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Maximum Inner Container Dose Rate That Will Ensure Meeting Regulatory Limit at Package Surface – 19206

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ABSTRACT
Often, the shipper of radioactive material does not know the exact radioactive isotopic composition of the materials that need to be shipped. This is especially important for legacy materials that need to be removed from a site that is in the process of being decommissioned. A method of determining the acceptability of such material for shipment before it is placed in into the shipping package will allow more flexibility in planning for decommissioning activities.

A series of Monte-Carlo calculations were performed to calculate the dose rate at the surface of a convenience container or a shielding pig separately and then at the surface of a new shipping package being designed by the Savannah River National Laboratory (SRNL). The purpose of these calculations is to determine the maximum dose rate at the surface of the convenience container or the shielded pig that will ensure the dose rate at the outer surface the shipping package is less that the regulatory limit of 200 mrem/hr. The calculations also considered the effect of shape of the radioactive material and its possible movement inside the convenience container along with movement of the convenience container inside the confinement vessel of the shipping package.

INTRODUCTION

The Department of Transportation (DOT) grants the Department of Energy (DOE) the authority to evaluate, approve, and certify packages used for the transportation of radioactive materials against packaging standards equivalent to those specified in 10 CFR 71 [1, 2]. The requirements applicable to shielding are detailed in 10 CFR 71.47 and 10 CFR 71.51:

> 10 CFR 71.47 requires that for each package of radioactive material offered for transportation that the radiation dose rate at any point on the external surface of a package cannot exceed 2 mSv/h, and the Transport Index must not exceed 10.
>
> 10 CFR 71.51 requires that the radiation dose rate not exceed 10 mSv/h at one meter from the external surface of the package under Hypothetical Accident Conditions.

Conformance with these requirements has typically been demonstrated through radiation transport calculation which require detailed knowledge of the source material composition and geometry. One of the bases for developing a new shipping package is the small gram quantity concept which relies on measurements of the dose rate at the external surface of the Content Container or on the outside of the Shielding Pig. To determine these allowable measured dose rates a series of calculations were performed using.

METHODS

Geometric Models

The 9982 packaging shown in Figures 1 and 2 comprises a Containment Vessel Assembly within an Outer Packaging (OP). Radioactive Contents are contained in a Content Container. The Content Container is assembled within a Shielding Pig or a Content Support Fixture in the Containment Vessel. Impact absorbing components are also assembled within the Containment Vessel.

The outer dimensions of the 9982 are nominally: 24″ outer diameter and 36″ high. The Containment Vessel is nominally: 15.5″ outer diameter (flange) and 27″ high with a 0.12″ wall. The payload region has a usable cavity nominally 12.5″ diameter x 25″. The Shielding is nominally 9″ diameter and 13″ high. The Content Container is nominally: 3″ diameter and 12″ high.

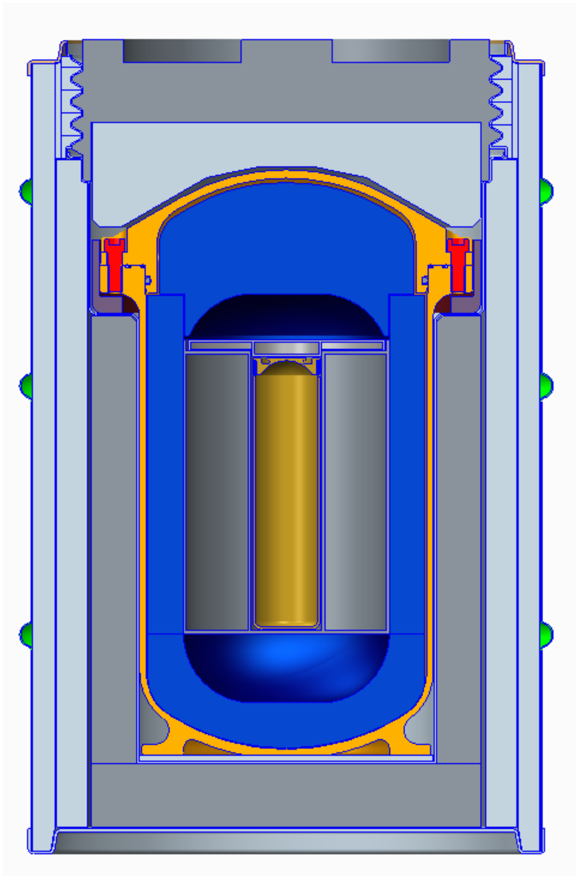

Figure 1 9982 Shipping Package with Content Container

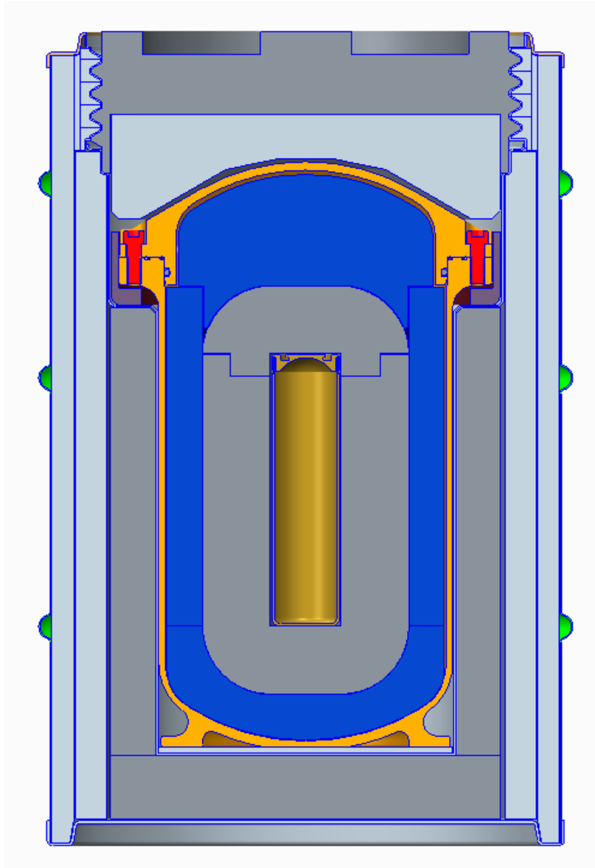

Figure 2 9982 Shipping Package with Shielding Pig

Radiation Transport Calculations

A simplified model of the 9982 shipping package was developed using concentric cylinders to model the Convenience Container, Shielding Pig (if present) and Containment Vessel. Shielding effects of other material in the package were conservatively ignored.

The MCNP6.1 code package [3] was used for three-dimensional Monte Carlo transport calculations to determine absorbed dose rates. ENDF/B-VII cross-section sets were used. The flux-to-dose-rate conversion factors used were those recommended by ANSI/ANS-6.1.1-1977 [4]. The values from the 1977 version of the standard were used rather than those from the 1991 version of the standard because the neutron dose conversion factors in the 1977 version more closely reflect those provided in 49 CFR 173.403, and the photon dose conversion factors in the 1977 version more closely correspond to the response measured by instrumentation.

The source was modeled as one milligram of either Co-60 or Cs-137 as a point or line source. The source was located at the center of either the Content Container or the Shielding Pig and at the edge of each container. The source spectra [5] are listed in Table I.

Dose rates were calculated at the surface of the Content Container (or Shielding Pig) and at the surface of the shipping package. For the calculation of dose rate at the surface of the package, the Content Container or Shielding Pig were moved 1.85″ outward to account for possible rearrangement of the package components during Normal Conditions of Transport.

TABLE I Source Strengths

Co-60		Cs-137	
Energy (MeV)	Intensity	Energy (MeV)	Intensity
8.500E-04	3.290E-06	4.470E-03	9.100E-03
7.461E-03	3.220E-05	3.182E-02	1.990E-02
7.478E-03	6.300E-05	3.219E-02	3.640E-02
8.265E-03	7.600E-06	3.630E-02	3.480E-03
8.265E-03	3.910E-06	3.638E-02	6.720E-03
3.471E-01	7.500E-05	3.726E-02	2.130E-03
8.261E-01	7.600E-05	2.835E-01	5.800E-06
1.173E+00	9.985E-01	6.617E-01	8.510E-01
1.332E+00	9.998E-01		
2.159E+00	1.200E-05		
2.506E+00	2.000E-08		

Point detectors were modeled on the source centerline:

- At the side of the Content Container or Shielding Pig and at the side of the overpack
- At the bottom of the Content Container or Shielding Pig and at the bottom of the overpack

DISCUSSION

The dose rate at the surface of the Content Container (or Shielding Pig) and at the surface of the shipping package are shown in Tables II and III.

TABLE II Dose Rate from Point Sources

Detector Location	Cobalt		Cesium	
	Centered	At Edge	Centered	At Edge
	Dose Rate (Sv/h)			
Side of Can	5.05E+00	1.06E+01	2.28E-01	4.76E-01
Side of Package	7.42E-01	1.47E+00	3.19E-02	6.37E-02
Bottom of Can	2.58E+00	1.78E+03	1.39E-01	4.63E-01
Bottom of Package	3.85E-01	1.27E+00	1.73E-02	5.67E-02
Side of Pig	1.01E-01	2.25E-01	7.33E-05	1.61E-04
Side of Package	1.26E-02	2.50E-02	7.68E-06	1.54E-05
Bottom of Pig	2.49E-02	1.96E-01	1.77E-05	1.72E-04
Bottom of Package	6.73E-03	2.15E-02	3.22E-06	1.31E-05

TABLE III Dose Rate from Cylindrical Sources

Detector Location	Cobalt		Cesium	
	Centered	At Edge	Centered	At Edge
	Dose Rate (Sv/h)			
Side of Can	1.40E+01	1.15E+02	6.21E-01	5.02E+00
Side of Package	6.83E-01	1.27E+00	2.92E-02	5.50E-02
Bottom of Can	9.19E+00	9.35E+00	3.76E-01	3.81E-01
Bottom of Package	2.28E-01	2.97E-01	9.27E-03	1.18E-02
Side of Pig	3.99E-02	5.61E-02	2.06E-05	3.31E-05
Side of Package	9.92E-03	1.41E-02	5.49E-06	8.45E-06
Bottom of Pig	3.67E-02	2.64E-02	2.78E-05	1.95E-05
Bottom of Package	4.86E-03	4.74E-03	3.18E-06	2.82E-06

TABLE IV Dose Rate Ratio

Type of Source	Source Location	Ratio	
		Cobalt	Cesium
Point Source	Pig Side	4.0	4.8
	Pig Bottom	1.2	1.4
	Can Side	3.4	3.6
	Can Bottom	2.0	2.5
Line Source	Pig Side	2.8	2.4
	Pig Bottom	7.8	9.8
	Can Side	11.0	11.3
	Can Bottom	30.9	31.7

CONCLUSIONS

Simplified calculations have demonstrated that measurement of dose rates below 2 mSv/h at the surface of the Content Container or Shielding Pig provides adequate assurance that the dose rate at the surface of the shipping package will below the regulatory limits specified for Normal Conditions of Transport. Since the material outside the containment vessel does not provide any additional shielding, this also ensures that the requirements for Hypothetical Accident Conditions will also be met because of the increased distance to the point of reference.

REFERENCES

1. 49 CFR 173, *Subpart I—Class 7 (Radioactive) Materials*, U.S Department of Transportation, Washington, DC, November 2015

2. 10 CFR 71, *Packaging and Transportation of Radioactive Material*, U.S Nuclear Regulatory Commission, Washington, DC, November 2017.

3. D. B. Pelowitz, Ed., *MCNP6™ USER'S MANUAL*, LA-CP-13-00634, Rev. 0, Los Alamos National Laboratory, Los Alamos, NM, May 2013.

4. ANSI/ANS-6.1.1-1977, *Neutron and Gamma-Ray Flux-to-Dose-Rate Factors*, American Nuclear Society, LaGrange Park, IL, March 1977.

5. https://www.nndc.bnl.gov/nudat2/indx_dec.jsp, Decay Radiation database version of 1/3/2018, National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY, January 2018.