1 GENERAL INFORMATION

1.1 INTRODUCTION

This safety analysis report (SAR) is for a Type B(U)-96 non-fissile transport package, hereafter identified as a Radioactive Transport Packaging System, AOS Transport Packaging System, or transport package (in general). The transport package is configured in three (3) different sizes, identified as Models AOS-025, AOS-050, and AOS-100. These package models consist of three (3) main components – cask, impact limiter, and cask lid seal – as presented in Section 1.2. The transport packages will be used to transport Type B quantities of encapsulated solid materials or solid metals that meet *Normal* or *Special Form* criteria. The authorized quantities of material to be transported is dependent upon the type of material being shipped and the associated decay heat load, or the radioactive shielding requirements, as appropriate, to provide containment and radiation shielding protection of the contents during Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC) of Transport, as required by *Title 10, Code of Federal Regulations, Part 71* (*10 CFR 71*) **[1.1]**. The AOS Transport Packaging System components are designed, fabricated, examined, and tested to the applicable requirements of the *ASME Boiler and Pressure Vessel (B&PV) Code* **[1.2]** (hereafter referred to as the "ASME Code"), as summarized in Subsection 2.1.4, "Identification of Codes and Standards for Package Design."

Methods and analysis for demonstrating compliance with the requirements of References **[1.1]** and **[1.2]** are present within this SAR. Chapter 2, "Structural Evaluation," documents compliance of the design and construction with the requirements of References **[1.1]** and **[1.2]**. Compliance is demonstrated by structural analyses and engineering evaluations for Normal and Hypothetical Accident Conditions of Transport requirements, and physical tests upon a prototype packaging, in accordance with *10 CFR 71.71* and *10 CFR 71.73* **[1.1]**. The mechanical properties for construction materials that affect the structural behavior of the transport packages are also included in Chapter 2.

In addition to the design criteria presented in Chapter 2, allowable stresses are evaluated for possible failure modes, including brittle fracture, fatigue, and buckling. Brittle fracture is not a consideration for the containment vessel, because the structural components are made of 300 series austenitic stainless steel, ASME/ASTM Type 304 or Type 316, including all components of the containment boundary. Austenitic stainless steels are not susceptible to brittle fracture at the minimum design and transport temperature, and their mechanical properties are relatively stable over the range of temperature required by regulations (References **[1.1]** and **[1.4]**).

The cask lid attachment bolts are fabricated from ASME SB-637, UNS N07718. This material is also excluded from brittle fracture consideration, in accordance with *ASME Code Section III, Division 1, paragraph NB-2311(a)(7)* in Reference **[1.2]**.

The structural analyses presented in Chapter 2 fully evaluates the mechanical requirements of the regulations (References **[1.1]** and **[1.4]**), and include the applied temperature effects generated by the thermal analyses. The evaluation results verify that the transport packages meet the performance requirements specified by *10 CFR 71* **[1.1]** and *IAEA TS-R-1* **[1.4]**.

Chapter 3, "Thermal Evaluation," documents the thermal evaluation required by the regulations, and verifies that the transport packages meet the performance requirements specified by References **[1.1]** and **[1.4]**.

Chapter 4, "Containment," documents the AOS Transport Packaging System's containment boundary and capabilities. The chapter also includes the cask lid attachment bolts analysis.

Chapter 5, “Shielding Evaluation,” documents the radiation shielding evaluation for the transport package design.

Chapter 6, “Criticality Evaluation,” is omitted from this SAR, because fissile materials and irradiated fissile materials containing fission products are not an authorized content for the AOS Transport Packaging System.

Chapter 7, “Package Operations,” summarizes the instructions for the safe operation of all AOS Transport Packaging System models.

Chapter 8, “Acceptance Tests and Maintenance Program,” presents the test program required by *10 CFR 71*, Subpart G **[1.1]**, to verify that the construction materials, fabrication processes, package design, and maintenance program requirements are fully addressed and satisfied at all times.

As previously noted, the AOS Transport Packaging System is available in three (3) model sizes – AOS-025, AOS-050, and AOS-100. The Model AOS-025 is scaled to 25% of the Model AOS-100, and the Model AOS-050 is scaled to 50% of the Model AOS-100. In addition to size, there are variations in shielding materials for the Model AOS-100, in which either tungsten alloy or carbon steel shielding is used. In the Model AOS-100, there is also a model that is double-ended (that is, the transport package opens on both ends). To distinguish the different models and their variations, the following designators are used throughout this SAR:

AOS-XXXY-Z

where:

XXX is the scale factor (25%, 50%, or 100%)

Y = A for tungsten alloy shielding (Models AOS-025A, AOS-050A, and AOS-100A) –or–

Y = B for carbon steel shielding (Model AOS-100B only)

Z = S to denote packages that have the double-ended opening configuration (Model AOS-100A-S only)

The transport packages are transported vertically, using a pallet design.

The difference between the Model AOS-100A and AOS-100B transport packages is the shielding material used. The difference between the Model AOS-100A and AOS-100A-S is the latter design has a double-ended opening configuration (that is, it can be loaded/unloaded from either end).

Figure 1-1 and Figure 1-2 provide isometric views of Models AOS-025A and AOS-050A, respectively. Figure 1-3 provides an isometric view of Models AOS-100A and AOS-100B. Figure 1-4 provides an isometric view of Model AOS-100A-S. Unless indicated otherwise throughout this SAR, all information related to the Model AOS-100A transport package is also applicable to the Model AOS-100B and AOS-100A-S transport packages.

The acceptance performance tests referenced in this SAR were conducted upon a prototype packaging, 165%-larger than the Model AOS-100, referred to herein, as the “AOS-165A prototype.” Data pertaining to the AOS-165A prototype is used within this SAR solely for the evaluation of the Model AOS-025A, AOS-050A, AOS-100A, AOS-100B, and AOS-100A-S transport packages. This SAR does not request approval of the AOS-165A prototype.

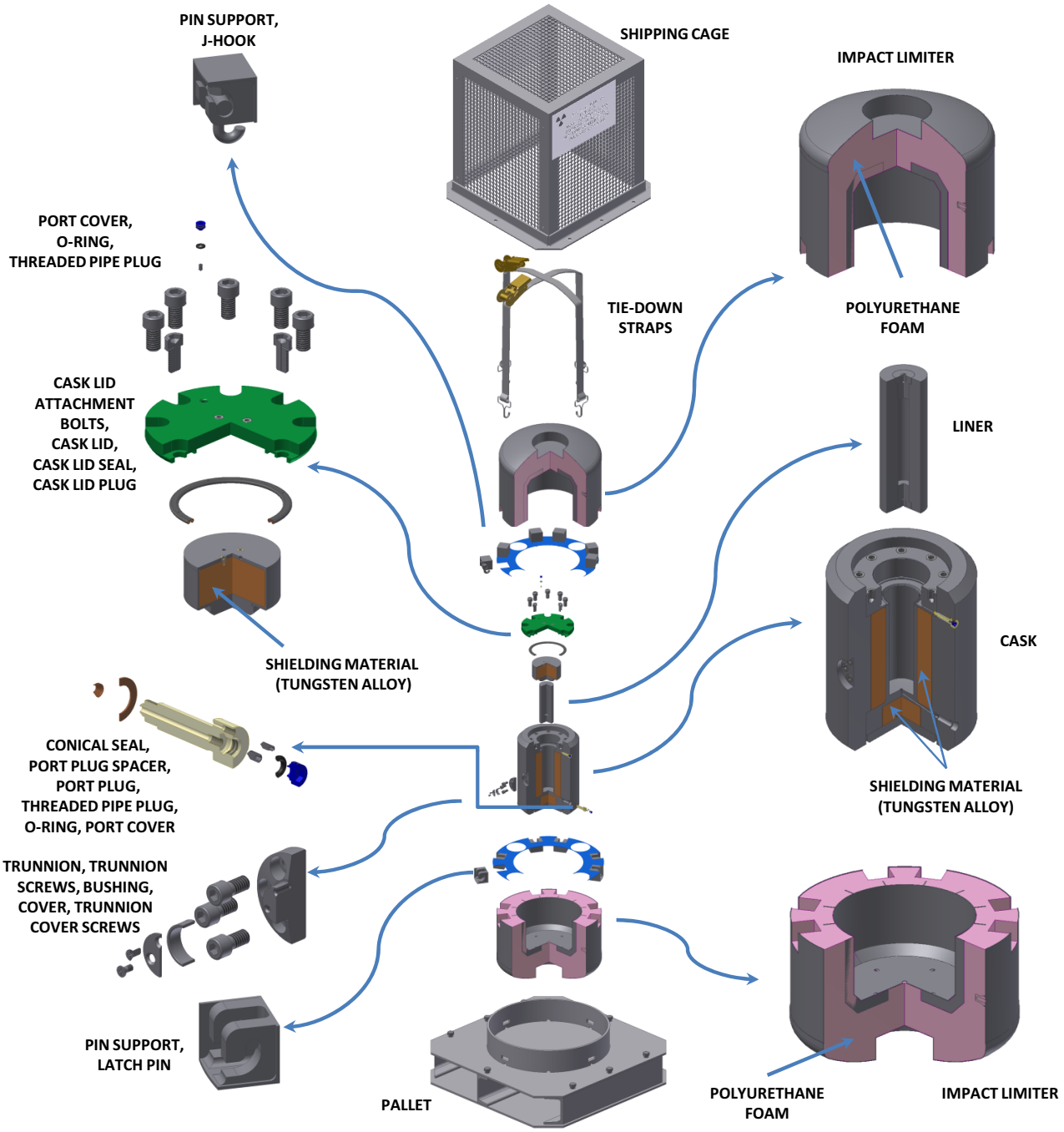

Figure 1-1. Isometric View – Model AOS-025A

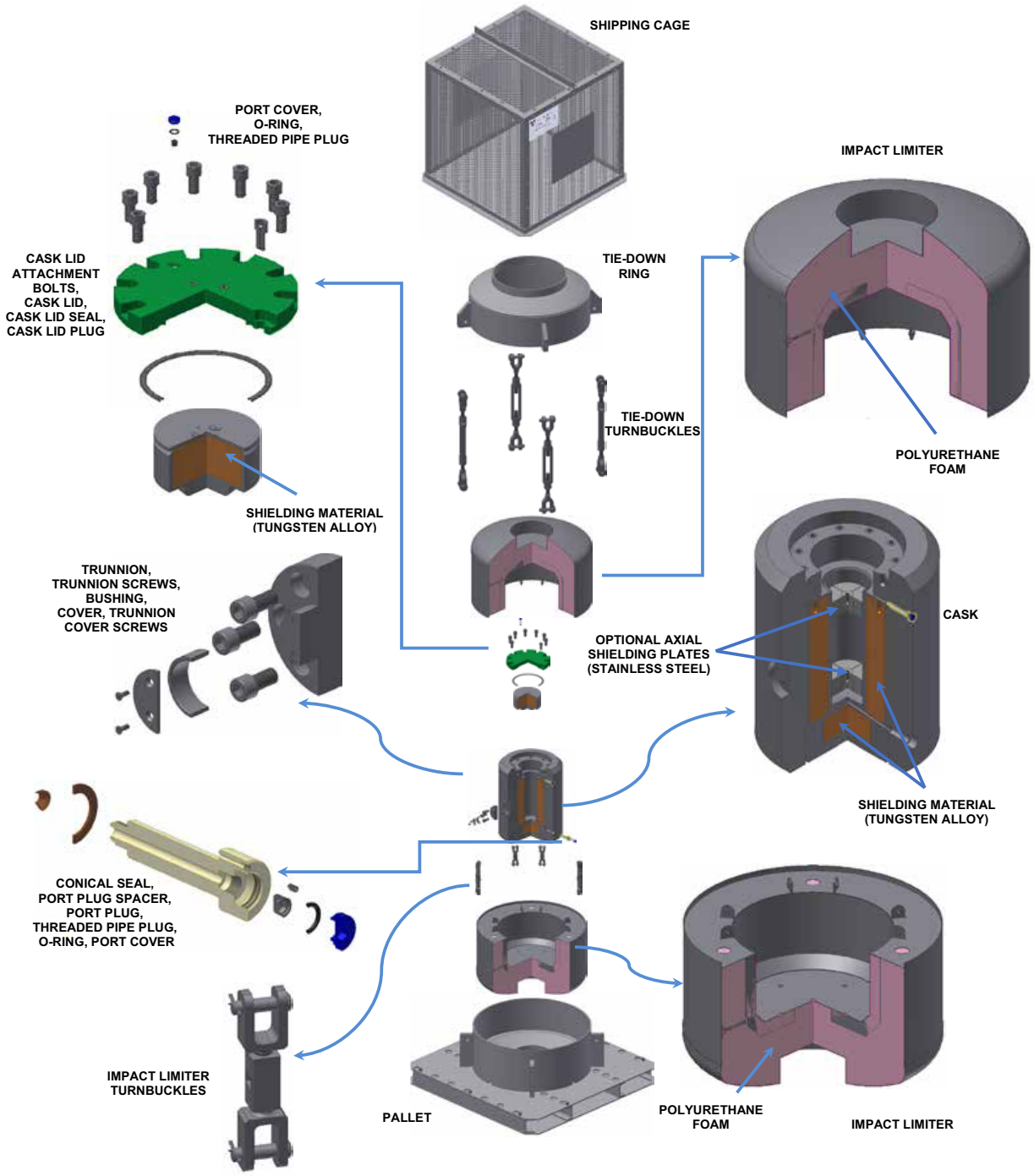

Figure 1-2. Isometric View – Model AOS-050A

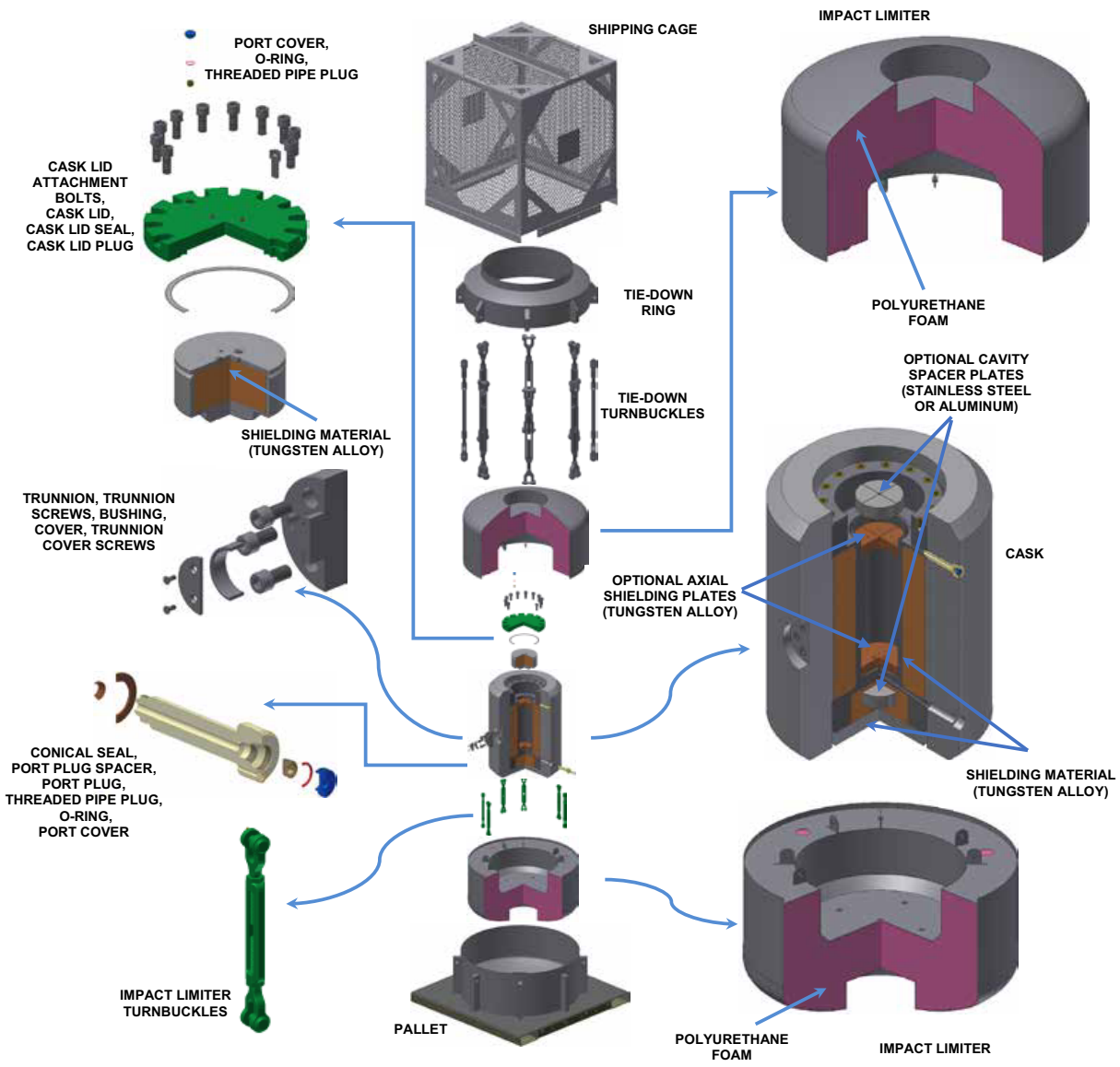

Figure 1-3. Isometric View – Models AOS-100A and AOS-100B

Note: *The Model AOS-100B is identical to the Model AOS-100A, with the exceptions that the Model AOS-100B uses carbon steel as its shielding material, and the optional axial shielding plates and cavity spacer plates are not permitted.*

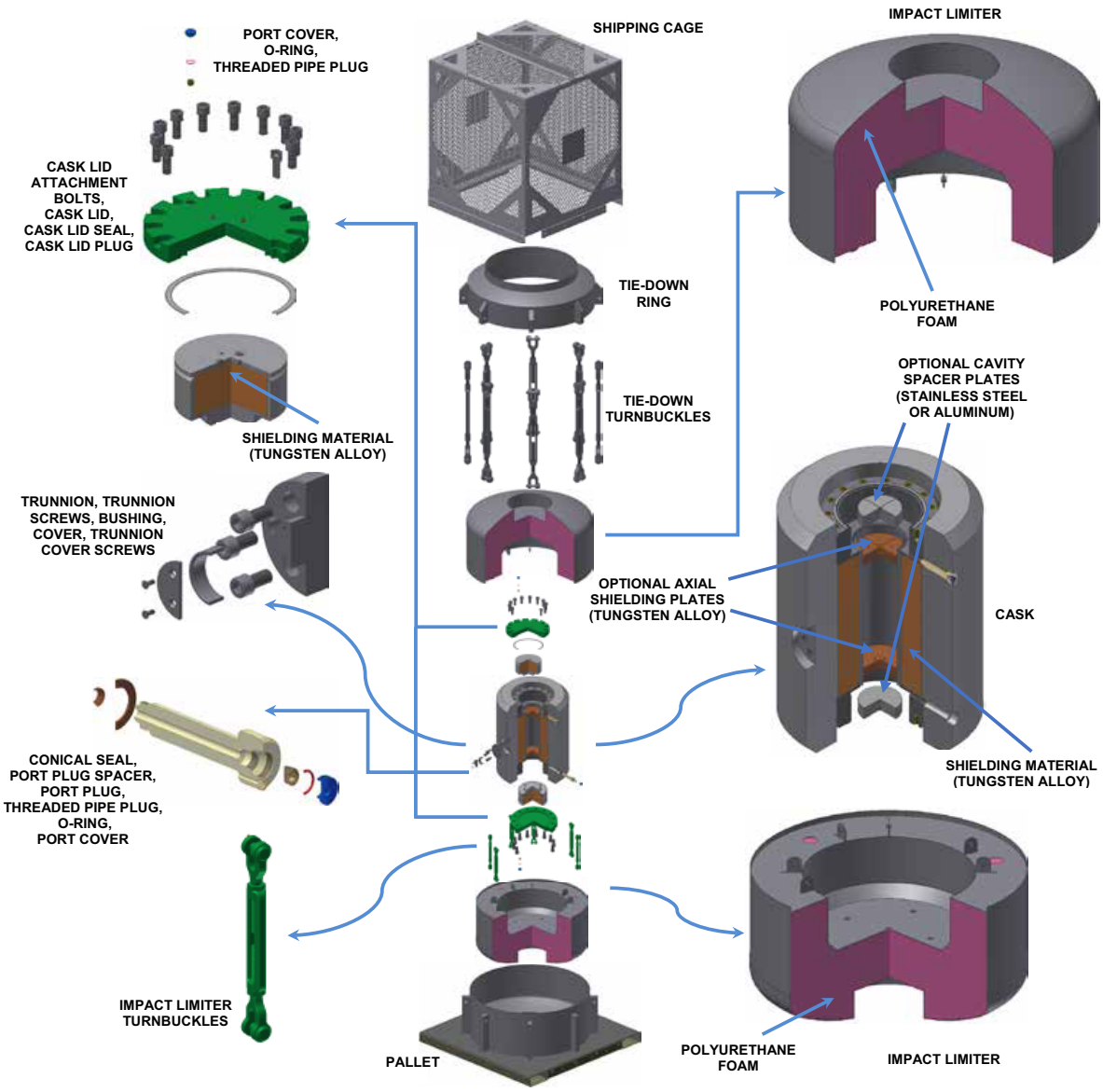

Figure 1-4. Isometric View – Model AOS-100A-S

1.2 PACKAGE DESCRIPTION

The AOS Transport Packaging System designs are symmetric vertically, as well as axisymmetric. Table 1-1 summarizes the dimensions of each AOS Transport Packaging System model's maximum authorized packaging weight (including contents and impact limiters). The maximum weight of the contents, including all associated hardware and packing material, shall not exceed the values listed in Table 1-1.

Each transport package shall be weighed after fabrication, and that weight plus the maximum allowable content weight shall be compared against the maximum gross weight provided in the corresponding certificate drawing.

Table 1-1. AOS Transport Packaging System Dimensions and Maximum Authorized Package Weight – All Models

Model	Category	Dimensions, Basic (cm / in.)						Maximum Authorized Package Weight[a] (kg / lbs.)
		Packaging		Cask		Cavity		
		Width	Height	OD	Height	OD	Height	
AOS-025A	I	45.72	54.30	17.78	22.86	4.12	12.70	100
		18.00	21.38	7.00	9.00	1.62	5.00	220
AOS-050A	I	90.81	98.12[b]	35.56	45.72	8.26	25.40	681
		35.75	38.63[b]	14.00	18.00	3.25	10.00	1,500
AOS-100A	I	154.99	191.52[b]	71.12	91.44	16.51	50.80	5,675
		61.02	75.40[b]	28.00	36.00	6.50	20.00	12,500
AOS-100B	II	154.99	191.52[b]	71.12	91.44	16.51	50.80	4,994
		61.02	75.40[b]	28.00	36.00	6.50	20.00	11,000
AOS-100A-S	I	154.99	191.52[b]	71.12	91.44	16.51	50.80	5,675
		61.02	75.40[b]	28.00	36.00	6.50	20.00	12,500

a. The weights that comprise the maximum authorized package weight are defined in Table 2-7, "AOS Transport Packaging System Maximum Authorized Package Weight and Cg Locations – All Models."

b. The height specified includes the optional lifting bar on the shipping cage.

1.2.1 Packaging

Each AOS transport package consists of three (3) main components:

- Cask
- Impact Limiter
- Cask Lid Seal

The cask is constructed of 300 series stainless steel (SS300) material. Tungsten alloy or carbon steel materials are embedded within the cask body and cask lid plug, to enhance the cask's shielding capability. Tungsten alloy is used as the shielding material in casks whose model number includes suffix A. Carbon steel is used as the shielding material in casks whose model number includes suffix B. Material designation to a national standard is provided in the certification drawings listed in Table 1-5.

The AOS Transport packaging system uses either elastomeric or metallic cask lid seals. The Model AOS-025 and AOS-050 cask lid elastomeric seal has two (2) O-Rings and one (1) flat metal ring. The Model AOS-100 cask lid elastomeric seal associated with the cask lid closure uses a pair of elastomeric O-Rings captured within two (2) SS300 series flat rings. The cask lid metallic seal for all models is a double "C" cross-section seal within the cask lid seal joint. When shipping *Normal Form* contents, the cask lid seal provides a leak-tight containment under Normal and Hypothetical Accident Conditions of Transport. The two (2) impact limiters are connected to one another by eight (8) connectors, such that the cask ends are protected. The impact limiters are constructed of thin SS300 shells filled with polyurethane foam, which has been demonstrated to mitigate mechanical damage and thermal loads generated during Normal and Hypothetical Accident Conditions of Transport.

In addition to the three (3) main package components, a shipping cage and pallet ensure that accessible package surfaces are protected.

1.2.1.1 Cask

The cask is a cylindrical structure with a cavity that contains the payload. The cask structure is composed of seven (7) major components:

- Cask outer shell
- Cask cavity shell
- Cask shielding (tungsten alloy or carbon steel)
- Cask end plug(s)
- Bottom plate
- Cask lid
- Cask lid plug

Figure 2-4, “Isometric View – Typical Cask,” presents an isometric view of the cask.

The cask outer shell and cask cavity shell interlock, to encase the cask shielding, which is a component constructed of tungsten alloy or carbon steel.

The cask shielding and cask end plug(s) enhance the cask’s shielding characteristics. To provide shielding in the axial direction, the cask lid plug is placed in the open end of the cavity. At the cavity’s closed end, the cask end plug is encased between the cavity bottom wall and bottom plate. The cask end plug encased on the cask lid plug is of the same size and material (tungsten alloy or carbon steel) as the one encased at the bottom of the cask.

The cask lid consists of a flat disk, with recessed areas concentric with the bolt holes on the top surface. This feature protects the cask lid attachment bolts from impact loads. Also, the cask lid’s bottom surface has a groove in which to house the seal. The groove upper surface is channeled, which provides a path for any leaked gas to travel to the leak testing port, so that the leaked gas can be detected. Four (4) threaded holes are also included on this surface, for use by the four (4) cask lid metallic seal attachment screws.

Additional cask assembly components are cask lid attachment bolts and port plugs, with threaded pipe plugs, O-Ring seals, and port plug covers.

Both the cask lid and bottom plate are located below the surface of the cask cavity shell, for protection during impact events.

When the radioactive contents are encapsulated in *Special Form* sources, containment is provided by the sealed source. For *Normal Form* material, containment for the AOS Transport Packaging System (containment boundary) is provided within the cask component. The dashed lines in Figure 4-1, "Containment Boundary (Cask Lid Metallic Seal Shown)," illustrate the containment boundary, typical to all transport package models. There are two (2) penetrations into the cask cavity, located within the cask's top and bottom regions of the side surface. These cavity penetrations are used to drain and vent the cavity. A third penetration, located in the cask lid, is used for testing the seal's leak tightness. Pre-shipment leak testing is performed by way of the cask lid test port for shipments of *Normal* and *Special Form* material. (For further details, refer to Chapter 4, "Containment.")

To augment the AOS Transport Packaging System's shielding characteristics, the AOS Transport Packaging System models may require the use of a liner, axial shielding plates, and/or cavity spacer plates, depending on the model, to convey certain quantities of radioactive materials. These liners, axial shielding plates, and cavity spacer plates are referenced in Table 1-5. To meet temperature regulation requirements, a shipping cage structure (refer to Paragraph 1.2.1.4) is used during package transport.

The AOS Transport Packaging System design does not require specific arrangement of the contents, other than those previously discussed, within the cavity. However, a basket or rack device can be used to shore the payload. These baskets or racks are typically made of aluminum or stainless steel material, and designed for the specific payload geometry.

1.2.1.2 Impact Limiter

The impact limiter is a major component consisting of a thin-walled cylindrical shell, with a dish head at one end and a flat disk at the other end. At the flat-disk end, there is a cylindrical recess, with an internal profile identical to that of the cask end profile. This cavity accommodates the cask in the transport configuration. Figure 2-5, "Isometric View – Typical Impact Limiter," presents an isometric view of the impact limiter.

Twelve (12) squared ribs are attached to the inside wall of the cylindrical recess section. Eight (8) of these ribs extend beyond the flat disk plate, which are used as turnbuckle attachment points. The turnbuckles are used to join the impact limiters and to partially enclose the cask component. For the Model AOS-025, the two (2) impact limiters entirely cover the cask, and the turnbuckles are replaced with "J" hooks.

The transport package exterior incorporates one (1) or more tamper-indicating devices, that are not readily breakable. While intact (that is, not broken), these devices provide evidence that the package has not been opened by unauthorized persons. (For further details regarding the tamper-indicating devices, refer to Chapter 7, "Package Operations.")

1.2.1.3 Cask Lid Seal

Two (2) types of cask lid seals are used. One consists of two (2) elastomeric O-Rings, a cross-section captured within one (1) or two (2) flat metal retainer rings to form a unit. The other is a metallic, double "C" cross-section arrangement.

The elastomeric seal is comprised of two (2) components:

- **O-Rings** – Silicone, Parker Compound S1224-70, ASTM D2000
- **Retainer Rings** – ASME SA-240/ ASTM A240, Type 304 or 316 Stainless Steel

The metallic seal is comprised of three (3) components:

- **Jacket** – Silver, ASTM B742
- **Spring** – Nickel-chromium alloy 90 UNS N07090
- **Lining** – SS304L UNS S30403 (may/may not be present)

The seal design provides a means for leak testing between the two (2) O-Rings (elastomeric seal) or double "C" cross-sections (metallic seal), by way of the cask lid's Test Port feature. (For further details regarding the cask lid seal, refer to Appendix 4.5.1, "Garlock Helicoflex Cask Lid Metallic Seal and AOS Cask Lid Elastomeric Seal Drawings.")

1.2.1.4 Other Components

In addition to the previously mentioned components, the AOS Transport Packaging System uses other components or structures, in support of its operations. A series of liners and shielding plates enhances the shielding characteristics for shipments of specific content. Refer to Table 1-2, Table 1-2a, and Table 1-2b for the requirements of when to use these shielding devices.

A transport pallet is used as a base for the transport packages, for tying down the package during transport.

The shipping cage is a five (5)-sided metal structure, with the pallet creating a sixth side, which completes a cube shape. Each side covered with an expandable metal mesh or screen material, that keeps unauthorized persons away from the transport package surfaces during transport, and provides a means to meet temperature regulation requirements.

The packages have no tie-down devices nor structural parts that can be used for unintended tie-down, thus satisfying the additional requirements of *10 CFR 71.45(b)* **[1.1]**.

1.2.2 Contents

Table 1-2 and Table 1-2a provide a list of the isotopes that are authorized for use with the AOS Transport Packaging System. Table 1-2a provides pre-determined mixtures of the Ir-192 and Ir-194 isotopes that are acceptable within each shipping cask model. Other isotope mixtures, including mixtures of Ir-192 and Ir-194 that do not fall directly under one the predetermined mixtures in Table 1-2a, are permitted within the shipping cask contents when external dose rate and decay heat limit compliance is demonstrated per the guidance specified in Appendix 7.5.1, "Dose Rate and Decay Heat Limit Compliance." Isotopes that emit only low-energy gammas and/or betas (that is, all emissions, including those from their progeny, are less than 0.3 MeV) are permitted for transport in the Model AOS-100A and AOS-100A-S shipping casks. To clarify, this requirement applies to the full beta spectrum, **not** the average beta energy (that is, $E_{max,\beta} \leq 0.3$). Isotopes that meet this criteria:

- Do not need to be considered for dose rate calculations
- Need to be accounted for only when calculating the shipping cask contents' total decay heat

Table 1-2 and Table 1-2a demonstrate the use of curie content to meet the radioactive and thermal maximum limits specified in Table 1-3, for individual isotopes within each transport package model. Furthermore, the shielding requirements specified in Table 1-2 and Table 1-2a apply, where applicable. The activity limits presented in Table 1-2a should be interpreted as follows: for a shipment with a total Ir-194 impurity up to the specified activity, the corresponding Ir-192 activity limit is listed (for example, for Model AOS-050A, any shipment with a total Ir-194 activity up to 10 Ci, the Ir-192 activity limit is 1,009 Ci). For Models AOS-100A and AOS-100A-S, if the isotope activities exceed the values listed in Table 1-2, the activity limits for each isotope specified in Table 1-2b may be used, provided that the shipping cask is shipped as exclusive use.

The AOS Transport Packaging System can be used for transporting solid radioactive materials in *Normal* and *Special Form*. Any materials with a melting point less than 538°C (1,000°F) are required to be in *Special Form*. *Special Form* materials require a current Special Form Competent Authority Certificate. Dispersible *Normal Form* materials are required to be enclosed within an inner container. An inner container is considered to be a "shoring device."

Fissile materials and irradiated fissile materials containing fission products are not authorized for this packaging. In addition, no free-standing liquid is permitted.

The package can be shipped by surface or air transport, and meets the requirements for non-exclusive transport. (Refer to Table 1-2 and Table 1-2a.) For air transport, quantities are limited to the lesser of Table 1-2, Table 1-2a, or 3,000 A_2.

All structural shoring materials used within the cask cavity must have a melting point greater than (i) 600°F for Co-60 in metallic form and Cs-137 in the form of cesium chloride and (ii) 900°F for all other contents.

Radioactive contents can be in any location within the cask cavity, and unconstrained within the inner containers. Holders, fixtures, and packaging materials (shoring devices) must be used to secure the inner containers, so that the inner containers are immobilized. The containers must be comprised of materials that are compatible with the radioactive contents and cask cavity.

Radioactive contents are limited by the external radiation levels specified in *10 CFR 71.47* and *71.51* **[1.1]**, and *49 CFR 173.441* **[1.3]**. Exclusive-Use mode of shipment is required whenever the radiation dose rates of the package exceed the external radiation standards in *10 CFR 71.47(a)* **[1.1]** for non-exclusive use shipment. For Models AOS-100A and AOS-100A-S, when shipped as exclusive use, the activity limits for each isotope are specified in Table 1-2b.

There are no materials added to the package for the purpose of neutron absorption nor moderation. Radiation shields (that is, liners, axial shielding plates, and/or cavity spacer plates) are required in certain cases, as stipulated in Table 1-2, Table 1-2a, and Table 1-2b.

The construction materials of the AOS Transport Packaging System and their proposed contents are compatible with one another; no chemical nor galvanic reactions are expected to occur, including the generation of combustible gas.

The transport packages shall be loaded under ambient atmospheric pressure and temperature conditions. The containment boundary will not normally be pressurized; however, internal heating of the enclosed gases can increase the pressure.

The maximum gross weight of the AOS Transport Packaging System, including contents, is listed in Table 1-1.

The maximum decay heats, listed in Table 1-2, Table 1-2a, and Table 1-2b, are calculated using the constants presented in Chapter 5, “Shielding Evaluation.”

Table 1-2. *10 CFR 71.47(a)*[a] Activity Limits (All Isotopes Except Ir-192 and Ir-194)[b] – All Models

Isotope[c]	Decay Heat (W/Ci)[d]	Model							
		AOS-025		AOS-050		AOS-100			
		A (10W)		A (100W)		A, A-S (400W)		B (400W)	
		TBq	Ci	TBq	Ci	TBq	Ci	TBq	Ci
Co-60	1.55E-02	4.92E-03	1.33E-01	2.76E-02	7.47E-01	1.01E+01	2.73E+02	3.66E-01	9.89E+00
Co-60-B	1.55E-02	–		–		3.05E+01	8.23E+02	–	
Co-60-C	1.55E-02	–		–		3.56E+02	9.63E+03	–	
Cs-137	4.99E-03	3.70E-01	1.00E+01	6.36E-01	1.72E+01	1.30E+03	3.50E+04	1.96E+01	5.29E+02
Hf-181	4.33E-03	–		2.83E+00	7.66E+01	3.41E+03[e]	9.23E+04[e]	1.46E+02	3.99E+03
Zr/Nb-95[f]	1.62E-02	–		9.84E-02	2.66E+00	1.30E+02	3.50E+03	2.43E+00	6.65E+01
Yb-169	2.55E-03	1.45E+02[e]	3.92E+03[e]	2.87E+02	7.77E+03	–		–	
Shipping Configuration		Use of Tungsten Alloy Shielding Liner 183C8485 is required		No additional shielding is required		**Co-60-B** quantities require use of Tungsten Alloy Axial Shielding Plates 183C8491 **Co-60-C** quantities require use of Tungsten Alloy Axial Shielding Plates 183C8491 and Stainless Steel –or– Aluminum Cavity Spacer Plates 183C8518		No additional shielding is required	

a. *Reference* **[1.1]**.

b. *Refer to Table 1-2a for Ir-192 and Ir-194 activity limits.*

c. *Solid material, including metals, that meets Normal or Special Form criteria. Special Form materials require a current Special Form Competent Authority Certificate.*

d. *For detailed calculations of these values, refer to Appendix 5.5.1, "AOS Cask Isotopic Heat Load Calculations."*

e. *Activity limit based on cask decay heat limit (rounded down to listed significant figures).*

f. *Activity limits for parent/daughter mixed isotope systems apply to the parent isotope. An equilibrium concentration of the daughter is assumed in the evaluations provided in Chapter 5, "Shielding Evaluation," to provide limiting dose and heat responses for the AOS Transport Packaging System.*

Table 1-2a. *10 CFR 71.47(a)*[a] Ir-192 and Ir-194 Activity Limits – All Models

Model	Ir-192 Limit		Ir-194 Impurity		Decay Heat (W)[b]	Shipping Configuration
	TBq	Ci	TBq	Ci		
AOS-025A (10W)	2.62	71	0.0185	0.5	0.44	Use of Tungsten Alloy Shielding Liner 183C8485 is required
	2.33	63	0.0740	2.0	0.40	
	2.10	57	0.1110	3.0	0.37	
AOS-050A (100W)	37.33	1,009	0.37	10	6.24	Use of Stainless Steel Axial Shielding Plates 183C8519 is required
	34.78	940	0.74	20	5.87	
	29.67	802	1.48	40	5.13	
	24.60	665	2.22	60	4.39	
	19.49	527	2.96	80	3.66	
	14.39	389	3.70	100	2.92	
AOS-100A, AOS-100A-S (400W)	2,286.37	61,794	148.00	4,000	400.00	No additional shielding is required
	2,094.42	56,606	370.00	10,000	400.00	
AOS-100B (400W)	80.51	2,176	3.70	100	13.87	No additional shielding is required
	67.37	1,821	8.51	230	12.39	

a. Reference **[1.1]**.

b. Ir-192 and Ir-194 generate 6.13E-03 W/Ci and 5.30E-03 W/Ci, respectively. (Refer to Table 5-22, "AOS Cask Isotopic Heat Load Results.")

Table 1-2b. *10 CFR 71.47(b)*[a] Activity Limits – Model AOS-100A and AOS-100A-S[b]

Isotope	Decay Heat (W/Ci)[c]	Models AOS-100A and AOS-100A-S (400W)	
		TBq	Ci
Co-60	1.55E-02	1.70E+01	4.60E+02
Co-60-B	1.55E-02	5.85E+01	1.58E+03
Co-60-C[d e]	1.55E-02	9.54E+02	2.58E+04
Cs-137	4.99E-03	2.09E+03	5.65E+04
Hf-181[e]	4.33E-03	3.41E+03	9.23E+04
Ir-192[e]	6.13E-03	2.41E+03	6.52E+04
Ir-194	5.30E-03	1.48E+03	4.00E+04
Zr/Nb-95[f]	1.62E-02	2.15E+02	5.81E+03
Shipping Configuration		**Co-60-B** quantities require use of Tungsten Alloy Axial Shielding Plates 183C8491 **Co-60-C** quantities require use of Tungsten Alloy Axial Shielding Plates 183C8491 and Stainless Steel –or– Aluminum Cavity Spacer Plates 183C8518	

a. Reference **[1.1]**.

b. Activity limits based on Table 5-39, "Exclusive Use Activity Limit Maximum Dose Rates and Decay Heat – Models AOS-100A and AOS-100A-S."

c. For detailed calculations of these values, refer to Appendix 5.5.1, "AOS Cask Isotopic Heat Load Calculations."

d. For Co-60-C quantities, the maximum allowable specific activity is 350 Ci/g (that is, no more than 350 Ci of Co-60 in a gram of Cobalt).

e. Activity limit based on the shipping cask's decay heat limit (rounded down to listed significant figures).

f. Activity limits for parent/daughter mixed isotope systems apply to the parent isotope. An equilibrium concentration of the daughter is assumed in the evaluations provided in Chapter 5, "Shielding Evaluation," to provide limiting dose and heat responses for the AOS Transport Packaging System.

Table 1-3. Content Limitations – All Models

Model	Type	Content[a]	Decay Heat		Weight[b]	
			Watt	Btu/hr.	kg	lbs.
AOS-025A	Solid Material	*Normal Form* or *Special Form*	10	34.15	4.5	10
AOS-050A			100	341.5	27	60
AOS-100A			400	1,366	227	500
AOS-100B						
AOS-100A-S						

a. Special Form materials require a current Special Form Competent Authority Certificate.

b. Maximum weight of contents including any additional shielding and shoring devices. Weight of contents can be adjusted so as not to exceed the maximum authorized gross weight of the package.

1.2.3 Special Requirements for Plutonium

Not applicable. Plutonium is not an authorized content for the AOS Transport Packaging System.

1.2.4 Operational Features

The AOS Transport Packaging System is simple and easy-to-use. The transport packages do not incorporate any valve nor another device that can allow the release or escape of the contents. Further, the package designs do not include any feature intended to allow continuous venting during transport. Positive closure for containment makes use of standard bolts and tools for opening and closing the packages. Cooling is provided by conduction and natural radiation from within the package. The seal is installed onto the cask lid. Only standard practices for seal handling and use (that is, cleanliness, scratch prevention, and proper installation) are required. (For further details, refer to Chapter 7, "Package Operations.")

1.2.5 Fabrication Codes, Standards, and Acceptance Tests

The AOS Transport Packaging System design and fabrication is controlled by the Codes, Engineering Specifications, and Standards listed in Table 2-8, "Applicable Codes and Standards for Design, Fabrication, and Testing of the AOS Transport Packaging System." In addition, Table 2-8 lists the Safety Classification of all major system components, per Reference **[1.6]** guidelines.

Evaluation of the AOS Transport Packaging System, to show compliance with the applicable regulations (References **[1.1]** and **[1.4]**), is conducted by analyses, using the Finite Element Method (LIBRA Code) for all structural and thermal requirements. (For further details regarding the structural and thermal analyses and results, refer to Chapter 2, "Structural Evaluation," and Chapter 3, "Thermal Evaluation," respectively.)

Shielding requirements were evaluated, primarily using the Monte Carlo N-Particle (MCNP) Code. (For further details regarding shielding evaluations, refer to Chapter 5, "Shielding Evaluation.")

Table 1-4 presents a summary of the engineering evaluation and analyses conducted upon each AOS Transport Packaging System model, and detailed in Chapter 2 and Chapter 3.

Table 1-4. AOS Transport Packaging System Analyses Summary – All Models

Item	*10 CFR 71* [1.1]	*IAEA TS-R-1* [1.4]	Model					Applied Conditions/Criteria
			AOS-025A	AOS-050A	AOS-100A	AOS-100B	AOS-100A-S	
Package Category			Table 1-1	Table 1-1	Table 1-1	Table 1-1	Table 1-1	
Maximum Authorized Package Weight			Table 1-1	Table 1-1	Table 1-1	Table 1-1	Table 1-1	
Content			Refer to Subsection 1.2.2	Refer to Subsection 1.2.2	Refer to Subsection 1.2.2	Refer to Subsection 1.2.2	Refer to Subsection 1.2.2	
Physical Form (Normal or Special)			Solid	Solid	Solid	Solid	Solid	
Decay Heat								
Activated Materials			10W	100W Isotope	400W Isotope	400W Isotope	400W Isotope	
General	71.33	606 – 616	✔	✔	✔	✔	✔	
Design Pressure			207 kPa (30 psia)	414 kPa (60 psia)	1,930 kPa (280 psia)	1,930 kPa (280 psia)	1,930 kPa (280 psia)	
Structural								
Weight and Cg			✔	✔	✔	✔	✔	
Lifting Devices	71.45(a)	607, 608	✔	✔	✔			
Tie-Down Devices	71.45(b)	612, 636	✔	✔	✔			
Containment Shell Buckling			✔	✔	✔	✔	✔	
Normal Conditions of Transport	71.71(c)	651						
Heat	71.71(c)(1)	653, 654, 664, 676	✔	✔	✔			38°C (100°F) shade < 50°C (122°F)

Table 1-4. AOS Transport Packaging System Analyses Summary – All Models (Continued)

Item	*10 CFR 71* [1.1]	*IAEA TS-R-1* [1.4]	Model					Applied Conditions/Criteria
			AOS-025A	AOS-050A	AOS-100A	AOS-100B	AOS-100A-S	
Differential Thermal Expansion			✔	✔	✔			
Cold	71.71(c)(2)	664, 676	✔	✔	✔			
Reduced External Pressure	71.71(c)(3)	643	✔	✔	✔			
Increased External Pressure	71.71(c)(4)		✔	✔	✔			
Vibration	71.71(c)(5)	612	✔	✔	✔			(5, 5 and 10 g's) ANSI N14.23 Draft
Water Spray	71.71(c)(6)	719, 721	✔	✔	✔			
Free Drop	71.71(c)(7)	720, 722	1.2m (4 ft.)	1.2m (4 ft.)	0.9m (3 ft.)			Solid: 0.9m (3 ft.) and 1.2m (4 ft.)
Corner Drop	71.71(c)(8)	722(b)&(c)	–	–	–	–	–	
Compression (Stacking)	71.71(c)(9)	723(a)	✔	✔	✔			5x Weight or 13 kPa (2 psi) * Projected Area
Penetration	71.71(c)(10)	724(b)	✔	✔	✔			3.2 cm (1.25 in.) and 6 kg (13 lbs.) dropped 1.7m (67 in.)

Table 1-4. AOS Transport Packaging System Analyses Summary – All Models (Continued)

Item	*10 CFR 71* [1.1]	*IAEA TS-R-1* [1.4]	Model					Applied Conditions/Criteria
			AOS-025A	AOS-050A	AOS-100A	AOS-100B	AOS-100A-S	
Hypothetical Accident Conditions of Transport	71.73(a)&(b)	726						
Free Drop	71.73(c)(1)	727(a)	✔	✔	✔			
Crush	71.73(c)(2)	727(c)	–	–	–	–	–	
Puncture	71.73(c)(3)	727(b)	✔	✔	✔			15 cm (6 in.) diameter 20 cm (8 in.) long Distance of 1.0m (40 in.)
Thermal	71.73(c)(4)	728	✔	✔	✔			
Immersion	71.73(c)(6)	729	✔	✔	✔			150 kPa (21.7 psi)
Deep Water Immersion	71.61	730	✔	✔	✔			2 MPa (290 psia)

Table 1-4. AOS Transport Packaging System Analyses Summary – All Models (Continued)

Item	*10 CFR 71* [1.1]	*IAEA TS-R-1* [1.4]	Model					Applied Conditions/Criteria
			AOS-025A	AOS-050A	AOS-100A	AOS-100B	AOS-100A-S	
Thermal								
Normal Conditions of Transport								
38°C (100°F) Ambient + Decay Heat + Solar			✔	✔	✔			
38°C (100°F) Ambient + Decay Heat			✔	✔	✔			
-29°C (-20°F) Ambient + Decay Heat			✔	✔	✔			
-29°C (-20°F) Ambient			✔	✔	✔			
-40°C (-40°F) Ambient + Decay Heat			✔	✔	✔			
-40°C (-40°F) Ambient			✔	✔	✔			
Hypothetical Accident Conditions of Transport								
Fire			✔	✔	✔			
Containment								
Internal Pressure (Fission Gases)			–	–	–	–	–	
Cask Lid Seal Joint			✔	✔	✔			
Shielding								
Source Term			✔	✔	✔	✔	✔	
Decay Heat			✔	✔	✔	✔	✔	
Gamma Dose			✔	✔	✔	✔	✔	
Transportation Index			✔	✔	✔	✔	✔	

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1.3 APPENDIX

1.3.1 AOS Transport Packaging System, Certification Drawings

Table 1-5 lists the certification drawings for the AOS Transport Packaging System's assembly, impact limiter, cask, liner, axial shielding plates, and cavity spacer plates, by model.

Table 1-5. AOS Transport Packaging System Certification Drawing List – All Models

Component	Drawing Part Number and Revision, by Model									
	AOS-025A	Rev.	AOS-050A	Rev.	AOS-100A	Rev.	AOS-100B	Rev.	AOS-100A-S	Rev.
Assembly	166D8142	K	105E9718	K	105E9711	L	105E9711	L	105E9711	L
Impact Limiter	105E9722	J	166D8138	I	105E9713	J	105E9713	J	105E9713	J
Cask[a]	166D8143	J	166D8137	J	105E9712G001	M	105E9712G002	M	105E9719	M
Liner	183C8485	H	–	–	–	–	–	–	–	–
Axial Shielding Plates	–	–	183C8519	A	183C8491	I	–	–	183C8491	I
Cavity Spacer Plates	–	–	–	–	183C8518	B	–	–	183C8518	B

a. The G00x number appended to select drawing numbers represents a group within the drawing.

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1.3.1.1 AOS Transport Packaging System Drawings – Model AOS-025A

AOS Drawing No. 166D8142

Model AOS-025A Assembly

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

AOS Drawing No. 105E9722

Model AOS-025A Impact Limiter

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

AOS Drawing No. 166D8143

Model AOS-025A Cask

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

AOS Drawing No. 183C8485

Model AOS-025A Liner

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

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1.3.1.2 AOS Transport Packaging System Drawings – Model AOS-050A

AOS Drawing No. 105E9718

Model AOS-050A Assembly

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

AOS Drawing No. 166D8138

Model AOS-050A Impact Limiter

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

AOS Drawing No. 166D8137

Model AOS-050A Cask

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

AOS Drawing No. 183C8519

Model AOS-050A Axial Shielding Plates

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

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1.3.1.3 AOS Transport Packaging System Drawings – Model AOS-100A, AOS-100B, and AOS-100A-S

AOS Drawing No. 105E9711

Model AOS-100A / AOS-100B / AOS-100A-S Assembly

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

AOS Drawing No. 105E9713

Model AOS-100A / AOS-100B / AOS-100A-S Impact Limiter

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

AOS Drawing No. 105E9712G001

Model AOS-100A Cask

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

AOS Drawing No. 105E9712G002

Model AOS-100B Cask

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

AOS Drawing No. 105E9719

Model AOS-100A-S Cask

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

AOS Drawing No. 183C8491

Model AOS-100A / AOS-100A-S Axial Shielding Plates

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

AOS Drawing No. 183C8518

Model AOS-100A / AOS-100A-S Cavity Spacer Plates

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

1.4 REFERENCES

[1.1] U.S. Nuclear Regulatory Commission (NRC), *Title 10, Code of Federal Regulations, Part 71 (10 CFR 71)*, "Packaging and Transportation of Radioactive Material."

[1.2] American Society of Mechanical Engineers, *ASME Boiler and Pressure Vessel Code*, 2004 Ed., No Addendum.

[1.3] U.S. Department of Transportation (DOT), *Title 49, Code of Federal Regulations, Part 173 (49 CFR 173)*, "Shippers – General Requirements for Shipments and Packagings."

[1.4] *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).

[1.5] Alpha-Omega Services, Inc. (AOS), *PR9000*, "Quality Assurance Program Radioactive Material Transport Packages," Latest.

[1.6] McConnell, J. W. Jr., A. L. Ayers, Jr., and M. J. Tyacke, *NUREG/CR-6407*, *Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety*, Idaho National Engineering Laboratory, Prepared for U.S. Nuclear Regulatory Commission (NRC), February, 1996.

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