Novel Design Models of Container Configurations to Increase Efficiency of Disposal of Remote-Handled Transuranic Waste at the Waste Isolation Pilot Plant – 14426

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ABSTRACT

Remote-handled (RH) transuranic (TRU) waste at the Waste Isolation Pilot Plant (WIPP) is currently being emplaced for permanent disposal in canisters 890 liter (0.89 m^3) in size, yet, on average, only about 10% of the volume of already emplaced canisters is made up of waste. Reasons for this low packaging density include physical limitations of the waste transfer process out of hot cells into payload packages, worker exposure considerations, and shipping limits on parameters such as total fissile content, wattage, and dose rate. With the current policy of first emplacing RH waste in the walls of rooms that will later be filled with contact-handled (CH) waste on the floor, additional panels will be needed at WIPP to dispose of all of the waste remaining in the RH TRU waste inventory destined for WIPP. A more efficient method of packaging RH waste could be to use smaller containers, similar to the volume of waste that is currently loaded into the canisters. In this scenario, 57- or 113-liter (15- or 30-gallon) drums would be directly loaded with waste, shipped in reusable shielded Type B containers, then disposed of on the floor in rows in separate disposal rooms dedicated to RH waste rather than in the walls of rooms containing CH waste. This emplacement concept could minimize the number of additional disposal panels needed for disposal of the future inventory of RH TRU waste.

This paper discusses the future inventory of RH TRU waste that could be more efficiently shipped in a new Type B container. Any new Type B cask used to ship this waste would be shielded with a combination of steel and lead, similar to the RH-72B shipping cask currently used to ship RH waste to WIPP. For this study, the thickness of lead shielding necessary to reduce the surface dose rate to within WIPP's limits was determined, while the mass of the container was minimized in order to maximize shipping efficiency. The analysis was performed for both 57- and 113-liter drums with options of packing to either 10 Sv/hr (1000 rem/hr) on the surface of the drum (the maximum allowable at WIPP) or 1 Sv/hr (100 rem/hr), which is the legislatively maximum allowable for 95% of RH waste to be emplaced in WIPP. Transportation regulations limit the surface contact dose rate on the Type B shipping container to less than 2 mSv/hr (200 mrem/hr).

Based on past packaging configurations, a 57-liter container is recommended to maximize shipping efficiency. If the 57-liter drums were packaged to just 50% of their total capacity, this would yield 0.5 m^3 of waste per shipment, which can be compared to the approximately 0.1 m^3 that is currently shipped if an RH canister is packaged to a net 10% waste capacity. Using this new disposal method would minimize the number of shipments while providing a method to dispose of all of the remaining RH waste.

INTRODUCTION

Remote-handled (RH) waste, transuranic (TRU) waste with a surface dose rate higher than 2 mSv/hr (200 mrem/hr), has been disposed of at the Waste Isolation Pilot Plant (WIPP) since 2007. Over 700 890-liter (0.89 m^3) RH canisters have been lowered 655 m (2,150 feet) underground into a 1000-m (3,000-foot) thick salt formation to be emplaced into horizontal holes drilled into walls of rooms that were later filled with drums, standard waste boxes, or ten-drum overpacks with contact-handled (CH) waste (TRU waste with surface dose rates below 2 mSv/hr). Most of the canisters contain three 113-liter (30-gallon) drums, which are a more suitable size for the packaging restraints in the hot cells at waste generating sites. The internal drums are only, at most, approximately one-third full of waste, which results in a fill efficiency for the RH canister of under 10%. Even if the internal drums were full, the RH canister would only contain 339 L of waste, a 38% overall fill efficiency.

The current RH TRU waste inventory estimate across the DOE complex totals 2,619 m^3 of WIPP-bound RH waste from 59 waste streams remaining that requires disposal. When the average TRU activity concentration (Bq or nCi of TRU isotopes per gram) is calculated, six of these waste streams appear to be low-level waste, with TRU activity concentrations far below the 3700 Bq/g (100 nCi/g) necessary to be labeled as TRU waste. Seven additional waste streams have contact dose rates below 2 mSv/hr, even when modeled conservatively as a point source with just 0.15 cm (0.06 inches) of iron shielding (the thickness of a drum wall) using Microshield®. It is possible that this waste could be shipped as CH waste. Discounting the waste streams that appear to be either low-level waste or CH, there are 46 waste streams remaining in the RH inventory, with a total 2,113 m^3 of waste.

The content of RH canisters shipped in the RH-72B is subject to a number of limits, including FGE (315 FGE per canister), decay heat (50 watts per canister), Pu-239 equivalent curies (8880 GBq or 240 Ci per canister), and mass (454 kg per canister) [1]. The dose rate from RH waste canisters cannot be more than 10 Sv/hr (1000 rem/hr) on the surface, but only 5% of the RH waste disposed of at WIPP may exceed 1 Sv/hr (100 rem/hr). The hypothetical accident condition shielding evaluations also introduces a limit of 1347 GBq (36.4 Ci) on an RH canister [2]. An analysis of the minimum number of RH canisters based on all of these limits, assuming containers are at the historical average for RH canisters of 9% full (containing 0.083 m^3 or 22 gallons of waste each), indicates that there would need to be in excess of 25,000 canisters of RH waste shipped to WIPP to dispose of all of the remaining inventory. This would require more than 250 years of shipping at the historical average of 102 shipments per year. Thus, new packaging, shipping, and emplacement concepts for RH TRU waste should be developed.

A portion of this waste may be shipped and disposed of like CH waste in shielded containers. RH TRU waste with low enough activity can be packaged into 113-liter (30-gallon) drums, which are loaded into lead-shielded containers with the approximate outer dimensions of a 208-liter (55-gallon) drum. Shielded containers are bound by a similar set of limits as RH canisters: 200 FGE per container, 30 watts, 80 PE-Ci, 2 mSv/hr (200 mrem/hr), and 227 kg [1]. The shielded containers dispositioned thus far contain an average of 0.041 m^3 of waste per container; it was assumed the remaining waste in the inventory would be packaged to the same efficiency.

Thirty-four of the waste streams, totaling 1,681 m^3, are limited only by the volume that would be packed into a drum. This waste could be packaged at the generating sites without repackaging into multiple drums due to radiological or other limits. This equates to about 41,000 shielded containers, which would require about 4600 shipments over 26 years at the historical shipping rate for RH waste. If the remaining RH inventory were packaged in RH canisters, it would require about 5,600 shipments over 55 years. This indicates that even packaging the majority of the RH waste in shielded containers to ship and dispose of as CH waste results in unreasonable shipping campaign spans.

The current method of disposing of RH waste at WIPP must be augmented to disposition the full RH inventory at DOE sites. The 113-liter overpacked drums in RH canisters are packed only 18-36% full, resulting in about 41 L (11 gallons) of waste per drum. Therefore, both future payload containers and associated shipping casks that might be developed to augment WIPP's RH TRU waste shipping capability should be sized accordingly. A nearly full 57-liter (15-gallon) drum would accommodate the same amount of waste as a 10% full RH canister, but would be more efficient to ship and take up one-fifteenth of the space in the repository. Therefore, the possibility of using a small reusable Type B container that would fit just one small drum was examined. Options for both 57-L and 113-L drums were pursued. Two different shielding strengths of Type B containers were examined: one for the 10 Sv/hr (1000 rem/hr) limit on RH waste and another for the 1 Sv/hr (100 rem/hr) limit that 95% of the RH waste must be below. The internal 57-L drum would be disposed of in designated panels; this would discontinue the dependence of RH emplacement on CH shipping rates, a current concern when CH waste covers RH boreholes before they can be filled.

DESCRIPTION

The dimensions and shielding thicknesses of four Type B containers – 57- and 113-liter drums packed to 1 and 10 Sv/hr – were determined to maximize the shielding and minimize the weight of the container, thus allowing more containers to be placed on one shipment without exceeding the Department of Transportation highway weight limit. The dimensions of the internal drums were allowed to vary under the assumption that drums could be ordered with a custom size in large batches. Microshield® software was used to determine the activity of Cs-137, a strong emitter of gamma radiation, that could be loaded into a drum before exceeding the dose rate limit.

The containers' layers of shielding are based on the RH-72B shipping cask, which includes 4.76 cm (1.875 inches) of lead between steel layers of 2.54 cm (1 inch) and 3.81 cm (1.5 inches). Because the new Type B container would be significantly smaller and lighter than an RH-72B cask and thus would not need as much steel to withstand the drop test that is required of radioactive waste shipping containers [3], only 1.91 cm (0.75 inch) of steel for the inner layer was used in the models. The thickness of the lead layer was varied to find the smallest amount that resulted in sufficient shielding.

An air gap of 2.54 cm (1 inch) around an internal drum filled with air (a conservative approach) was included in the Microshield® model. In addition, the thickness was found for an iron shield below and above the internal cavity of the Type B container that would reduce the surface dose rate on the outside of the container to 2 mSv/hr (200 mrem/hr). Iterations of Microshield® models and mass calculations were repeated to find the thickness of the bottom and top shields, the amount of lead shielding in the side shields, and the dimensions of the Type B container that resulted in the highest activity of Cs-137 in the internal drum with the lowest mass of the Type B container.

Table 1 and Figures 1 through 4 show the dimensions found for the four different Type B designs. Based on past packaging configurations, the 57-liter container is recommended to maximize shipping efficiency. If all of the RH waste streams (not including those that appear to be low-level or CH waste) are packed in the lighter containers designed for internal drums under 1 Sv/hr, 225,212 drums would be required. Twenty-two of these Type B containers could be shipped at once without exceeding Department of Transportation weight limits, resulting in over 10,000 shipments over 58 years at the historical average of 176 shipments per year for CH waste. If the heavier Type B container, designed for internal drums packaged up to 10 Sv/hr, were used for all the waste, about 47,000 containers would be required. At 16 containers per shipment, about 3,000 shipments over 17 years would be necessary. Choosing the container that results in the minimum number of shipments would require slightly more containers than using all heavy Type B containers, at over 47,000 containers, but would require only 2,400 shipments over 14 years. This would consist of 33,000 of the lighter and 14,000 of the heavier Type B containers.

TABLE I. Dimensions of new Type B containers

container	maximum surface dose rate (based on Cs-137) (Sv/hr)	maximum Cs-137 (GBq)	radius of 15-gallon drum (cm)	height of 15-gallon drum (cm)	side shielding: inner steel (cm)	side shielding: lead (cm)	side shielding: outer steel (cm)	top and bottom shield thickness (cm)	weight of empty Type B cntr (kg)
57-L inner drum	1	566.1	20.02	46.15	1.91	3.10	3.81	12.22	1252
113-L inner drum	1	873.2	25.10	58.45	1.91	3.12	3.81	12.29	1792
57-L inner drum	10	5735	19.69	47.70	1.91	5.18	3.81	16.54	1798
113-L inner drum	10	8836	24.71	60.25	1.91	5.21	3.81	16.64	2535

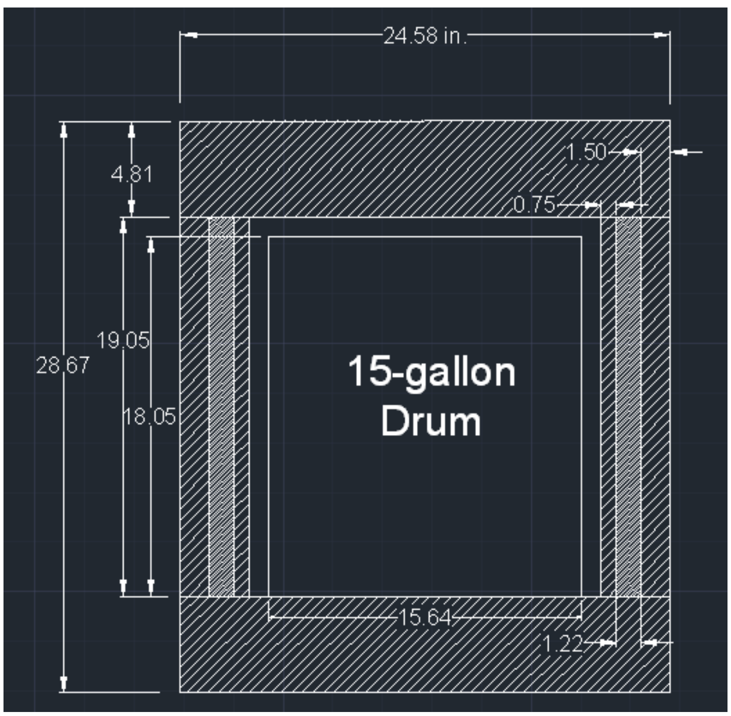

Figure 1. Diagram of Type B container with shielding for an internal 57-L (15-gallon) drum with surface dose rate of 1 Sv/hr (100 rem/hr).

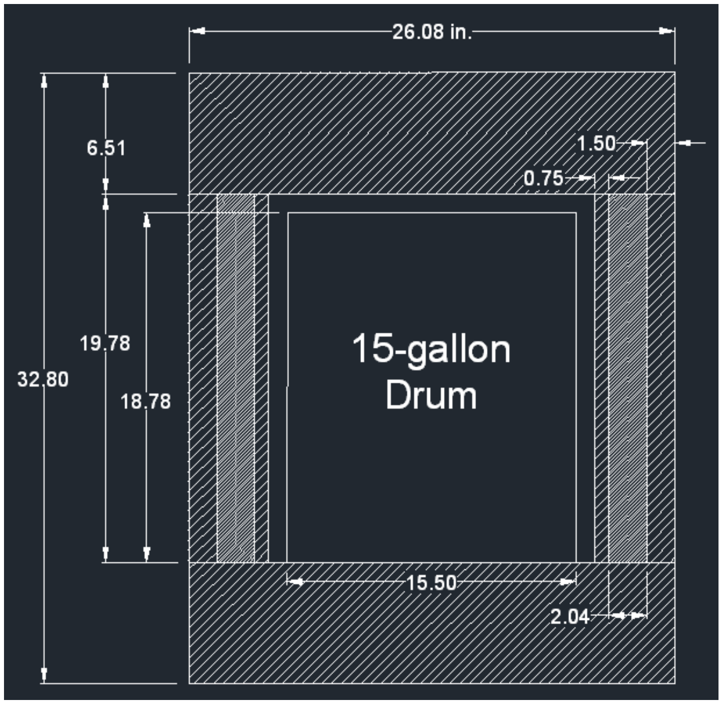

Figure 2. Diagram of Type B container with shielding for an internal 57-L (15-gallon) drum with surface dose rate of 10 Sv/hr (1000 rem/hr).

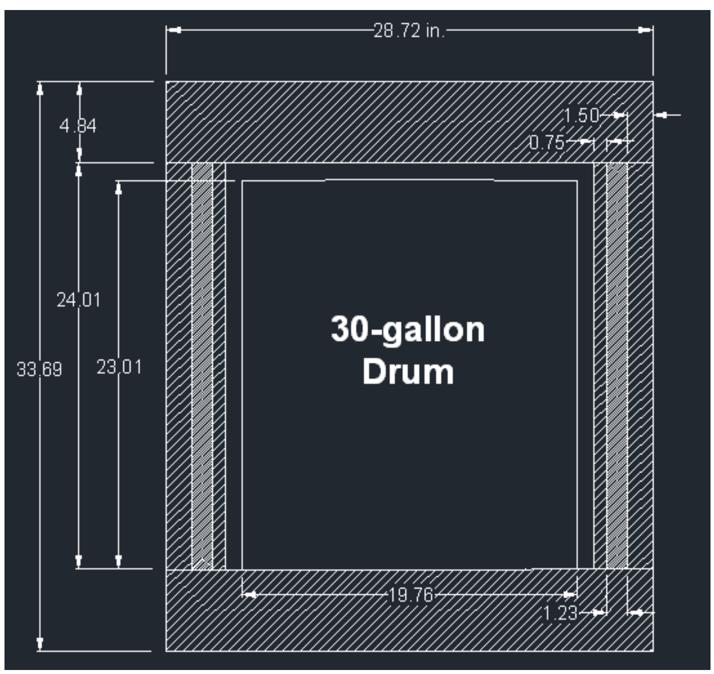

Figure 3. Diagram of Type B container with shielding for an internal 113-L (30-gallon) drum with surface dose rate of 1 Sv/hr (100 rem/hr).

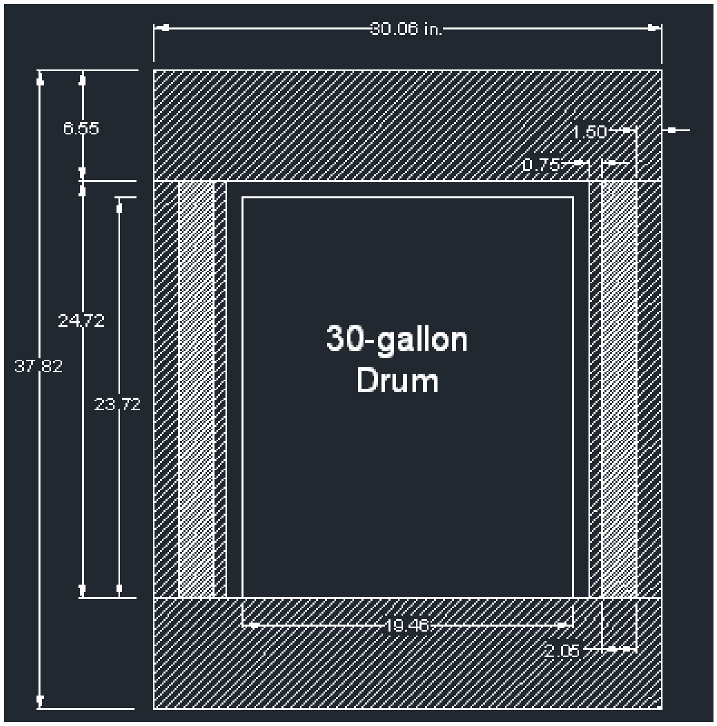

Figure 4. Diagram of Type B container with shielding for an internal 113-L (30-gallon) with surface dose rate of 10 Sv/hr (1000 rem/hr).

COST COMPARISON

In addition to requiring unreasonably long shipping times, necessitating additional panels, and exceeding regulatory volume limits, shipping the remaining RH inventory with the current system of RH canisters would be far more expensive than reusing small shielded Type B containers. Taking into account drums, shielding containers, transportation containers, trailers, maintenance, shipments, and replacements of transportation containers, shipping the waste using a combination of RH canisters and shielding containers would cost six times more than using these new Type B containers. Even reusing the shielded containers, similar to a Type B container, instead of permanently disposing of them would cost twice as much as using the new Type B containers.

ENGINEERING CONSIDERATIONS

The design of these Type B containers was based only on shielding considerations and total mass, not taking into account the practical considerations in the engineering of a new waste container. Type B containers must be able to withstand drop, puncture, and fire tests [3]. The thick steel walls of the small Type B container should be adequate for the drop and puncture test, but preparing for a fully engulfing fire might require design features not considered here.

Type-B shipping casks licensed by the Nuclear Regulatory Commission (NRC) must be sealed in transit, and the radiolytic hydrogen generation rates limit the radioactivity limits that can be sealed inside for a given shipping duration. Therefore, the more volume there is inside the shipping cask, the higher the payload limits in general. The small Type-B casks described herein were not optimized with respect to payload limits imposed by flammability considerations. A larger Type B cask containing multiple small drums would include more void space, allowing for higher gas generation limits appropriate for the NRC deflagration regulations.

CONCLUSIONS

The current method of packaging and shipping RH TRU waste to WIPP has been shown to need augmentation to allow for cleanup of the remaining RH TRU waste inventory in a reasonable timeframe. These new Type B containers, designed for the volume of RH waste currently packaged into one drum, will result in more efficient shipments and direct emplacement on the floors of disposal rooms, which will thereby enhance RH waste disposal operations. This paper described one possible design for a new system of packaging, shipping, and disposing of RH waste at WIPP.

REFERENCES

1. Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant, rev. 7.3, February 2013. U.S. Department of Energy Carlsbad Field Office.

2. RH-TRU 72-B Safety Analysis Report, rev. 5, February 2011.

3. Land Withdrawal Act (Pub. L. 102-579, 106 stat. 4777, as amended by Pub. L. 104-201, 110 stat. 2422).