The TRUPACT Transuranic Waste Transportation System *

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INTRODUCTION

Contact-handled transuranic (CH-TRU) waste is generated at numerous locations in the United States as a by-product of defense related programs. Some of these facilities are incapable of storing large quantities of waste and must periodically transport Type B quantities to other Department of Energy (DOE) sites. At some time in the future the majority of the existing retrievably stored waste will be placed in a federal waste repository. CH-TRU waste will require transportation from its present storage locations to the repository. If processing is required prior to disposal, an additional transportation step will be added for those sites which cannot process their own waste. Since existing transportation systems either have uncertain futures or cannot be used efficiently to convey this type of waste, there is a need for the development of new generation systems.

The Transportation Technology Center at Sandia National Laboratories is responsible for the development of new generation transportation systems to be utilized in the management of defense related CH-TRU waste. The development program places particular emphasis on the compatibility of transportation hardware with both waste generating and receiving facilities. An initial design concept has been completed and scale models are being fabricated and tested. Concurrent structural analysis, thermal analysis, and material test programs are being conducted to support the design effort. This paper presents a summary of the activities involved in the development program and a brief overview of the progress to date.

DEFINITION OF CARGO

A list of the inventory of the transuranic waste at a number of DOE sites[1] in the United States is given in Table I. Both the buried and retrievably stored waste as well as the projected annual storage rates are given for each site. The

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buried waste mentioned in the table was accumulated at the sites prior to 1970. In 1970 the United States Atomic Energy Commission initiated a policy whereby TRU waste with actinide activities greater than 10 nCi/gm must be retrievably stored. Much of the stored waste and buried waste (were it retrieved and packaged) indicated in Table I is CH-TRU.

Retrievably stored CH-TRU waste typically consists of plutonium contaminated metal scrap, sludge, paper, filters, and other materials resulting from weapons production and reprocessing operations. The activitiy of the waste is low with the maximum dose rate at the surface of a container of CH-TRU being less than 200 mrem/hr. Most of the waste has a plutonium content of less than 18 Ci/m^3.

Table I. Inventory and Storage Rates of Transuranic Waste at DOE Sites

Site	Inventory (m^3) Buried	Inventory (m^3) Stored	Estimated 5 Year Storage Rates (m^3/year)
Oak Ridge National Laboratory	6300	1200	70
Los Alamos Scientific Laboratory	11500	3500	550
Savannah River Plant	27000	2400	150
Nevada Test Site	5700	240	25
Hanford Site	225000	8000	1400
Idaho National Engineering Labortory	57000	40000	2800

The stored waste is contained primarily in steel drums and plywood boxes strengthened with fiberglass reinforced polyester (FRP Box). However, a small amount is being stored in rectangular steel containers known as M-3 bins. Table II itemizes the existing waste units with which the new generation transportation systems will need to be compatible.

Table II. Containers of Waste Requiring Transport

Container	Container Dimensions (m, LxHxW)	Container Mass, Max. (kg)
Steel drum	0.9 x 0.6 (dia)	380
FRP Box	1.2 x 1.3 x 2.1	2300
M-3 Bin	1.2 x 1.8 x 1.5	1500

As currently constructed the FRP box probably will not meet the acceptance criteria of a repository since it is made of combustible materials. Hence, an FRP overpack is among the several containers which have been proposed for use but are not yet in service. These are listed in Table III and with the exception of the overpack just mentioned, their dimensions will allow efficient use of volume in the new generation transportation system to be described later. The item "six-pack" in the table refers to a proposed efficient method of handling six 200-litre (55-gallon) steel drums. In this method a rectangular array of six drums is placed between two welded steel frames (a frame being placed at the top and bottom of the drum array) and the assembly is then banded together into a unit with steel strapping. A side view of an assembled six pack is shown in Fig. 1. Also shown in Fig. 1 is a side view of the modular box. This box is constructed of corrugated sheet metal and is meant to serve as a primary waste container or as an overpack for up to six damaged or otherwise unserviceable 200-litre drums. Used as a primary waste container, the modular box is obviously more efficient volume wise (i.e., can contain more waste) than the six drums it replaces. The box is also estimated to be less expensive than six drums with rigid polyethylene liners. The FRP replacement box, reference truck box, and efficient truck box are similar to the modular box with the only essential difference being their dimensions. However, it is not intended that these will be used as overpacks.

Table III. Proposed CH-TRU Waste Containers

Container	Container Dimensions (m, LxHxW)	Container Mass (max.) kg
FRP Overpack	1.4 x 1.4 x 2.2	3200
Six-Pack	1.3 x 1.0 x 1.9	2300
Modular Box	1.3 x 1.0 x 1.9	2700
FRP Replacement	1.2 x 1.2 x 2.1	2700
Reference Truck Box	1.4 x 1.0 x 1.7	2300
Efficient Truck Box	0.8 x 1.0 x 1.7	2300

Type B quantities of some radionuclides (particularly plutonium) may be present in one or groups of the waste containers. Type B packaging is therefore required and the new transportation systems must provide protection to the waste in accident environments as specified in Appendix B, Hypothetical Accident Conditions, of 10CFR71. The hypothetical accident conditions may be summarized as follows:

1. 9 m free drop onto an unyielding surface in an orientation for which maximum damage is expected.

2. 1 m free drop onto 15 cm diameter mild steel punch bar in the most vulnerable position.

3. Exposure to an 800°C engulfing fire for 1/2 hour.

4. Complete immersion in water for a minimum of eight hours.

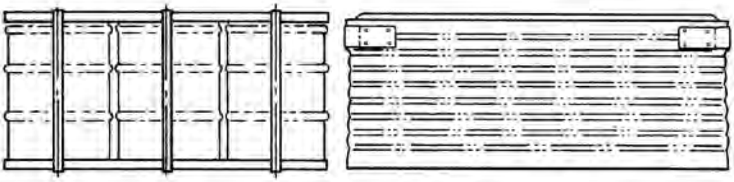

Fig. 1. Six-Pack and Modular Box CH-TRU Waste Containers

PACKAGE DESCRIPTION

A preliminary design for a transportation system known as the TRansUranic PACkage Transporter (TRUPACT) has been completed and its resistance to the hypothetical accident conditions has been assessed. It is intended that the TRUPACT will provide safe cost-effective Type B packaging for the drums and boxes outlined in the preceding tables. A phototraph of a TRUPACT model is shown in Fig. 2. As illustrated in the figure, the TRUPACT is a large metal container consisting of inner and outer tubular steel frameworks which are separated by rigid polyurethane foam and sheathed with steel plate. To minimize the package weight and maintain ductility at low temperatures, a high-strength, low-alloy steel is used in both frames and the exterior skin. The sides of the cargo compartment are constructed of stainless steel to facilitate decontamination if required. The inner structure is made secure with a hinged, 13-cm-thick door that has a steel framework and is filled with metal honeycomb. This door is fitted with an elastomeric seal and bolted in place during transport. The exterior door is 90 cm thick and utilizes a single elastomeric seal. This hinged door is bolted in place during transport. There is approximately 90 cm of foam in the package ends and 36 cm in the walls to provide impact energy mitigation and thermal protection. Cargo loading and unloading will be accommodated by using either a rolling pallet or roller conveyor system on the floor of the TRUPACT. Heavy handling equipment cannot be used inside the packaging because the floor covering is thin steel sheets supported on and attached to widely spaced tubular steel framework members and the rigid foam between the framework has a relatively low compressive strength.

Although making the TRUPACT transportable by rail and truck was a design goal early in the program, transportation constraints and payload maximization considerations suggested the need for a different version of the package for each transport mode. The TRUPACT will subsequently be available in both rail and truck transported versions. Figures 3 and 4 show the rail and legal weight truck versions, respectively, of TRUPACT loaded with 2 x 3 arrays (six-packs) of 55-gallon drums.

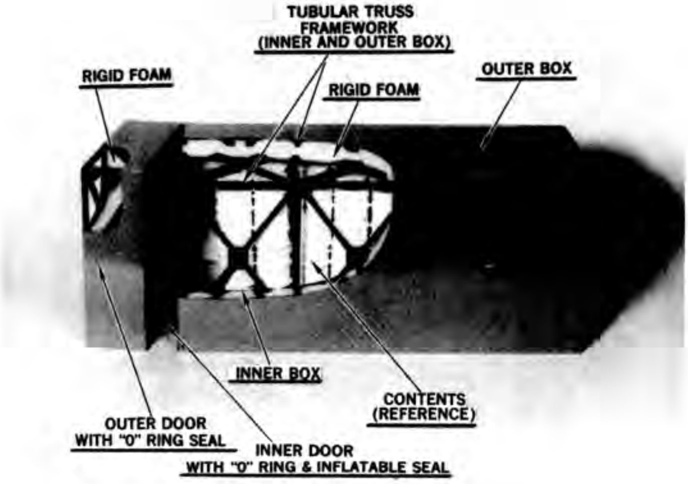

Fig. 2. Photograph of TRUPACT Model

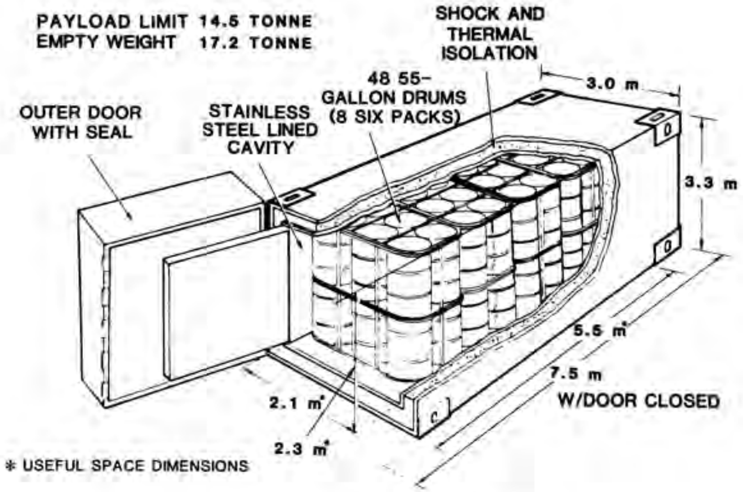

Fig. 3. TRUPACT Rail Version Loaded with Six-Packs

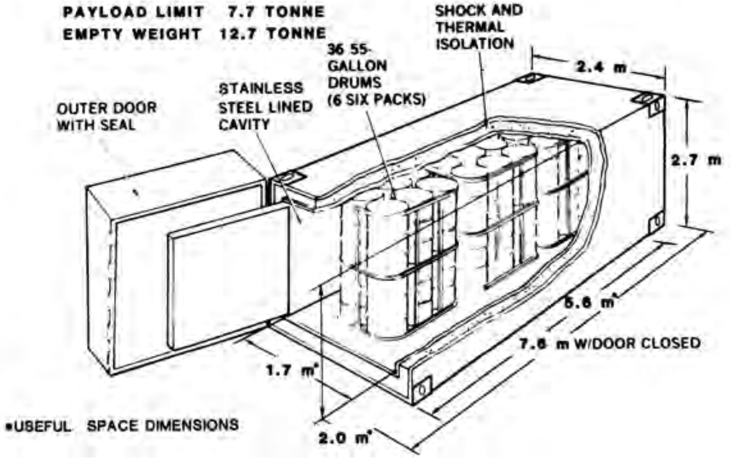

Fig. 4. TRUPACT Legal Weight Truck Version Loaded with Six-Packs

Truck Version

The truck system is being designed to allow unrestricted operation throughout the United States. Thus the gross vehicle weight (GVW) of the system will be 33.3 tonne (73,280 lbs) or less. In addition, the entire rig will have to be smaller than 16.8 m (55 ft) long, 2.4 m (8 ft.) wide, and 4.1 m (13.5 ft.) high since these are the most restrictive limits for a five axle tractor and semi-trailer combination (as published in 1979 by the Truck Trailer Manufacturing Association). Although the TRUPACT dimensions are slightly over those recommended for cargo containers by the International Organization for Standardization (ISO) the package will be attached to the vehicle bed with standard ISO hardware. The dimensions for the truck version are as follows:

Outside Dimensions

Length: 7.6 m (25 ft., 0 in.)
Width: 2.4 m (8 ft., 0 in.)
Height: 2.7 m (9 ft., 0 in.)

Inside Dimensions

Length: 5.7 m (18 ft., 10 in.)
Width: 1.8 m (6 ft., 0 in.)
Height: 2.1 m (7 ft., 0 in.)

Inside Useful Dimensions

Length: 5.6 m (18 ft., 6 in.)
Width: 1.7 m (5 ft., 8 in.)
Height: 2.0 m (6 ft., 5 in.)

Weights

Empty Packaging: 12.7 tonne (28,000 lb.)
Payload Capacity: 7.7 tonne (17,000 lb.)
Gross Weight: 20.4 tonne (45,000 lb.)

Rail Version

The rail version is also being designed to allow unrestricted access throughout the United States. To do this, the Plate B Envelope dimensions published by the American Association of Railroads (AAR) are being used as a design criterion. The railcars used will have a minimum GVW of 200,000 lb. (90.8 tonne) and a minimum cargo capacity of 140,000 lb. (63.5 tonne), i.e., two rail TRUPACTS loaded to their maximum rated capacity. The TRUPACT packagings will be attached to the railcar using moveable ISO tiedowns located in the railcar flatbed surface. However, these like the truck version do not exactly comply with the dimensions for cargo containers recommended by ISO. The dimensions for the rail versions are as follows:

Outside Dimensions

Length: 7.5 m (24 ft., 6 in.)
Width: 3.0 m (10 ft., 0 in.)
Height: 3.3 m (10 ft., 11 in.)

Inside Dimensions

Length: 5.6 m (18 ft., 4 in.)
Width: 2.3 m (7 ft., 8 in.)
Height: 2.6 m (8 ft., 7 in.)

Inside Useful Dimensions

Length: 5.5 m (18 ft., 0 in.)
Width: 2.1 m (7 ft., 0 in.)
Height: 2.3 m (7 ft., 8 in.)

Weights

Empty Packaging:	17.2 tonne (38,000 lb.)
Payload Capcity:	14.5 tonne (32,000 lb.)
Gross Weight:	31.7 tonne (70,000 lb.)

PACKAGE RESPONSE TO HYPOTHETICAL ACCIDENT CONDITIONS

An extensive test program has been pursued during the TRUPACT development with the goals of validating the concept, obtaining data for comparison with numerical analyses of the package, and providing visual evidence for public information purposes. Many impact and puncture tests have been performed with quarter scale models of the TRUPACT which include the predominant structural features of the package. A series of drop tests were conducted with individual and arrays of eighth-, quarter-, and full-scale Type A waste containers to determine their response to impacts and to aid in developing parameters for modeling cargo loadings in the numerical analyses. In addition, samples of a number of candidate foams have been tested to obtain input parameters for thermal analyses and to determine which are best suited for this application.

9-m Drop Tests

Several 1/4 scale models of the TRUPACT were fabricated to evaluate the packages response in the 9 m impact test. Each model was subjected to one or more tests in different orientations. These are summarized in Table IV. Although the models sustained appreciable exterior damage, particularly those subjected to three or more impacts, virtually no distortion of the package interiors was evident. This result suggests that the TRUPACT exterior structure provides sufficient protection for the inner structure in impact type situations. In addition, finite element analyses were carried out for the end-on and center of gravity over corner impact orientations. While analytical predictions were found to agree well with experimental results for the end-on impact, only modest agreement was obtained for the center of gravity over corner impact orientation. However, the package response in this latter orientation was bracketed by analyses (i.e, one analytical model predicted severe damage to the outer frame but small loadings on the inner frame while another predicted minor damage to the outer frame but more severe loadings on the inner frame) and it was predicted that for the range of impacts considered no yielding of the inner frame would occur. As was mentioned earlier, this was verified by the test results.

Table IV. Quarter-Scale Model TRUPACT Tests

Quarter-Scale Model Number	Tests Performed	Comments
1	End-on impact, corner impact, puncture	Punch penetrated since puncture plates not used
2	Quasi-static attempt to axially move inner frame relative to the outer frame	Test demonstrated that the frames are rigidly connected by the foam
3	Corner, corner-slapdown, edge-slapdown, side-on, edge impacts, puncture	Partial length puncture plates were not penetrated, modular box cargo not breeched
4	Corner impact (twice), puncture	1.2 cm thick (full scale) full length puncture plates not penetrated, 36,000 kg load equivalent
5	Model to be used for puncture testing alternate sidewall configurations	Model in final stages of fabrication

Puncture Test

Extensive scale model and simulation testing has been used to develop features in the TRUPACT wall design which will provide penetration resistance in the 1 m puncture test. Initial test efforts concentrated on evaluating the puncture resistance of clamped edge, circular metallic plates subjected to dynamic punch loading. Mild and stainless steel plates 23 cm and 56 cm in diameter with and without foam backing were impacted with weighted puncture bars 1.2 cm and 2.4 cm, respectively, in diameter. These early tests demonstrated the validity of scaling in the puncture phenomena and the minimal effect on puncture resistance of roll direction during plate fabrication. Subsequent tests with circular plates, in conjunction with other lighter weight materials such as Kevlar, have been performed to evaluate the advantages of such composites. The goal of the use of composites is the replacement of the metal plates, in part, with panels of lighter materials. The circular plate tests have been used to provide guidance in including puncture resistant panels in the walls of the quarter-scale TRUPACT models. Several TRUPACT models with many different wall configurations have been fabricated and puncture tested. These tests have determined the puncture plate thickness required to avoid penetration if a single monolithic metal plate is used and the additional puncture resistance provided by the incorporation of Kevlar in the design. Additional guidance in developing a workable puncture resistant design for the TRUPACT has been obtained by performing full-scale puncture tests on square panels which simulate the wall configuration in a single bay of the container.

The puncture test program has been supported by analysis to the extent possible. The puncture test presents a very difficult analytical problem and progress in analysis of the event has been limited to consideration of centrally punched circular plates. An approximate theoretical treatment of the problem based on energy conservation and variational mechanics principles has been developed which conservatively predicts the deflection to be expected in puncture tests of unsupported and foam-backed plates. The theory, however, is not applicable to composite plates. Finite element analyses of the puncture tests with single circular plates have also been done. These analyses are expensive and do not provide results which are significantly better than those obtainable with the theoretical treatment of the problem. The analyses of the puncture problem in relation to TRUPACT are more fully discussed in References 3 and 4.

Thermal Tests

As mentioned earlier, thermal tests are being conducted to evaluate candidate foams and determine input parameters for thermal analyses. In screening tests, the response of a foam cube exposed to a uniform temperature for a specified time interval was measured. Test objectives were to identify degradation characteristics (especially the tendency to melt), identify physical characteristics of the charred foam, and establish performance rankings of candidate foams (char yield and integrity). In these tests eleven candidates were tested and three were recommended for wall-fire testing. The objective of the wall-fire tests is to simulate a pool fire environment using radiant lamps to heat candidate foams in a stainless steel enclosure and to develop one-dimensional heat and mass transfer data. Preliminary analyses indicate that foam materials of the type being tested will limit the interior temperature rise in the 1/2 hour regulatory fire to about 22°C if the foam thickness is 10.2 cm (4 inches) or 0°C, if 20.3 cm (8 inches). As indicated previously, the TRUPACT wall thickness exceeds 20.3 cm (8 inches). Data are still being collected and evaluated but the tests indicate that suitable materials are available. Hence, efforts are now being focused on selecting the optimum material for this application.

PROGRAM SCHEDULE

The program schedule has been revised to emphasize final design of the truck configuration and to provide a test prototype in FY 83 and five production units in late FY 83 and early FY 84. Final design of the rail configuration will begin after the truck version is completed and will be finished in FY 84 with prototype hardware available in FY 86 and production units available about FY 88 or 89. A program schedule for TRUPACT is shown in Table V. Successful completion of this schedule will provide a safe cost-effective transportation system for CH-TRU waste.

Table V. TRUPACT Program schedule.

	Fiscal Year							
Activity/Milestone	81	82	83	84	85	86	87	88
Technology Development	-------	-------						
Preliminary Design	-------							
Final Design								
Truck		--------						
Rail			-------	-----				
Safety Analysis Report (Truck)								
Prepared		-----	-------					
DOE Certificated			---					
SAR Updated				------				
NRC Certificated					--------			
Safety Analysis Report (Rail)								
Prepared			---	---				
DOE Certificated				----				
SAR Updated							------	
NRC Certificated								-------
Prototype								
Truck Hardware		---	----					
Rail Hardware					--------			
Truck Tests			----					
Rail Tests						----		
Production Units Available								
Truck (5 Units)				-----				
Rail (1 unit)								----

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