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**Hypothetical Accident Conditions,
Free Drop and Thermal Tests:
Specification 6M**

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Hypothetical Accident Conditions, Free Drop and Thermal Tests Specification 6M

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HYPOTHETICAL ACCIDENT CONDITIONS

FREE DROP AND THERMAL TESTS

SPECIFICATION 6M

by

Ronald W. Blankenship

ABSTRACT

The 30 gallon Specification 6M shipping container with rolled-top food pack cans as inner containers is evaluated under conditions required by 10 CFR 71.42. One kilogram of depleted uranium as UO_2 was packaged in each of the inner containers. After completion of a free drop test and a simulated thermal test, the maximum observed leakage of UO_2 for the following week was 3.2 μg . This leakage is well below the allowable leakage per week for most plutonium isotopic mixtures. Using the examples provided, any plutonium isotopic mixture can be easily compared with the allowable leakage per week. Test conditions and results are reported.

I. INTRODUCTION

A series of free drop tests was completed with different impact attitudes using the 30 gallon Specification 6M shipping container (DOT-6M). Each DOT-6M contained three inner packages. Each inner package consisted of one kilogram of depleted uranium as oxide (UO_2) contained in a rolled-top food pack can which was inside a slightly larger rolled-top food pack can. After the free drop test, the inner packages were placed in a drying oven to simulate the effect of the thermal test.

These tests are an evaluation of the inner containers under conditions required by 10 CFR 71.42, "Special Requirements for Plutonium Shipments After

June 17, 1978." The requirement as stated is that there shall be no leakage of material when the entire package is subjected sequentially to the accident test conditions. The tests completed here are:

Free Drop - A free drop through a distance of 30 feet onto a flat essentially unyielding horizontal surface, striking the surface in a position for which maximum damage is expected.

Thermal - Exposure to a thermal test in which the heat input to the package is not less than that which would result from exposure of the whole package to a radiation environment of 1,475°F for 30 minutes with an emissivity coefficient of 0.9, assuming the surfaces of the package have an absorption coefficient of 0.8. The package shall not be cooled artificially until 3 hours after the test period unless it can be shown that the temperature on the inside of the package has begun to fall in less than 3 hours.

The food pack cans used as inner containers for these tests are the type normally used for PuO_2 shipments from Los Alamos Scientific Laboratory (LASL). An inspection of the several types of cans used as inner containers by Rockwell Hanford Operations showed them to be equivalent to the cans used in these tests.

Depleted uranium oxide was chosen as a substitute for plutonium. The density of the UO_2 was slightly less than 5 g/cc with an average particle size between 4 and 5 microns. The density of the FFTF plutonium oxide shipped from LASL is approximately half that of the UO_2 used in these tests. Seventy percent of the PuO_2 particles are typically less than 4.5 microns in diameter. The diameter of the PuO_2 particles has been observed to range between 2.8 and 9.5 microns.

II. DROP TEST FACILITIES

The Los Alamos Technical Area 11 (K-Site) was chosen as the site for the drop tests. This site has a tower capable of drops up to 160 feet with a maximum capacity of 6,000 pounds. A bomb rack with remote electric release was used in all drops. Each DOT-6M was supported from the bomb rack in the intended position of impact by 1/8 inch diameter aircraft cable.

The target surface for the drops was a 5 feet by 5 feet by 5 inch thick steel pad. This was on top of a 7 feet by 7 feet by 2 feet thick concrete pad.

Two high-speed motion picture cameras placed at 90° apart in relation to the impact target were used to verify the attitude at impact. Pictures taken at 3,000 frames per second would allow close inspection of how damage to the containers occurs.

Figure 1 shows the test facilities with a DOT-6M at 30 feet ready to drop. The impact target is immediately behind the inclined target surface used in other types of drop tests.

III. PREPARATIONS

The normal configuration for shipment of PuO_2 by LASL is the following:

- A. Three packages inside the Specification 2R container (DOT-2R) of the 30 gallon DOT-6M.
- B. Each of the three packages consists of two food pack cans with the PuO_2 inside the inner can.

For the test, each package contained one kilogram of depleted uranium as UO_2 , the same quantity as the plutonium that is normally shipped in each package.

Figure 2 shows the level of the UO_2 in the inner food pack can (3-3/8 inch diameter x 4-1/2 inch high). This can was sealed using a canning machine and packaged inside a 2 mil plastic bag as shown in Figure 3. This was placed in the second food pack can (4-1/4 inch diameter x 4-7/8 inch high) shown in Figure 3 and sealed using a canning machine.

Three packages prepared as described were placed in a DOT-2R with vermiculite as a shock absorbing medium. The DOT-2R was tapped vigorously to aid in packing the vermiculite. The level of vermiculite before placing the lid on the container is shown in Figure 4. Fel-Pro C-5A luting compound was spread on the threads and the cap screwed into place and tightened using strap wrenches.

The DOT-2R was placed in a 30 gallon drum. The centering rings, lid, and locking ring were put in place. The securing bolt was aligned with the seam of the drum and tightened. This was to align the weakest points of the container. Each DOT-6M for the tests was prepared in this manner.

IV. DROP TEST RESULTS

The test results are considered in two parts. First, the damage to each DOT-6M, which consists of the DOT-17C 30 gallon drum and DOT-2R, is evaluated. Then the damage to the inner containers, the food pack cans, is evaluated.

A. Damage to the DOT-6M

The attitude of the drum for the first drop is shown in Figure 5. The bomb rack and 1/8 inch aircraft cable for holding the drum are clearly shown. The points of support for the drum are the securing bolt and the C-clamp. The drum was positioned as shown, lifted to a height of 30 feet, and released.

Figure 1

Drop test facilities with 6M at 30 feet ready to drop.

Figure 2

Level of UO_2 in inner food pack can.

Figure 3

Inner food pack can in plastic bag with outer food pack can and lid.

Figure 4

Level of vermiculite in DOT-2R before drop test.

Most of the damage to the drum is shown in Figure 6. Note the compression of the lower rolling hoop, primarily on the left side. The only other damage was slight bulging of the bottom of the drum.

The impact attitude for the second drop is shown in Figure 7. The high-speed cameras verified that the initial impact was on the securing bolt. The securing bolt folded back against the drum and then the drum landed flat on its side.

Figure 8 shows the flattened side of the drum caused by the impact. Figure 9 shows the drum with the locking ring removed. Note that there is no separation of the seam or puncture at the impression of the securing bolt.

The impact attitude for the third drop is shown in Figure 10. A 1/8 inch hole was drilled through the lower edge of the drum to provide an easy means of supporting the drum with the aircraft cable. The impact was on the locking ring at the securing bolt.

The damage to the drum is shown in Figures 11 and 12, first with the locking ring in place and then with it removed. As in the previous drop, there was no separation of the seam or puncture at the impression of the securing bolt.

Figure 13 shows an impression of the cap of the DOT-2R in a centering disc in the drum used for the third drop. No other damage to any internal part of the DOT-6M was visible from any of the three drops.

B. Damage to the Internal Containers

Figure 14 shows the effect of impact on the level of vermiculite in each DOT-2R. Left to right, the containers were in the corner, bottom, and side impacts. Note the vermiculite packed in the lid of the container used in the corner impact. The vermiculite was very tightly packed in each DOT-2R, which made removal of the food pack cans difficult.

The remainder of the photographs are the food pack cans that were in each DOT-2R. The photographs were chosen to show the most damage in each case. From left to right in each photograph, the positions of the cans were top, middle, and bottom as packed in the DOT-2R.

Figures 15 and 16 show the outer and inner food pack cans that were in the bottom impact. There was only minor wrinkling of the outer cans. One of the inner cans was considerably wrinkled, but there was no separation of the seams that would cause leakage from the cans. The can which was packed at the bottom of the DOT-2R in this impact suffered more damage than those in the other parts of the test.

Figure 17 shows the outer food pack cans used in the side impact with Figure 18 showing the inner cans in this impact. There is very little damage (only

Figure 5

Impact attitude for first drop (bottom impact).

Figure 6

Damage to DOT-6M caused by bottom impact.

Figure 7

Impact attitude for second drop (side impact).

Figure 8

Damage to DOT-6M caused by side impact.

Figure 9

Damage to DOT-6M used in side impact (locking ring removed).

Figure 10

Impact attitude for third drop (corner impact).

Figure 11

Damage to DOT-6M caused by corner impact. Damage to DOT-6M caused by corner im-

Figure 12

act (locking ring removed).

Figure 13

Internal damage to DOT-6M centering disc.

Figure 14

Level of vermiculite in DOT-2R containers after drop tests.

Figure 15

Damage to outer food pack cans used in bottom impact.

Figure 16

Damage to inner food pack cans used in bottom impact.

slightly wrinkled sides) to the cans.

Figures 19 and 20 show the damage to the cans that were in the corner impact. Damage in this case was slight wrinkling of the sides of the inner cans. There was no evidence of damage that would result in leakage from the cans.

V. THERMAL TEST

The DOT-6M specification was based on a test program conducted by the Rocky Flats Plant with a cane fiberboard insulated container originally designated as the Model 1518. Tests of this container in the 15 gallon size supported the DOT-6M requirement that contents of the inner container be stable at 250°F. Larger DOT-6M's usually have thicker insulation, so the use of 250°F test conditions is conservative for general use.

The food pack cans for the thermal test were ones which had been used in a bottom impact free drop test. The food pack cans were placed in a drying oven which had been preheated to 250°F. The cans were left in the drying oven at this temperature for two hours. They were then removed from the oven and allowed to cool. There was no visible damage caused by this thermal test.

VI. DISCUSSION

To ensure that the DOT-6M met the qualification of the free drop test with regard to the container hitting the target surface in a position for which the most damage is expected, this series of free drops with different impact attitudes was completed.

The outer drum in each case suffered only minor damage. There was no separation of the seams of any drum. No drum was punctured by the securing bolt being forced against the drum by the impact. The outer drum remained intact in each drop. There was no significant damage to the internal parts of the DOT-6M.

Damage to the outer food pack cans was minor. Only slight wrinkles and dents were evident with no damage bad enough to allow leakage of material from the cans. The damage to the inner food pack cans was more extensive. Wrinkling of one of the cans in the bottom impact was considerable. There was still no separation of the seams that would allow leakage from the cans.

One additional free drop test was completed with a bottom impact, the position in which maximum damage was done in previous drop tests. The damage to the entire package was almost identical to the previous drop test. The food pack cans from this drop test were the ones that were used in the thermal test.

Figure 17

Damage to outer food pack cans used in side impact.

Figure 18

Damage to inner food pack cans used in side impact.

Figure 19

Damage to outer food pack cans used in corner impact.

Figure 20

Damage to inner food pack cans used in corner impact.

Nu-Con Smears* were used to determine the extent of leakage after each test and for a period of one week after the tests. These smears were analyzed for total alpha activity by the LASL Health Physics group (H-1). The lower limit of detection of the alpha counting system used for this analysis 0.826 pCi.

Table 1 shows the results of the alpha analysis of the smears. The drop test results are for the outer food pack cans. The outer food pack cans were opened after the thermal test, so the results for the thermal test and for the week after the tests are reported for the inner food pack cans. Only one significant figure is available for less than 1.1 pCi except for the lower limit of detection which was established after repeated counts to determine counting system background. The highest leakage for an inner food pack can for the week following the tests was 3.2 μ g.

TABLE 1
Results of Nu-Con Smear Alpha Analysis
Leakage of UO₂ in pCi (UC₂ Leakage in μ g)

<u>Can Number</u>	<u>Drop Test</u>	<u>Thermal Test</u>	One Week
			<u>After Tests</u>
1	$\leq 0.826 (\leq 1.89)$	$\leq 0.826 (\leq 1.89)$	$\leq 0.826 (\leq 1.89)$
2	1 (2)	$\leq 0.826 (\leq 1.89)$	1.4 (3.2)
3	$\leq 0.826 (\leq 1.89)$	1 (2)	1.3 (3.0)

Although 10 CFR 71.42 states that there shall be no leakage caused by the tests, Regulatory Guide 7.4 which was issued in June 1975 implements American National Standards Institute Standard N14.5 (ANSI N14.5) as acceptable for evaluating containment properties of shipping containers. ANSI N14.5 establishes the quantity, $A_2 \times 10^{-3}$, as the allowable leakage in one week for accident conditions of transport for a type B(U) shipping container. The value of A_2 for each radioactive isotope can be found in the International Atomic Energy Agency regulations¹ governing radioactive materials transport. The type B(U) shipping container is a type B packaging, together with its radioactive contents which, since it is designed in accordance with specified design and containment criteria, requires unilateral approval only of the package design and of any stowage provisions that may be necessary for heat dissipation.

Table 2 shows the calculation of the A_2 quantity per gram of plutonium (70%

* Nu-Con Smears - registered trademark for swipe test materials

^{239}Pu , 20% ^{240}Pu , and 10% ^{241}Pu). Leakage of one gram in this example would be equal to $A_2 \times 156$, which is the total of the fractions $A_2/\text{g Pu}$ for each isotope. The maximum observed leakage for the week following the tests was 3.2 μg , which corresponds to $A_2 \times 5.0 \times 10^{-4}$. With an allowable leakage of $A_2 \times 10^{-3}$ per week, the observed leakage is only half the allowable leakage.

TABLE 2
 $A_2/\text{g Pu}$ (70% ^{239}Pu , 20% ^{240}Pu , 10% ^{241}Pu)

Isotope	Ci/g*	Ci/g Pu**	A_2 (Ci)	Fraction $A_2/\text{g Pu}$
^{239}Pu	0.0614	0.0430	0.002	21.5
^{240}Pu	0.226	0.0452	0.002	22.6
^{241}Pu	112	11.2	0.1	112

* Specific activity for each isotope.

** Contribution of each isotope to the total specific activity for this isotope mixture.

Table 3 shows the calculation of $A_2/\mu\text{g}$ FFTF plutonium oxide (86.5% ^{239}Pu , 12% ^{240}Pu , and 1.5% ^{241}Pu). Leakage of 1 μg in this example would be equal to $A_2 \times 5.70 \times 10^{-5}$. The maximum observed leakage of 3.2 μg per week corresponds to $A_2 \times 1.8 \times 10^{-4}$ which is well below the allowable leakage of $A_2 \times 10^{-3}$ per week. Certainly weapon grade plutonium (93.6% ^{239}Pu , 6% ^{240}Pu , and 0.4% ^{241}Pu) would also be well below the allowable leakage rate. In these examples, it is assumed that the quantity of PuO_2 leakage would be equal to the observed leakage of UO_2 .

TABLE 3
 $A_2/\mu\text{g}$ FFTF Plutonium Oxide
(86.5% ^{239}Pu , 12% ^{240}Pu , 1.5% ^{241}Pu)

Isotope	$\mu\text{Ci}/\mu\text{g}^*$	A_2 (μCi)	Fraction $A_2/\mu\text{g Pu}$
^{239}Pu	0.0531	2,000	2.66×10^{-5}
^{240}Pu	0.0271	2,000	1.36×10^{-5}
^{241}Pu	1.68	100,000	1.68×10^{-5}

* Contribution of each isotope to the total specific activity for this isotopic mixture.

In summary, the entire package was subjected to the free drop test with no significant leakage. The simulated thermal test caused no significant leakage. The other hypothetical accident test conditions should have little effect on the shipping container and its contents in comparison with the completed tests. The material leakage from the inner containers was well below the allowable leakage rate. The food pack cans as tested, packaged in the Specification 6M shipping container, meet the requirements of 10 CFR 71.42 for most plutonium isotopic mixtures.

REFERENCE

1. International Atomic Energy Agency, Regulations for the Safe Transport of Radioactive Materials 1973 Revised Edition, (IAEA, Vienna, 1973).