DEVELOPMENT OF THE TRU WASTE TRANSPORTATION FLEET – A SUCCESS STORY

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ABSTRACT

Since March 1999, the Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico, has been operated by the U.S. Department of Energy (DOE), Carlsbad Field Office (CBFO), as a repository for the permanent disposal of defense-related transuranic (TRU) waste. More than 1,450 shipments of TRU waste for WIPP disposal have been completed, and the WIPP is currently receiving 12 to 16 shipments per week from five DOE sites around the nation. One of the largest fleets of Type B packagings supports the transportation of TRU waste to WIPP. This paper discusses the development of this fleet since the original Certificate of Compliance (C of C) for the Transuranic Package Transporter-II (TRUPACT-II) was issued by the U.S. Nuclear Regulatory Commission (NRC) in 1989. Evolving site programs, closure schedules of major sites, and the TRU waste inventory at the various DOE sites have directed the sizing and packaging mix of this fleet. This paper discusses the key issues that guided this fleet development, including the following:

- While the average weight of a 55-gallon drum packaging debris could be less than 300 pounds (lbs.), drums containing sludge waste or compacted waste could approach the maximum allowable weight of 1,000 lbs. A TRUPACT-II shipment may consist of three TRUPACT-II packages, each of which is limited to a total weight of 19,250 lbs. Payload assembly weights dictated by “as-built” TRUPACT-II weights limit each drum to an average weight of 312 lbs when three TRUPACT-IIs are shipped. To optimize the shipment of heavier drums, the HalfPACT packaging was designed as a shorter and lighter version of the TRUPACT-II to accommodate a heavier load.

- Additional packaging concepts are currently under development, including the “TRUPACT-III” packaging being designed to address “oversized” boxes that are currently not shippable in the TRUPACT-II or HalfPACT due to size constraints.

- Shipment optimization is applicable not only to the addition of new packagings, but also to the addition of new payload containers (used inside the NRC-approved Type B packaging) with revised design limits. For example, to address the shipment of specific TRU waste forms, a series of pipe overpack payload containers have been designed and approved by the NRC. The “standard” pipe overpack configuration is designed to allow the shipment of higher fissile gram containers, each with a maximum fissile gram equivalent (FGE) loading of 200 grams (g). For shipments of waste packaged in the
standard pipe overpack, the FGE limit is 2,800 g per TRUPACT-II and 1,400 g per HalfPACT. The “S100” and “S200” pipe overpack configurations allow the use of shielded configurations of the pipe overpack for shipment of specific gamma- and neutron-emitting waste forms.

- The 72-B Cask and the 10-160B Cask have been approved by the NRC for the transportation of remote-handled (RH) TRU waste, which comprises a small fraction of the overall inventory that will be shipped to WIPP.

INTRODUCTION

The WIPP facility, located in southeastern New Mexico, is the nation's first geological repository for the permanent disposal of TRU radioactive waste. Congress authorized the development of WIPP in 1980 to demonstrate the safe disposal of radioactive waste resulting from defense programs of the United States, including weapons production and research and development. TRU waste generally consists of protective clothing, tools, glassware, and equipment contaminated with radioactive materials. TRU waste is contaminated with alpha-emitting radioisotopes (e.g., plutonium-239), with half-lives greater than 20 years and atomic numbers greater than 92, in concentrations greater than 100 nanocuries per gram of waste. TRU wastes are classified as either CH or RH, depending on the radiation dose rate at the surface of the waste container. CH-TRU waste containers have an external radiation dose rate less than or equal to 200 millirem per hour (mrem/hr) at the surface of the container; RH-TRU waste containers have an external radiation dose rate greater than 200 mrem/hr at the container surface. CH-TRU waste constitutes the vast majority (~97 volume percent) of the overall DOE TRU waste inventory (1). Currently, TRU waste is generated and/or stored at ten major DOE sites across the country and several small quantity sites, as shown in Figure 1. The site chosen for the underground WIPP repository is a 16-square-mile tract of federal land. The WIPP repository is located 2,150 feet below the surface in a bedded salt formation of Permian age known as the Salado Formation.

WIPP CH-TRU WASTE TRANSPORTATION PROGRAM

The Land Withdrawal Act (2) requires that all waste to be disposed of at WIPP be transported in NRC-certified packagings. The NRC regulations governing transportation of TRU waste are codified in Title 10, Code of Federal Regulations (CFR), Part 71 (10 CFR 71), which requires double-contained Type B packagings for wastes containing more than 20 curies of plutonium (3). In 1989, after extensive analysis and testing, the DOE submitted the TRUPACT-II Safety Analysis Report (SAR) to the NRC, demonstrating compliance with 10 CFR 71 and seeking to transport CH-TRU waste to WIPP in the TRUPACT-II.

As required by the NRC regulations, the key issues addressed in the TRUPACT-II SAR were containment, shielding, and criticality. In addressing these issues, the TRUPACT-II SAR included requirements and limits on gas generation (containment), fissile gram loadings (FGE) (criticality), and dose rates (shielding). In order to obtain NRC certification, the TRUPACT-II underwent extensive testing, with four test units being subjected to multiple test sequences.
Fig. 1. DOE TRU Waste Generator and Storage Sites

Tests performed included nine 30-foot drop tests, fifteen puncture drops, and two fully engulfing pool fires. In late 1989, the NRC issued the C of C for the TRUPACT-II (4).

The first shipment of CH-TRU waste to WIPP in the TRUPACT-II was made on March 26, 1999. To date, over 1,450 shipments of CH-TRU waste have been made to WIPP in the TRUPACT-II from five DOE sites:

- Hanford
- Idaho National Engineering and Environmental Laboratory (INEEL)
- Los Alamos National Laboratory (LANL)
- Rocky Flats Environmental Technology Site (RFETS)
- Savannah River Site (SRS).

There are currently 70 TRUPACT-II units in service, with a projected fleet of 84 TRUPACT-IIs and 15 HalfPACTs. Currently, the TRUPACT-II is the only packaging being used for CH-TRU waste transportation to WIPP. The containers shipped have been primarily 55-gallon drums, with pipe overpacks and standard waste boxes (SWBs) also being transported.

There are several key waste attributes, in conjunction with the TRUPACT-II limits, that determine the shippable portion of the TRU waste inventory. The following sections discuss
those attributes that have dictated the composition of the TRU waste transportation fleet, as well as improvements in the form of SAR amendments and new container design.

**KEY VARIABLES IN DETERMINING CH-TRU TRANSPORTATION FLEET**

The key factor in determining the CH-TRU waste transportation fleet is the inventory of waste to be transported and disposed of at WIPP. The following are the primary waste characteristics that determine waste shippability and, therefore, impact the transportation fleet:

- **Container Weight and Size**: Wastes in heavy (>1,000 lbs.) and oversized containers (e.g., 4- by 4- by 7-foot boxes) are not shippable in the TRUPACT-II due to weight and size constraints. (In addition to shipping issues, large containers also present challenging characterization issues.)

- **Fissile Content**: Fissile limits applicable to the TRUPACT-II may limit the average FGE per payload container and may result in inefficient shipments.

- **Dose Rate**: Gamma- and neutron-emitting TRU wastes >200 mrem/hr at the surface are not shippable in the TRUPACT-II without shielding.

- **Flammable Gas Concentrations**: Some wastes may not be shippable due to gas generation issues resulting from the high potential for flammable gas concentrations in the waste.

**Weight-Limited Waste**

There are multiple weight restrictions that govern the amount of waste that may be shipped in a TRUPACT-II shipment. For example, there are weight limits on individual payload containers (e.g., 1,000 lbs. per drum), payload assemblies (e.g., 7,265 lbs. for 14 drums), each loaded TRUPACT-II (19,250 lbs.), and the total loaded tractor-trailer (80,000-lbs. U.S. Department of Transportation limit). In 1995, DOE developed a decision-making tool and performed a packaging optimization study to determine the optimum fleet of packagings for WIPP shipments. At that time it was determined that approximately 40 percent of the CH-TRU waste inventory was not shippable in the TRUPACT-II at the maximum capacity of 14 drums per TRUPACT-II or 42 drums per shipment because of weight restrictions (5). A portion of the shipments made to date have consisted of only two TRUPACT-IIs per trailer, thereby allowing for higher average payload and payload container weights. Examples of these shipments include pipe overpack shipments from RFETS. To supplement the packaging optimization study, DOE commissioned the “TRUPACT-II Payload Expansion Plan,” which addressed weight-limited and size-limited waste (6).

One of the recommendations from the CH-TRU Waste Packaging Optimization Report (5) was development of the HalfPACT, which is a shorter version of the TRUPACT-II that has a greater payload weight capacity. The HalfPACT can accommodate seven drums or one SWB (as opposed to fourteen drums and two SWBs that may be shipped in the TRUPACT-II). A shipment of three TRUPACT-IIs is limited to a total payload of 13,090 lbs. after the weight of
the tractor, trailer, and empty TRUPACT-IIs is accounted for, which results in an average drum weight limit of 312 lbs. However, a shipment of three HalfPACTs is limited to a payload of 21,000 lbs., with the resulting maximum allowable drum weight limited by the overall drum weight restriction of 1,000 lbs. and not a packaging weight limit. Based on this study, DOE funded the design, testing, and certification effort for the HalfPACT, and the NRC certified the HalfPACT in November 2000 (7). Effectively the same payloads are authorized for both the TRUPACT-II and the HalfPACT packagings, which have been certified by separate applications to the NRC. The next applications for revision of the TRUPACT-II SAR and the HalfPACT SAR will fully merge the payload requirement documents for the two packagings, resulting in one document controlling the payloads to be shipped in the TRUPACT-II or the HalfPACT. Currently, DOE has 3 HalfPACTs with 12 more to be fabricated for a total of 15 HalfPACTs. Heavier waste forms, like the compacted and solidified wastes from the Advanced Mixed Waste Treatment Facility at INEEL, are expected to use the HalfPACT for shipment.

Size-Limited Waste

As shown in Figure 2, approximately 25 percent (by volume) of the CH-TRU inventory at the DOE sites is estimated to exist in oversized containers that are not transportable in the TRUPACT-II or the HalfPACT (8).

![Fig. 2. Distribution of Waste by Size and Weight Limitations](image)

The largest box that can be transported in a TRUPACT-II (e.g., in a ten-drum overpack) is approximately 4 x 4 x 5.5 feet. The oversized container inventory at the DOE sites consists primarily of boxes that are 4 x 4 x 7 feet or larger. This oversized container inventory is located at several of the DOE sites, including Hanford, INEEL, Lawrence Livermore National
Laboratory, Nevada Test Site, and SRS. The options available for transporting this waste include repackaging/size reduction of the waste for transport in the TRUPACT-II or the HalfPACT, design/development of a new packaging, modification of an existing packaging, or some combination of these options.

Due to the cost, schedule, and safety considerations associated with building new facilities and repackaging all of the waste currently in oversized containers, the DOE-CBFO initiated an effort to investigate the feasibility and effectiveness of designing a new packaging, the TRUPACT-III, for the shipment of the oversized CH-TRU waste inventory. In response to this initiative, a workshop and trade study were held in 2001. Subsequently, a Subject Matter Expert Panel concluded that design and implementation of a TRUPACT-III packaging was viable and cost effective (9, 10). In addition, the NRC is currently considering a rulemaking that may eliminate the requirement for double containment, which would make truck shipment of a packaging for large sized boxes more viable. A contract was recently issued to Packaging Technology, Inc., for the design, development, testing, and certification of the TRUPACT-III, with submittal to the NRC of the SAR and associated documents scheduled for the end of July 2003. The current design basis requires the TRUPACT-III to be designed as a single-containment unit, with the option for a double-containment conversion if the proposed NRC rulemaking is not realized.

**Fissile Mass and Dose Rate Limited Waste**

In order to ensure subcritical conditions during transportation, the TRUPACT-II and HalfPACT C of Cs specify FGE limits per payload container and per payload assembly. While the payload container limits are 200 FGE per drum and 325 FGE per SWB, the limit per TRUPACT-II or HalfPACT payload is only 325 FGE. For a payload of fourteen 55-gallon drums, this translates to an average of only 23 FGE per drum. To alleviate this limitation, DOE developed a series of “pipe overpack” payload containers consisting of a pipe component overpacked in a 55-gallon drum. The FGE limit for a “standard” pipe overpack is 200 FGE, resulting in a TRUPACT-II FGE limit of 2,800 for a payload of 14 standard pipe overpacks. With the pipe overpack payload configuration, larger amounts of fissile material may be shipped in each TRUPACT-II or HalfPACT, which results in a reduction in the number of shipments required. Since the approval of the standard pipe overpack in 1999, DOE has developed three shielded pipe overpack configurations (i.e., S100, S200, and S300 pipe overpacks), which allow the shipment of gamma- and neutron-emitting TRU waste forms. The S100 and S200 pipe overpacks are currently authorized for transport in the TRUPACT-II. An application is currently under review by the NRC that would allow transport of a new S300 pipe overpack in the TRUPACT-II and transport of the S100, S200, and S300 pipe overpacks in the HalfPACT. The four pipe overpack configurations are as follows:

- **Standard Pipe Overpack**: The standard pipe overpack is available in 6-inch and 12-inch sizes, with weight limitations based on the size of the pipe component. The standard pipe overpack is currently authorized for transport in both the TRUPACT-II and HalfPACT. Several thousand standard pipe overpacks have been shipped to WIPP in the TRUPACT-II from RFETS.
- **S100 Pipe Overpack**: The S100 pipe overpack is a shielded version of the standard pipe component. It consists of a 6-inch diameter pipe component positioned with a 55-gallon drum by means of fiberboard/plywood dunnage and neutron shielding materials. This container will primarily be used for the shipment of neutron sources from LANL.

- **S200 Pipe Overpack**: The S200 pipe overpack is a shielded version of the standard pipe component. It consists of a lead gamma-shield insert located by rigid polyurethane foam dunnage inside a 12-inch diameter pipe component, which is positioned within a 55-gallon drum by means of fiberboard/plywood dunnage. The lead gamma-shield insert is a two-component assembly consisting of a cylindrical body with an integral bottom cap and a detachable lid. The shield insert is available in two sizes, with the two variations called the “S200-A” and “S200-B.”

- **S300 Pipe Overpack**: The S300 pipe overpack is a shielded version of the standard pipe component. It consists of a neutron shield insert located in a 12-inch diameter pipe component positioned with a 55-gallon drum by means of fiberboard/plywood dunnage. The neutron shield insert is a two-part assembly consisting of a cylindrical body and stepped lid made from solid, high density polyethylene.

These containers were designed and developed to support closure activities (e.g., RFETS), consent agreements (e.g., INEEL), and special projects (e.g., sealed-source recovery program at LANL) at the DOE sites.

**Waste Restricted Due to Gas Generation Issues**

Shippability of approximately 5 to 10 percent of the overall CH-TRU waste inventory is limited due to the potential for flammable gas generation, primarily due to radiolysis (8). The NRC limits the hydrogen concentration in the innermost confinement layer in the waste to less than 5 percent. The waste inventory limited by gas generation issues includes solidified organic waste, Pu-238 waste, and other high-loaded Pu-239 wastes.

While the fraction of this inventory is relatively small, impacts from not being able to ship these wastes are severe, including impacts on RFETS closure goals (requires path forward for solidified organic waste) and the need to establish expensive repackaging facilities (e.g., for shipment of Pu-238 waste from SRS). Solutions being studied to resolve this issue include potential regulatory relief and technology development, such as the use of hydrogen gas getters that scavenge hydrogen generated during transportation and the development of a bag-breacher technology to reduce layers of confinement and reduce hydrogen concentrations in containers. One other concept being considered is a strong, robust container, called the ARROW-PAK™, which would overpack the drums and would be designed to withstand any potential deflagration without impacting the transport packaging (e.g., the TRUPACT-II). Recent feedback from the NRC indicates that this will be a 10 CFR 71 exemption (and an exemption from the 5-percent limit on hydrogen concentration). An exemption application will need to be submitted to the NRC for approval of the ARROW-PAK™.
WIPP RH-TRU WASTE TRANSPORTATION PROGRAM

Similar to the CH-TRU waste transportation program, the RH-TRU waste inventory influences packaging design. Due to the nature of RH-TRU waste with higher surface dose rates, a shielded cask is required for the transportation of this waste. The NRC issued the original C of C for the 72-B Cask in March 2000 (11). The 72-B Cask is designed to transport one RH-TRU waste canister either directly loaded with waste or overpacking three 55- or 30-gallon drums. DOE-CBFO has accepted five 72-B Casks, with seven additional units on order.

To expedite RH-TRU waste shipments from small quantity sites, DOE purchased a 10-160B Cask, a commercial shipping cask designed and fabricated by Chem-Nuclear Systems, LLC, and now owned by Duratek, Inc., for waste shipments containing less than 20 curies of plutonium. The 10-160B Cask is a single containment cask that can transport up to ten 55-gallon drums. The 10-160B Cask is currently authorized for use in transporting TRU waste from Battelle Columbus Laboratories (BCL), the Energy Technology Engineering Center (ETEC), Lawrence Livermore National Laboratory, and the Missouri University Research Reactor based on the approval by the NRC of Revision 18 of the 10-160B SAR(12). The first shipments in the 10-160B Cask were made on December 18, 2002, when BCL and ETEC shipped CH- and RH-TRU waste to Hanford for interim storage prior to disposal at WIPP.

SUMMARY

The WIPP transportation program has safely and successfully made over 1,450 shipments of TRU waste from five DOE sites covering more than 1.4 million miles. The program is positioned to accommodate the efficient shipment of the waste inventory as dictated by key waste characteristics. By the end of the operational life of WIPP, it is expected that over 20,000 shipments will have been made. A key attribute of this successful strategy is the fact that the packaging fleet development has always been closely linked to the characteristics of the waste inventory planned for WIPP disposal and evolving needs at the sites.

Table I presents a summary of the current and planned TRU waste transportation fleet mix and size. The TRU waste transportation program remains dynamic and flexible, while actively using and maintaining one of the largest fleets of Type B packagings in the world with an excellent safety record.

Table I. TRU Waste Transportation Fleet

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<th>Anticipated Fleet Size</th>
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REFERENCES


