RADIOACTIVE PARTICULATE RELEASE FROM THE DOT SPECIFICATION 6M CONTAINER UNDER HYPOTHETICAL ACCIDENT CONDITIONS

J.M. TAYLOR, P.J. RANEY
Battelle Pacific Northwest Laboratories*,
Richland, Washington,
United States of America

Abstract

RADIOACTIVE PARTICULATE RELEASE FROM THE DOT SPECIFICATION 6M CONTAINER UNDER HYPOTHETICAL ACCIDENT CONDITIONS.

A testing programme was conducted to determine the amount of depleted uranium dioxide powder (DUO) that would leak from the inner containment components of the United States Department of Transportation's (DOT) specification 6M container under hypothetical accident conditions. Depleted uranium dioxide was selected as a surrogate for plutonium oxide because of the similarities in powder characteristics, density and particle size and because of the special handling and special facilities required for plutonium oxide. The DUO was packaged inside food-pack cans and then placed inside the 2R vessel of the 6M container. The gas rates of the food-pack cans tested ranged from 1.6 cm^3/s to approximately 38 cm^3/s. The packaging configurations were subjected to 9 m drops, 1 m drops onto a 15 cm diameter cylinder and to heating (inner vessel only) at 150°C in a furnace that could be rotated and vibrated. The DUO leakage rate from the containment barriers after the impact and heating tests was measured using a dissolution technique and a laser fluorometer. The amount of DUO powder leakage ranged from nothing detectable to a high of 1×10^{-4} g. Impact forces had no effect on the leakage of particles with the packaging configurations used. The tests showed that when the gas leak rate was between 1.6 cm^3/s and 3.2 cm^3/s, the amount of particulate material that could be transmitted through the leak sites would be less than the allowable release limits ($<3 \times 10^{-8}$ g/h) of plutonium.

1. INTRODUCTION

The purpose of this study was to determine the particulate (powder) leakage characteristics of the DOT-specification 6M container when subjected to hypothetical accident tests. The DOT-specification container is a drum-type container (see Figure 1) that is approved for use in the United States for packaging Type B quantities of solid radioactive material. In most European countries, the 6M container is not approved for use because it has not been demonstrated that the 6M container would not release radioactive material to a sensitivity of $A_2 \times 10^{-3}$ quantity per week under hypothetical accident conditions.

* Operated by the Battelle Memorial Institute for the US Department of Energy under Contract No. DE-AC06-76RLO-1830.

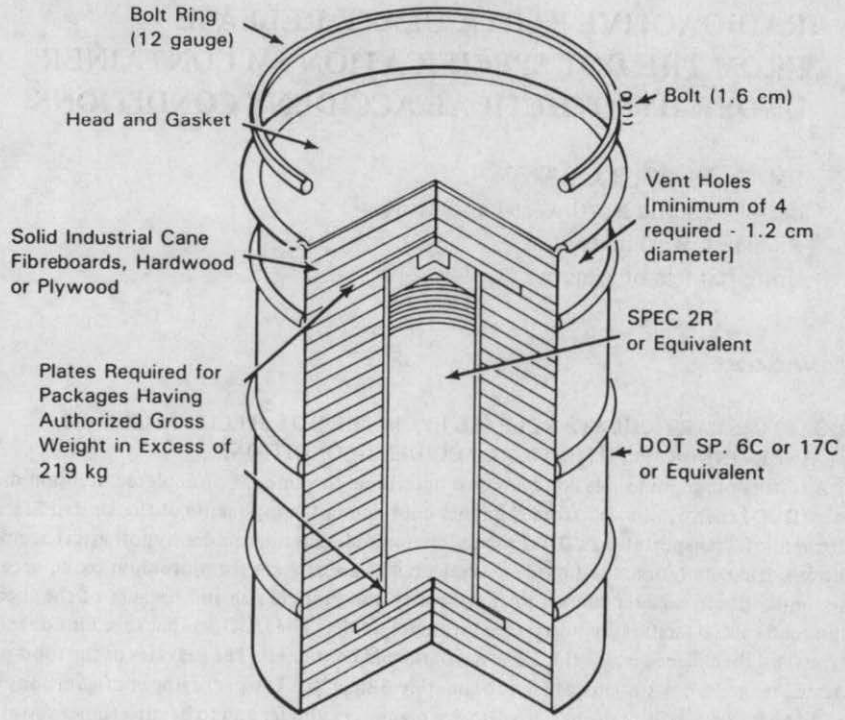

FIG. 1. DOT Specification 6M container.

In the United States, when the 6M container is used to package powders such as plutonium oxide, the powder is placed in mechanically crimped, sealed cans that are placed in the 2R vessel, which is then sealed. Consequently, there are several barriers that the powder must escape through in order to contaminate the environment.

This study was undertaken to determine how tight the seals of the metal cans must be, in terms of gas flow rate, to meet the allowable leakage of plutonium oxide under accident conditions according to the current International Atomic Energy Agency (IAEA) Regulations.

2. BACKGROUND

The allowable leakage rate of radioactive material is specified in the IAEA Regulations [1]. The Regulations state that following certain mechanical tests, thermal tests and an immersion test, the accumulated loss of radioactive

contents from a Type B(U) package is $A_2 \times 10^{-3}$ (6×10^{-6} A_2/h) quantity in 1 week. For typical reactor-grade plutonium (approximately 25 wt% plutonium-241), the allowable amount of plutonium leakage would be 3×10^{-8} g/h from a Type B(U) package.

In studies correlating gas leakage with radioactive material release for fine powders, no consistent correlation between gas flow and particle flow through orifices and capillaries could be established due to plugging of the openings [2,3]. When vigorous vibration was employed to prevent plugging, a particle flow was established [3].

The powder-leak studies provided a conservative upper limit for leakage of particulate material through small openings; however, these conservative limits may not describe the actual leakage that occurs with radioactive material containers under accident conditions. If actual packaging configurations were tested for particulate releases, a more realistic leakage assessment could be made.

Because of its size and weight, the 6M container could be handled easily for testing. In addition, the 2R vessel could be removed from the drum and heated separately without subjecting the whole container to the fire test. Consequently, the 6M container was a convenient container to use for determining radioactive material release under accident conditions.

3. EXPERIMENTAL PROCEDURE

Depleted uranium dioxide powder was used as a surrogate for plutonium oxide because of the special handling and special facilities required. The DUO powder was selected because it has similar density and particle size and should closely relate to the leakage characteristics of PUO_2 powder. The DUO powder had a mass medium diameter of about 2 μm. The minimum particle size measured was 0.4 μm.

The DUO powder (400 to 800 g) was packaged in metal cans and placed inside the 2R vessel of the 6M container (see Figure 2). The gas leak rates of the metal cans tested ranged from $<10^{-5}$ cm^3/s to approximately 38 cm^3/s. The gas leak rates for the metal cans tested were determined either by a vacuum, glycol bath (bubble test) or by pressurizing the cans with nitrogen gas and measuring the flow of gas through in-line rotometers. The 2R vessel was sealed ($<10^{-5}$ cm^3/s leakage) to prevent powder leakage during testing. The loaded 6M containers were subjected to 9 m

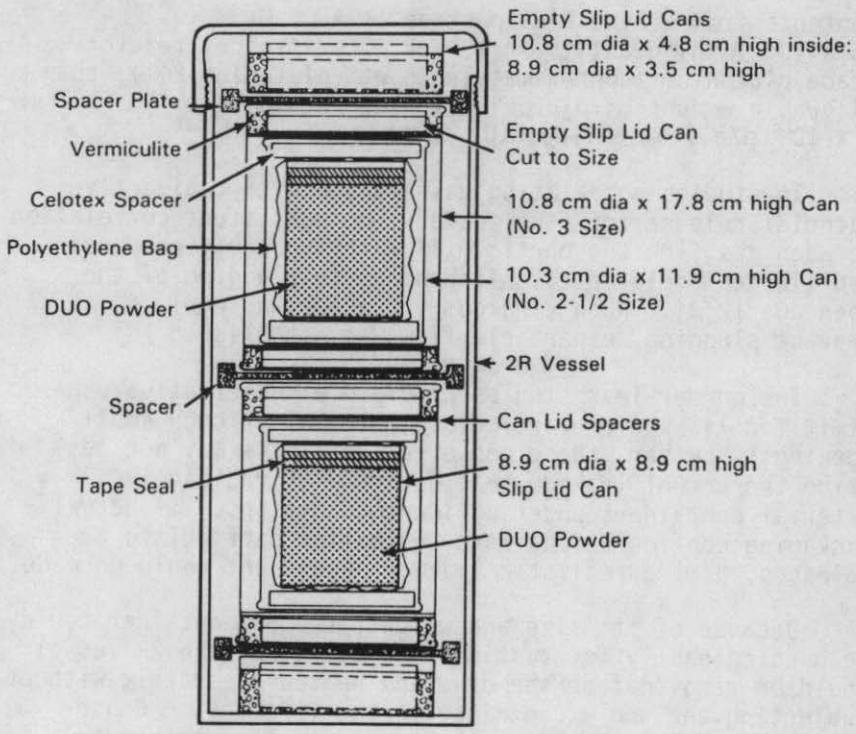

FIG. 2. Packaging configuration for DUO powder inside a 6M container.

drops onto an unyielding surface and 1 m drops onto a 15 cm diameter cylinder.

After impact, the 2R vessels were heated to above 150°C in a tube furnace to simulate the fire test. During heating, the tube furnace was rotated (2 rev./min) and vibrated (120 Hz, 0.6 g to 0.8 g). The leakage of the DUO powder from the containment barriers was measured by dissolving any released DUO using a peroxide bicarbonate solution. The solution was added to the 2R vessels and the outer sealed cans through special openings in the containers. After agitating the containers for sufficient time to dissolve the DUO powder, samples were taken and analyzed.

The uranium analysis was performed using a laser fluorometer developed to analyze very low concentrations (picograms) of uranium in natural waters [4].

TABLE 1. DUO Powder Release from Metal Cans Inside the 2R Vessel of a 6M Container After Impact and Heat Tests

Test No.	Type of Can	Gas Leak Rate, cm^3/s		Uranium Leakage Inside Barriers, g/h
		Before Test	After Test	
1	#2-1/2	2.5	38	
	#3	2.5	NM [a]	1×10^{-5}
	2R ves.	sealed	sealed [b]	3×10^{-7}
2	#2-1/2	7	NM	
	#3	$<10^{-5}$	NM	1×10^{-7}
	2R ves.	sealed	sealed [b]	ND [c]
3	#2-1/2	2.3	8.3	
	#3	3.2	3.2	1×10^{-7}
	2R ves.	sealed	sealed [b]	ND
4	#2-1/2	$<10^{-5}$	1.6	
	#3	$<10^{-5}$	$<10^{-5}$	ND
	2R ves.	sealed	sealed [b]	ND

a NM means not measured.
b The 2R vessel was vented through a filter to generate higher pressures inside the metal cans during heating and cooling.
c ND means none detected ($<1 \times 10^{-8}$).

4. RESULTS AND DISCUSSION

The test results (see Table 1) indicate the amount of uranium leakage through the leak site of the metal cans.

The amount of uranium leakage was determined after a 20 h period, which was the time period required for the 2R vessel to return to ambient conditions after heating and cooling. The total uranium leakage was normalized to a 1 h period.

The higher gas leak rates after testing (see Table 1) resulted from deformation of the can lids due to gas pressurization during the heating and cooling cycle. The source of the pressure buildup was principally from moisture associated with the DUO powder.

TABLE 2. Comparison of DUO Powder Leakage from Various Experimental Studies

Type of Leak Path	Dia. μm	Pres. kPa [a]	Gas Flow atm·cm³/min	DUO μg [a]
Capillary [b]	120	207	96	18[c]
Capillary [b]	182	103	29-67	89[d]
Capillary [b]	276	207	520-1650	649[c]
Orifice [b]	100	103	160-180	287[d]
Orifice [b]	200	207	860-1000	744[d]
Orifice [e]	100	103	96	7300
Orifice [e]	200	103	378	30400
Tortuous path [f]	200-300	-- [g]	-- [g]	167
Tortuous path [f]	190-350	--	--	22
Tortuous path [f]	140-220	--	--	2
Tortuous path [f]	110-135	--	--	2
Tortuous path [f]	100-180	--	--	0.3

a Release is based on 1 hour.
b From Sutter et al. [2].
c Leak path above the static powder level.
d Leak path under the static powder level.
e From Curren and Bond [3].
f Distance through crimp seal on lid of No. 2 1/2 food pack can.
g Not measured during tests.

The metal cans were not deformed or damaged from impact testing due to the way the cans were stacked and protected inside the 2R container (see Figure 2).

Metal cans that had gas leak rates from 1.6 cm³/s to 3.2 cm³/s (tests 3 and 4) did not transmit a detectable amount of DUO powder during hypothetical accident testing.

A comparison was attempted (see Table 2) between the particulate release observed in this study and the release reported in the studies by Sutter et al. [2] and Curren and Bond [3]. The data in Table 2 were obtained from equations presented by Sutter et al. [2] and from curves by Curren and Bond [3].

Direct comparisons among the studies were not possible because of the difference in test parameters; only descriptive comparisons could be made. The comparisons that were

made were based on leak-site diameter. This was a tentative comparison because the leak paths through the crimp-sealed lids were probably not circular, and in most cases, there was more than one leak site. In the tests by Curren and Bond and Sutter et al., only one leak site of known circular cross section was present.

Another variable that influenced the leakage of powder in the tests reported here was the increased size or number of leak sites during the heat test. The increase in size or number of leak sites was due to the pressure increase during heating, which caused the cans to deform and increased the size or number of the leak sites. The range of diameters seen in Table 2 is due to the increased size of the leak-site area during the test run. The leak-site diameters for the data were estimated by comparing the measured airflow rates through capillaries of known diameter [5] with the measured gas flow rate through the leak sites in the no. 2 1/2 size cans. A correction factor was applied to account for the number of leak sites. Only the leakage rate of DUO powder from the no. 2 1/2 cans is presented in Table 2.

The tabulated values indicated greater releases were observed by Sutter et al. [2] for corresponding leak-site diameters. The leakage reported by Curren and Bond [3] was noticeably greater for corresponding leak-site diameter. The significantly higher leakage may be explained, in part, by the fact that, during Curren's and Bond's tests, vigorous vibration was used, which may have prevented the orifices from plugging.

In general, it may be speculated from the results shown in Table 2 that the powder leakage would be greater for the tests made with capillaries and orifices than for metal cans that have more complicated leak-path geometries.

The conclusion can be reached that, under accident conditions where gross gas leaks occur (approximately $<3.2\ cm^3/s$), particle leakage will be less than the allowable amount for the packaging configurations tested in this study.

REFERENCES

[1] International Atomic Energy Agency, Safety Series No. 6, Regulations for the Safe Transport of Radioactive Materials, 1973 Rev. Ed. (as amended), Vienna (1979).

[2] SUTTER, S. L., et al., Depleted Uranium Dioxide Powder Flow Through Very Small Openings, NUREG/CR-1099, PNL-3177, Pacific Northwest Laboratory, Richland, Washington (1980).

[3] CURREN, W. D. and BOND, R. D., "Leakage of radioactive powders from containers," Proceedings of the Sixth International Symposium on Packaging and Transportation of Radioactive Materials, Vol. 1, K. O. Storck & Co., Verlag und Druckerei GmbH, Hamburg (1980).

[4] ROBBINS, J. C., Field techniques for the measurement of uranium in natural waters, CIM Bulletin (1978), pp. 2-8.

[5] OWZARSKI, P. C. et al., Measured and Predicted Gas Flow Rates Through Rough Capillaries, NUREG/CR-0734, PNL-2623, Pacific Northwest Laboratory, Richland, Washington (1979).