

Shielded Payload Containers Will Enhance the Safety and Efficiency of the DOE's Remote Handled Transuranic Waste Disposal Operations - 8199

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ABSTRACT

The Waste Isolation Pilot Plant (WIPP) disposal operation currently employs 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. This poses a significant logistical constraint on waste handling operations by requiring significant coordination between waste characterization and preparations for shipping among the various generators.

To improve operational efficiency, the Department of Energy (DOE) is proposing a new waste emplacement process for certain RH waste streams that can be safely managed in shielded containers. 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 appears essentially the same as a nominal 208-liter drum, but is built with about 2.5 cm of lead, sandwiched between thick steel sheet. The top and bottom are made of very thick plate steel, for strengthening the package to meet transportation requirements, and provide similar gamma attenuation. This robust configuration provides an overpack for waste that otherwise would be remotely handled. Up to a 3:1 reduction in number of shipments is projected if RH waste were transported in the proposed shielded containers.

This paper describes the container design and testing, as well as the regulatory approach used to meet the requirements that apply to WIPP and its associated transportation system. This paper describes the RH transuranic waste inventory that may be candidates for packaging and emplacement in shielded containers. DOE does not propose to use shielded containers to increase the amount of RH waste allowed at WIPP. DOE's approach to gain approval for the transportation of shielded containers and to secure regulatory approval for use of shielded containers from WIPP regulators is discussed. Finally, the paper describes how DOE proposes to count the waste packaged into shielded containers against the RH waste inventory and how this will comply with the volume and radioactivity limitations imposed in the many and sometimes overlapping regulations that apply to WIPP.

INTRODUCTION

The Waste Isolation Pilot Plant has safely operated as America's first deep geologic repository licensed to dispose of long-lived radioactive waste for almost nine 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 materials. These same provisions bound transuranic (TRU) 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, would exceed the 3700 Bq/g lower bound and qualify as transuranic.

The vast majority of the waste emplaced in WIPP since opening 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). Within the last year, WIPP received regulatory authorization from the EPA and the State of New Mexico to begin emplacing Remote Handled (RH) waste. Remote Handled 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, this very subjective bright line between RH and CH waste has taken on an aura of significance and controversy that greatly transcends the risk-based importance of the distinction. In reality, the difference is quite gray, when based on radiation protection practice for workers managing radioactive materials. Radiation protection practices do not suddenly change when working with materials above 2 mSv/h versus those below 2 mSv/h.

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 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 that slip 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 thereby 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, 3-packs of 380-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.

Currently, RH waste is disposed in RH-TRU waste canisters, which are 306 cm long and 66 cm diameter cylinders. The canister walls are 0.64 cm 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 drums or 113-liter 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.

As is evident from Figure 1, 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 need to coordinate timing of RH emplacement with CH emplacement puts a significant strain on overall repository operations.



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 CH disposal room.

The existing baseline RH waste emplacement scheme at WIPP is a one-size-fits-all approach. Regardless of the activity and penetrating gamma exposure rates, the current 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 arbitrary statutory limit of 2 mSv/h. For waste that would otherwise result in dose rates of about 2 - ~100 mSv/h, DOE is proposing to use shielded containers to over-pack 113-liter (nominal 30-gallon) drums and place them alongside the other CH waste in the disposal rooms. This would avoid the use of the very robust shielding and emplacement scheme for that fraction of waste in the RH inventory that is far below the activity and penetrating gamma exposure rates for which the baseline RH emplacement equipment was designed.

SHIELDED CONTAINER PROPOSAL

DOE is proposing to develop, license and permit the use of shielded containers as a new packaging scheme for remote handled transuranic waste destined for permanent disposal at WIPP. DOE proposes to ship RH waste inside shielded containers using 3-pack assemblies in the existing HalfPACT shipping package [2], 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 TRU waste. After receipt at the WIPP facility, 3-pack assemblies will be removed from the HalfPACT transportation container using existing lifting fixtures and equipment in the CH waste handling bay at WIPP. The 3-pack assemblies will remain intact, and will enter the sequence of operations and be processed, downloaded to the underground repository, and emplaced along with other 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 3-pack assemblies of shielded containers will be emplaced as received (i.e., randomly) in the underground disposal rooms along with other CH wastes. They will typically be emplaced as the top row of three since their footprint is smaller than the more common 7-pack configuration of CH drums.

The handling and emplacement of shielded containers will have minimal impact on the configuration of waste handling equipment and ventilation systems. Shielded containers are simply another proposed waste package configuration for RH waste. For example, the slip sheets between tiers of containers will be modified to accommodate the 3-pack assemblies. The WWIS (WIPP Waste Information System) [3] 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, DOE recognized the need to retain the baseline RH disposal scheme using canisters and disposal behind concrete plugs in the walls of the repository. DOE estimates the candidate waste volumes that may be able to be shipped in the shielded container described herein may make up almost a third of the total RH inventory. Indeed, all of the RH waste that has been emplaced in WIPP using the canister-in-wall method during the first year of RH waste disposal operations, could have been successfully emplaced using the new shielded container method if testing and regulatory approval of DOE's proposal had been completed.

DOE is proposing to employ a simple shielded container assembly (SCA) as shown in Figure 2. DOE decided to employ a single design at this time to minimize complexity. Although there are at least two shielded container configurations currently available in the marketplace, DOE chose instead to develop a more robust container tailored to use with the existing HalfPACT transportation container [2] certified by the Nuclear Regulatory Commission (NRC). 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 (i.e., the HalfPACT).

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

To maximize shipping efficiency without exceeding the US weight limit that would require overweight permits, DOE chose to design the SCA so that three could be shipped in a Type B HalfPACT shipping package. Details of the shipping configuration are provided in the next section. 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 lead in the outer cylindrical walls (plus the steel shell) was matched by the shielding from solid steel in the top and bottom closures. This resulted in ~7.5 cm steel top and bottom thickness, which is structurally more than 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 through the bottom into the side-wall annulus, with the container inverted. The completed container exposes no uncovered lead surfaces.

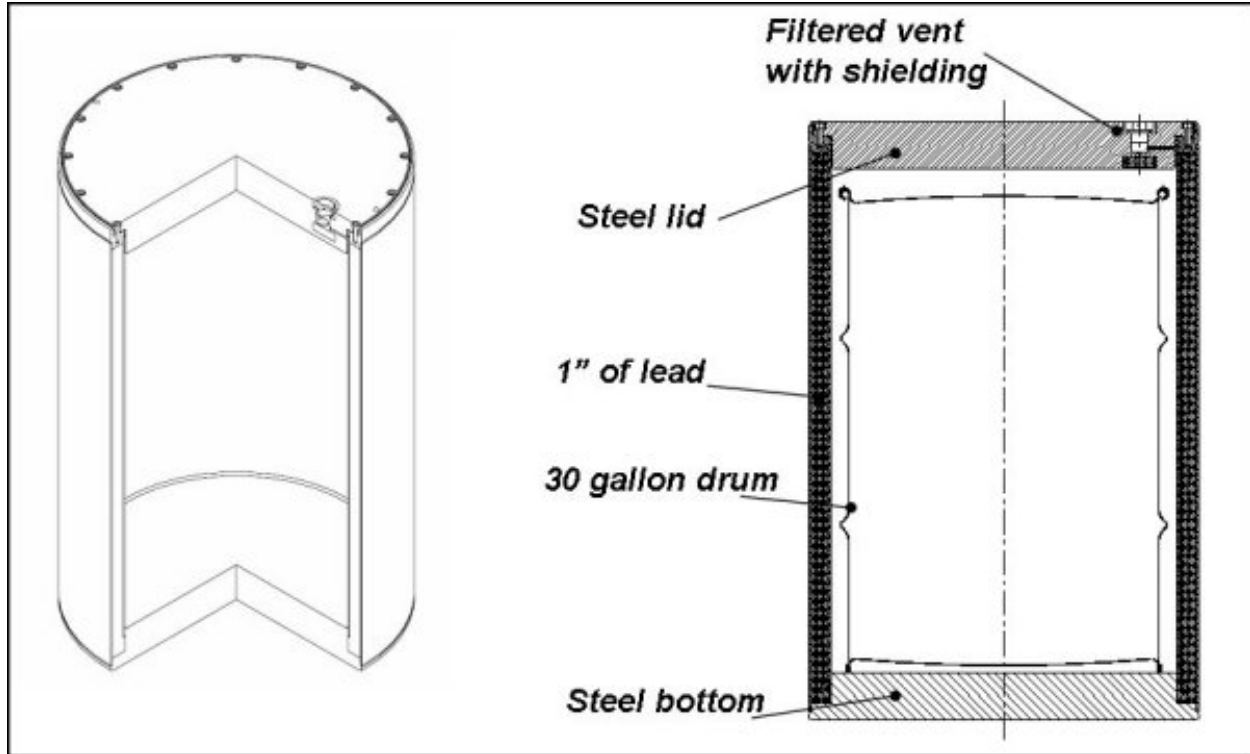


Figure 2. The Shielded Container design is optimized to accommodate a significant fraction of the RH TRU waste inventory. Note the schematic representation of a 113-liter drum inside the shielded container.

The dominant other criterion that affected the SCA 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 confinement when dropped from 122 cm (typical handling height above non-yielding surface)
2. containers maintain their shielding capability when dropped from 122 cm
3. containers can support 5 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. As with other currently available shielded containers, the SCA design is amenable to manufacture using recycle stocks of DOE lead.

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 SCA assemblies during shipping. The HAC conditions that the Nuclear Regulatory Commission (NRC) uses to evaluate the ability of a type B shipping package to confine 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 (10CFR71). In order to meet the DOT-7A 122 cm drop test requirements, the SCA design is clearly robust. However, the shock absorber (hereinafter called dunnage) that surrounds the SCA assembly

during shipping must also ensure that the shielding efficacy remains intact even after a 9-meter drop test (within the shipping package) requirement of the HAC.

The design of the dunnage that surrounds the 3-pack SCA assembly during shipping is shown in Figure 3. It consists of an aluminum-shelled reusable fixture that is filled with foam, similar to the foam employed elsewhere in the construction of the HalfPACT [2] (and TRUPACT-II). Remote handled waste shipped in SCA assemblies 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 100-gallon drums or 7-packs of 55-gallon drums). DOE does not propose to disassemble the 3-pack SCA assemblies 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 WIPP.

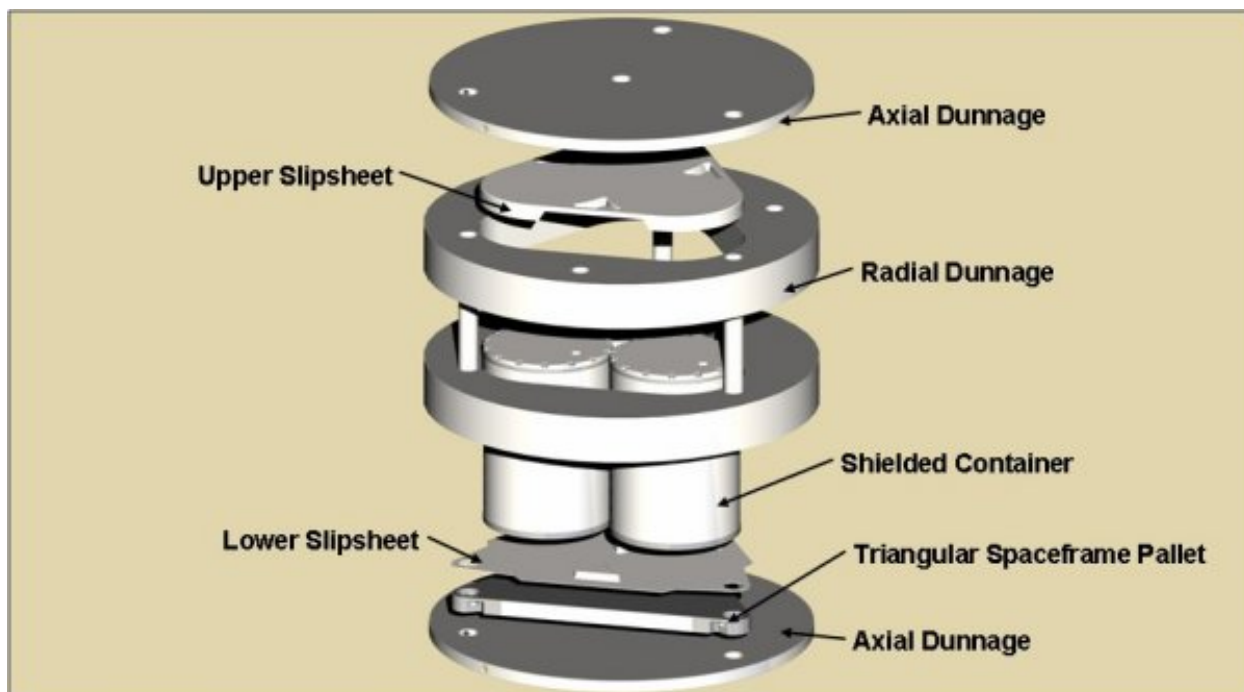


Figure 3. Shipping configuration (exploded view) showing dunnage used to cushion SCA packages inside the Type B HalfPACT to meet the HAC conditions.

SHIELDED CONTAINER PERFORMANCE TESTING

Tests of the SCA and associated shipping dunnage in the HalfPACT shipping configuration were successfully conducted in the autumn of 2007. These tests demonstrated that the SCA would meet both DOT-7A requirements for container integrity, as well as NRC 10CFR71 requirements for confinement and shielding integrity under transportation accident conditions. A photo of the moment of impact during 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.

During some of these punishing 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 confinement and no significant reduction in shielding through all surfaces and angles. Gamma scans were performed before and after each drop. Only minor deformation was 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 drums), and prevent any possible buildup of

radiolytically generated hydrogen. To test the confinement performance, the test units were filled with a fluorescing particulate material, and black-light examination for loss of confinement was performed after every test.

The right pane of Figure 4 shows one of the 9-meter drop tests. Three fully loaded shielded container assemblies 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 and an outer containment vessel that is surrounded by shock absorbing and thermally insulating foam, which is itself surrounded by an additional protective shell. The SCA HAC drop test did not employ the outer containment assembly (i.e., outer containment vessel, foam, and additional protective shell) that would be present in a real accident, which made the test extremely conservative. The 9-meter drop test documented the ability of the shock absorbing dunnage to maintain the SCA shielding efficacy under NRC-required hypothetical accident conditions. The 9-meter drop test documented the ability of the dunnage to protect the shielding capability of the SCA, and was not intended to test the HalfPACT inner containment vessel, since the SCA and dunnage were designed within the licensed payload limits of the HalfPACT. After all cumulative drops, the shielded container test units suffered only minor, almost “cosmetic” damage.



Figure 4. Drop testing the Shielded Container (left pane) and inside a shipping container (right pane).

It is fair to say that the SCA, as designed, performed flawlessly. This is not surprising. Due to the need to provide the same shielding through the top and bottom as that from the lead-filled cylinder walls, the thickness of the top and bottom is structurally much greater than necessary to ensure no significant deformation occurs during even the most punishing test conditions.

DISPOSAL AND LONG TERM REPOSITORY PERFORMANCE

One of the many regulatory requirements that 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

change request as described in Chapter 40 of the Code of Federal Regulations, Part 194 [4] (40CFR194). An assessment [5] 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 may 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 shielded containers 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, spillings, direct brine releases, groundwater releases, and total releases. It is ironic that RH waste disposal in WIPP has engendered such substantial controversy, yet it has an essentially negligible effect on long-term repository performance in any emplacement configuration.

The comparison showed that the projected releases from WIPP using the assumed human intrusion scenarios required under 40CFR194 were essentially the same, no matter which disposal configuration was assumed. This is not surprising since the repository performance is dominated by the assumed multiple penetrations of the waste footprint by future societies repeatedly drilling for assumed natural resources underlying 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.

Indeed, the use of shielded containers should actually improve the long-term performance of the repository through a number of processes if these were actually quantitatively considered in the analysis. The substantial amount of lead will add to the already reducing conditions in the long-term evolution of the waste-rock matrix and thereby reduce the solubility of actinides, should brine ever be introduced via inadvertent human intrusion. In addition, the structurally robust nature of the shielded containers (over that of the horizontally emplaced RH canisters in the disposal room walls) would add to the strength of the waste matrix, and releases via assumed human intrusion scenarios by cuttings and cavings mechanisms would be commensurately reduced.

WIPP PERMIT MODIFICATION WILL BE REQUIRED

Another key approval for the use of shielded containers will be by the New Mexico Environment Department (NMED) for changes to the Resource Conservation and Recovery Act permit for the WIPP facility to allow their receipt and emplacement. After approval by NRC to ship RH waste in the shielded container, and after approval by EPA that the shielded container will not affect long term repository performance, DOE will submit a permit modification request to NMED to receive and emplace RH waste packaged into shielded containers. DOE does not propose to count the waste emplaced in the shielded configuration as CH waste, although technically that is what it is. DOE will honor the RH volume limits that are imposed by PL 102-579 [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 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). 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).

BENEFITS OF SHIELDED CONTAINERS

RH waste is currently shipped to WIPP in RH-72B shipping casks [6] which can transport the equivalent of one facility disposal canister, and typically over-packs three 113-liter 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 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.

The cost of the SCA will be significant, but large quantity pricing has not yet been developed. It is expected that the cost to ship and emplace RH waste using the shielded containers will be significantly less than the cost of the baseline canister-in-wall scheme, and the use of recycle lead may make the cost of the shielded containers competitive with the baseline RH canister cost.

The inefficiency of the baseline disposal scheme should be apparent. A single RH waste canister evolution from receipt of the RH-72B until emplacement in the wall 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.

Another difficult to quantify benefit of the use of shielded containers may be realized if DOE is able to use its vast stockpiles of formerly used lead in the DOE inventory with which to manufacture the shielded containers. To keep costs low, and to provide an environmentally prudent pathway for usefully managing some of that inventory, DOE intends to use recycled lead to the maximum extent possible. The joint EPA/NRC guidance (EPA OSWER Directive 9432.00-2) on use of lead containers for shielding in disposal operations recommends such use, and states that such lead is not considered hazardous waste under the Resource Conservation and Recovery Act [7]. Furthermore, since DOE's lead reuse program is designed to ensure that recycled lead meets supplemental limits approved for directed reuse, the lead is released from radiological control for such purposes (i.e., the lead is a safety element and not a waste product).

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 waste handling operations will not be affected since the shielded containers will be handled and managed as CH waste (which it actually is). Significant infrastructure modifications at 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, and potentially even improved. There are no anticipated changes needed in the storage capacities already approved in the hazardous waste facility permit for WIPP.

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

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