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Evaluating a Type B Radioactive Material Packaging to Air Transport Conditions

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ABSTRACT

Type B Radioactive Material Packagings are designed and built to performance standards under normal conditions of transport and hypothetical accident conditions as defined by Title 10 Part 71 of the Code of Federal Regulations. Recently, Type B RAM Packages were transported by air. This event raised the question as to the expected performance and resultant condition of these packagings following this experience. This paper discusses the similarities and differences in the regulatory requirements for Type B and air transport packagings and evaluates the performance, both hypothetical and by testing, of the packages that were transported by air.

Background

In June of 2017 two Model 9977 Radioactive Material Packagings (RAM) Packages (9977s), Figure 1, Serial Numbers 100041 and 100043, were used to ship plutonium by air to the Savannah River National Laboratory (SRNL). The Model 9977 is a Type B(M)-F RAM Packaging that is certified by the NNSA Office of Packaging and Transportation (NNSA-OPT) for ground transport only. The 9977 is not currently authorized for the transport of any RAM by air. The 9977 is designed, and shown through testing and analysis, to withstand the structural loads and thermal stresses from the normal conditions of transport (NCT) and hypothetical accident conditions (HAC) as defined by Title 10, Part 71 of the Code of Federal Regulations (CFR) Sections 71 and 73, respectively. A package designed and intended for the transport of plutonium by air must meet the performance requirements of 10 CFR 71.64, “Special requirements for plutonium air shipments”, and 10 CFR 71.74, “Accidents conditions for air transport of plutonium.” The ground and air transport requirements are summarized in the Table below.

Tests	Type B		Pu Air Transport [1]
	NCT §71.71	HAC §71.73	§71.64 & §71.74
Heat	38 °C & insolation		54 °C
Cold	-40 °C		-40 °C
Reduced Pressure	25 kPa		
Increased External Pressure	140 kPa		
Vibration	Normal to transport		
Water Spray	5 cm/hr for 1 hr		
Free Drop	1.2 m	9 m	129 m/sec
Corner Drop	NA [6]		
Compression	5 × Package weight or 13 kPa × vertical area		31800 pounds static load Plate and 2.5 cm bar
Penetration	3.2 cm dia 6 kg steel rod dropped 1 m		
Crush		500-kg plate dropped 9 m	227 kg probe dropped 3 m [2]
Puncture		1 m onto 15 cm dia. bar	angle [3] falling 46 m
Thermal		800 °C for 30 min	JP-4 or -5 fuel for 60 min
Immersion – Fissile Material		0.9 m [4]	0.9 m [4]
Immersion – All Packages		15 m [5]	Pressure of 4 MPa

1	Package weighing less than 500 pounds
2	End of Probe the shape of the frustum of a right circular cone, 30 cm long, 20 cm in diameter at the base, and 2.5 cm in diameter at the end
3	Angle to be 1.8 m long with section legs 13 cm long by 1.3 cm thick
4	Test done to a HAC tested package.
5	Test done to an undamaged Package.
6	Not Applicable, Package weight exceeds 100 kg.

Discussion

In order to assess the condition of these two Packages, the conditions of the transport of the 9977s by air was evaluated against its baseline design and evaluation criterion. Since there was no accident occurrence during the air shipment, comparison of the 9977 design performance with the Aircraft HAC is not pertinent. However, comparison of the conditions of the air transport with the baseline ground transport conditions is germane to evaluating the package condition and to prepare for possible packaging condition prior to disassembly and removal of the contents.

The Packages traveled, at least once, via FedEx in a cargo plane. While FedEx does provide special "Temperature Control" for the containers of Shippers who request such, the 9977s were not shipped with special temperature controls. The FedEx "Temperature Control Services Team" was contacted to establish the temperature and pressure conditions on cargo aircraft without the "Temperature Controls." These aircraft are minimally heated and the temperature depends upon into which "cabin" the cargo is place. The rear cabin temperature is between 2ºC and 8ºC (35.6°F and 46.4°F). The middle cabin temperature is between 8ºC and 20ºC (46.4°F and 68°F). The forward cabin temperature is between 7ºC and 15ºC (44.6°F and 59°F). The cabins are pressurized to prevent "lowered pressure" damage to the cargo, but the actual pressure was unknown. However, these cabins are crew accessible (habitable) during flight so the pressure cannot be too low.

In order to evaluate the expected performance of the Packages during the air transport, each air transport performance criterion was compared against the comparable 10 CFR 71.71 NCT performance criteria or the actual aircraft conditions during transport, and the packages design and testing performance.

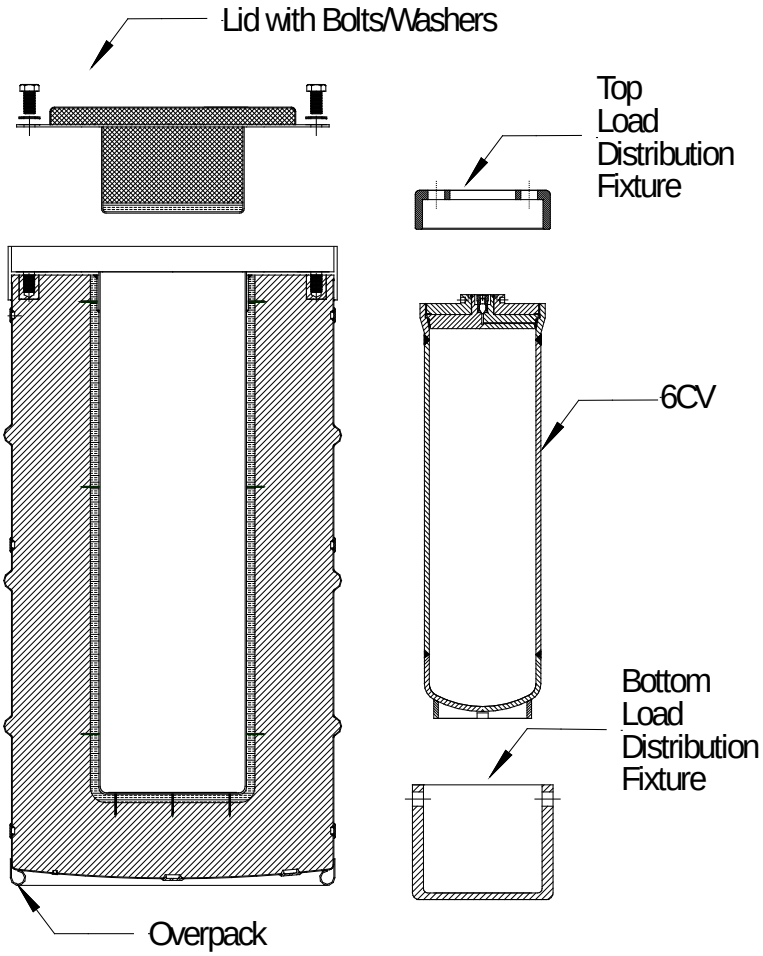

Figure 1 - Exploded View of the Model 9977 Packaging

10 CFR 71.71 - "Normal conditions of transport"

Paragraph (c) of this Section defines the "Conditions and tests" to which the package must be evaluated.

Requirement (1) – Heat
"An ambient temperature of 38°C (100°F) in still air and insolation."

The 9977 was tested and evaluated for an ambient temperature of 100°F with insolation. As discussed with the FedEx Temperature Control Team, the aircraft maximum ambient temperature in flight is 68°F. This temperature is less than the regulatory required ambient temperature.

Therefore, the aircraft maximum ambient temperature condition was bounded by the evaluated "Heat" criterion and does not challenge the 9977 package condition or performance.

Requirement (2) – Cold
"An ambient temperature of -40°C (-40°F) in still air and shade."

The 9977 was evaluated for an ambient temperature of -40°C (-40°F) and physically tested at a package temperature of -20°F. Per discussions with the FedEx Temperature Control Team, the aircraft minimum ambient temperature in flight is 35.6°F.

This aircraft minimum ambient temperature condition was bounded by the evaluated "Cold" criterion and does not challenge the package condition or performance.

Requirement (3) - Reduced external pressure
"An external pressure of 25 kPa (3.5 lbf/in^2) absolute."

Although the pressure in the cargo cabin was not measured it is known to be "habitable." Therefore, the aircraft pressure cannot be less than 0 psia. This reduction in pressure can be evaluated as an equal increase to the 6CV design pressure (800 psig at 300 °F):

$$800 + 14.7 = 814.7 \text{ psig}$$

This pressure bounds the 9977's Containment Vessel's the Maximum Normal Operating Pressure (MNOP) of 422 psig and is below the ASME Section III, Level A service limits for the design. The Safety Analysis Report for Packaging for the 9977 Appendix 2.2 shows a minimum ASME Code margin of 46% (rounded from 45.7%) at a Containment Vessel's internal pressure of 800 psig. Increasing the Containment Vessel's internal pressure to 814.7 psig results in a minimum ASME Code margin of 45% (rounded from 44.7%).

Therefore, this reduced external pressure condition during the air transport is bounded by the evaluated "Reduced External Pressure" criterion and will not challenge the package.

Requirement (4) - Increased external pressure
"An external pressure of 140 kPa (20 lbf/in^2) absolute"

As established with the FedEx Temperature Control Team, their cargo aircraft are pressurized to permit human occupancy of the cargo area, but not to a pressure greater than sea level atmospheric. The 9977 has been analyzed for an absolute overpressure of 20 lbf/in2 with no discernable effect on the package drum overpack or the 6CV.

This aircraft maximum external pressure condition was bounded by the evaluated "over-pressure" criterion and will not challenge the package.

Requirement (5) – Vibration – "Vibration normally incident to transport"

Ground Transport

The 9977 was analyzed for random vibrations based on the power spectral density for the Safe Secure Transport which demonstrated that vibration and shock loadings are small and would not cause any fatigue concerns. Service vibration loads are very small compared to drum closure-bolt preload, the bolts will not loosen during normal transport. A prototype package was vibration and shock tested when assembled in the heaviest configuration; loaded with a 100 lb payload. The package was subjected to a series of random vibrations and shocks that simulated over-the-road transport, forklift handling, and loading operations. The vibration and shock spectrum used is considered conservative in respect to that required by 10 CFR 71.71(c)(5). The random vibrations and shocks are conservative with respect to the power spectral density plots indicative of the SST/SGT and other large truck and trailer combinations. There was no observable external damage to the package or material degradation inside the package.

Air Transport

The 9977 H-Gear, the H1700, has for the last 7 years been transported by air. While the type of aircraft used is probably different than that used by FedEx to ship these two 9977s, the number and the distance of the H1700 shipments is significantly greater. There have been no recorded instances of use related damage to the H1700 and only minor internal wear attributable to vibrations, less than that observed in the solely ground transported 9977.

This aircraft vibration conditions were bounded by the evaluated "Vibration normally incident to transport" criterion, for both ground and air transport, and will not challenge the package.

Requirement (6) - Water spray
"A water spray that simulates exposure to rainfall of approximately 5 cm/h (2 in/h) for at least 1 hour."

Water spray is not expected during transportation by aircraft. Nor was there any evidence of rain on or other wetting of the package during the loading or unloading operations. However, the 9977 was tested for water spray and, while it did retain water during the NCT test, there was no adverse effect on its subsequent performance.

The water spray event, if it occurred, would not challenge the package.

Requirement (7) - Free drop
"Between 1.5 and 2.5 hours after the conclusion of the water spray test, a free drop through the distance specified below onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected."

A drop was not reported nor was there any visible external evidence of a drop during the package transportation to SRNL. However, the 9977 was tested and analyzed for 4-foot drops at various orientations and initial conditions and showed minimal damage to the drum and negligible stress in the package 6CV closure assembly.

There is no report or evidence of a free drop event during the air transport of the 9977s, however, a drop of 4-feet or less will not challenge the package.

Requirement (8) - Corner drop
"A free drop onto each corner of the package in succession, or in the case of a cylindrical package onto each quarter of each rim, from a height of 0.3 m (1 ft) onto a flat, essentially unyielding, horizontal surface. This test applies only to fiberboard, wood, or fissile material rectangular packages not exceeding 50 kg (110 lbs) and fiberboard, wood, or fissile material cylindrical packages not exceeding 100 kg (220 lbs)."

Corner drop evaluation is not applicable to the 9977, because its minimum weight of 250 lb exceeds the maximum weight requirement of 220 lb for a cylindrical fissile material package.

Requirement (9) – Compression
"For packages weighing up to 5000 kg (11,000 lbs), the package must be subjected, for a period of 24 hours, to a compressive load applied uniformly to the top and bottom of the package in the position in which the package would normally be transported."

The 9977s were not stacked or subjected to compression loads during transportation by aircraft. Moreover, the 9977 was tested for a compressive load of 1,750 lb applied for 24 hours with no observable deformation of the packaging.

Were the 9977s stacked (compressed), the condition would not challenge the package.

Requirement (10) – Penetration
"Impact of the hemispherical end of a vertical steel cylinder of 3.2 cm (1.25 in) diameter and 6 kg (13 lbs) mass, dropped from a height of 1 m (40 in) onto the exposed surface of the package that is expected to be most vulnerable to puncture. The long axis of the cylinder must be perpendicular to the package surface."

There is no report of impacts to the 9977s during transportation by aircraft and no apparent damage. However, these 9977s will be examined prior to unloading for impact damage.

An impact (penetration) event of this magnitude would not challenge the package.

Conclusion:

The environmental conditions to which the Model 9977 Packages were subjected during the air transport are not considered a challenge to its design safety basis. Most conditions are within the baseline design and test conditions. One condition, vibration, may be outside the as tested ground transport condition. However, empirical data from the (nearly) identical H1700 Packaging demonstrates that the vibrations normal to air transport do not adversely affect the wear or performance of the 9977. It is concluded that the air transport of the two Model 9977 packages did not adversely affect their wear or performance under NCT nor has it reduced its capability for future ground transport use.

Upon receipt of the two 9977s at SRNL. The Packages were moved to a controlled storage location until they could be opened. The Packages were then moved to a Radiological Buffer Area where they were opened and inspected in accordance with a special procedure. The opening of the Packagings was video recorded while the Packagings were fully inspected and their condition was documented photographically. The Packaging operation (opening, removal of the RAM Contents and closure) was performed normally. There was no damage or evidence of wear attributable to the air transport. There was no release of contamination within the Containment Vessel. These packagings were subsequently returned to service.