161
06/30/80
HPL

LA-8367-MS

Informal Report

44. 1419

MASTER

Hypothetical Accident Conditions

Free Drop and Thermal Tests

USA/5791/BLF (ERDA-AL)

University of California

LOS ALAMOS SCIENTIFIC LABORATORY

Post Office Box 1663 Los Alamos, New Mexico 87545

HYPOTHETICAL ACCIDENT CONDITIONS

FREE DROP AND THERMAL TESTS

USA/5791/BLF (ERDA-AL)

by

Ronald W. Blankenship

ABSTRACT

The USA/5791/BLF (ERDA-AL) 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 3.0 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 drop tests was completed with different impact attitudes using the 55 gallon USA/5791/BLF (ERDA-AL) which is designated AL-M6. Each AL-M6 contained three inner packages. Each inner package consisted of one kilogram of depleted uranium as oxide (UO_2) in two rolled-top food pack cans with the UO_2 in the inner can. After the 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 PuO₂ 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 UO₂ 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 one half that of the UO₂ used in these tests. Seventy per cent of the PuO₂ particles are typically less than 4.5 microns in diameter. This diameter value 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 capacity up to 6000 pounds. A bomb rack with remote electric release was used in all drops. The AL-M6 shipping containers were 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 inch thick steel pad 5 feet x 3 feet. This was on top of a 2 foot thick concrete pad 7 feet x 7 feet.

Two high speed motion picture cameras placed at 90° apart in relation to the impact target were used to verify the attitude at impact. The 3000 frames per second would allow close inspection of how damage to the containers occurs.

Fig. 1 shows the drop tower with an AL-M6 at 30 feet ready to be dropped.

The flat target surface is just to the right of the inclined target surface and is surrounded by sand bags. The high speed camera housings can be seen at the lower right of the picture.

III. PREPARATIONS

The AL-M6 shipping containers were selected from the supply at LASL with little consideration for minor dents and scratches. The containers are stored outside so there are some areas of rust that will be noticed in some of the photographs. The dimensions of the 2R type container allow space for three of the normal inner packages as shipped by LASL. Each package consists of the PuO_2 inside two food pack cans. For the tests, each package contained one kilogram of depleted uranium as UO_2 , the quantity of PuO_2 that is normally shipped in each package.

Fig. 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 can sealer and packaged inside a 0.002 inch thick plastic bag. This was placed in a second food pack can

Figure 1

Test facilities with AL-M6 at 30 feet, ready to drop.

Figure 2

Level of UO_2 in inner food pack cans.

(4-1/4 inch diameter x 4-7/8 inch high) and sealed. The outer can and lid and the inner can in the plastic bag are shown in Fig. 3.

Three inner packages prepared as described were placed in the 2R type container with 0.001 inch thick aluminum foil as the packing material. The foil was tightly packed around each inner package. Some compression of the packing material was necessary to properly seal the lid on the 2R type container. The eight bolts were then placed in the lid and torqued to 15 ft-lb then to 25 ft-lb in the sequence: 1, 5, 3, 7, 4, 8, 2, 6.

The 2R type container was lowered into the insulation well of the 55 gallon drum. The insulation plug, fibrous pad, and drum lid were put in place. The modified locking ring with skirt was then placed on the drum with the locking bolt about 90° from the drum seam. The locking bolt was tightened to aid in alignment of the holes in the skirt with the nuts welded to the drum. The cap screws with washers were put in place and tightened finger tight. The locking bolt was tightened to 40 ft-lb torque and the locking nut tightened. The skirt ring cap screws were then tightened using a screwdriver.

Three AL-M6 shipping containers were prepared as described, one for each of the free drops planned for this series of tests.

IV. DROP TEST RESULTS

The damage to the containers caused by the free drop tests will be considered in two parts. First the damage to the AL-M6, which consists of the 55 gallon 17C outer drum and the 2R type container, will be shown. Then the damage to the inner containers, the food pack cans, will be shown.

A. Damage to the AL-M6

The impact attitude for the first drop is shown in Fig. 4. A 1/8 inch hole was drilled in the drum through which the aircraft cable was inserted. The drum was lifted to a height of 30 feet as was shown in Fig. 1 and released. Figs. 5 and 6 show the damage to the drum caused by this drop. The locking ring and all the cap screws remained in place. The side of the drum folded up over the locking ring skirt, but there was still no separation of the seam.

Fig. 7 shows the top of the insulation plug with the drum lid and fibrous pad removed. Because of the drum side being folded over the locking ring skirt, the locking ring could not be removed, only bent back to allow removal of the lid. The insulation plug had to be broken up for removal from the drum to get to the 2R type container. The cracks in the insulation plug caused by the drop

Figure 3

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

Figure 4

Impact attitude for first drop (corner impact).

Figure 5

Damage caused by corner impact.

Figure 6

Damage caused by corner impact.

were not deep enough to help in the removal of the insulation from the drum.

Fig. 8 shows the impact attitude for the second drop. The drum was horizontal, so the initial contact was with the locking bolt. The bolt folded back and then the drum landed flat on the side.

Fig. 9 shows the flattened side of the drum with the locking bolt folded back against the drum and all the cap screws still in place. Fig. 10 shows another view of the flattened side plus the damage to the lid of the drum. There was some difficulty in removing the drum lid because of the damage to the lid. As in the first drop, the insulation plug had to be broken up for removal.

Fig. 11 shows the impact attitude for the third drop. The drum was positioned level so it would land as flat as possible on the bottom.

Fig. 12 shows the damage to the drum caused by the drop. There was some flattening of the bottom rolling hoop and slight distortion of the side near the bottom of the drum. The bottom was bulged out slightly but not enough to be seen in photographs.

Fig. 13 shows the internal damage caused by the bottom impact. The impression of the eight bolts in the lid of the 2R type container can be clearly seen. Close examination shows that the plywood disc on which the 2R type container rests has been moved by impact. This was the worst damage to the insulation in the three drums.

Fig. 14 shows the effect of the bottom impact on the packing material inside the 2R type container. The aluminum foil had to be compressed slightly when the lid was put in place. After the drop, the level of the foil is approximately one inch below the lid.

B. Damage to the Inner Containers

The food pack cans in the photographs from left to right are as they were placed top, middle, and bottom in the 2R type containers. The cans have been oriented to show as much damage as possible. Both the free drop and thermal tests had to be completed before the outer food cans were opened. Since there was no visible damage caused by the thermal test, the photographs are presented as damage caused only by the drops.

Fig. 15 shows the damage to the outer food pack cans caused by the corner impact. There are only a few small dents from the inside caused by inner cans. Fig. 16 shows the inner cans used in the corner drop. The sides of the cans are slightly wrinkled and the top bulged out slightly, but there is no separation of the seams.

Figure 7

Internal damage caused by corner impact.

Figure 8

Impact attitude for second drop (side impact).

Figure 9

Damage caused by side impact.

Figure 10

Damage caused by side impact.

Figure 11

Impact attitude for third drop (bottom impact).

Figure 12

Damage caused by bottom impact.

Figure 13

Internal damage caused by bottom impact.

Figure 14

2R type container used in bottom impact.

Figure 15

Outer food pack cans (corner impact).

Figure 16

Inner food pack cans (corner impact).

Fig. 17 shows the outer food pack cans used in the side drop. There are only minor dents caused by the inner cans. Fig. 18 shows the inner cans, all of which have been inverted from their position in the 2R type container to show the most damage. There was only slight wrinkling and flattening of one side of the cans.

Fig. 19 shows the outer cans used in the bottom drop. The two cans on the left have been inverted to show the bulging of the bottom of the cans. Fig. 20 shows the inner cans used in this drop. These have all been inverted to better show the damage. Even with the extensive damage to the cans, there was no separation of the seams of the cans.

V. THERMAL TEST

Tests were completed at Mound Laboratory for certification of the AL-M6.¹ When subjected to the thermal test, the maximum temperature of the 2R type container after the 30 minutes fire was 244°F.

Figure 17
Outer food pack cans (side impact).

Figure 18
Inner food pack cans (side impact).

Figure 19
Outer food pack cans (bottom impact).

Figure 20
Inner food pack cans (bottom impact).

Eight of the nine inner containers, both outer and inner food pack cans, which were removed from the AL-M6 containers after the free drop tests, were placed in a drying oven. The oven had been preheated to 250°F. The inner containers were left in the oven at this temperature for two hours. They were then removed and allowed to cool to room temperature overnight.

Fig. 21 shows the condition of the plastic bag around the inner cans. The middle can is the one of the nine that was not used in this test. The temperature caused the bag to melt enough that part of the bag stuck to the inside of the outer food pack can.

VI. DISCUSSION

To insure that the AL-M6 met the qualification of the free drop test with regard to hitting the target surface in a position for which the most damage is expected, a series of three drops with different impact attitudes was completed.

The drum in each drop suffered only minor damage. There is no separation of the seams of any drum. Neither the locking ring nor the lid was separated from any drum. The cap screws in the locking ring skirt all remained in place. No drum was punctured by the securing bolt being forced against the side of the drum by the impact. The outer drum remained intact in each drop.

Figure 21

Inner food pack cans (corner impact) after thermal test.

The thermal insulation that holds the 2R type container in place showed only minor damage but not enough to allow a change in the position of the 2R type container. The 2R type containers showed no signs of damage.

The aluminum foil used for packing around the food pack cans was very tightly compacted by the impact in each drop.

Damage to the food pack cans was minor. Most of this damage was the badly wrinkled sides of the cans. There was still no separation of the seams of the cans.

The inner containers, outer and inner food pack cans, were heated in an oven at 250°F for two hours after they had been subjected to the drop test. The outer cans were opened after the thermal test. There was no visible damage except for the plastic bags, which had melted and shrunk around the inner cans. Some of the plastic stuck to the inside of the outer can when the inner can was removed.

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. The lower limit of detection of the alpha counting system used for this analysis was 0.826 pCi.

Table 1 shows the results of the alpha analysis of the smears. Cans 1, 2, and 3 were used in the corner impact; cans 4, 5, and 6 in the side impact; and cans 7, 8, and 9 in the bottom impact. Only one significant figure is available for less than 1.1 pCi UO₂ 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 3.0 µg.

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

TABLE 1
Results of Nu-Con Smear Alpha Analysis
Leakage of UO_2 in pCi (UO_2 Leakage in μg)

<u>Can Number</u>	<u>Drop Test</u>	<u>Thermal Test</u>	<u>One Week After Tests</u>
1	1.5 (3.4)	≤ 0.826 (≤ 1.89)	≤ 0.826 (≤ 1.89)
2	≤ 0.826 (≤ 1.89)	not used	not used
3	≤ 0.826 (≤ 1.89)	≤ 0.826 (≤ 1.89)	1.3 (3.0)
4	≤ 0.826 (≤ 1.89)	1.1 (2.5)	≤ 0.826 (≤ 1.89)
5	≤ 0.826 (≤ 1.89)	1.4 (3.2)	≤ 0.826 (≤ 1.89)
6	≤ 0.826 (≤ 1.89)	≤ 0.826 (≤ 1.89)	≤ 0.826 (≤ 1.89)
7	≤ 0.826 (≤ 1.89)	≤ 0.826 (≤ 1.89)	≤ 0.826 (≤ 1.89)
8	1 (2)	≤ 0.826 (≤ 1.89)	1.3 (3.0)
9	1.3 (3.0)	≤ 0.826 (≤ 1.89)	1 (2)

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 regulations² 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 with specific 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% ^{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 3.0 μg which corresponds to $A_2 \times 4.7 \times 10^{-4}$. With an allowable leakage of $A_2 \times 10^{-3}$ per week, the observed leakage is less than half the allowable leakage.

TABLE 2
A₂/g Pu (70% ²³⁹Pu, 20% ²⁴⁰Pu, 10% ²⁴¹Pu)

Isotope	Ci/g*	Ci/g Pu**	A ₂ (Ci)	Fraction A ₂ /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 A₂/μg FFTF plutonium oxide (86.5% ²³⁹Pu, 12% ²⁴⁰Pu, and 1.5% ²⁴¹Pu). Leakage of 1 μg in this example would be equal to A₂ x 5.70 x 10⁻⁵. The maximum observed leakage of 3.0 μg per week corresponds to A₂ x 1.7 x 10⁻⁴ which is well below the allowable leakage of A₂ x 10⁻³ per week. Certainly weapon grade plutonium (93.6% ²³⁹Pu, 6% ²⁴⁰Pu, and 0.4% ²⁴¹Pu) would also be well below the allowable leakage rate. In these examples, it is assumed that the quantity of PuO₂ leakage would be equal to the observed leakage of UO₂.

TABLE 3
A₂/μg FFTF Plutonium Oxide
(86.5% ²³⁹Pu, 12% ²⁴⁰Pu, 1.5% ²⁴¹Pu)

Isotope	μCi/μg*	A ₂ (μCi)	Fraction A ₂ /μg Pu
²³⁹ Pu	0.0531	2,000	2.66 x 10 ⁻⁵
²⁴⁰ Pu	0.0271	2,000	1.36 x 10 ⁻⁵
²⁴¹ Pu	1.68	100,000	1.68 x 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 from any container. During the certification of the AL-M6, the puncture test produced only a minor dent, nothing that would affect the contents of the 2R type container. The inner containers were then subjected to conditions equivalent to what would be encountered in the thermal test, again with

no significant leakage from any container. The immersion test should have little effect on metal cans that were intact after the previous tests. The material leakage from the inner containers was well below the allowable leakage rate. The food pack cans as tested, packaged in the AL-M6, meet the requirements of 10 CFR 71.42.

REFERENCES

1. James F. Griffin, Richard E. Bertram, Richard K. Blauvelt, Don A. Edling, Thomas M. Flanagan, Jones B. Peterson, and David L. Prosser, "Safety Analysis Report for Packaging (SARP): USA/5790/BLF (ERDA-AL) and USA/5791/BLF (ERDA-AL)," Mound Laboratory Report MLM-2242 (April 30, 1976).
2. International Atomic Energy Agency, Regulations for the Safe Transport of Radioactive Materials 1973 Revised Edition, (IAEA, Vienna, 1973).