AOS-FM9054
Rev. H-3, May 3, 2017
(Docket No. 71-9316)

Radioactive Material Transport Packaging System

Safety Analysis Report

for Model AOS-025, AOS-050, and AOS-100 Transport Packages

Prepared by
Alpha-Omega Services, Inc.
Bellflower, CA

Revision History

Revision	Date	Description of Changes
A	January 11, 2008	Preliminary release.
B	June 20, 2009	Preliminary release.
C	September 11, 2009	Preliminary release.
D	September 28, 2010	Preliminary release.
E	October 11, 2011	Preliminary release.
F	February 1, 2012	Initial Release.
G	July 27, 2012	Update to include cask lid elastomeric seal, and included text so the cask lid metallic seal is differentiated from the new elastomeric seal. Applied miscellaneous corrections (table of changes included with cover page of the submittal).
H	December 30, 2012	Updated in response to NRC RAIs. Applied miscellaneous corrections (table of changes included with cover page of the submittal).
H-1	March 11, 2016	Updated to add new isotope, Ir-194. General update to correct errors and incorporate changes communicated to NRC in letters dated April 4, May 14, and September 26, 2013, and May 6, June 5, and August 5, 2015. Applied miscellaneous updates and corrections (table of changes included with cover page of the submittal).
H-2	June 27, 2016	Updated in response to NRC RAI.
H-3	May 3, 2017	Clarified *Special Form* material shipment requirements and applied miscellaneous corrections.

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.

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.

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.

1.2.2 Contents

Table 1-2 and Table 1-2a provide a list of the isotopes authorized for use with the AOS Transport Packaging System. Additionally, 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 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 1,117 Ci).

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, except for Co-60-C quantities. (Refer to Table 1-2.) For air transport, quantities are limited to the lesser of Table 1-2, Table 1-2a, or 3,000 A_2.

All 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.

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 and Table 1-2a.

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 heat, listed in Table 1-2 and Table 1-2a, is calculated using the constants presented in Chapter 5, "Shielding Evaluation."

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

Isotope[b]	Decay Heat Ci/Watt[c]	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	6.45E+01	4.92E-03	1.33E-01	2.78E-02	7.50E-01	1.01E+01	2.73E+02	4.03E-01	1.09E+01
Co-60-B	6.45E+01	–		–		3.05E+01	8.23E+02	–	
Co-60-C[d e]	6.45E+01	–		–		7.48E+02	2.02E+04	–	
Cs-137	2.00E+02	3.70E-01	1.00E+01	7.13E-01	1.93E+01	1.32E+03	3.55E+04	2.15E+01	5.82E+02
Hf-181	2.31E+02	–		3.41E+00	9.23E+01	3.42E+03[f]	9.24E+04[f]	1.62E+02	4.39E+03
Zr/Nb-95[g]	6.17E+01	–		1.07E-01	2.90E+00	1.34E+02	3.61E+03	2.70E+00	7.31E+01
Ho-166	2.33E+02	4.87E-01	1.32E+01	2.81E+00	7.59E+01	–		–	
Yb-169	3.92E+02	1.45E+02[f]	3.92E+03[f]	3.49E+02	9.44E+03	–		–	
Shipping Configuration		Use of Liner 183C8485 is required		No additional shielding is required		**Co-60-B** quantities require use of Axial Shielding Plate 183C8491 **Co-60-C** quantities require use of Axial Shielding Plates 183C8491 and Cavity Spacer Plates 183C8518		No additional shielding is required	

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

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

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. *Must be shipped by Exclusive Use.*

f. *Activity limit based on cask decay heat limit.*

g. *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. Ir-192 and Ir-194 Activity Limits – All Models

Model	Ir-192 Limit		Ir-194 Impurity		Decay Heat Ci/Watt[a]	Shipping Configuration
	TBq	Ci	TBq	Ci		
AOS-025A (10W)	2.62	71	0.0185	0.5	0.44	Use of 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)	41.32	1,117	0.37	10	6.90	Use of Axial Shielding Plates 183C8519 is required
	39.84	1,077	0.74	20	6.71	
	36.88	997	1.48	40	6.33	
	33.92	917	2.22	60	5.94	
	30.96	837	2.96	80	5.56	
	28.04	758	3.70	100	5.18	
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)	89.31	2,414	3.70	100	15.33	No additional shielding is required
	76.22	2,060	8.51	230	13.85	

a. *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 1-3. 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.*

2.12.12.11 Stress in Tie-Down Ring – Model AOS-100

Figure 2-97 shows the maximum principal membrane stress for bending about the x-axis. The maximum stress occurs at location ‘a’, and is 31.7 ksi. For bending about the y-axis, the stress at location ‘b’ corresponds to the stress at location ‘a’. The stress at location ‘b’ is 18.5 ksi for 10g loading. The combined stress due to 10g about the x-axis, and 5g about the y-axis, is then:

$$f = 32.2 + (1 / 2) * 18.5 = 41.5 \text{ ksi}$$

For ASME SA-240/ASTM A240 Type XM-19 steel, yield stress F_y = 55.0 ksi, and ultimate strength Fu = 100.0 ksi:

$$MS = 55.0 / 41.5 - 1.0 = 0.32$$

2.12.12.12 Stress in Cables – Model AOS-100

P_1 = Maximum cable load (Table 2-345, cable 5) due to 10g forward inertia

P_2 = Maximum cable load due to 5g lateral inertia

P_3 = Cable load due to 1g vertical inertia

$$P_1 = 20.9 \text{ k}$$

$$P_2 = (1 / 2) * 20.9 = 10.5 \text{ k}$$

$$P_3 = 12 / 8 = 1.5 \text{ k}$$

$$P = P_1 + P_2 + P_3 = 32.9 \text{ k}$$

From *ASTM F1145 - 05(2011)*, Table 3 (Reference **[2.27]**), Jaw-Jaw, P_u = 60 k:

$$MS = 60 / 32.9 - 1.0 = 0.82$$

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 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*.

When the radioactive contents are encapsulated in *Special Form* sources, containment is provided by the sealed source. For *Normal Form* material, containment is provided by the cask's Containment Boundary, as described in the following section.

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.

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

When the radioactive contents are encapsulated in *Special Form* sources, containment under Normal Conditions of Transport is provided by the sealed source. For *Normal Form* material, containment is provided by the cask's containment system. The ability of the cask's containment system to withstand Normal Conditions of Transport is presented below.

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.

4.3 CONTAINMENT UNDER HYPOTHETICAL ACCIDENT CONDITIONS

When the radioactive contents are encapsulated in *Special Form* sources, containment under Hypothetical Accident Conditions of Transport is provided by the sealed source. For *Normal Form* material, containment is provided by the cask's containment system. The ability of the cask's containment system to withstand Hypothetical Accident Conditions of Transport is presented below.

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]."

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, axial shielding plates, and/or cavity spacer 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-050A, AOS-100A, and AOS-100A-S

Model	Component	Certification Drawing[a]	Comments
AOS-025A	Liner	183C8485	Shielding liner is mandatory for all contents (Refer to Table 1-2, "Activity Limits (All Isotopes Except Ir-192 and Ir-194) – All Models."
AOS-050A	Axial Shielding Plates[b]	183C8519	Use when additional shielding is required. (Refer to Table 1-2a, "Ir-192 and Ir-194 Activity Limits – All Models.")
AOS-100A AOS-100A-S	Axial Shielding Plates	183C8491	Use when additional shielding is required. (Refer to Table 1-2, "Activity Limits (All Isotopes Except Ir-192 and Ir-194) – All Models.")
	Cavity Spacer Plates	183C8518	

a. Refer to Table 1-5, "AOS Transport Packaging System Certification Drawing List – All Models," for drawing revision levels.

b. If the Model AOS-050A axial shielding plates include threaded screw holes, each hole must be filled with a setscrew during shipment.

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, prior to the shipment of Normal Form material, 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. Carefully monitor this operation to ensure that the cask lid is properly aligned. During the placement of the cask lid, two lid guide pins may be 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.

7.1.3.2 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

To verify that the containment system of the transport package is properly assembled for shipment, perform one of the following Pre-Shipment Leak tests – Test A1, A2 or B – depending on the cask lid seal type.

Note: *When the Model AOS-100A-S is used, both cask lid seals must be leak tested.*

Test A1 – Gas Pressure Rise: When Using Elastomeric Cask Lid Seals (Tests: Cask Lid(s), Vent and Drain Ports)

To leak test the containment system:

a. Perform the test by evacuating the space between the cask lid seal's elastomeric O-Ring seals, –or– the cavities outside the cask vent and drain ports, and then measuring the pressure rise.

Note: *The cask vent port and cask drain port must only be leak tested if they have been opened since they were last tested.*

Note: *The gas pressure rise leak test is performed using a test manifold, isolation valve, vacuum gauge, and vacuum pump. The internal volume of the test apparatus upstream of the isolation valve must be known and considered to achieve the required test sensitivity for the test hold time. Use only the test apparatus described in the test procedure.*

Note: *Leak Test criteria for leak rates must meet the requirement of Reference* **[7.8]**.

b. Connect the test manifold to the test port. Evacuate the test volume to the required level. and then close the isolation valve.

c. Disconnect the vacuum pump and then wait for the prescribed hold time. After the hold time, the acceptance criterion is a pressure rise corresponding to 1×10^{-3}ref-cm^3/sec.

Test A2 – Gas Pressure Drop: When Using Elastomeric Cask Lid Seals (Tests: Cask Lid(s), Vent and Drain Ports)

To leak test the containment system:

a. Perform the test by pressurizing the space between the cask lid seal's elastomeric O-Ring seals, –or– the cavities outside the cask vent and drain ports, and then measuring the pressure drop.

Note: *The cask vent port and cask drain port must only be leak tested if they have been opened since they were last tested.*

Note: *The gas pressure drop leak test is performed using a test manifold, isolation valve, pressure gauge, and pump. The internal volume of the test apparatus downstream of the isolation valve must be known and considered to achieve the required test sensitivity for the test hold time. Use only the test apparatus described in the test procedure.*

Note: *Leak Test criteria for leak rates must meet the requirement of Reference* **[7.8]**.

b. Connect the test manifold to the test port. Evacuate the test volume to the required level. and then close the isolation valve.

c. Disconnect the pump and then wait for the prescribed hold time. After the hold time, the acceptance criterion is a pressure drop corresponding to 1×10^{-3}ref-cm^3/sec.

Test B – Tracer Gas When Using Metallic Cask Lid Seal –or– Optionally for Elastomeric Cask Lid Seal (Tests: Lid (Cask Lid Seal), Vent and Drain Ports)

To leak test the containment system:

a. Perform a leak test of the cask lid seal, drain threaded pipe plugs, and vent threaded pipe plugs, with a thermal conductivity sensing instrument or mass spectrometer device with a sensitivity of at least 1.0×10^{-8} ref-cm^3/sec.

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. Evacuate the cask cavity and then backfill the cask cavity with helium to a pressure of at least one (1) atmosphere.

d. With the instrument selected in step a calibrated with a calibration standard within the range of 1.0×10^{-8} to 5.0×10^{-7} ref-cm^3/sec, check the following for indications of leakage:
   - Package containment with the test instrument, through the test port
   - Volume between the double "C" cross-sections
   - Around the threaded joint area of the drain and vent threaded pipe plugs

e. If leakage greater than 1×10^{-7}ref-cm^3/sec, corrected for the nature of the tracer gas and temperature condition at the time of the test, is detected, repair or replace the damaged component(s), and then re-test for indications of leakage.

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

   Pre-shipment leak testing must be performed before each shipment, after the content is loaded and the containment system is assembled. Perform the test as described in Paragraph 7.1.3.3.

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 < 1×10^{-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.

Note: *For shipments of Special Form material, a Periodic Leak Test is not necessary after replacement of an elastomeric cask lid seal, provided that a Periodic Leak Test has been performed on the cask's containment system within the past 12 months.*