Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

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Extra-Regulatory Performance Criteria for US Certified Radioactive Material Packages

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ABSTRACT

Type B and Type AF radioactive material shipping packages in the United States are designed, analyzed and tested to demonstrate and document performance in satisfying the regulatory safety requirements set forth in the U.S. Code of Federal Regulations (CFR) 10 CFR 71. The results of the package analysis and testing performed are presented in a Safety Analysis Report for Packaging, which is prepared in accordance with U.S. Department of Energy Order 460.1C and in the format specified in the Nuclear Regulatory Commission Regulatory Guides. In many instances these packages are utilized within DOE facilities as storage packages and, as such, these packages are subsequently subjected to facility safety basis conditions and accidents that differ from and, in some instances, exceed those specified in the Code. This paper discusses some of these extra-regulatory conditions, why they exist, and how the packages perform outside their transportation design basis.

Background

Savannah River National Laboratory (SRNL) develops Type B and Type A-Fissile Radioactive Material (RAM) Packaging for the Department of Energy (DOE) and the National Nuclear Security Administration (NNSA). The design and performance of these RAM shipping packages are documented in Safety Analysis Reports for Packaging (SARP) to justify authorization by the DOE Environmental Management (EM) Packaging Certification Program (PCP) or the NNSA Office of Packaging and Transportation (OPT) via Certificates of Compliance (CoC). The SARP and CoC authorized the shipment of specific contents, in specified container configurations and under specific operating procedures. The SARPs establish the design of the packaging, demonstrated its compliance with the requirements of Title 10 of the Code of Federal Regulations (CFR) Part 71 [Ref 1] (documenting is ability of meet the transportation Normal Conditions of Transport (NCT) and the Hypothetical Accident Conditions (HAC) without loss of containment), its design pressures, temperatures, shielding and criticality features, its minimum essential operating procedures, its acceptance and maintenance requirements, and its Quality Assurance program. Facilities within the DOE and NNSA Complexes receive and store nuclear materials in these shipping Packages. Facilities typically credit the shipping packages as serving a facility safety function, as the package's robust and validated design and certified construction provides a creditable containment boundary that could prevent the release of nuclear material during facility normal and hypothetical accident conditions. These facility safety functions may,

and often do, exceed the similar Regulatory Transportation safety functions. Table 1 lists the 10 CFR requirements for Transportation during NCT and HAC in comparison with some similar facility safety conditions. Not every condition in one regime has an equivalent in the other.

Table 1: 10CFR Transportation and Typical Facility Packaging Safety Conditions

Condition	Transportation	Facility
NCT		
Heat	100°F ambient w/ insolation	(1) ambient w/o insolation
Cold	-40°F	(1)
External Pressure	3.5 lb_f/in^2 and 20 lb_f/in^2	-
Vibration	normal to transportation	earthquake
Water Spray	2 in/h for min 1 hour	flood
Free Drop	4 ft	stacking height
Corner Drop	1 ft	-
Compression	5x weight or 2 lb_f/in^2	stacking
Penetration	13 lb cylinder - 40 in	-
HAC		
Free Drop	30 ft	stacking height
Crush	1100 lb - 30 ft	earthquake
Puncture	40 in onto 6-in bar	forklift
Thermal	1475°F for 30 min	1832°F for 1 h
Immersion	3 ft / 50 ft	flood
Ballistic Impact/Munitions	-	.223 round – plus

Note 1: Varies by facility

Discussion

Packaging Design Authorities and Design Agencies typically perform the minimum essential package design to meet the CFRs for the transport of their intended RAM Content and configuration and to meet the interface requirements for the facilities in which it is know that they will be loaded and unloaded and the conveyances by which they will be transported. Due to the number of storage facilities and the lack of uniformity in the safety requirements for those facilities, designing a transportation package to meet every storage requirement is not cost effective. Alternatively, certified Type B RAM Packages are very robust in design and can typically meet (if not attenuate) storage facility safety requirements. Being able to credit a shipping Package while in storage may permit increases in facility inventory limits or reduce the need for ancillary safety systems such as fire suppression. Facility safety criteria can be classified into three categories when compared to transportation conditions; extensions (e.g longer time, more energy, etc.), alternatives (e.g other types of impacts) and new challenges (i.e. scenarios not considered during or applicable to transportation).

Thermal

Facility fire scenarios fall within the class of "extended" transportation accidents conditions. The Model 9975 and 9977 Packages have been evaluated and/or tested for the thermal conditions of NCT and the HAC (1/2 hour duration fire of 1475°F (800°C). Facility fire scenarios are typically both hotter and of a longer duration due to the increased fuel loading anticipated for a building. Therefore, both Packages have additionally been evaluated for their thermal response during the postulated 2 hour duration of a Savannah River Site (SRS) storage facility 1832°F (1000°C) fire. [Refs 2 & 3] Tables 2 and 3 lists the predicted maximum temperatures for the O-Rings and the vessel wall of the Packages' containment vessels (the Primary and Secondary CVs and the 6CV) which are the key components in the 9975 in the 9977 Packages, respectively.

Table 2 – Maximum Temperatures of the 9975 Primary and Secondary Containment Vessels in Transportation and Facility Fires

Scenario	Condition	SCV		PCV	
		O-Rings	CV Wall	O-Rings	CV Wall
	(°F/min)	(°F)	(°F)	(°F)	(°F)
Transportation	1475 / 30	192	192	194	195
Facility	1832 / 120	280	553	284	416

Table 3 – Maximum Temperatures of the 9977 6CV in Transportation and Facility Fires

Scenario	Condition	O-Rings	CV Wall
	(°F/min)	(°F)	(°F)
Transportation	1475 / 30	381	400
Facility	1832 / 120	362	365

As expected, the longer hotter facility fire produces greater key components temperatures in the 9975, but, unexpectedly, the same didn't happen with the Model 9977. Why? The difference arises from the bases of the Model 9977's fire scenario evaluations. The Model 9977 uses polyurethane foam as thermal insulating shock absorbing material within the drum. The thermal decomposition of the polyurethane foam involves melting, endothermic combustion, intumescence and mass/energy transport out of the drum volume. This behavior is very difficult to model. Therefore, the "fire" portion of the transportation fire event was conservatively modeled as a temperature increase (as measured on a package that was fire tested without foam insulation). This increase was superimposed on all internal component pre-fire temperatures to determine the initial post-fire temperatures. For the facility fire the specific char rate of the foam insulation was set to 0.1 mol/m^{3}s, the average char rate observed in the transportation fire tests. The use of measured properties, even with higher fire temperatures and longer exposure, resulted in lower 6CV temperatures. It is apparent that the transportation fire analysis is overly conservative.

Forklift Impact

The facility Forklift impact is an "alternate" scenario to those proposed for the 10 CFR transportation conditions and accidents. There are two Regulatory Transportation "penetration/Impact" events; the NCT Penetration and the HAC Puncture tests, respectively. Both of these are relatively low energy/low mass events. The facility postulated Forklift impact is much more energetic, consisting to two 20,000 pound forklifts traveling at 7 mph simultaneously impacting a Package from opposite directions. The impact is made even more severe due to the small impact area of the forklift tine. The 9975 Package has been analyzed for this impact [Ref 4] and its ability of the Primary Containment Vessel to continue to provide containment of the RAM contents has been established. Figure 1 illustrates two scenarios with the times impacting the 9975 at different elevations. The PCV maintains containment.

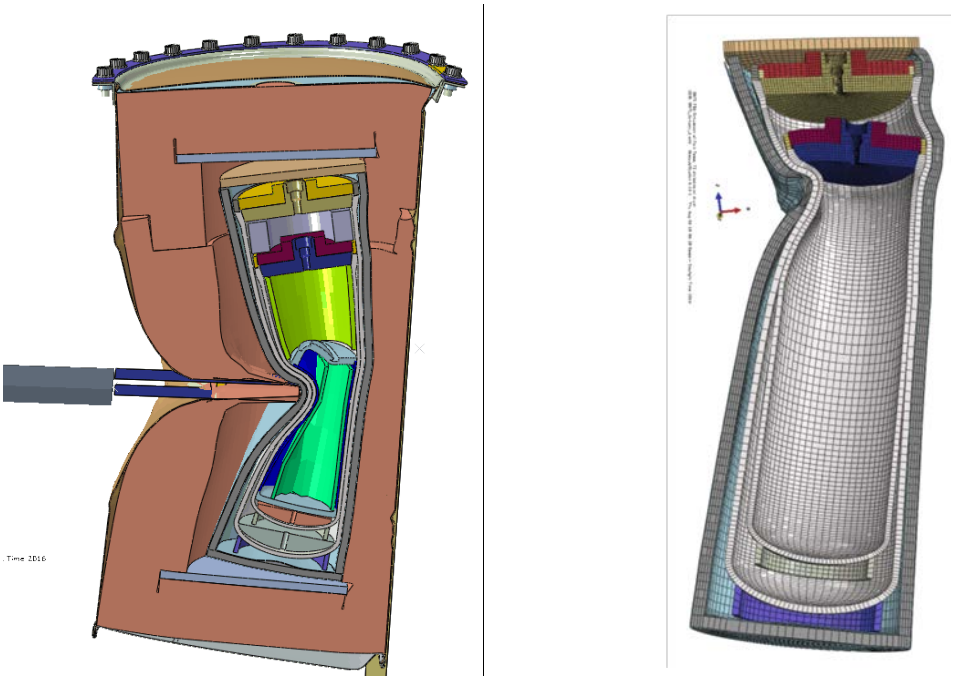

Figure 1 – Forklift Impacts to the Model 9975 Package

Ballistics/Munitions

The ballistics and munitions accident scenarios are a completely new class of accident that are not considered in the 10 CFR transportation conditions and accidents. The ballistics and munitions accident scenarios evaluate the Packages response to the facility protective forces' accidental discharge of a weapon or a munition. Since all accidents must be considered and then either tested or analyzed, the completely unanalyzed ballistics tests were performed on these shipping packages to validate the ability of the packages to withstand such an event. To date, three Type B shipping packages have undergone ballistics testing; the 9975, the 9977, and the ES-3100.

The ballistics test involves the firing of a .223 caliber projectile into a package from a rifle from a distance of 30 feet that was aimed at the Content Containers. The acceptance criterion was limiting the damage to the package to the extent that there would be no release of the content material. The munitions test involves the detonation a device in contact with the surface of the package. In order to establish the vulnerability of the package three devices were independently detonated, one each on the top, bottom and the side of the Package. The acceptance criterion again was no release of content material. All three packages passed the ballistics and munitions tests. Figures 2 and 3 illustrate the testing of the Models 9975, 9977 and ES-3100 Packages.

Figure 2 – Ballistic Tests of the Model 9977 (Left) and ES-3100 (Right) Packages

Figure 3 – Munition Tests of the Model 9975 (Top), 9977 (Middle) and ES-3100 (Bottom) Packages

Conclusion

Type B and Type A-Fissile Radioactive Material (RAM) Packagings are designed and tested to meet the safety requirements set forth in the U.S. Code of Federal Regulations 10 CFR 71 for the transport of their RAM Contents. Due to the robust designs of these packages they can typically also meet the safety requirements of Storage Facilities. This functionality provides Storage Facility operators with the option to save money and reduce worker exposure by not requiring the unloading of the RAM contents from the transport container just to be reloaded into a facility specific storage package. The containment, shielding, and assurance of sub-criticality provided by the transport package may permit increases in facility inventory limits or reduce the need for ancillary safety systems.

References

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