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Status and Use of the Rocky Flats Environmental Technology Site Pipe Overpack Container for TRU Waste Storage and Shipments

Donald T. Thorp, Safe Sites of Colorado, L.L.C.
Michael A. Rivera, Los Alamos Technical Associates
Richard R. Geinitz, Safe Sites of Colorado, L.L.C.

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ABSTRACT

The Pipe Overpack Container was designed to optimize shipments of high plutonium content transuranic waste from Rocky Flats Environmental Technology Site (RFETS) to Waste Isolation Pilot Plant (WIPP). The container was approved for use in the TRUPACT-II shipping container by the Nuclear Regulatory Commission in February 1997. The container optimizes shipments to WIPP by increasing the TRUPACT-II criticality limit from 325 fissile grams equivalent (FGE) to 2800 FGE and provides additional shielding for handling wastes with high americium-241(Am^{241}) content. The container was subsequently evaluated and approved for storage of highly dispersible TRU wastes and residues at RFETS.

Thermal evaluation of the container shows that the container will mitigate the impact of a worst case thermal event from reactive or potentially pyrophoric materials. These materials contain hazards postulated by the Defense Nuclear Facilities Safety Board for interim storage. Packaging these reactive or potentially pyrophoric residues in the container without stabilizing the materials is under consideration at RFETS.

The design, testing, and evaluations used in the approvals, and the current status of the container usage, will be discussed.

INTRODUCTION

The Rocky Flats Environmental Technology Site located near Denver, Colorado, is currently storing a backlog of approximately 756 m^3 (3700 0.21 m^3 drums and 3500 smaller containers) of plutonium-bearing residues. These materials comprise a category of materials that, during the weapons production era, due to sufficiently high concentrations of plutonium, recovery of the plutonium was considered to be economically favorable. With the change in mission for RFETS and the Department of Energy (DOE) complex from weapons production to environmental restoration and waste management, plutonium recovery operations will not be required for the foreseeable future. The ultimate disposition of the residue backlog still needs to be performed.

Since the early 1950's residues were generated at Rocky Flats as a by-product of production operations. They consist of a variety of materials such as incinerator ash, pyrochemical salts, casting materials, paper, cloth, plastic, metal, glass, rubber gloves, filters, insulation, firebrick, and ion exchange resins. At RFETS each residue type is given a unique identifier known as an Item Description Code (IDC). Residues and wastes are packaged according to their IDC. There are approximately 100 residue IDCs at RFETS awaiting disposition.

Over the past several years, the Residue Stabilization Program at RFETS has developed a robust stainless steel container inside a 0.21 m^3 drum, commonly known as the Pipe Overpack

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Container. This was developed as a means to ship residues to WIPP in a more efficient and cost-effective manner. More recently, the RFETS Residue Stabilization organization has proposed that the Pipe Overpack Container, due to its large mass and high heat capacity, could be used to store and ship selected residues without performing costly and time-consuming stabilization operations. These operations are designed to eliminate possible hazards associated with interim storage (Reference 1). By undertaking this course of action, RFETS could accelerate the reduction of risks to both RFETS workers and the public, reduce operator exposure to both radioactive and hazardous materials, and realize significant cost savings. By far, the most significant advantage would be the early closure of former plutonium production buildings and the decommissioning of RFETS by the year 2006.

PIPE OVERPACK CONTAINER DESIGN

The Pipe Overpack Container system, which includes the Pipe Component as its central feature, was originally designed, tested, and qualified as a Nuclear Regulatory Commission approved, enhanced TRUPACT-II payload container. This system allows for more efficient transport and disposal of certain RFETS residues and wastes at WIPP.

The Pipe Components are placed within a standard DOT-17C Type A 0.21m^3 drum. The drum is lined with the standard rigid drum liner. Celotex® fiberboard and plywood are used as spacers. They also serve to preclude damage to the pipe on impact and function as thermal insulation. The drum lid is fitted with a polyethylene-housed carbon composite filter. The drum lid is secured to the drum with a standard drum lid locking ring. A schematic of the entire Pipe Overpack Container system is shown in Figure 1.

The Pipe Component was designed in two sizes: 15.2 cm and 30.5 cm in diameter, each with a nominal length of 63.5 cm. The usable volumes are approximately 12,000 cm^3 and 48,000 cm^3, respectively. These volumes will accommodate a large majority of the RFETS residues when it is desirable to package a drum to the 200 FGE limit. The 15.2 cm diameter version is constructed of Schedule 40 304L stainless steel. The 30.5 cm diameter model is fabricated from Schedule 20 stock. The nominal wall thickness in both cases is 0.63 cm. The bottom end of the pipe is closed with a 0.63 cm minimum thick weld cap. The top end of the pipe is fitted with a 59 kg weld neck flange for the 15.2 cm diameter component and a non-standard, lighter weight flange for the 30.5 cm diameter component which accommodates 2.54 cm thick bolt-on lids. The flange is machined to incorporate a 3.2 mm cross-section diameter ethylene propylene O-ring gasket to ensure containment of particulate material. Incorporated into the lid design is a sintered stainless steel filter similar to one utilized to vent flammable gases from 0.21 m^3 drums.

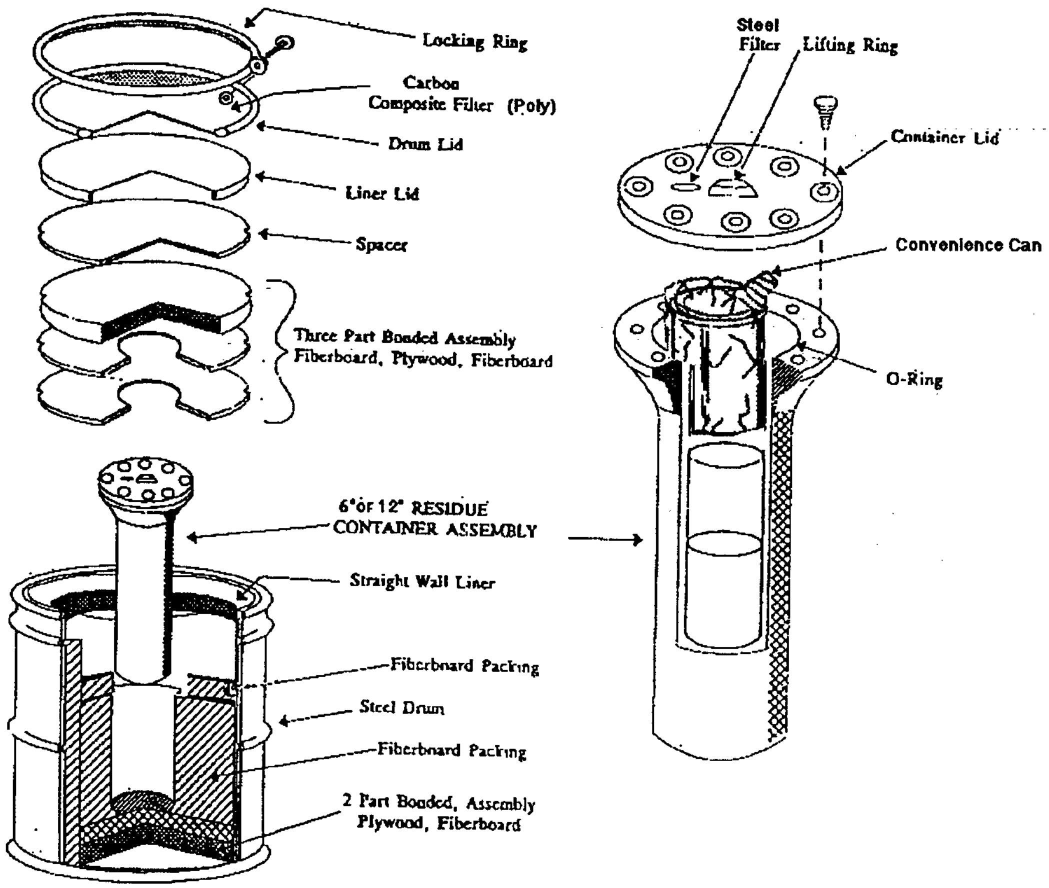

Figure 1.
Pipe Overpack Container

Up to fourteen Pipe Overpack Containers can be shipped in a TRUPACT-II. Each container may have a maximum fissile gram equivalent loading of 200 grams, for a total TRUPACT-II load of 2800 FGE. For shipments of waste packaged in payload containers other than the Pipe Overpack Container, the limit is 325 FGE per TRUPACT-II. The Pipe Overpack Container also provides for radiation shielding. After additional testing, this system was also approved at RFETS as a safe interim storage container for the storage of highly dispersible materials.

PIPE OVERPACK CONTAINER TESTING

A test program was developed and implemented to demonstrate the integrity of the Pipe Overpack Container under hypothetical accident conditions. Normal conditions of transport were bounded by the test program. The test program procedures and results are documented in References 2 and 3 and are summarized below.

Two series of tests, consisting of 9.1 m top and side impact drops of loaded Pipe Overpack Containers, were performed. The drop tests simulated the interaction effects of other fully loaded Pipe Overpack Containers within a TRUPACT-II.

Three top-impact drop tests were performed. In each test, two drums were strapped end-to-end as if positioned for transport within a TRUPACT-II. Top impact tests were performed for the following configurations of overpacks:

- Two 0.21 m^3 drums containing 15.2 cm diameter pipe components.
- Two 0.21 m^3 drums containing 30.5 cm diameter pipe components.
- Two 0.21 m^3 drums: one containing a 30.5 cm diameter pipe component and one containing a 15.2 cm diameter pipe component.

One side impact test was performed by dropping an uncertified but functional TRUPACT-II Inner Containment Vessel (ICV) with a payload assembly. The payload assembly consisted of a top layer of seven Pipe Overpack Containers containing 15.2 cm diameter pipe components and a bottom layer of seven Pipe Overpack Containers containing 30.5 cm diameter pipe components. This drop demonstrated a worst case, as damage to the Pipe Overpack Containers would be less severe within the entire TRUPACT-II package, which includes ten inches of impact-absorbing foam.

A dynamic crush test of the Pipe Overpack Container was performed where the container was placed on an unyielding target, and a 500 kg steel plate 1 m square was dropped from 9 m height onto the package. The test was performed with the container in an upright orientation as it is the orientation they will be in during storage, and the test was designed to simulate loading on the container if the roof of the storage building were to collapse onto the package.

A bare Pipe Component drop test was performed. This test consisted of dropping bare inner Pipe Components onto an essentially unyielding target from a height of 3 m. The tests were performed with the bolted closure of the pipe impacting the target first. The tests were performed to simulate a handling accident in which the pipe is dropped prior to being placed within the overpack. The test also demonstrated safety for a scenario where the interim storage of the pipes in racks without the protective overpack.

The final test was an engulfing pool fire test. In this test four Pipe Overpack Containers were placed on an open support stand with 1 m spacing between them in a square array. The bottom of the units were 1 m above the surface of a 10 m^2 pool of jet fuel floating on top of a layer of water. The fuel is ignited and allowed to burn for 30 minutes. This type of fire test generally results in a flame temperature between 1073 K and 1373 K. The test was performed to simulate a fire in a storage building. Two designs of drum filters were tested in the fire: A stainless steel housing - carbon media filter, and a polyethylene housing - carbon filter media filters.

All tests were performed at the Sandia National Laboratories (SNL) testing facilities in Albuquerque, New Mexico. The first set of tests were performed in March 1995, and testing was completed in December 1996. A helium leak test was one of the methods used to determine if the Pipe Component passed or failed the tests. The Pipe Components used in the tests were fitted with leak test ports to allow connection to the leak detector. To facilitate this test, the outlet ports of the filters were sealed with vacuum putty or a clamping fixture, which allowed the gasket between the filter and the Pipe Component to be tested. After the tests, the filters were removed, and an evaluation of the filter performance was conducted by the filter manufacturer.

There was no loss of containment in any drop or crush tests. All Pipe Components had a leakage rate of less than $1X10^{-7}$ cm^3/s. The filters showed no damage from the drop and crush tests. They were verified to have met flow and filtering requirements.

The engulfing pool fire test had mixed results. With one exception, all Pipe Components were found to be leak tight after the fire test. One Pipe Component was found to have a helium leak rate of approximately 24 cm^3/s after the fire test where leakage was detected between the lid and the weld neck flange and between the filter and the lid. The drum which contained this unit had the stainless steel-housed filter rather than the polyethylene filter. During the fire test, this drum became sufficiently pressurized to blow off the drum lid. At this point, the Pipe Component was exposed directly to the heat from the fire, and the elastomeric O-ring and filter gasket were both destroyed. The polyethylene-housed drum filters installed in the lids of the other three drums melted and were blown out of the drum lid. This provided a pressure relief pathway sufficient enough to prevent the lids from blowing off. Although the containment provided by the drum was compromised, the Pipe Components contained therein retained their integrity and did not leak.

CRITICALITY ANALYSIS OF THE PIPE OVERPACK CONTAINER

A series of criticality analyses modeled TRUPACT-II payload assemblies of Pipe Overpack Containers to evaluate the highest system "k-effective" value possible (Reference 4). The analyses constructed potential configurations of postulated accident geometries for a payload of Pipe Overpack Containers. The model evaluated a loading of 200 grams of Pu^{239} per Pipe Overpack Container in both dry and water-saturated forms. The following conservative assumptions were used in the analyses under normal transport conditions and hypothetical accidents:

- Elimination of the 0.21 m^3 drums, packing material, and any cans used inside the Pipe Components as migration barriers.
- Uniform distribution of water moderator in the waste.
- Closely packed geometry of fourteen Pipe Components without the presence of any other material.
- Flooding of the TRUPACT-II with the moderation medium.
- Reflection of escaping neutrons into the system.

These assumptions are comparable to those used in the criticality analyses performed for other authorized payload containers with one exception. One key assumption used to analyze the criticality potential and to establish control limits for other payload containers was that all fissile material within the payload containers would breach the packaging to come together under hypothetical accident conditions. The Pipe Component impact testing results demonstrate that the structural integrity of the Pipe Component prevents the release of its contents under hypothetical accident conditions. Thus, the criticality analyses assume no loss of containment by the Pipe Component despite the elimination of the drum, packing material, and any layers of confinement used inside the Pipe Component.

The results of the analysis show that no simulation of TRUPACT-II payload assemblies of Pipe Overpack Containers exceeded an average k-effective value of 0.9. This demonstrates that the system was subcritical in all cases. Therefore, a TRUPACT-II shipment of fourteen Pipe Overpack Containers with 200 FGE each is safe for transportation and meets criticality requirements for transport during normal and hypothetical accident conditions.

SHIELDING ANALYSIS OF THE PIPE OVERPACK CONTAINER

The Pipe Overpack Container has been assessed for its radiation shielding (Reference 5). Effective radiation shielding depends on a continuous barrier of dense material (i.e., steel) without openings that would allow radiation "streaming" or leakage. Both Pipe Component designs provide a nominal 0.63 cm of steel for shielding of 60 Kev gamma radiation from americium (Am^{241}). The Pipe Component has the following design features to prevent radiation streaming through the relatively low density filter media of the filter vents. Puncture protection is also provided to the filter media via the same design.

The design of the 15.2 and 30.5 cm diameter Pipe Components is such that the filter vent does not penetrate the entire thickness of the lid, and shielding is provided by the remaining steel at the bottom of the tapped hole for the filter vent. Continuous venting is provided by four small holes that penetrate the remaining steel lid thickness. The holes are offset from the filter media, avoiding a line of sight radiation streaming path.

The Pipe Overpack Container must meet the TRUPACT-II Safety Analysis Report for Packaging (SARP) requirements for dose rate limits. The measured radiation dose rates of each Pipe Overpack Container must comply with the 200 millirem/hour at the container surface and 10 millirem/hour at two meters requirement. It is estimated that the worst case loading using the Pipe Overpack Container will produce no more than 10 millirem/hour combined gamma and neutron at the surface of the container.

Use of the Pipe Overpack Container does not remove the requirement that all containers to be transported in the TRUPACT-II be individually measured to evaluate compliance with the dose rate limits.

FINITE ELEMENT ANALYSIS OF THE PIPE OVERPACK CONTAINER

Finite element modeling was used to support analysis of the Pipe Overpack Container to resolve storage accident scenarios where physical testing of the container could not be easily performed. Two scenarios were evaluated (Reference 6). One risk to the integrity of the Pipe Overpack Container during handling and storage is an accident where the Pipe Overpack Container drum is punctured by the tine of a forklift. The other accident scenario analyzed involves the collapse of the roof of a storage building.

The forklift accident scenario assumed a 4920 kg forklift traveling at 4.5 m/s pinning the Pipe Overpack Container against a rigid wall. The impacting position of the tine was chosen to maximize damage of the Pipe Component. Both the 15.2 and 30.5 cm diameter Pipe Components were capable of stopping the forklift without a total failure of the component. The pipes were bent significantly but remained relatively intact. The strain concentrations caused when the outside tip of the tine impacted the pipe were high enough to assume that localized tearing of the pipe wall would occur at this location. The design of the tine used in the analyses had a squared off end which greatly contributed to the strain concentration.

A slightly off-center impact was analyzed to determine whether it was a more severe impact than the symmetrical impact conditions. The ability of the Pipe Component to move away from the tine was effective at keeping the strains in the Pipe Component to below the failure strain limits.

The building collapse scenario evaluated the collapse of the roof structure of the storage building onto the Pipe Overpack Container. Three possible impact orientations were selected for the analysis: a flat section of roof impacting the top of the Pipe Overpack Container, a flat section of roof impacting the side of the container, and the edge of a roof section impacting the side of the container. In all of these analyses, the roof section was assumed to be rigid and traveling at constant velocity. The amount of energy absorbed by the package at its failure point was calculated, thus which allowed the risk assessment to determine the weight of a roof section necessary to cause the package to fail.

In a real accident, it is possible that more than one container will be impacted by the collapsing roof structure. Under these conditions, the total energy absorbed will be equal to energy absorbed by each package times the number of packages impacted by the falling roof structure. The amount of energy absorbed by a single package gives an indication of how massive a roof section can fall from a given height without causing package failure. From the analysis, a single 15.2 cm Pipe Overpack Container in an end impact orientation implies that this package would not fail if impacted by a 2950 kg roof section falling from 6.1 m. For a 10.2 cm thick reinforced concrete slab, this equates to a section more than 3.65 meter square. For the impact of an edge of a roof section onto the side of the 30.5 cm Pipe Overpack Container, the absorbed energy is equal to a 232 kg roof section falling from 6.1 m. For a 10.2 cm thick roof slab, this weight is equal to a 1.06 meter square section. The edge of a roof section falling on the side of a 30.5 cm Pipe Overpack Container in its most vulnerable location is the most damaging case.

PIPE OVERPACK CONTAINER APPROVALS

The Pipe Overpack Container testing and analyses demonstrate the ability of the container to provide three significant control functions: 1) criticality control, 2) shielding of high Am^{241} content materials, and 3) containment of fine particulate waste materials during normal conditions of transport and hypothetical accident conditions.

As a result of the testing and analyses described above, the Nuclear Regulatory Commission approved the use of the Pipe Component as part of the Pipe Overpack Container system. This approval was granted with the issuance of a new Certificate of Compliance for Radioactive Materials Packages (Reference 7). In a related approval, Kaiser-Hill, the integration contractor at RFETS, evaluated the Pipe Overpack Container and credited the container as a safe storage system for the storage of highly dispersible materials (Reference 8).

When the Pipe Overpack Container is to be used for shipping wastes to WIPP, appropriate content codes designating specific waste material and packaging must be in the TRUPACT-II Content Codes (TRUCON) document.

RFETS USE OF THE PIPE OVERPACK CONTAINER

RFETS may use the Pipe Overpack Container in the following cases:

- Shipment of wastes to WIPP. The use of the Pipe Overpack Container will maximize the plutonium per TRUPACT-II shipment. This will involve the shipment of non-gas generating inorganic materials, packaged in a metal can, and will allow a maximum of 200 FGE per drum. The material being shipped will have appropriate plutonium content and density to allow packaging of the full 200 FGE in the Pipe Overpack Container.
- Optimize shipment of high Am^{241} content wastes to WIPP. The high americium content in some of the waste forms substantially restricted the amount of material which could be placed in a waste drum and still meet the 200 millirem/hour surface radiation exposure requirement. Use of the Pipe Overpack Container radiation shielding capability allows the packaging of 200 FGE high-americium content materials while still meeting the exposure criteria. Use of the Pipe Overpack Container results in an estimated reduction of 40,000 TRU waste drums for the Rocky Flats Molten Salt Extraction Salt residues.
- On-site storage of waste forms at RFETS. The use of the Pipe Overpack Container as a structurally enhanced storage container reduces risk to the worker and the public while storing high americium content residues and dispersible materials. Use of the Pipe Overpack Container to store dispersible residues is one of the seismic risk mitigation methods to be used as part of RFETS response to the Defense Nuclear Facilities Safety Board Recommendation 94-3.

RFETS PIPE AND GO INITIATIVE

Future potential use for the Pipe Overpack Container is in evaluation. Reactive metals, including elemental plutonium, contained in selected residues are a continuing concern to the Defense Nuclear Facilities Safety Board. It is part of the subject of their Recommendation 94-1 and the recommendation calls for the stabilization of these forms. Recent calculations have shown that the Pipe Overpack Container is sufficiently robust to mitigate the impact of the heat that may be generated by the untoward oxidation of worst-case concentrations of reactive materials in the selected residue forms. This analysis resulted in a proposal for using packaging in the Pipe Overpack Container as a mitigation for selected potentially unstable residues instead of performing currently planned oxidation stabilization processes. This proposal supports the expedited closure of RFETS by allowing residue stabilization operations to be expedited in Building 707, quicker reduction of risk to the public and worker, and a substantial cost savings over the planned stabilization operations. The proposal covers the processing of the RFETS pyrochemical salt and ash residues.

RFETS has a team of personnel demonstrating the viability of the proposal for the selected residues and seeking approval of the option as a means to expedite the disposition of the selected residues. The following activities are being performed or monitored by the team:

- Obtaining Safeguards Termination Limit Variances for the selected residues.
- Demonstration and verification of compliance with WIPP Waste Acceptance Criteria.
- Demonstration and verification of compliance with Interim Safe Storage Criteria (Reference 9).

- Verification of the perceived hazard through the results of the Rocky Flats Residue Characterization program.
- Development of cost savings estimates.
- Development of schedules.
- Verification of compliance with National Environmental Policy Act requirements.
- Development of a radiation exposure savings estimate for the alternative.
- Verification of temperature transient calculations.
- Development of possible pressure transient calculations.
- Additional Pipe Overpack Container structural calculations.
- Pressure testing at SNL, Albuquerque, New Mexico.
- Assessment of corrosion potential for the unprocessed residue forms.

CONCLUSION

The development, testing, and approval of the Pipe Overpack Container have resulted in its approval for use. Utilization of the Pipe Overpack Container results in substantial optimization of packaging TRU wastes and their shipment to WIPP. It further reduces risk to the worker and the public. A follow-on initiative is underway to use the Pipe Overpack Container to mitigate the perceived risk of selected residue forms. If implemented, this initiative will support the expedited closure of Rocky Flats, reduce risk to the worker and the public, and result in a substantial cost savings to the DOE.

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