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Advantages of the Shielded Containers at the Waste Isolation Pilot Plant

Sean C. Dunagan
Sandia National Laboratories
Performance Assessment and Decision Analysis Dept.
4100 National Parks Highway, Carlsbad, NM 88220

Roger A. Nelson
U. S. Department of Energy
P.O. Box 3090, Carlsbad, NM 88221

ABSTRACT

The Waste Isolation Pilot Plant (WIPP) disposal operations currently employ two different disposal methods: one for Contact Handled (CH) waste and another for Remote Handled (RH) waste. CH waste is emplaced in a variety of payload container configurations on the floor of each disposal room. In contrast, RH waste is packaged into a single type of canister and emplaced in pre-drilled holes in the walls of disposal rooms. Emplacement of the RH waste in the walls must proceed in advance of CH waste emplacement and therefore poses logistical constraints, in addition to the loss of valuable disposal capacity.

To improve operational efficiency and disposal capacity, the Department of Energy (DOE) has proposed a shielded container for certain RH waste streams. RH waste with relatively low gamma-emitting activity would be packaged in lead-lined containers, shipped to WIPP in existing certified transportation packages for CH waste and emplaced in WIPP among the stacks of CH waste containers on the floor of a disposal room. RH waste with high gamma-emitting activity would continue to be emplaced in the boreholes along the walls. The new RH container is similar to the nominal 208-liter (55-gallon) drum, however it includes about 2.5 cm (1 in) of lead, sandwiched between thick steel sheets. Furthermore, the top and bottom are made of thick plate steel to strengthening the package to meet transportation requirements. This robust configuration provides an overpack for materials that otherwise would be RH waste.

This paper describes the container and the regulatory approach used to meet the requirements imposed by regulations that apply to WIPP. This includes a Performance Assessment used to evaluate WIPP's long-term performance and the DOE's approach to gain approval for the transportation of shielded containers. This paper also describes estimates of the DOE's RH transuranic waste inventory that may be packaged and emplaced in shielded containers. Finally, the paper includes a discussion of how the DOE proposes to track the waste packaged into shielded containers against the RH waste inventory and how this will comply with the regulated volume.

INTRODUCTION

The Waste Isolation Pilot Plant (WIPP) has safely operated as America's first deep geologic repository licensed to dispose of long-lived radioactive waste for more than 10 years. Both legislation (Public Law 102-579, WIPP Land Withdrawal Act) [1] and legally binding agreements between the Department of Energy (DOE) and the State of New Mexico (Stipulated Amendment to the Agreement for Cooperation and Consultation) limit the waste that may be emplaced in WIPP to defense-related transuranic (TRU) materials. These same provisions bound transuranic waste as material containing more than 3700 Becquerel per gram (Bq/g) of radioactive elements greater than the atomic number of Uranium (92) and with half lives greater than 20 years. To put this into perspective, TRU waste typically contains the most common transuranic element, Plutonium-239, which if present, at a mass concentration of about 1 part per million (ppm), would exceed the 3700 Bq/g lower bound and qualify as transuranic.

Containment of the TRU waste at WIPP is regulated by the U.S. Environmental Protection Agency (EPA) according to the requirements set forth in Title 40 of the Code of Federal Regulations (CFR), Part 191. The DOE demonstrates compliance with the containment requirements according to the Certification Criteria in Title 40 CFR, Part 194 [2] by means of performance assessment (PA) calculations.

The majority of the waste emplaced in WIPP has been “Contact Handled” (CH) transuranic waste, which is defined as waste exhibiting an external dose rate at the surface of the disposal package less than 2 milli-sieverts per hour (2 mSv/h). Remote Handled (RH) waste is defined as waste that exhibits a dose rate at the surface of the packaged material in excess of 2 mSv/h. The WIPP Land Withdrawal Act [1] legislated these definitions and numerical criterion (200 mSv/h). Over the years, RH waste has been an area of concern by the WIPP stakeholders as it is presumed to have a more significant impact on the workers and the repository’s long-term performance. In reality, radiation protection practices do not suddenly change when working with materials above 2 mSv/h vs. those below 2 mSv/h and RH waste has never been shown to have a significant impact on long-term repository performance.

Both the isotopic makeup of a waste and the way it is containerized result in the final dose rate at the surface of the package surface and determine whether the waste is categorized as RH or CH waste. Typically, waste containing significant amounts of gamma-emitting isotopes with photon energies of a few hundred keV result in dose rates over the 2 mSv/h line. These higher energy gamma rays typically are associated with fission products. However, even the relatively low energy dominant gamma ray produced in the decay of Americium-241 (60 keV) in a waste containing enough activity concentration can result in a waste package with a surface dose rate of more than 2 mSv/h, and therefore be categorized as RH waste.

WIPP operations currently use different disposal methods for CH and RH waste. CH waste is emplaced in a number of different container configurations. Examples of the different waste container configurations include 7-packs of 208-liter drums, 10-drum overpacks (TDOPs), and standard waste boxes (SWBs). The CH waste container configurations are generally placed in stacks of three on the disposal room floors, with TDOPs being the exception. TDOPs are approximately the height of two stacks of drums, and they are always placed directly on the room floor with a single additional waste container configuration on top. The CH waste is emplaced in the rooms as it arrives. Figure 1 shows an example of CH waste emplaced in WIPP with various container configurations.

Figure 1. A previously emplaced RH waste canister has been inserted in the borehole in the wall at left, with a concrete plug in front to shield personnel working in the disposal room.

Currently, RH waste is disposed in RH-TRU waste canisters, which are a 306 cm (120 in) long and 66 cm (26 in) diameter cylinders. The canister walls are 0.64 cm (0.25 in) thick and are made entirely of steel. The canister is either directly loaded with RH waste, or it over-packs other RH waste containers (e.g., 208-liter (55-gallon) drums or 113-liter (30-gallon) drums). The canisters are placed in horizontal holes that are drilled perpendicular to the faces of the walls of the repository rooms, with a concrete plug emplaced in front of the canister to provide shielding for personnel working in the open disposal room. Once the walls of a disposal room have been filled with RH canisters, CH waste is placed on the floor in front of the walls, completely filling the available volume.

Emplacement of RH waste must occur well before the advancing stack of CH waste reaches individual RH boreholes. In addition, the current RH disposal process requires the use of specialized equipment to drill holes perpendicular to the faces of the repository walls. Only activities solely dedicated to RH borehole drilling may be conducted while emplacing RH canisters into the boreholes. The disruption of the CH emplacement puts a significant strain on overall repository operations.

Currently, regardless of the activity and penetrating gamma exposure rates, the RH waste emplacement scheme can be used to handle waste streams with surface exposure rates from 2 mSv/hr up to more than 1 Sv/h. However, the use of such substantial shielding is not necessary to protectively handle those RH waste streams with dose rates that are only slightly above the limit of 2 mSv/h. For waste that would result in dose rates of about 2 to 100 mSv/h, the DOE is proposing to use shielded containers to over-pack 113-liter (30-gallon) drums and place them in the same manner as CH waste in the disposal rooms. This would avoid the use of the robust shielding and emplacement scheme for the waste which is far below the activity and penetrating gamma exposure rates that the baseline RH emplacement equipment was designed to handle.

SHIELDED CONTAINER DESIGN

The DOE is proposing to develop, license and permit the use of shielded containers as a new packaging scheme for RH that is destined for disposal at WIPP. The DOE is proposing to ship RH waste in shielded containers with 3-pack assemblies (shielded container assemblies, SCAs) inside the HalfPACT shipping package [3,4], which is licensed for payload packages with contact surface dose rates less than 2 mSv/h. Upon arrival at the WIPP facility, the shielded containers will be processed in the same fashion as CH waste. After receipt at the WIPP facility, SCAs will be removed from the HalfPACT transportation container using existing lifting fixtures and equipment in the CH waste handling bay at the WIPP. The SCAs will remain intact, and will enter the sequence of operations and be processed, downloaded to the underground repository, and emplaced along with CH containers. However, the waste they contain will be counted as RH waste to comply with the volume limits placed on the WIPP repository.

The SCAs will be emplaced as received (i.e., randomly) in the underground disposal rooms along with other CH wastes. SCAs will be emplaced using existing waste handling equipment and fixtures.

The handling and emplacement of SCAs will have minimal impact on the configuration of waste handling equipment and ventilation systems. For example the slip sheets between tiers of containers will be modified to accommodate the SCAs. The WIPP Waste Information System (WWIS) [5] will be used to track the waste components, packaging, transportation and emplacement information in the same method as other waste that is transported and emplaced at the WIPP. Certain data fields in the WWIS will be modified to accommodate the new payload container and associated waste component limits.

Because there will be many RH waste streams that will not be suitable for packaging in the SCA, the DOE recognized the need to retain the baseline RH disposal scheme using canisters and disposal behind concrete plugs in the walls of the repository. The DOE estimates the candidate waste volumes that may be able to be shipped in the SCA could make up almost a third of the total RH inventory. If regulatory approval of the DOE's proposal were completed, the vast majority of RH waste that has been emplaced in WIPP could have been emplaced using the new SCA.

The DOE is proposing to employ a SCA as shown in Figure 2. Although there are at least two shielded container configurations currently available in the marketplace, the DOE chose instead to develop a more robust container tailored to use with the existing Nuclear Regulatory Commission (NRC) certified HalfPACT transportation container [3]. The container design was primarily influenced by the need to successfully pass through the NRC certification process for shipping what otherwise would be RH waste in an existing certified transportation package licensed to ship CH waste.

The shielded container has approximately the same exterior dimensions as a standard 208-liter (55-gallon) drum and is designed to hold a 113-liter (30-gallon) drum with a lever-locking lid. The cylindrical sidewall of the shielded container has 2.5 cm (1 in) thick lead shielding sandwiched between a double-walled steel shell. The top and bottom are constructed of 7.5 cm (3 in) thick steel. The empty weight of the container is approximately 770 kg (1700 lbs). The shielded container and the inner 113-liter (30-gallon) drum will both be vented.

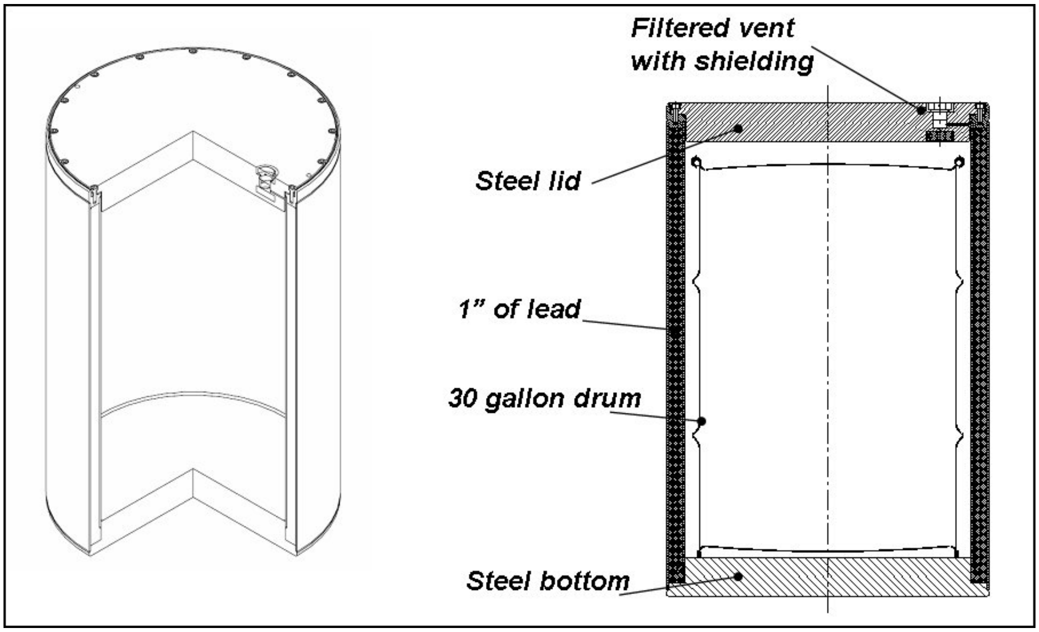

Figure 2. The Shielded Container design is optimized to accommodate a significant fraction of the RH TRU waste inventory. Note the schematic representation of a 113-liter (30-gallon) drum inside the shielded container

To maximize shipping efficiency, without exceeding the US weight limit that would require overweight permits, the DOE chose to design the shielded containers so that three could be shipped in a Type B HalfPACT shipping package. The payload limit of the HalfPACT then constrained the design of the SCA and introduced several other limits. The shielding provided by 2.5 cm (1 in) lead in the outer cylindrical walls (plus the steel shell) must be matched by the shielding provided by solid steel in the top and bottom closures. This resulted in ~7.5 cm (3 in) steel top and bottom thickness, which is structurally adequate to distribute the loads resulting from other criteria. Fifteen bolts fasten the top to the cylinder, while the bottom is welded. Special molten lead filling fixtures are built into the bottom plate, and lead is poured into the bottom, with the container inverted. The completed container exposes no uncovered lead surfaces.

The other dominant criterion that affected the shielded container design was the requirement that the shipping package meet Department of Transportation (DOT) 7A requirements. These requirements are imposed on all payload containers of waste destined for emplacement in WIPP. DOT-7A certification requires that:

1. containers maintain containment when dropped from 1.2 m (4 ft) (typical handling height above non-yielding surface)
2. containers maintain their shielding efficacy when dropped from 122 cm (48 in)
3. containers can support 4 layers of similar containers when stacked on top of each other

With these considerations in mind, the SCA design was optimized to ship as much waste weight as possible within the HalfPACT limits and to keep manufacturing costs as low as possible.

SHIPPING CONSIDERATIONS

To ensure that the shielded container would maintain its shielding efficacy even as a result of a hypothetical accident condition (HAC), special consideration was given to designing a shock-absorbing fixture that would surround the SCAs during shipping. The HAC conditions that the NRC uses to evaluate the ability of a type B shipping package to contain radioactive materials and protect against releases and exposure to emergency response personnel responding to the event are contained in Chapter 10 of the Code of Federal Regulations, Part 71 (10 CFR Part 71). In order to meet the DOT-7A 1.2 m (4 ft) drop test requirements, the shielded container design must be robust. However, the shock absorber (hereafter called dunnage) that surrounds the SCA during shipping must also ensure that the shielding efficacy remains intact within the shipping package even after a 9.1 m (30 ft) drop test requirement of the HAC.

The design of the dunnage that will surround the 3-pack SCA during shipping is shown in Figure 3. It consists of an aluminum-shelled reusable dunnage fixture that is filled with foam, similar to the foam employed elsewhere in the construction of the HalfPACT [4] (and TRUPACT-II). RH waste shipped in SCAs would be loaded at generator sites, with the 3-pack strapped together as a single payload assembly, similar to other payload assemblies shipped to WIPP as CH waste (e.g., 3-packs of 379-liter (100-gallon) drums or 7-packs of 208-liter (55-gallon) drums). The DOE does not propose to disassemble the 3-pack SCAs once they are received at WIPP and unloaded from the HalfPACT. The dunnage and payload assemblies are designed to be completely compatible with the existing CH payload unloading equipment and procedures currently employed at the WIPP.

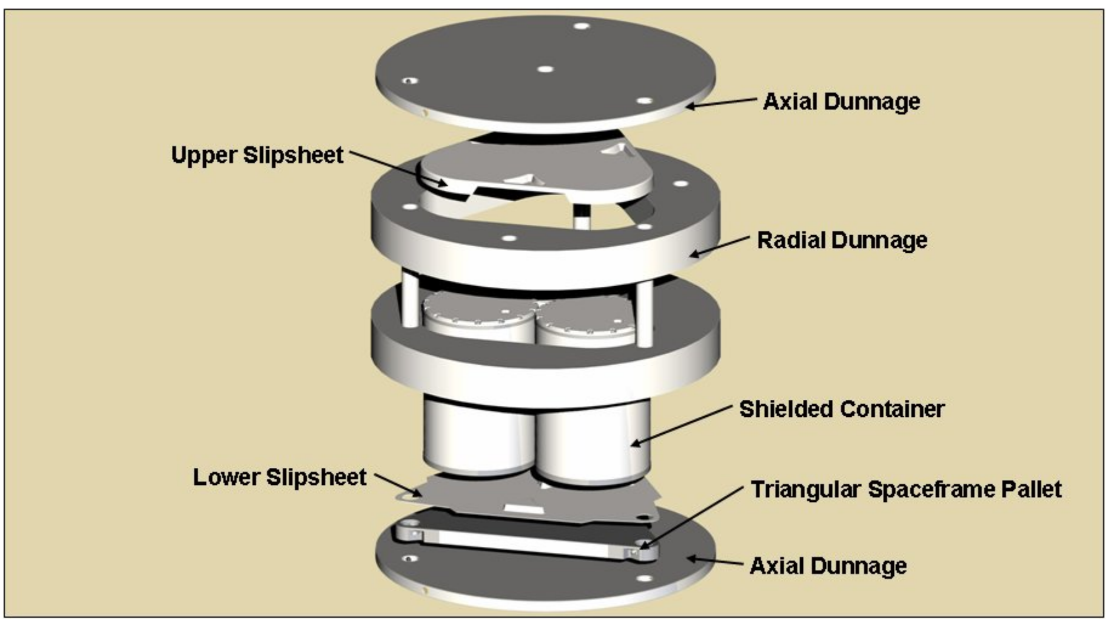

Figure 3. Shipping configuration (exploded view) showing dunnage used to cushion SCA packages inside the Type B HalfPACT to meet the HAC conditions.

SHIELDED CONTAINER PERFORMANCE TESTING

Tests of the SCA and associated shipping dunnage in the HalfPACT shipping configuration were successfully conducted in 2007. These tests demonstrated that the SCA would meet both DOT-7A requirements for container integrity, as well as NRC 10 CFR 71 requirements for containment under transportation accident conditions. A photo of the testing of a maximally loaded SCA when dropped with its center of gravity directly over a corner onto an unyielding surface is shown in the left pane of Figure 4.

Figure 4. Drop testing the Shielded Container on unyielding surface.

During some of these drops, the SCA experienced 600-800 g forces (600-800 times the acceleration of gravity at the Earth's surface). Throughout the tests, the shielded drums demonstrated complete particulate containment and no reduction in shielding efficacy through all surfaces and angles. Gamma scans were performed before and after each drop. Only minor deformations were observed after numerous cumulative drop tests. The SCA is vented to allow gas exchange between the inside and outside (as will be the inner over-packed 113-liter (30-gallon) drums), and prevent any possible buildup of radiolytically generated hydrogen. So to test the containment performance, the test units were filled with a fluorescing particulate material, and black-light examination for loss of containment was performed after every test.

The right pane of Figure 4 shows one of the 9.1 m (30 ft) drop tests. Three fully loaded SCAs were placed inside the shock absorbing dunnage (shown in Figure 3), and the entire payload was then placed into the inner containment vessel of a HalfPACT shipping container for the drop test. The HalfPACT is a NRC licensed type B package that consists of an inner containment vessel, surrounded by shock absorbing and thermally insulating foam, which is itself surrounded by a second, outer containment vessel. The SCA HAC drop test did not employ the outer containment vessel or the foam that would be present in a real accident, which made the test extremely conservative. The 9.1 m (30 ft) drop test documented the ability of the shock absorbing dunnage to maintain the SCA shielding efficacy under NRC-required hypothetical accident conditions. After all cumulative drops, the shielded container test units suffered only minor, almost "cosmetic" damage. In May of 2009 the NRC approved the shielded container for use and transportation in HalfPACTs [4].

DISPOSAL AND LONG-TERM REPOSITORY PERFORMANCE

One of the many regulatory requirements that the DOE must meet for approval to employ shielded containers to dispose of RH waste in WIPP is the demonstration that the SCA container itself would not deleteriously affect long-term repository performance. The vehicle for such a demonstration is a planned changed request as described in Chapter 40 of the Code of Federal Regulations, Part 194 [1] (40 CFR 194). An assessment [6] was conducted to evaluate the impact of emplacing RH TRU waste in shielded containers on the long-term performance of the repository. Given the uncertainty in the exact amount of RH TRU waste that can be emplaced in shielded containers, the analysis employed a bounding approach that considered several extreme cases, including a case with all RH TRU waste in RH containers in the walls (the current baseline) and a case with all RH TRU waste in SCAs on the floor. The results demonstrated that the packaging and emplacement of RH waste in shielded containers would have no discernable impact on future long-term releases from the WIPP repository. This applies to all release pathways: cuttings and cavings, spallings, direct brine releases, groundwater releases, and total releases.

The comparison showed that the projected releases from WIPP using the assumed human intrusion scenarios required under 40 CFR 194 were essentially the same and within the regulatory release limits, no matter which disposal configuration was assumed, Figure 5. This is not surprising since the repository performance is dominated by the multiple penetrations of the waste footprint by future societies repeatedly drilling for natural resources underlying the WIPP. Since the modeling assumes that this drilling brings all waste in its path up to the surface regardless of waste packaging, the radioactivity released from this repeated inadvertent human intrusion is not different, regardless of whether the RH inventory is packaged in shielded containers on the floor of disposal rooms or in canisters inserted horizontally into the walls of disposal rooms.

SHIPPING BENEFITS OF SHIELDED CONTAINERS

RH waste is currently shipped to WIPP in RH-72B shipping casks [7] which can transport the equivalent of one facility disposal canister, and typically over-packs three 113-liter (30-gallon) drums. Using the proposed shielded container scheme it may be possible to ship a total of nine shielded containers, each over-packing a 113-liter (30-gallon) drum. This represents a potential 3 to 1 efficiency gain over RH-72B based transport. Such efficiencies, in turn represent a potential significant reduction in the overall number of shipments to the facility, thus reducing risks from transportation.

Due to the inefficiency of the baseline disposal scheme, a single RH waste canister evolution from receipt of the RH-72B until emplacement in the ribs of the underground disposal room requires more than 10 hours. WIPP is limited to a maximum of 6 baseline RH shipments per week just from the operational constraints. In contrast, the CH waste handling processes routinely allow 4-5 shipments (i.e., 3 HalfPACTs per shipment) per day to be received, unloaded and emplaced per day.

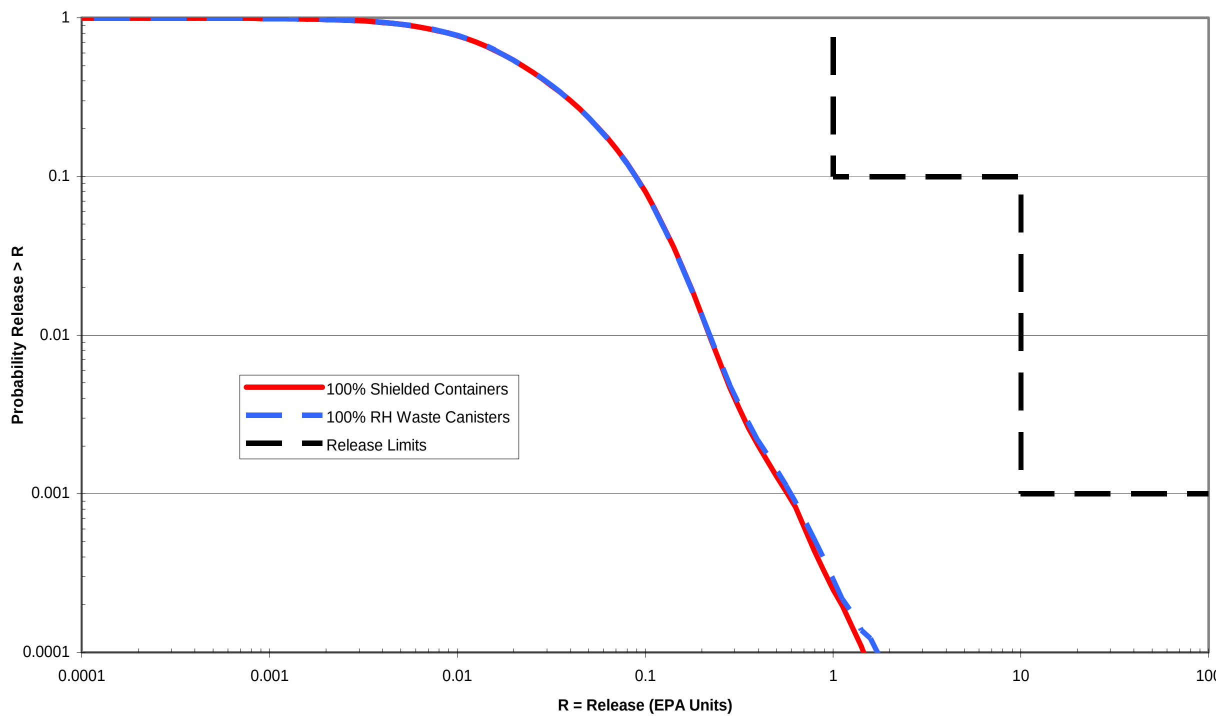

Figure 5. Complementary Cumulative Distribution Functions of Mean Total Releases of two bounding cases.

REGULATORY ROADMAP

Several regulatory approvals are still required now that the DOE has successfully demonstrated the efficacy of disposing of RH waste in the shielded container configuration, primarily with the EPA and New Mexico Environment Department (NMED). A Planned Change Request was submitted to the EPA for shielded containers [8] in 2007 and is awaiting approval. Additional approval will be needed from the NMED for changes to the Resource Conservation and Recovery Act permit for the WIPP facility to allow receipt and emplacement of shielded containers. After approval by the EPA that the shielded container will not affect long term repository performance, The DOE will submit a permit modification request to the NMED to receive and emplace RH waste packaged into shielded containers. The DOE does not propose to count the waste emplaced in the shielded configuration as CH waste. The DOE will honor the RH volume limits that are imposed by PL 102-459 [1] and the Stipulated Amendments to the Cooperation and Consultation Agreement with the State by counting any waste received in shielded containers against the existing RH volume limits imposed on the WIPP.

The current Hazardous Waste Facility Permit issued by the State of New Mexico limits the total volume of RH waste that may be emplaced in each disposal panel (a disposal panel consists of 7 contiguous disposal rooms). The DOE proposes to limit the number of shielded containers in each panel to meet these existing volume limits. As an example, for future panel seven, the volume limit is equivalent to about 820 shielded containers per disposal room (~5750 shielded containers distributed throughout that panel, assuming that there was no other RH waste emplaced in the canister-in-wall configuration).

CONCLUSION

Use of shielded containers for shipping and emplacement of waste will meet all requirements of the WIPP waste acceptance criteria. Transportation will be via the existing licensed HalfPACT, with no modifications to the shipping package required. Up to a 3:1 reduction in number of shipments is projected when RH waste is transported in the proposed shielded containers. WIPP facility operations will not be affected since the shielded containers will be handled and managed as CH waste. Significant infrastructure modifications at the WIPP will not be needed to accommodate shielded containers. No changes to the waste handling processes for CH waste will be required. The long-term repository performance will be unaffected. There are no anticipated changes needed in the storage capacities already approved in the hazardous waste facility permit for the WIPP.

Use of shielded containers will result in a more efficient way of emplacing RH waste in the WIPP for permanent isolation, and will aid in faster generator site cleanup.

NOTES

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