ABSTRACT

Contact-handled transuranic defense waste is being, and will continue to be, moved between a number of locations in the United States. The DOE is sponsoring development of safe, efficient, licensable, and cost-effective transportation systems to handle this waste. The systems being developed have been named TRUPACT which stands for TransUranic Package Transporter. The system will be compatible with Type A packagings used by waste generators, interim storage facilities, and repositories. TRUPACT is required to be a Type B packaging since larger than Type A quantities of some radionuclides (particularly plutonium) may be involved in the collection of Type A packagings. TRUPACT must provide structural and thermal protection to the waste in hypothetical accident environments specified in DOT regulations 49CFR173 and NRC regulations 10CFR71.

Preliminary design of the systems has been completed and final design for a truck system is underway. The status of the development program is reviewed in this paper and the reference design is described. Tests that have been conducted are discussed and long-term program objectives are reviewed.

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INTRODUCTION

The Contact-Handled Transuranic (CH-TRU) waste transportation system under development at Sandia National Laboratories is known as the TRUPACT (TRansUranic Package Transporter). The TRUPACT is a Type B packaging system which is being developed to transport a variety of low-level, transuranic contaminated waste forms.

Type A packagings are normally used to transport low concentrations of radionuclides and must be shown to withstand, without loss of integrity, test conditions which simulate environments encountered in normal transportation as specified in 49CFR173.398, Section b. Type B packagings, in addition to satisfying the Type A packaging requirements, must also be shown to withstand, without loss of package integrity, the hypothetical accident conditions of transportation given in Section c of 49CFR173.398.

Type A packagings may be used for containing and transporting Type A quantities or less of radionuclides. Greater than Type A quantities may only be transported in a Type B packaging. The Type A and Type B quantities of a particular nuclide are determined by the nuclides transport group. Specific information concerning transport groups and Type A and B quantities is given in 49CFR173.389 and 49CFR173.390.

Type B packaging is required for transporting CH-TRU waste since greater than Type A quantities of some radionuclides (particularly plutonium) may be present in individual or groups of CH-TRU waste containers. The TRUPACT is being designed to meet the Type B requirements.

The TRUPACT will be available in both rail and truck transported versions. The truck configuration which is being sized for legal weight and size highway transport also will be transportable by rail. The packaging dimensions and capacities are expected to be:

**Rail Configuration**

**Overall Dimensions**

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

Inside Dimensions

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

Inside Useful Dimensions

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

Weights

Empty Packaging: 38,000 lb (17.2 tonne)
Cargo Capacity: 32,000 lb (14.5 tonne)
Gross Weight: 70,000 lb (31.7 tonne)

Truck Configuration

Overall Dimensions

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

Inside Dimensions

Length: 19 ft, 2 in (5.8 m)
Width: 6 ft, 2 in (1.9 m)
Height: 7 ft, 2 in (2.2 m)

Inside Useful Dimensions

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

Weights

Empty Packaging: 33,000 lb (15.0 tonne) | For
Cargo Capacity: 17,000 lb (7.7 tonne) | -- 80,000 lb GVW
Gross Weight: 50,000 lb (22.7 tonne) | (36.3 tonne)

Empty Packaging: 33,000 lb (15.0 tonne) | For
Cargo Capacity: 12,000 lb (5.4 tonne) | -- 73,280 lb GVW
Gross Weight: 45,000 lb (20.4 tonne) | (33.3 tonne)
TRUCK TRANSPORT DESIGN BASIS

The truck TRUPACT configuration semi-trailer and tractor transport are being designed to operate as a legal system throughout the United States, i.e., at a Gross Vehicle Weight (GVW) of 73,280 lb (33.3 tonne) or less. The weight distribution will be such that the limiting loads of 32,000 lb (14.5 tonne) for a tandem axle, and 9000 lb (4.0 tonne) for a single steering axle are not exceeded. Most states now have GVW limits of 80,000 lb (36.3 tonne) or more; however, the practical limit for a tandem axle semi-trailer with a three-axle tractor is about 78,000 lb (35.4 tonne). In states that use "bridge formulas", the distance between the steering axle and the rear axle of the trailer is used to limit the allowable GVW.

The most restrictive limits for a five-axle tractor and semi-trailer combination according to a 1979 chart published by the Truck Trailer Manufacturing Association are

| Length     | 55 ft, 0 in (16.8 m) |
| Width      | 8 ft, 0 in (2.4 m)   |
| Height     | 13 ft, 6 in (4.1 m)  |

The position of the packaging on the trailer will be adjusted to uniformly distribute the load between the tractor and semi-trailer axles. The Type B package will be attached to the trailer bed using standard container mounting hardware (as recommended by the International Organization for Standardization (ISO)) which will be installed into the trailer frame to provide rigid attachments. The package tiedown hardware will be designed to provide a static strength equal to 2, 5, and 10 times the maximum weight of the loaded packaging in the vertical, transverse, and longitudinal directions, respectively (10CFR71.31 (d)). Design loads for packaging analysis will be determined using the normal and hypothetical accident test conditions discussed in the introduction material. The truck configuration will also be readily transportable by rail.

RAIL TRANSPORT DESIGN BASIS

The railcar transported TRUPACT option will provide a system that can be operated throughout the U.S. rail system in unrestricted interchange service. To permit unrestricted interchange of railcars, the Plate B Envelope dimensions imposed by the American Association of Railroads (AAR) have been selected. The railcars used will have a maximum GVW of 263,000 lb (119.3 tonne) and a nominal cargo capacity of 140,000 lb (63.5 tonne), i.e., two rail TRUPACTS loaded to their maximum rated capacity. The overall length of the railcar will be approximately 60 ft (18.3 m).

The TRUPACT packaging will be attached to the railcar using moveable ISO tiedowns located in the railcar flatbed surface. The package tiedown hardware will be designed to provide a static capacity of 2, 5, and 10 times the maximum weight of a loaded packaging in the vertical, transverse, and longitudinal directions, respectively (10CFR71.31 (d)). Design loads
for packaging analysis will be determined using the normal and hypothetical accident test conditions referenced in the introduction.

REFERENCE DESIGN DESCRIPTION

The TRUPACT configuration is illustrated in Figure 1. The structure consists of inner and outer tubular-steel frames separated by rigid polyurethane foam. Package weight is minimized by using a ductile high strength, low alloy steel in both frameworks.

The packaging cavity, which serves as the containment system, is lined with stainless steel because of its ductility and ease of decontamination. The inner containment is made secure by closing and bolting into place a hinged 4 in (10 cm) thick door which also has a tubular steel framework and a honeycomb core. This door is sealed with three elastomeric seals. The outer framework is covered with thin mild steel or stainless steel sheet. An exterior door is attached to the outer framework with hinges, is foam filled, measures 36 in (90 cm) thick, utilizes a single elastomeric seal, and is also bolted in place for transport.

There is approximately 36 in (91 cm) of foam in the packaging ends and 13 in (33 cm) and 11 in (28 cm) in the walls of the rail and truck configurations, respectively, to provide thermal protection and to absorb impact and puncture energy. Puncture protection is provided by placing ductile stainless steel plates or composites of other puncture resistant materials on the inside surface of the outer framework to distribute the penetrator energy over a large area of low strength foam.

Cargo loading and unloading will be accommodated by using a pallet or roller conveyor system on the floor of the TRUPACT. Heavy handling equipment will not be used inside the packaging. Figures 2 and 3 show the rail and legal weight truck versions, respectively, of TRUPACT loaded with 2x3 arrays (six-packs) of 55-gallon drums.

TRUPACT ANALYSES AND TESTS CONDUCTED

An extensive test program has been pursued during the TRUPACT development with 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. Numerous puncture tests were also performed to enable correlations to be made between test results and theoretical predictions. Foam samples have been tested for a number of candidate materials to obtain input parameters for the thermal analysis code and
to screen materials. The screening tests were performed to measure response of commercially available foam materials by exposing small samples to a uniform temperature for a specified time interval. 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 foam candidates were tested and three were recommended for wall-fire testing. The objective of the wall-fire tests was to simulate a regulatory fire environment using radiant lamps to heat candidate foams in a stainless steel enclosure and to develop one-dimensional heat and mass transfer data. The tests have been completed and the results are being analyzed. The entire thermal test program is briefly summarized in Reference 1. Data are still being collected and analyzed but suitable materials are available. The requirements for the foam are foam-in-place fabrication, minimum density, low thermal diffusivity, high char yield, fine grain char, and dimensional stability. There are also additional considerations related to impact and puncture performance that must be considered. A one-dimensional thermal model is being developed to predict response of the charred material as degradation occurs. Numerical one-dimensional analyses utilizing the measured physical properties of the candidate foams predict a temperature rise of the inner surface of a foam slab of about 40°F (22°C) for a slab thickness of 4 in (10.2 cm) and no temperature rise for an 8 in (20.3 cm) thick slab when the outer surface is exposed to a half-hour regulatory fire. As indicated previously, the TRUPACT wall thickness exceeds 8 in (20.3 cm).

Evaluation of the TRUPACT dynamic response in a regulatory 30 ft (9 m) free fall in its most damaging orientation is necessary to assess survivability. Three-dimensional finite element models of the structure have been developed and evaluated numerically for end, side, and center-of-gravity-over-corners impact orientations. In these analyses, truss elements were utilized to model frame members, three-dimensional elements were used for foam, and, in some instances, shell elements were used to model the interior and exterior skins. Additional model details are given in Reference 2. Since energy dissipation by cargo deformation during impact was considered important, the cargo was modeled using truss elements. A drop-test program (described in Reference 3) involving eighth-, quarter-, and full-scale 55-gallon drums and rectangular steel boxes loaded with simulated waste was performed to obtain cargo material properties for input to the finite element model. Quarter scale models of TRUPACT were designed, built, and loaded with quarter-scale waste containers prior to drop testing from 30 ft (9 m) in a variety of impact orientations. Table 1 contains a summary of the tests to which these models were subjected. Measurements and films were taken from each test for comparison with the predictions obtained by corresponding analyses. Additional models are being fabricated to incorporate the latest design changes and these will be tested in April 1982. Results of the quarter-scale TRUPACT model drop
tests indicated that no unacceptable damage was delivered to the internal containment boundary. In all of the impact tests, noticable damage was observed on the exterior surfaces. Simulated waste containers were breached and released a minimal amount of contents to the packaging’s interior when the cargo was 55-gallon drums banded into a "six-pack" configuration. Simulated waste containers experienced no loss of contents when rectangular steel boxes were used. Visual inspection of the TRUPACT models after testing indicated no yielding of the inner frame or penetration of the inner wall.

The development and evaluation of puncture resistant wall concepts for use in TRUPACT has involved: (1) developing an approximate theoretical treatment of the problem (2) evaluating the puncture event using finite element analysis techniques, (3) pursuing a laboratory scale puncture program for the case of single and multiple layered circular plates, (4) developing a full-scale puncture test facility, and (5) puncture testing of quarter-scale TRUPACT models.

Table 1
Quarter-Scale Model TRUPACT Tests

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<th>Quarter-Scale Model Number</th>
<th>Tests Performed</th>
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<tr>
<td>1</td>
<td>End-on impact, corner impact, puncture</td>
<td>Punch penetrated since puncture plates not used</td>
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<td>2</td>
<td>Attempts to move quasi-statically the inner frame axially relative to the outer frame</td>
<td>Test demonstrated that the frames are rigidly connected by the foam</td>
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<td>3</td>
<td>Corner, corner-slapdown, edge-slapdown, side-on, edge impacts, puncture</td>
<td>Partial length puncture plates were not penetrated, modular box cargo not breeched</td>
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<td>4</td>
<td>Corner impact (twice), puncture</td>
<td>.48 in (1.2 cm) thick (full scale) full length puncture plates not penetrated, 80,000 lb (36.3 tonne) load equivalent</td>
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<td>5</td>
<td>Model to be used for puncture testing alternate sidewall configurations</td>
<td>Model in final stages of fabrication</td>
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The theoretical treatment was developed to provide an early and inexpensive assessment method for evaluating concepts. Details of this theory are given in Reference 4. Evaluations using finite element analysis were used to support the laboratory scale puncture program. The results of the theoretical and numerical treatment of the puncture phenomena, and comparisons with the laboratory scale test results, will be published in Reference 5. The laboratory scale test program, in turn, has been used to obtain data for comparison with predictions based on the approximate theory and the numerical analyses, to validate scaling in the puncture event, to test novel puncture resistant concepts such as multiple layers of various materials, and to provide supportive information for the full-scale test fixture. The full-scale puncture test facility enables puncture testing with the regulatory puncture bar and full-scale drop weights. Finally, puncture plates were incorporated into some of the quarter-scale models which were subjected to the regulatory puncture test (see Table 1). The emphasis to-date has been to define an acceptable sidewall configuration for the 50,000 lb (22.7 tonne) truck configuration. The early reference design incorporated a single sheet of stainless steel on the inside surface of the outer frame having a thickness of between 7/16 and 5/8 inch (1.1 to 1.6 cm). Recent investigations have shown a number of other materials, and combinations of materials, provide improved puncture resistance while reducing weight. Results of these tests are summarized in Figure 4. Based on these results the combination of Kevlar backed with stainless steel is being vigorously pursued and will probably replace all stainless steel plates as the reference design.

PROGRAM SCHEDULE

The program schedule was revised at the beginning of FY 82 to emphasize final design of the truck configuration and to provide a test prototype in FY83 and five production units in late FY83 and early FY84. Final design of the rail configuration will begin after the truck version is completed and will be finished in FY84 with prototype hardware available in FY86 and production units available about FY88 or 89. A program schedule for TRUPACT is shown in Table 2.

CONCLUSION

Design of TRUPACT packagings for highway and rail transport is proceeding in an orderly fashion through iterations of design and analysis. Analyses performed have shown good agreement between numerical solutions and full-scale or sub-scale tests. The schedule for development of test, prototype and production hardware is shown in Table 1. The probability of delivering hardware on schedule is very high.
REFERENCES


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Figure 1. Photograph of a TRUPACT model, partially cutaway to show internal structure.
![Diagram of a container with specifications and dimensions.](image)

**Figure 2. TRIPACT Container (10 ft wide) Showing Railroad Configuration with Six-Packs**

- **Payload Limit**: Empty weight 32,000 lbs, 38,000 lbs.
- **Shock and Thermal Isolation**: 48 55-gallon drums (8 six packs).
- **Outer Door with Seal**: Stainless steel lined cavity.
- **Useful Internal Space Dimensions**:
  - 7'-0" (2.1 m)
  - 7'-8" (2.3 m)
  - 10'-9" (3.3 m)
  - 18'-0" (5.5 m)
  - 24'-6" (7.5 m) W/Door Closed
**PAYLOAD LIMIT**

- 17,000 LBS
- 33,000 LBS

**EMPTY WEIGHT**

- 33,000 LBS

**OUTER DOOR WITH SEAL**

- 6'(1.8 m)

**STAINLESS STEEL LINED CAVITY**

**36 55-GALLON (0.2 m³) DRUMS (6 SIX PACKS)**

**SHOCK AND THERMAL ISOLATION**

**USEFUL INTERNAL SPACE DIMENSIONS**

- 18'10" (5.7 m)
- 25'(7.6 m)
- 7'(2.1 m)
- 6'(1.8 m)

**WITH DOOR CLOSED**

Figure 3. TRIPACCT Packaging Showing Truck Configuration with Six-Packs
Figure 4. Phase 1 Puncture Test Results