MEASUREMENT OF RELEASE FRACTION OF CONTENTS FOR TRUPACT-I SUBJECTED TO NORMAL TRANSPORT AND ACCIDENT CONDITIONS

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ABSTRACT

A series of full-scale experiments were conducted to characterize the release of simulated waste from waste containers packaged in a Transuranic Package Transporter (TRUPACT) subjected to a series of drop, puncture, and thermal environments. The measurement techniques and procedures used in this study to characterize and quantify the release of airborne and non-airborne waste material from the secondary containers to the TRUPACT-I cavity are described.

INTRODUCTION

The Transuranic Package Transporter, Configuration I (TRUPACT-I), is a Type B packaging being developed by the U.S. Department of Energy (DOE) for transporting contact-handled transuranic (CH-TRU) waste in the USA. A photograph of TRUPACT-I, Unit 0 is shown in Fig. 1. TRUPACT-I has been subjected to a series of drop, puncture, and thermal tests to determine the package's resistance to normal transport and hypothetical accident conditions. In particular, three impacts of a 6-kilogram bar onto the outer surface of the package, one 0.3-m drop flat onto the bottom surface, two 9-m drops, first onto the top left edge and then onto the bottom left corner of the outer door of the package, and four successive 1-m drops onto a 0.15-m diameter puncture bar were performed. The damaged package was then subjected to a JP4-fueled pool fire for thirty minutes.

Fig. 1. Photograph of Transuranic Package Transporter-I (TRUPACT-I)

A Type B package is required to prevent the release of radioactive contents as demonstrated to a sensitivity of 10^{-6} A_2 per hour [1] for normal conditions and may release no more than A_2 per week[1] for hypothetical accident conditions (10CFR71.51). These requirements could be satisfied by first estimating the fraction of the radioactive contents that have been released from any secondary packaging and then estimating the quantity available for release through seals or other leak paths of the primary packaging using gas leakage tests. Limited experimental data are available on release fractions for actual or simulated waste forms contained within a packaging subjected to the normal or hypothetical accident conditions. The TRUPACT-I full-scale tests provided a unique opportunity for obtaining experimental data on the fraction of waste material released from secondary waste packaging.

Aerosol and surface deposition measurements were performed during the full-scale test series to provide experimental data on fractions of simulated waste released into the TRUPACT-I cavity from secondary waste containers inside TRUPACT-I. The measurement techniques and procedures are presented in this paper.

OBJECTIVES

The objectives of the study were as follows:

1. To provide experimental data on the quantity and species of simulated waste forms (i.e., soft waste, hard waste, etc.) which leaked from the secondary packaging into the TRUPACT-I cavity as a result of the drop, puncture, and thermal tests.

2. To provide experimental data on the particle size distributions and particle morphology of simulated waste material released from secondary packaging into TRUPACT-I as a result of the drop, puncture, and thermal tests.

3. To determine the respirable *and nonrespirable* fractions of simulated waste material released from the secondary waste packaging as a result of the test series.

4. To use the experimental data to estimate the respirable and nonrespirable quantities (in curies) of plutonium-bearing waste that might be released from secondary waste containers into the TRUPACT-I as a result of drop, puncture, and thermal tests.

PROCEDURE

To accomplish these objectives, tracer particles of a predetermined size distribution, and purity were added to and mixed with the simulated wastes, a different tracer material for each six-pack, and for each different waste form within a six-pack for a total of seven different tracer materials. Two-hundred liter aerosol samples of the air volume within the TRUPACT-I packaging were taken before and after selected test events (the 0.3-m drop test, the two 9-m drop tests, one puncture test, and the thermal test) to provide data on the quantity and characteristics of waste form tracer aerosols released to the TRUPACT-I cavity. Surface deposition pads were also placed at selected locations inside the TRUPACT-I cavity to provide data on quantities and characteristics of particles of all sizes released to the TRUPACT-I cavity. Damage to the secondary packaging and containment failure was assessed qualitatively during disassembly of TRUPACT-I, and the results of this assessment were compared with that of the extractive aerosol sampling and surface deposition measurement techniques to corroborate waste form release predictions.

Tests

The sequence of tests and type of test performed on TRUPACT-I are shown in Table I. As outlined in Table I, TRUPACT-I was subjected to a series of ten impact tests at ORNL after which the package was shipped back to SNLA where it was subjected to a thirty-minute fire test. Tracer release measurements were performed for the 0.3-m drop test, the 9-m edge drop, the 9-m c.g.-over-corner drop, the 1-m inner door seal puncture, and the thermal test. No tracer release measurements were performed for the 6-kg steel bar penetration tests or the other three puncture tests. In addition, an aerosol sample of the TRUPACT-I cavity air was taken before shipment to ORNL and again after return from ORNL shortly before the thermal test. Details of the TRUPACT-I design, components, and measurements, other than the particle release measurements conducted during the impact, puncture, and fire tests, are described in Ref. 2.

Waste Loading

Four waste forms simulating hard, concreted, soft, and sludge wastes were packaged in 36, 55-gallon drums; and the drums were assembled into six, six-drum units (six-packs). The TRUPACT-I cargo consisted of three six-packs containing soft wastes, one six-pack of hard wastes, one six-pack of simulated sludge, and one six-pack containing two drums of concrete and four drums of simulated sludge. Figure 2 shows the drum and the associated waste form loading configuration. The total package weight, including TRUPACT-I packaging, six-packs, and the dunnage materials (foam and packaging material), was approximately 22.7 metric tons. The heavy six-packs (hard wastes, concrete, and simulated sludge) were placed on the bottom row in the manner recommended for normal use; the six-pack of hard wastes (Six-Pack No. 5) was placed next to the inner door of TRUPACT-I.

Tracer Materials

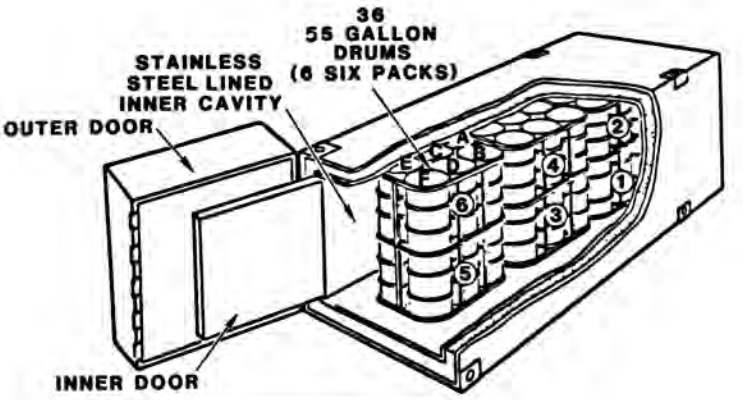
Seven distinct tracer powders of a predetermined purity and particle size distribution were mixed with the simulated wastes in order to provide a mechanism for measuring the quantity of released waste materials and to allow some indication of the leaking drums. The tracer materials were procured in powder form as sulfate and oxide compounds of the elements Cs, Co, Mn, V, Ta, Sb, and In. The tracer compounds were selected on the basis of chemical stability, melting point, and insolubility under the conditions expected for the tests and their ability to be unambiguously detected and identified above background traces of these elements in the simulated waste materials and collection substrates used for the tests. The tracer powders were ground to a median count diameter ranging from 1.7 m to 2.7 m. On the average, 99.5 percent of the tracer particles were smaller than 10 m, real diameter. Table II shows the physical characteristics and quantity of each tracer powder placed inside TRUPACT-I.

The seven tracer compounds were mixed with the four waste forms, packaged in the 36 drums, and placed within TRUPACT-I according to the scheme shown in Fig. 3. Tantalum pentoxide was mixed with the sludge in Six-Pack No. 1. Vanadium dioxide was mixed with the sludge in Drums 3A, 3B, 3E, and 3F; indium sesquioxide was mixed with the concrete in Drums 3C and 3D. Cesium sulfate, cobalt oxide, and antimony trioxide were mixed with the soft waste in Six-pack Nos. 6, 4, and 2, respectively. A powder dispenser was designed and fabricated for mixing the tracer powders uniformly with each of the four waste forms. In the case of the hard waste (Six-Pack No. 5), the manganese dioxide was sprinkled directly onto the metal surfaces. A chute-and-glove bag arrangement was fabricated to ensure a clean environment and to minimize potential loss of tracer materials and cross contamination of the external surfaces of the drums during loading. To ensure decontamination, all external surfaces of the drums and frames of the six-packs were washed with one-molar nitric acid after the drums were loaded and sealed.

Release Measurements

Two-hundred liter aerosol samples of the air volume within the TRUPACT-I cavity were taken before and after selected test events as shown in Table I. The aerosol samples were extracted through a 9.5-mm-i.d. stainless steel tube and into a sampling tree (shown in Fig. 3 consisting of a Lovelace multijet (LMJ) cascade impactor, [3] a 47-mm filter cassette, [4] a point-to-plane electrostatic precipitator, [5] and a vacuum pump. The flow rate through each sampler was controlled by means of a critical flow orifice between each sampler and the vacuum pump. A second 9.5-mm-i.d. port, which penetrated the TRUPACT-I wall, was opened to the atmosphere during sampling for air intake.

Seventy-two 47-mm Nuclepore filter pads were attached to the six-pack frames and drum surfaces (12 per six-pack). The purpose of these deposition pads was to provide data on the quantity of each tracer material deposited on the surfaces inside TRUPACT-I. In contrast to the aerosol sampling extractive technique, this measurement technique does not provide for size differentiation; therefore, the estimated total mass deposited on surfaces inside TRUPACT-I is for all particle sizes. The deposition pads were placed in horizontal and vertical orientations inside the TRUPACT-I package to provide deposition surfaces for different test orientations of the package. The data obtained from these measurements provided an upper bound estimate of the fraction (including the respirable component) of waste contents released from the secondary waste containers into the TRUPACT-I cavity as a result of the complete test series.



SIX-PACK NO.	WASTE
1	SLUDGE
2	SOFT WASTE
3A, 3B, 3E, 3F	SLUDGE
3C, 3D	CONCRETE
4	SOFT WASTE
5	HARD WASTE
6	SOFT WASTE

Fig. 2. Drum Loading Configuration for TRUPACT-I Tests (not shown are plywood sheets placed between stacked six-packs, foam dunnage placed around cargo, and metal pallets placed under the bottom row of six-packs)

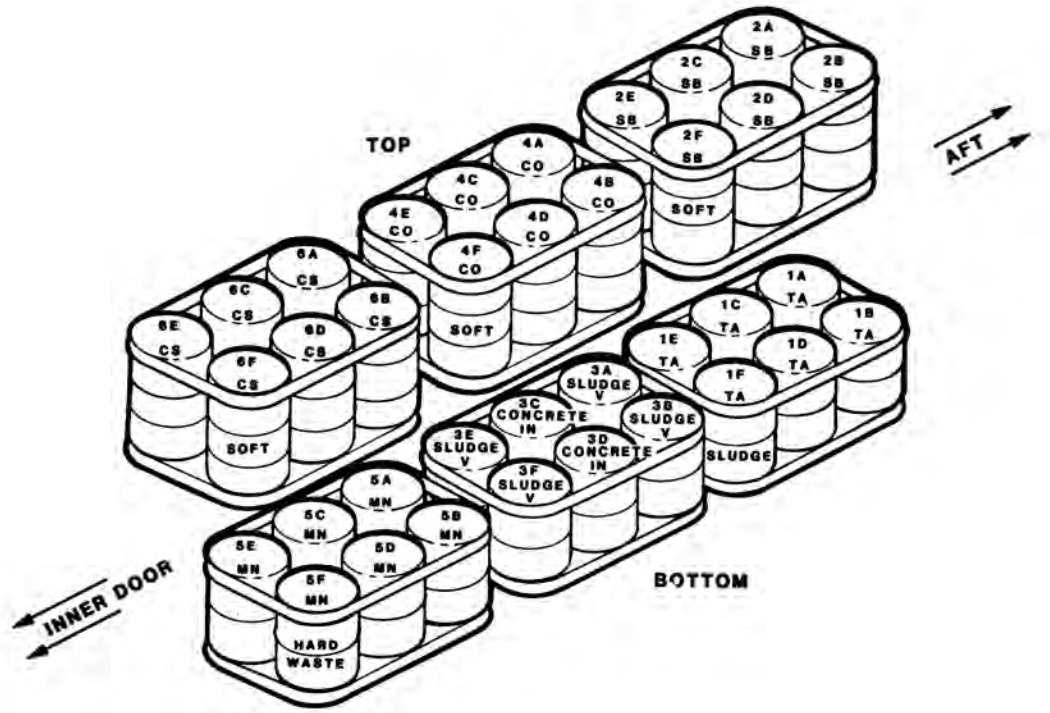


Fig. 3. Schematic Showing Placement of Six-Packs and Corresponding Waste Forms and Tracers

TABLE I

Outline of TRUPACT-I Tests Performed

TEST EVENT NO.	TYPE OF TEST	MEASUREMENTS PERFORMED
UZ-0	preshipment measurement	aerosol measurement after loading but before shiping
UZ-1	6-Kg bar penetration (center)	no aerosol measurement
UZ-2	6-Kg bar penetration (corner)	no aerosol measurement
UZ-3	6-Kg bar penetration (edge)	no aerosol measurement
UZ-4	0.30-m bottom drop	aerosol measurement before and after test
UZ-5	9-m drop on edge	aerosol measurement before and after test
UZ-6	9-m drop C. G. -over -corner	aerosol measurement before and after test
UZ-7	1-m puncture, bottom panel	no aerosol measurement
UZ-8	1-m puncture, end panel	no aerosol measurement
UZ-9	1-m puncture, corner drop	no aerosol measurement
UZ-10	1-m puncture, inner door seal	aerosol measurement after test only
UZ-12	thermal test	aerosol measurement before and after test

TABLE II

Tracer Material Characteristics

Element	Cs	Co	Mn	V	Ta	Sb	In
Compound	Cs_2SO_4	Co_3O_4	MnO_2	V_2O_4	Ta_2O_5	Sb_2O_3	In_2O_3
At. Wt (g)	132.9	58.9	54.9	50.9	180.9	121.8	114.8
Mol. Wt. (g)	361.9	240.8	86.9	165.9	441.9	291.5	277.6
Cryst. Form	colorless rhomb or hex	pink cubic	black rhombic	blue --	colorless rhombic	white cubic	brown yellow
Solubility in grams per 100 cc cold H_2O (g)	167[a]	insol.	sol.	insol.	insol.	very slight soluble	insoluble
Solubility in grams per 100 cc hot H_2O (g)	220[b]	insol.	insol.	insol.	insol.	slightly soluble	no info
Melt Point (°C)	1010	1795	535	1967	1872	656	1910
Decomposes	no	no	no	no	at 1470°C	no	HVP at 1290°C
Assoc. Waste Form	soft	soft	hard	sludge	sludge	soft	concrete
Six-Pack No.	6	4	5	3A, 3B 3E, 3F	1	2	3C, 3D
Quantity of Tracer in TRUPACT-I (g)	603.8	603.5	602.8	400.4	604.4	599.9	200.2

[a]at 0°C
[b]at 100°C
HVP = high vapor pressure

Sample Analysis

The quantity of each tracer collected on each sample substrate was determined by instrumental neutron activation analysis [6] and x-ray fluorescence. [7] Scanning electron microscopic (SEM) analysis and energy dispersive x-ray analysis (EDSA) were used, in addition to the LMJ cascade impactors, to help determine particle size of the released tracers. X-ray fluorescence was also used to analyze wash samples taken from sampling lines in an effort to quantify line losses. Carbon planchets and copper grids from the electrostatic precipitator samples were analyzed for tracer particle size and morphology using SEM and EDSA. Smear samples of the drum and liner surface areas taken during post-test disassembly and inspection were analyzed for tracer particles using SEM and EDSA.

Data Reduction

The mass of each tracer element deposited on each substrate (from filters and cascade impactors) was determined using INA and corrected for blank substrate background levels. Tracer aerosol concentrations in the TRUPACT-I cavity were determined for each tracer. The maximum aerosol concentration values were used to obtain a peak tracer aerosol concentration in the cavity before and after each test event. The aerosol mass of each tracer in the cavity was determined before and after a given test event by multiplying the peak tracer aerosol concentration by the cavity void volume. The net airborne particle mass released to the cavity as a result of a test event was determined for each tracer by subtracting the aerosol mass measured before a test event from the aerosol mass measured after an event. An aerosol release fraction was determined for each tracer by dividing the net airborne mass released to the cavity as a result of a test event by the net mass of tracer material remaining in a six-pack (or drum) for that test. Particle size distributions of the released tracer material were determined from cascade impactor data. SEM and EDSA analysis were also used to help determine tracer particle size and morphology. The respirable fractions of waste materials (sludge, hard, concrete, and soft) released to the TRUPACT-I cavity were determined for each test event by assuming that the waste forms were uniformly mixed with the tracers.

In the case of the surface deposition samples, a surface deposition concentration was determined for each tracer and for each six-pack. The total mass of each tracer deposited on each six-pack and associated TRUPACT-I cavity surface areas was determined by multiplying the tracer surface concentration by the surface area associated with each six-pack location. The total mass of each tracer deposited over all exposed surfaces inside TRUPACT-I was determined by summing the deposited masses. The fraction of tracer material (all sizes) released to the TRUPACT-I cavity as a result of all test events was determined by dividing the total mass released to the cavity by the initial mass of each tracer packaged inside the secondary waste containers.

The quantity of respirable plutonium-bearing waste that might be released to the TRUPACT-I cavity as a result of the test series will be estimated by assuming the maximum plutonium activity which could be shipped in a TRUPACT-I containing 36, 55-gallon drums. The respirable release fractions measured in this study for each waste form (and six-pack) will be used to determine the quantity of respirable plutonium that might be released to the TRUPACT cavity for each test event, assuming that the maximum activity that could be shipped in TRUPACT-I was divided equally among the 36 drums. That interior source term will be used, together with TRUPACT seal leakage data, to estimate release rates from the package in support of certification applications.

CONCLUSIONS

A series of full-scale experiments were performed to determine the fraction of respirable and nonrespirable simulated waste material that could be released to the package cavity as a result of subjecting a TRUPACT-I to a series of drop, puncture, and fire environments. The results of these experiments will provide the following information:

1. The quantity and species of simulated waste released from the secondary packaging to the TRUPACT-I cavity as a result of the drop, puncture, and thermal environments;
2. An indication of the particle size distribution and particle morphology of simulated waste released to the TRUPACT-I cavity as a result of the test environments;
3. The fraction of respirable waste material released to the TRUPACT-I cavity as a result of the drop, puncture, and thermal tests;
4. An estimate of the respirable (and nonrespirable) quantities of plutonium-bearing waste that might be released from secondary waste containers into the TRUPACT-I cavity as a result of drop, puncture, and thermal environments.

The results of this study are currently in review and will be published in subsequent reports.

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