Safer Transportation and Disposal of Remote Handled Transuranic Waste - 12033

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ABSTRACT

Since disposal of remote handled (RH) transuranic (TRU) waste at the Waste Isolation Pilot Plant (WIPP) began in 2007, the Department of Energy (DOE) has had difficulty meeting the plans and schedule for disposing this waste. PECOS Management Services, Inc. (PECOS) assessed the feasibility of proposed alternate RH-TRU mixed waste containerization concepts that would enhance the transportation rate of RH-TRU waste to WIPP and increase the utilization of available WIPP space capacity for RH-TRU waste disposal by either replacing or augmenting current and proposed disposal methods. In addition engineering and operational analyses were conducted that addressed concerns regarding criticality, heat release, and worker exposure to radiation. The results of the analyses showed that the concept, development, and use of a concrete pipe based design for an RH-TRU waste shipping and disposal container could be potentially advantageous for disposing a substantial quantity of RH-TRU waste at WIPP in the same manner as contact-handled RH waste. Additionally, this new disposal method would eliminate the hazard associated with repackaging this waste in other containers without the requirement for NRC approval for a new shipping container.

INTRODUCTION

Since authorization for the disposal of remote handled (RH) transuranic (TRU) waste in Panel 4 at the Waste Isolation Pilot Plant (WIPP) was granted in 2007, the Department of Energy (DOE) has had difficulty meeting the plans and schedule for disposing this waste. Despite having access to an increased budget from American Reinvestment and Recovery Act (ARRA) funds as of 2009, DOE has yet to make any gains in reducing the RH-TRU waste disposal deficit and fulfilling the volumes of RH-TRU waste planned for disposal in WIPP. The scope of this task covers all current and planned activities involving operations of the WIPP related to handling and disposal of RH-TRU waste canisters.

The purpose of this paper is to assess the feasibility of proposed alternate RH-TRU mixed waste emplacement concepts that would enhance available WIPP space capacity by either replacing or augmenting horizontal borehole or shielded container disposal methods. In addition to engineering and operational analyses associated with these proposed emplacement concepts, this paper also addresses concerns regarding criticality, heat release, and worker exposure to radiation.

BACKGROUND

Limits placed on management, storage, and disposal of TRU waste in the WIPP geologic repository are established in the Land Withdrawal Act of 1992 (LWA)[1]. As summarized in the WIPP RH Waste Documented Safety Analysis (DSA) [2], the WIPP facility is intended to have a total disposal capacity for TRU waste of 175,600 cubic meters (6.2 million cu. ft.)[3]. Of that total volume, disposal of RH-TRU Waste is limited to 7.080 m^3 cubic meters (250,000 cu. ft.) as established by the Record of Decision (46 Federal Register 9162) authorizing WIPP. In addition, the WIPP Land LWA limits the total RH-TRU activity to be disposed in WIPP to 5.1 million curies. RH-TRU waste with a radiation level between 0.2 rem per hour (rem/hr) and less than 1000 rem/hr is considered RH waste.

Each RH-TRU waste canister accommodates a volume of 0.89 m^3 cubic meters (31.43 cubic feet), which means approximately 7,955 canisters are required in order to dispose of the 7,080 m^3 cubic meters of the RH-TRU waste presently authorized for disposal. The LWA prohibits receipt of TRU waste with a canister surface dose rate in excess of 1,000 rem/hr; and no more than five percent by volume of RH-TRU waste canisters with surface gamma ray doses of greater than 100 rem/hr can be emplaced in this manner.

The remaining constraints placed on the RH-TRU waste disposal capacity of WIPP are established in the Hazardous Waste Facility Permit (HWFP) that was issued in November, 2010.[3] That HWFP allows a total RH-TRU waste disposal of no more than 2,634 m^3 cubic meters (93,018.83 cu ft) in the approved eight disposal panels. These limits were based on the design limits for RH-TRU waste disposal in horizontal boreholes of 650 cubic meters per panel as presented by the DOE. Therefore, without implementing other RH-TRU waste disposal options, there are no available mechanism for use in disposing of the approximately remaining 4,446 m^3 cubic meters (157,009 cu. ft.) of RH-TRU waste that could still be legally disposed in WIPP.

Present Operations

As described in the 2004 Compliance Recertification Application, WIPP is located within an approximately 610 meter (2,000 feet) thick bedded salt formation called the Salado Formation and is designed for disposal of TRU mixed waste consisting of contact handled (CH) and RH-TRU wastes that are stored in containers. Disposal is conducted in eight underground panels mined perpendicular to the four main access drifts. Each panel consists of seven rooms and two access drifts. Each room measures approximately 3.96 meters (13 feet) high by (10.06 meters (33 feet) wide by 91.44 meters (300 feet) long, and these rooms are separated by pillars 30.48 metters (100 feet) wide. The main panel access drift to the rooms is 6.1 meters (20 feet) wide.[4] Under the new HWFP, RH-TRU waste is currently authorized for disposal in Panels 4 through 8.

Disposal of RH-TRU waste at WIPP is accomplished through emplacement of RH-TRU waste canisters in boreholes drilled horizontally into the walls of disposal rooms and certain panel access drifts. As a result of geotechnical engineering and equipment limitations, DOE developed a borehole configuration design of a maximum of 730 boreholes per panel. (The HWFP limited the number of these boreholes in Panels 4, 5, & 6.) These boreholes are 76.2 centimeters (30 inches) in diameter and are drilled horizontally 5.18 meters (17 feet) deep on 2.44 meters (eight-foot) centers about mid-height in the long sides of the disposal room. The first borehole is positioned 10.36 meters (34 feet) from the projected corner of the salt pillars separating the disposal rooms. Radiation from filled boreholes is shielded from the room by a shield ring and a shield plug.

Currently, canisters containing RH-TRU mixed waste are shipped to WIPP in RH-72B shipping containers. When they arrive at the Waste Handling Building (WHB), they are removed from the shipping container into the WHB hot cell, where they are transferred into the facility cask. The facility cask is then transferred from the WHB to the underground via the waste handling shaft, at which point a 41-ton forklift transports the facility cask to the disposal panel. The cask is then placed on the horizontal emplacement and retrieval equipment (HERE), which is used to emplace the RH-TRU mixed waste canister into the borehole. The emplacement process includes placement of the shield plug in order to close the borehole after the canister is pushed in place inside. The shield plug reduces the radiation dose rate measured 30 centimeters (11.81

inches) from the closed borehole to less than 10 mrem/hr for a canister surface dose rate of 100 rem/hr.

Present operations require emplacement of RH-TRU waste canisters to be completed in a room prior to emplacement of CH TRU waste containers in that room. The major basis for this approach involves the difficulty of moving borehole drilling equipment and HERE in and out of a room in order to accommodate sequential disposal of both TRU waste types in a room. As a result, if deliveries of RH-TRU waste to WIPP are not sufficient to fill all boreholes in a room before the room is needed for CH TRU waste, then any unfilled boreholes in that room are bypassed. Thus, there are several reasons why an alternative disposal method would be advantageous for RH-TRU waste streams with canister surface dose rates of less than 100 rem/hr. Borehole drilling is limited to one to two boreholes per shift, and those boreholes must be drilled and filled before any CH TRU waste can be deposited in front of them. Disposal operations are time-consuming: A single RH-TRU waste canister evolution—from receipt in a 72-B shipping cask at the WIPP site to emplacement in the wall of the underground disposal room—requires more than 10 hours. These operational restraints result in a practical limit of six RH-TRU waste canister emplacements per week at WIPP if all authorized boreholes are used in each room; however, other operational issues at the complex (e.g., the fact that it is more difficult and time-consuming to characterize and repackage RH-TRU waste than CH TRU waste), have resulted in an approximate average of only two RH shipments per week.

One operational improvement that would enhance disposal of RH-TRU waste is the projection of a new light-weight facility cask (LWFC) expected to be in use at the facility in 2011.[5] Empty, the LWFC weighs 20,970.94 kilograms (46,233 pounds) and when filled with a RH-TRU waste canister (approximately 2,721.55 kilograms or 6,000 pounds). Therefore, it is likely WIPP will augment the 41-ton forklift with newer, more maneuverable forklifts to accommodate the LWFC, which should accelerate the disposal process and result in less RH-TRU boreholes being bypassed.

Alternate Disposal Options

During the design phase of WIPP starting in the 1970's through the present day, the DOE has conducted evaluations of numerous alternate disposal options with respect to the RH-TRU waste. Briefly, the alternatives evaluated are known to include:

- Separate disposal level for RH-TRU waste,
- Disposal of 2 RH-TRU waste canisters in a horizontal borehole,
- Closer spacing of horizontal boreholes,
- Installation of horizontal boreholes in main tunnels and cross-shafts after Panel 8 is filled,
- Larger/deeper disposal panels,
- Lead shielded containers,
- Neutron absorbing containers, and
- Addition of two additional panels with the same configuration of the first 8 panels.

Of these, only the last three have been formally proposed to the regulators. The most advanced alternative, in terms of possible regulatory approval, that has been proposed for disposal of RH-TRU waste in containers is to use standard waste drums lined with 2.54 centimeters (one-inch)-thick lead liners so as to minimize surface dose rate to 200 mrem/hr or less. This would allow personnel to handle these shielded containers as CH TRU waste using a disposal method similar to that used for other CH TRU waste. However, DOE estimates these shielded containers can accommodate no more than 25 to 30 percent of the remaining RH-TRU waste. Further, it appears that the maximum RH-TRU waste container surface dose rate for disposal in shielded containers is only three to four rem/hr.

Most recently, the DOE submitted documentation to the EPA stating their objective of adding two additional panels to the underground disposal area as shown in Figure 1 on the following page. The primary reason given for this proposed change was the concern about the instability of the tunnels and cross-drifts with respect to installation of horizontal boreholes. However, using the current HWFP and actual disposal operating experience as a guide, it is estimated that the addition of these two panels would only result in additional capacity for RH-TRU waste of about 1500 cubic meters (52,972 cubic feet) leaving DOE well short of either the authorized disposal capacity or anticipated disposal volume.

METHOD

As the Independent Oversight Contractor for WIPP, PECOS conducted several assessments of the effectiveness and efficiency of the RH-TRU waste disposal operations at WIPP. These assessments evaluated the current operations processes and procedures, revisited some of the past disposal options such as the two canisters per borehole option, and assessed the effectiveness of the proposed new alternatives. The assessments confirmed that a large amount of remaining RH-TRU waste would still need to be disposed [up to 4,446 cubic meters (157,009 cu. ft) per the LWA and approximately 4,676 cubic meters (165,131 cu. ft.) per the 2009 Annual TRU Waste Inventory Report). Therefore, PECOS personnel applied their knowledge and experience with radioactive waste management and disposal, emphasizing health and safety, to identify other possible disposal approaches for RH-TRU waste that might enable DOE to accomplish the disposal of all anticipated RH-TRU waste without major structural changes to the repository.

RESULTS

In order to potentially fill the gap between RH-TRU waste suitable for shielded containers and the RH-TRU waste with canister surface dose rates of up to 100 rem./hr, it is proposed that RH-TRU waste canisters be transferred at WIPP into a new disposal container in the form of a hollow concrete cylinder capped at one end and equipped with a shield plug for the open end be fabricated. The RH-TRU waste canister inside the sealed concrete cylinder can then be disposed of on the floor of rooms/panels in lieu of being emplaced into a borehole at the disposal panel using the HERE emplacement equipment.

The new disposal container will measure 76.2 centimeters (30 inches) inside diameter by approximately 3.81 meters (12.5 feet) long and will be fabricated of high-density concrete of sufficient thickness to limit surface dose rate to 200 mrem/hr or less (*Figure 2*). The disposal container could be handled as CH TRU waste and could be disposed within the rooms rather than in horizontal boreholes.

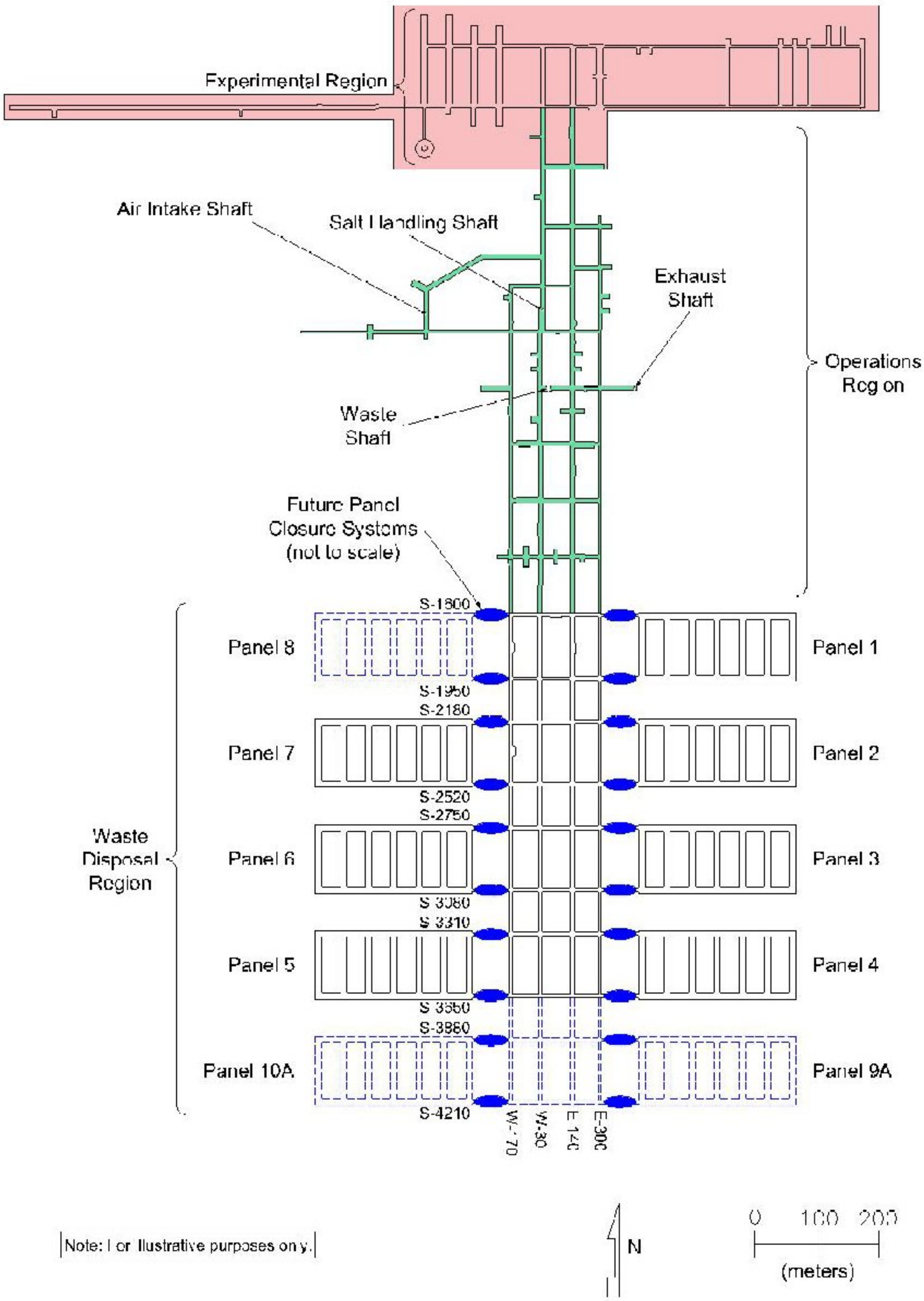

Fig. 1 Proposed Revised Configuration of Panels in WIPP

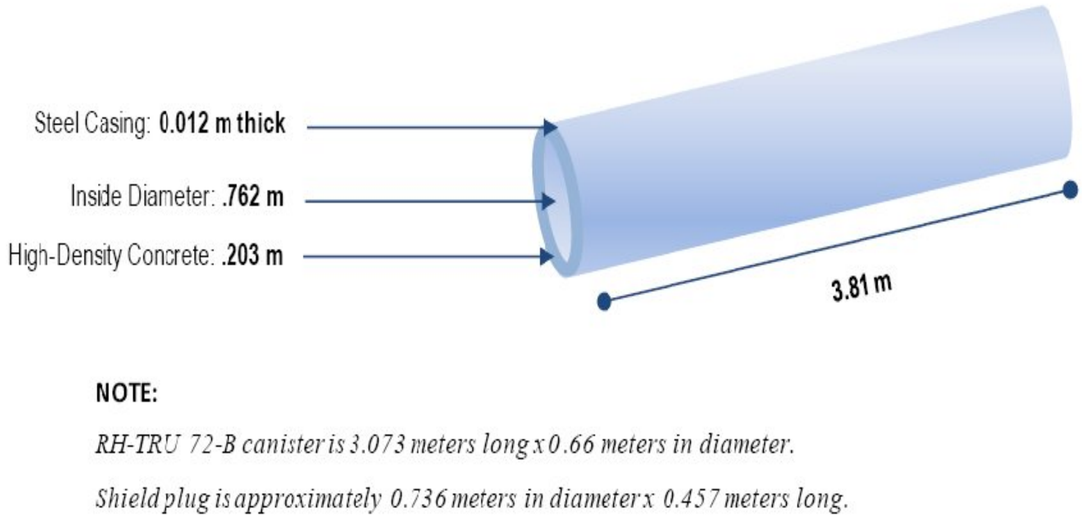

Fig. 2. Disposal Container Construction (*not to scale*).

As shown in more detail in *Figure 3,* this disposal container will be fabricated as a cylinder closed at one end with the other end remaining open to receive the RH-TRU waste canister. A shield plug is then placed to cover the open end of the disposal container, allowing it to be handled as CH TRU waste. This procedure is similar to current operations for disposal of a RH-TRU waste canister in a borehole. Since the surface dose rate of the canisters to be loaded into this new disposal container will be 100 rem/hr or less, it is estimated the thickness of the shield plug would be between 30 and 45 centimeters (1 to 1.5 ft) to achieve a surface dose rate of 0.2 rem/hr or less.

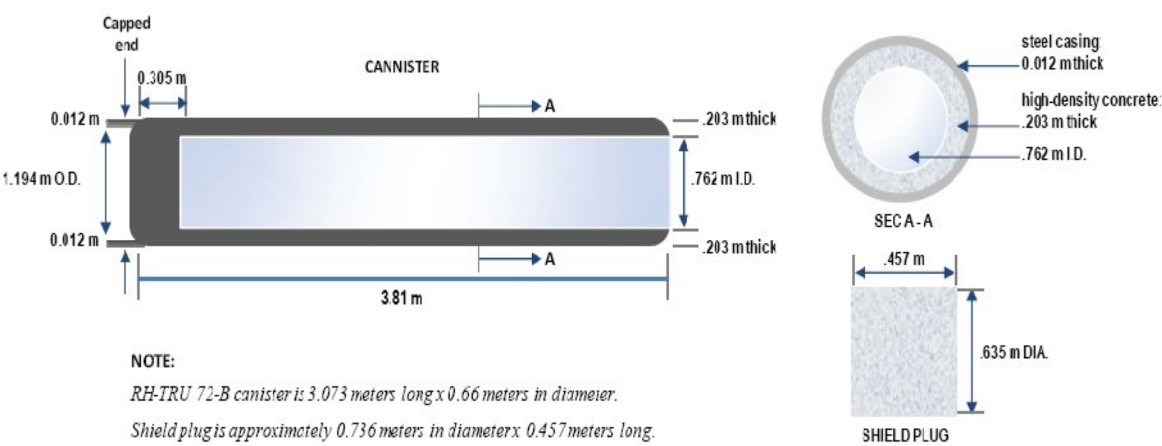

Figure 3. Disposal Container Detail (*not to scale*).

The construction of a disposal container as described above must address four considerations: 1) shielding, 2) physical integrity, 3) dimensions/weight, and 4) operational requirements.

Shielding: Ordinary Portland cement concrete, high-density concrete, and steel were considered. Following preliminary evaluation, ordinary Portland cement concrete was not chosen since the resulting disposal container would have been too large in diameter. Steel was not chosen based upon the anticipated difficulty in locating a fabrication facility as well as its high cost. Thus, high-density concrete, 5.2 grams per cubic centimeter, was assumed for the purpose of concept development and used as the basis of other assumptions and evaluations. All gamma radiation was represented by Cs-137 with energy 0.662 MeV. It is noted that at this energy level as well as those up to near 10 MeV, the mass attenuation coefficient is essentially inversely proportional to density. Flat plate radiation was assumed—with the curvature of a cylinder ignored—and we used ordinary concrete properties, including density corrections in cases where high-density concrete data were unavailable.

Using the following formula (Eq. 1) presented in the scientific text book "Atoms, Radiation, and Radiation Protection," [6] and a desired attenuation of 100 rem/hr to 200 mrem/hr, the required thickness was calculated to be approximately 22.9 centimeters (nine inches)

$$I = I_o B e^{-\mu x} \qquad \text{(Eq. 1)}$$

where

I and I_0 = required and source intensity respectively

B = the Build-up factor

μ = the linear attenuation coefficient, and

x = the shield thickness

Physical Integrity: Given the structural damage potential of concrete, the concept was modified to include a 1.27 centimeter (half-inch) outer steel skin, which reduced the concrete thickness required to attenuate radiation to 20.32 centimeters (eight inches). Thus, the final configuration is a cylinder with 20.32 centimeter (eight-inch)-thick, high-density concrete walls enclosed on one end and encased in a 1.27 centimeter (half-inch) steel casing. The open end is constructed to mate with the HERE. This combination of a thick concrete cylinder with a exterior steel casing is estimated to attenuate the surface dose rate from 100 rem/hr at the RH-TRU canister surface to 200 mrem/hr or less on the surface of the new disposal container. In considering the heat release from the proposed disposal container, Section 3 of the RH-TRU Waste Study[7] stated that “The RH-TRU radionuclide inventory in appendix B was used to estimate an initial average heat output of less than 1 Watt per canister, much less than the 300 W allowed by the WIPP WAC. A 300 W heat output corresponds to a formation temperature increase of less than 10 degrees Centigrade (C)”.[7] Based on this study, the potential for canister temperature increase from heat release would be insignificant.

Dimensions/Weight: The disposal container would be 76.2 centimeter (30 inches) internal diameter and 1.19 meters (47 inches) outside diameter with an overall length of approximately 3.81 meters (12.5 feet). The calculated empty weight (without shield plug and end cap) is approximately 13,063.46 kilograms (28,800 pounds), which is approximately 17,644.74 kilograms (38,900 pounds) lighter than the facility cask [30,708.20 kilograms (67,700 pounds) empty weight]. It is also projected to be approximately 892.51 kilograms (17,400 pounds) lighter than the new LWFC [20,955.97 kilograms (46,200 pounds) empty weight]. Thus, either the current 41-ton forklift or any 20-ton forklift that will lift and transport the LWFC will also be able to lift and transport the overall weight of the new disposal container loaded with a 2,721.55 kilogram (6,000-pound) RH waste container.

DISCUSSION

Once it was determined that the proposed new RH-TRU waste disposal container was feasible to construct and would adequately protect workers from radiation exposure, the next step was to develop an alternate means of transferring the RH-TRU waste canisters to the new disposal containers and then dispose of those containers in the repository in a place other than boreholes.

PECOS initially evaluated the approach of transferring the RH-TRU waste canisters into the new disposal containers, placing them longitudinally on a modular steel rack along the length of the disposal room or alternatively, placing the disposal containers on a modular steel rack transversely along the length of the disposal room. However, neither arrangement is efficient for the transfer of RH-TRU waste canisters to the ultimate emplacement site within a disposal panel, because both approaches require extensive maneuvering of the HERE equipment and the 41-ton forklift. Consequently, we evaluated two other approaches to transferring waste from the shipping cask to the new disposal container prior to emplacement:

Alternative 1: **Transfer RH-TRU waste canisters to new disposal containers in the hot cell in the WHB prior to moving underground.** While this approach is beneficial from some perspectives, we estimate it will require significant modifications to the hot cell and handling equipment—possibly a Class 3 modification to the HWFP—and it would possibly increase the potential for radiation exposure. This alternative was therefore given no further consideration.

Alternative 2: **Transfer RH-TRU waste canisters to the new disposal containers underground.** This alternative provides a staging area located underground, either near the waste handling shaft or at the head of each panel, where personnel could transfer an RH-TRU waste canister into a disposal container (*Figure 4*).

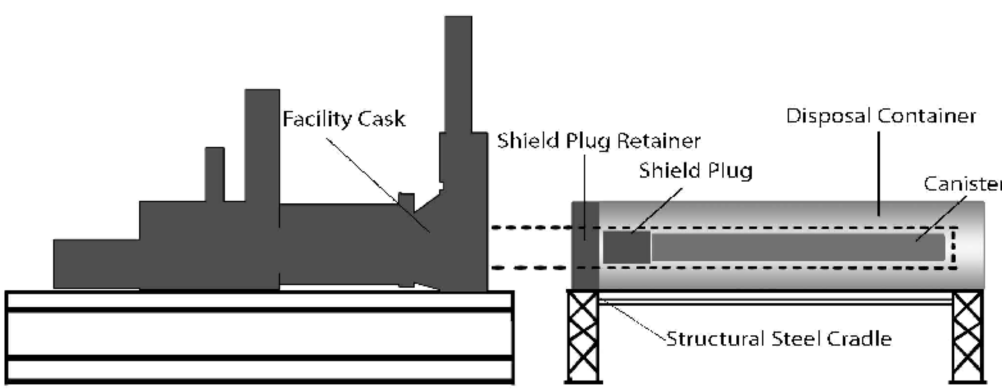

Fig. 4 Canister Transfer to Disposal Container (not to scale)

The RH-TRU waste container would be transported underground in the facility cask, as is the current practice, and then transferred from the facility cask to the new disposal container using the existing 41-ton forklift and the HERE emplacement equipment. The HERE, or similar equipment, is then placed where it could be accessed for receiving the facility cask and transferring the RH-TRU waste canister to the disposal container. The disposal container in turn is placed on a cradle so as to be connected (mated) to the HERE, and the transfer is accomplished in a manner similar to the current method of transferring canisters into boreholes. Following transfer, the disposal container is sealed with a shield plug, similar to the current practice employed at the borehole. The disposal container is then ready for transport for final disposal in a panel.

Following transfer, the disposal container is moved by the same forklifts used to transport CH TRU waste to the panel currently being filled to augment RH-TRU waste disposal, or perhaps to Panels 9 and 10 to substitute for drilling boreholes at those locations. The new disposal containers could be placed on the floor perpendicular to the length of the room, two in a row, with approximately 75 rows per room or 150 disposal containers per room, which would enable disposal of at least 1050 RH-TRU waste canisters per panel without using panel access drifts. A platform could be constructed above the new disposal containers to allow the remainder of the space in the room to be used for more waste disposal—either normally packaged CH TRU waste or other rows of new disposal containers as appropriate. Further, the small number of RH-TRU waste canisters with surface dose rates of between 100 and 1000 rem/hr could still be disposed in horizontal boreholes prior to disposing the remaining RH-TRU waste in the new disposal containers on the floors of the rooms.

PECOS has considered potential health and safety (H&S) impacts of each step of the alternative arrangements, comparing them with existing operations, but requires a more detailed assessment than that provided herein, as well as a more complete and detailed assessment of associated technical aspects.

CONCLUSIONS

The concept, development, and use of a disposal container as described above could be potentially advantageous for disposing a substantial quantity of RH-TRU waste at WIPP. Specific advantages include the following:

- Provision of a disposal means for RH-TRU waste containers with surface dose rates between four and 100 rem/hr.
- Provision of a way to dispose of RH-TRU waste currently stored in standard waste drums, thus eliminating the hazard associated with repackaging this waste in other containers.
- No requirement for NRC approval for a new shipping container.
- Supplemental means of disposing RH-TRU waste in Panels 6-8 in addition to the boreholes.
- No necessity to drill boreholes if RH-TRU waste could be deposited in access drifts (Panels 9 & 10).

Establishment of a “staging area” as described above appears to be the most practical approach to disposing of RH-TRU waste canisters, as it uses existing equipment—including the HERE and the 41-ton forklift—and follows many current H&S procedures. This approach also appears to require the least amount of new equipment or procedures.

A disposal container in the form of a cylinder with a 76.2 centimeter (30-inch) inside diameter fabricated from a combination of high-density concrete pipe with walls 20.32 centimeters (eight inches) thick and a 1.27 centimeter (half-inch) thick exterior steel casing appears to be a potential alternate method for permanently disposing RH-TRU waste canisters in other than horizontal boreholes.

The proposed alternative disposal method will help increase operational efficiency primarily because emplacement of RH-TRU waste canisters in disposal containers in a staging area will mitigate the need to move the HERE equipment in the limited space in the disposal room following any initial emplacement of higher activity RH-TRU waste canisters in boreholes in a room.

RECOMMENDATIONS

At the completion of this project, PECOS submitted a report describing the alternate RH-TRU waste disposal concept entitled: "*ASSESSMENT OF AN ALTERNATE APPROACH FOR REMOTE HANDLED TRANSURANIC WASTE DISPOSAL*" in September 2010. This report, which is available on the EPA WIPP website (http://www.epa.gov/radiation/wipp/index.html) recommended that the following actions be taken by DOE to ensure all issues, questions, assumptions, and concerns are adequately addressed in using cylindrical disposal containers as an alternate method for safe disposal of RH-TRU waste canisters:

1. DOE should conduct a conceptual evaluation of the proposed alternative to confirm the descriptions and conclusions presented above.
2. DOE should evaluate H&S impacts of the proposed alternative.
3. As an alternative to a steel plate liner, DOE should consider using tungsten shielding material to control surface dose rates.
4. DOE should perform an economic comparison study comparing the cost of using the proposed new disposal container and disposal methods to the cost of drilling horizontal boreholes and filling them with RH-TRU waste canisters.
5. If the results of the above recommendations are favorable, DOE should prepare technical, operational, and safety documentation and proceed with required regulatory change requests.

REFERENCES

1. Public Law 102-579, "Waste Isolation Pilot Plant Land Withdrawal Act," as amended by Public Law 104-201, Washington, DC, September 23, 1996.

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3. WIPP Hazardous Waste Facility Permit, New Mexico Environment Department, Santa Fe, NM, November, 2010.

4. Title 40 CFR, Part 191 Subparts B and C, Compliance Recertification Application 2004, DOE/WIPP 2004-3231, Carlsbad, NM, March 2004.

5. New Light-Weight Facility Cask for Remote-Handled Waste Disposal at the WIPP Facility, WM2010 Conference (presented March 7-11, 2010, Phoenix, AZ).

6. J.E. Turner, "Atoms, Radiation, and Radiation Protection," Third Edition, Wiley & Co., Somerset, NJ, July, 2007.

7. WIPP RH-TRU Waste Study – 3.0 Comparison of Contact-Handled and Remote-Handled Transuranic Wastes, DOE/CAO 95-1095, Carlsbad, NM, 1995.