) ...    0.39707E+04
AVE BOLT DIRECT STRESS .............    0.87967E+04
TOTAL BOLT SHEAR STRESS ............    0.34511E+05
AVE BOLT SHEAR STRESS ..............    0.17256E+05


CODE EVALUATION FOR NORMAL COND, TABLE 6.1
---------------------------------------------------
Rt (AXIAL_STRESS/Sm) ...............    0.92597E-01
Rs (SHEAR_STRESS/0.6Sm) ............    0.30273E+00
Rtý+Rsý ............................    0.10022E+00
VON MISES EQUIVALENT STRESS (Se) ...    0.70354E+05
Se/1.35Sm ..........................    0.54857E+00


FLANGE SEPARATION EVALUATION
---------------------------------------------------
BOLT CLAMPING FORCE ................   -0.32060E+03
DISPLACEMENT ACROSS BOLT ...........   -0.22164E-04
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............   -0.28854E+03
TOTAL BOLT SHEAR FORCE .............    0.24239E+02


FATIGUE EVALUATION
---------------------------------------------------
USEAGE FOR NORMAL OPERATION ........    0.95935E-01
USEAGE FOR VIBRATION  ..............    0.24817E-02
ACCUMULATIVE FATIGUE USEAGE ........    0.98417E-01
```

4.5.3.2.1.2 Output, Normal Conditions of Transport, 30-Ft. Drop, -40°C (-40°F) Ambient – Model AOS-025

```
NORMAL CONDITION - AXIAL=10g,LATERAL=5g, AOS-025, -40F AMBIENT


*************** INPUT DATA ****************

NUMBER OF BOLTS .....................(NB)            8
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.39000E+01
LID DIAMETER AT GASKET  .............(DLG) 0.30700E+01
NOMINAL BOLT DIAMETER ................(DB) 0.37500E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.26300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.46500E+01
THICKNESS OF LID .....................(TL) 0.37000E+00
THICKNESS OF LID FLANGE .............(TLF) 0.48000E+00
THICKNESS OF CASK WALL ...............(TC) 0.10300E+01
BOLT LENGTH ..........................(BL) 0.15000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.10000E-02

YOUNG'S MODULUS FOR LID ..............(EL) 0.28300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.28300E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.28300E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.29100E+08
POISSON'S RATIO FOR LID ............(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.86000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.70000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.86000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.30000E+02
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.30000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL)-0.34000E+02
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)-0.34000E+02
TEMPERATURE CHG ACROSS WALL .......(TEMPC)-0.34000E+02
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)-0.34000E+02
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)-0.34000E+02

WEIGHT OF CASK CONTENTS ..............(WC) 0.14000E+02
WEIGHT OF CASK LID ...................(WL) 0.20000E+01
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.00000E+00
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.00000E+00
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.10000E+02
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.50000E+01
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE .......................(Q) 0.42000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.95300E+01

Sm STRESS ............................(SM) 0.10000E+03
Sy STRESS ............................(SY) 0.15000E+03
Su STRESS ............................(SU) 0.18500E+03
CODE EVALUATION TYPE.................(CET)           1

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.15000E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          16


******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.13879E+02
SHEAR LOAD DUE TO PRESSURE..........    0.22989E+02
EDGE LOAD DUE TO PRESSURE...........    0.14625E+02
EDGE MOMENT DUE TO PRESSURE.........    0.71297E+01


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......   -0.17484E+03
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........    0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.00000E+00
SHEAR LOAD DUE TO IMPACT............    0.00000E+00
EDGE LOAD DUE TO IMPACT.............    0.00000E+00
EDGE MOMENT DUE IMPACT..............    0.00000E+00
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.25000E+01
SHEAR LOAD DUE TO VIBRATION.........    0.12500E+01
EDGE LOAD DUE TO VIBRATION..........    0.16324E+01
EDGE MOMENT DUE VIBRATION...........    0.79577E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.74667E+04
AXIAL LOAD DUE TO GASKET SEATING....    0.36168E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.34468E+03
TORQUE DUE TO PRELOAD...............    0.21000E+03
TORQUE DUE TO GASKET ...............    0.10172E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.76529E+04
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.72918E+04
AXIAL LOAD LESS TEMP & PRELOAD......    0.36106E+03
TOTAL EDGE LOAD.....................    0.16257E+02
TOTAL EDGE MOMENT...................    0.79255E+01


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.67006E+04
BENDING MOMENT DUE TO PRYING........    0.67654E+01


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.59126E+03
TOTAL BOLT SHEAR LOAD...............    0.24239E+02
TOTAL BOLT BENDING MOMENT...........    0.14691E+02
TOTAL BOLT TORSIONAL MOMENT.........    0.21000E+03
```

TOTAL BOLT STRESSES

TOTAL BOLT DIRECT STRESS (+MC/I) ...	0.12459E+05
TOTAL BOLT DIRECT STRESS (-MC/I) ...	0.28017E+04
AVE BOLT DIRECT STRESS	0.76302E+04
TOTAL BOLT SHEAR STRESS	0.34511E+05
AVE BOLT SHEAR STRESS	0.17256E+05

CODE EVALUATION FOR NORMAL COND, TABLE 6.1

Rt (AXIAL_STRESS/Sm)	0.76302E-01
Rs (SHEAR_STRESS/0.6Sm)	0.28759E+00
Rtý+Rsý	0.88532E-01
VON MISES EQUIVALENT STRESS (Se) ...	0.70138E+05
Se/1.35Sm	0.51954E+00

FLANGE SEPARATION EVALUATION

BOLT CLAMPING FORCE	-0.23020E+03
DISPLACEMENT ACROSS BOLT	-0.15313E-04
ALLOWABLE FLANGE SEPARATION	0.30000E-02
FLANGE FRICTION FORCE	-0.20718E+03
TOTAL BOLT SHEAR FORCE	0.24239E+02

FATIGUE EVALUATION

USEAGE FOR NORMAL OPERATION	0.83058E-01
USEAGE FOR VIBRATION	0.24817E-02
ACCUMULATIVE FATIGUE USEAGE	0.85540E-01

4.5.3.2.1.3 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, 38°C (100°F) Ambient – Model AOS-025

```
30 FT DROP - HEAD ON, AOS-025, 100F AMBIENT



*************** INPUT DATA ****************

NUMBER OF BOLTS .....................(NB)            8
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.39000E+01
LID DIAMETER AT GASKET  .............(DLG) 0.30700E+01
NOMINAL BOLT DIAMETER ................(DB) 0.37500E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.26300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.46500E+01
THICKNESS OF LID .....................(TL) 0.37000E+00
THICKNESS OF LID FLANGE .............(TLF) 0.48000E+00
THICKNESS OF CASK WALL ...............(TC) 0.10300E+01
BOLT LENGTH ..........................(BL) 0.15000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.10000E-02

YOUNG'S MODULUS FOR LID ..............(EL) 0.27300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.27300E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.27300E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.28000E+08
POISSON'S RATIO FOR LID ............(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.90000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.72000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.90000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.30000E+02
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.30000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL) 0.18500E+03
TEMPERATURE CHG ACROSS BOLT .......(TEMPB) 0.18500E+03
TEMPERATURE CHG ACROSS WALL .......(TEMPC) 0.18500E+03
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO) 0.18500E+03
TEMPERATURE AT INSIDE OF LID .....(TEMPLI) 0.18500E+03

WEIGHT OF CASK CONTENTS ..............(WC) 0.14000E+02
WEIGHT OF CASK LID ...................(WL) 0.20000E+01
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.90000E+02
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.88300E+03
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE .......................(Q) 0.42000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.95300E+01

Sm STRESS ............................(SM) 0.95000E+02
Sy STRESS ............................(SY) 0.14200E+03
Su STRESS ............................(SU) 0.17500E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.14200E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          16


******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.13879E+02
SHEAR LOAD DUE TO PRESSURE..........    0.22989E+02
EDGE LOAD DUE TO PRESSURE...........    0.14625E+02
EDGE MOMENT DUE TO PRESSURE.........    0.71297E+01


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.10298E+04
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........    0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.27214E+04
SHEAR LOAD DUE TO IMPACT............   -0.96493E-05
EDGE LOAD DUE TO IMPACT.............    0.17769E+04
EDGE MOMENT DUE IMPACT..............    0.86625E+03
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.74667E+04
AXIAL LOAD DUE TO GASKET SEATING....    0.36168E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.34468E+03
TORQUE DUE TO PRELOAD...............    0.21000E+03
TORQUE DUE TO GASKET ...............    0.10172E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.11576E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.84965E+04
AXIAL LOAD LESS TEMP & PRELOAD......    0.30800E+04
TOTAL EDGE LOAD.....................    0.17915E+04
TOTAL EDGE MOMENT...................    0.87338E+03


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.20240E+04
BENDING MOMENT DUE TO PRYING........    0.74469E+03


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.64725E+04
TOTAL BOLT SHEAR LOAD...............    0.22989E+02
TOTAL BOLT BENDING MOMENT...........    0.16181E+04
TOTAL BOLT TORSIONAL MOMENT.........    0.21000E+03
```

```
TOTAL BOLT STRESSES
---------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.61535E+06
TOTAL BOLT DIRECT STRESS (-MC/I) ...   -0.44830E+06
AVE BOLT DIRECT STRESS .............    0.83527E+05
TOTAL BOLT SHEAR STRESS ............    0.34511E+05
AVE BOLT SHEAR STRESS ..............    0.17256E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
---------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......    0.12250E+06
ALLOWABLE SHEAR STRESS (Ta) ........    0.73500E+05
Rt (AVE AXIAL STRESS/Sa) ...........    0.68185E+00
Rs (AVE SHEAR_STRESS/Ta) ...........    0.23477E+00
Rtý+Rsý ............................    0.52004E+00


FLANGE SEPARATION EVALUATION
---------------------------------------------------
BOLT CLAMPING FORCE ................   -0.33925E+04
DISPLACEMENT ACROSS BOLT ...........   -0.23454E-03
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............   -0.30533E+04
TOTAL BOLT SHEAR FORCE .............    0.22989E+02
```

4.5.3.2.1.4 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, -40°C (-40°F) Ambient – Model AOS-025

```
30 FT DROP - HEAD ON, AOS-025, -40F AMBIENT



*************** INPUT DATA ****************

NUMBER OF BOLTS .....................(NB)           8
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.39000E+01
LID DIAMETER AT GASKET  .............(DLG) 0.30700E+01
NOMINAL BOLT DIAMETER ................(DB) 0.37500E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.26300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.46500E+01
THICKNESS OF LID .....................(TL) 0.37000E+00
THICKNESS OF LID FLANGE .............(TLF) 0.48000E+00
THICKNESS OF CASK WALL ...............(TC) 0.10300E+01
BOLT LENGTH ..........................(BL) 0.15000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.10000E-02

YOUNG'S MODULUS FOR LID ..............(EL) 0.28300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.28300E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.28300E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.29100E+08
POISSON'S RATIO FOR LID ............(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.86000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.70000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.86000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.30000E+02
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.30000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL)-0.34000E+02
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)-0.34000E+02
TEMPERATURE CHG ACROSS WALL .......(TEMPC)-0.34000E+02
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)-0.34000E+02
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)-0.34000E+02

WEIGHT OF CASK CONTENTS ..............(WC) 0.14000E+02
WEIGHT OF CASK LID ...................(WL) 0.20000E+01
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.90000E+02
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.12370E+04
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE .......................(Q) 0.42000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.95300E+01

Sm STRESS ............................(SM) 0.10000E+03
Sy STRESS ............................(SY) 0.15000E+03
Su STRESS ............................(SU) 0.18500E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.15000E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          16



******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........   0.13879E+02
SHEAR LOAD DUE TO PRESSURE..........   0.22989E+02
EDGE LOAD DUE TO PRESSURE...........   0.14625E+02
EDGE MOMENT DUE TO PRESSURE.........   0.71297E+01


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......  -0.17484E+03
SHEAR LOAD DUE TO TEMPERATURE.......   0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........   0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........   0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............   0.38124E+04
SHEAR LOAD DUE TO IMPACT............  -0.13518E-04
EDGE LOAD DUE TO IMPACT.............   0.24893E+04
EDGE MOMENT DUE IMPACT..............   0.12135E+04
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.74667E+04
AXIAL LOAD DUE TO GASKET SEATING....    0.36168E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.34468E+03
TORQUE DUE TO PRELOAD...............    0.21000E+03
TORQUE DUE TO GASKET ...............    0.10172E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.11463E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.72918E+04
AXIAL LOAD LESS TEMP & PRELOAD......    0.41710E+04
TOTAL EDGE LOAD.....................    0.25039E+04
TOTAL EDGE MOMENT...................    0.12207E+04


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............    0.14155E+04
BENDING MOMENT DUE TO PRYING........    0.10420E+04


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.87073E+04
TOTAL BOLT SHEAR LOAD...............    0.22989E+02
TOTAL BOLT BENDING MOMENT...........    0.22627E+04
TOTAL BOLT TORSIONAL MOMENT.........    0.21000E+03
```

```
TOTAL BOLT STRESSES
---------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.85605E+06
TOTAL BOLT DIRECT STRESS (-MC/I) ...   -0.63132E+06
AVE BOLT DIRECT STRESS .............    0.11237E+06
TOTAL BOLT SHEAR STRESS ............    0.34511E+05
AVE BOLT SHEAR STRESS ..............    0.17256E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
---------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......    0.12950E+06
ALLOWABLE SHEAR STRESS (Ta) ........    0.77700E+05
Rt (AVE AXIAL STRESS/Sa) ...........    0.86770E+00
Rs (AVE SHEAR_STRESS/Ta) ...........    0.22208E+00
Rtý+Rsý ............................    0.80223E+00


FLANGE SEPARATION EVALUATION
---------------------------------------------------
BOLT CLAMPING FORCE ................   -0.17054E+04
DISPLACEMENT ACROSS BOLT ...........   -0.11344E-03
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............   -0.15348E+04
TOTAL BOLT SHEAR FORCE .............    0.22989E+02
```

4.5.3.2.1.5 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, 38°C (100°F) Ambient – Model AOS-025

```
30 FT DROP - SIDE ORIENTATION, AOS-025, 100F AMBIENT


*************** INPUT DATA ****************

NUMBER OF BOLTS .....................(NB)            8
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.39000E+01
LID DIAMETER AT GASKET  .............(DLG) 0.30700E+01
NOMINAL BOLT DIAMETER ................(DB) 0.37500E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.26300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.46500E+01
THICKNESS OF LID .....................(TL) 0.37000E+00
THICKNESS OF LID FLANGE .............(TLF) 0.48000E+00
THICKNESS OF CASK WALL ...............(TC) 0.10300E+01
BOLT LENGTH ..........................(BL) 0.15000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.10000E-02

YOUNG'S MODULUS FOR LID ..............(EL) 0.27300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.27300E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.27300E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.28000E+08
POISSON'S RATIO FOR LID ............(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.90000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.72000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.90000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.30000E+02
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.30000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL) 0.18500E+03
TEMPERATURE CHG ACROSS BOLT .......(TEMPB) 0.18500E+03
TEMPERATURE CHG ACROSS WALL .......(TEMPC) 0.18500E+03
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO) 0.18500E+03
TEMPERATURE AT INSIDE OF LID .....(TEMPLI) 0.18500E+03

WEIGHT OF CASK CONTENTS ..............(WC) 0.14000E+02
WEIGHT OF CASK LID ...................(WL) 0.20000E+01
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.00000E+00
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.12860E+04
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE .......................(Q) 0.42000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.95300E+01

Sm STRESS ............................(SM) 0.95000E+02
Sy STRESS ............................(SY) 0.14200E+03
Su STRESS ............................(SU) 0.17500E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.14200E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          16


******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.13879E+02
SHEAR LOAD DUE TO PRESSURE..........    0.22989E+02
EDGE LOAD DUE TO PRESSURE...........    0.14625E+02
EDGE MOMENT DUE TO PRESSURE.........    0.71297E+01


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.10298E+04
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........    0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.00000E+00
SHEAR LOAD DUE TO IMPACT............    0.32150E+03
EDGE LOAD DUE TO IMPACT.............    0.00000E+00
EDGE MOMENT DUE IMPACT..............    0.00000E+00
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.74667E+04
AXIAL LOAD DUE TO GASKET SEATING....    0.36168E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.34468E+03
TORQUE DUE TO PRELOAD...............    0.21000E+03
TORQUE DUE TO GASKET ...............    0.10172E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.88550E+04
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.84965E+04
AXIAL LOAD LESS TEMP & PRELOAD......    0.35856E+03
TOTAL EDGE LOAD.....................    0.14625E+02
TOTAL EDGE MOMENT...................    0.71297E+01


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.78201E+04
BENDING MOMENT DUE TO PRYING........    0.60792E+01


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.67633E+03
TOTAL BOLT SHEAR LOAD...............    0.34449E+03
TOTAL BOLT BENDING MOMENT...........    0.13209E+02
TOTAL BOLT TORSIONAL MOMENT.........    0.21000E+03
```

```
TOTAL BOLT STRESSES
-------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.13069E+05
TOTAL BOLT DIRECT STRESS (-MC/I) ...    0.43866E+04
AVE BOLT DIRECT STRESS .............    0.87280E+04
TOTAL BOLT SHEAR STRESS ............    0.34511E+05
AVE BOLT SHEAR STRESS ..............    0.17256E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
-------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......    0.12250E+06
ALLOWABLE SHEAR STRESS (Ta) ........    0.73500E+05
Rt (AVE AXIAL STRESS/Sa) ...........    0.71249E-01
Rs (AVE SHEAR_STRESS/Ta) ...........    0.23477E+00
Rtý+Rsý ............................    0.60193E-01


FLANGE SEPARATION EVALUATION
-------------------------------------------------
BOLT CLAMPING FORCE ................   -0.31777E+03
DISPLACEMENT ACROSS BOLT ...........   -0.21969E-04
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............   -0.28600E+03
TOTAL BOLT SHEAR FORCE .............    0.34449E+03
```

4.5.3.2.1.6 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, -40°C (-40°F) Ambient – Model AOS-025

```
30 FT DROP - SIDE ORIENTATION, AOS-025, -40F AMBIENT



*************** INPUT DATA ****************

NUMBER OF BOLTS .....................(NB)            8
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.39000E+01
LID DIAMETER AT GASKET  .............(DLG) 0.30700E+01
NOMINAL BOLT DIAMETER ................(DB) 0.37500E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.26300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.46500E+01
THICKNESS OF LID .....................(TL) 0.37000E+00
THICKNESS OF LID FLANGE .............(TLF) 0.48000E+00
THICKNESS OF CASK WALL ...............(TC) 0.10300E+01
BOLT LENGTH ..........................(BL) 0.15000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.10000E-02

YOUNG'S MODULUS FOR LID ..............(EL) 0.28300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.28300E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.28300E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.29100E+08
POISSON'S RATIO FOR LID ............(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.86000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.70000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.86000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.30000E+02
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.30000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL)-0.34000E+02
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)-0.34000E+02
TEMPERATURE CHG ACROSS WALL .......(TEMPC)-0.34000E+02
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)-0.34000E+02
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)-0.34000E+02

WEIGHT OF CASK CONTENTS ..............(WC) 0.14000E+02
WEIGHT OF CASK LID ...................(WL) 0.20000E+01
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.00000E+00
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.17980E+04
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE ......................(Q) 0.42000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.95300E+01

Sm STRESS ............................(SM) 0.10000E+03
Sy STRESS ............................(SY) 0.15000E+03
Su STRESS ............................(SU) 0.18500E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.15000E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          16



******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.13879E+02
SHEAR LOAD DUE TO PRESSURE..........    0.22989E+02
EDGE LOAD DUE TO PRESSURE...........    0.14625E+02
EDGE MOMENT DUE TO PRESSURE.........    0.71297E+01


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......   -0.17484E+03
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........    0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.00000E+00
SHEAR LOAD DUE TO IMPACT............    0.44950E+03
EDGE LOAD DUE TO IMPACT.............    0.00000E+00
EDGE MOMENT DUE IMPACT..............    0.00000E+00
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
-------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
-------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
-------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.74667E+04
AXIAL LOAD DUE TO GASKET SEATING....    0.36168E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.34468E+03
TORQUE DUE TO PRELOAD...............    0.21000E+03
TORQUE DUE TO GASKET ...............    0.10172E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
-------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.76504E+04
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.72918E+04
AXIAL LOAD LESS TEMP & PRELOAD......    0.35856E+03
TOTAL EDGE LOAD.....................    0.14625E+02
TOTAL EDGE MOMENT...................    0.71297E+01


PRYING ACTION FORCES, TABLE 2.1 & 2.2
-------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.67059E+04
BENDING MOMENT DUE TO PRYING........    0.60861E+01


TOTAL BOLT FORCES
-------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.58594E+03
TOTAL BOLT SHEAR LOAD...............    0.47249E+03
TOTAL BOLT BENDING MOMENT...........    0.13216E+02
TOTAL BOLT TORSIONAL MOMENT.........    0.21000E+03
```

```
TOTAL BOLT STRESSES
--------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.11905E+05
TOTAL BOLT DIRECT STRESS (-MC/I) ...    0.32178E+04
AVE BOLT DIRECT STRESS .............    0.75615E+04
TOTAL BOLT SHEAR STRESS ............    0.34511E+05
AVE BOLT SHEAR STRESS ..............    0.17256E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
--------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......    0.12950E+06
ALLOWABLE SHEAR STRESS (Ta) ........    0.77700E+05
Rt (AVE AXIAL STRESS/Sa) ...........    0.58390E-01
Rs (AVE SHEAR_STRESS/Ta) ...........    0.22208E+00
Rtý+Rsý ............................    0.52729E-01


FLANGE SEPARATION EVALUATION
--------------------------------------------------
BOLT CLAMPING FORCE ................   -0.22738E+03
DISPLACEMENT ACROSS BOLT ...........   -0.15125E-04
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............   -0.20464E+03
TOTAL BOLT SHEAR FORCE .............    0.47249E+03
```

4.5.3.2.1.7 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, 38°C (100°F) Ambient – Model AOS-025

```
30FT DROP @ 45 DEG, AOS-025, 100F AMBIENT


*************** INPUT DATA ****************

NUMBER OF BOLTS ......................(NB)            8
LID DIAMETER AT BOLT CIRCLE .........(DLB)  0.39000E+01
LID DIAMETER AT GASKET  .............(DLG)  0.30700E+01
NOMINAL BOLT DIAMETER ................(DB)  0.37500E+00
LID DIAMETER AT INNER EDGE ..........(DLI)  0.26300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO)  0.46500E+01
THICKNESS OF LID .....................(TL)  0.37000E+00
THICKNESS OF LID FLANGE .............(TLF)  0.48000E+00
THICKNESS OF CASK WALL ...............(TC)  0.10300E+01
BOLT LENGTH ..........................(BL)  0.15000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB)  0.10000E-02

YOUNG'S MODULUS FOR LID ..............(EL)  0.27300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF)  0.27300E+08
YOUNG'S MODULUS FOR CASK .............(EC)  0.27300E+08
YOUNG'S MODULUS FOR BOLT .............(EB)  0.28000E+08
POISSON'S RATIO FOR LID ............(XNUL)  0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC)  0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL)  0.90000E-05
BOLT THERMAL EXPANSION COEFF .........(AB)  0.72000E-05
WALL THERMAL EXPANSION COEFF .........(AC)  0.90000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF)  0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI)  0.30000E+02
OUTSIDE PRESSURE AT LID .............(PLO)  0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI)  0.30000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO)  0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL)  0.18500E+03
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)  0.18500E+03
TEMPERATURE CHG ACROSS WALL .......(TEMPC)  0.18500E+03
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)  0.18500E+03
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)  0.18500E+03

WEIGHT OF CASK CONTENTS ..............(WC)  0.14000E+02
WEIGHT OF CASK LID ...................(WL)  0.20000E+01
DROP ANGLE OF IMPACT, deg .......(XI_DROP)  0.45000E+02
CG/CORNER IMPACT ACCEL, g ..........(ACCI)  0.79900E+03
DYNAMIC LOAD FACTOR ................(DYLF)  0.11500E+01

PUNCTURE LOAD ......................(PUNC)  0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)  0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE ........................(Q) 0.42000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.95300E+01

Sm STRESS ............................(SM) 0.95000E+02
Sy STRESS ............................(SY) 0.14200E+03
Su STRESS ............................(SU) 0.17500E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.14200E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          16


******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.13879E+02
SHEAR LOAD DUE TO PRESSURE..........    0.22989E+02
EDGE LOAD DUE TO PRESSURE...........    0.14625E+02
EDGE MOMENT DUE TO PRESSURE.........    0.71297E+01


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.10298E+04
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........    0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.17413E+04
SHEAR LOAD DUE TO IMPACT............    0.14124E+03
EDGE LOAD DUE TO IMPACT.............    0.11369E+04
EDGE MOMENT DUE IMPACT..............    0.55426E+03
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.74667E+04
AXIAL LOAD DUE TO GASKET SEATING....    0.36168E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.34468E+03
TORQUE DUE TO PRELOAD...............    0.21000E+03
TORQUE DUE TO GASKET ...............    0.10172E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.10596E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.84965E+04
AXIAL LOAD LESS TEMP & PRELOAD......    0.20998E+04
TOTAL EDGE LOAD.....................    0.11516E+04
TOTAL EDGE MOMENT...................    0.56139E+03


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.41115E+04
BENDING MOMENT DUE TO PRYING........    0.47867E+03


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.43849E+04
TOTAL BOLT SHEAR LOAD...............    0.16423E+03
TOTAL BOLT BENDING MOMENT...........    0.10401E+04
TOTAL BOLT TORSIONAL MOMENT.........    0.21000E+03
```

```
TOTAL BOLT STRESSES
---------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...     0.39843E+06
TOTAL BOLT DIRECT STRESS (-MC/I) ...    -0.28526E+06
AVE BOLT DIRECT STRESS .............     0.56587E+05
TOTAL BOLT SHEAR STRESS ............     0.34511E+05
AVE BOLT SHEAR STRESS ..............     0.17256E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
---------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......     0.12250E+06
ALLOWABLE SHEAR STRESS (Ta) ........     0.73500E+05
Rt (AVE AXIAL STRESS/Sa) ...........     0.46194E+00
Rs (AVE SHEAR_STRESS/Ta) ...........     0.23477E+00
Rtý+Rsý ............................     0.26850E+00


FLANGE SEPARATION EVALUATION
---------------------------------------------------
BOLT CLAMPING FORCE ................    -0.22851E+04
DISPLACEMENT ACROSS BOLT ...........    -0.15798E-03
ALLOWABLE FLANGE SEPARATION ........     0.30000E-02
FLANGE FRICTION FORCE ..............    -0.20566E+04
TOTAL BOLT SHEAR FORCE .............     0.16423E+03
```

4.5.3.2.1.8 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, -40°C (-40°F) Ambient – Model AOS-025

```
30FT DROP @ 45 DEG, AOS-025, -40F AMBIENT


*************** INPUT DATA ****************

NUMBER OF BOLTS .....................(NB)           8
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.39000E+01
LID DIAMETER AT GASKET  .............(DLG) 0.30700E+01
NOMINAL BOLT DIAMETER ................(DB) 0.37500E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.26300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.46500E+01
THICKNESS OF LID .....................(TL) 0.37000E+00
THICKNESS OF LID FLANGE .............(TLF) 0.48000E+00
THICKNESS OF CASK WALL ...............(TC) 0.10300E+01
BOLT LENGTH ..........................(BL) 0.15000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.10000E-02

YOUNG'S MODULUS FOR LID ..............(EL) 0.28300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.28300E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.28300E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.29100E+08
POISSON'S RATIO FOR LID ............(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.86000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.70000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.86000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.30000E+02
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.30000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL)-0.34000E+02
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)-0.34000E+02
TEMPERATURE CHG ACROSS WALL .......(TEMPC)-0.34000E+02
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)-0.34000E+02
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)-0.34000E+02

WEIGHT OF CASK CONTENTS ..............(WC) 0.14000E+02
WEIGHT OF CASK LID ...................(WL) 0.20000E+01
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.45000E+02
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.11250E+04
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE .......................(Q) 0.42000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.95300E+01

Sm STRESS ............................(SM) 0.10000E+03
Sy STRESS ............................(SY) 0.15000E+03
Su STRESS ............................(SU) 0.18500E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.15000E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          16


******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE.........    0.13879E+02
SHEAR LOAD DUE TO PRESSURE.........    0.22989E+02
EDGE LOAD DUE TO PRESSURE..........    0.14625E+02
EDGE MOMENT DUE TO PRESSURE........    0.71297E+01


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......  -0.17484E+03
SHEAR LOAD DUE TO TEMPERATURE.......   0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........   0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........   0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT...........    0.24517E+04
SHEAR LOAD DUE TO IMPACT...........    0.19887E+03
EDGE LOAD DUE TO IMPACT............    0.16008E+04
EDGE MOMENT DUE IMPACT.............    0.78041E+03
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.74667E+04
AXIAL LOAD DUE TO GASKET SEATING....    0.36168E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.34468E+03
TORQUE DUE TO PRELOAD...............    0.21000E+03
TORQUE DUE TO GASKET ...............    0.10172E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.10102E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.72918E+04
AXIAL LOAD LESS TEMP & PRELOAD......    0.28103E+04
TOTAL EDGE LOAD.....................    0.16155E+04
TOTAL EDGE MOMENT...................    0.78754E+03


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.14832E+04
BENDING MOMENT DUE TO PRYING........    0.67226E+03


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.58087E+04
TOTAL BOLT SHEAR LOAD...............    0.22186E+03
TOTAL BOLT BENDING MOMENT...........    0.14598E+04
TOTAL BOLT TORSIONAL MOMENT.........    0.21000E+03
```

```
TOTAL BOLT STRESSES
-------------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.55476E+06
TOTAL BOLT DIRECT STRESS (-MC/I) ...   -0.40484E+06
AVE BOLT DIRECT STRESS .............    0.74961E+05
TOTAL BOLT SHEAR STRESS ............    0.34511E+05
AVE BOLT SHEAR STRESS ..............    0.17256E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
-------------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......    0.12950E+06
ALLOWABLE SHEAR STRESS (Ta) ........    0.77700E+05
Rt (AVE AXIAL STRESS/Sa) ...........    0.57885E+00
Rs (AVE SHEAR_STRESS/Ta) ...........    0.22208E+00
Rtý+Rsý ............................    0.38438E+00


FLANGE SEPARATION EVALUATION
-------------------------------------------------------
BOLT CLAMPING FORCE ................   -0.29984E+04
DISPLACEMENT ACROSS BOLT ...........   -0.19945E-03
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............   -0.26986E+04
TOTAL BOLT SHEAR FORCE .............    0.22186E+03
```

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4.5.3.2.2 Cask Lid Attachment Bolt Fortran Program Output Files – Model AOS-050

This appendix provides the following output files, that are used to build the content in Table 4-2:

- Output, Normal Conditions of Transport, 30-Ft. Drop, 38°C (100°F) Ambient – Model AOS-050
- Output, Normal Conditions of Transport, 30-Ft. Drop, -40°C (-40°F) Ambient – Model AOS-050
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, 38°C (100°F) Ambient – Model AOS-050
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, -40°C (-40°F) Ambient – Model AOS-050
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, 38°C (100°F) Ambient – Model AOS-050
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, -40°C (-40°F) Ambient – Model AOS-050
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, 38°C (100°F) Ambient – Model AOS-050
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, -40°C (-40°F) Ambient – Model AOS-050

4.5.3.2.2.1 Output, Normal Conditions of Transport, 30-Ft. Drop, 38°C (100°F) Ambient – Model AOS-050

```
NORMAL CONDITION - AXIAL=10g,LATERAL=5g AOS-050 ,100F AMBIENT



*************** INPUT DATA ****************

NUMBER OF BOLTS .....................(NB)          10
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.74140E+01
LID DIAMETER AT GASKET  .............(DLG) 0.60900E+01
NOMINAL BOLT DIAMETER ................(DB) 0.50000E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.55300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.89000E+01
THICKNESS OF LID .....................(TL) 0.75000E+00
THICKNESS OF LID FLANGE .............(TLF) 0.97000E+00
THICKNESS OF CASK WALL ...............(TC) 0.17050E+01
BOLT LENGTH ..........................(BL) 0.41000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.30000E-02

YOUNG'S MODULUS FOR LID ..............(EL) 0.27100E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.27100E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.27100E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.27900E+08
POISSON'S RATIO FOR LID ............(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.90000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.73000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.90000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.60000E+02
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.60000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL) 0.21600E+03
TEMPERATURE CHG ACROSS BOLT .......(TEMPB) 0.21600E+03
TEMPERATURE CHG ACROSS WALL .......(TEMPC) 0.21600E+03
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO) 0.21600E+03
TEMPERATURE AT INSIDE OF LID .....(TEMPLI) 0.21600E+03

WEIGHT OF CASK CONTENTS ..............(WC) 0.95000E+02
WEIGHT OF CASK LID ...................(WL) 0.14000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.00000E+00
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.00000E+00
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.10000E+02
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.50000E+01
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE ........................(Q) 0.75000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.31800E+01

Sm STRESS ............................(SM) 0.94000E+02
Sy STRESS ............................(SY) 0.14100E+03
Su STRESS ............................(SU) 0.17400E+03
CODE EVALUATION TYPE.................(CET)            1

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.14100E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)           13



******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.13108E+03
SHEAR LOAD DUE TO PRESSURE..........    0.24416E+03
EDGE LOAD DUE TO PRESSURE...........    0.83407E+02
EDGE MOMENT DUE TO PRESSURE.........    0.77298E+02


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.20116E+04
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........    0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.00000E+00
SHEAR LOAD DUE TO IMPACT............    0.00000E+00
EDGE LOAD DUE TO IMPACT.............    0.00000E+00
EDGE MOMENT DUE IMPACT..............    0.00000E+00
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.14000E+02
SHEAR LOAD DUE TO VIBRATION.........    0.70000E+01
EDGE LOAD DUE TO VIBRATION..........    0.60107E+01
EDGE MOMENT DUE VIBRATION...........    0.55704E+01


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.10000E+05
AXIAL LOAD DUE TO GASKET SEATING....    0.57397E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.54757E+03
TORQUE DUE TO PRELOAD...............    0.37500E+03
TORQUE DUE TO GASKET ...............    0.21524E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.12704E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.12012E+05
AXIAL LOAD LESS TEMP & PRELOAD......    0.69265E+03
TOTAL EDGE LOAD.....................    0.89418E+02
TOTAL EDGE MOMENT...................    0.82868E+02


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.96539E+04
BENDING MOMENT DUE TO PRYING........    0.34543E+02


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.23577E+04
TOTAL BOLT SHEAR LOAD...............    0.25116E+03
TOTAL BOLT BENDING MOMENT...........    0.11741E+03
TOTAL BOLT TORSIONAL MOMENT.........    0.37500E+03
```

```
TOTAL BOLT STRESSES
--------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.32189E+05
TOTAL BOLT DIRECT STRESS (-MC/I) ...    0.10424E+04
AVE BOLT DIRECT STRESS .............    0.16616E+05
TOTAL BOLT SHEAR STRESS ............    0.24870E+05
AVE BOLT SHEAR STRESS ..............    0.12435E+05


CODE EVALUATION FOR NORMAL COND, TABLE 6.1
--------------------------------------------------
Rt (AXIAL_STRESS/Sm) ...............    0.17676E+00
Rs (SHEAR_STRESS/0.6Sm) ............    0.22048E+00
Rtý+Rsý ............................    0.79854E-01
VON MISES EQUIVALENT STRESS (Se) ...    0.59246E+05
Se/1.35Sm ..........................    0.46687E+00


FLANGE SEPARATION EVALUATION
--------------------------------------------------
BOLT CLAMPING FORCE ................   -0.16651E+04
DISPLACEMENT ACROSS BOLT ...........   -0.17244E-03
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............   -0.14986E+04
TOTAL BOLT SHEAR FORCE .............    0.25116E+03


FATIGUE EVALUATION
--------------------------------------------------
USEAGE FOR NORMAL OPERATION ........    0.22829E+00
USEAGE FOR VIBRATION  ..............    0.75894E-02
ACCUMULATIVE FATIGUE USEAGE ........    0.23588E+00
```

4.5.3.2.2.2 Output, Normal Conditions of Transport, 30-Ft. Drop, -40°C (-40°F) Ambient – Model AOS-050

```
NORMAL CONDITION - AXIAL=10g,LATERAL=5g AOS-050, -40F AMBIENT



*************** INPUT DATA ****************

NUMBER OF BOLTS .....................(NB)          10
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.74140E+01
LID DIAMETER AT GASKET  .............(DLG) 0.60900E+01
NOMINAL BOLT DIAMETER ................(DB) 0.50000E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.55300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.89000E+01
THICKNESS OF LID .....................(TL) 0.75000E+00
THICKNESS OF LID FLANGE .............(TLF) 0.97000E+00
THICKNESS OF CASK WALL ...............(TC) 0.17050E+01
BOLT LENGTH ..........................(BL) 0.41000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.30000E-02

YOUNG'S MODULUS FOR LID ..............(EL) 0.28300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.28300E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.28300E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.28900E+08
POISSON'S RATIO FOR LID .............(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.86000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.70000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.86000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.60000E+02
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.60000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL) 0.15000E+02
TEMPERATURE CHG ACROSS BOLT .......(TEMPB) 0.15000E+02
TEMPERATURE CHG ACROSS WALL .......(TEMPC) 0.15000E+02
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO) 0.15000E+02
TEMPERATURE AT INSIDE OF LID .....(TEMPLI) 0.16000E+02

WEIGHT OF CASK CONTENTS ..............(WC) 0.95000E+02
WEIGHT OF CASK LID ...................(WL) 0.14000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.00000E+00
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.00000E+00
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.10000E+02
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.50000E+01
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE .......................(Q) 0.75000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.31800E+01

Sm STRESS ............................(SM) 0.10000E+03
Sy STRESS ............................(SY) 0.15000E+03
Su STRESS ............................(SU) 0.18500E+03
CODE EVALUATION TYPE.................(CET)           1

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.15000E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          13



******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
--------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.13108E+03
SHEAR LOAD DUE TO PRESSURE..........    0.24416E+03
EDGE LOAD DUE TO PRESSURE...........    0.83407E+02
EDGE MOMENT DUE TO PRESSURE.........    0.77298E+02


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
--------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.13619E+03
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........   -0.16298E+02


BOLT FORCES DUE TO IMPACT, TABLE 4.5
--------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.00000E+00
SHEAR LOAD DUE TO IMPACT............    0.00000E+00
EDGE LOAD DUE TO IMPACT.............    0.00000E+00
EDGE MOMENT DUE IMPACT..............    0.00000E+00
```

BOLT FORCES DUE TO PUNCTURE, TABLE 4.7

AXIAL LOAD DUE TO PUNCTURE..........	0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........	0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........	0.00000E+00
EDGE MOMENT DUE PUNCTURE............	0.00000E+00

BOLT FORCES DUE TO VIBRATION, TABLE 4.8

AXIAL LOAD DUE TO VIBRATION.........	0.14000E+02
SHEAR LOAD DUE TO VIBRATION.........	0.70000E+01
EDGE LOAD DUE TO VIBRATION..........	0.60107E+01
EDGE MOMENT DUE VIBRATION...........	0.55704E+01

BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2

AXIAL LOAD DUE TO PRELOAD...........	0.10000E+05
AXIAL LOAD DUE TO GASKET SEATING....	0.57397E+04
AXIAL LOAD DUE TO GASKET OPERATION..	0.54757E+03
TORQUE DUE TO PRELOAD...............	0.37500E+03
TORQUE DUE TO GASKET	0.21524E+03

TOTAL NON-PRYING BOLT FORCES, TABLE 4.9

TOTAL NON-PRYING AXIAL LOAD.........	0.10829E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..	0.10136E+05
AXIAL LOAD LESS TEMP & PRELOAD......	0.69265E+03
TOTAL EDGE LOAD.....................	0.89418E+02
TOTAL EDGE MOMENT...................	0.66571E+02

PRYING ACTION FORCES, TABLE 2.1 & 2.2

AXIAL LOAD DUE TO PRYING............	-0.81174E+04
BENDING MOMENT DUE TO PRYING........	0.27565E+02

TOTAL BOLT FORCES

TOTAL BOLT AXIAL LOAD...............	0.20188E+04
TOTAL BOLT SHEAR LOAD...............	0.25116E+03
TOTAL BOLT BENDING MOMENT...........	0.94136E+02
TOTAL BOLT TORSIONAL MOMENT.........	0.37500E+03

TOTAL BOLT STRESSES

TOTAL BOLT DIRECT STRESS (+MC/I) ...	0.26713E+05
TOTAL BOLT DIRECT STRESS (-MC/I) ...	0.17412E+04
AVE BOLT DIRECT STRESS	0.14227E+05
TOTAL BOLT SHEAR STRESS	0.24870E+05
AVE BOLT SHEAR STRESS	0.12435E+05

CODE EVALUATION FOR NORMAL COND, TABLE 6.1

Rt (AXIAL_STRESS/Sm)	0.14227E+00
Rs (SHEAR_STRESS/0.6Sm)	0.20725E+00
Rtý+Rsý	0.63193E-01
VON MISES EQUIVALENT STRESS (Se) ...	0.56459E+05
Se/1.35Sm	0.41821E+00

FLANGE SEPARATION EVALUATION

BOLT CLAMPING FORCE	-0.13262E+04
DISPLACEMENT ACROSS BOLT	-0.13259E-03
ALLOWABLE FLANGE SEPARATION	0.30000E-02
FLANGE FRICTION FORCE	-0.11936E+04
TOTAL BOLT SHEAR FORCE	0.25116E+03

FATIGUE EVALUATION

USEAGE FOR NORMAL OPERATION	0.17809E+00
USEAGE FOR VIBRATION	0.75894E-02
ACCUMULATIVE FATIGUE USEAGE	0.18568E+00

4.5.3.2.2.3 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, 38°C (100°F) Ambient – Model AOS-050

```
30-FT DROP HEAD ON AOS-050 CONFIGURATION, 100F AMBIENT



*************** INPUT DATA ****************

NUMBER OF BOLTS ......................(NB)          10
LID DIAMETER AT BOLT CIRCLE .........(DLB)  0.74140E+01
LID DIAMETER AT GASKET  .............(DLG)  0.60900E+01
NOMINAL BOLT DIAMETER ................(DB)  0.50000E+00
LID DIAMETER AT INNER EDGE ..........(DLI)  0.55300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO)  0.89000E+01
THICKNESS OF LID .....................(TL)  0.75000E+00
THICKNESS OF LID FLANGE .............(TLF)  0.97000E+00
THICKNESS OF CASK WALL ...............(TC)  0.17050E+01
BOLT LENGTH ..........................(BL)  0.41000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB)  0.30000E-02

YOUNG'S MODULUS FOR LID ..............(EL)  0.27100E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF)  0.27100E+08
YOUNG'S MODULUS FOR CASK .............(EC)  0.27100E+08
YOUNG'S MODULUS FOR BOLT .............(EB)  0.27900E+08
POISSON'S RATIO FOR LID ............(XNUL)  0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC)  0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL)  0.90000E-05
BOLT THERMAL EXPANSION COEFF .........(AB)  0.73000E-05
WALL THERMAL EXPANSION COEFF .........(AC)  0.90000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF)  0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI)  0.60000E+02
OUTSIDE PRESSURE AT LID .............(PLO)  0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI)  0.60000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO)  0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL)  0.21600E+03
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)  0.21600E+03
TEMPERATURE CHG ACROSS WALL .......(TEMPC)  0.21600E+03
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)  0.21600E+03
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)  0.21600E+03

WEIGHT OF CASK CONTENTS ..............(WC)  0.95000E+02
WEIGHT OF CASK LID ...................(WL)  0.14000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP)  0.90000E+02
CG/CORNER IMPACT ACCEL, g ..........(ACCI)  0.31400E+03
DYNAMIC LOAD FACTOR ................(DYLF)  0.11500E+01

PUNCTURE LOAD ......................(PUNC)  0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)  0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE .......................(Q) 0.75000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.31800E+01

Sm STRESS ............................(SM) 0.94000E+02
Sy STRESS ............................(SY) 0.14100E+03
Su STRESS ............................(SU) 0.17400E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.14100E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          13



******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
-------------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........     0.13108E+03
SHEAR LOAD DUE TO PRESSURE..........     0.24416E+03
EDGE LOAD DUE TO PRESSURE...........     0.83407E+02
EDGE MOMENT DUE TO PRESSURE.........     0.77298E+02


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
-------------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......     0.20116E+04
SHEAR LOAD DUE TO TEMPERATURE.......     0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........     0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........     0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
-------------------------------------------------------
AXIAL LOAD DUE TO IMPACT............     0.52742E+04
SHEAR LOAD DUE TO IMPACT............    -0.19216E-04
EDGE LOAD DUE TO IMPACT.............     0.22644E+04
EDGE MOMENT DUE IMPACT..............     0.20985E+04
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.10000E+05
AXIAL LOAD DUE TO GASKET SEATING....    0.57397E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.54757E+03
TORQUE DUE TO PRELOAD...............    0.37500E+03
TORQUE DUE TO GASKET ...............    0.21524E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.17964E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.12012E+05
AXIAL LOAD LESS TEMP & PRELOAD......    0.59529E+04
TOTAL EDGE LOAD.....................    0.23478E+04
TOTAL EDGE MOMENT...................    0.21758E+04


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............    0.23234E+03
BENDING MOMENT DUE TO PRYING........    0.90699E+03


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.12244E+05
TOTAL BOLT SHEAR LOAD...............    0.24416E+03
TOTAL BOLT BENDING MOMENT...........    0.30828E+04
TOTAL BOLT TORSIONAL MOMENT.........    0.37500E+03
```

```
TOTAL BOLT STRESSES
--------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.49519E+06
TOTAL BOLT DIRECT STRESS (-MC/I) ...   -0.32261E+06
AVE BOLT DIRECT STRESS .............    0.86286E+05
TOTAL BOLT SHEAR STRESS ............    0.24870E+05
AVE BOLT SHEAR STRESS ..............    0.12435E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
--------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......    0.12180E+06
ALLOWABLE SHEAR STRESS (Ta) ........    0.73080E+05
Rt (AVE AXIAL STRESS/Sa) ...........    0.70843E+00
Rs (AVE SHEAR_STRESS/Ta) ...........    0.17015E+00
Rtý+Rsý ............................    0.53082E+00


FLANGE SEPARATION EVALUATION
--------------------------------------------------
BOLT CLAMPING FORCE ................   -0.58264E+04
DISPLACEMENT ACROSS BOLT ...........   -0.60339E-03
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............   -0.52437E+04
TOTAL BOLT SHEAR FORCE .............    0.24416E+03
```

4.5.3.2.2.4 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, -40°C (-40°F) Ambient – Model AOS-050

```
30-FT DROP HEAD ON AOS-050 CONFIGURATION, -40F AMBIENT



*************** INPUT DATA ****************

NUMBER OF BOLTS .....................(NB)           10
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.74140E+01
LID DIAMETER AT GASKET  .............(DLG) 0.60900E+01
NOMINAL BOLT DIAMETER ................(DB) 0.50000E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.55300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.89000E+01
THICKNESS OF LID .....................(TL) 0.75000E+00
THICKNESS OF LID FLANGE .............(TLF) 0.97000E+00
THICKNESS OF CASK WALL ...............(TC) 0.17050E+01
BOLT LENGTH ..........................(BL) 0.41000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.30000E-02

YOUNG'S MODULUS FOR LID ..............(EL) 0.28300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.28300E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.28300E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.28900E+08
POISSON'S RATIO FOR LID ............(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.86000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.70000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.86000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.60000E+02
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.60000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL) 0.15000E+02
TEMPERATURE CHG ACROSS BOLT .......(TEMPB) 0.15000E+02
TEMPERATURE CHG ACROSS WALL .......(TEMPC) 0.15000E+02
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO) 0.15000E+02
TEMPERATURE AT INSIDE OF LID .....(TEMPLI) 0.16000E+02

WEIGHT OF CASK CONTENTS ..............(WC) 0.95000E+02
WEIGHT OF CASK LID ...................(WL) 0.14000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.90000E+02
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.43900E+03
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE .......................(Q) 0.75000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.31800E+01

Sm STRESS ............................(SM) 0.10000E+03
Sy STRESS ............................(SY) 0.15000E+03
Su STRESS ............................(SU) 0.18500E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.15000E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          13



******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.13108E+03
SHEAR LOAD DUE TO PRESSURE..........    0.24416E+03
EDGE LOAD DUE TO PRESSURE...........    0.83407E+02
EDGE MOMENT DUE TO PRESSURE.........    0.77298E+02


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.13619E+03
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........   -0.16298E+02


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.73738E+04
SHEAR LOAD DUE TO IMPACT............   -0.26865E-04
EDGE LOAD DUE TO IMPACT.............    0.31659E+04
EDGE MOMENT DUE IMPACT..............    0.29340E+04
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
--------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
--------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
--------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.10000E+05
AXIAL LOAD DUE TO GASKET SEATING....    0.57397E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.54757E+03
TORQUE DUE TO PRELOAD...............    0.37500E+03
TORQUE DUE TO GASKET ...............    0.21524E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
--------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.18189E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.10136E+05
AXIAL LOAD LESS TEMP & PRELOAD......    0.80525E+04
TOTAL EDGE LOAD.....................    0.32493E+04
TOTAL EDGE MOMENT...................    0.29950E+04


PRYING ACTION FORCES, TABLE 2.1 & 2.2
--------------------------------------------------
AXIAL LOAD DUE TO PRYING............    0.56965E+04
BENDING MOMENT DUE TO PRYING........    0.12401E+04


TOTAL BOLT FORCES
--------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.15833E+05
TOTAL BOLT SHEAR LOAD...............    0.24416E+03
TOTAL BOLT BENDING MOMENT...........    0.42351E+04
TOTAL BOLT TORSIONAL MOMENT.........    0.37500E+03
```

```
TOTAL BOLT STRESSES
--------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.67331E+06
TOTAL BOLT DIRECT STRESS (-MC/I) ...   -0.45016E+06
AVE BOLT DIRECT STRESS .............    0.11158E+06
TOTAL BOLT SHEAR STRESS ............    0.24870E+05
AVE BOLT SHEAR STRESS ..............    0.12435E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
--------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......    0.12950E+06
ALLOWABLE SHEAR STRESS (Ta) ........    0.77700E+05
Rt (AVE AXIAL STRESS/Sa) ...........    0.86160E+00
Rs (AVE SHEAR_STRESS/Ta) ...........    0.16004E+00
Rtý+Rsý ............................    0.76797E+00


FLANGE SEPARATION EVALUATION
--------------------------------------------------
BOLT CLAMPING FORCE ................    0.36128E+04
DISPLACEMENT ACROSS BOLT ...........    0.36120E-03
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............    0.32515E+04
TOTAL BOLT SHEAR FORCE .............    0.24416E+03
```

4.5.3.2.2.5 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, 38°C (100°F) Ambient – Model AOS-050

```
30-FT DROP SIDE ORIENTATION AOS-050 , 100F AMBIENT


*************** INPUT DATA ****************

NUMBER OF BOLTS .......................(NB)          10
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.74140E+01
LID DIAMETER AT GASKET  .............(DLG) 0.60900E+01
NOMINAL BOLT DIAMETER ................(DB) 0.50000E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.55300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.89000E+01
THICKNESS OF LID .....................(TL) 0.75000E+00
THICKNESS OF LID FLANGE .............(TLF) 0.97000E+00
THICKNESS OF CASK WALL ...............(TC) 0.17050E+01
BOLT LENGTH ..........................(BL) 0.41000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.30000E-02

YOUNG'S MODULUS FOR LID ..............(EL) 0.27100E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.27100E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.27100E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.27900E+08
POISSON'S RATIO FOR LID ...........(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.90000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.73000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.90000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.60000E+02
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.60000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL) 0.21600E+03
TEMPERATURE CHG ACROSS BOLT .......(TEMPB) 0.21600E+03
TEMPERATURE CHG ACROSS WALL .......(TEMPC) 0.21600E+03
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO) 0.21600E+03
TEMPERATURE AT INSIDE OF LID .....(TEMPLI) 0.21600E+03

WEIGHT OF CASK CONTENTS ..............(WC) 0.95000E+02
WEIGHT OF CASK LID ...................(WL) 0.14000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.00000E+00
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.33500E+03
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE .......................(Q) 0.75000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.31800E+01

Sm STRESS ............................(SM) 0.94000E+02
Sy STRESS ............................(SY) 0.14100E+03
Su STRESS ............................(SU) 0.17400E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.14100E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          13


******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
-------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........   0.13108E+03
SHEAR LOAD DUE TO PRESSURE..........   0.24416E+03
EDGE LOAD DUE TO PRESSURE...........   0.83407E+02
EDGE MOMENT DUE TO PRESSURE.........   0.77298E+02


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
-------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......   0.20116E+04
SHEAR LOAD DUE TO TEMPERATURE.......   0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........   0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........   0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
-------------------------------------------------
AXIAL LOAD DUE TO IMPACT............   0.00000E+00
SHEAR LOAD DUE TO IMPACT............   0.46900E+03
EDGE LOAD DUE TO IMPACT.............   0.00000E+00
EDGE MOMENT DUE IMPACT..............   0.00000E+00
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........     0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........     0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........     0.00000E+00
EDGE MOMENT DUE PUNCTURE............     0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........     0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........     0.00000E+00
EDGE LOAD DUE TO VIBRATION..........     0.00000E+00
EDGE MOMENT DUE VIBRATION...........     0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........     0.10000E+05
AXIAL LOAD DUE TO GASKET SEATING....     0.57397E+04
AXIAL LOAD DUE TO GASKET OPERATION..     0.54757E+03
TORQUE DUE TO PRELOAD...............     0.37500E+03
TORQUE DUE TO GASKET ...............     0.21524E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........     0.12690E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..     0.12012E+05
AXIAL LOAD LESS TEMP & PRELOAD......     0.67865E+03
TOTAL EDGE LOAD.....................     0.83407E+02
TOTAL EDGE MOMENT...................     0.77298E+02


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............    -0.96802E+04
BENDING MOMENT DUE TO PRYING........     0.32221E+02


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............     0.23314E+04
TOTAL BOLT SHEAR LOAD...............     0.71316E+03
TOTAL BOLT BENDING MOMENT...........     0.10952E+03
TOTAL BOLT TORSIONAL MOMENT.........     0.37500E+03
```

```
TOTAL BOLT STRESSES
--------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.30957E+05
TOTAL BOLT DIRECT STRESS (-MC/I) ...    0.19038E+04
AVE BOLT DIRECT STRESS .............    0.16430E+05
TOTAL BOLT SHEAR STRESS ............    0.24870E+05
AVE BOLT SHEAR STRESS ..............    0.12435E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
--------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......    0.12180E+06
ALLOWABLE SHEAR STRESS (Ta) ........    0.73080E+05
Rt (AVE AXIAL STRESS/Sa) ...........    0.13489E+00
Rs (AVE SHEAR_STRESS/Ta) ...........    0.17015E+00
Rtý+Rsý ............................    0.47149E-01


FLANGE SEPARATION EVALUATION
--------------------------------------------------
BOLT CLAMPING FORCE ................   -0.16528E+04
DISPLACEMENT ACROSS BOLT ...........   -0.17116E-03
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............   -0.14875E+04
TOTAL BOLT SHEAR FORCE .............    0.71316E+03
```

4.5.3.2.2.6 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, -40°C (-40°F) Ambient – Model AOS-050

```
30-FT DROP SIDE ORIENTATION AOS-050, -40F AMBIENT



*************** INPUT DATA ****************

NUMBER OF BOLTS .....................(NB)          10
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.74140E+01
LID DIAMETER AT GASKET  .............(DLG) 0.60900E+01
NOMINAL BOLT DIAMETER ................(DB) 0.50000E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.55300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.89000E+01
THICKNESS OF LID .....................(TL) 0.75000E+00
THICKNESS OF LID FLANGE .............(TLF) 0.97000E+00
THICKNESS OF CASK WALL ...............(TC) 0.17050E+01
BOLT LENGTH ..........................(BL) 0.41000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.30000E-02

YOUNG'S MODULUS FOR LID ..............(EL) 0.28300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.28300E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.28300E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.28900E+08
POISSON'S RATIO FOR LID ............(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.86000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.70000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.86000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.60000E+02
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.60000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL) 0.15000E+02
TEMPERATURE CHG ACROSS BOLT .......(TEMPB) 0.15000E+02
TEMPERATURE CHG ACROSS WALL .......(TEMPC) 0.15000E+02
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO) 0.15000E+02
TEMPERATURE AT INSIDE OF LID .....(TEMPLI) 0.16000E+02

WEIGHT OF CASK CONTENTS ..............(WC) 0.95000E+02
WEIGHT OF CASK LID ...................(WL) 0.14000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.00000E+00
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.46900E+03
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE ........................(Q) 0.75000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.31800E+01

Sm STRESS ............................(SM) 0.10000E+03
Sy STRESS ............................(SY) 0.15000E+03
Su STRESS ............................(SU) 0.18500E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.15000E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          13



******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.13108E+03
SHEAR LOAD DUE TO PRESSURE..........    0.24416E+03
EDGE LOAD DUE TO PRESSURE...........    0.83407E+02
EDGE MOMENT DUE TO PRESSURE.........    0.77298E+02


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.13619E+03
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........   -0.16298E+02


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.00000E+00
SHEAR LOAD DUE TO IMPACT............    0.65660E+03
EDGE LOAD DUE TO IMPACT.............    0.00000E+00
EDGE MOMENT DUE IMPACT..............    0.00000E+00
```

BOLT FORCES DUE TO PUNCTURE, TABLE 4.7

AXIAL LOAD DUE TO PUNCTURE..........	0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........	0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........	0.00000E+00
EDGE MOMENT DUE PUNCTURE............	0.00000E+00

BOLT FORCES DUE TO VIBRATION, TABLE 4.8

AXIAL LOAD DUE TO VIBRATION.........	0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........	0.00000E+00
EDGE LOAD DUE TO VIBRATION..........	0.00000E+00
EDGE MOMENT DUE VIBRATION...........	0.00000E+00

BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2

AXIAL LOAD DUE TO PRELOAD...........	0.10000E+05
AXIAL LOAD DUE TO GASKET SEATING....	0.57397E+04
AXIAL LOAD DUE TO GASKET OPERATION..	0.54757E+03
TORQUE DUE TO PRELOAD...............	0.37500E+03
TORQUE DUE TO GASKET	0.21524E+03

TOTAL NON-PRYING BOLT FORCES, TABLE 4.9

TOTAL NON-PRYING AXIAL LOAD.........	0.10815E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..	0.10136E+05
AXIAL LOAD LESS TEMP & PRELOAD......	0.67865E+03
TOTAL EDGE LOAD.....................	0.83407E+02
TOTAL EDGE MOMENT...................	0.61000E+02

PRYING ACTION FORCES, TABLE 2.1 & 2.2

AXIAL LOAD DUE TO PRYING............	-0.81436E+04
BENDING MOMENT DUE TO PRYING........	0.25259E+02

TOTAL BOLT FORCES

TOTAL BOLT AXIAL LOAD...............	0.19925E+04
TOTAL BOLT SHEAR LOAD...............	0.90076E+03
TOTAL BOLT BENDING MOMENT...........	0.86259E+02
TOTAL BOLT TORSIONAL MOMENT.........	0.37500E+03

TOTAL BOLT STRESSES

TOTAL BOLT DIRECT STRESS (+MC/I) ...	0.25483E+05
TOTAL BOLT DIRECT STRESS (-MC/I) ...	0.26009E+04
AVE BOLT DIRECT STRESS	0.14042E+05
TOTAL BOLT SHEAR STRESS	0.24870E+05
AVE BOLT SHEAR STRESS	0.12435E+05

CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3

ALLOWABLE TENSILE STRESS (Sa)	0.12950E+06
ALLOWABLE SHEAR STRESS (Ta)	0.77700E+05
Rt (AVE AXIAL STRESS/Sa)	0.10843E+00
Rs (AVE SHEAR_STRESS/Ta)	0.16004E+00
Rtý+Rsý	0.37369E-01

FLANGE SEPARATION EVALUATION

BOLT CLAMPING FORCE	-0.13139E+04
DISPLACEMENT ACROSS BOLT	-0.13136E-03
ALLOWABLE FLANGE SEPARATION	0.30000E-02
FLANGE FRICTION FORCE	-0.11825E+04
TOTAL BOLT SHEAR FORCE	0.90076E+03

4.5.3.2.2.7 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, 38°C (100°F) Ambient – Model AOS-050

```
30-FT @ 45 DEG CORNER AOS-050 CONFIGURATION, 100F AMBIENT



*************** INPUT DATA ****************

NUMBER OF BOLTS ......................(NB)           10
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.74140E+01
LID DIAMETER AT GASKET  .............(DLG) 0.60900E+01
NOMINAL BOLT DIAMETER ................(DB) 0.50000E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.55300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.89000E+01
THICKNESS OF LID .....................(TL) 0.75000E+00
THICKNESS OF LID FLANGE .............(TLF) 0.97000E+00
THICKNESS OF CASK WALL ...............(TC) 0.17050E+01
BOLT LENGTH ..........................(BL) 0.41000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.30000E-02

YOUNG'S MODULUS FOR LID ..............(EL) 0.27100E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.27100E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.27100E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.27900E+08
POISSON'S RATIO FOR LID ............(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.90000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.73000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.90000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.60000E+02
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.60000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL) 0.21600E+03
TEMPERATURE CHG ACROSS BOLT .......(TEMPB) 0.21600E+03
TEMPERATURE CHG ACROSS WALL .......(TEMPC) 0.21600E+03
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO) 0.21600E+03
TEMPERATURE AT INSIDE OF LID .....(TEMPLI) 0.21600E+03

WEIGHT OF CASK CONTENTS ..............(WC) 0.95000E+02
WEIGHT OF CASK LID ...................(WL) 0.14000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.45000E+02
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.17600E+03
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE ........................(Q) 0.75000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.31800E+01

Sm STRESS ............................(SM) 0.94000E+02
Sy STRESS ............................(SY) 0.14100E+03
Su STRESS ............................(SU) 0.17400E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.14100E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          13


******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.13108E+03
SHEAR LOAD DUE TO PRESSURE..........    0.24416E+03
EDGE LOAD DUE TO PRESSURE...........    0.83407E+02
EDGE MOMENT DUE TO PRESSURE.........    0.77298E+02


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.20116E+04
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........    0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.20904E+04
SHEAR LOAD DUE TO IMPACT............    0.17423E+03
EDGE LOAD DUE TO IMPACT.............    0.89748E+03
EDGE MOMENT DUE IMPACT..............    0.83174E+03
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.10000E+05
AXIAL LOAD DUE TO GASKET SEATING....    0.57397E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.54757E+03
TORQUE DUE TO PRELOAD...............    0.37500E+03
TORQUE DUE TO GASKET ...............    0.21524E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.14781E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.12012E+05
AXIAL LOAD LESS TEMP & PRELOAD......    0.27690E+04
TOTAL EDGE LOAD.....................    0.98089E+03
TOTAL EDGE MOMENT...................    0.90904E+03


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.57514E+04
BENDING MOMENT DUE TO PRYING........    0.37893E+03


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.62601E+04
TOTAL BOLT SHEAR LOAD...............    0.41839E+03
TOTAL BOLT BENDING MOMENT...........    0.12880E+04
TOTAL BOLT TORSIONAL MOMENT.........    0.37500E+03
```

```
TOTAL BOLT STRESSES
---------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.21495E+06
TOTAL BOLT DIRECT STRESS (-MC/I) ...   -0.12672E+06
AVE BOLT DIRECT STRESS .............    0.44117E+05
TOTAL BOLT SHEAR STRESS ............    0.24870E+05
AVE BOLT SHEAR STRESS ..............    0.12435E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
---------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......    0.12180E+06
ALLOWABLE SHEAR STRESS (Ta) ........    0.73080E+05
Rt (AVE AXIAL STRESS/Sa) ...........    0.36221E+00
Rs (AVE SHEAR_STRESS/Ta) ...........    0.17015E+00
Rtý+Rsý ............................    0.16015E+00


FLANGE SEPARATION EVALUATION
---------------------------------------------------
BOLT CLAMPING FORCE ................   -0.34911E+04
DISPLACEMENT ACROSS BOLT ...........   -0.36155E-03
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............   -0.31420E+04
TOTAL BOLT SHEAR FORCE .............    0.41839E+03
```

4.5.3.2.2.8 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, -40°C (-40°F) Ambient – Model AOS-050

```
30-FT @ 45 DEG CORNER AOS-050 CONFIGURATION, -40F AMBIENT



*************** INPUT DATA ****************

NUMBER OF BOLTS ......................(NB)          10
LID DIAMETER AT BOLT CIRCLE .........(DLB)  0.74140E+01
LID DIAMETER AT GASKET  .............(DLG)  0.60900E+01
NOMINAL BOLT DIAMETER ................(DB)  0.50000E+00
LID DIAMETER AT INNER EDGE ..........(DLI)  0.55300E+01
LID DIAMETER AT OUTER EDGE ..........(DLO)  0.89000E+01
THICKNESS OF LID .....................(TL)  0.75000E+00
THICKNESS OF LID FLANGE .............(TLF)  0.97000E+00
THICKNESS OF CASK WALL ...............(TC)  0.17050E+01
BOLT LENGTH ..........................(BL)  0.41000E+00
BOLT MOMENT OF INERTIA / CIR ........(XIB)  0.30000E-02

YOUNG'S MODULUS FOR LID ..............(EL)  0.28300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF)  0.28300E+08
YOUNG'S MODULUS FOR CASK .............(EC)  0.28300E+08
YOUNG'S MODULUS FOR BOLT .............(EB)  0.28900E+08
POISSON'S RATIO FOR LID ............(XNUL)  0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC)  0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL)  0.86000E-05
BOLT THERMAL EXPANSION COEFF .........(AB)  0.70000E-05
WALL THERMAL EXPANSION COEFF .........(AC)  0.86000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF)  0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI)  0.60000E+02
OUTSIDE PRESSURE AT LID .............(PLO)  0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI)  0.60000E+02
OUTSIDE PRESSURE AT CASK WALL .......(PCO)  0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL)  0.15000E+02
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)  0.15000E+02
TEMPERATURE CHG ACROSS WALL .......(TEMPC)  0.15000E+02
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)  0.15000E+02
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)  0.16000E+02

WEIGHT OF CASK CONTENTS ..............(WC)  0.95000E+02
WEIGHT OF CASK LID ...................(WL)  0.14000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP)  0.45000E+02
CG/CORNER IMPACT ACCEL, g ..........(ACCI)  0.24700E+03
DYNAMIC LOAD FACTOR ................(DYLF)  0.11500E+01

PUNCTURE LOAD ......................(PUNC)  0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)  0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE ........................(Q) 0.75000E+03
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.31800E+01

Sm STRESS ............................(SM) 0.10000E+03
Sy STRESS ............................(SY) 0.15000E+03
Su STRESS ............................(SU) 0.18500E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.15000E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)          13



******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.13108E+03
SHEAR LOAD DUE TO PRESSURE..........    0.24416E+03
EDGE LOAD DUE TO PRESSURE...........    0.83407E+02
EDGE MOMENT DUE TO PRESSURE.........    0.77298E+02


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.13619E+03
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........   -0.16298E+02


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.29337E+04
SHEAR LOAD DUE TO IMPACT............    0.24452E+03
EDGE LOAD DUE TO IMPACT.............    0.12595E+04
EDGE MOMENT DUE IMPACT..............    0.11673E+04
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.10000E+05
AXIAL LOAD DUE TO GASKET SEATING....    0.57397E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.54757E+03
TORQUE DUE TO PRELOAD...............    0.37500E+03
TORQUE DUE TO GASKET ...............    0.21524E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.13749E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.10136E+05
AXIAL LOAD LESS TEMP & PRELOAD......    0.36123E+04
TOTAL EDGE LOAD.....................    0.13429E+04
TOTAL EDGE MOMENT...................    0.12283E+04


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.26374E+04
BENDING MOMENT DUE TO PRYING........    0.50860E+03


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.74988E+04
TOTAL BOLT SHEAR LOAD...............    0.48868E+03
TOTAL BOLT BENDING MOMENT...........    0.17369E+04
TOTAL BOLT TORSIONAL MOMENT.........    0.37500E+03
```

```
TOTAL BOLT STRESSES
--------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.28322E+06
TOTAL BOLT DIRECT STRESS (-MC/I) ...   -0.17753E+06
AVE BOLT DIRECT STRESS .............    0.52846E+05
TOTAL BOLT SHEAR STRESS ............    0.24870E+05
AVE BOLT SHEAR STRESS ..............    0.12435E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
--------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......    0.12950E+06
ALLOWABLE SHEAR STRESS (Ta) ........    0.77700E+05
Rt (AVE AXIAL STRESS/Sa) ...........    0.40808E+00
Rs (AVE SHEAR_STRESS/Ta) ...........    0.16004E+00
Rtý+Rsý ............................    0.19214E+00


FLANGE SEPARATION EVALUATION
--------------------------------------------------
BOLT CLAMPING FORCE ................   -0.38865E+04
DISPLACEMENT ACROSS BOLT ...........   -0.38857E-03
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............   -0.34978E+04
TOTAL BOLT SHEAR FORCE .............    0.48868E+03
```

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4.5.3.2.3 Cask Lid Attachment Bolt Fortran Program Output Files – Model AOS-100

This appendix provides the following output files, that are used to build the content in Table 4-2:

- Output, Normal Conditions of Transport, 30-Ft. Drop, 38°C (100°F) Ambient – Model AOS-100
- Output, Normal Conditions of Transport, 30-Ft. Drop, -40°C (-40°F) Ambient – Model AOS-100
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, 38°C (100°F) Ambient – Model AOS-100
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, -40°C (-40°F) Ambient – Model AOS-100
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, 38°C (100°F) Ambient – Model AOS-100
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, -40°C (-40°F) Ambient – Model AOS-100
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, 38°C (100°F) Ambient – Model AOS-100
- Output, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, -40°C (-40°F) Ambient – Model AOS-100

4.5.3.2.3.1 Output, Normal Conditions of Transport, 30-Ft. Drop, 38°C (100°F) Ambient – Model AOS-100

```
NORMAL CONDITION - AXIAL=10g,LATERAL=5g AOS-100, 100F AMBIENT



*************** INPUT DATA ****************

NUMBER OF BOLTS ......................(NB)           14
LID DIAMETER AT BOLT CIRCLE .........(DLB)  0.14064E+02
LID DIAMETER AT GASKET  .............(DLG)  0.12172E+02
NOMINAL BOLT DIAMETER ................(DB)  0.87500E+00
LID DIAMETER AT INNER EDGE ..........(DLI)  0.11040E+02
LID DIAMETER AT OUTER EDGE ..........(DLO)  0.16590E+02
THICKNESS OF LID .....................(TL)  0.15100E+01
THICKNESS OF LID FLANGE .............(TLF)  0.19400E+01
THICKNESS OF CASK WALL ...............(TC)  0.28050E+01
BOLT LENGTH ..........................(BL)  0.10600E+01
BOLT MOMENT OF INERTIA / CIR ........(XIB)  0.29000E-01

YOUNG'S MODULUS FOR LID ..............(EL)  0.27100E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF)  0.27100E+08
YOUNG'S MODULUS FOR CASK .............(EC)  0.27100E+08
YOUNG'S MODULUS FOR BOLT .............(EB)  0.27900E+08
POISSON'S RATIO FOR LID ............(XNUL)  0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC)  0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL)  0.91000E-05
BOLT THERMAL EXPANSION COEFF .........(AB)  0.73000E-05
WALL THERMAL EXPANSION COEFF .........(AC)  0.91000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF)  0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI)  0.28000E+03
OUTSIDE PRESSURE AT LID .............(PLO)  0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI)  0.28000E+03
OUTSIDE PRESSURE AT CASK WALL .......(PCO)  0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL)  0.22300E+03
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)  0.22300E+03
TEMPERATURE CHG ACROSS WALL .......(TEMPC)  0.22300E+03
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)  0.22400E+03
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)  0.22400E+03

WEIGHT OF CASK CONTENTS ..............(WC)  0.78600E+03
WEIGHT OF CASK LID ...................(WL)  0.96000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP)  0.00000E+00
CG/CORNER IMPACT ACCEL, g ..........(ACCI)  0.00000E+00
DYNAMIC LOAD FACTOR ................(DYLF)  0.11500E+01

PUNCTURE LOAD ......................(PUNC)  0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)  0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.10000E+02
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.50000E+01
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE .......................(Q) 0.60000E+04
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.54000E+00

Sm STRESS ............................(SM) 0.94000E+02
Sy STRESS ............................(SY) 0.14100E+03
Su STRESS ............................(SU) 0.17400E+03
CODE EVALUATION TYPE.................(CET)           1

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.14100E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)           9



******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.22026E+04
SHEAR LOAD DUE TO PRESSURE..........    0.45227E+04
EDGE LOAD DUE TO PRESSURE...........    0.93174E+03
EDGE MOMENT DUE TO PRESSURE.........    0.16380E+04


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.67342E+04
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........    0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.00000E+00
SHEAR LOAD DUE TO IMPACT............    0.00000E+00
EDGE LOAD DUE TO IMPACT.............    0.00000E+00
EDGE MOMENT DUE IMPACT..............    0.00000E+00
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
--------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........     0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........     0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........     0.00000E+00
EDGE MOMENT DUE PUNCTURE............     0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
--------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........     0.68571E+02
SHEAR LOAD DUE TO VIBRATION.........     0.34286E+02
EDGE LOAD DUE TO VIBRATION..........     0.21728E+02
EDGE MOMENT DUE VIBRATION...........     0.38197E+02


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
--------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........     0.45714E+05
AXIAL LOAD DUE TO GASKET SEATING....     0.81942E+04
AXIAL LOAD DUE TO GASKET OPERATION..     0.78172E+03
TORQUE DUE TO PRELOAD...............     0.30000E+04
TORQUE DUE TO GASKET ...............     0.53774E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
--------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........     0.55501E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..     0.52449E+05
AXIAL LOAD LESS TEMP & PRELOAD......     0.30529E+04
TOTAL EDGE LOAD.....................     0.95347E+03
TOTAL EDGE MOMENT...................     0.16762E+04


PRYING ACTION FORCES, TABLE 2.1 & 2.2
--------------------------------------------------
AXIAL LOAD DUE TO PRYING............    -0.34461E+05
BENDING MOMENT DUE TO PRYING........     0.63726E+03


TOTAL BOLT FORCES
--------------------------------------------------
TOTAL BOLT AXIAL LOAD...............     0.17988E+05
TOTAL BOLT SHEAR LOAD...............     0.45570E+04
TOTAL BOLT BENDING MOMENT...........     0.23135E+04
TOTAL BOLT TORSIONAL MOMENT.........     0.30000E+04
```

TOTAL BOLT STRESSES

TOTAL BOLT DIRECT STRESS (+MC/I) ...	0.91234E+05
TOTAL BOLT DIRECT STRESS (-MC/I) ...	-0.13320E+05
AVE BOLT DIRECT STRESS	0.38957E+05
TOTAL BOLT SHEAR STRESS	0.33895E+05
AVE BOLT SHEAR STRESS	0.16948E+05

CODE EVALUATION FOR NORMAL COND, TABLE 6.1

Rt (AXIAL_STRESS/Sm)	0.41444E+00
Rs (SHEAR_STRESS/0.6Sm)	0.30049E+00
Rtý+Rsý	0.26205E+00
VON MISES EQUIVALENT STRESS (Se) ...	0.11366E+06
Se/1.35Sm	0.89569E+00

FLANGE SEPARATION EVALUATION

BOLT CLAMPING FORCE	-0.14935E+05
DISPLACEMENT ACROSS BOLT	-0.12289E-02
ALLOWABLE FLANGE SEPARATION	0.30000E-02
FLANGE FRICTION FORCE	-0.13442E+05
TOTAL BOLT SHEAR FORCE	0.45570E+04

FATIGUE EVALUATION

USEAGE FOR NORMAL OPERATION	0.64705E+00
USEAGE FOR VIBRATION	0.11424E-01
ACCUMULATIVE FATIGUE USEAGE	0.65847E+00

4.5.3.2.3.2 Output, Normal Conditions of Transport, 30-Ft. Drop, -40°C (-40°F) Ambient – Model AOS-100

```
NORMAL CONDITION - AXIAL=10g,LATERAL=5g AOS-100, -40F Ambient



*************** INPUT DATA ****************

NUMBER OF BOLTS .....................(NB)         14
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.14064E+02
LID DIAMETER AT GASKET  .............(DLG) 0.12172E+02
NOMINAL BOLT DIAMETER ................(DB) 0.87500E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.11040E+02
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.16590E+02
THICKNESS OF LID ....................(TL) 0.15100E+01
THICKNESS OF LID FLANGE .............(TLF) 0.19400E+01
THICKNESS OF CASK WALL ...............(TC) 0.28050E+01
BOLT LENGTH ..........................(BL) 0.10600E+01
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.29000E-01

YOUNG'S MODULUS FOR LID ..............(EL) 0.28300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.28300E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.28300E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.28900E+08
POISSON'S RATIO FOR LID ............(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.86000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.70000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.86000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.28000E+03
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.28000E+03
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL) 0.15000E+02
TEMPERATURE CHG ACROSS BOLT .......(TEMPB) 0.15000E+02
TEMPERATURE CHG ACROSS WALL .......(TEMPC) 0.15000E+02
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO) 0.16000E+02
TEMPERATURE AT INSIDE OF LID .....(TEMPLI) 0.16000E+02

WEIGHT OF CASK CONTENTS ..............(WC) 0.78600E+03
WEIGHT OF CASK LID ...................(WL) 0.96000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.00000E+00
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.00000E+00
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.10000E+02
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.50000E+01
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE ........................(Q) 0.60000E+04
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.54000E+00

Sm STRESS ............................(SM) 0.10000E+03
Sy STRESS ............................(SY) 0.15000E+03
Su STRESS ............................(SU) 0.18500E+03
CODE EVALUATION TYPE.................(CET)           1

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.15000E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)           9



******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.22026E+04
SHEAR LOAD DUE TO PRESSURE..........    0.45227E+04
EDGE LOAD DUE TO PRESSURE...........    0.93174E+03
EDGE MOMENT DUE TO PRESSURE.........    0.16380E+04


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.41708E+03
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........    0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.00000E+00
SHEAR LOAD DUE TO IMPACT............    0.00000E+00
EDGE LOAD DUE TO IMPACT.............    0.00000E+00
EDGE MOMENT DUE IMPACT..............    0.00000E+00
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.68571E+02
SHEAR LOAD DUE TO VIBRATION.........    0.34286E+02
EDGE LOAD DUE TO VIBRATION..........    0.21728E+02
EDGE MOMENT DUE VIBRATION...........    0.38197E+02


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.45714E+05
AXIAL LOAD DUE TO GASKET SEATING....    0.81942E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.78172E+03
TORQUE DUE TO PRELOAD...............    0.30000E+04
TORQUE DUE TO GASKET ...............    0.53774E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.49184E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.46131E+05
AXIAL LOAD LESS TEMP & PRELOAD......    0.30529E+04
TOTAL EDGE LOAD.....................    0.95347E+03
TOTAL EDGE MOMENT...................    0.16762E+04


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.29592E+05
BENDING MOMENT DUE TO PRYING........    0.63273E+03


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.16539E+05
TOTAL BOLT SHEAR LOAD...............    0.45570E+04
TOTAL BOLT BENDING MOMENT...........    0.23089E+04
TOTAL BOLT TORSIONAL MOMENT.........    0.30000E+04
```

TOTAL BOLT STRESSES

TOTAL BOLT DIRECT STRESS (+MC/I) ...	0.87994E+05
TOTAL BOLT DIRECT STRESS (-MC/I) ...	-0.16355E+05
AVE BOLT DIRECT STRESS	0.35819E+05
TOTAL BOLT SHEAR STRESS	0.33895E+05
AVE BOLT SHEAR STRESS	0.16948E+05

CODE EVALUATION FOR NORMAL COND, TABLE 6.1

Rt (AXIAL_STRESS/Sm)	0.35819E+00
Rs (SHEAR_STRESS/0.6Sm)	0.28246E+00
Rtý+Rsý	0.20809E+00
VON MISES EQUIVALENT STRESS (Se) ...	0.11108E+06
Se/1.35Sm	0.82281E+00

FLANGE SEPARATION EVALUATION

BOLT CLAMPING FORCE	-0.13486E+05
DISPLACEMENT ACROSS BOLT	-0.10713E-02
ALLOWABLE FLANGE SEPARATION	0.30000E-02
FLANGE FRICTION FORCE	-0.12138E+05
TOTAL BOLT SHEAR FORCE	0.45570E+04

FATIGUE EVALUATION

USEAGE FOR NORMAL OPERATION	0.58663E+00
USEAGE FOR VIBRATION	0.11424E-01
ACCUMULATIVE FATIGUE USEAGE	0.59805E+00

4.5.3.2.3.3 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, 38°C (100°F) Ambient – Model AOS-100

```
30-FT DROP - Head-on  AOS-100, 100F Ambient


 *************** INPUT DATA ****************

 NUMBER OF BOLTS .....................(NB)          14
 LID DIAMETER AT BOLT CIRCLE .........(DLB)  0.14064E+02
 LID DIAMETER AT GASKET  .............(DLG)  0.12172E+02
 NOMINAL BOLT DIAMETER ................(DB)  0.87500E+00
 LID DIAMETER AT INNER EDGE ..........(DLI)  0.11040E+02
 LID DIAMETER AT OUTER EDGE ..........(DLO)  0.16590E+02
 THICKNESS OF LID ....................(TL)  0.15100E+01
 THICKNESS OF LID FLANGE .............(TLF)  0.19400E+01
 THICKNESS OF CASK WALL ...............(TC)  0.28050E+01
 BOLT LENGTH ..........................(BL)  0.10600E+01
 BOLT MOMENT OF INERTIA / CIR ........(XIB)  0.29000E-01

 YOUNG'S MODULUS FOR LID ..............(EL)  0.27100E+08
 YOUNG'S MODULUS FOR LID FLANGE ......(ELF)  0.27100E+08
 YOUNG'S MODULUS FOR CASK .............(EC)  0.27100E+08
 YOUNG'S MODULUS FOR BOLT .............(EB)  0.27900E+08
 POISSON'S RATIO FOR LID ............(XNUL)  0.30000E+00
 POISSON'S RATIO FOR CASK ...........(XNUC)  0.30000E+00
 LID THERMAL EXPANSION COEFF ..........(AL)  0.91000E-05
 BOLT THERMAL EXPANSION COEFF .........(AB)  0.73000E-05
 WALL THERMAL EXPANSION COEFF .........(AC)  0.91000E-05
 FLANGE COEFFICIENT OF FRICTION ......(FCF)  0.90000E+00

 INSIDE PRESSURE AT LID ..............(PLI)  0.28000E+03
 OUTSIDE PRESSURE AT LID .............(PLO)  0.15000E+02
 INSIDE PRESSURE AT CASK WALL ........(PCI)  0.28000E+03
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)  0.15000E+02

 TEMPERATURE CHG ACROSS LID ........(TEMPL)  0.22300E+03
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)  0.22300E+03
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)  0.22300E+03
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)  0.22400E+03
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)  0.22400E+03

 WEIGHT OF CASK CONTENTS ..............(WC)  0.78600E+03
 WEIGHT OF CASK LID ...................(WL)  0.96000E+02
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)  0.90000E+02
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)  0.15600E+03
 DYNAMIC LOAD FACTOR ................(DYLF)  0.11500E+01

 PUNCTURE LOAD ......................(PUNC)  0.00000E+00
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)  0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE ........................(Q) 0.60000E+04
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.54000E+00

Sm STRESS ............................(SM) 0.94000E+02
Sy STRESS ............................(SY) 0.14100E+03
Su STRESS ............................(SU) 0.17400E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.14100E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)           9


******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.22026E+04
SHEAR LOAD DUE TO PRESSURE..........    0.45227E+04
EDGE LOAD DUE TO PRESSURE...........    0.93174E+03
EDGE MOMENT DUE TO PRESSURE.........    0.16380E+04


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.67342E+04
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........    0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.15145E+05
SHEAR LOAD DUE TO IMPACT............   -0.46759E-04
EDGE LOAD DUE TO IMPACT.............    0.47988E+04
EDGE MOMENT DUE IMPACT..............    0.84364E+04
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.45714E+05
AXIAL LOAD DUE TO GASKET SEATING....    0.81942E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.78172E+03
TORQUE DUE TO PRELOAD...............    0.30000E+04
TORQUE DUE TO GASKET ...............    0.53774E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.70578E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.52449E+05
AXIAL LOAD LESS TEMP & PRELOAD......    0.18129E+05
TOTAL EDGE LOAD.....................    0.57306E+04
TOTAL EDGE MOMENT...................    0.10074E+05


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.69982E+04
BENDING MOMENT DUE TO PRYING........    0.38301E+04


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.45450E+05
TOTAL BOLT SHEAR LOAD...............    0.45227E+04
TOTAL BOLT BENDING MOMENT...........    0.13904E+05
TOTAL BOLT TORSIONAL MOMENT.........    0.30000E+04
```

```
TOTAL BOLT STRESSES
---------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.41263E+06
TOTAL BOLT DIRECT STRESS (-MC/I) ...   -0.21576E+06
AVE BOLT DIRECT STRESS .............    0.98434E+05
TOTAL BOLT SHEAR STRESS ............    0.33895E+05
AVE BOLT SHEAR STRESS ..............    0.16948E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
---------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......    0.12180E+06
ALLOWABLE SHEAR STRESS (Ta) ........    0.73080E+05
Rt (AVE AXIAL STRESS/Sa) ...........    0.80816E+00
Rs (AVE SHEAR_STRESS/Ta) ...........    0.23191E+00
Rtý+Rsý ............................    0.70691E+00


FLANGE SEPARATION EVALUATION
---------------------------------------------------
BOLT CLAMPING FORCE ................   -0.27321E+05
DISPLACEMENT ACROSS BOLT ...........   -0.22481E-02
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............   -0.24589E+05
TOTAL BOLT SHEAR FORCE .............    0.45227E+04
```

4.5.3.2.3.4 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Head-On Drop, -40°C (-40°F) Ambient – Model AOS-100

```
30-FT DROP - Head-on  AOS-100, -40F Ambient



*************** INPUT DATA ****************

NUMBER OF BOLTS ......................(NB)            14
LID DIAMETER AT BOLT CIRCLE .........(DLB) 0.14064E+02
LID DIAMETER AT GASKET  .............(DLG) 0.12172E+02
NOMINAL BOLT DIAMETER ................(DB) 0.87500E+00
LID DIAMETER AT INNER EDGE ..........(DLI) 0.11040E+02
LID DIAMETER AT OUTER EDGE ..........(DLO) 0.16590E+02
THICKNESS OF LID .....................(TL) 0.15100E+01
THICKNESS OF LID FLANGE .............(TLF) 0.19400E+01
THICKNESS OF CASK WALL ...............(TC) 0.28050E+01
BOLT LENGTH ..........................(BL) 0.10600E+01
BOLT MOMENT OF INERTIA / CIR ........(XIB) 0.29000E-01

YOUNG'S MODULUS FOR LID ..............(EL) 0.28300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF) 0.28300E+08
YOUNG'S MODULUS FOR CASK .............(EC) 0.28300E+08
YOUNG'S MODULUS FOR BOLT .............(EB) 0.28900E+08
POISSON'S RATIO FOR LID ............(XNUL) 0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC) 0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL) 0.86000E-05
BOLT THERMAL EXPANSION COEFF .........(AB) 0.70000E-05
WALL THERMAL EXPANSION COEFF .........(AC) 0.86000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF) 0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI) 0.28000E+03
OUTSIDE PRESSURE AT LID .............(PLO) 0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI) 0.28000E+03
OUTSIDE PRESSURE AT CASK WALL .......(PCO) 0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL) 0.15000E+02
TEMPERATURE CHG ACROSS BOLT .......(TEMPB) 0.15000E+02
TEMPERATURE CHG ACROSS WALL .......(TEMPC) 0.15000E+02
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO) 0.16000E+02
TEMPERATURE AT INSIDE OF LID .....(TEMPLI) 0.16000E+02

WEIGHT OF CASK CONTENTS ..............(WC) 0.78600E+03
WEIGHT OF CASK LID ...................(WL) 0.96000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP) 0.90000E+02
CG/CORNER IMPACT ACCEL, g ..........(ACCI) 0.21800E+03
DYNAMIC LOAD FACTOR ................(DYLF) 0.11500E+01

PUNCTURE LOAD ......................(PUNC) 0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC) 0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE ........................(Q) 0.60000E+04
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.54000E+00

Sm STRESS ............................(SM) 0.10000E+03
Sy STRESS ............................(SY) 0.15000E+03
Su STRESS ............................(SU) 0.18500E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.15000E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)           9



******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........   0.22026E+04
SHEAR LOAD DUE TO PRESSURE..........   0.45227E+04
EDGE LOAD DUE TO PRESSURE...........   0.93174E+03
EDGE MOMENT DUE TO PRESSURE.........   0.16380E+04


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......   0.41708E+03
SHEAR LOAD DUE TO TEMPERATURE.......   0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........   0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........   0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............   0.21164E+05
SHEAR LOAD DUE TO IMPACT............  -0.65342E-04
EDGE LOAD DUE TO IMPACT.............   0.67061E+04
EDGE MOMENT DUE IMPACT..............   0.11789E+05
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.45714E+05
AXIAL LOAD DUE TO GASKET SEATING....    0.81942E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.78172E+03
TORQUE DUE TO PRELOAD...............    0.30000E+04
TORQUE DUE TO GASKET ...............    0.53774E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.70280E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.46131E+05
AXIAL LOAD LESS TEMP & PRELOAD......    0.24148E+05
TOTAL EDGE LOAD.....................    0.76378E+04
TOTAL EDGE MOMENT...................    0.13427E+05


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............    0.87598E+04
BENDING MOMENT DUE TO PRYING........    0.50685E+04


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.54891E+05
TOTAL BOLT SHEAR LOAD...............    0.45227E+04
TOTAL BOLT BENDING MOMENT...........    0.18496E+05
TOTAL BOLT TORSIONAL MOMENT.........    0.30000E+04
```

```
TOTAL BOLT STRESSES
---------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...    0.53683E+06
TOTAL BOLT DIRECT STRESS (-MC/I) ...   -0.29907E+06
AVE BOLT DIRECT STRESS .............    0.11888E+06
TOTAL BOLT SHEAR STRESS ............    0.33895E+05
AVE BOLT SHEAR STRESS ..............    0.16948E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
---------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......    0.12950E+06
ALLOWABLE SHEAR STRESS (Ta) ........    0.77700E+05
Rt (AVE AXIAL STRESS/Sa) ...........    0.91800E+00
Rs (AVE SHEAR_STRESS/Ta) ...........    0.21812E+00
Rtý+Rsý ............................    0.89030E+00


FLANGE SEPARATION EVALUATION
---------------------------------------------------
BOLT CLAMPING FORCE ................   -0.13223E+05
DISPLACEMENT ACROSS BOLT ...........   -0.10504E-02
ALLOWABLE FLANGE SEPARATION ........    0.30000E-02
FLANGE FRICTION FORCE ..............   -0.11901E+05
TOTAL BOLT SHEAR FORCE .............    0.45227E+04
```

4.5.3.2.3.5 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, 38°C (100°F) Ambient – Model AOS-100

```
30-FT DROP - Side  AOS-100, 100F Ambient



 *************** INPUT DATA ****************

 NUMBER OF BOLTS ......................(NB)            14
 LID DIAMETER AT BOLT CIRCLE .........(DLB)  0.14064E+02
 LID DIAMETER AT GASKET  .............(DLG)  0.12172E+02
 NOMINAL BOLT DIAMETER ................(DB)  0.87500E+00
 LID DIAMETER AT INNER EDGE ..........(DLI)  0.11040E+02
 LID DIAMETER AT OUTER EDGE ..........(DLO)  0.16590E+02
 THICKNESS OF LID .....................(TL)  0.15100E+01
 THICKNESS OF LID FLANGE .............(TLF)  0.19400E+01
 THICKNESS OF CASK WALL ...............(TC)  0.28050E+01
 BOLT LENGTH ..........................(BL)  0.10600E+01
 BOLT MOMENT OF INERTIA / CIR ........(XIB)  0.29000E-01

 YOUNG'S MODULUS FOR LID ..............(EL)  0.27100E+08
 YOUNG'S MODULUS FOR LID FLANGE ......(ELF)  0.27100E+08
 YOUNG'S MODULUS FOR CASK .............(EC)  0.27100E+08
 YOUNG'S MODULUS FOR BOLT .............(EB)  0.27900E+08
 POISSON'S RATIO FOR LID ............(XNUL)  0.30000E+00
 POISSON'S RATIO FOR CASK ...........(XNUC)  0.30000E+00
 LID THERMAL EXPANSION COEFF ..........(AL)  0.91000E-05
 BOLT THERMAL EXPANSION COEFF .........(AB)  0.73000E-05
 WALL THERMAL EXPANSION COEFF .........(AC)  0.91000E-05
 FLANGE COEFFICIENT OF FRICTION ......(FCF)  0.90000E+00

 INSIDE PRESSURE AT LID ..............(PLI)  0.28000E+03
 OUTSIDE PRESSURE AT LID .............(PLO)  0.15000E+02
 INSIDE PRESSURE AT CASK WALL ........(PCI)  0.28000E+03
 OUTSIDE PRESSURE AT CASK WALL .......(PCO)  0.15000E+02

 TEMPERATURE CHG ACROSS LID ........(TEMPL)  0.22300E+03
 TEMPERATURE CHG ACROSS BOLT .......(TEMPB)  0.22300E+03
 TEMPERATURE CHG ACROSS WALL .......(TEMPC)  0.22300E+03
 TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)  0.22400E+03
 TEMPERATURE AT INSIDE OF LID .....(TEMPLI)  0.22400E+03

 WEIGHT OF CASK CONTENTS ..............(WC)  0.78600E+03
 WEIGHT OF CASK LID ...................(WL)  0.96000E+02
 DROP ANGLE OF IMPACT, deg .......(XI_DROP)  0.00000E+00
 CG/CORNER IMPACT ACCEL, g ..........(ACCI)  0.17100E+03
 DYNAMIC LOAD FACTOR ................(DYLF)  0.11500E+01

 PUNCTURE LOAD ......................(PUNC)  0.00000E+00
 PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)  0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE ........................(Q) 0.60000E+04
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.54000E+00

Sm STRESS ............................(SM) 0.94000E+02
Sy STRESS ............................(SY) 0.14100E+03
Su STRESS ............................(SU) 0.17400E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.14100E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)           9



******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.22026E+04
SHEAR LOAD DUE TO PRESSURE..........    0.45227E+04
EDGE LOAD DUE TO PRESSURE...........    0.93174E+03
EDGE MOMENT DUE TO PRESSURE.........    0.16380E+04


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.67342E+04
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........    0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.00000E+00
SHEAR LOAD DUE TO IMPACT............    0.11726E+04
EDGE LOAD DUE TO IMPACT.............    0.00000E+00
EDGE MOMENT DUE IMPACT..............    0.00000E+00
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.45714E+05
AXIAL LOAD DUE TO GASKET SEATING....    0.81942E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.78172E+03
TORQUE DUE TO PRELOAD...............    0.30000E+04
TORQUE DUE TO GASKET ...............    0.53774E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.55433E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.52449E+05
AXIAL LOAD LESS TEMP & PRELOAD......    0.29843E+04
TOTAL EDGE LOAD.....................    0.93174E+03
TOTAL EDGE MOMENT...................    0.16380E+04


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.34586E+05
BENDING MOMENT DUE TO PRYING........    0.62274E+03


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.17863E+05
TOTAL BOLT SHEAR LOAD...............    0.56953E+04
TOTAL BOLT BENDING MOMENT...........    0.22607E+04
TOTAL BOLT TORSIONAL MOMENT.........    0.30000E+04
```

```
TOTAL BOLT STRESSES
---------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...     0.89772E+05
TOTAL BOLT DIRECT STRESS (-MC/I) ...    -0.12399E+05
AVE BOLT DIRECT STRESS .............     0.38687E+05
TOTAL BOLT SHEAR STRESS ............     0.33895E+05
AVE BOLT SHEAR STRESS ..............     0.16948E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
---------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......     0.12180E+06
ALLOWABLE SHEAR STRESS (Ta) ........     0.73080E+05
Rt (AVE AXIAL STRESS/Sa) ...........     0.31763E+00
Rs (AVE SHEAR_STRESS/Ta) ...........     0.23191E+00
Rtý+Rsý ............................     0.15467E+00


FLANGE SEPARATION EVALUATION
---------------------------------------------------
BOLT CLAMPING FORCE ................    -0.14879E+05
DISPLACEMENT ACROSS BOLT ...........    -0.12243E-02
ALLOWABLE FLANGE SEPARATION ........     0.30000E-02
FLANGE FRICTION FORCE ..............    -0.13391E+05
TOTAL BOLT SHEAR FORCE .............     0.56953E+04
```

4.5.3.2.3.6 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Side Drop, -40°C (-40°F) Ambient – Model AOS-100

```
30-FT DROP - Side  AOS-100, -40F Ambient


*************** INPUT DATA ****************

NUMBER OF BOLTS ......................(NB)           14
LID DIAMETER AT BOLT CIRCLE .........(DLB)  0.14064E+02
LID DIAMETER AT GASKET  .............(DLG)  0.12172E+02
NOMINAL BOLT DIAMETER ................(DB)  0.87500E+00
LID DIAMETER AT INNER EDGE ..........(DLI)  0.11040E+02
LID DIAMETER AT OUTER EDGE ..........(DLO)  0.16590E+02
THICKNESS OF LID .....................(TL)  0.15100E+01
THICKNESS OF LID FLANGE .............(TLF)  0.19400E+01
THICKNESS OF CASK WALL ...............(TC)  0.28050E+01
BOLT LENGTH ..........................(BL)  0.10600E+01
BOLT MOMENT OF INERTIA / CIR ........(XIB)  0.29000E-01

YOUNG'S MODULUS FOR LID ..............(EL)  0.28300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF)  0.28300E+08
YOUNG'S MODULUS FOR CASK .............(EC)  0.28300E+08
YOUNG'S MODULUS FOR BOLT .............(EB)  0.28900E+08
POISSON'S RATIO FOR LID ............(XNUL)  0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC)  0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL)  0.86000E-05
BOLT THERMAL EXPANSION COEFF .........(AB)  0.70000E-05
WALL THERMAL EXPANSION COEFF .........(AC)  0.86000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF)  0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI)  0.28000E+03
OUTSIDE PRESSURE AT LID .............(PLO)  0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI)  0.28000E+03
OUTSIDE PRESSURE AT CASK WALL .......(PCO)  0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL)  0.15000E+02
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)  0.15000E+02
TEMPERATURE CHG ACROSS WALL .......(TEMPC)  0.15000E+02
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)  0.16000E+02
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)  0.16000E+02

WEIGHT OF CASK CONTENTS ..............(WC)  0.78600E+03
WEIGHT OF CASK LID ...................(WL)  0.96000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP)  0.00000E+00
CG/CORNER IMPACT ACCEL, g ..........(ACCI)  0.24000E+03
DYNAMIC LOAD FACTOR ................(DYLF)  0.11500E+01

PUNCTURE LOAD ......................(PUNC)  0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)  0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE .......................(Q) 0.60000E+04
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.54000E+00

Sm STRESS ............................(SM) 0.10000E+03
Sy STRESS ............................(SY) 0.15000E+03
Su STRESS ............................(SU) 0.18500E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.15000E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)           9


******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........   0.22026E+04
SHEAR LOAD DUE TO PRESSURE..........   0.45227E+04
EDGE LOAD DUE TO PRESSURE...........   0.93174E+03
EDGE MOMENT DUE TO PRESSURE.........   0.16380E+04


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......   0.41708E+03
SHEAR LOAD DUE TO TEMPERATURE.......   0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........   0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........   0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............   0.00000E+00
SHEAR LOAD DUE TO IMPACT............   0.16457E+04
EDGE LOAD DUE TO IMPACT.............   0.00000E+00
EDGE MOMENT DUE IMPACT..............   0.00000E+00
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
---------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
---------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
---------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.45714E+05
AXIAL LOAD DUE TO GASKET SEATING....    0.81942E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.78172E+03
TORQUE DUE TO PRELOAD...............    0.30000E+04
TORQUE DUE TO GASKET ...............    0.53774E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
---------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.49116E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.46131E+05
AXIAL LOAD LESS TEMP & PRELOAD......    0.29843E+04
TOTAL EDGE LOAD.....................    0.93174E+03
TOTAL EDGE MOMENT...................    0.16380E+04


PRYING ACTION FORCES, TABLE 2.1 & 2.2
---------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.29717E+05
BENDING MOMENT DUE TO PRYING........    0.61831E+03


TOTAL BOLT FORCES
---------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.16414E+05
TOTAL BOLT SHEAR LOAD...............    0.61685E+04
TOTAL BOLT BENDING MOMENT...........    0.22563E+04
TOTAL BOLT TORSIONAL MOMENT.........    0.30000E+04
```

```
TOTAL BOLT STRESSES
---------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...     0.86535E+05
TOTAL BOLT DIRECT STRESS (-MC/I) ...    -0.15436E+05
AVE BOLT DIRECT STRESS .............     0.35549E+05
TOTAL BOLT SHEAR STRESS ............     0.33895E+05
AVE BOLT SHEAR STRESS ..............     0.16948E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
---------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......     0.12950E+06
ALLOWABLE SHEAR STRESS (Ta) ........     0.77700E+05
Rt (AVE AXIAL STRESS/Sa) ...........     0.27451E+00
Rs (AVE SHEAR_STRESS/Ta) ...........     0.21812E+00
Rtý+Rsý ............................     0.12293E+00


FLANGE SEPARATION EVALUATION
---------------------------------------------------
BOLT CLAMPING FORCE ................    -0.13430E+05
DISPLACEMENT ACROSS BOLT ...........    -0.10668E-02
ALLOWABLE FLANGE SEPARATION ........     0.30000E-02
FLANGE FRICTION FORCE ..............    -0.12087E+05
TOTAL BOLT SHEAR FORCE .............     0.61685E+04
```

4.5.3.2.3.7 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, 38°C (100°F) Ambient – Model AOS-100

```
30-FT DROP - @ 45 DEG CORNER AOS-100, 100F AMBIENT


*************** INPUT DATA ****************

NUMBER OF BOLTS ......................(NB)            14
LID DIAMETER AT BOLT CIRCLE .........(DLB)  0.14064E+02
LID DIAMETER AT GASKET  .............(DLG)  0.12172E+02
NOMINAL BOLT DIAMETER ................(DB)  0.87500E+00
LID DIAMETER AT INNER EDGE ..........(DLI)  0.11040E+02
LID DIAMETER AT OUTER EDGE ..........(DLO)  0.16590E+02
THICKNESS OF LID .....................(TL)  0.15100E+01
THICKNESS OF LID FLANGE .............(TLF)  0.19400E+01
THICKNESS OF CASK WALL ...............(TC)  0.28050E+01
BOLT LENGTH ..........................(BL)  0.10600E+01
BOLT MOMENT OF INERTIA / CIR ........(XIB)  0.29000E-01

YOUNG'S MODULUS FOR LID ..............(EL)  0.27100E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF)  0.27100E+08
YOUNG'S MODULUS FOR CASK .............(EC)  0.27100E+08
YOUNG'S MODULUS FOR BOLT .............(EB)  0.27900E+08
POISSON'S RATIO FOR LID ............(XNUL)  0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC)  0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL)  0.91000E-05
BOLT THERMAL EXPANSION COEFF .........(AB)  0.73000E-05
WALL THERMAL EXPANSION COEFF .........(AC)  0.91000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF)  0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI)  0.28000E+03
OUTSIDE PRESSURE AT LID .............(PLO)  0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI)  0.28000E+03
OUTSIDE PRESSURE AT CASK WALL .......(PCO)  0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL)  0.22300E+03
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)  0.22300E+03
TEMPERATURE CHG ACROSS WALL .......(TEMPC)  0.22300E+03
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)  0.22400E+03
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)  0.22400E+03

WEIGHT OF CASK CONTENTS ..............(WC)  0.78600E+03
WEIGHT OF CASK LID ...................(WL)  0.96000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP)  0.45000E+02
CG/CORNER IMPACT ACCEL, g ..........(ACCI)  0.88000E+02
DYNAMIC LOAD FACTOR ................(DYLF)  0.11500E+01

PUNCTURE LOAD ......................(PUNC)  0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)  0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE ..........................(Q) 0.60000E+04
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.54000E+00

Sm STRESS ............................(SM) 0.94000E+02
Sy STRESS ............................(SY) 0.14100E+03
Su STRESS ............................(SU) 0.17400E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.14100E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)           9


******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........    0.22026E+04
SHEAR LOAD DUE TO PRESSURE..........    0.45227E+04
EDGE LOAD DUE TO PRESSURE...........    0.93174E+03
EDGE MOMENT DUE TO PRESSURE.........    0.16380E+04


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......    0.67342E+04
SHEAR LOAD DUE TO TEMPERATURE.......    0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........    0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........    0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............    0.60410E+04
SHEAR LOAD DUE TO IMPACT............    0.42669E+03
EDGE LOAD DUE TO IMPACT.............    0.19142E+04
EDGE MOMENT DUE IMPACT..............    0.33651E+04
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
--------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........    0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........    0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........    0.00000E+00
EDGE MOMENT DUE PUNCTURE............    0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
--------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........    0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........    0.00000E+00
EDGE LOAD DUE TO VIBRATION..........    0.00000E+00
EDGE MOMENT DUE VIBRATION...........    0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
--------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........    0.45714E+05
AXIAL LOAD DUE TO GASKET SEATING....    0.81942E+04
AXIAL LOAD DUE TO GASKET OPERATION..    0.78172E+03
TORQUE DUE TO PRELOAD...............    0.30000E+04
TORQUE DUE TO GASKET ...............    0.53774E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
--------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........    0.61474E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..    0.52449E+05
AXIAL LOAD LESS TEMP & PRELOAD......    0.90253E+04
TOTAL EDGE LOAD.....................    0.28459E+04
TOTAL EDGE MOMENT...................    0.50031E+04


PRYING ACTION FORCES, TABLE 2.1 & 2.2
--------------------------------------------------
AXIAL LOAD DUE TO PRYING............   -0.23581E+05
BENDING MOMENT DUE TO PRYING........    0.19021E+04


TOTAL BOLT FORCES
--------------------------------------------------
TOTAL BOLT AXIAL LOAD...............    0.28867E+05
TOTAL BOLT SHEAR LOAD...............    0.49494E+04
TOTAL BOLT BENDING MOMENT...........    0.69052E+04
TOTAL BOLT TORSIONAL MOMENT.........    0.30000E+04
```

```
TOTAL BOLT STRESSES
--------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...     0.21855E+06
TOTAL BOLT DIRECT STRESS (-MC/I) ...    -0.93517E+05
AVE BOLT DIRECT STRESS .............     0.62519E+05
TOTAL BOLT SHEAR STRESS ............     0.33895E+05
AVE BOLT SHEAR STRESS ..............     0.16948E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
--------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......     0.12180E+06
ALLOWABLE SHEAR STRESS (Ta) ........     0.73080E+05
Rt (AVE AXIAL STRESS/Sa) ...........     0.51329E+00
Rs (AVE SHEAR_STRESS/Ta) ...........     0.23191E+00
Rtý+Rsý ............................     0.31725E+00


FLANGE SEPARATION EVALUATION
--------------------------------------------------
BOLT CLAMPING FORCE ................    -0.19842E+05
DISPLACEMENT ACROSS BOLT ...........    -0.16326E-02
ALLOWABLE FLANGE SEPARATION ........     0.30000E-02
FLANGE FRICTION FORCE ..............    -0.17858E+05
TOTAL BOLT SHEAR FORCE .............     0.49494E+04
```

4.5.3.2.3.8 Output, Hypothetical Accident Conditions of Transport, 30-Ft. Cg/Corner Drop, -40°C (-40°F) Ambient – Model AOS-100

```
30-FT DROP - @ 45 DEG CORNER AOS-100, -40F AMBIENT



*************** INPUT DATA ****************

NUMBER OF BOLTS .....................(NB)             14
LID DIAMETER AT BOLT CIRCLE .........(DLB)  0.14064E+02
LID DIAMETER AT GASKET  .............(DLG)  0.12172E+02
NOMINAL BOLT DIAMETER ................(DB)  0.87500E+00
LID DIAMETER AT INNER EDGE ..........(DLI)  0.11040E+02
LID DIAMETER AT OUTER EDGE ..........(DLO)  0.16590E+02
THICKNESS OF LID .....................(TL)  0.15100E+01
THICKNESS OF LID FLANGE .............(TLF)  0.19400E+01
THICKNESS OF CASK WALL ...............(TC)  0.28050E+01
BOLT LENGTH ..........................(BL)  0.10600E+01
BOLT MOMENT OF INERTIA / CIR ........(XIB)  0.29000E-01

YOUNG'S MODULUS FOR LID ..............(EL)  0.28300E+08
YOUNG'S MODULUS FOR LID FLANGE ......(ELF)  0.28300E+08
YOUNG'S MODULUS FOR CASK .............(EC)  0.28300E+08
YOUNG'S MODULUS FOR BOLT .............(EB)  0.28900E+08
POISSON'S RATIO FOR LID ............(XNUL)  0.30000E+00
POISSON'S RATIO FOR CASK ...........(XNUC)  0.30000E+00
LID THERMAL EXPANSION COEFF ..........(AL)  0.86000E-05
BOLT THERMAL EXPANSION COEFF .........(AB)  0.70000E-05
WALL THERMAL EXPANSION COEFF .........(AC)  0.86000E-05
FLANGE COEFFICIENT OF FRICTION ......(FCF)  0.90000E+00

INSIDE PRESSURE AT LID ..............(PLI)  0.28000E+03
OUTSIDE PRESSURE AT LID .............(PLO)  0.15000E+02
INSIDE PRESSURE AT CASK WALL ........(PCI)  0.28000E+03
OUTSIDE PRESSURE AT CASK WALL .......(PCO)  0.15000E+02

TEMPERATURE CHG ACROSS LID ........(TEMPL)  0.15000E+02
TEMPERATURE CHG ACROSS BOLT .......(TEMPB)  0.15000E+02
TEMPERATURE CHG ACROSS WALL .......(TEMPC)  0.15000E+02
TEMPERATURE AT OUTSIDE OF LID ....(TEMPLO)  0.16000E+02
TEMPERATURE AT INSIDE OF LID .....(TEMPLI)  0.16000E+02

WEIGHT OF CASK CONTENTS ..............(WC)  0.78600E+03
WEIGHT OF CASK LID ...................(WL)  0.96000E+02
DROP ANGLE OF IMPACT, deg .......(XI_DROP)  0.45000E+02
CG/CORNER IMPACT ACCEL, g ..........(ACCI)  0.12400E+03
DYNAMIC LOAD FACTOR ................(DYLF)  0.11500E+01

PUNCTURE LOAD ......................(PUNC)  0.00000E+00
PUNCTURE ANGLE OF IMPACT, deg ...(XI_PUNC)  0.45000E+02
```

```
AXIAL VIBRATION ACCELERATION ........(AVA) 0.00000E+00
TRANSVERSE VIBRATION ACCELERATION ...(AVT) 0.00000E+00
VIBRATION TRANSMISSIBILITY FACTOR ...(VTR) 0.10000E+01

PRELOAD TORQUE ........................(Q) 0.60000E+04
NUT FACTOR FOR PRELOAD TORQUE ........(QK) 0.15000E+00
GASKET SEATING WIDTH .................(GB) 0.10000E+01
GASKET SEATING STRESS ................(GY) 0.30000E+04
GASKET FACTOR ........................(GM) 0.54000E+00

Sm STRESS ............................(SM) 0.10000E+03
Sy STRESS ............................(SY) 0.15000E+03
Su STRESS ............................(SU) 0.18500E+03
CODE EVALUATION TYPE.................(CET)           2

OPERATING FATGIGUE STRESS (ksi) .....(FSO) 0.15000E+03
VIBRATION FATIGUE STRESS (ksi) ......(FSV) 0.13000E+02
NUMBER OF BOLT THREADS / INCH .......(NTI)           9


******** BOLT LOADS & STRESSES *********


BOLT FORCES DUE TO PRESSURE, TABLE 4.3
---------------------------------------------------
AXIAL LOAD DUE TO PRESSURE..........   0.22026E+04
SHEAR LOAD DUE TO PRESSURE..........   0.45227E+04
EDGE LOAD DUE TO PRESSURE...........   0.93174E+03
EDGE MOMENT DUE TO PRESSURE.........   0.16380E+04


BOLT FORCES DUE TO TEMPERATURE, TABLE 4.4
---------------------------------------------------
AXIAL LOAD DUE TO TEMPERATURE.......   0.41708E+03
SHEAR LOAD DUE TO TEMPERATURE.......   0.00000E+00
EDGE LOAD DUE TO TEMPERATURE........   0.00000E+00
EDGE MOMENT DUE TEMPERATURE.........   0.00000E+00


BOLT FORCES DUE TO IMPACT, TABLE 4.5
---------------------------------------------------
AXIAL LOAD DUE TO IMPACT............   0.85124E+04
SHEAR LOAD DUE TO IMPACT............   0.60124E+03
EDGE LOAD DUE TO IMPACT.............   0.26972E+04
EDGE MOMENT DUE IMPACT..............   0.47417E+04
```

```
BOLT FORCES DUE TO PUNCTURE, TABLE 4.7
-----------------------------------------------------
AXIAL LOAD DUE TO PUNCTURE..........     0.00000E+00
SHEAR LOAD DUE TO PUNCTURE..........     0.00000E+00
EDGE LOAD DUE TO PUNCTURE...........     0.00000E+00
EDGE MOMENT DUE PUNCTURE............     0.00000E+00


BOLT FORCES DUE TO VIBRATION, TABLE 4.8
-----------------------------------------------------
AXIAL LOAD DUE TO VIBRATION.........     0.00000E+00
SHEAR LOAD DUE TO VIBRATION.........     0.00000E+00
EDGE LOAD DUE TO VIBRATION..........     0.00000E+00
EDGE MOMENT DUE VIBRATION...........     0.00000E+00


BOLT FORCES DUE TO PRELOAD, TABLE 4.1, 4.2
-----------------------------------------------------
AXIAL LOAD DUE TO PRELOAD...........     0.45714E+05
AXIAL LOAD DUE TO GASKET SEATING....     0.81942E+04
AXIAL LOAD DUE TO GASKET OPERATION..     0.78172E+03
TORQUE DUE TO PRELOAD...............     0.30000E+04
TORQUE DUE TO GASKET ...............     0.53774E+03


TOTAL NON-PRYING BOLT FORCES, TABLE 4.9
-----------------------------------------------------
TOTAL NON-PRYING AXIAL LOAD.........     0.57628E+05
TEMP & PRELOAD NON-PRYING AXIAL LD..     0.46131E+05
AXIAL LOAD LESS TEMP & PRELOAD......     0.11497E+05
TOTAL EDGE LOAD.....................     0.36290E+04
TOTAL EDGE MOMENT...................     0.63797E+04


PRYING ACTION FORCES, TABLE 2.1 & 2.2
-----------------------------------------------------
AXIAL LOAD DUE TO PRYING............    -0.14241E+05
BENDING MOMENT DUE TO PRYING........     0.24082E+04


TOTAL BOLT FORCES
-----------------------------------------------------
TOTAL BOLT AXIAL LOAD...............     0.31890E+05
TOTAL BOLT SHEAR LOAD...............     0.51240E+04
TOTAL BOLT BENDING MOMENT...........     0.87880E+04
TOTAL BOLT TORSIONAL MOMENT.........     0.30000E+04
```

```
TOTAL BOLT STRESSES
---------------------------------------------------
TOTAL BOLT DIRECT STRESS (+MC/I) ...     0.26765E+06
TOTAL BOLT DIRECT STRESS (-MC/I) ...    -0.12951E+06
AVE BOLT DIRECT STRESS .............     0.69066E+05
TOTAL BOLT SHEAR STRESS ............     0.33895E+05
AVE BOLT SHEAR STRESS ..............     0.16948E+05


CODE EVALUAT. FOR ACCIDENT COND, TABLE 6.3
---------------------------------------------------
ALLOWABLE TENSILE STRESS (Sa) ......     0.12950E+06
ALLOWABLE SHEAR STRESS (Ta) ........     0.77700E+05
Rt (AVE AXIAL STRESS/Sa) ...........     0.53333E+00
Rs (AVE SHEAR_STRESS/Ta) ...........     0.21812E+00
Rtý+Rsý ............................     0.33201E+00


FLANGE SEPARATION EVALUATION
---------------------------------------------------
BOLT CLAMPING FORCE ................    -0.20393E+05
DISPLACEMENT ACROSS BOLT ...........    -0.16200E-02
ALLOWABLE FLANGE SEPARATION ........     0.30000E-02
FLANGE FRICTION FORCE ..............    -0.18354E+05
TOTAL BOLT SHEAR FORCE .............     0.51240E+04
```

4.6 REFERENCES

[4.1] U.S. Nuclear Regulatory Commission (NRC), *Title 10, Code of Federal Regulations, Part 71 (10 CFR 71)*, "Packaging and Transportation of Radioactive Material."

[4.2] U.S. Department of Transportation (DOT), *Title 49, Code of Federal Regulations, Part 173 (49 CFR 173)*, "Shippers – General Requirements for Shipments and Packagings."

[4.3] *International Atomic Energy Agency (IAEA) Safety Standards Series No. TS-R-1* (*IAEA TS-R-1*), "Regulations for the Safe Transport of Radioactive Material," 1996 Ed. (as amended 2003).

[4.4] American National Standards Institute, *ANSI N14.5-1997*, "Radioactive Materials – Leakage Tests on Packages for Shipment," February 5, 1998.

[4.5] American Society of Mechanical Engineers, *ASME Boiler and Pressure Vessel Code*, Section III, Division 3, 2004, No Addenda.

[4.6] Mok, G. C., L. E. Fischer, and S. T. Hsu, *NUREG/CR-6007, Stress Analysis of Closure Bolts for Shipping Casks*, Lawrence Livermore National Laboratory and Kaiser Engineering, Prepared for U.S. Nuclear Regulatory Commission, April, 1992.

[4.7] *Machinery's Handbook*, "Fasteners" Section, Industrial Press, 26th Ed., 1988.

[4.8] Alcoa Fastening Systems, *Keenserts Inserts and Studs*, Technical Information and Product Data Sheets, November 9, 2006, accessed July 3, 2011, http://alcoafastener.thomasnet.com/item/keenserts-reg-inserts-general-purpose-inserts/heavy-duty-insert/knh1409j?&plpver=10&origin=keyword&by=prod&filter=0.

5 SHIELDING EVALUATION

This chapter identifies, describes, discusses, and analyzes the principal radiation shielding design of the AOS cask, which is important to safety.

5.1 DESCRIPTION OF SHIELDING DESIGN

5.1.1 Design Features

The cask is a cylindrical container, with a cylindrical cavity in which radioactive materials are placed. Tungsten alloy or carbon steel shields for radiation attenuation are located on the top, bottom, and sides of the cavity. Figure 5-1 illustrates the main cask components.

Cask components important to shielding, including the radiation shields and cask cavity, are discussed in this subsection. For all shielding evaluations, the impact limiter is ignored. Other transport package design features, such as the shipping cage, securing lines, and internal structure, are irrelevant from a shielding standpoint and are also not considered. The absence of these components in the shielding model provides a more-conservative dose rate estimate. From a dose rate-point location, however, the shipping cages are important, because they move the normal shipping configuration-accessible surface away from the cask surface. This distance is included in the dose rate point location selection; however, the materials occupying the shipping cage space are treated as air.

Tests applied to the packaging and its contents, under Normal Accident conditions of transport (NCT) and Hypothetical Accident conditions (HAC) of transport, demonstrated that the cask components modeled can maintain their structural integrity for all considered events. This allowed a single geometric model to be developed for each cask size being considered.

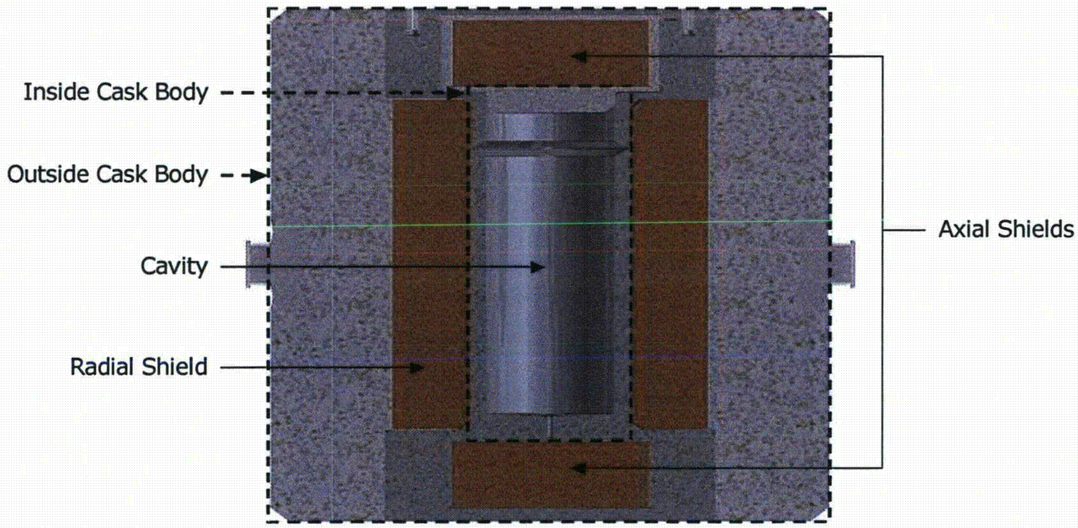

Figure 5-1. Cross-Sectional View of Cask Components

Table 5-1 lists the outside radius and half-height of each model's cask components. The half-height is the distance from the center of the cask to the top of the component, as illustrated in Figure 5-2. For example, the actual cavity height of the Model AOS-100 is 50.80 cm (20.00 in.), and the height of its axial shield is 11.12 cm (4.38 in.). This is calculated using Equation 5-1.

$$h_{axial\_shield} = HalfHeight_{axial\_shield} - HalfHeight_{inner\_cask\_body} \quad (5\text{-}1)$$

Table 5-1. Cask Component Dimensions, Outside Radius and Half-Height – All Models

Model	Component	Outside Radius		Half-Height[a]	
		cm	in.	cm	in.
AOS-025	Cavity	2.06	0.81	6.35	2.50
	Inside Cask Body	2.59	1.02	7.41	2.92
	Radial Shield	5.03	1.98	6.90	2.72
	Axial Shield	3.15	1.24	10.19	4.01
	Outside Cask Body	8.89	3.50	11.43	4.50
AOS-050	Cavity	4.12	1.62	12.70	5.00
	Inside Cask Body	5.18	2.04	14.82	5.83
	Radial Shield	10.06	3.96	13.80	5.43
	Axial Shield	6.30	2.48	20.38	8.02
	Outside Cask Body	17.78	7.00	22.86	9.00
AOS-100	Cavity	8.25	3.25	25.40	10.00
	Inside Cask Body	10.36	4.08	29.64	11.67
	Radial Shield	20.12	7.92	27.59	10.86
	Axial Shield	12.60	4.96	40.76	16.05
	Outside Cask Body	35.56	14.00	45.72	18.00

a. Axial distance from cask centerline.

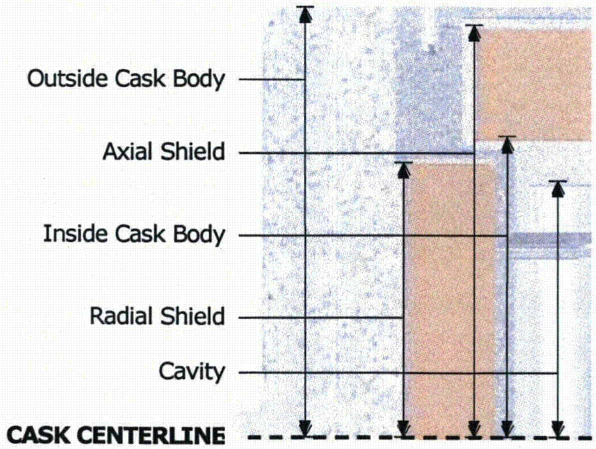

Figure 5-2. Cask Component Half-Height – All Models

Table 5-2 lists the cavity height and axial shield thickness for each AOS Transport Packaging System model.

Table 5-3 lists the materials for each cask component that is important to shielding. Tungsten alloy is used as the shielding material in casks whose model numbers include the suffix A. Carbon steel is used as the shielding material in casks whose model numbers include the suffix B. Therefore, the only difference between the Model AOS-100A and AOS-100B transport packages is the shielding material.

Table 5-2. Cask Component Dimensions, Cavity Height and Axial Shield Thickness – All Models

		Dimensions	
Model	**Component**	**cm**	**in.**
AOS-025A	Cavity Height	12.70	5.00
	Axial Shield Thickness	2.78	1.09
AOS-050A	Cavity Height	25.40	10.00
	Axial Shield Thickness	5.56	2.19
AOS-100A AOS-100B AOS-100A-S	Cavity Height	50.80	20.00
	Axial Shield Thickness	11.12	4.38

Table 5-3. Cask Component Materials Important to Shielding – All Models

		Model Type		Material Composition		
Component	**Material**	**AOS-025A AOS-050A AOS-100A**	**AOS-100B**	**Element**	**Weight Fraction**	**Density (g/cm^3)**
Cavity	Air	✔	✔	Nitrogen	0.7454	1.29E-03
				Oxygen	0.2284	
				Argon	0.0261	
Shield	Tungsten	✔		Tungsten	1.0000	17.8
	Carbon Steel		✔	Carbon	0.0100	7.8212
				Iron	0.9900	
Cask	Stainless Steel	✔	✔	Iron	0.7200	7.8
				Manganese	0.0200	
				Chromium	0.1800	
				Nickel	0.0800	

5.1.2 Summary Table of Maximum Radiation Levels

Table 5-4 and Table 5-5 list the maximum dose rates for both Normal and Hypothetical Accident conditions of transport, at the appropriate locations for non-exclusive or exclusive use (or both), as applicable. A conservative 10% reduction in allowable *10 CFR 71.47 (a)* (Reference **[5.1]**) limits is applied for maximum radiation levels.

Table 5-4. Maximum Radiation Level Summary for Normal Conditions of Transport – All Models

Normal Conditions of Transport	External Surface[a] (mRem/hr)		1m from External Surface[a] (mRem/hr)	
Radiation	Axial	Radial	Axial	Radial
Gamma	180	180	9	9
Neutron	0	0	0	0
Total	180	180	9	9
10 CFR 71.47(a) Limit **[5.1]**	200	200	10[b]	10[b]

a. *For this analysis, the external surface is considered to be the deformed impact limiter surface.*

b. *Transport index may not exceed 10.*

Table 5-5. Maximum Radiation Level Summary for Hypothetical Accident Conditions of Transport – All Models

Hypothetical Accident Conditions of Transport	1m from External Surface[a] (mRem/hr)	
Radiation	Axial	Radial
Gamma	14.25	11.80
Neutron	0	0
Total	14.25	11.80
10 CFR 71.51(a)(2) Limit **[5.1]**	1,000	1,000

a. *For this analysis, the external surface is considered to be the cask surface.*

5.2 SOURCE SPECIFICATION

Table 5-6 lists the activation products to be loaded in the AOS transport package, for each transport package model.

Because of the penetration power of neutral radiation, such as gamma rays, these were the main concern for shielding calculations. Charged particles, such as alpha and beta particles, are not able to penetrate the cask's thick shield layers, and the assumption was made to ignore these charged particles and their secondary particles (such as bremsstrahlung photons induced by beta particles) for shielding evaluations.

Table 5-6. Isotopes Analyzed for AOS Transport Packages – All Models

Isotope	Model		
	AOS-025	AOS-050	AOS-100
Co-60	✔	✔	✔
Cs-137	✔	✔	✔
Hf-181		✔	✔
Ir-192	✔	✔	✔
Zr/Nb-95		✔	✔
Ho-166	✔	✔	
Yb-169	✔	✔	

5.2.1 Gamma Source

The source description for activation products is obtained from isotope decay schemes that detail the gamma particle energies and their absolute probabilities of emission per disintegration (decay). For all of those isotopes except Ir-192 and Zr/Nb-95, these decay schemes are explicitly modeled in the cask, based upon discrete gamma energy and emission probability source terms extracted from the ORIGEN-ARP [5.2] gamma spectrum library. All available gamma energies from the library are considered in the shielding calculations. Total photon/decay values are also calculated and used, based upon the information contained in the ORIGEN-ARP library, by summing the total absolute probability of emission, per decay, from all possible energies for a given isotope.

Ir-192 is an exception to the above methodology, because the ORIGEN-ARP-defined source term for Ir-192 was found to be missing several high-energy gamma rays when compared to those values listed in the Table of Nuclides [5.3]. For this reason, the more conservative spectrum resulting from the use of all the energies available in the Table of Nuclides from the decay of Ir-192, into either Os-192 or Pt-192, is used to calculate the limiting dose rates for Ir-192 in the cask. The total photons/decay value is calculated based on the sum of the total absolute probability of emission per decay from all energies listed in the Table of Nuclides.

The gamma source assumed for mixtures of Zr/Nb-95 is also developed differently than the other isotopes in this evaluation. This is the case because the curie limit provided in Table 1-2, "Activity Limits – All Models," for mixtures of Zr/Nb-95 applies only to the total quantity of curies of Zr-95 inside the cask. The only source of Nb-95 in a shipment must be from a decay of Zr-95. Because this is the case, the maximum amount of Nb-95 relative to Zr-95 occurs when the isotopes are in equilibrium. By assuming Nb-95 exists in equilibrium with Zr-95 in any shipment, the total system activity is maximized. The activity ratio of the parent and daughter, at equilibrium, is determined using Equation 5-2.

$$\frac{A_{Nb}}{A_{Zr}} = \frac{\lambda_{Nb}}{\lambda_{Nb} - \lambda_{Zr}} = 2.20 \qquad (5\text{-}2)$$

where:

A_{Nb}	=	Activity of Nb (daughter)
A_{Zr}	=	Activity of Zr (parent)
λ_{Nb}	=	Nb decay constant
λ_{Zr}	=	Zr decay constant

Thus, a maximum of 2.2 decays from Nb-95 occur for every one decay from Zr-95. Equation 5-2 is confirmed using basic Bateman equations. For conservatism, the total number of decays per Becquerel of Zr-95 is assumed to be the total from both Nb-95 and Zr-95. This is equivalent to 3.2 photons per Becquerel of Zr-95. The fact that the dominant decay energies from both isotopes are very close allows for the use of a single, bounding decay energy of 0.766 MeV to be assumed for the isotope mixture.

Table 5-17 and Table 5-18 in Appendix 5.5.2 list the source spectra used in the shielding models.

The dose rate analysis is performed only on gamma-ray shielding, by neglecting the transport of charged particles. Because charged particles do not have the same penetrating abilities as neutral particles, their energy losses are assumed to be deposited in the shielding material, in the form of heat. The production and transport of secondary particles from charged particles (such as bremsstrahlung photons generated by beta particles in the shielding materials) is also neglected. This assumption is valid if the energies and/or emission probabilities of secondary particles are negligible, compared to those of primary gamma rays. For those isotopes with zero (0) or very low gamma-ray emission probabilities, their limits are calculated based upon heat loads only.

5.2.2 Neutron Source

Not applicable. Neutron-emitting materials are not authorized for this transport package design.

5.3 SHIELDING MODEL

5.3.1 Configuration of Source and Shielding

An explicit 3D model of the cask, representative of the dimensions tabulated in Table 5-1 and Table 5-2, was developed using the particle transport code *Monte Carlo N-Particle (MCNP).* The use of these nominal dimensions, to define the shield model, is consistent with standard engineering practices. The increase in possible dose rates, due to the very small tolerances on these dimensions, is bounded by the conservative 10% reduction in allowable dose limits described in Subsection 5.1.2. The impact limiter, shipping cage, and any internal or external components were modeled as air, for conservatism. A sketch of the cask components modeled is provided in Figure 5-1. Tests applied to the packaging and their contents, under Normal and Hypothetical Accident conditions of transport, demonstrated that the cask components modeled maintained their structural integrity for all considered events. This allowed a single geometric model to be developed for each cask size that is being considered.

All isotopes are modeled as point sources, located at the center of the cavity's top edge for axial cases (Z-axis, in positive direction), and at the center of the cavity's radial edge for radial cases (Y-axis, in positive direction) for Normal and Hypothetical Accident conditions of transport. This is a more conservative approach than modeling a point source at the center of the cask, or explicitly modeling the internal source geometry and other internal structural components. Point sources do not account for the self-shielding effects due to the actual source geometry and density, nor for the shielding due to internal components, such as source racks. By placing the point sources directly against the cask cavity wall, the most likely source displacements are modeled in an appropriately conservative way. This choice is further justified by noting that an actual radioactive load in the container would be distributed over significantly more volume than a point source, even in Hypothetical Accident conditions of transport and, therefore, only a small fraction of source radiation would directly penetrate through the shield depletions. Practically, any maximum dose rate from streaming or localized source concentrations will be detected during the mandatory radiation surveys on loaded transport packages, before shipment. Therefore, the point source model provides assurance that the dose rate, at locations fairly close to the source, is over-estimated. Because the dose rate obtained from the point source model meets regulatory requirements, the transport packages meet regulatory requirements in their as-shipped configuration.

All dose point locations are modeled as point detectors located on the cask's positive Y-axis for radial cases, and the cask's positive Z-axis for axial cases. These dose point locations are selected to allow for the minimum amount of shielding material and distance between the source point and point detector. The use of point geometries at these locations provides for conservative estimates of dose rates from the radioactive sources being transported. Due to this appropriate conservatism, no reduction in nominal shield thickness was made for voids, streaming paths, nor irregular geometries.

The selection of dose point locations is based upon the deformed surface of the impact limiter, which is considered as the external package surface under Normal conditions of transport. The crushed and deformed surface of the impact limiter creates the closest accessible area during transit and, therefore, is used to calculate the dose rate from radioactive contents under Normal conditions of transport. The maximum deformations in the impact limiter surfaces resulting from an End Drop (axial direction) or Side Drop (radial direction) consistent with Normal conditions of transport are provided in Chapter 2 , "Structural Evaluation," for all AOS transport package models. The external surface deformations used in dose calculations, as provided in Table 5-7 and Table 5-8, conservatively bound the maximum end and side deformations.

Table 5-9 and Table 5-10 define the distances from the center of the cask to the dose point locations that are used to evaluate the radiation levels on the external surfaces, and 1m from the cask and from the external surface.

Table 5-7. External Surface Deformation Used for Dose Calculation in Axial Direction – End Drop

Model	Impact Limiter Half-Height		Impact Limiter End Drop Deformation		Deformed Impact Limiter Half-Height	
	cm	in.	cm	in.	cm	in.
AOS-025	20.65	8.13	1.84	0.72	18.81	7.41
AOS-050	40.08	15.78	3.81	1.50	36.27	14.28
AOS-100	80.19	31.57	8.61	3.39	71.58	28.18

Table 5-8. External Surface Deformation Used for Dose Calculation in Radial Direction – Side Drop

Model	Impact Limiter Radius		Impact Limiter Side Drop Deformation		Deformed Impact Limiter Radius	
	cm	in.	cm	in.	cm	in.
AOS-025	14.43	5.68	1.03	0.40	13.40	5.28
AOS-050	28.85	11.36	3.30	1.30	25.55	10.06
AOS-100	57.71	22.72	5.08	2.00	52.63	20.72

Table 5-9. Distances from Center of Cask Used for Dose Calculations – Axial Case

Model	External Surface[a]		1m from Cask Surface		1m from External Surface[a]	
	cm	in.	cm	in.	cm	in.
AOS-025	18.81	7.41	111.43	43.87	118.81	46.78
AOS-050	36.27	14.28	122.86	48.37	136.27	53.65
AOS-100	71.58	28.18	145.72	57.37	171.58	67.55

a. *For this analysis, the external surface is considered to be deformed.*

Table 5-10. Distances from Center of Cask Used for Dose Calculations – Radial Case

Model	External Surface[a]		1m from Cask Surface		1m from External Surface[a]	
	cm	in.	cm	in.	cm	in.
AOS-025	13.40	5.28	108.89	42.87	113.40	44.65
AOS-050	25.55	10.06	117.78	46.37	125.55	49.43
AOS-100	52.63	20.72	135.56	53.37	152.63	60.09

a. *For this analysis, the external surface is considered to be deformed.*

The model for the axial dose calculation assumes that the notch at the end of the impact limiter is not accessible during Normal conditions of transport. This assumption is based upon the fact that the shipping cage on top and pallet on bottom will be pushed against the notch on the impact limiter in the case of an End Drop. In addition, a hat will be put on the top of the Model AOS-050 and AOS-100 shipping cage, which forms a physical barrier that further prevents the notch on the impact limiter from being accessible.

Radiation levels at the deformed external surface resulting from a center of gravity over corner drop (Cg/ Corner) were not evaluated in this analysis. In the case of a Cg/Corner drop, the distance from the external surface at the deformed corner to the source is greater than those in the cases of End and Side Drops. The dose rates will be lower, because the attenuation of source gamma rays is larger over a longer transmission path from the source to the external surface at the corner.

5.3.2 Material Properties

Material compositions and densities used in the AOS casks are provided in Table 5-3. All the material compositions are modeled in the shielding evaluation, as prescribed in Table 5-3, with the exception of tungsten. The tungsten alloy is modeled as pure tungsten, with a density lower than the actual density of the tungsten alloy used in the construction of the casks.

5.4 SHIELDING EVALUATION

5.4.1 Methods

MCNP (version 5) **[5.4]**, a general-purpose Monte Carlo N-Particle transport code developed by Los Alamos National Laboratory, is used to calculate the dose rates of the AOS cask. The code has the capability of simulating neutron, photon, electron, or coupled neutron/photon/electron transport, in an arbitrary 3D geometric configuration of materials.

MCNP for photon transport uses continuous-energy atomic data libraries (ENDF/B-VI) for all elements from Z = 1 through Z = 100. The data in the photon interaction tables allow MCNP to account for coherent and incoherent scattering, photoelectric absorption with the possibility of fluorescent emission, and pair production. Scattering angular distributions are modified by atomic form factors and incoherent scattering functions.

Important standard features that make MCNP versatile and easy to use for photon transport include a powerful general source, both geometry and output tally plotters, a rich collection of variance reduction techniques for heavy shielding problems, a flexible tally structure, and an extensive collection of cross-section data.

Use of the Monte Carlo transport method for the dose rate calculation in heavy shielding systems requires application of variance reduction techniques to obtain precise solutions in a timely manner. Correct implementation of variance reduction techniques yields the same solution with a similar statistical variance as an analog Monte Carlo simulation, but in a shorter amount of computer time.

The primary variance reduction techniques used in the MCNP modeling of AOS casks are:

- (1) Mesh-Based Weight Windows
- (2) Source Biasing
- (3) Exponential Transform
- (4) Point Detector

Each is described in the text that follows.

(1) Mesh-Based Weight Windows

Mesh-based weight window is one of particle population control methods available in MCNP. This method helps keep the particle weight dispersion within reasonable bounds throughout the problem, by using particle splitting and Russian roulette to control the quantity of particles taken in various regions of phase space. The mesh weight window generator makes it possible to generate an importance function, with respect to both an energy grid and/or a spatial grid that overlays the problem geometry. Particle splitting and Russian roulette can then be played as a function of both particle position and energy.

A cylindrical or rectangular mesh is defined with various spatial resolutions in different regions, depending upon the detector (Z-axis for axial dose calculation, and Y-axis for radial dose calculation) and the shielding material and location (particularly those regions between the detector and source). The mesh-based importance function is generated in a single energy bin. To enhance the weight window generator's performance, the exponential transform and/or source biasing are used. In addition, the density reduction technique is applied, to produce an initial importance function. Use of the initial importance function, with the shield density reset to its natural value, the importance function is sufficiently improved through several iterations with reasonable FOM (Figure of Merit, a measure of how quickly the desired precision is achieved).

Because the dose rates are needed outside radial and axial cask surfaces, implementation of mesh-based weight windows requires the separation of each transport package model into two (2) cases – axial and radial. Doing so simplifies the mesh structure, for both weight window generation and usage.

Figure 5-3 illustrates a sample model showing weight window mesh structure for axial and radial shielding cases.

The density reduction technique is used to improve the mesh-based weight window generation. This technique can generate initial weight windows at reduced densities of shielding materials. With the density reset to its natural value, the subsequent-generation weight windows are sufficiently improved through several iterations.

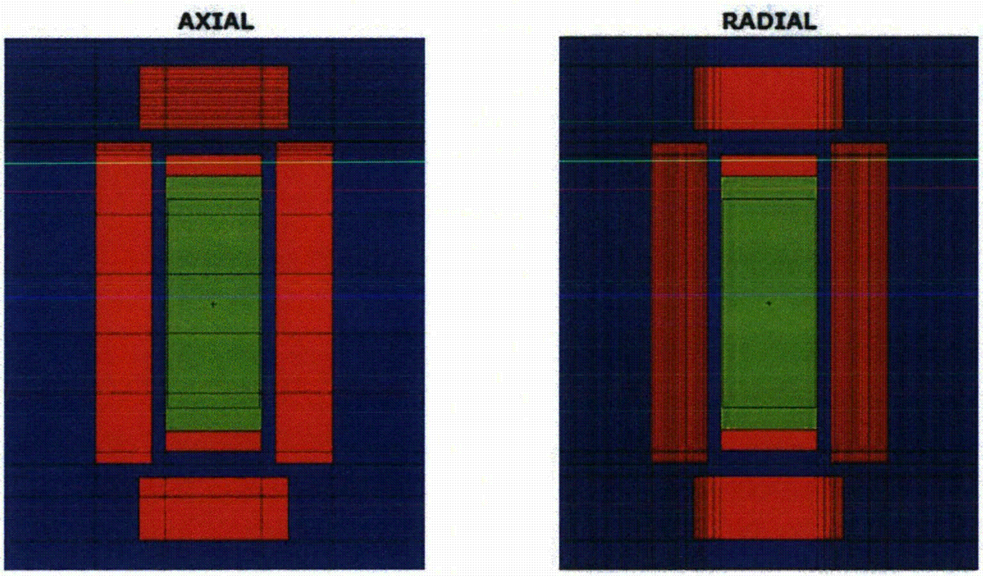

Figure 5-3. Weight Window Mesh of Axial and Radial Shielding Cases

(2) Source Biasing

Source biasing is one of modified sampling methods that alter the statistical sampling of a problem, to increase the quantity of tallies per particle. Both source direction biasing and energy biasing are applied in the modeling.

Source direction biasing involves changing the source's emission angle. In radioactive decay, particles are emitted isotropically (that is, the probability of emission for all angles is the same). To make more source particles emit toward a more-desired direction for higher tally efficiency, an exponential biasing function is applied.

Source energy biasing involves changing the source's emission energy. For some isotopes, their emission spectra have very low mean energies. It becomes extremely difficult to obtain any answer for low-energy photon transmission in a heavy shielding system. The source energy biasing used in the modeling favors the emission of source particles with higher energies.

(3) Exponential Transform

Exponential transform is also one of modified sampling methods. It transports particles a longer distance between collisions, in a preferred direction. In the modeling, this method is used to allow particles more likely to enter a region containing dose point locations.

(4) Point Detector

Point detector is one of partially deterministic methods that circumvent the normal random walk process, by using deterministic-like techniques. This method forces fluence contributions to be made from collision sites removed from the detector, thus greatly improving scoring efficiency. In the modeling, multiple point detectors are placed on the cylindrical and polar axes of the cask, including the locations of the external surface, 1m from the cask surface, and 1m from the external surface, for both axial and radial shielding cases, as provided in Table 5-9.

5.4.2 Input and Output Data

5.4.2.1 Input Data

The MCNP input data includes:

- Cask's geometry and material description
- Source definition
- Variance reduction (mesh-based weight window, source biasing, exponential transform, and point detector)
- Flux-to-dose conversion factors
- Point detector tallies

The mesh structure parameters for weight window generation and usage are defined by the MESH card in the input, which divides the transport package into coarse and fine subsections. The importance values for subsections are calculated by the weight window generator. These importance values are problem-dependent (that is, they vary with system geometry and materials, as well as source characteristics, and most importantly the location of the dose rate points). Figure 5-3 illustrates the difference in mesh structure between the axial and radial cases, for the same transport package model.

An exponentially biasing function is used for source emission direction biasing. For both axial and radial cases, approximately 50% of all source particles are emitted in the desired axial and radial direction, within a cone angle of 96°.

An MCNP input example for the calculation of Model AOS-100A radial dose from Co-60 is provided in Appendix 5.5.3.1.

5.4.2.2 Output Data

The key MCNP output data includes dose rates per starting source photon (Rem/hour-photon) at specified locations and their relative errors. The relative error forms confidence intervals about the calculated dose rate. For point detector tallies, a relative error less than 5% is required to produce generally reliable confidence intervals.

An MCNP output example for the calculation of Model AOS-100A radial dose from Co-60 is provided in Appendix 5.5.3.2.

5.4.3 Flux-to-Dose-Rate Conversion

The dose rate is determined by using flux-to-dose-rate conversion factors, which convert the point detector flux (particles/cm^2) to the dose rate (Rem/hr). Conversion factors from *ANSI/ANS-6.1.1 1977* provided in Appendix H of Reference **[5.4]** are used to obtain the gamma-ray dose rate. The conversion is implemented in MCNP by dose rate energy and dose rate function cards **[5.4]**. The calculated dose rates are normalized values per starting source particle.

The point detectors are used to obtain the particle flux at the dose calculation points. The point detector units are in particles per square centimeter. In this analysis, gamma rays are the particles of interest. This can then be used to calculate the limiting curie content that maintains all dose rate values below the regulated values, at all surfaces.

5.4.4 External Radiation Levels

The bounding limit for an isotope is found by determining the curie level that, if any greater, would just exceed the regulatory limits at any one of the detection points. To add conservatism to this process, a margin was added to the final dose rate limits. The process was as follows – all final values were calculated for only 90% of the regulatory dose rate limits:

- 200 mRem/hr limit at the external surface became a 180 mRem/hr limit
- 1m from the external surface for Normal conditions of transport limit became a 9 mRem/hr limit
- 1m from the cask surface for Hypothetical Accident conditions of transport limit became a 900 mRem/hr limit

This conservative methodology provides additional margin, to ensure that the cask contents do not exceed the regulatory dose rate limits.

The maximum allowable curie level for each isotope is calculated using Equations 5-3, 5-4, and 5-5. First, the MCNP output [$Tally_{out}$] for each isotope and dose rate location is converted to units of mRem/hr-Ci, using Equation 5-3.

$$\frac{Dose[mREM]}{[hour-Ci]} = \frac{Tally_{out}[REM]}{[hour-photon]} * \frac{1000[mREM]}{[REM]} * \frac{[photons]}{[Bq]} * \frac{3.7E10[Bq]}{[Ci]} \quad (5\text{-}3)$$

Additional conservatism is applied by adding two times of relative error (2σ) to this term, as is done in Equation 5-4.

$$\frac{Dose_{+2sig}[mREM]}{[hour-Ci]} = \frac{Dose\ [mREM]}{[hour-Ci]} + \frac{Dose\ [mREM]}{[hour-Ci]} * 2\sigma \quad (5\text{-}4)$$

The maximum source strength that will meet the regulatory dose rate limit at the location being analyzed is then calculated using Equation 5-5.

$$Source_{Max}[Ci] = \frac{0.9 * Dose_{LIMIT}[mREM / hour]}{Dose_{+2sig}[mREM / hour - Ci]} \quad (5\text{-}5)$$

The maximum curie content of each isotope, at each dose rate location, is solved for, using this approach. Results are then tabulated, and the minimum of the source values obtained is reported as the maximum source strength viable for shipment based on dose rate limits. The dose rates based upon these source values for locations of interest are reported in Table 5-11 through Table 5-14.

A single model (identical geometry and source specifications) is used for both Normal and Hypothetical Accident conditions of transport simulations. The dose rates reported are applicable to both scenarios.

The following dose rate limits are met for all isotopes, in compliance with *10 CFR 71.47(a)* and *71.51(a)(2)* **[5.1]** (Normal and Hypothetical Accident conditions of transport, respectively):

- A surface limit of 200 mRem/hr (2mSv/h) on the outside surface of the shipping cage, to comply with Normal conditions of transport limits
- A limit of 1,000 mRem/hr (10 mSv/h) at 1m from the cask surface, to comply with Hypothetical Accident conditions of transport limits
- A limit of 10 mRem/hr at 1m from the shipping cage, to comply with Normal conditions of transport limits

For the activity limits of all isotopes, refer to Table 1-2, "Activity Limits – All Models."

Shipment Transportation Index (TI) can be calculated by using the highest dose (either radial or axial) at 1m from the shipping cage, for each isotope and transport package combination, to define a conservative transport index. These numbers are defined in Table 5-11 through Table 5-14. The dose rates reported result in a single package always having a TI less than 10, allowing for non-exclusive shipment of a single cask. If multiple casks are shipped together, their respective TI values must be summed, to determine whether their shipment must be for exclusive or non-exclusive use.

Table 5-11. Maximum Radiation Levels – Model AOS-025A

Isotope	Source Strength (Ci)	Photon/Bq	Location	Radial Dose Rate (mRem/hr)	Axial Dose Rate (mRem/hr)	Limit (mRem/hr)	Comments
Co-60	1.23E-01	2	External Surface	180.00	111.39	200	Tungsten thickness of 2.15 cm axially and 1.397 cm radially inside cavity
			1m from Cask Surface	2.18	2.06	1,000	
			1m from External Surface	2.01	1.80	10	
Cs-137	1.06E+01	0.85	External Surface	180.00	89.18	200	
			1m from Cask Surface	1.97	1.78	1,000	
			1m from External Surface	1.82	1.56	10	
Ir-192	7.23E+01	2.16	External Surface	180.00	89.47	200	
			1m from Cask Surface	1.95	1.79	1,000	
			1m from External Surface	1.80	1.57	10	
Ho-166	1.19E+01	0.26	External Surface	180.00	115.80	200	
			1m from Cask Surface	2.21	2.11	1,000	
			1m from External Surface	2.03	1.84	10	
Yb-169	2.69E+05	3.82	External Surface	180.00	92.15	200	Tungsten thickness of 2.15 cm axially and 1.397 cm radially inside cavity
			1m from Cask Surface	1.94	1.91	1,000	
			1m from External Surface	1.78	1.67	10	

Table 5-12. Maximum Radiation Levels – Model AOS-050A

Isotope	Source Strength (Ci)	Photon/Bq	Location	Radial Dose Rate (mRem/hr)	Axial Dose Rate (mRem/hr)	Limit (mRem/hr)	Comments
Co-60	2.12E+00	2	External Surface	105.36	180.00	200	
			1m from Cask Surface	2.99	8.25	1,000	
			1m from External Surface	2.62	6.55	10	
Cs-137	3.01E+02	0.85	External Surface	45.11	167.99	200	
			1m from Cask Surface	1.13	11.30	1,000	
			1m from External Surface	0.99	9.00	10	
Hf-181	2.20E+03	1.93	External Surface	3.00	133.36	200	
			1m from Cask Surface	0.09	11.27	1,000	
			1m from External Surface	0.08	9.00	10	
Ir-192	1.29E+03	2.16	External Surface	31.39	158.09	200	
			1m from Cask Surface	0.82	11.29	1,000	
			1m from External Surface	0.71	9.00	10	
Zr/Nb-95	2.87E+01	3.2	External Surface	73.29	180.00	200	
			1m from Cask Surface	1.88	10.37	1,000	
			1m from External Surface	1.64	8.24	10	
Ho-166	1.77E+02	0.26	External Surface	110.74	180.00	200	
			1m from Cask Surface	3.17	8.09	1,000	
			1m from External Surface	2.77	6.42	10	
Yb-169	3.92E+05	3.82	External Surface	1.99	127.78	200	
			1m from Cask Surface	0.08	11.27	1,000	
			1m from External Surface	0.07	9.00	10	

Table 5-13. Maximum Radiation Levels – Model AOS-100A and AOS-100A-S

Isotope	Source Strength (Ci)	Photon/Bq	Location	Radial Dose Rate (mRem/hr)	Axial Dose Rate (mRem/hr)	Limit (mRem/hr)	Shipping Configuration
Co-60	3.33E+03	2	External Surface	20.12	94.08	200	No Liner
			1m from Cask Surface	1.79	13.39	1,000	
			1m from External Surface	1.37	9.00	10	
Co-60-B	2.19E+04	2	External Surface	132.78	22.57	200	Axial tungsten liner modeled as 3.56 cm-thick plate (top and bottom)
			1m from Cask Surface	11.80	3.44	1,000	
			1m from External Surface	9.00	2.33	10	
Cs-137	2.85E+06	0.85	External Surface	0.46	52.34	200	
			1m from Cask Surface	0.04	13.06	1,000	
			1m from External Surface	0.03	9.00	10	
Hf-181	5.43E+07	1.93	External Surface	0.02	51.39	200	
			1m from Cask Surface	0.01	13.03	1,000	
			1m from External Surface	0.01	9.00	10	
Ir-192	1.28E+07	2.16	External Surface	5.47	61.19	200	
			1m from Cask Surface	0.47	13.11	1,000	
			1m from External Surface	0.36	9.00	10	
Zr/Nb-95	2.15E+05	3.2	External Surface	2.41	56.48	200	
			1m from Cask Surface	0.20	13.08	1,000	
			1m from External Surface	0.15	9.00	10	

Table 5-14. Maximum Radiation Levels – Model AOS-100B

Isotope	Source Strength (Ci)	Photon/Bq	Location	Radial Dose Rate (mRem/hr)	Axial Dose Rate (mRem/hr)	Limit (mRem/hr)	Shipping Configuration
Co-60	9.78E+00	2	External Surface	10.76	111.40	200	No Liner
			1m from Cask Surface	1.02	13.57	1,000	
			1m from External Surface	0.78	9.00	10	
Co-60-B	1.12E+02	2	External Surface	124.31	45.20	200	Axial tungsten liner modeled as 3.56 cm-thick plate (top and bottom)
			1m from Cask Surface	11.77	5.69	1,000	
			1m from External Surface	9.00	3.79	10	
Cs-137	5.28E+02	0.85	External Surface	4.75	121.95	200	
			1m from Cask Surface	0.40	13.70	1,000	
			1m from External Surface	0.31	9.00	10	
Hf-181	3.73E+03	1.93	External Surface	2.76	125.98	200	
			1m from Cask Surface	0.23	13.73	1,000	
			1m from External Surface	0.17	9.00	10	
Ir-192	2.32E+03	2.16	External Surface	3.92	123.72	200	
			1m from Cask Surface	0.33	13.71	1,000	
			1m from External Surface	0.25	9.00	10	
Zr/Nb-95	6.39E+01	3.2	External Surface	5.85	119.91	200	
			1m from Cask Surface	0.51	13.70	1,000	
			1m from External Surface	0.39	9.00	10	

5.5 APPENDIX

5.5.1 AOS Cask Isotopic Heat Load Calculations

Table 5-15 provides the heat load values generated from *MicroShield Version 7.02* (Reference **[5.6]**), for each isotope analyzed in this chapter. It should be noted that MicroShield uses two different libraries – Grove and ICRP-38 – to calculate the heat load. The heat load is generated for each library, then the higher value of the two is provided in Table 5-15 for conservatism.

For Cs-137, it is assumed that this isotope is combined with Ba-137m (due to the short half-life of Ba-137m). As a result, the heat load for Cs-137 in the Conclusion, presented later in this appendix, contains the heat load from Ba-137m as well.

To be consistent with the shielding evaluation supporting Zr/Nb-95, the heat load is determined by multiplying the higher heat load of the two isotopes (Zr-95 as seen in Table 5-15) by a factor of 3.2. The resulting value is 1.62E-02 W/Ci for Zr/Nb-95.

Table 5-16 summarizes the final heat load values applicable to the isotopes analyzed in this chapter. These values are reported in Table 1-2, "Activity Limits – All Models," and are used to calculate activity limits based upon heat loads.

Table 5-15. AOS Cask Isotopic Heat Loads (Reference [5.6])

Isotope	Heat Load (W/Ci)
Co-60	1.54E-02
Cs-137	1.11E-03
Ba-137m	3.92E-03
Hf-181	4.38E-03
Ir-192	6.13E-03
Zr-95	5.06E-03
Nb-95	4.80E-03
Ho-166	4.29E-03
Yb-169	2.51E-03

Table 5-16. AOS Cask Isotopic Heat Load Results

Isotope	Heat Load (W/Ci)
Co-60	1.54E-02
Cs-137	5.03E-03
Hf-181	4.38E-03
Ir-192	6.13E-03
Zr/Nb-95	1.62E-02
Ho-166	4.29E-03
Yb-169	2.51E-03

5.5.2 Isotope Values for Calculations

Table 5-17. Isotope Photon per Decay – All Models

Isotope	Photons/Decay	Model		
		AOS-025	AOS-050	AOS-100
Co-60	2.00	✔	✔	✔
Cs-137	0.85	✔	✔	✔
Hf-181	1.93		✔	✔
Ir-192	2.16	✔	✔	✔
Zr/Nb-95	3.20		✔	✔
Ho-166	0.26	✔	✔	
Yb-169	3.82	✔	✔	

Table 5-18. Activation Product Gamma Spectra Used in Shielding Models – All Models

Isotope	Energy (MeV)	Absolute Probability of Emission per Decay	Model		
			AOS-025	AOS-050	AOS-100
Co-60	8.6830E-04	1.4900E-06	✔	✔	✔
	7.4609E-03	3.2500E-05			
	7.4781E-03	6.4000E-05			
	8.2647E-03	1.3000E-05			
	3.4693E-01	7.6000E-05			
	8.2628E-01	7.6000E-05			
	1.1732E+00	9.9900E-01			
	1.3325E+00	9.9982E-01			
	2.1588E+00	1.1100E-05			
	2.5050E+00	2.0000E-08			
Cs-137	6.6200E-01	8.5000E-01	✔	✔	✔

Table 5-18. Activation Product Gamma Spectra Used in Shielding Models – All Models (Continued)

Isotope	Energy (MeV)	Absolute Probability of Emission per Decay	Model		
			AOS-025	AOS-050	AOS-100
Hf-181	8.1500E-03	1.5000E-01		✔	✔
	5.6277E-02	9.1000E-02			
	5.7532E-02	1.5800E-01			
	6.5200E-02	6.6400E-02			
	3.9000E-03	1.6905E-05			
	6.3000E-03	1.1512E-04			
	1.3302E-01	4.3309E-01			
	1.3626E-01	5.8524E-02			
	1.3686E-01	8.6135E-03			
	3.4593E-01	1.5118E-01			
	4.7599E-01	7.0277E-03			
	4.8218E-01	8.0500E-01			
	6.1517E-01	2.3345E-03			
	6.1866E-01	2.5035E-04			

Table 5-18. Activation Product Gamma Spectra Used in Shielding Models – All Models (Continued)

Isotope	Energy (MeV)	Absolute Probability of Emission per Decay	Model AOS-025	Model AOS-050	Model AOS-100
Ir-192	1.1040E-01	1.2200E-04	✔	✔	✔
	2.0131E-01	4.7300E-03			
	2.0579E-01	3.3400E-02			
	2.8327E-01	2.6600E-03			
	3.2917E-01	1.7400E-04			
	3.7449E-01	7.2600E-03			
	4.2052E-01	6.9000E-04			
	4.8458E-01	3.1870E-02			
	4.8906E-01	4.3800E-03			
	7.0387E-01	5.3000E-05			
	1.3634E-01	1.9900E-03			
	1.7698E-01	4.3000E-05			
	2.8027E-01	9.0000E-05			
	2.9596E-01	2.8720E-01			
	3.0846E-01	2.9680E-01			
	3.1651E-01	8.2710E-01			
	4.1647E-01	6.6900E-03			
	4.6807E-01	4.7810E-01			
	4.8530E-01	2.3000E-05			
	5.8858E-01	4.5170E-02			
	5.9349E-01	4.2100E-04			
	5.9941E-01	3.9000E-05			
	6.0441E-01	8.2000E-02			
	6.1246E-01	5.3400E-02			
	7.6580E-01	1.3000E-05			
	8.8454E-01	2.9100E-03			
	1.0615E+00	5.3000E-04			
	1.0899E+00	1.2000E-05			
	1.3782E+00	1.2000E-05			
Zr/Nb-95	7.6600E-01	3.2000E+00		✔	✔

Table 5-18. Activation Product Gamma Spectra Used in Shielding Models – All Models (Continued)

Isotope	Energy (MeV)	Absolute Probability of Emission per Decay	Model		
			AOS-025	AOS-050	AOS-100
Ho-166	7.8110E-03	7.8000E-02	✔	✔	
	4.8221E-02	2.9200E-02			
	4.9128E-02	5.2000E-02			
	5.5577E-02	1.6400E-02			
	5.7036E-02	4.7000E-03			
	8.0574E-02	6.3300E-02			
	1.8441E-01	1.6000E-05			
	5.2096E-01	3.0000E-06			
	6.7402E-01	1.6400E-04			
	7.0531E-01	1.2700E-04			
	7.8589E-01	1.1600E-04			
	1.2633E+00	1.4000E-05			
	1.3794E+00	9.3000E-03			
	1.4477E+00	9.3000E-06			
	1.5286E+00	2.0000E-06			
	1.5819E+00	1.8300E-03			
	1.6625E+00	1.2100E-03			
	1.7499E+00	2.6000E-04			
	1.8306E+00	8.3000E-05			

Table 5-18. Activation Product Gamma Spectra Used in Shielding Models – All Models (Continued)

Isotope	Energy (MeV)	Absolute Probability of Emission per Decay	Model		
			AOS-025	AOS-050	AOS-100
Yb-169	7.1800E-03	4.8300E-01	✔	✔	
	4.9773E-02	5.2900E-01			
	5.0742E-02	9.3400E-01			
	5.7500E-02	3.8500E-01			
	8.4103E-03	3.3294E-03			
	2.0752E-02	1.8974E-03			
	4.2760E-02	1.0740E-03			
	4.5940E-02	5.3700E-05			
	5.0610E-02	2.8640E-03			
	5.0860E-02	2.8640E-03			
	5.1510E-02	1.0740E-04			
	6.3120E-02	4.4213E-01			
	6.5860E-02	5.3700E-05			
	8.5090E-02	1.4320E-05			
	9.3620E-02	2.6062E-02			
	9.5700E-02	1.0740E-05			
	9.5850E-02	1.0740E-05			
	1.0140E-01	3.5800E-05			
	1.0519E-01	2.5776E-05			
	1.0980E-01	1.7470E-01			
	1.1360E-01	5.3700E-05			
	1.1400E-01	4.2960E-05			
	1.1738E-01	3.9738E-04			
	1.1820E-01	1.8688E-02			
	1.2990E-01	2.8640E-03			
	1.3050E-01	1.1313E-01			
	1.5673E-01	9.9882E-05			
	1.7720E-01	2.2160E-01			
	1.9315E-01	7.5180E-05			
	1.9800E-01	3.5800E-01			
	1.9980E-01	1.7900E-04			
	2.0599E-01	4.0812E-05			
	2.1394E-01	2.8998E-05			
	2.4033E-01	1.1384E-03			

Table 5-18. Activation Product Gamma Spectra Used in Shielding Models – All Models (Continued)

Isotope	Energy (MeV)	Absolute Probability of Emission per Decay	Model		
			AOS-025	AOS-050	AOS-100
Yb-169 (Continued)	2.6110E-01	1.7148E-02	✔	✔	
	2.9119E-01	4.2960E-05			
	3.0750E-01	2.5060E-03			
	3.0770E-01	1.0053E-01			
	3.3397E-01	1.7900E-05			
	3.3662E-01	9.0932E-05			
	3.7086E-01	7.1958E-05			
	3.7929E-01	1.2172E-05			
	4.6472E-01	3.5800E-08			
	4.9436E-01	1.4857E-05			
	5.0035E-01	8.8068E-08			
	5.1510E-01	4.1385E-05			
	5.4616E-01	1.4678E-08			
	6.2489E-01	4.9046E-05			
	6.9346E-01	8.6636E-08			
	7.3942E-01	1.8258E-08			
	7.6024E-01	8.2340E-09			
	7.8164E-01	3.0072E-08			

5.5.3 MCNP Input and Output Files for Co-60 Radial Dose Calculation – Model AOS-100A

5.5.3.1 MCNP Input File for Co-60 Radial Dose Calculation – Model AOS-100A

```
AOS-100A radial c-60 dose calculation (3.56 cm liner)
c
c cells
c
c source
1    4   -1.29e-3 -1    2   -3
c cavity
2    4   -1.29e-3 -10   76   -56  (1:-2:3)
c liner
54   3   -17.8          -10   56  -12
74   3   -17.8          -10   11  -76
c ss lining
100  1   -7.8       10 -202   11  -12
101  1   -7.8          -202   12  -201
102  1   -7.8          -202   200 -11
103  1   -7.8          -307   201 -600
104  1   -7.8          -307   650 -200
c radial shield
200  3   -17.8     202 -215   200 -201
c cask
500  1   -7.8    -307  302   600 -615
550  1   -7.8    -307  302   665 -650
302  1   -7.8      215 -307   200 -201
c axial shield
400  3  -17.8          -302   600 -615
c
450  3  -17.8          -302   665 -650
c cask lids
504  1   -7.8          -307   615 -300
554  1   -7.8          -307   301 -665
c detection region
73   4   -1.29e-3 307 -405 301 -300
c outside world
99   0            405:300:-301

c surfaces
c
c source
1    CZ   7.8
2    PZ  -17.89938
3    PZ   17.89938
c cavity
10   cz   8.2499
11   pz  -25.4
12   pz   25.4
c axial liner
56   PZ  21.84377585
76   PZ -21.84377585
c radial shield
200 pz  -27.59456
201 pz   27.59456
```

```
202 cz   10.36
215 cz   20.1193
c cask
300 pz   45.72
301 pz  -45.72
302 cz   12.60348
307 cz   35.56
c axial shield
600 pz   29.63926
615 pz   40.76192
650 PZ  -29.63926
665 PZ  -40.76192
c
405 cz   235.56

c data
c
mode p
phys:p 100 0 1
c material
m1    26000.04p -0.72
      25055.04p -0.02
      24000.04p -0.18
      28000.04p -0.08
m4     7000.04p  0.7809
       8000.04p  0.2095
      18000.04p  0.0096
m3    74000.04p  1
c source
sdef pos=0.0 8.24 0.0 erg=d4 vec=0 1 0 dir=d5
c Co-60
si4  1 8.6830E-04  7.4609E-03  7.4781E-03  8.2647E-03  3.4693E-01  8.2628E-01
       1.1732E+00  1.3325E+00  2.1588E+00  2.5050E+00
sp4    1.4900E-06  3.2500E-05  6.4000E-05  1.3000E-05  7.6000E-05  7.6000E-05
       9.9900E-01  9.9982E-01  1.1100E-05  2.0000E-08
sb5  -31 2.0
c tally
f5:p    0   35.570  0  0.01
f15:p   0   47.549  0  0.01
f25:p   0   50.089  0  0.01
f35:p   0   52.629  0  0.01
f45:p   0   55.169  0  0.01
f55:p   0   57.963  0  0.01
f65:p   0   84.000  0  0.01
f75:p   0  135.560  0  0.01
f85:p   0  147.549  0  0.01
f95:p   0  150.089  0  0.01
f105:p  0  152.629  0  0.01
f115:p  0  155.169  0  0.01
f125:p  0  157.963  0  0.01
f135:p  0  184.000  0  0.01
c dose conversion factors
de0  1.0E-2 3.0E-2 5.0E-2 7.0E-2 1.0E-1 1.5E-1 2.0E-1
     2.5E-1 3.0E-1 3.5E-1 4.0E-1 4.5E-1 5.0E-1 5.5E-1
     6.0E-1 6.5E-1 7.0E-1 8.0E-1 1.0000 1.4000 1.8000
     2.2000 2.6000 2.8000 3.2500 3.7500 4.2500 4.7500
     5.0000 5.2500 5.7500 6.2500 6.7500 7.5000 9.0000
     11.000 13.000 15.000
df0  3.96E-06 5.82E-07 2.90E-07 2.58E-07 2.83E-07 3.79E-07
```

```
     5.01E-07 6.31E-07 7.59E-07 8.78E-07 9.85E-07 1.08E-06
     1.17E-06 1.27E-06 1.36E-06 1.44E-06 1.52E-06 1.68E-06
     1.98E-06 2.51E-06 2.99E-06 3.42E-06 3.82E-06 4.01E-06
     4.41E-06 4.83E-06 5.23E-06 5.60E-06 5.80E-06 6.01E-06
     6.37E-06 3.74E-06 7.11E-06 7.66E-06 8.77E-06 1.03E-05
     1.18E-05 1.33E-05
c
ext:p sy 16r 0 0
imp:p 1  17r 0
c mesh weight window
wwp:p 4j -1
mesh  geom cyl ref 0 0 0 origin 0 0 -45.721
      imesh 8.25 10.36 20.12 35.56 235.561 iints 1 2 20 30 1
      jmesh 20.321 71.121 91.442 jints 1 1 1
      kmesh 1 kints 1
c
nps 1e7
```

5.5.3.2 MCNP Output File for Co-60 Radial Dose Calculation – Model AOS-100A

Note: *Only key sections of the output are included here.*

```
        Thread Name & Version = MCNP5_RSICC, 1.30
                                       _
        ._ _    _ ._   ._   |_
        | | |  (_  | |  .|_)   _)
                        |
+---------------------------------------------------------------------+
|   This program was prepared by the Regents of the University of     |
|California at Los Alamos National Laboratory (the University) under |
|  contract number W-7405-ENG-36 with the U.S. Department of Energy   |
|(DoE).  The University has certain rights in the program pursuant to|
|  the contract and the program should not be copied or distributed   |
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| University makes any warranty, express or implied, or assumes any  |
|      liability or responsibility for the use of this software.      |
+---------------------------------------------------------------------+

1Global Nuclear Fuel - Americas Code MCNP-05P Production Version 1, Rev.2

=========================================================================
Omitted Sections
=========================================================================

 tally    result of statistical checks for the tfc bin (the first check not passed is
          listed) and error magnitude check for all bins

    5   missed  2 of 10 tfc bin checks: the relative error exceeds the recommended value
          of 0.05 for point detector tallies
        missed all bin error check:     2 tally bins had     0 bins with zeros and     1
          bins with relative errors exceeding 0.05
   15  passed the 10 statistical checks for the tally fluctuation chart bin result
       passed all bin error check:     2 tally bins all have relative errors less than
          0.05 with no zero bins
   25  passed the 10 statistical checks for the tally fluctuation chart bin result
       passed all bin error check:     2 tally bins all have relative errors less than
          0.05 with no zero bins
   35  passed the 10 statistical checks for the tally fluctuation chart bin result
       passed all bin error check:     2 tally bins all have relative errors less than
          0.05 with no zero bins
   45  passed the 10 statistical checks for the tally fluctuation chart bin result
       passed all bin error check:     2 tally bins all have relative errors less than
          0.05 with no zero bins
   55  passed the 10 statistical checks for the tally fluctuation chart bin result
       passed all bin error check:     2 tally bins all have relative errors less than
          0.05 with no zero bins
   65  passed the 10 statistical checks for the tally fluctuation chart bin result
       passed all bin error check:     2 tally bins all have relative errors less than
          0.05 with no zero bins
```

```
  75  passed the 10 statistical checks for the tally fluctuation chart bin result
       passed all bin error check:     2 tally bins all have relative errors less than
         0.05 with no zero bins
  85  passed the 10 statistical checks for the tally fluctuation chart bin result
       passed all bin error check:     2 tally bins all have relative errors less than
         0.05 with no zero bins
  95  passed the 10 statistical checks for the tally fluctuation chart bin result
       passed all bin error check:     2 tally bins all have relative errors less than
         0.05 with no zero bins
 105  passed the 10 statistical checks for the tally fluctuation chart bin result
       passed all bin error check:     2 tally bins all have relative errors less than
         0.05 with no zero bins
 115  passed the 10 statistical checks for the tally fluctuation chart bin result
       passed all bin error check:     2 tally bins all have relative errors less than
         0.05 with no zero bins
 125  passed the 10 statistical checks for the tally fluctuation chart bin result
       passed all bin error check:     2 tally bins all have relative errors less than
         0.05 with no zero bins
 135  passed the 10 statistical checks for the tally fluctuation chart bin result
       passed all bin error check:     2 tally bins all have relative errors less than
         0.05 with no zero bins

 the 10 statistical checks are only for the tally fluctuation chart bin and do not apply
         to other tally bins.

1tally fluctuation charts

                  tally   5                                   tally  15
         tally   25
          nps      mean     error   vov  slope    fom      mean     error   vov  slope
          fom      mean     error   vov  slope    fom
       512000   2.8735E-16 0.1104 0.0729  2.2      44   1.3008E-16 0.0687 0.0347  4.6
          113   1.1058E-16 0.0661 0.0319  5.1     122
      1024000   2.3215E-16 0.0796 0.0459  2.8      41   1.1548E-16 0.0480 0.0195  5.2
          113   9.8496E-17 0.0461 0.0178  5.6     123
      1536000   2.5583E-16 0.0775 0.1728  3.3      29   1.1672E-16 0.0375 0.0114  9.1
          124   9.9350E-17 0.0360 0.0105  7.1     134
      2048000   2.7238E-16 0.0721 0.1155  3.4      25   1.1486E-16 0.0331 0.0108  5.6
          120   9.7687E-17 0.0317 0.0096  6.0     131
      2560000   2.6347E-16 0.0634 0.0916  3.3      26   1.1185E-16 0.0295 0.0085  7.8
          121   9.5228E-17 0.0282 0.0075  8.6     132
      3072000   2.9005E-16 0.0903 0.3807  3.0      11   1.1115E-16 0.0268 0.0069  7.8
          122   9.4668E-17 0.0256 0.0061  9.3     133
      3584000   3.2295E-16 0.1080 0.2949  2.4 6.5E+00   1.1031E-16 0.0248 0.0061  7.0
          123   9.3961E-17 0.0237 0.0053  8.6     134
      4096000   3.2240E-16 0.0965 0.2729  2.6 7.1E+00   1.1149E-16 0.0232 0.0050  8.4
          123   9.4955E-17 0.0222 0.0044  7.9     134
      4608000   3.1285E-16 0.0889 0.2674  2.7 7.5E+00   1.1073E-16 0.0219 0.0043  7.8
          123   9.4264E-17 0.0209 0.0038  7.2     134
      5120000   3.0390E-16 0.0829 0.2605  2.9 7.7E+00   1.0957E-16 0.0207 0.0038  7.7
          124   9.3306E-17 0.0198 0.0034  8.8     135
      5632000   3.0150E-16 0.0771 0.2457  2.8 8.1E+00   1.0992E-16 0.0196 0.0035  7.5
          125   9.3638E-17 0.0188 0.0031  7.2     137
      6144000   2.9674E-16 0.0724 0.2381  2.6 8.5E+00   1.1008E-16 0.0187 0.0031  7.2
          127   9.3793E-17 0.0179 0.0028  8.0     138
      6656000   2.9549E-16 0.0685 0.2199  2.7 8.7E+00   1.0943E-16 0.0180 0.0029  7.1
          127   9.3263E-17 0.0172 0.0026  7.2     138
      7168000   2.9443E-16 0.0645 0.2110  2.7 9.2E+00   1.0949E-16 0.0174 0.0027  8.6
          126   9.3305E-17 0.0166 0.0024  8.7     138
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 7680000   2.9433E-16 0.0608 0.2036  2.9 9.6E+00   1.0975E-16 0.0167 0.0024 10.0
     127    9.3532E-17 0.0160 0.0022 10.0      139
 8192000   2.9535E-16 0.0589 0.1785  2.9 9.6E+00   1.0943E-16 0.0161 0.0022 10.0
     128    9.3276E-17 0.0155 0.0020 10.0      140
 8704000   2.9257E-16 0.0563 0.1742  3.1 9.9E+00   1.0912E-16 0.0157 0.0021 10.0
     128    9.3029E-17 0.0150 0.0019 10.0      140
 9216000   2.8894E-16 0.0542 0.1702  3.1      10   1.0870E-16 0.0152 0.0020 10.0
     129    9.2674E-17 0.0146 0.0018 10.0      140
 9728000   2.8879E-16 0.0519 0.1625  3.2      10   1.0835E-16 0.0148 0.0019 10.0
     128    9.2380E-17 0.0142 0.0017 10.0      140
10000000   2.8927E-16 0.0509 0.1575  3.2      11   1.0858E-16 0.0146 0.0019 10.0
     127    9.2562E-17 0.0140 0.0017 10.0      139


           tally  35                              tally  45
     tally   55
     nps      mean     error   vov  slope    fom      mean     error   vov  slope
     fom      mean     error   vov  slope    fom
  512000   9.5107E-17 0.0641 0.0299  5.4    130   8.2623E-17 0.0625 0.0284  5.6
     137    7.1499E-17 0.0610 0.0270  5.9    144
 1024000   8.4949E-17 0.0445 0.0166  5.9    132   7.3971E-17 0.0433 0.0157  6.8
     139    6.4154E-17 0.0422 0.0149  6.3    147
 1536000   8.5557E-17 0.0349 0.0098  6.2    143   7.4430E-17 0.0339 0.0092  5.5
     151    6.4507E-17 0.0331 0.0088  5.7    159
 2048000   8.4091E-17 0.0306 0.0087  6.7    141   7.3140E-17 0.0297 0.0081  7.0
     149    6.3383E-17 0.0290 0.0075  7.3    157
 2560000   8.2049E-17 0.0273 0.0068  9.4    141   7.1415E-17 0.0265 0.0063 10.0
     150    6.1930E-17 0.0258 0.0059 10.0    158
 3072000   8.1588E-17 0.0247 0.0055 10.0    143   7.1033E-17 0.0240 0.0051 10.0
     151    6.1618E-17 0.0234 0.0048 10.0    160
 3584000   8.0988E-17 0.0229 0.0048 10.0    144   7.0518E-17 0.0222 0.0044 10.0
     153    6.1178E-17 0.0217 0.0041 10.0    161
 4096000   8.1828E-17 0.0215 0.0040  9.1    144   7.1230E-17 0.0209 0.0037 10.0
     152    6.1778E-17 0.0203 0.0035 10.0    160
 4608000   8.1202E-17 0.0202 0.0035  7.9    144   7.0667E-17 0.0197 0.0032  8.4
     152    6.1277E-17 0.0192 0.0030 10.0    160
 5120000   8.0399E-17 0.0192 0.0031  8.4    145   6.9982E-17 0.0186 0.0029  8.4
     153    6.0693E-17 0.0182 0.0027  9.6    161
 5632000   8.0699E-17 0.0182 0.0029  7.4    146   7.0260E-17 0.0177 0.0027  7.5
     155    6.0942E-17 0.0172 0.0025  7.9    163
 6144000   8.0840E-17 0.0173 0.0025  6.9    148   7.0387E-17 0.0168 0.0024  8.2
     156    6.1055E-17 0.0164 0.0022  7.0    165
 6656000   8.0403E-17 0.0166 0.0023  9.9    148   7.0022E-17 0.0162 0.0022  7.4
     156    6.0750E-17 0.0158 0.0021  8.2    165
 7168000   8.0434E-17 0.0161 0.0022  9.4    147   7.0044E-17 0.0156 0.0021  7.9
     156    6.0767E-17 0.0152 0.0019  7.8    164
 7680000   8.0634E-17 0.0155 0.0020  9.6    149   7.0221E-17 0.0150 0.0019 10.0
     157    6.0923E-17 0.0147 0.0018  8.1    165
 8192000   8.0422E-17 0.0149 0.0018  9.9    150   7.0041E-17 0.0145 0.0017 10.0
     158    6.0772E-17 0.0142 0.0016  9.9    166
 8704000   8.0220E-17 0.0145 0.0017  9.6    149   6.9872E-17 0.0141 0.0016 10.0
     158    6.0631E-17 0.0137 0.0015 10.0    166
 9216000   7.9914E-17 0.0141 0.0016 10.0    150   6.9607E-17 0.0137 0.0015 10.0
     159    6.0403E-17 0.0133 0.0014 10.0    167
 9728000   7.9666E-17 0.0137 0.0016 10.0    150   6.9392E-17 0.0133 0.0015 10.0
     158    6.0220E-17 0.0130 0.0014 10.0    166
10000000   7.9812E-17 0.0136 0.0015 10.0    149   6.9512E-17 0.0132 0.0014 10.0
     157    6.0318E-17 0.0128 0.0014 10.0    166
1tally fluctuation charts
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```
            tally  65                                  tally  75
    tally   85
     nps       mean      error    vov  slope    fom      mean      error    vov  slope
     fom       mean      error    vov  slope    fom
  512000   2.6219E-17 0.0544 0.0214 10.0      181   8.2335E-18 0.0507 0.0185 10.0
     208    6.7766E-18 0.0503 0.0182 10.0      212
 1024000   2.3827E-17 0.0373 0.0115  6.3      188   7.5331E-18 0.0346 0.0099  6.4
     219    6.2065E-18 0.0343 0.0097  6.5      222
 1536000   2.3865E-17 0.0293 0.0068  7.1      203   7.5447E-18 0.0272 0.0058  9.7
     234    6.2147E-18 0.0270 0.0057  9.4      238
 2048000   2.3464E-17 0.0255 0.0055  8.0      203   7.4235E-18 0.0237 0.0046 10.0
     236    6.1157E-18 0.0235 0.0045  8.9      240
 2560000   2.3000E-17 0.0228 0.0043 10.0      203   7.2921E-18 0.0211 0.0036 10.0
     236    6.0090E-18 0.0209 0.0035 10.0      240
 3072000   2.2916E-17 0.0207 0.0035 10.0      205   7.2695E-18 0.0192 0.0029 10.0
     237    5.9904E-18 0.0190 0.0029 10.0      241
 3584000   2.2770E-17 0.0191 0.0030 10.0      206   7.2262E-18 0.0178 0.0025 10.0
     239    5.9549E-18 0.0176 0.0024 10.0      243
 4096000   2.2952E-17 0.0180 0.0026 10.0      204   7.2762E-18 0.0167 0.0022 10.0
     236    5.9951E-18 0.0166 0.0021 10.0      240
 4608000   2.2742E-17 0.0170 0.0023 10.0      204   7.2074E-18 0.0158 0.0019 10.0
     237    5.9382E-18 0.0157 0.0019 10.0      241
 5120000   2.2540E-17 0.0161 0.0020 10.0      205   7.1465E-18 0.0149 0.0017 10.0
     238    5.8882E-18 0.0148 0.0017 10.0      242
 5632000   2.2649E-17 0.0153 0.0019 10.0      207   7.1833E-18 0.0142 0.0016 10.0
     240    5.9185E-18 0.0141 0.0016 10.0      244
 6144000   2.2688E-17 0.0145 0.0017 10.0      209   7.1959E-18 0.0135 0.0014 10.0
     242    5.9285E-18 0.0134 0.0014 10.0      246
 6656000   2.2595E-17 0.0140 0.0016  9.5      210   7.1708E-18 0.0130 0.0013 10.0
     242    5.9081E-18 0.0129 0.0013 10.0      246
 7168000   2.2602E-17 0.0135 0.0015  9.4      209   7.1742E-18 0.0126 0.0013 10.0
     241    5.9109E-18 0.0125 0.0012 10.0      246
 7680000   2.2668E-17 0.0130 0.0013  7.4      210   7.1948E-18 0.0121 0.0012 10.0
     243    5.9280E-18 0.0120 0.0011 10.0      247
 8192000   2.2619E-17 0.0126 0.0012  9.9      212   7.1810E-18 0.0117 0.0011 10.0
     245    5.9168E-18 0.0116 0.0011 10.0      249
 8704000   2.2576E-17 0.0122 0.0012 10.0      212   7.1699E-18 0.0113 0.0010 10.0
     245    5.9078E-18 0.0112 0.0010 10.0      249
 9216000   2.2494E-17 0.0118 0.0011 10.0      212   7.1452E-18 0.0110 0.0009 10.0
     246    5.8876E-18 0.0109 0.0009 10.0      250
 9728000   2.2427E-17 0.0115 0.0011 10.0      212   7.1247E-18 0.0107 0.0009 10.0
     245    5.8709E-18 0.0106 0.0009 10.0      249
10000000   2.2454E-17 0.0114 0.0010 10.0      211   7.1318E-18 0.0106 0.0009 10.0
     244    5.8765E-18 0.0105 0.0009 10.0      248
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            tally  95                                  tally  105
    tally  115
     nps       mean      error    vov  slope    fom      mean      error    vov  slope
     fom       mean      error    vov  slope    fom
  512000   6.5181E-18 0.0502 0.0181 10.0      212   6.2731E-18 0.0501 0.0181 10.0
     213    6.0428E-18 0.0500 0.0180 10.0      214
 1024000   5.9708E-18 0.0342 0.0097  6.6      223   5.7480E-18 0.0342 0.0096  6.7
     224    5.5381E-18 0.0341 0.0096  6.7      225
 1536000   5.9779E-18 0.0270 0.0057  9.4      239   5.7547E-18 0.0269 0.0057  9.3
     240    5.5437E-18 0.0269 0.0057  9.3      240
 2048000   5.8828E-18 0.0234 0.0045  8.9      240   5.6633E-18 0.0234 0.0045  8.8
     241    5.4559E-18 0.0234 0.0045  8.7      242
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  2560000   5.7803E-18 0.0209 0.0035 10.0     240   5.5649E-18 0.0209 0.0035 10.0
      241    5.3613E-18 0.0209 0.0035 10.0     242
  3072000   5.7626E-18 0.0190 0.0028 10.0     242   5.5479E-18 0.0190 0.0028 10.0
      242    5.3450E-18 0.0190 0.0028 10.0     243
  3584000   5.7285E-18 0.0176 0.0024 10.0     244   5.5151E-18 0.0176 0.0024 10.0
      244    5.3134E-18 0.0176 0.0024 10.0     245
  4096000   5.7670E-18 0.0166 0.0021 10.0     240   5.5519E-18 0.0166 0.0021 10.0
      241    5.3486E-18 0.0165 0.0021 10.0     242
  4608000   5.7123E-18 0.0156 0.0019 10.0     241   5.4992E-18 0.0156 0.0019 10.0
      242    5.2979E-18 0.0156 0.0019 10.0     243
  5120000   5.6643E-18 0.0148 0.0017 10.0     243   5.4529E-18 0.0148 0.0017 10.0
      243    5.2534E-18 0.0148 0.0017 10.0     244
  5632000   5.6935E-18 0.0140 0.0016 10.0     245   5.4810E-18 0.0140 0.0016 10.0
      245    5.2805E-18 0.0140 0.0016 10.0     246
  6144000   5.7031E-18 0.0134 0.0014 10.0     247   5.4902E-18 0.0134 0.0014 10.0
      248    5.2893E-18 0.0134 0.0014 10.0     248
  6656000   5.6835E-18 0.0129 0.0013 10.0     247   5.4715E-18 0.0129 0.0013 10.0
      248    5.2712E-18 0.0128 0.0013 10.0     249
  7168000   5.6861E-18 0.0124 0.0012 10.0     246   5.4741E-18 0.0124 0.0012 10.0
      247    5.2737E-18 0.0124 0.0012 10.0     248
  7680000   5.7027E-18 0.0120 0.0011 10.0     248   5.4900E-18 0.0120 0.0011 10.0
      248    5.2890E-18 0.0119 0.0011 10.0     249
  8192000   5.6919E-18 0.0116 0.0011 10.0     249   5.4797E-18 0.0116 0.0010 10.0
      250    5.2791E-18 0.0115 0.0010 10.0     251
  8704000   5.6833E-18 0.0112 0.0010 10.0     250   5.4715E-18 0.0112 0.0010 10.0
      250    5.2712E-18 0.0112 0.0010 10.0     251
  9216000   5.6640E-18 0.0109 0.0009 10.0     251   5.4529E-18 0.0109 0.0009 10.0
      251    5.2534E-18 0.0109 0.0009 10.0     252
  9728000   5.6480E-18 0.0106 0.0009 10.0     250   5.4374E-18 0.0106 0.0009 10.0
      251    5.2386E-18 0.0106 0.0009 10.0     252
 10000000   5.6533E-18 0.0105 0.0009 10.0     249   5.4425E-18 0.0105 0.0009 10.0
      250    5.2435E-18 0.0104 0.0009 10.0     251
1tally fluctuation charts

                     tally  125                                tally  135
      nps       mean      error   vov  slope     fom      mean      error   vov  slope
      fom
   512000   5.8031E-18 0.0500 0.0180 10.0     214   4.1227E-18 0.0494 0.0175 10.0
      219
  1024000   5.3198E-18 0.0341 0.0096  6.8     225   3.7826E-18 0.0337 0.0093  6.8
      231
  1536000   5.3250E-18 0.0269 0.0056  9.2     241   3.7837E-18 0.0265 0.0055  9.5
      247
  2048000   5.2408E-18 0.0233 0.0045  8.4     243   3.7252E-18 0.0230 0.0044  8.5
      248
  2560000   5.1502E-18 0.0208 0.0035 10.0     242   3.6618E-18 0.0206 0.0034 10.0
      248
  3072000   5.1347E-18 0.0189 0.0028 10.0     244   3.6511E-18 0.0187 0.0028 10.0
      250
  3584000   5.1042E-18 0.0175 0.0024 10.0     246   3.6294E-18 0.0173 0.0024 10.0
      252
  4096000   5.1379E-18 0.0165 0.0021 10.0     243   3.6527E-18 0.0163 0.0021 10.0
      248
  4608000   5.0891E-18 0.0156 0.0019 10.0     243   3.6194E-18 0.0154 0.0018 10.0
      249
  5120000   5.0464E-18 0.0147 0.0017 10.0     245   3.5894E-18 0.0146 0.0016 10.0
      250
  5632000   5.0724E-18 0.0140 0.0016 10.0     247   3.6078E-18 0.0138 0.0015 10.0
      252
```

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     6144000     5.0808E-18 0.0133 0.0014 10.0      249    3.6137E-18 0.0132 0.0014 10.0
         255
     6656000     5.0635E-18 0.0128 0.0013 10.0      249    3.6019E-18 0.0127 0.0013 10.0
         255
     7168000     5.0659E-18 0.0124 0.0012 10.0      248    3.6037E-18 0.0122 0.0012 10.0
         254
     7680000     5.0806E-18 0.0119 0.0011 10.0      250    3.6154E-18 0.0118 0.0011 10.0
         255
     8192000     5.0710E-18 0.0115 0.0010 10.0      252    3.6086E-18 0.0114 0.0010 10.0
         257
     8704000     5.0636E-18 0.0112 0.0010 10.0      252    3.6037E-18 0.0110 0.0010 10.0
         258
     9216000     5.0465E-18 0.0108 0.0009 10.0      253    3.5916E-18 0.0107 0.0009 10.0
         258
     9728000     5.0323E-18 0.0106 0.0009 10.0      252    3.5814E-18 0.0104 0.0009 10.0
         258
    10000000     5.0369E-18 0.0104 0.0009 10.0      251    3.5845E-18 0.0103 0.0008 10.0
         257
===============================================================================
          ==============================================
Omitted Sections
===============================================================================
          ==============================================
```

5.6 REFERENCES

[5.1] U.S. Nuclear Regulatory Commission (NRC), *Title 10 Code of Federal Regulations, Part 71 (10 CFR 71)*, "Packaging and Transportation of Radioactive Material."

[5.2] *ORNL/TM-2005/39*. "ORIGEN-ARP: Automatic Rapid Processing for Spent Fuel Depletion, Decay, and Source Term Analysis," November, 2006.

[5.3] Korea Atomic Energy Research Institute, *Table of Nuclides*, accessed September, 2006, http://atom/kaeri.re.kr/.

[5.4] Los Alamos National Laboratory X-5 Monte Carlo Team, *MCNP-A General Monte Carlo N-Particle Transport Code*, Version 5, 2003.

[5.5] American Nuclear Society, *ANSI/ANS-6.1.1-1977*, "Neutron and Gamma-Ray Fluence-to-Dose Factor," 1977.

[5.6] Grove Engineering, *MicroShield Version 7.02*, October, 2006.

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6 CRITICALITY EVALUATION

Not applicable. A criticality evaluation is not provided in this SAR, because fissile material is not requested as content.

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7 PACKAGE OPERATIONS

The information within this chapter provides the operations used to load the AOS Transport Packaging System and prepare it for transport. These operations describe the fundamental steps needed to ensure the requirements of this SAR. The transport packages should be operated using detailed written procedures that are based upon, and consistent with, the operations described in this chapter. During actual operation, these procedures can be supplemented with engineering personnel, training classes, and/or site-specific procedures, as applicable.

Figure 7-1 through Figure 7-3 provide an isometric view of each model's packaging (Models AOS-025, AOS-050, and AOS-100, respectively).

Note: *Unless indicated otherwise, all information related to the Model AOS-100A is also applicable to Models AOS-100B and AOS-100A-S.*

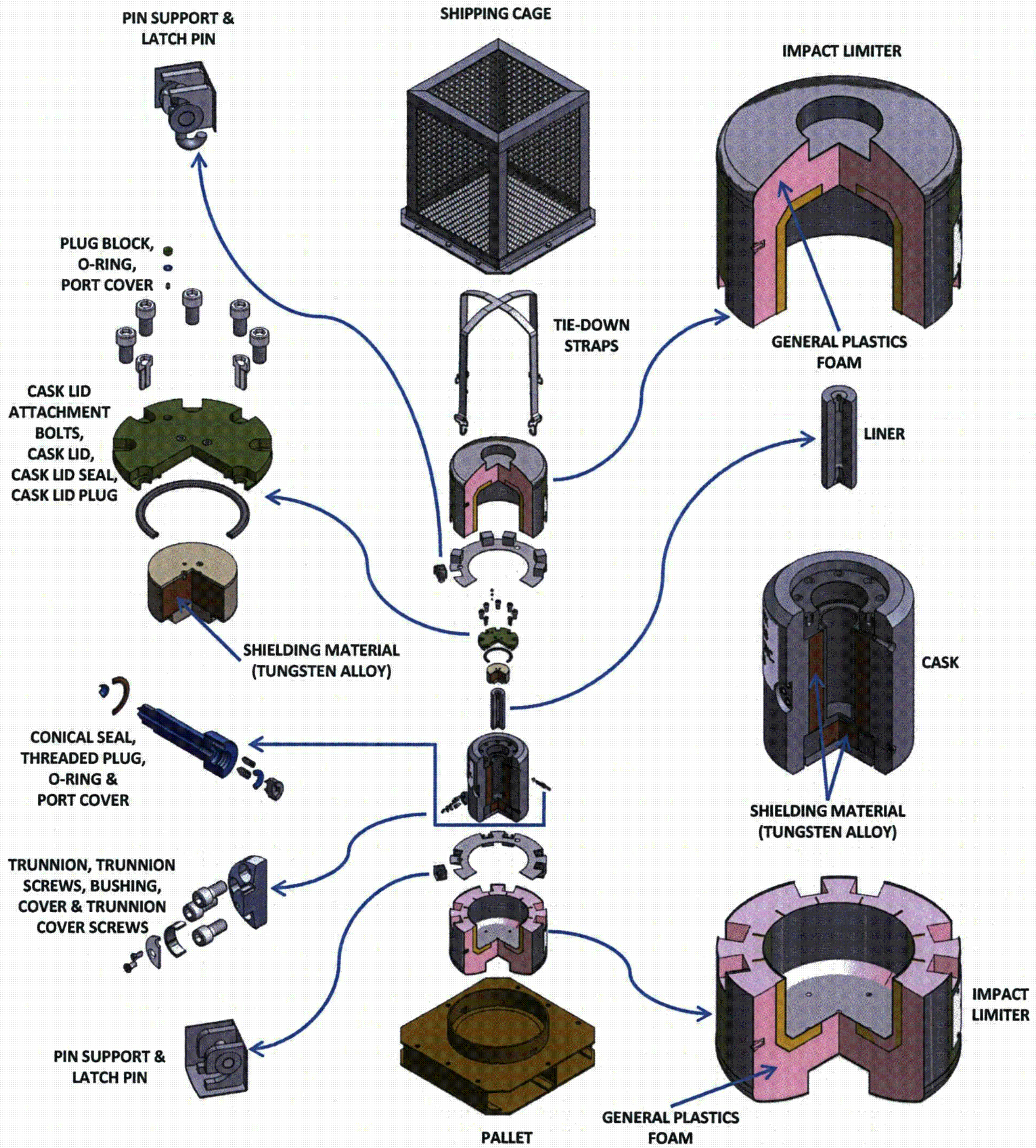

Figure 7-1. Isometric View – Model AOS-025A

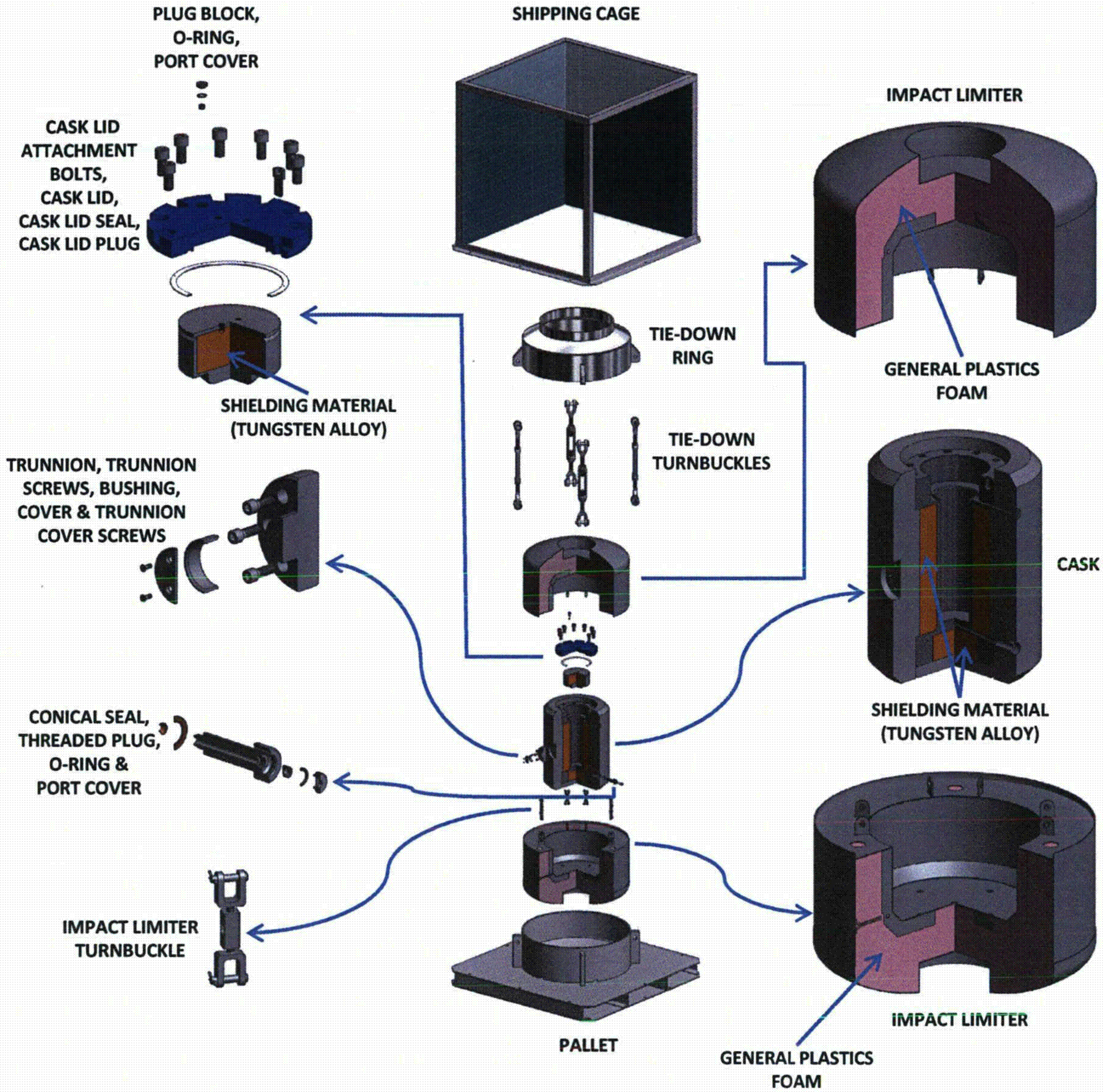

Figure 7-2. Isometric View – Model AOS-050A

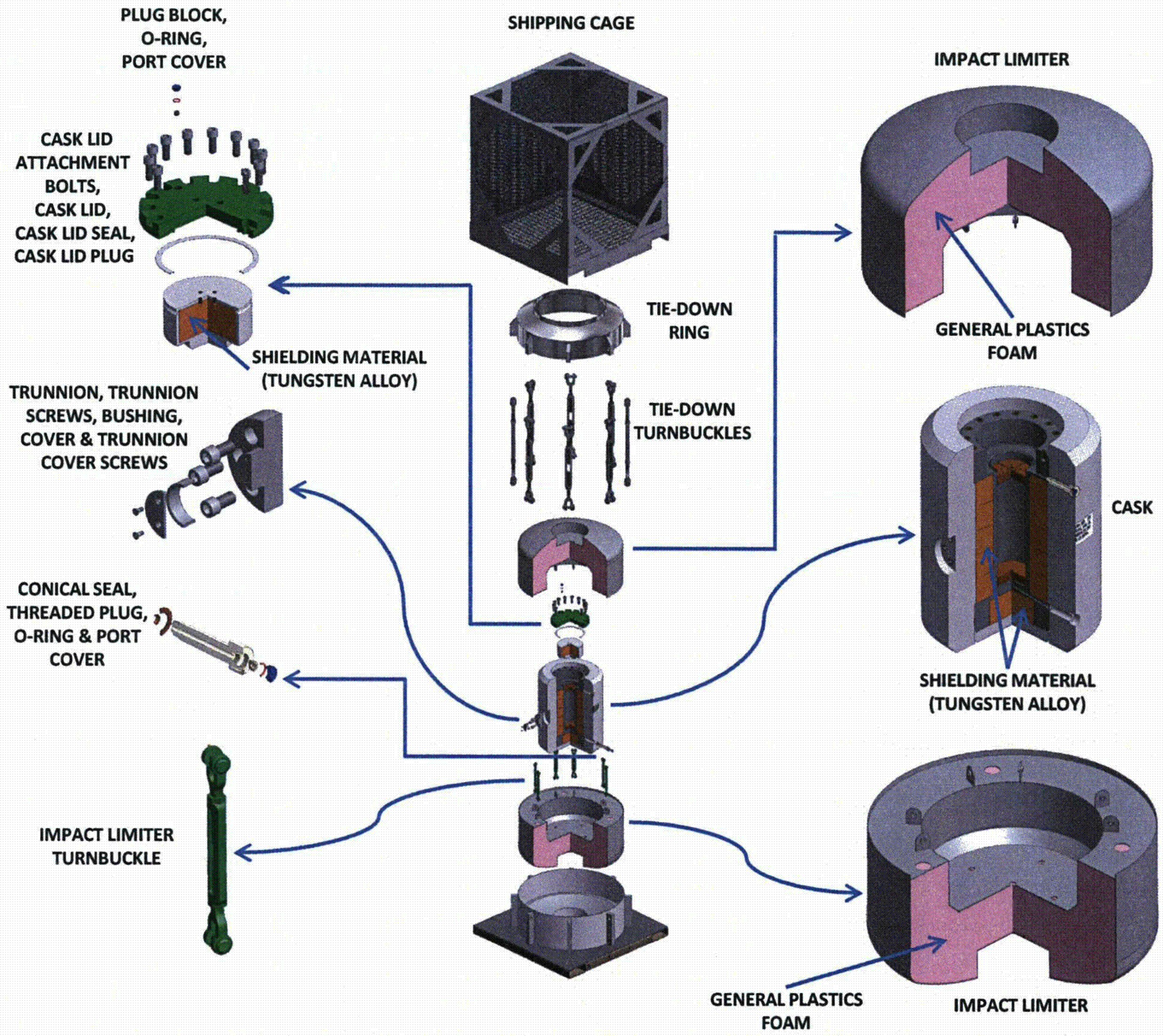

Figure 7-3. Isometric View – Models AOS-100A

Note: *The Model AOS-100A shown is typical for all Model AOS-100 configurations.*

7.1 PACKAGE LOADING

Note: *The operational steps provided in this section apply to all AOS Radioactive Material Transport Packaging System models (Models AOS-025A, AOS-050A, AOS-100A, AOS-100B, and AOS-100A-S). Any step specific to a given Model is identified within the step.*

Part of the transport package loading preparation is to perform a Pre-Shipment Engineering Evaluation following *IAEA TS-R-1, Paragraph 502*, *10 CFR 71.87*, and *49 CFR 173.475* (References **[7.1]**, **[7.2]**, and **[7.3]**, respectively). The evaluation is used to ensure that the packaging, with its proposed contents, satisfies the applicable requirements of the transport package's license or certificate. This evaluation includes, but is not limited to, the review of the following:

- Proposed contents' isotopic composition, quantities, and decay heat;
- Proposed contents' form, weight, and geometry. If the content is defined as *Special form*, verify its certification from the competent authorities;
- Identify shoring device to be used. Shoring device materials used within the cask cavity shall have a melting point greater than 538°C (1,000°F);
- Shielding requirements (use of additional shielding devices may be required for shipment);
- Structural requirements;
- Thermal requirements;
- Pressure requirements;
- Shipping hardware (such as liners, racks, dividers, baskets, and shoring devices);
- Maintenance records.
- Personnel qualification.

In addition, operations at the loading facility must safely support a range of activities, from receiving and inspecting the package, to preparing the loaded transport package for shipment. Each loading facility must provide fully trained personnel and detailed operating procedures to cover these activities.

7.1.1 Preparation for Loading

7.1.1.1 Receiving and Inspecting the Empty Transport Package

To receive and inspect the empty transport package:

a. Position the transport vehicle in the Receiving Inspection area.
b. Visually inspect the transport package for damage and proper labeling and marking. Refer to the shipping paper for shipment category and compare the marking and labels on the package to the requirement of Reference **[7.3]**.
c. Verify that the radiation and contamination levels are in compliance with regulatory requirements – *IAEA TS-R-1, Paragraphs 508* and *530* through *532*, *10 CFR 71.47* and *71.87(i)*, *49 CFR 173.441* and *173.443*, and *10 CFR 20.1906* (References **[7.1]**, **[7.2]**, **[7.3]**, and **[7.4]**, respectively).
d. Record any finding(s), and notify the Job Supervisor for disposition of the finding(s). Findings must be evaluated against *10 CFR 71.95* **[7.2]**, to determine whether they require regulatory notification, so proper action can be taken. The Job Supervisor is the person responsible for direct oversight of the personnel that are performing the work.

7.1.1.2 Removing the Transport Package from the Transport Vehicle

To remove the transport package from the transport vehicle:

a. Position the transport vehicle, in the job staging area, for transport package removal. This operation can be aided by the use of a overhead crane or forklift truck.

b. Position the spreader bar or forks, then connect the appropriate slings and shackles to remove the shipping cage.

c. Remove the shipping cage and tie-down hardware.

d. Depending upon site-specific constraints, do one of the following:
   - Remove the upper impact limiter from the cask, then place the impact limiter into temporary storage.
   - Install trunnions. Prior to the installation, apply an anti-vibration compound on the trunnion bolt threads.
   - Lift and remove the entire package from the transport vehicle, then set down the package in an appropriate location. Next, remove the impact limiters from the cask, and place them into temporary storage.

e. Remove the cask, using the appropriate rigging equipment.

f. Transfer the cask to the loading area.

7.1.2 Loading of Contents

7.1.2.1 Preparing for Loading

To prepare the transport package for loading:

a. Verify that the content to be loaded is authorized by the current transport package's Certificate of Compliance. (Refer to the Pre-Shipment Engineering Evaluation in Section 7.1.)

b. Perform a visual inspection. Note any damage or unusual conditions. If part functionality is impaired, repair or replace the part, as required, and document the repair or replacement, then re-inspect the part. Notification and approval of AOS is required. Replacement or repair of any component requires that all original examinations and tests initially prescribed be performed.

c. Depending upon the particular transport package model, remove the cask trunnions and install a lifting device specific to the facility. If using a forklift to transport the cask, protect the cask surface and secure the cask to the forks with straps. If lifting by crane, with or without a spreader bar, the lifting slings must not make an angle greater than 30°, measured from the vertical.

d. With proper radiological protection and monitoring, remove the cask lid and cask lid plug for visual inspection of the cavity.

e. Record any finding(s), and notify the Job Supervisor for disposition of the finding(s). Findings must be evaluated against *10 CFR 71.95* **[7.2]**, to determine whether they require regulatory notification, so that proper action can be taken.

f. Visually inspect the cask and cask lid sealing surfaces for damage or foreign material. Repair or replace damage noted, as required, then re-inspect.

g. Remove the cask drain port, test port, and cask vent port covers, and pipe plugs.

h. Install the lid guide pins, 90° apart. Use of the lid guide pins is mainly required for proper alignment of the cask lid with the cask lid attachment bolt holes. It also protects the cask lid elastomeric or metallic seal.

7.1.2.2 Loading Irradiated Hardware or Other Contents

To load contents:

a. Place the radioactive contents to be shipped into a shoring device (such as a rack, basket, or other such device).

   The liner and axial shielding plates listed in Table 7-1 are used during the shipment of radioisotope capsules, either in *Normal* or *Special form*, when identified in the Pre-Shipment Engineering Evaluation (refer to Section 7.1), as required for shipment to meet regulatory requirements.

b. Shore the load within the cavity, if needed.

c. Place the cask lid plug into the cask.

Table 7-1. Additional Required Shielding – Models AOS-025A, AOS-100A, AOS-100B, and AOS-100A-S

Model	Device	Drawing No.	Rev.	Comments
AOS-025A	Liner	183C8485	Latest	Use when additional shielding is required. (Refer to Table 1-2, "Activity Limits – All Models.")
AOS-100A AOS-100B AOS-100A-S	Axial Shielding Plates	183C8491	Latest	

7.1.2.3 Installing the Cask Lid

Note: *Visually inspect the cask and lid sealing surfaces, as well as the cask lid seal to be used, for damage that can prevent proper sealing of the sealing joint. Refer to Subsection 8.2.2, "Leakage Tests [8.4]," for detailed inspection of these items. If the cask lid seal (elastomeric or metallic) is replaced, a Maintenance Test must be performed, in accordance with ANSI N14.5 (Reference* **[7.8]**).

To install the cask lid, after verifying that the cask lid seal is properly installed, use proper rigging to slowly lower the cask lid onto the cask, over the lid guide pins. Carefully monitor this operation to ensure that the cask lid is properly aligned. During the placement of the cask lid, two lid guide pins are installed in the cask lid threaded holes perpendicular to each other to maintain alignment of the cask lid attachment bolt holes with the cask lid threaded holes.

7.1.3 Preparation for Transport

7.1.3.1 Securing the Cask Lid

To secure the cask lid, in preparation for transport:

Note: *Torque sequence is stamped on top surface of the cask lid, about the bolt location.*

a. Torque the cask lid attachment bolts (refer to Table 7-2), using one of the two conditions listed below.

   1. **If the cask was dry loaded** – Torque the cask lid attachment bolts in a crisscross pattern, with a final pass all the way around, to ensure even seal compression after the elastomeric seal has been visually inspected and installed, –or– a new metallic seal has been installed.

   2. **If the cask was wet loaded** – To torque the cask lid attachment bolts, if the cask was wet loaded:

      a. Install a minimum of at least five (5) bolts in the cask lid, as the cask breaks the water's surface.

      b. Drain the cask over the pool area. After the water has drained from the cask, move the cask to the decontamination pad.

      c. Remove the bolts (previously installed for the transfer) and cask lid.

      d. Dry the sealing surfaces and the bolt threaded holes.

      e. Install the cask lid elastomeric seal after it has been visually inspected, –or– a new cask lid metallic seal onto the cask lid, then re-install the bolts and torque the cask lid attachment bolts in a crisscross pattern, with a final pass all the way around, to ensure even seal compression.

      f. Flush the cask cavity with dry air or nitrogen, to displace any remaining water within the cavity.

      g. Vacuum-dry the cavity until the cask cavity pressure is 1 torr or less.

         The vacuum source must be isolated after the pressure is 1 torr or less. The pressure within the cask cavity must remain at or below 1 torr, for at least 30 minutes. Gas discharged from the vacuum pump should be filtered, to prevent airborne release of radioactive material that might be present within the gas stream. After completing this operation, fill the cask cavity with helium, to 2 psig ±0.5 psig.

      h. Figure 7-4 illustrates a typical vacuum drying system and its basic components. These components include an ultrafine vacuum pump, vacuum pressure gauge, cryogenic water trap, vacuum connectors, and valves.

         If the vacuum pump used in this procedure is equipped with a "gas ballast" device, turn off the device during the cask cavity vacuum drying operation. The gas ballast device is used to dry any moisture that might be trapped within the vacuum pump oil. If it is necessary to remove water vapor from the pump oil during the vacuum drying operation, isolate the system. Turn on the gas ballast device until the water vapor is removed from the oil, turn off the gas ballast, then place the system back online.

b. Install the cask drain port plugs, cask vent port plugs, and covers, as applicable. Prior to installation, apply pipe thread sealant on the plug thread areas.

Table 7-2. Cask Lid Attachment Bolt Size and Preload Torque – All Models[a]

Model	Function	Bolt Size / ASME and ANSI Standards	Preload Torque	
			N-m	ft-lb
AOS-025	Cask Lid Attachment Bolt	3/8-16 UNC-2A / ASME SB-637, UNS N07718	47	35
AOS-050	Cask Lid Attachment Bolt	1/2-13 UNC-2A / ASME SB-637, UNS N07718	85	62.5
AOS-100	Cask Lid Attachment Bolt	7/8-9 UNC-2A / ASME SB-637, UNS N07718	678	500

a. Refer to Table 1-5, "AOS Transport Packaging System Certification Drawing List – All Models."

Figure 7-4 illustrates a typical Leak testing setup (vacuum drying system and its basic components) that can be used for all AOS Radioactive Material Transport Packaging System models (Models AOS-025A, AOS-050A, AOS-100A, AOS-100B, and AOS-100A-S).

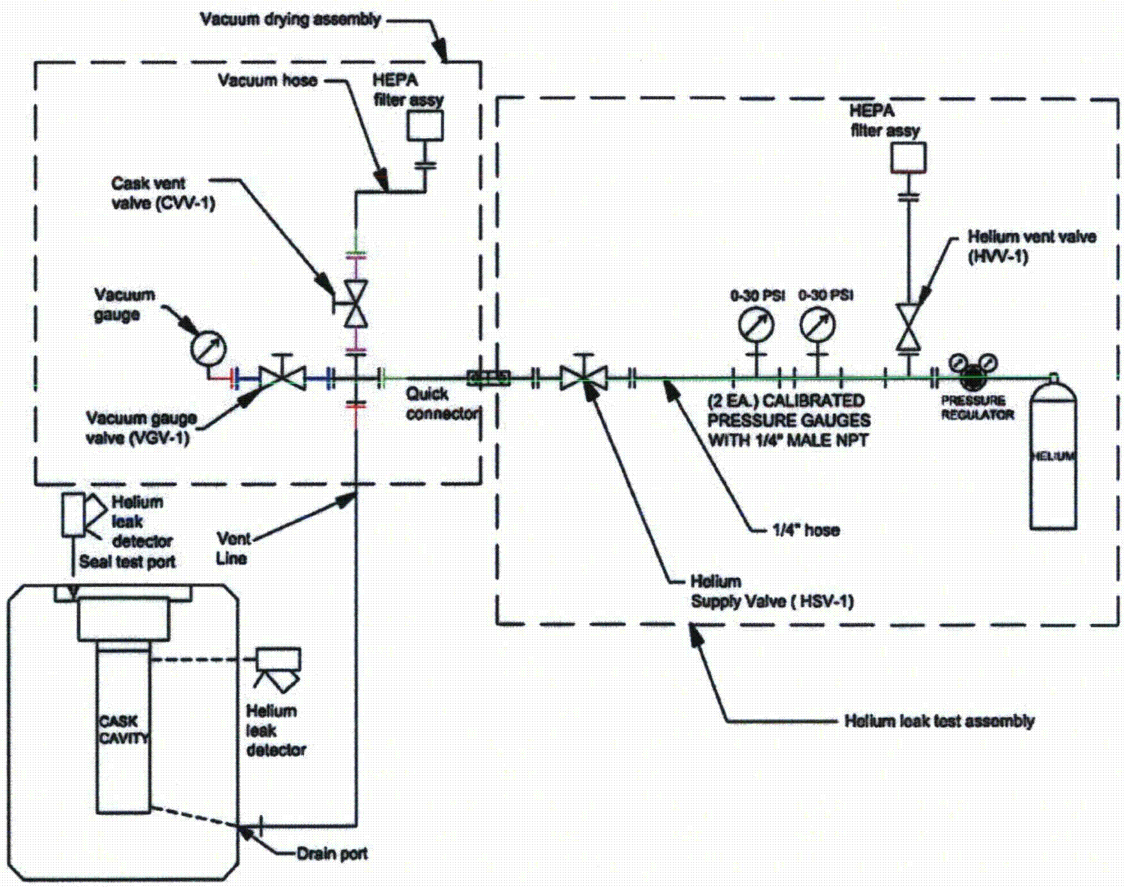

Figure 7-4. Typical Vacuum Drying System Setup and Equipment

7.1.3.2 Removing the Cask from the Loading Area

To remove the cask from the loading area, in preparation for transport:

a. Carefully measure the cask radiation levels, while removing the cask from the storage basin or cell area.

b. Decontaminate the cask to a level consistent with *IAEA TS-R-1, Paragraph 508*, *10 CFR 71.87(i)*, and *49 CFR 173.443* (References [7.1], [7.2], and [7.3], respectively).

7.1.3.3 Pre-Shipment Leak Testing (*Normal Form* Content Only)

To verify that the containment system of the transport package is properly assembled for shipment, perform the following Pre-Shipment Leak test:

Note: *When the Model AOS-100A-S is used, each cask closure seal must be leak tested.*

a. Perform a leak test of the cask closure seal, drain threaded pipe plugs, and vent threaded pipe plugs, with a thermal conductivity sensing instrument or mass spectrometer device, using the sniffer method. These types of instruments are sufficiently sensitive to detect and quantify the presence of helium within a gas stream. Pressurize the cask cavity to a pressure differential of one (1) atmosphere relative to the outside of the containment boundary.

   Helium can be introduced, using the "quick connect" fitting at the cask vent port, with approved plugs re-installed at the end of the test. (Refer to Paragraph 7.1.3.1 for test setup.)

b. Set up the test instrument, in accordance with written procedures and the instrument manufacturer's guidance.

Note: *Leak Test criteria for leak rates must meet the requirement of Reference* [7.8].

c. With the instrument selected in step a calibrated to a sensitivity of at least 1×10^{-5} cm^3/sec if the cask lid elastomeric seal is used, –or– 1×10^{-9} cm^3/sec if the cask lid metallic seal is used (helium), check the package containment, by sniffing with the test instrument, through the test port, the volume between seal O-Rings and retainer rings (elastomeric seal) or double "C" cross-sections (metallic seal), and around the threaded joint area of the drain and vent threaded pipe plugs, for indications of leakage.

d. If leakage greater than 1×10^{-3} atm cm^3/sec for the elastomeric seal or 1×10^{-7} cm^3/sec for the metallic seal is detected, repair or replace the damaged component(s), then re-test for leakage.

7.1.3.4 Preparing the Cask for Transport of Radioactive Material

To prepare the cask for transporting radioactive material:

a. Transport the cask to the staging area.

b. Perform a radiological survey of all cask surfaces (refer to Table 7-3), to demonstrate compliance with applicable shipping regulations.

Table 7-3. Maximum Distance from Loaded Cask Surface to Take Surface Dose Measurements – All Models

Model	Axial Dose Point Maximum Distance from Cask Surface in.	Radial Dose Point Maximum Distance from Cask Surface in.
AOS-025	2	1
AOS-050	5	3
AOS-100	10	6

c. Remove any site-specific lifting devices from the cask.

Note: *The transport packages require that the lower impact limiter must first be installed on the pallet, before placing the cask in the impact limiter.*

d. Verify that the lower impact limiter is installed on the pallet:

1. **If the lower impact limiter was left on the pallet** – Place the cask into the impact limiter/ pallet assembly.
2. **If the complete transport package was removed** – Place the lower impact limiter on the pallet, then place the cask into the lower impact limiter.

e. Install and secure the upper impact limiter.

f. Verify that the lettering on the identification nameplate is distinguishable and conforms to the Packaging Certification drawing requirement. Re-stamp the lettering or replace the nameplate, if necessary.

g. Remove old shipping labels and apply new ones, based upon the proposed payload, meeting the requirements of *IAEA TS-R-1, Paragraphs 526* and *541* through *543* and/or *49 CFR 172.403* (References **[7.1]** and/or **[7.7]**, respectively).

h. Apply security seals to two opposite latch pins or turnbuckles, as illustrated in Figure 7-5 and Figure 7-6, respectively.

i. Install the shipping cage.

Note: *The transport package does not contain any parts nor devices that need to be rendered inoperable, pursuant to IAEA TS-R-1, Paragraph 608, 10 CFR 71.45(a), and 49 CFR 173.410(b) (References* ***[7.1]****,* ***[7.2]****, and* ***[7.3]****, respectively).*

j. Complete the radiological survey of the transport package and transport vehicle, consistent with *IAEA TS-R-1, Paragraphs 508* and *530* through *532*, *10 CFR 71.47* and *71.87(i)*, *49 CFR 173.441* and *173.433*, and *10 CFR 20.1906* (References **[7.1]**, **[7.2]**, **[7.3]**, and **[7.4]**, respectively).

k. Apply any additional shipping label or marking that might be required to properly represent the transport package and its content, in accordance with Reference [7.3].

Note: *Repeat step l until two (2) consecutive readings taken at least five (5) minutes apart show a temperature difference of less than 3°F.*

l. Using a hand-held infrared thermometer or equivalent device, conduct a thermal survey for maximum temperature upon:
   - All reachable surfaces of the cask, if any
   - Impact limiters
   - Shipping cage
   - Pallet or shipping cradle

   This step verifies that the requirements of *IAEA TS-R-1, Paragraph 652*, and *10 CFR 71.43(g)* (References [7.1] and [7.2], respectively) are met.

m. Apply the security seal, if used, to the shipping cage, as illustrated in Figure 7-7.

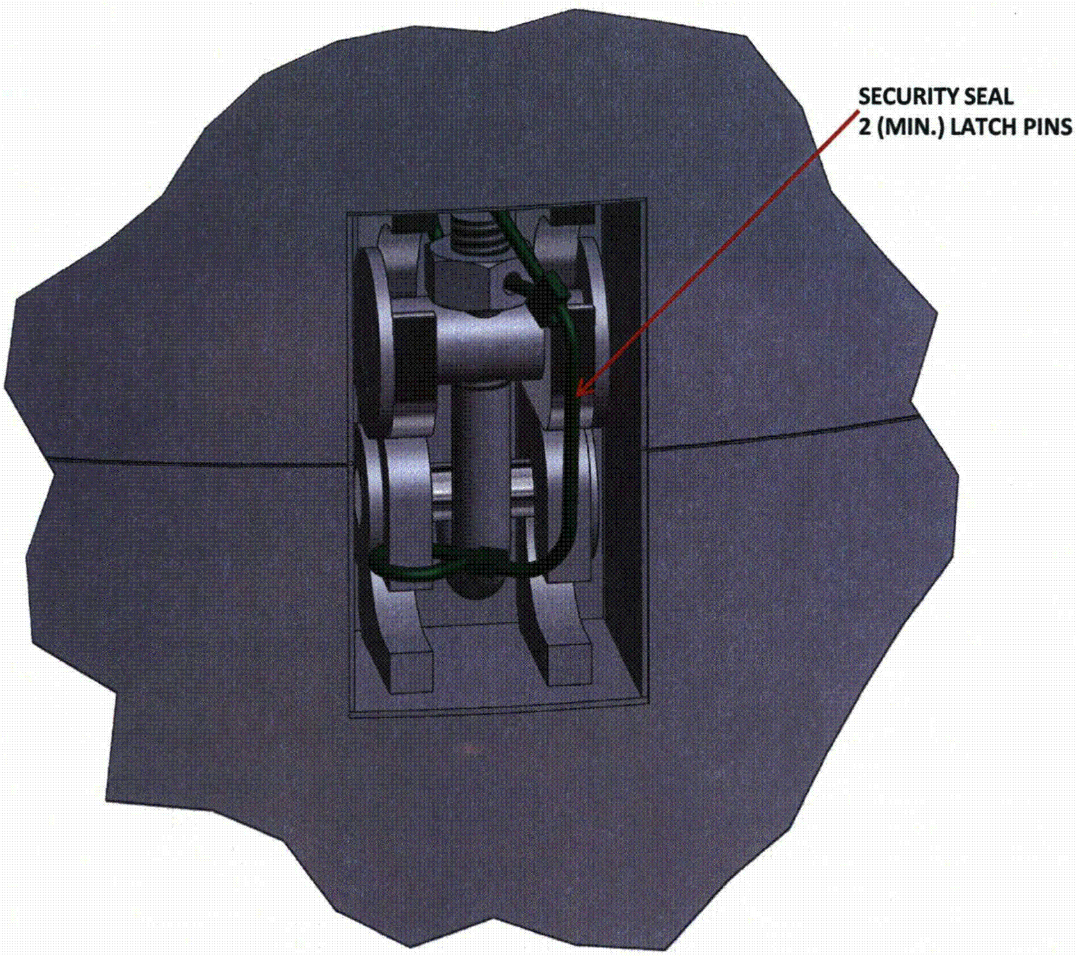

Figure 7-5. Latch Pin Security Seal

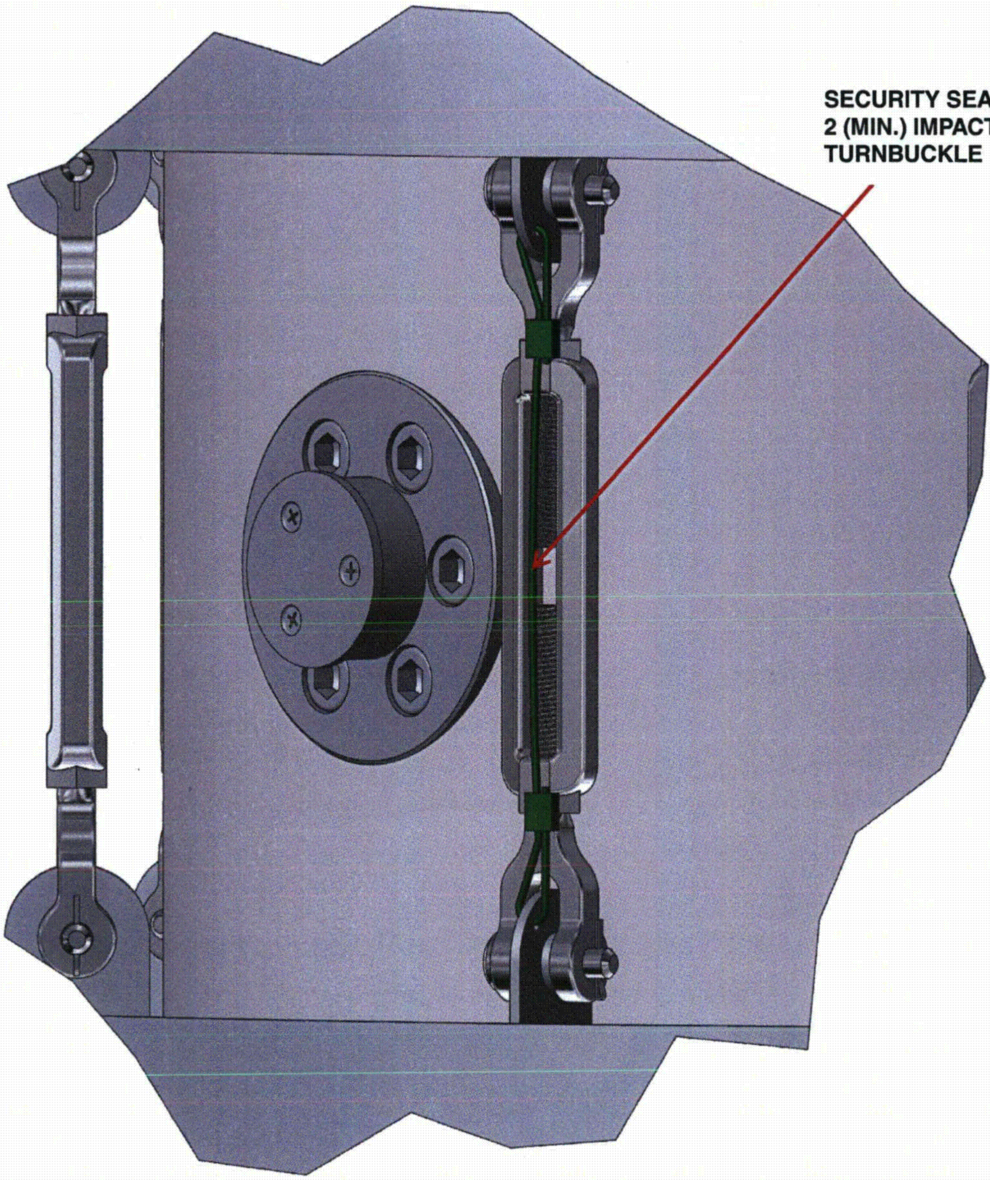

Figure 7-6. Turnbuckle Security Seal

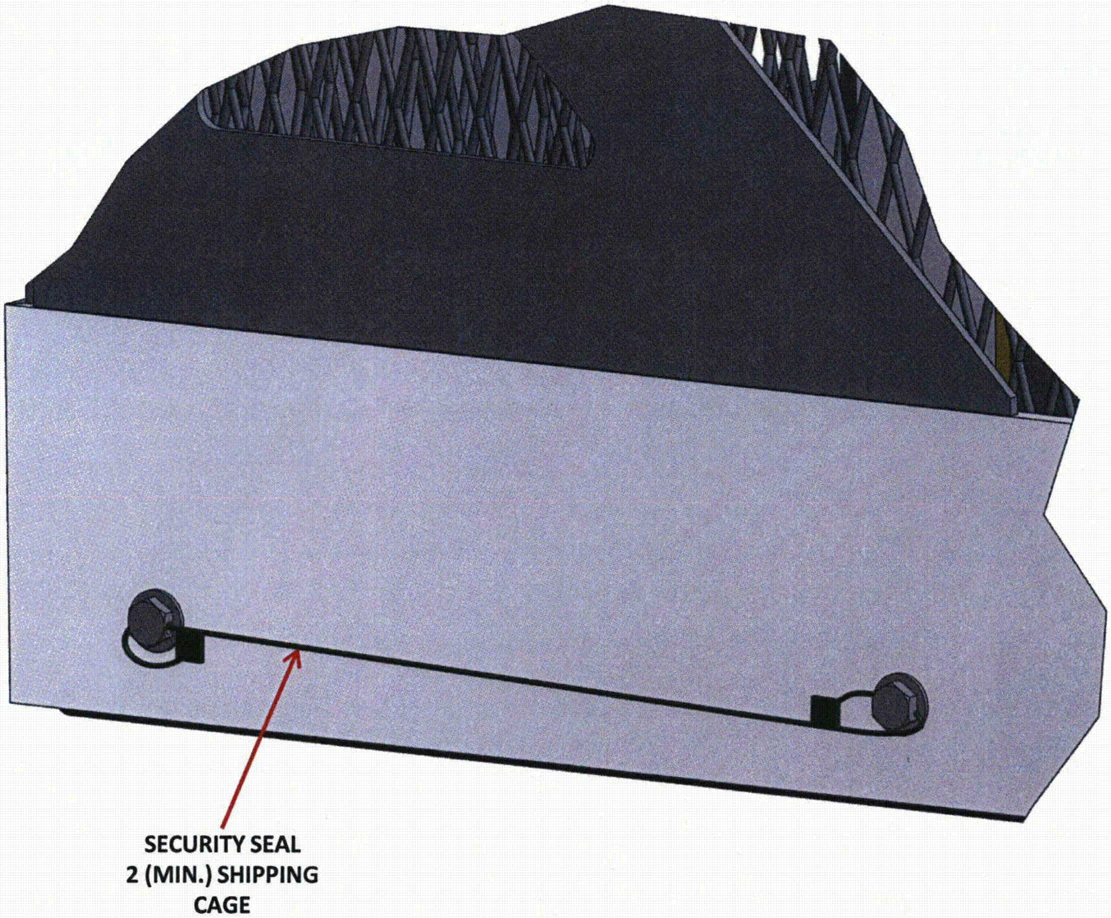

Figure 7-7. Shipping Cage Security Seal

7.2 PACKAGE UNLOADING

Note: *The operational steps provided in this section apply to all AOS Radioactive Material Transport Packaging System models (Models AOS-025A, AOS-050A, AOS-100A, AOS-100B, and AOS-100A-S). Any step specific to a given Model is identified within the step.*

Operations at the unloading facility are largely the reverse of the loading operations. Each unloading facility must provide fully trained personnel, and supply detailed operating procedures to cover all activities, as required by *10 CFR 71.89* **[7.2]**.

Before handling the packages, consider the following items:

a. Review all shipping manifests against what is expected.

b. Ensure that personnel involved in operations of the AOS Transport Packaging System are familiar with all documents pertinent to the operation and maintenance of the transport packages, and that they have received HAZMAT training, per *49 CFR 172.704* **[7.7]**.

c. Review Table 2-7, "AOS Transport Packaging System Maximum Authorized Package Weight and Cg Locations – All Models" (which lists the packages and their components weights), for the purpose of selecting the proper handling devices.

d. Review Table 3-3, "Maximum Temperature Summary, Normal Conditions of Transport – All Models," Table 3-4, "Maximum Temperature Summary, Hypothetical Accident Conditions of Transport (Condition 3) – All Models," Table 4-6, "Maximum Cask Cavity Pressure Due to Normal Conditions of Transport – All Models," and Table 4-7, "Maximum Cask Cavity Pressure Due to Fire Condition – All Models," to be apprised of the packaging surface temperature and cavity pressures. These values represent maximum conditions.

e. Review the Activity Limits listed in Table 1-2, "Activity Limits – All Models." These values represent maximum conditions.

f. Review the AOS Transport Packaging System drawings listed in Table 1-5, "AOS Transport Packaging System Certification Drawing List – All Models," in preparation for Receiving Inspection.

g. All repairs require AOS approval prior to performing the repairs. Any replacement of components requires notification to AOS.

7.2.1 Receipt of Package from Carrier

To receive the transport package from the carrier:

a. Verify the integrity of the transport package's security seals. If seals are broken, indicating package tampering, isolate the transport package and immediately notify the site's Safeguards organization, then wait for their instructions. Otherwise, remove the security seal, by cutting the wires, then properly dispose of them.

Note: *"Safeguards organization" refers to the organization or person at the facility responsible for radioactive material control and accounting.*

b. Repeat steps a through d in Paragraph 7.1.1.1, and steps b through e in Paragraph 7.1.1.2, to remove the package from the carrier.

c. Perform radiological and smear surveys of the cask surfaces, as described in step a in Paragraph 7.2.2.

7.2.2 Removal of Contents

Note: *The removal of content for all AOS Radioactive Material Transport Packaging System models (Models AOS-025A, AOS-050A, AOS-100A, and AOS-100B) is in the vertical orientation, with the exception of the Model AOS-100A-S, which is in the horizontal orientation.*

To prepare to unload contents:

a. Perform radiological and smear surveys of the cask surfaces. Compare the survey results with the pre-shipment data survey. Report any major discrepancies in the readings to the Job Supervisor, for disposition.
b. 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 Safeguards organization, then wait for their instructions.
c. Release the torque of the cask lid attachment bolts, then remove all but five (5) of the bolts, with the exception of the Model AOS-100A-S. For the Model AOS-100A-S, all bolts should remain in place, until the cask is ready to be unloaded.

Note: *At least five (5) cask lid attachment bolts must remain connected, while the cask is in transit within the site facility, for all models except the Model AOS-100A-S.*

d. Transfer the cask to the unloading area.
e. Remove the payload from the cask, following the detailed procedure developed for the facility, based upon the guidelines provided in this chapter.
f. If the cask contents are unloaded underwater or in a hot cell facility, perform the work as specified by the user (site) procedure.
g. After the cask contents are removed, confirm that the cask cavity is empty.

7.2.3 Installing the Cask Lid

Note: *The torque sequence is stamped on the top surface of the cask lid, about the bolt location.*

To install the cask lid:

a. Using proper rigging, slowly lower the cask lid, over the lid guide pins and onto the cask. Carefully monitor this operation, to ensure that the cask lid is properly aligned.
b. After the cask lid is seated, remove the lid guide pins.

Note: *Verify that the cask contents have been removed and that the cask cavity is empty of all material, before placing the lid onto the cask.*

7.2.4 Removing the Cask from the Staging Area

To remove the cask from the staging area:

a. Install and hand-tighten the cask lid attachment bolts.
b. Remove the cask to the storage area, per user (site) procedure.

7.2.5 Securing the Cask Lid

To secure the cask lid, perform steps b and c in Paragraph 7.3.2.

7.3 PREPARATION OF EMPTY PACKAGE FOR TRANSPORT

Note: *The operational steps provided in this section apply to all AOS Radioactive Material Transport Packaging System models (Models AOS-025A, AOS-050A, AOS-100A, AOS-100B, and AOS-100A-S). Any step specific to a given Model is identified within the step.*

This section describes operations that are typically performed after transporting radioactive material.

7.3.1 Inspecting the Cask Cavity

To inspect the cask cavity:

a. Remove the cask lid and cask lid plug from the empty cask and verify that the cask is empty.

b. Gather the necessary information, per site procedure, so that personnel can certify the transport package is "empty."

c. Perform a radiological survey of the cavity, to determine the extent of any contamination, in accordance with user (site) procedures.

d. If the cask is shipped as "empty," decontaminate the cavity to the limits defined in *IAEA TS-R-1, Paragraph 520*, and *49 CFR 173.428* (References **[7.1]** and **[7.3]**, respectively).

e. Visually inspect the cask cavity and ensure that there is no free-standing water. If free-standing water is present, dry the cask cavity. (The drying instructions are provided in Paragraph 7.1.3.1.)

7.3.2 Installing and Securing the Cask Lid

Note: *Re-use of the lid seal is allowed for empty packaging.*

To install and secure the cask lid:

a. Using proper rigging, slowly lower the cask lid plug and lid onto the cask, over the lid guide pins. Carefully monitor this operation, to ensure that the cask lid is properly aligned.

Note: *The torque sequence is stamped on the top surface of the cask lid, about the bolt location.*

b. Torque the cask lid attachment bolts (refer to Table 7-2) in a crisscross pattern, with a final pass all the way around, to ensure even seal compression.

c. Inspect the cask, to ensure that the cask drain port plugs, cask vent port plugs, and covers are properly installed.

7.3.3 Leak Testing to Verify the Assembly

Not applicable. Leak testing is not performed on empty packaging.

7.3.4 Preparing the Empty Cask for Transport

Decontaminate the external surfaces of the empty cask, to a level consistent with *IAEA TS-R-1, Paragraph 520*, and *49 CFR 173.428* (References **[7.1]** and **[7.3]**, respectively).

7.4 OTHER OPERATIONS

7.4.1 Records and Reporting Requirements

7.4.1.1 Records for Each Shipment

AOS Transport Packaging System users must maintain records of their shipments, per the requirements of *10 CFR 71.91* **[7.2]**, for at least three (3) years. In addition, shipment radiological surveys and monitoring must be recorded, per *10 CFR 20.2103* **[7.4]**. All records must be maintained, as per requirements documented in *10 CFR 21.51* **[7.5]**.

7.4.1.2 Package History Records

AOS maintains all historical records of the AOS Transport Packaging System, at their headquarters QA office. These records fulfill the requirements of *10 CFR 71.91* **[7.2]**, and are available to the NRC for inspection, upon request.

7.4.1.3 Reports

All notifications shall be as required by the applicable portion of *10 CFR 21* (Reference **[7.5]**).

Report all incidents that involve any significant reduction in package effectiveness during use, as well as any defect of safety significance, found after the first use of the package and thereof, any loss or theft of licensed material, radiation exposure to personnel or to the public above the limits specified in *10 CFR 20.1301* **[7.4]**, contamination or suspected contamination, and any fire, spillage, or breakage, as required by *10 CFR 21*, *10 CFR 20*, *49 CFR 171*, and *49 CFR 172* (References **[7.2]**, **[7.4]**, **[7.6]**, and **[7.7]**, respectively).

7.5 APPENDIX (NONE)

7.6 REFERENCES

[7.1] *International Atomic Energy Agency (IAEA) Safety Standards Series No. TS-R-1* (*IAEA TS-R-1*), "Regulations for the Safe Transport of Radioactive Material," 1996 Ed. (as amended 2003).

[7.2] U.S. Nuclear Regulatory Commission (NRC), *Title 10, Code of Federal Regulations, Part 71 (10 CFR 71)*, "Packaging and Transportation of Radioactive Material."

[7.3] U.S. Department of Transportation (DOT), *Title 49, Code of Federal Regulations, Part 173 (49 CFR 173)*, "Shippers – General Requirements for Shipments and Packagings."

[7.4] U.S. Nuclear Regulatory Commission (NRC), *Title 10, Code of Federal Regulations, Part 20 (10 CFR 20)*, "Standards for Protection Against Radiation."

[7.5] U.S. Nuclear Regulatory Commission (NRC), *Title 10, Code of Federal Regulations, Part 21 (10 CFR 21)*, "Reporting of Defects and Noncompliance."

[7.6] U.S. Department of Transportation (DOT), *Title 49, Code of Federal Regulations, Part 171 (49 CFR 171)*, "General Information, Regulations, and Definitions."

[7.7] U.S. Department of Transportation (DOT), *Title 49, Code of Federal Regulations, Part 172 (49 CFR 172)*, "Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements."

[7.8] American National Standards Institute, *ANSI N14.5-1997*, "Radioactive Materials – Leakage Tests on Packages for Shipment," February 5, 1998.

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8 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

This chapter describes the acceptance tests and maintenance program to be used for the AOS Transport Packaging System, required by *10 CFR 71*, Subpart G **[8.1]**. The acceptance tests are prescribed to verify materials of construction, fabrication processes, and the transport package's design to adequately meet the regulations, while the maintenance program outlined in this chapter assures the packaging's performance during its service life, in full compliance with this SAR.

General information related to the AOS Transport Packaging System given in the early chapters of this SAR. Refer to the drawings in Table 1-5, "AOS Transport Packaging System Certification Drawing List – All Models," for dimensions and materials of construction. Refer to Section 2.3, "Fabrication and Examination," for applicable Codes and Standards for design, fabrication, and testing of the AOS Transport Packaging System.

8.1 ACCEPTANCE TESTS

Table 8-1 presents a summary of the acceptance test program imposed on the AOS Transport Packaging System. The table is divided into two horizontal regions. The upper region of the table identifies the tests that are imposed to accept the material prior their use in the AOS Transport Packaging System. The lower region of the table identifies the tests that are imposed to verify the adequacy of the materials and/or components to meet their functionality. The vertical axis of the table identifies the type of test to be conducted, while the horizontal axis shows all AOS Transport Packaging System models. The information presented in this table is further detailed in the series of tables that follow. Additional details regarding the material specifications and specific test plans used during fabrication and maintenance follow in subsequent sections of this chapter.

Table 8-1. Acceptance Test Matrix

Test Type	Model		
	AOS-025A	AOS-050A	AOS-100A AOS-100B AOS-100A-S
Acceptance			
Materials			
Metals	✔	✔	✔
Foam[a]	✔	✔	✔
Seal[b]	✔	✔	✔
Welding Rods	✔	✔	✔
Verification			
Design Features			
Foam[c]	✔	✔	✔
Containment during fabrication[d]	✔	✔	✔
Thermal[e]	✔	✔	✔
Mechanical	Analytical procedure benchmarked by a Drop test of a transport package 165%-larger than the Model AOS-100A. Refer to Appendix 2.12.6, "Impact (Free-Drop) Test Report."		
Containment at assembly[f]	✔	✔	✔
Shielding[g]	✔	✔	✔

a. *Formulation tests are conducted upon initial order or formulation change.*

b. *Seal supplier to conduct independent material verification, per its Quality Assurance Program.*

c. *Batch tests are conducted upon each batch required to fulfill each impact limiter. Pour tests are conducted upon each pour of every batch.*

d. *Pressure test at 150% design pressure 10 CFR 71.85(b)* **[8.1]**.

e. *Thermal test is conducted upon the first unit of each model fabricated. Refer to Subsection 8.1.7.*

f. *MSLD He Test at least 2.00E-09 Std atm cm^3/sec sensitivity.*

g. *Refer to Subsection 8.1.6.*

8.1.1 Visual Inspections and Measurements

Visual examinations of all component surfaces, including welds and dimensional inspections, are conducted during packaging fabrication. These inspections, as well any other NDE inspections, are conducted according to approved written procedures. Their objectives are to identify harmful discontinuities or indications (such as overlaps, seams, cracks, porosity, crevices, and excessive oxidation), and to verify that the component or item critical dimensions are met, as specified in the certification drawings. (Refer to Table 1-5, "AOS Transport Packaging System Certification Drawing List – All Models," for a complete list.)

Visual and dimensional inspection results are recorded in accordance with the Purchaser's approved Quality Assurance and Fabrication plan. Refer to Subsection 2.3.2, "Examination," for additional details.

8.1.2 Weld Examinations

All welds within the cask component and impact limiters are visually inspected and liquid-penetrant tested (root and final passes). Also, the weld within the containment boundary must be ultrasonically examined and liquid-penetrant tested. These inspections are conducted to ensure that no cracks, incomplete fusion, nor lack of penetration exist. Parts that do not meet the established criteria are repaired or replaced, in accordance with written procedures issued by the Fabricator and approved by AOS.

The Model AOS-025, AOS-050, and AOS-100 transport packages use an ASME Code corner type C weld. This weld configuration is presented in Figure 4-2, "Typical Corner Cask Cavity Shell Weld Joint Configuration – All Models."

8.1.3 Structural and Pressure Tests

In addition to the test described in Subsection 8.1.2, the cask cavity is hydrostatically tested, to verify that the containment boundary can support the Design Pressure, per the requirements of NB6200, Subsection NB, Section III, of the ASME Code **[8.2]** and **[8.3]**. The Test Pressure is 1.5 times (1.5x) the Design Pressure. If this test were to fail, each component of the containment boundary must be evaluated and replaced, if necessary.

8.1.4 Leakage Tests

The AOS Transport Packaging System cask's entire containment boundary is leak-tested per Subsection 8.2.2(b), before its first use, and after its third use. The Periodic Leak test is to be performed in accordance with Subsection 8.2.2(b), every 12 months thereafter. The Leak test procedure shall meet the *ANSI N14.5-1997* **[8.4]** standard. The test uses a mass spectrometer leak detector (MSLD) in an evacuated envelope, with back pressurization technique. This technique consists of creating a 1-atm pressure differential across the boundary, and evacuating outside surfaces of the boundary, at critical locations (such as penetrations and seal joints) with the MSLD. The evacuated gases are passed through the instrument's spectrum portion to detect, quantitatively, the presence of gas, typically helium, used in the pressurization of the containment boundary. The criteria that is required to be met to establish the containment boundary's leak-tightness is 10^{-7} atm cm^3/sec or less, based upon dry air at 25°C (32°F) and for a pressure differential of 1 atm. The MSLD instrument must be sensitive to at least a 10^{-9} atm cm^3/sec reading.

Critical locations within the AOS Transport Packaging System are the cask lid seal joint, cask drain port, and cask vent port. These locations are tested by connecting the test probe to the test port that is located between the seal's two (2) seal rings (in the case of the seal joint) and port cover areas, and then determining the leak rate. If the leak-tightness criterion, per Reference **[8.4]**, is not met, the containment boundary is checked, damaged components (such as a seal or pipe plug) are replaced, and the unit is re-tested.

8.1.5 Component and Material Tests

8.1.5.1 Valve, Rupture Disks, and Fluid Transport Devices

Not applicable. Component tests of valve, rupture disks, and/or fluid transport devices are not applicable, because these components do not exist in the AOS Transport Packaging System.

8.1.5.2 Materials

Materials and testing requirements are denoted in Table 8-2 through Table 8-7. Materials are selected and tested in accordance with these specifications, following the approved Manufacturing and Fabrication Quality Assurance Plan when packages are manufactured or repaired.

With respect to FR-3700 series foam, Table 8-6 and Table 8-7 list the maximum value limits for acceptance of the foam formulation test results. These values include the +15% variation resulting from the manufacturing process.

Table 8-2. Type 304 and 316 Material Requirements

Definition	Requirements	Test Frequency	Remarks
Base Specification			
Suffix W	ASME SA-479/ASTM A 479 Type 304	–	Bar and Shapes
Suffix W1	ASME SA-479/ASTM A 479 Type 316	–	Bar and Shapes
Suffix X	ASME SA-312/ASTM A 312, Grade TP 304	–	Pipe
Suffix X1	ASME SA-312/ASTM A 312, Grade TP 316	–	Pipe
Suffix Y	ASME SA-182/ASTM A 182, Grade F 304	–	Forgings
Suffix Y1	ASME SA-182/ASTM A 182, Grade F 316	–	Forgings
Suffix Z	ASME SA-240/ASTM A 240, Type 304	–	Plate, Sheet, and Strip
Suffix Z1	ASME SA-240/ASTM A 240, Type 316	–	Plate, Sheet, and Strip
Chemistry Modification	$C \leq 0.050$ (all suffixes) N[a]	One Chemical Analysis Required per Heat	–
Heat Treatment	**Inventory Material** – 1,040°C (1,900°F), minimum, in accordance with the Base Specification. **New Wrought Material** – 1,040 to 1,149°C (1,900 to 2,100°F) for 15 minutes/25 mm (15 minutes/1 in.) of thickness, but not less than 15 minutes. **All Materials – Alternate quenching methods require prior AOS approval.**	One per Heat and Heat Treat Lot	Certification Statement
Descaling (Oxide Removal)	Pickling is conducted in accordance with Treatment Code A of ASTM A380. **Other descaling methods are permitted with prior AOS approval.**	–	After final solution heat treatment
Mechanical Tests	Properties at Room Temperature, as required by the Base Specification.	One per Heat and Heat Treat Lot	After final solution heat treatment
Hardness Test	Not to exceed Rockwell B90, per ASTM A370.	One per Heat and Heat Treat Lot	After final solution heat treatment

Table 8-2. Type 304 and 316 Material Requirements (Continued)

Definition	Requirements	Test Frequency	Remarks
Sensitization Test	ASTM A262 Practice A - Modified – Material having ditching greater than 5% is unacceptable. Can be waived by AOS for material not exposed to reactor water environments at elevated temperatures for extended periods of time.	**Inventory Material** – 10% of Supplied Pieces **New Material** – One per Heat and Heat Treat Lot	After final solution heat treatment
Intergranular Attack	Surface sample after pickling or if pickling is not used after final heat treatment – IGA or pitting in excess of 0.025 mm (0.001 in.) deep is unacceptable.	**Inventory Material** – 10% of Supplied Pieces **New Material** – One per Heat and Heat Treat Lot	After final solution heat treatment and oxide removal (if applicable)
Non-Destructive Examination	As required by the Base Specification and/or applicable ASME Section III requirements (References **[8.2]** and **[8.3]**).	100%	–

a. Nitrogen can be added, as necessary (up to the limits of the Base Specification), to achieve mechanical properties.

Table 8-3. Bolting/Screw Material Requirements

Definition	Requirements	Test Frequency	Remarks
Base Specification			
Suffix W	ASME SA-193, Grade B6 UNS S41000	–	Screw materials
Suffix Z	ASME SB-637, UNS N07718	–	Bolting materials
Chemistry Modification (Weight %)	No modification. Chemistry as required by the Base Specification.	One Chemical Analysis Required, per Heat	–
Heat Treatment	As required by the ASME Specification.	One per Heat and Heat Treat Lot	Certification Statement
Mechanical Tests	As required by the ASME Specification.	One per Heat and Heat Treat Lot	After heat treatment, per ASME SA370
Hardness Test	As required by the ASME Specification.	One per Heat and Heat Treat Lot	After final heat treatment
Sensitization Test	Test not required.	–	–
Intergranular Attack (IGA)	Surface sample after pickling, or if pickling is not used, after final heat treatment. IGA or pitting in excess of 0.025 mm (0.001 in.) deep is unacceptable.	After Pickling	AOS to approve sampling plan
Weld Repair	Weld repair is not permitted on bolting materials.	–	–
Non-Destructive Examination	As required by Code, as a minimum.	100%	–

Table 8-4. Casting Pipe/Casting Material Requirements (Type CPF-8, CF-8)

Definition	Requirements	Test Frequency	Remarks
Base Specification			
Suffix T	ASME SA-451/ASTM A 451 Grade CPF8	–	Cast Pipe
Suffix U	ASME SA-351/ASTM A 351 Grade CF8	–	Casting
Chemistry Modification	As required by the ASME Specification.	One Chemical Analysis Required per Heat	–
Ferrite Content	Controlled within the allowable limits of the Base Specification, to produce a minimum ferrite content of 5%, as determined magnetically by Practice ASTM A800, S1.	One Analysis Required per Heat and Heat Treat Lot	Ferrite to be measured on an actual casting, after final solution heat treatment
Heat Treatment	Solution Heat Treat at 1,066 to 1,149°C (1,950 to 2,100°F) for 15 minutes/25 mm (15 minutes/1 in.) of thickness, but not less than 15 minutes, in accordance with the Base Specification.	One per Heat and Heat Treat Lot	Certification Statement
Mechanical Tests	Properties at Room Temperature, as required by the Base Specification.	One per Heat and Heat Treat Lot	After final solution heat treatment
Hardness Test	As required by the Base Specification.	One per Heat and Heat Treat Lot	After final solution heat treatment
Sensitization Test	Not required.	–	–
Intergranular Attack (IGA)	Surface sample after pickling or if pickling is not used after final heat treatment. IGA or pitting in excess of 0.025 mm (0.001 in.) deep is unacceptable.	**Inventory Material** – 10% of Supplied Pieces **New Material** – One per Heat and Heat Treat Lot	After final solution heat treatment and oxide removal (if applicable)
Non-Destructive Examination	As required by the Base Specification, Radiography per NB-2575, and additional applicable requirements of ASME Section III (References [8.2] and [8.3]).	100%	–
Weld Repair	Procedures require AOS approval prior to performance of the repair work. Repairs to castings subsequent to solution annealing must be documented and submitted to AOS.	–	Buyer approval required for repair procedure

Table 8-4. Casting Pipe/Casting Material Requirements (Type CPF-8, CF-8) (Continued)

Definition	Requirements	Test Frequency	Remarks
Cleaning/Surface Preparation	Surfaces shall be visibly free of miscellaneous processing materials and essentially free of contaminants of concern, including chlorides, fluorides, sulfur, bromides, lead, mercury, and other low-melting-point metals. Water used for cleaning must meet the following requirements: **Attribute** / **Potable Water** / **Demineralized** pH at 25°C (77°F) / 5.5 to 8.0 / 5.5 to 8.0 Chlorine, ppm / < 35 / < 1 Fluorine, ppm / < 10 / < 1 Sulfide, ppm / < 1 / < 1 Silica / – / < 0.05 ppm Conductivity µS/cm / – / < 3 Final cleaning must be conducted with demineralized water, and can be conducted by the Fabricator.	All Materials	–

Table 8-5. LAST-A-FOAM FR-3700 Series Foams – Testing Program

Type of Test[a]	Test Description	Applicable Reference	Number of Samples	Nominal Value	Tolerance (of Nominal)	Sample size (in.)
Formulation	Density, pcf	ASTM D1622-03	3	18, 8, and 11[b]	Each ±15% Increment ±10%	2 × 2 × 1
	Static Crush Strength, psi[c]	General Plastics Manufacturing Company, TM-9704, Rev. K	3[d]	Report Value	Report Value	1 × 1 × 1 and 2 × 2 × 2
	Flame Retardancy	ASTM D1622-03	3	Burn length ≤ 6 in.	–	0.5 × 3 × 6+
	Intumescence	General Plastics Manufacturing Company, 9952037-00 and TM-9704, Rev. K	2	50%	Minimum	2 × 2 × 2
	Leachable Chlorides	General Plastics Manufacturing Company, GP-TM9510, Rev. B and EPA 300.0	1	1 ppm	< 1 ppm	2 × 2 × 2
	Thermal Conductivity, Btu-in/(ft^2-°F-h)	ASTM D1622-03	1	0.349	Each ±15%	8.0 diameter × 1.0 L
	Specific Heat, Btu/lb-°F	ASTM E1269-05	1	0.351	Each ±20%	As Required
	Water Absorption	ASTM E1269-05	3	0.05 lbs. of water per ft^2 in 96 hours	Not to exceed nominal	6 × 6 × 3
	Chemical Composition	–	1 per formulation	Report Value	Report Value	As Required

Table 8-5. LAST-A-FOAM FR-3700 Series Foams – Testing Program (Continued)

Type of Test[a]	Test Description	Applicable Reference	Number of Samples	Nominal Value	Tolerance (of Nominal)	Sample size (in.)
Batch	Density, pcf	ASTM D1622-03	3	18, 8, and 11[b]	Each ±15% Increment ±10%	2 × 2 × 1
	Static Crush Strength, psi[e]	General Plastics Manufacturing Company, TM-9704, Rev. K	3[f]	General Plastics Manufacturing Company, Technical Specification	Increment ±15%	2 × 2 × 1
	Flame Retardancy	14CFR14.25.853	3	Burn length ≤ 6 in.	–	0.5 × 3 × 6+
	Intumescence	General Plastics Manufacturing Company, 9952037-00 and GP-TM9510, Rev. B	3	50%	Minimum	2 × 2 × 2
	Leachable Chlorides	General Plastics Manufacturing Company, GP-TM9510, Rev. B & EPA 300.0	2	1 ppm	< 1 ppm	2 × 2 × 2
Pour	Static Crush Strength, psi[e]	General Plastics Manufacturing Company, TM-9704, Rev. K	3[f]	General Plastics Manufacturing Company, Technical Specification	Increment ±15%	2 × 2 × 1
	Density, pcf	ASTM D1622-03	3	18, 8, and 11[b]	Each ±15% Increment ±10%	2 × 2 × 1

a. *Formulation tests are conducted upon initial order or formulation change. Batch tests are conducted upon each batch required to fulfill each impact limiter. Pour tests are conducted upon each pour of every batch.*

b. *Density nominal values of 18, 8, and 11 pcf are associated with the Model AOS-025, AOS-050, and AOS-100, respectively.*

c. *The foam manufacturer will perform the Static Crush Strength test. In addition, a dynamic test will be performed by an independent testing laboratory as part of the Dedication Process toward a safety "Category A." The dynamic test shall be per ASTM D1621-10, and will follow the recommendation of this Standard, with the exception of the strain rate. The test will use a controlled dynamic strain rate of $60s^{-1}$. The values obtained from this test must be less than or equal to the corresponding values in Table 8-6 and Table 8-7.*

d. *Three (3) samples are tested at -40, 75, and 250°F, at strains of 10, 40, and 60% in each direction; Parallel to Direction of Rise and Perpendicular to Direction of Rise.*

e. *Strain Rate value for this test is approximately 0.14 in./min. Each sample shall meet the tolerance for the indicated test. In cases where multiple samples are taken, the indicated tolerance applies to the numerical average result of the samples. For example, the results of each Static Crush test must be ±20% of the nominal value, and the average of the three samples must be ±15% of the nominal value.*

f. *Three (3) samples are tested at 75°F, at strains of 10, 40, and 60% in each direction; Parallel to Direction of Rise and Perpendicular to Direction of Rise.*

Table 8-6. LAST-A-FOAM FR-3700 Series Foam Dynamic Crush Strength Limits, Parallel to Rise – All Models

Temp	Model					
	AOS-025		AOS-050		AOS-100	
at -28.9°C (-20°F)	Stress (psi)	Strain (in/in)	Stress (psi)	Strain (in/in)	Stress (psi)	Strain (in/in)
	2,556	0.1	608	0.1	994	0.1
	2,459	0.2	616	0.2	930	0.2
	2,558	0.3	630	0.3	964	0.3
	2,840	0.4	660	0.4	1,028	0.4
	3,411	0.5	750	0.5	1,195	0.5
	–	0.6	974	0.6	1,542	0.6
	–	0.65[a]	1,260	0.65[a]	1,983	0.65[a]
at 23.9°C (75°F)	Stress (psi)	Strain (in/in)	Stress (psi)	Strain (in/in)	Stress (psi)	Strain (in/in)
	1,893	0.1	471	0.1	736	0.1
	1,849	0.2	453	0.2	699	0.2
	1,938	0.3	477	0.3	730	0.3
	2,168	0.4	512	0.4	785	0.4
	2,604	0.5	595	0.5	912	0.5
	–	0.6	761	0.6	1,186	0.6
	–	0.65[a]	977	0.65[a]	1,549	0.65[a]
at 126.7°C (260°F)	Stress (psi)	Strain (in/in)	Stress (psi)	Strain (in/in)	Stress (psi)	Strain (in/in)
	757	0.1	212	0.1	294	0.1
	740	0.2	199	0.2	280	0.2
	795	0.3	219	0.3	299	0.3
	911	0.4	241	0.4	330	0.4
	1,068	0.5	286	0.5	374	0.5
	–	0.6	373	0.6	510	0.6
	–	0.65[a]	479	0.65[a]	666	0.65[a]

a. *The 65% values have been included for the completeness of data from General Plastics publications (Reference* [8.8]*); however, in the testing program, the 65% strain rate test is not conducted.*

Table 8-7. LAST-A-FOAM FR-3700 Series Foam Dynamic Crush Strength Limits, Perpendicular to Rise – All Models

Temp	Model					
	AOS-025		AOS-050		AOS-100	
at -28.9°C (-20°F)	Stress (psi)	Strain (in/in)	Stress (psi)	Strain (in/in)	Stress (psi)	Strain (in/in)
	2,632	0.1	586	0.1	913	0.1
	2,559	0.2	598	0.2	894	0.2
	2,628	0.3	642	0.3	928	0.3
	2,935	0.4	660	0.4	1,013	0.4
	3,432	0.5	748	0.5	1,169	0.5
	–	0.6	1,012	0.6	1,528	0.6
	–	0.65[a]	1,341	0.65[a]	1,978	0.65[a]
at 23.9°C (75°F)	Stress (psi)	Strain (in/in)	Stress (psi)	Strain (in/in)	Stress (psi)	Strain (in/in)
	1,964	0.1	444	0.1	681	0.1
	1,924	0.2	443	0.2	672	0.2
	1,991	0.3	479	0.3	703	0.3
	2,207	0.4	500	0.4	762	0.4
	2,640	0.5	567	0.5	899	0.5
	–	0.6	761	0.6	1,194	0.6
	–	0.65[a]	1,001	0.65[a]	1,595	0.65[a]
at 126.7°C (260°F)	Stress (psi)	Strain (in/in)	Stress (psi)	Strain (in/in)	Stress (psi)	Strain (in/in)
	766	0.1	200	0.1	266	0.1
	750	0.2	199	0.2	262	0.2
	796	0.3	225	0.3	281	0.3
	905	0.4	240	0.4	312	0.4
	1,082	0.5	272	0.5	369	0.5
	–	0.6	365	0.6	478	0.6
	–	0.65[a]	480	0.65[a]	638	0.65[a]

a. The 65% values have been included for the completeness of data from General Plastics publications (Reference [8.8]*); however, in the testing program, the 65% strain rate test is not conducted.*

8.1.5.3 Seal Testing

The testing conducted upon the seal during its fabrication is based upon the manufacturer's QA system requirements to produce a "Safety Classification A Component" [8.7].

8.1.5.4 Fabrication

Table 8-8 summarizes the AOS Transport Packaging System Fabrication examination program.

Table 8-8. Fabrication Examination Program Summary

Test Category	Test Type	Reference	Test Description
Component	Adherence to Drawing	Certification Drawings. Refer to Table 1-5, "AOS Transport Packaging System Certification Drawing List – All Models."	Visual and Dimensional inspections.
Sub-assembly			
Assembly	Pressure and Containment	ASME Code, Section V, and applicable requirements of *NB-6112*, Section III, and *ANSI N14.5*, Section 7.3.	Pneumatic and Leakage test, per Reference [8.4].
Weldment	NDE	ASME Code, Section V, and applicable requirements of *NX-5000*, Section III.	Visual, Penetrant, and Ultrasonic tests (VT, PT, and UT, respectively).

8.1.6 Shielding Tests

The AOS Transport Packaging System models use either tungsten alloy or carbon steel as their shielding material. Conducting a 100% UT examination of the shielding material surface provides the necessary inspection process for verifying the shielding attribute of these materials. As an alternate method, prior to the first use of the transport package, a Co-60 source can also be used. The source is placed inside the cask cavity, and its outside surface is surveyed with a gamma detection instrument. The source strength must be high enough to generate an external reading consistent with the capability of the survey instrument. Equally spaced meridian and circumferential lines, along the vertical axis, divide the cask outside surface into approximately 10 x 10 cm (4 x 4 in.) squares. Dose rate readings are taken over each corner and center of the square area created by these lines. The criterion used to evaluate the effect of material defects (such as voids and cracks) is that the dose rate cannot exceed 1.5 times (1.5x) the mean measurable dose rate.

8.1.7 Thermal Tests

The thermal test is conducted upon the AOS Transport Packaging System's cask component, to verify that the cask's temperature distribution is similar to the analytical model's predicted temperature distribution. Temperature variations are acceptable, as long as the test results are within 15% of the values predicted by the analytical model. The test is conducted upon the first unit produced of each AOS Transport Packaging System model (Models AOS-025, AOS-050, AOS-100A, AOS-100B, and AOS-100A-S). The new analytical models developed for this test must have the same component arrangement as that of the test prototype, to allow a direct comparison of results.

The selection of using only the transport package's cask component as the thermal test prototype is based upon its geometrical design and the materials used. The cask design consists of two concentric shells, creating an internal hollow space occupied by a series of rings or solid cylinder components. The shells are comprised of 300 series stainless steel material. The rings or solid cylinders are comprised of tungsten alloy or carbon steel. There are gaps and contact resistance areas created by the manufacturing and/or assembly of the cask components. The gaps can be occupied either by air or packed stainless steel wool. Understanding the heat transfer characteristic across these boundaries is essential to the accuracy of the analytical model. Furthermore, the cask component houses the transport package contents and containment boundary. The heat transfer characteristic across the boundaries between the cask and inner surface of the impact limiter, outside surface of the impact limiter, and exposed cask section are, in general, well-defined. Therefore, these characteristics can be modeled with few problems in a general-purpose computer code, and are not required to be verified by testing.

The thermal test consists of concentrically placing an electrical heat source, equal to the AOS Transport Packaging System model's maximum decay heat within its cask cavity. (Refer to Table 3-2, "Contents' Decay Heat – All Models.") Temperature-sensing devices are strategically placed (refer to Figure 8-1):

- At various locations within the cask cavity
- On exterior surfaces of the cask
- In the environment surrounding the cask

The packaging undergoing test is placed within a pit or closed room, to minimize outside effects that can be caused by the surrounding environment. The heat source is turned on, to a value equal to or greater than the decay heat value of the radioactive content proposed for the cask. Temperature data is recorded at a minimum interval of one (1) minute during the transient event, until the cask reaches a steady state and remains significantly unchanged for approximately one (1) hour. This completes the "heating cycle." Thereafter, the heat source is turned off, to allow the cask to cool down. The "cool-down cycle" is also recorded, as in the previous cycle.

Refer to Appendix 3.5.8, "Heat Test Report – AOS-165A Prototype," for a detailed discussion and results of this test, when conducted upon a 165%-larger package version of the Model AOS-100A.

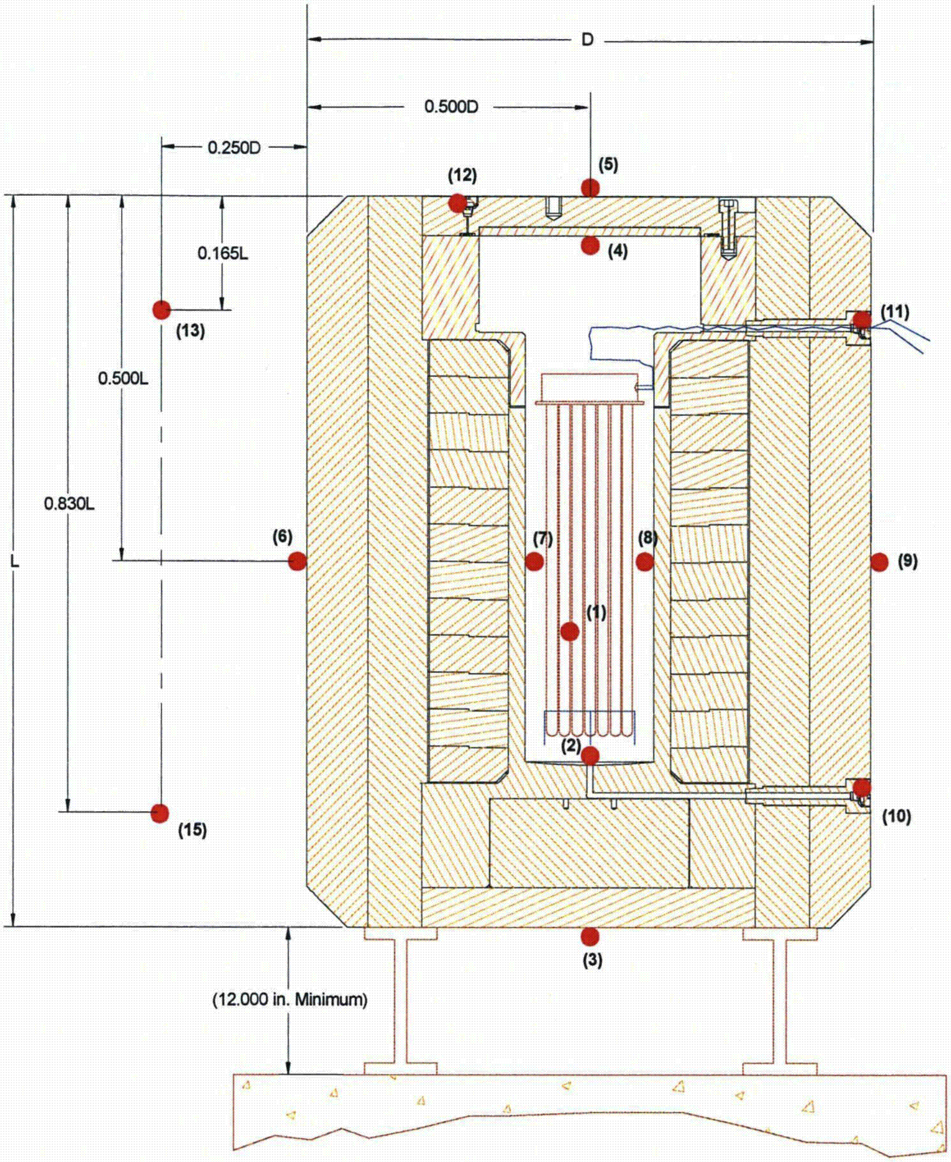


Figure 8-1. Typical Thermal Test Setup

Notes: *The numbered red dots in Figure 8-1 represent thermocouple locations.*

The cask lid plug component is removed, to allow the heater power wire to exit the cask body.

8.1.8 Miscellaneous Tests

No additional tests, other than those described in this chapter, are conducted on the AOS Transport Packaging System prior to it being placed into service.

8.2 MAINTENANCE PROGRAM

The cask maintenance program is described, in detail, in an Engineering Specification provided to all AOS Transport Packaging System users. This Specification shall implement the requirements established in this chapter. Packaging System operators can develop procedures of their own, to include site-specific requirements, if they remain within the Engineering Specification requirements.

Pre-shipment Inspections are conducted prior to each shipment. These inspections include visual checks of the packaging and any support structure(s) or device(s) required to properly assemble the transport package. They might also include pressurization of the cask cavity, which is part of the Leak test for *Normal form* content. Additionally, more detailed inspections are conducted annually, or prior to being used after a storage period of more than one (1) year, as detailed in Subsection 8.2.2(b). Pre-shipment Leak tests are conducted only when shipping *Normal form* material.

8.2.1 Structural and Pressure Tests

The only periodic pressure test performed on the AOS Transport Packaging System is the Leak test detailed in Subsection 8.2.2(b).

8.2.2 Leakage Tests [8.4]

Prior to leak testing, the cask lid seal, sealing surfaces, cask lid attachment bolts, and seal attachment screws must be inspected for damage such as scratches, dents, dirt, and oil residue. Also, the female thread holes for the cask lid attachment bolts and seal attachment screws must be checked. After completing the inspection, and repairing or replacing any damaged components, the seal is installed on the cask lid groove by the four (4) seal attachment screws, as illustrated in Figure 8-2 for the cask lid metallic seal, which also shows the location of the leak-testing hole.

Note: *Elastomeric O-Rings must be visually inspected for cuts, blemishes, debris, and/or permanent local deformation on the sealing surface. Damaged seals must be replaced. Elastomeric O-Rings must be replaced every 12 uses or once per year, whichever comes first.*

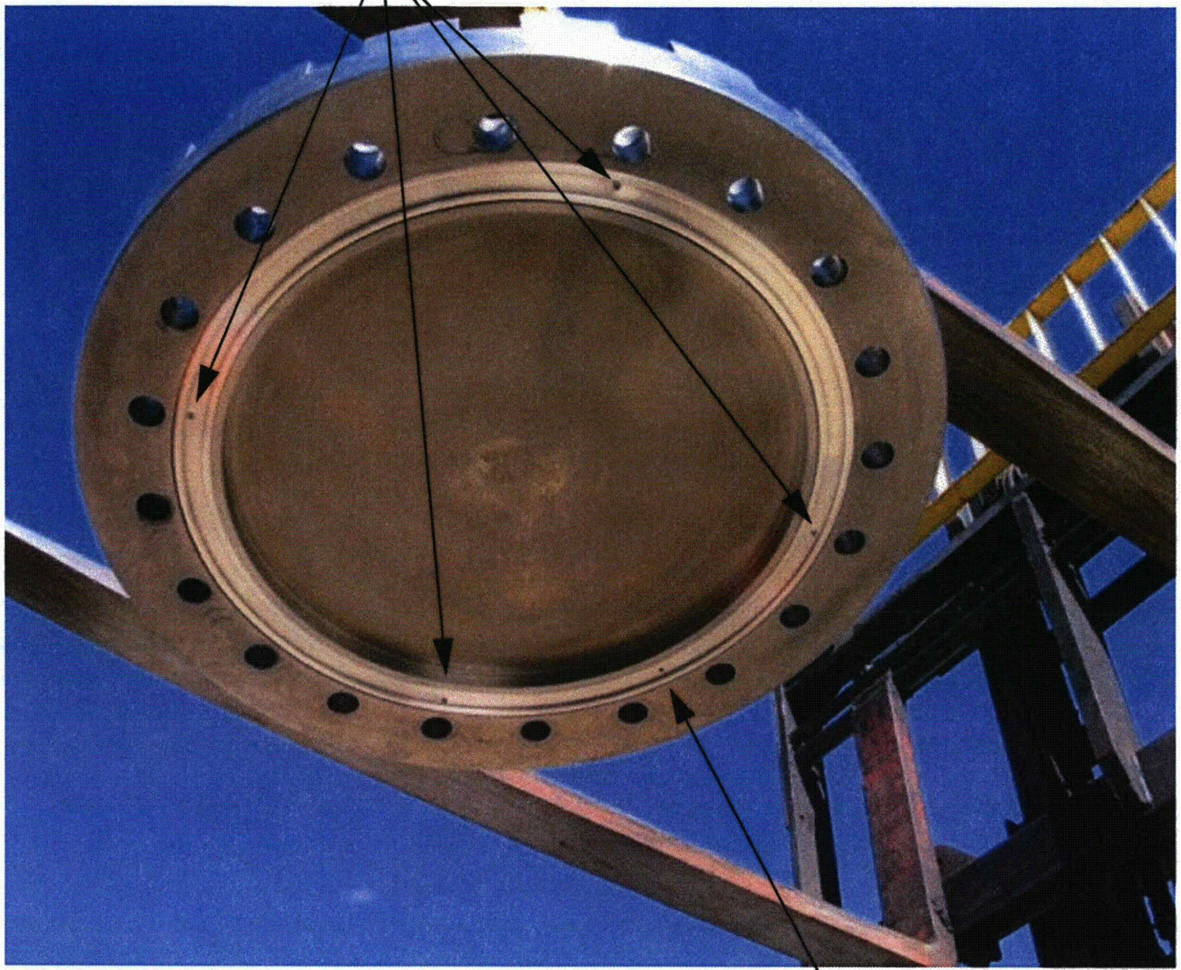
a. Pre-shipment Leak Testing (Conduct for *Normal form* content only)

Pre-shipment leak testing must be performed ***only*** before each shipment of *Normal form* content, after the content is loaded and the containment system is assembled. Perform the test with a thermal conductivity sensing instrument or mass spectrometer device, using the sniffer method. These types of instruments are sufficiently sensitive to detect and quantify the presence of helium within a gas stream. Pressurize the cask cavity to a pressure differential of one (1) atmosphere relative to the outside of the containment boundary. This test leakage rate need not be more sensitive than 1×10^{-3} ref-cm^3/sec.

b. Periodic Leak Testing

Periodic leak testing must be performed annually, or prior to the transport package being used, after a storage period of more than one (1) year, or prior to returning to service after repairs (such as weld repair) and/or replacing containment components. The cask lid seal, vent and drain threaded pipe plugs, and the port plug conical seal must be leak-checked with a helium MSLD. This instrument has a sensitivity of $< 1 \times 10^{-9}$ ref-cm^3/sec (helium). Conduct this test by pressurizing the cask cavity to one (1) atm pressure differential across the boundary to be tested (verified with a double pressure gauge), then use the MSLD to test all components of the containment boundary for leaks. If leakage greater than 2×10^{-7} ref-cm^3/sec helium at standard conditions is detected, repair or replace the damaged component(s), then re-test for leakage, to the same criteria as previously tested.

Cask Lid Metallic Seal Attachment Screws
(4 places, evenly spaced around seal)



Hole Used for Leak Testing

Figure 8-2. Cask Lid Showing the Cask Lid Metallic Seal Installed – Attachment by way of Four (4) Screws, and Leak-Testing Hole

8.2.3 Component and Material Tests

The AOS Transport Packaging System does not have any auxiliary cooling systems nor other subsystems that require maintenance other than those mentioned herein.

8.2.4 Thermal Tests

Thermal testing is conducted to verify the heat transfer characteristics of the AOS Transport Packaging System's cask component, as described in Subsection 8.1.7. No additional maintenance-related tests are conducted, because the materials of construction are stable, and routine operating procedures monitor the integrity of the transport package's thermal performance.

8.2.5 Miscellaneous Tests

No additional tests are conducted upon the AOS Transport Packaging System models other than those described within this chapter.

8.3 APPENDIX (NONE)

8.4 REFERENCES

[8.1] U.S. Nuclear Regulatory Commission (NRC), *Title 10, Code of Federal Regulations, Part 71 (10 CFR 71)*, "Packaging and Transportation of Radioactive Material."

[8.2] American Society of Mechanical Engineers, *ASME Boiler and Pressure Vessel Code*, Section III, Division 1, 2004, No Addenda.

[8.3] American Society of Mechanical Engineers, *ASME Boiler and Pressure Vessel Code*, Section III, Division 3, 2004, No Addenda.

[8.4] American National Standards Institute, *ANSI N14.5-1997*, "Radioactive Materials – Leakage Tests on Packages for Shipment," February 5, 1998.

[8.5] *International Atomic Energy Agency (IAEA) Safety Standards Series No. TS-R-1* (*IAEA TS-R-1*), "Regulations for the Safe Transport of Radioactive Material," 1996 Ed. (as amended 2003).

[8.6] U.S. Nuclear Regulatory Commission (NRC), *Title 10, Code of Federal Regulations, Part 71 (10 CFR 71)*, "Packaging and Transportation of Radioactive Material."

[8.7] NUREG/CR-6407, *Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety,* Idaho National Engineering Laboratory, Idaho Falls, Idaho, February, 1996.

[8.8] General Plastics Manufacturing Company, *Design Guide for Use of LAST-A-FOAM FR-3700 for Crash & Fire Protection of Radioactive Material Shipping Containers*, Tacoma, WA, March, 1998 (revised October, 2003).

In memory of Sean O'Flaherty Fahey, PhD.
CSA Engineering, Inc.

December 4, 1973 – January 22, 2006

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