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Alpha-Omega Services, Inc.

A NEW FAMILY OF TYPE B RADIOACTIVE MATERIAL TRANSPORT PACKAGES

PATRAM 2007

October 21-26, 2007

Marriott Doral, Miami, Florida USA





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Executive Summary

Alpha-Omega Services, Inc. (AOS) owns and operates a series of Type B quantities radioactive material transport containers to support their commercial operations. AOS provides radioactive material sources, primarily Co-60 and Ir-192, for medical applications. After October 2008, with the implementation of the new NRC rules, these containers will no longer be certified; therefore, a solution must be found and executed to allow distribution of the sources to their customers after this date.

Development and licensing costs of a Type B quantity container are currently in the millions of dollars. The cost of several designs, as is required by AOS, is prohibitive because they are a small company.

For the above reason, AOS found and executed a solution which was to design one container in such a way that its features could be scaled to the required sizes. This approach has created a family of Type B containers at a fraction of the cost of developing each individual container size.



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Applied Method

- Identify requirements
- Find commonalities among requirements
- Create a basic conceptual design
- Validate basic design against commonalities
- Establish scale relationships
- Iterate the above steps to maximize the number of commonalities incorporated into basic design
- Establish licensing strategy



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Identify Requirements

- Payload
 - ✓ Composition
 - ✓ Physical form
 - ✓ Quantity
- Facility
 - ✓ Loading/Unloading
 - ✓ Lifting/Handling equipment
- Transportation Mode
 - ✓ Road/Air/Vessel
 - ✓ Common/Special carrier



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Find Commonalities Among Requirements

- Type, quantity, form, geometry of payload
- Handling conditions at users' sites
- Weight limits of carriers
- Domestic and/or international shipments



Customer Requirements

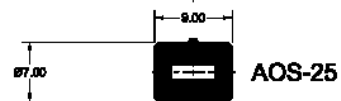
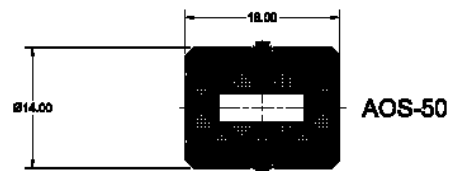
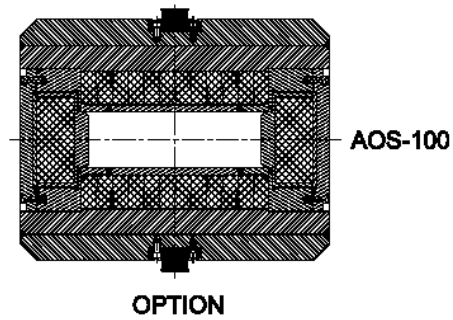
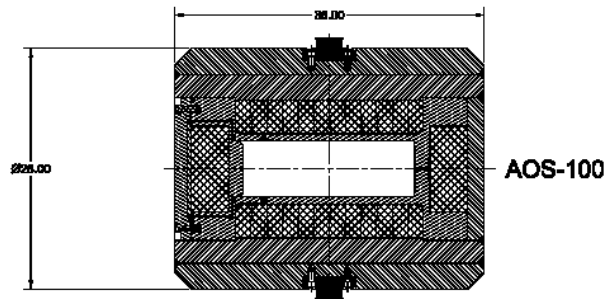
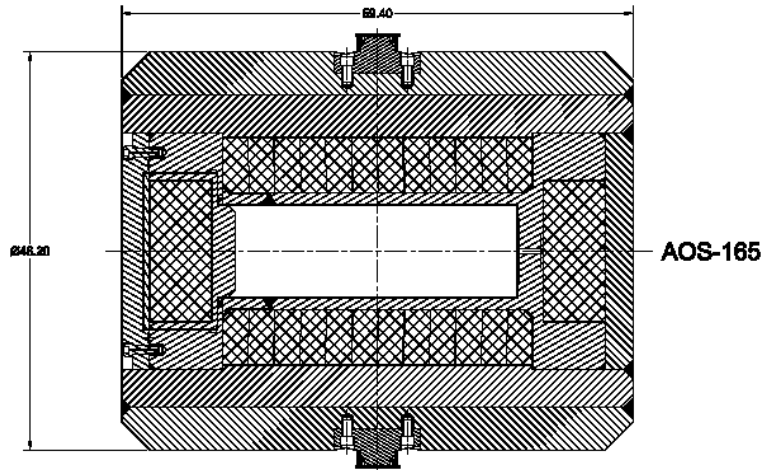
- Design and license, for domestic and international use, a group of Type B, normal form packaging, for shipment of irradiated fuel rods, which can be cut or segmented, by product, source, or special nuclear material in solid form.
- Basic package:

Cavity Dimensions (in.)		Cask Dimensions (in.)			Content (Ci)
Diameter	Height	Diameter	Height	Lid	
6.5	20	26	36	10	20,000 Co-60

- There will be a minimum of four packaging designs developed – the base design and three other scaled designs.
- Ground and air transportation.
- Dry and wet loading/unloading.



Packaging Designs





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Conceptual Design Approach

Scaling Relations

Assumptions:

- Monolithic structure, preferred
- Same materials
- Bolting based on MS
- Length ratio (basic/member) = λ

Quantity:

- | | |
|------------------|-------------|
| • Length | λ |
| • Mass or weight | λ^3 |
| • Time | λ |
| • Velocity | 1 |
| • Acceleration | $1/\lambda$ |
| • Force | λ^2 |



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Iterate Procedure to Maximize Commonalities Incorporated into Basic Design

- Review requirements as how they are met by the design
- Review commonalities among the scaled designs:
 - ✓ Geometry
 - ✓ Materials selection
 - ✓ Special features or components
- Evaluate scaled designs against regulations



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Establish Licensing Strategy

- Major applicable regulations:
 - ✓ DOT 49CFR173, Subpart I, “Class 7 (Radioactive) Materials”
 - ✓ NRC 10CFR71, “Packaging and Transportation of Radioactive Material,” 2004
 - ✓ IAEA, “Regulations for the Safe Transport of Radioactive Material,” 1996 Edition (Revised), 2003
 - ✓ NUREG/CR-6407, “Classification of Transport Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety,” February, 1996



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Establish Licensing Strategy (cont.)

AOS Transport Packaging System Analyses Summary

Item	AOS-025A	AOS-050A	AOS-100A	AOS-100B	AOS-100A-S	AOS-165A	AOS-165B
Package Category	III	III	II	III	II	I	I
Weight	128 kg	590 kg	3,900 kg	3,300 kg	3,900 kg	18,300 kg	15,500 kg
Content	Activated	Activated	Activated / Fissile	Activated	Activated	Activated / Fissile	Activated
Form	Solid / Liquid	Solid / Liquid	Solid	Solid	Solid	Solid	Solid
Decay Heat							
Activated Materials	10W (34 BTU/hr)	100W (683 BTU/hr) Isotope	0.4 kW (1.4k BTU/hr) Isotope	0.4 kW (1.4k BTU/hr) Isotope	0.4 kW (1.4k BTU/hr) Isotope	7 kW (23.9k BTU/hr) Isotope	7 kW (23.9k BTU/hr) Isotope
Fissile Material	N/A	N/A	0.4 kW (1.4k BTU/hr) Fuel	N/A	N/A	1.2 kW (4.1k BTU/hr) Fuel	1.2 kW (4.1k BTU/hr) Fuel
General	✓	✓	✓	✓	✓	✓	✓
Design Pressure	207 kPa (30 psia)	414 kPa (60 psia)	1,930 kPa (280 psia)	517 kPa (75 psia)	517 kPa (75 psia)	1,517 kPa (220 psia)	1,517 kPa (220 psia)



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Establish Licensing Strategy (cont.)

AOS Transport Packaging System Analyses Summary (cont.)

Item	AOS-025A	AOS-050A	AOS-100A	AOS-100B	AOS-100A-S	AOS-165A	AOS-165B
Structural							
Weight and Cg	✓	✓	✓	✓	✓	✓	✓
Lifting Devices	✓	✓	✓			✓	
Tie-down Devices	✓	✓	✓			✓	
Containment Shell Buckling	✓	✓	✓	✓	✓	✓	✓
Normal Conditions							
Heat	✓	✓	✓			✓	
Diff. Thermal Exp.	✓	✓	✓			✓	
Cold	✓	✓	✓			✓	
Reduced Ext. Press.	✓	✓	✓			✓	
Increased Ext. Press.	✓	✓	✓			✓	
Vibration	✓	✓	✓			✓	
Water Spray	✓	✓	✓			✓	
Free Drop	9.0m (30 ft.)	9.0m (30 ft.)	1.2m (4 ft.)			0.30m (1 ft.)	
Corner Drop	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Compression (Stacking)	✓	✓	✓			N/A	N/A
Penetration	✓	✓	✓			✓	



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Establish Licensing Strategy (cont.)

AOS Transport Packaging System Analyses Summary (cont.)

Item	AOS-025A	AOS-050A	AOS-100A	AOS-100B	AOS-100A-S	AOS-165A	AOS-165B
Structural (cont.)							
<i>Hypothetical Accident Conditions</i>							
Free Drop	✓	✓	✓			✓	□
Crush	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Puncture	✓	✓	✓			✓	□
Thermal	✓	✓	✓			✓	□
Immersion (F. M.)	N/A	N/A	✓	N/A	N/A	✓	N/A
Immersion [150 kPa (21.7 psig)]	✓	✓	✓			✓	□
Deep Water Immersion	✓	✓	✓			✓	□



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Establish Licensing Strategy (cont.)

AOS Transport Packaging System Analyses Summary (cont.)

Item	AOS-025A	AOS-050A	AOS-100A	AOS-100B	AOS-100A-S	AOS-165A	AOS-165B
Thermal							
<i>Normal Conditions</i>							
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	✓	✓	✓			✓	
<i>Hypothetical Accident Conditions</i>							
Fire	✓	✓	✓			✓	
Containment							
Internal Pressure (Fission Gases)	N/A	N/A	✓			✓	
Lid Joint	✓	✓	✓			✓	



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Establish Licensing Strategy (cont.)

AOS Transport Packaging System Analyses Summary (cont.)

Item	AOS-025A	AOS-050A	AOS-100A	AOS-100B	AOS-100A-S	AOS-165A	AOS-165B
Shielding							
Source Term	✓	✓	✓	✓	✓	✓	
Decay Heat	✓	✓	✓	✓	✓	✓	
Gamma Dose	✓	✓	✓	✓	✓	✓	
Neutron Dose			✓			✓	
Transportation Index	✓	✓	✓	✓	✓	✓	
Criticality							
Criticality Safety Index (CSI)			✓			✓	
Normal Conditions of Transport			✓			✓	
Hypothetical Accident Conditions of Transport			✓			✓	



Establish Licensing Strategy (cont.)

Acceptance Test Matrix

Matrix	AOS-025	AOS-050	AOS-100A	AOS-100B	AOS-100A-s	AOS-165A	AOS-165B
Acceptance							
Materials							
Metals	✓	✓	✓	✓	✓	✓	✓
Foam ^[1]						✓	
Seal ^[2]	✓	✓	✓	✓	✓	✓	✓
Weld	✓	✓	✓	✓	✓	✓	✓
Verification							
Materials							
Foam ^[3]	✓	✓	✓	✓	✓	✓	✓
Weld	✓	✓	✓	✓	✓	✓	✓
Seal ^[4]	✓	✓	✓	✓	✓	✓	✓
Containment ^[5]	✓	✓	✓	✓	✓	✓	✓
Thermal	N/A	N/A	N/A	N/A	N/A	✓	N/A
Mechanical	N/A	N/A	N/A	N/A	N/A	✓	N/A
Containment ^[6]	✓	✓	✓	✓	✓	✓	✓
Gamma ^[7]	✓	✓	✓	✓	✓	✓	✓

[1] Formulation tests to be performed upon initial order or formulation change.

[2] Vendor to perform independent material verification.

[3] Batch tests are to be performed on each batch required to fulfill an order. Increment or pour test is performed on each pour of every batch.

[4] Vendor to perform environmental test upon initial order or material change.

[5] Pressure testing at 150% design pressure 10 CFR 71.85(b).

[6] MSLD He Test at least 2.00E-08 Std atm-cc/sec sensitivity.

[7] To be performed prior to first shipment or sooner.



Establish Licensing Strategy (cont.)

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Package Components or Features	Component Safety Group											
	Containment		Criticality	Other Safety								
	Cask Cavity Shell; Lid; Lid Bolts; Port Plug; Pipe Plug.	Lid seal	Criticality Liner	Tungsten shielding	Outer Shell; Lid Plug; Cask End Plate.	Port Plug Seal.	Neutron Shielding Liner.	Cask Trunions; Cask Ears	Heat Transfer Jacket	Tie-Down Cradle	Impact Limiter	
Reference	183C8452; 166D8125; 218B6177183C8444, P2 & P4.	183C8450.		183C8446.	105E9696; 183C8445.	183C8444, P2.		183C8438; 183C8437.		105E9701	105E9694	
Safety classification	A	A	A	B	B	B	B	B	A	C	A	
B&PV Code Section	Sec. III, Division 3		Sec. III, Division 1, Sub-section NG	Sec. III, Division 1, Sub-sections NG & NF							Sec VIII, Division 1	
Material Requirements	WB-2000		NG-2000	SAE-AMS-T-21014, Class 3	NG-2000		NF-2000	NF-2000	NG-2000	NF-2000	UG	
Forming, fitting and aligning	WB-4200		NG-4200		NG-4200		NF-4200	NF-4200	NG-4200	NF-4200	UG	
Welding	WB-4400		NG-4400		NG-4400		NF-4400	NF-4400	NG-4400	NF-4400	UW	
Qualification of weld procedure and personnel	WB-4300		NG-4300		NG-4300		NF-4300	NF-4300	NG-4300	NF-4300	UW	
Weld Heat Treatment	WB-4600		NG-4600		NG-4600		NF-4600	NF-4600	NG-4600	NF-4600	UW	
Examination	WB-5000		NG-5000		NG-5000		NF-5000	NF-5000	NG-5000	NF-5000	UW/UG	
Acceptance Testing	WB-6000	(ANSI N14.5)	GE Spec. 22A9419	Guidelines ASTM B311-93 (2002)	Per Applicable Code Or Standard	ANSI N14.5	later	ANSI N14.6	GE Spec. 22A9419	ANSI N14.6	GE Spec. 22A9420	

Table A Fabrication, Examination, and Testing Criteria for the Package Design

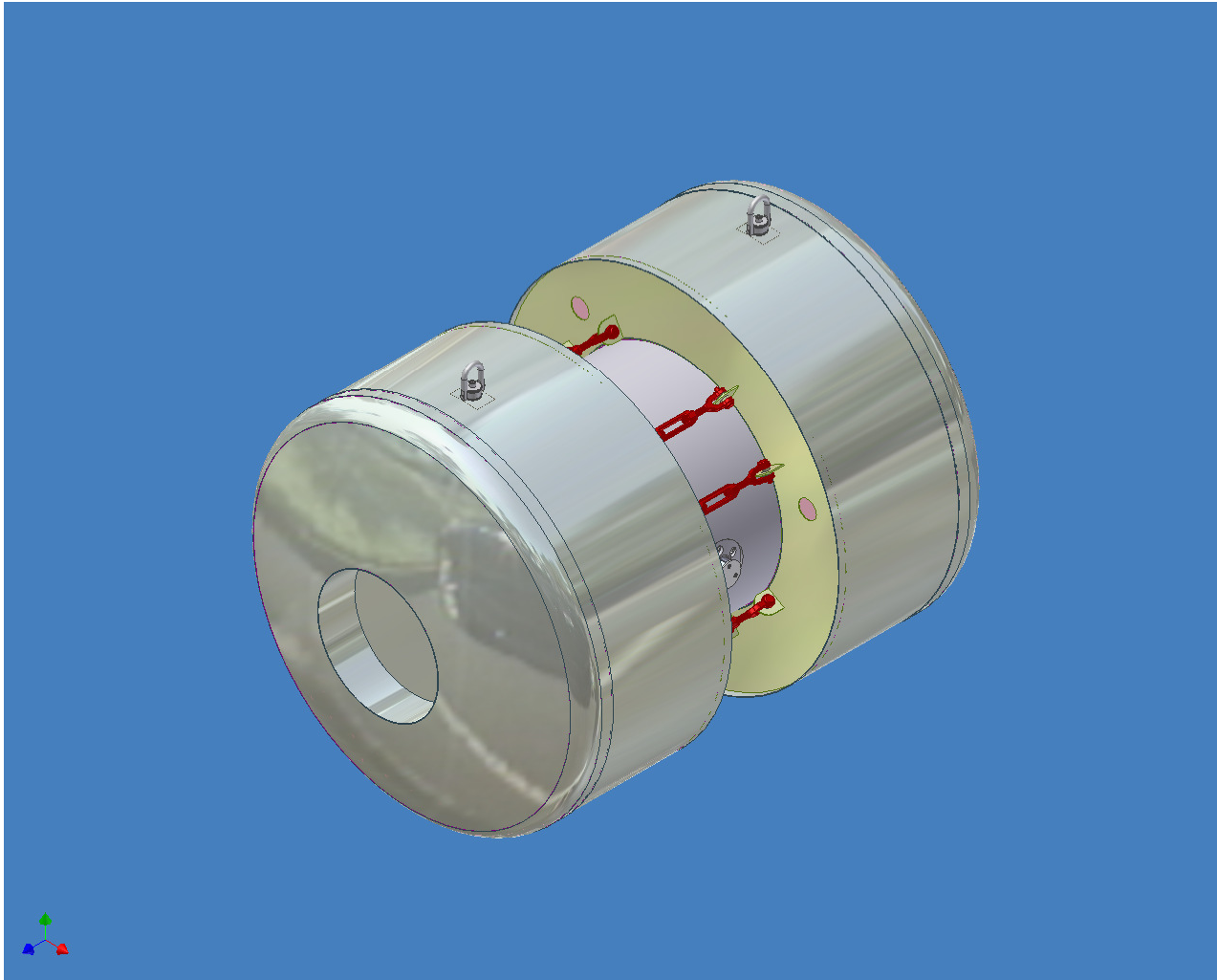


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Current Design

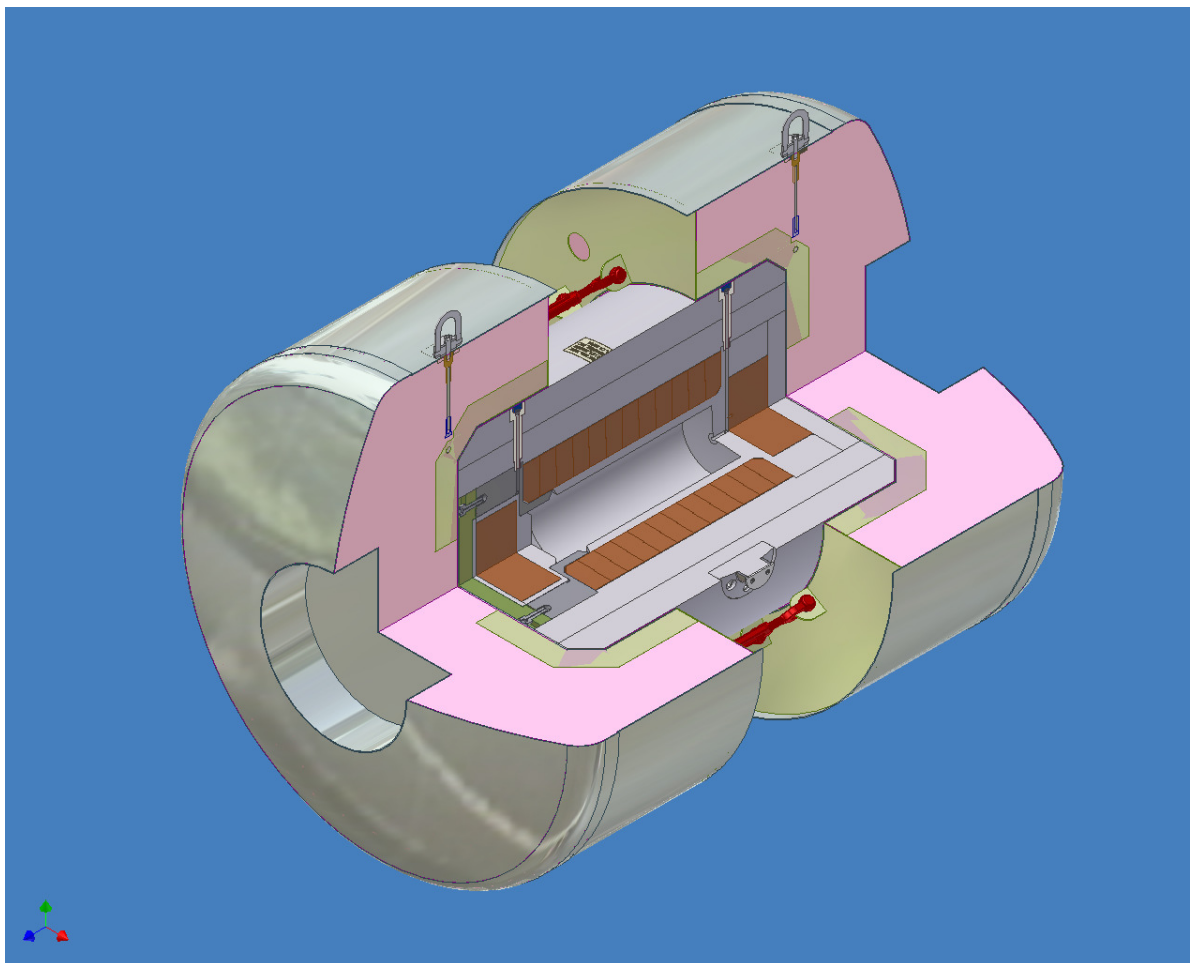




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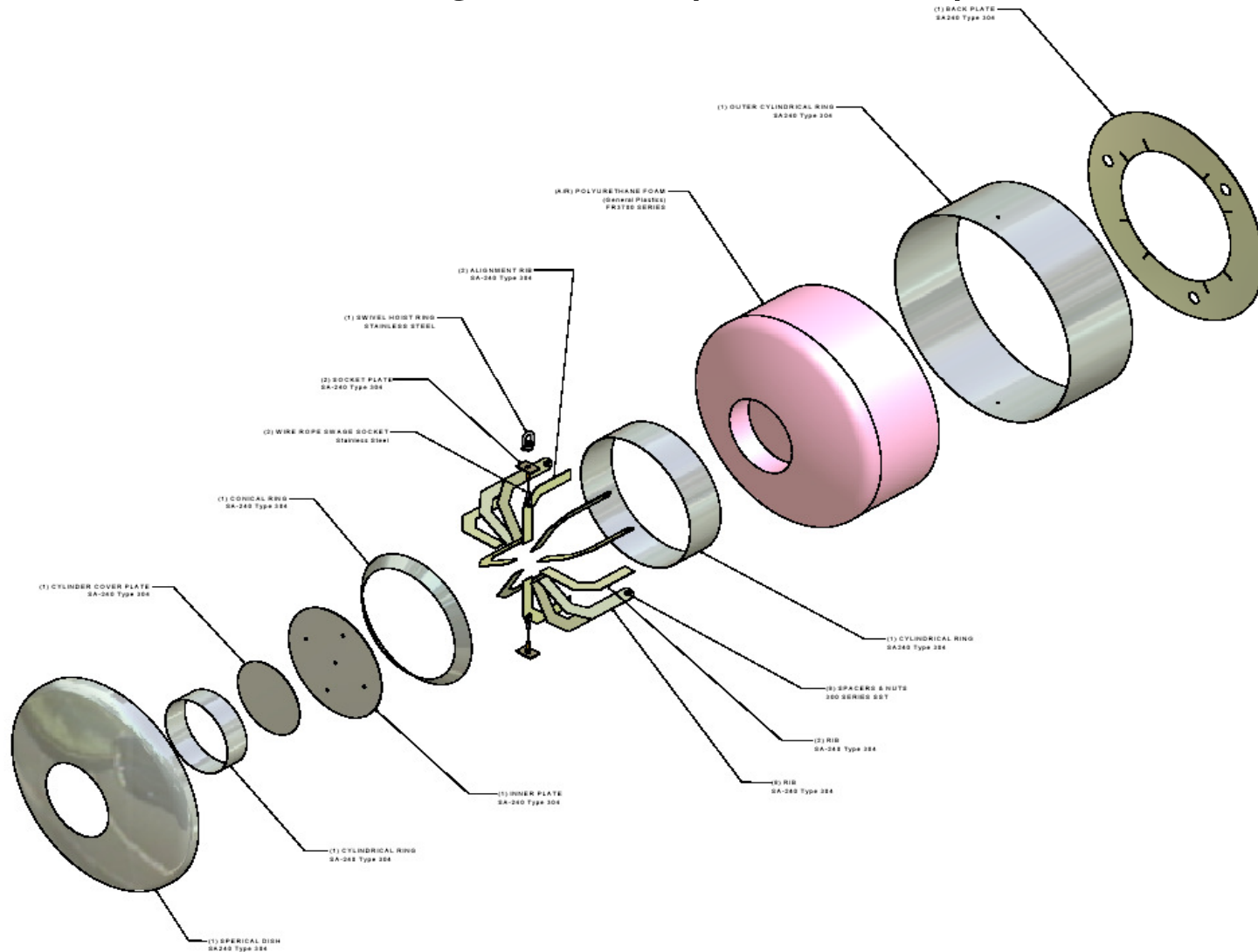


Current Design (cont.)



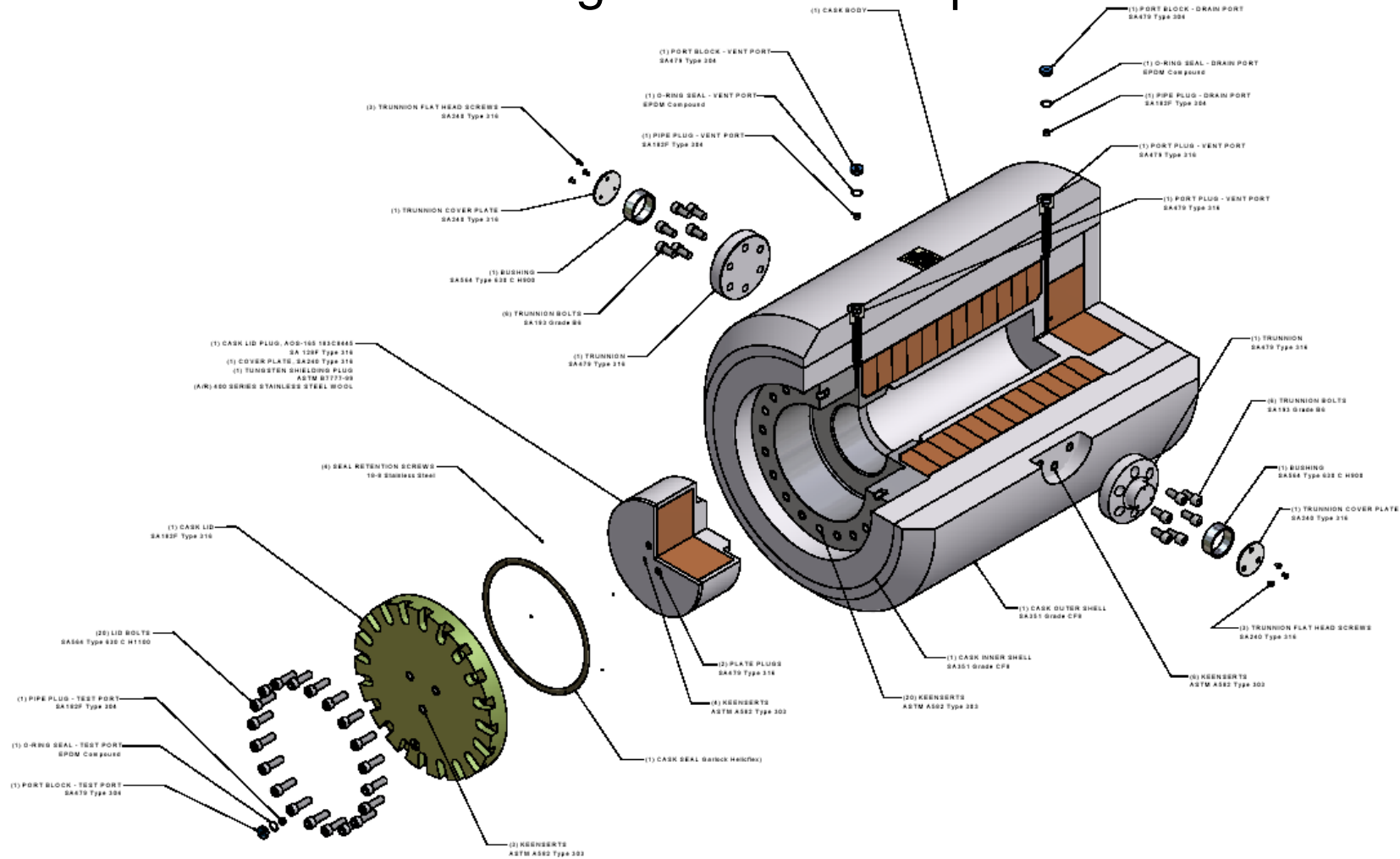


Current Design – Overpack or Impact Limiter





Current Design – Cask Component



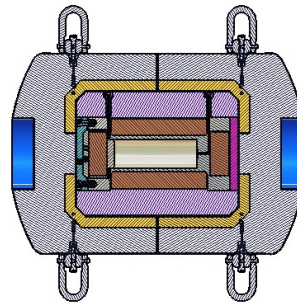


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Current Design (cont.)



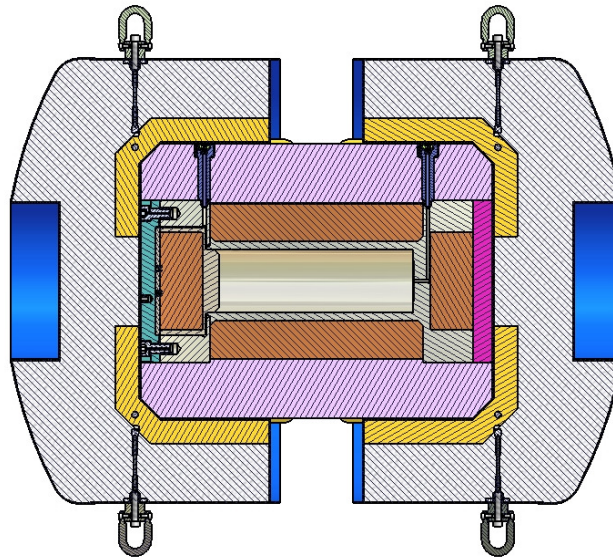
AOS-025A Cask Assembly



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Current Design (cont.)



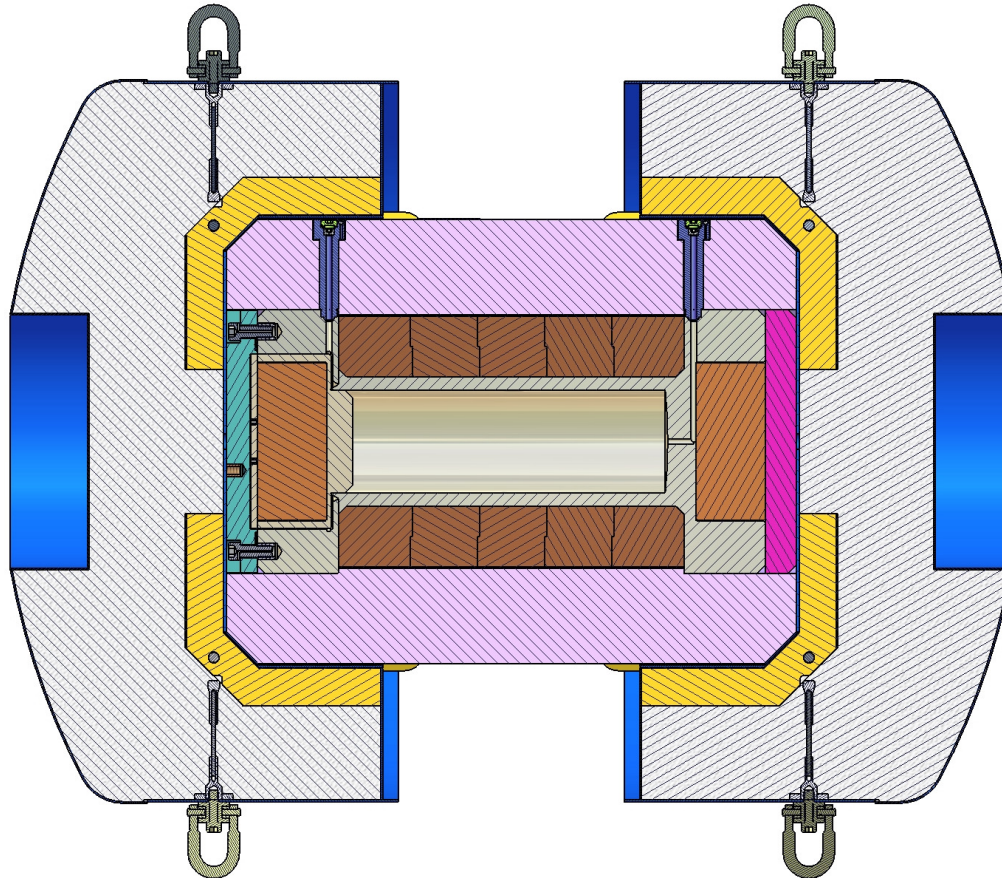
AOS-050A Cask Assembly



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Current Design (cont.)



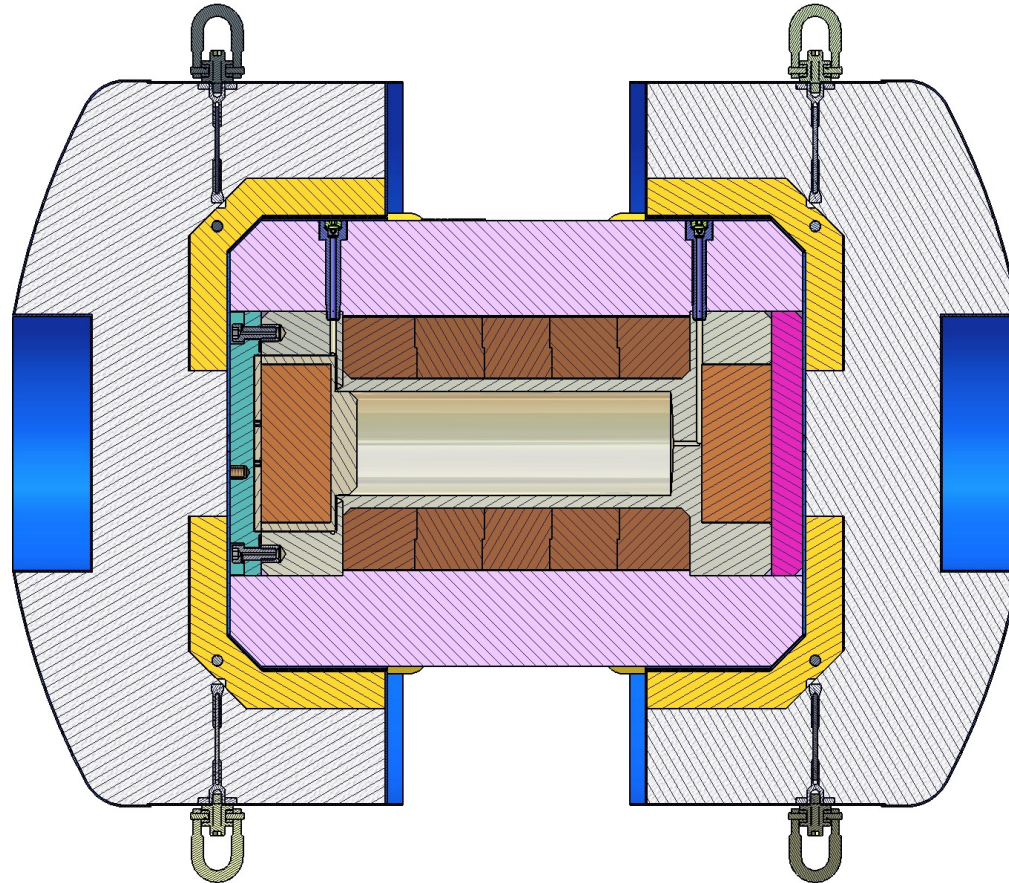
AOS-100A Cask Assembly



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Current Design (cont.)



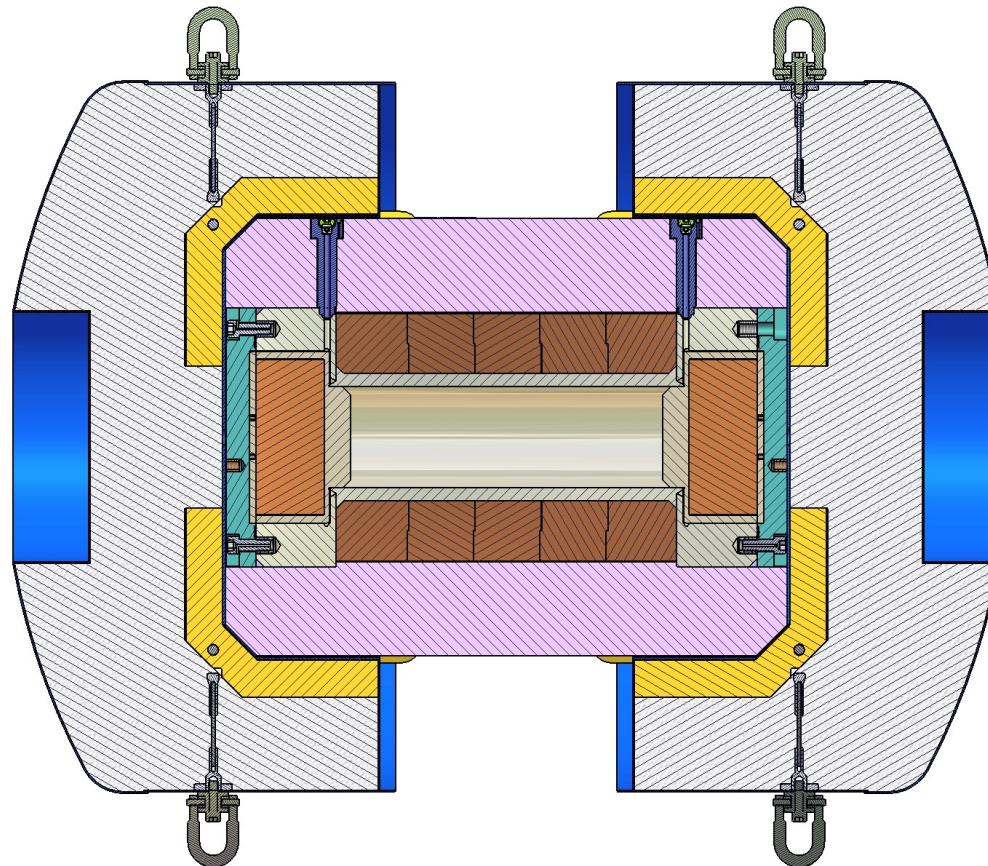
AOS-100B Cask Assembly



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Current Design (cont.)



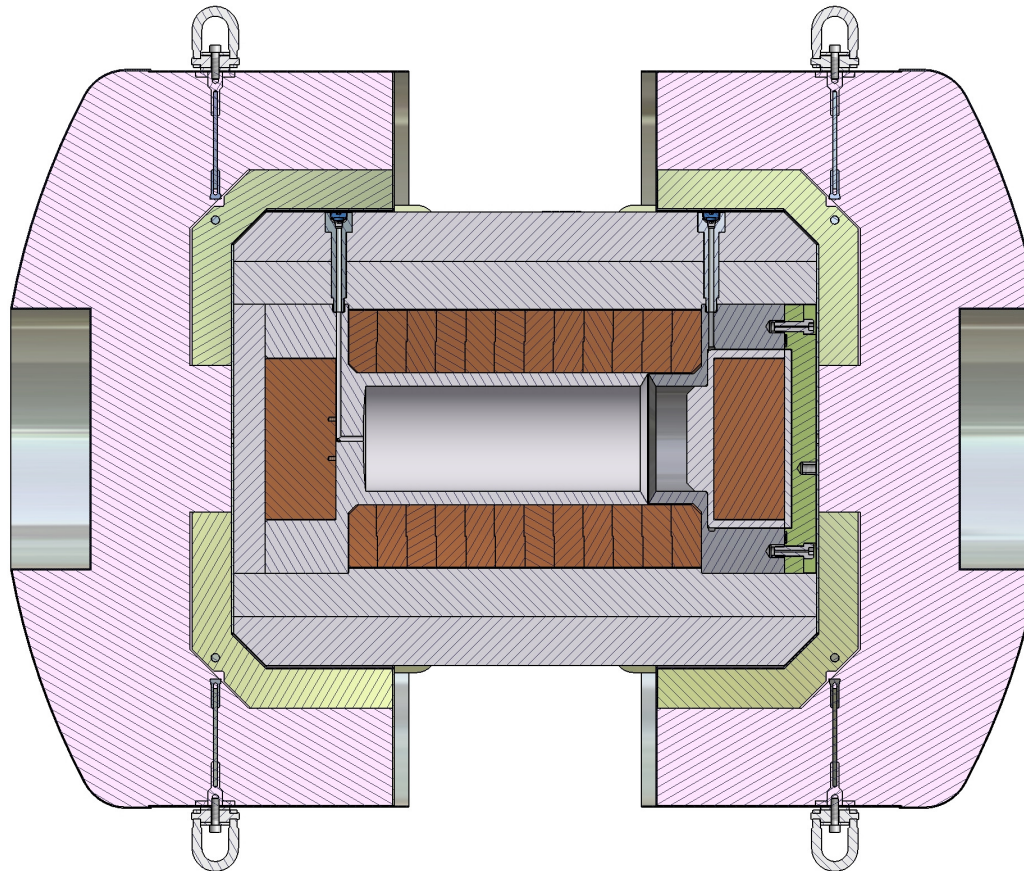
AOS-100A-S Cask Assembly



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Current Design (cont.)



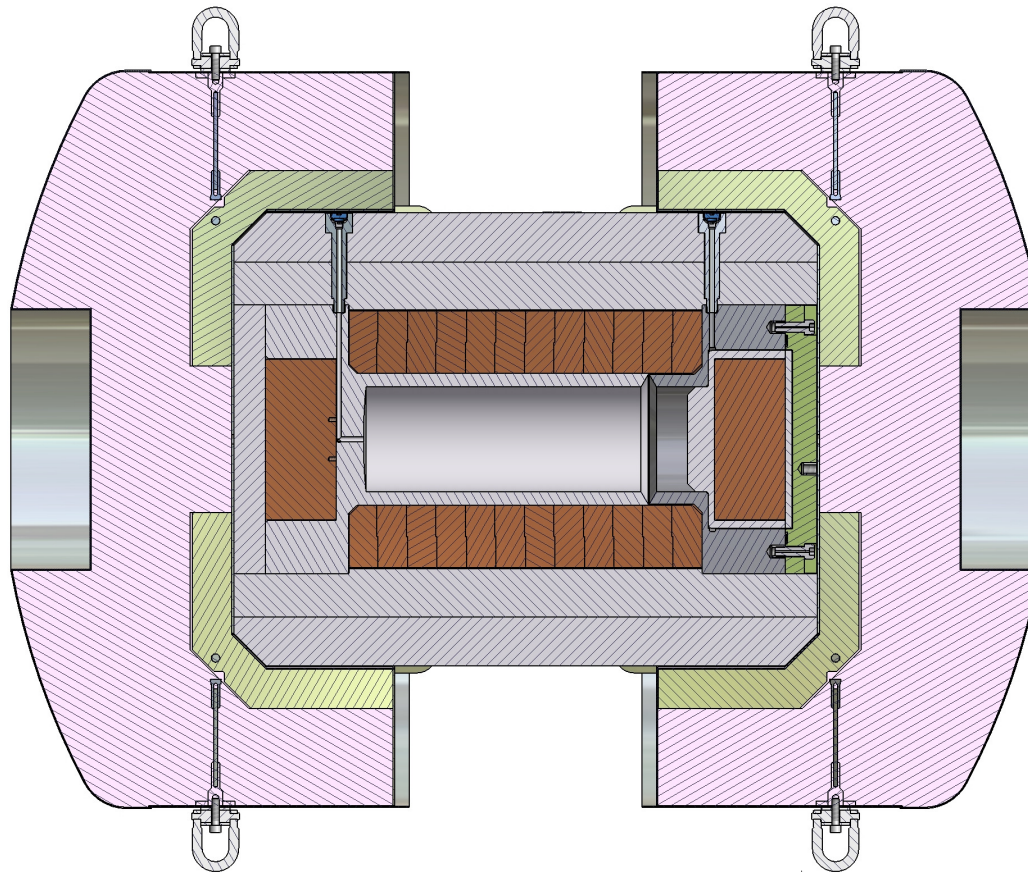
AOS-165A Cask Assembly



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Current Design (cont.)



AOS-165B Cask Assembly



General Information

AOS Transport Packaging System Summary

Model	Category	Dimensions, cm / in.						Content					Weight, kg / lb.			
		Packaging		Cask		Cavity		Radioisotope ^[1] , Ci / TBq		Fissile Materials, U-235 eq/Bup/ Cool	Decay Heat, BTU/hr - Watts		Packaging	Cask	Limiters	Content
		OD	Height	OD	Height	OD	Height									
AOS-025A	III	28.96	39.62	17.78	22.86	4.14	12.70	128			10	3	128	53	68	7
		11.40	15.60	7.00	9.00	1.63	5.00	345	Ir-192				282	117	150	15
AOS-050A	III	57.96	79.25	35.56	45.72	8.26	25.40	555			100	29	590	426	136	27
		22.82	31.20	14.00	18.00	3.25	10.00	1,500	Ir-192				1,300	940	300	60
AOS-100A	II	115.93	158.50	71.12	91.44	16.51	50.80	720		400/ 100,000/ 120	400	117	3,901	3,402	272	227
		45.64	62.40	28.00	36.00	6.50	20.00	20,000	Co-60				8,600	7,500	600	500
AOS-100B	III	115.93	158.50	71.12	91.44	16.51	50.80	8			400	117	3,232	2,733	272	227
		45.64	62.40	28.00	36.00	6.50	20.00	209	Co-60				7,125	6,025	600	500
AOS-100A-S	II	115.93	158.50	71.12	91.44	16.51	50.80	720			400	117	3,901	3,402	272	227
		45.64	62.40	28.00	36.00	6.50	20.00	20,000	Co-60				8,600	7,500	600	500
AOS-165A	I	191.26	264.16	117.35	150.88	27.23	83.82	16,200		1,200/ 100,000/ 120	7,000	2,051	18,234	14,968	2,268	998
		75.30	104.00	46.20	59.40	10.72	33.00	450,000	Co-60				40,200	33,000	5,000	2,200
AOS-165B	II	191.26	264.16	117.35	150.88	27.23	83.82	16,200			1,500	440	15,535	12,270	2,268	998
		75.30	104.00	46.20	59.40	10.72	33.00	450,000	Co-60				34,250	27,050	5,000	2,200

[1] Representative Isotope. Additional isotopes are authorized for shipment in the AOS Transport Packaging System.



General Information (cont.)

Activity Limits

Isotope	AOS-025A		AOS-050A		AOS-100A		AOS-100B		AOS-165A		AOS-165B	
	TBq	Ci	TBq	Ci	TBq	Ci	TBq	Ci	TBq	Ci	TBq	Ci
Hf-181	N/A	N/A	7.05E+01	1.94E+03	3.20E+06	8.80E+07	3.82E+02	1.05E+04	1.35E+11	3.70E+12	1.02E+06	2.80E+07
Ir-192	1.25E+01	345 ^[2]	5.45E+01	1.50E+03	7.27E+05	2.00E+07	2.48E+02	6.81E+03	8.73E+09	2.40E+11	2.84E+05	7.80E+06
Cs-137	1.82E-01	5.00E+00	4.11E+00	1.13E+02	8.36E+04	2.30E+06	4.69E+01	1.29E+03	1.60E+09	4.40E+10	3.60E+04	9.90E+05
Zr/Nb-95	N/A	N/A	1.13E+00	3.10E+01	1.58E+04	4.35E+05	1.52E+01	4.19E+02	1.93E+08	5.30E+09	7.64E+03	2.10E+05
Co-60	2.00E-03	5.50E-02	7.27E-02	2.00E+00	7.27E+02	20,000 ^[2]	7.60E+00	209 ⁴	8.73E+04	2.40E+06	1.64E+04	450,000 ³
Sr/Y-90	Unbounded											
C-14	Unbounded											
Na-24	5.82E-04	1.60E-02	1.27E-02	3.50E-01	No Analysis							
P-32	Unbounded											
P-33	Unbounded											

[1] Package radial surface is 6.00 cm (2.36 in.) from cask outer surface.

[2] Package axial surface is 70.43 cm (27.73 in.) from cask top surface.

[3] Axial and radial tungsten liner used.

[4] Axial tungsten liners used.



General Information (cont.)

Activity Limits (cont.)

Isotope	AOS-025A		AOS-050A		AOS-100A		AOS-100B		AOS-165A		AOS-165B	
	TBq	Ci	TBq	Ci	TBq	Ci	TBq	Ci	TBq	Ci	TBq	Ci
Sc-46	5.16E-03	1.42E-01	7.27E-02	2.00E+00	No Analysis							
Fe-59	5.24E-03	1.44E-01	1.45E-01	4.00E+00	No Analysis							
Se-75	1.37E+02	3.76E+03	2.51E+02	6.90E+03	No Analysis							
Sr-89	Unbounded											
Sb-124	1.02E-03	2.80E-02	1.64E-02	4.50E-01	No Analysis							
Ba-135	Unbounded											
Sm-153	1.28E+03	3.52E+04	2.09E+03	5.75E+04	No Analysis							
Ho-166	2.43E-01	6.68E+00	3.17E-01	8.71E+00	No Analysis							
Yb-169	2.73E+02	7.52E+03	5.02E+02	1.38E+04	No Analysis							
Yb-175	3.48E+03	9.57E+04	6.36E+03	1.75E+05	No Analysis							
Fissile, Enrichment less or equal 5%	No Analysis				400/100,000/120 ^[3]		No Analysis		1,200/100,000/120 ⁵		No Analysis	
Fissile, Enrichment greater than 5%, to 94%	No Analysis				300/100,000/120 ⁵		No Analysis		600/100,000/120 ⁵		No Analysis	

[1] Package radial surface is 6.00 cm (2.36 in.) from cask outer surface.

[2] Package axial surface is 70.43 cm (27.73 in.) from cask top surface.

[3] U-235 mass equivalent / Burn up / Cooling days.