THE OPERATIONAL IMPORTANCE OF RADIOLOGICAL IMPROVEMENTS IN REMOTE HANDLED TRANSURANIC WASTE PROCESSING AT THE IDAHO CLEANUP PROJECT - 11055

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ABSTRACT

For purposes of disposal at the Waste Isolation Pilot Plant (WIPP), Remote Handled Transuranic (RH TRU) waste is defined as transuranic waste that exhibits a dose equivalent rate of $\geq$ 200 millirem/hour (mrem/hr) and $\leq$ 1,000 mrem/hr at the surface of the container holding the waste. With the currently established occupational dose limit for general employees at 5 rem/year and a company set administrative control limit of 700 mrem/year, a variety of engineered and administrative controls have been implemented within each waste management facility to ensure facility workers remain within these limits while handling and processing RH TRU waste for disposal at WIPP. In 2005, workers began the task of retrieval of 675 RH TRU drums from below ground storage vaults for processing and disposal at WIPP in accordance with the scope established by the United States Department of Energy (US DOE) in the Idaho Cleanup Project (ICP) contract. This waste, generated during the 1970s, 1980s and 1990s, was generated at Argonne National Laboratory – East, as well as other locations at the Idaho National Laboratory (INL), from the examination of irradiated and un-irradiated fuel pins and other reactor materials from various reactor programs at Argonne National Laboratory – West and other US DOE reactor sites. Once retrieved, the drums were transported in shielded transfer containers across the Idaho desert to the ultimate processing location at the Idaho Nuclear Technology and Engineering Center (INTEC). Existing "hot cell" facilities were renovated and placed into service to be able to safely process the RH TRU waste drums, while still being protective of the health and safety of the worker. The highest recorded dose equivalent rate at the time the drums were placed into storage was 52 rem/hr at the container surface. Throughout the process, from inception through to final disposition, radiological control was a key element of the design, fabrication, and operation of equipment needed to complete the job. Based upon the success of this effort, beginning in mid-2009, the US DOE provided the opportunity to process an additional 160 canisters and large liners containing RH TRU waste, also generated decades ago. This waste, generated during the 1970s through late 2007, has been in underground storage vaults for nearly that long, and is currently being retrieved and transported to INTEC, where processing is already underway. This added work scope provides new challenges in the form of waste containers that are much larger in size than the original drums and possess significantly higher dose equivalent rates (the highest recorded dose equivalent rate at the time of storage was reported to be 20,000 rem/hour at the surface of the container) causing additional concern for worker protection during processing. As a result, a variety of initiatives are being implemented to enhance the RH TRU waste processing capabilities based on lessons learned from the initial campaign and from the rest of the US DOE complex. This paper details the genesis of the RH TRU waste processing approach, the role that radiological control practices played in the approach, and the benefits provided to the workforce by having a robust radiological control program.

INTRODUCTION AND HISTORY

The INL began providing interim storage of RH TRU waste in 1976 for eventual characterization, certification, packaging, and transportation to a final disposition location. The waste was originally stored in underground storage vaults located at the Intermediate Level Transuranic Storage Facility (ILTSF) within the facility boundary of the Radioactive Waste Management Complex (RWMC). The ILTSF was constructed in 1976 for the purpose of providing a location for intermediate storage prior to ultimate disposition. The ILTSF consists of 256 below-grade steel vaults that stored between 5 and 11 drums each. The initial inventory of RH TRU waste for disposition was slightly over 80 m^3 (675 drums) and is summarized in Table I. Beginning in 2005, retrieval from these underground storage locations was initiated. The drums of RH TRU were retrieved and placed in temporary above ground storage in specially fabricated Interim Storage Containers (ISC) and/or Shielded Overpacks (SO) while waiting transport to INTEC for further processing.

Argonne National Laboratory-East (ANL-E) sent 617 30-gal waste drums with a total volume of 70.4 m3 waste from 1976 through 1995 to the RWMC. The waste consisted of mixtures of combustible and noncombustible waste. The ANL-E RH TRU waste was generated at the Alpha Gamma Hot Cell Facility as a result of the destructive examination of experimental fuel and associated materials at that facility between 1976 and 1995.

The Materials and Fuels Complex (MFC) generated and sent four 55-gal drums in 1988. The waste consisted of glassware, paper, polyethylene, and miscellaneous laboratory waste.

From 1977 through 1981, the Naval Reactors Facility (NRF) sent 3.1 m3 of RH TRU waste to the RWMC for temporary disposal. The waste in these 27 containers includes process equipment, containers, and combustible materials.

Three shipments were sent from the Test Reactor Area (TRA) to the RWMC from 1990 through 1996, for a total of 5.2 m3 (25 containers). In 1990, 10 drums of waste from the drains of TRA Hot Cells and the Alpha Wing Laboratories were sent for disposal. In 1994, 14 drums of RH TRU waste were sent from the TRA to the RWMC. The waste consisted of resin from the mixed bed ion exchange columns at TRA 605. The last shipment occurred in 1996 and consisted of several radioactive sources.

One shipment of RH TRU waste from INTEC was sent to RWMC for storage in 1978. The waste was packaged in two 30-gal drums and was generated from the analysis of irradiated fuel. The waste consisted of glass, plastics, and metal; miscellaneous laboratory equipment; and diatomaceous earth.

Table I – Inventory of RH TRU

Generating Source	Storage Configuration	Quantity (drums)	Form	Maximum Dose equivalent rate (rem/hour @ container surface)	Average Dose equivalent rate (rem/hour @ container surface)
Argonne National Lab – East	30-gallon drum	617	Debris	52	3.6
Naval Reactors Facility	30-gallon drum	27	Debris		
Idaho Nuclear Technology and Engineering Center	30-gallon drum	2	Debris		
Materials and Fuels Complex (formerly ANL - West)	55-gallon drum	4	Debris		
Advanced Test Reactor Complex (formerly Test Reactor Area)	55-gallon drum	25	10 Solid, 15 Debris		

Because of the success of the initial processing effort, beginning in 2009, the US DOE identified an additional population of RH TRU waste to be processed in existing facilities. With the added boost of American Recovery and Reinvestment Act (ARRA) funding, planning for processing this additional RH TRU waste inventory began. This waste population consists of 160 containers, largely consisting of 6 foot tall, 12 inch diameter canisters generated from the Materials and Fuels Complex (formerly known as ANL-W), ANL-E, and Bettis Atomic Power Laboratory (BAPL). Table II provides a summary.

The Hot Fuel Examination Facility (HFEF) canisters from MFC were generated during “hot cell” and analytical chemistry operations conducted in various “hot cell” locations from April 1977 to September 2007. Waste from these operations was generated primarily in support of Liquid Metal Fast Breeder Reactor and Integral Fast Reactor irradiation studies performed on alloy fuel, and sample materials irradiated in the Experimental Breeder Reactor (EBR)-II. The waste consists predominantly of organic and inorganic debris waste generated during the examination of irradiated fuels.

The waste from ANL-E is similar in generation origin to the drums described in Table I above, and includes fissile scrap, recoverable and non-recoverable, segregated from intermediate level TRU waste shipped to INL in the 30-gallon drums. These "scrap" materials have since been determined to be waste. The waste was originally packaged and shipped to INL between March 1975 and November 1995. Waste from this stream was contaminated primarily with fissile materials and mixed fission products.

Table II – Additional Inventory of RH TRU

Generating Source	Storage Configuration	Dimensions	Quantity (containers)	Maximum Dose equivalent rate (rem/hour @ 30 cm)	Average Dose equivalent rate (rem/hour @ 30 cm)
MFC (formerly known as ANL-W)	HFEF canister	12.75" dia. X 73.5" long	86	1,490	39
	Large Liners	24" dia. X 13' 8" long	12	52	9.4
	SLSF canister	22" dia. X 134" long	8	355	107
	Boxes	4' X 4' X 7'	3	0.06	0.05
	EBR donut liner	24" dia. X 76" long	1	0.03	0.03
Argonne National Lab – East	ANL-E canister	9.25" dia. X 72" long	48	183	134
Bettis Atomic Power Lab	HFEF canister	12.75" dia. X 73.5" long	2	5	3

Until recently, all of these containers had been safely stored in underground storage vaults at the MFC Radioactive Scrap and Waste Facility. To date, 149 of the containers have been successfully retrieved (all except for 9 of the Large Liners and 2 of the SLSF canisters) and transported to INTEC for processing. Of the 139 containers, 105 have been successfully processed through December 2010.

DESCRIPTION OF THE PROCESS

The work includes opening the original containers, removal of items that are prohibited by WIPP, sampling when required, sampling and analysis of headspace gases, conducting real-time radiography (RTR) to examine and document the contents of the containers, and finally, measurement of radiological characteristics to estimate the quantities of radionuclides present via a Dose-to-Curie (DTC) conversion. The equipment necessary to perform the RTR and DTC is configured to accept 30-gallon and 55-gallon drums. All waste in containers of other dimensions destined for disposition at WIPP is repackaged to allow for the characterization and transportation process. For repackaging, the original container is placed into a "hot cell" through a port designed and installed for that purpose. The container is opened and inner containers are removed and opened as necessary. The waste is placed into 30-gallon drums that are then overpacked into 55-gallon drums as part of the process of removing the waste from the "hot cell". The 55-gallon drums are maintained free of contamination.

When not being managed in one of the operating "hot cells", the waste containers are stored and transported in an ISC. After characterization and approval to ship, the 55-gallon drums are loaded in Removable Lid Canisters, which are subsequently loaded in the RH-72B transport cask for shipment to WIPP.

INITIAL FACILITY CONFIGURATION

One of the early advantages in the processing of the initial 675 drums of RH TRU was the existence of several “hot cells” (i.e., heavily shielded enclosures designed for processing highly radioactive materials) for use in processing RH TRU waste. While in many respects this is a significant advantage as it avoided the need to design, build and startup a brand new facility from the ground up, it was also a noticeable disadvantage in that the available “hot cells” were not specifically designed for, nor operated in, the routine processing of RH TRU waste that would eventually be shipped to WIPP. These “hot cells” themselves provided an immediate measure of worker protection by providing a safe and secure location to perform the processing steps needed to be able to repackage and characterize RH TRU waste remotely; however the logistics of moving containers into, and removing the resultant product drums from, the “hot cells” for further characterization and shipment were a challenge. In performing the initial facility configuration to accomplish the goal of characterizing, repackaging (if necessary), and loading for shipment to WIPP, four main initiatives were undertaken to transform the existing “hot cells” from their former mission to the current RH TRU disposition mission:

- modifying an existing “hot cell” to perform container repackaging
- modifying a second “hot cell” to accommodate a real-time radiography system and dose-to-curie measure equipment
- modifying a third “hot cell” to provide RH72B transportation cask loading capability including canister loading and lag storage; cask loading platform; and cask/trailer loading capability
- modifying existing facility and equipment outside of the “hot cell” facility to allow for remote handling of the waste from the storage container to transfer in and out of the “hot cell”.

INITIAL RADIATION PROTECTION MEASURES

Beginning with the initial retrieval effort in which the drums were to be retrieved from an underground storage location, transported across public highways to INTEC, stored at an above ground storage location pending renovation and retrofit of existing “hot cells” for processing, it became apparent that because of the dose equivalent rates associated with these containers, that a typical above ground storage facility utilized for non-remote handled waste would be inadequate. The solution to this problem came in the form of an Interim Storage Container (ISC) and the use of Shielded Overpack (SO) containers. An ISC is a specially designed and fabricated concrete storage box approximately 80” by 80” by 43” with between 9”-10.5” thick walls. Each ISC (shown in Figure I) can contain up to four 55-gallon drums. The ISC was designed to ensure enough shielding to maintain the radiation levels on the outside of the ISC to a level that did not require implementation of controls associated with a “locked high radiation area” for storage of 99% of the waste. Besides radiation protection, the construction of the ISC provided adequate protection from the environment allowing for safe and compliant outdoor storage. In the Documented Safety Analysis (DSA) for the facility, the ISC was analyzed and was demonstrated to be adequate protection from fire and criticality as well. A SO is a single drum storage container fabricated from steel and lead that provides similar features.


Figure I – Interim Storage Container

Prior to bringing the RH TRU waste to the INTEC facility for storage and processing, the waste was analyzed from a radiological exposure perspective during handling and processing. The last known recorded dose and radionuclide data, mostly decades old, were obtained, adjusted for age, and evaluated for potential of contamination and exposure consequence. Any operation, facility design or modification, or equipment planned in the facility was based on the expected worst case to ensure that a conservative approach was implemented and minimal rework would be required when actual data was obtained. Accidents and abnormal situations were evaluated from a response perspective in the facility. For example, a crane failure involving a heavy, high exposure, suspended load was of major concern based on floor loading and personnel exposure consequence. All equipment and a contingent recovery action plan were put in place to be able to deal with the occurrence of such an event, should it happen, prior to bringing any of the waste into the facility. Each operation was evaluated in a time/motion study to determine approaches to minimize personnel exposure. The time/motion study was conducted during mock-ups and dry runs in the facility.

The first facility used for RH TRU operations was the New Waste Calcine Facility (NWCF). The facility contains a "hot cell" that was used for decontamination of equipment associated with the calcining operations between 1980-2000. Operations for the RH TRU program began in 2005. The facility modifications required were primarily to ensure efficient radiation protection. The facility crane and hoist systems were modified to allow for remote operation. The hoisting and rigging evolutions were evaluated and adjusted to allow for remote connection and disconnect. The cell hatches were modified to allow an easy access port-vs.-total removal of a hatch to simplify the container entry/container removal process. A contamination control tent was designed, built and installed to allow use of the facility crane, an independent hoist, and provide contamination control for items being removed from the cell. Equipment, such as reach tools required for handling and opening of the containers, was developed and tested prior to placement in the cell. Innovative cutting tools were also designed and fabricated in-house and put into use. The operators were allowed to dry run all of the equipment prior to placing in the cell to ensure that remote maintenance and operations could be conducted effectively, with minimal personnel exposure.

EVOLUTION OF PROTECTION MEASURES

The operational approach was based on consideration of the risks associated with increasing radiation levels. All previous waste handling experience involved only contact handled radioactive waste. As a result, while all necessary precautions had been taken prior to processing (as described above), in order to be adequately prepared for the actual remote handled waste hazard, the processing operation began with the lowest exposure level RH TRU waste. The processing of the lowest dose equivalent rate drums first was done to ensure that the engineered and administrative controls would provide adequate protection and so that experience would be obtained prior to dealing with the higher hazard radiation levels. This was controlled through the development and approval of the radiological work permits in phases. As the operation started and progressed, the operators and radiological control technicians (RCTs) implemented additional shielding controls and developed hand tools and bagging devices that were highly effective in minimizing exposure and contamination. Adjustments in paper and equipment were made based on lessons learned as the radiation levels allowed in the facility were increased.

Over the first four years of RH TRU waste operations in the NWCF, the data from actual personnel monitoring showed that the highest exposure potential in the operation occurred during the removal of the repackaged product drums from the cell. In that operation, the repackaged 30-gallon drum is removed from the "hot cell" via a bag-out evolution and placed into a 55-gallon drum to reduce the potential for contamination to exit the "hot cell". It is at this point that the drum is in close contact with the operator and personnel shielding is minimal due to the non-remote aspect of placing and closing the 55-gallon drum lid. The process was improved several times to reduce exposure in this operation. The time to perform the steps was evaluated and a bagging system, nicknamed the "speed loader", from the cell port into the contamination tent was developed by the operators. The bagging system reduced the amount of time in that step from several minutes to several seconds – a significant reduction in exposure time, which is one of the main variables in the time-distance-shielding equation common to radiation protection. The second improvement came with the use of an elevated SO to provide shielding of the 55- gallon product drums during the lid closure. Finally, as operations continued, it became apparent that personnel exposures could be further reduced by replacing the existing 1" thick lead blanket curtains with 24" thick concrete blocks for minimal investment.

EFFECTIVENESS OF EARLY PROTECTION MEASURES

The RH TRU waste radiation levels encountered in the first years of operations were usually in the 20 rem/hr on-contact range with the highest "hot spot" at approximately 50 rem/hr. The early protection measures implemented in the equipment, operations, facility modifications and designs and procedural controls ensured that the personnel exposures and contamination spreads were minimal. As a result, while the dose equivalent rate per container processed was increasing, the dose to the worker remained constant or decreased.

ADDITION OF NEW FACILITY AND NEW RADIATION PROTECTION CHALLENGES WITH CHANGING WORK SCOPE

The RH TRU operations as discussed above began in the NWCF in 2005. In 2009, the scope of work increased causing the need for higher production capacity. A "hot cell" originally used for fuel processing in the 1980's was located near the NWCF also at INTEC. The "hot cell" is located within the Fluorinal Dissolution Processing Area

(FDPA) facility, which also houses the ICP spent fuel storage pools. The FDPA facility and "hot cell" (shown in Figure II) were evaluated against the NWCF facility and "hot cell" and it was determined the FDPA could be used and would provide several advantages that would complement the operations at the NWCF. The FDPA facility was much larger, allowing for the better use of distance factor in radiation protection equation. The facility also had room to establish a remote, well shielded operator control station. The larger size provided room for two production lines, as opposed to the single production line in NWCF, and it had a remote waste load out capability (see Figure III) in which containers to be processed could enter through the top of the "hot cell" while the product drums could exit the bottom through a shielded transfer chamber that was originally designed to remove waste from the "hot cell", unlike NWCF which does not possess such a design feature. Additionally, the close physical location of the FDPA to the NWCF allowed a very efficient approach to safety basis documents. The "hot cell" was made available, brought up to current operating standards, and operations began in January 2010.

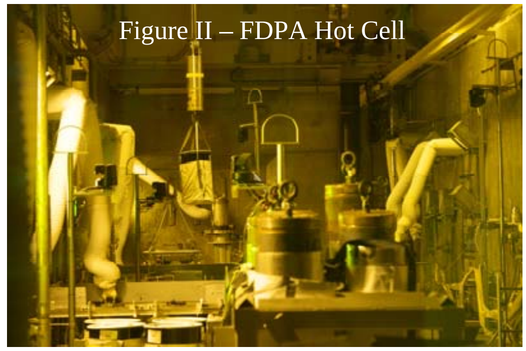


Figure II – FDPA Hot Cell

Figure III – FDPA Remote Waste Loadout Area

As operations progressed, it became evident that the major difference in radiological protection between the two facilities for RH TRU waste handling was that the FDPA cell had the waste load out capability. The NWCF "hot cell" requires hands-on handling for closure of the drum lid and removal from the cell. The data from the radioactive work permit tracking in each facility clearly demonstrates the benefit of remote handling of the product drums. The allowed dose equivalent rates for handling in the FDPA are an order of magnitude higher then in the NWCF while the highest dose received by a worker, the average dose per person, and the average dose per container are almost a magnitude lower. Table III provides a comparison between the two facilities.

In addition to the waste load out system, the FDPA has several other features that contribute to the lower personnel exposure levels. Some of these include the FDPA hatch covers, which provide better shielding from the "hot cell" due to more robust design, more shielding was installed in the facility due to increased space and floor loading design, and a much bigger facility gives increased distances.

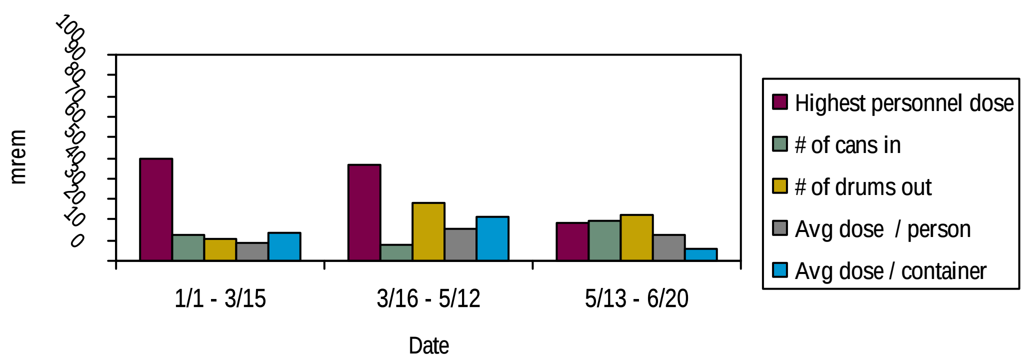
Table III – Comparison of Radiation Protection Measures for NWCF and FDPA
(January 1, 2010 through June 30 2010)

	NWCF	FDPA
Facility Container Limits	< 20 rem/hr @ 30 cm from container surface	< 230 rem/hr @ 30 cm from container surface
Approved Dose Estimate	3,923 mrem	2,225 mrem
Total Accumulated Dose	1,233 mrem	941 mrem
Total Personnel on Radiological Work Permit (RWP)	47	62
Highest Person Dose	225 mrem	68 mrem
Number of Containers Placed in Cell	10	40
Number of Product Drums Removed From Cell	18	61
Average Dose/Person on RWP	26.2 mrem	17.1 mrem
Average Dose/Container Processed	44 mrem	9.3 mrem

CONTINUOUS EVOLUTION OF PROTECTION MEASURES

As work progressed in the FDPA over the first six months, improvements were made in the operations. Initial operations in the facility utilized a drum out port similar to the NWCF for waste reading <20 rem/hr at 30 cm from the surface of the container. In March 2010, the waste load out capability was placed into service and the allowed radiation limit was increased to <100 rem/hr at 30 cm from the container surface. As seen in the Figure IV, there was a slight increase in the average dose per container and per person but was far less than the 5 fold increase in allowed radiation exposure levels. From January 2010 through mid-March 2010, up to 20 rem/hr input containers were allowed to be processed and the top cell tent drum out process was used to remove the product drums.

Figure IV – Effect of Radiation Protection Measures Over Time



Beginning in mid-March 2010 through mid-May 2010, up to 100 rem/hr input containers were allowed to be processed. In April 2010, a shielded transfer device (STD) (shown in Figure V) was placed into use for waste transfers within the facility. The need for this device was driven by the evaluation of the potential for a crane failure in the facility and it was determined that with a suspended load of >100 rem/hr @ 30 cm from the surface of the load, the crane could not be approached for repair. Beginning in mid-May 2010, after several weeks of STD use, the exposure limit for waste was increased to <230 rem/hr @ 30 cm from the container surface and there was a one time operation conducted with the highest dose equivalent rate waste can which was 1,450 rem/hr @ 30cm from the surface of the can. As shown in Figure IV, once the STD was placed into use, the exposures actually decreased even with a doubling in the allowed radiation limits. In addition, this figure provides an indication of the effectiveness of the continuous improvement process applied to radiological protection. As the number of containers processed increased and the dose equivalent rate increased dramatically, the average dose incurred per person increased only slightly, while the average dose per person per container processed actually decreased.

Figure V – Shielded Transfer Device

The challenges described have been specific to the hazards involved with dealing with high radiation levels. The scope of the initial RH TRU operations in the NWCF involved repackaging of 30 gallon drums. Therefore, all of the radiation protection and facility operations were geared accordingly. With the addition of the ARRA work scope, the waste containers presented some challenges that were compounded by the high radiation levels. The radiation levels were predicted to increase from a prior high of 50 rem/hr on contact to up to 5,000 rem/hr on contact. The waste containers were much different from the 30 gallon drums; they were welded closed stainless steel containers ranging from 6 feet tall to approximately 14 feet tall. This presented challenges for handling and placement in cell. There were many places where hoisting and rigging considerations in relation to stack height caused several iterations in design. The opening of these containers in cell caused the need to develop a cutting method, a waste sorting table, and a way to get “clean” drums of the process for characterization, storage, and shipping. The waste in general was packaged over 20 years ago so the best information available was provided for designing the equipment required for the operation. As would be expected, there were many surprises on different container and waste configurations. The work force has been diligent on stepping back when encountering unexpected situations and has therefore successfully recovered from the surprises encountered.

The challenges presented by the ARRA work scope caused an evolution of the protective measures. The ISC was first modified to allow the taller waste cans and then was upgraded with additional shielding to allow for the higher radiation level product cans. The STD was used as the basis for a design for a new facility transfer container (FTC) to be used for the taller containers and was also designed to be used as a storage container for the new, taller waste containers, thus eliminating one step in the process. A method for transfer of the tall waste containers into the facility was developed, designed, fabricated, and implemented that eliminated the need for any facility modification.

Besides the significant changes, like the FTC, there are still changes being made as lessons are learned or the operators find a more efficient approach. Specific areas where the continuous improvement process has been beneficial include the amount and locations of shielding, bagging of the waste for contamination control, and use of remote/reach tools. An engineer is placed on each crew so that problems can be addressed immediately and so that engineered changes can be made easily in the next evolution of the operation.

In order to ensure that the operation is continuously improving for protection and efficiencies, it is very important to engage the work force within the engineering and management process. The process used for developing new RH TRU equipment or operations is similar to a value engineering process. All affected work disciplines are involved in a brain storming session. The session conclusions and paths forward are documented, and all parties agree prior to doing any design work. The group meets periodically through the design and fabrication stages to be informed of any changes required. Any equipment is then mocked up outside of the facility and placed in the facility for dry runs. To ensure day to day continuous improvements, the facility management has to have an open mind for suggestions or changes from the work force and observing organizations.

CONCLUSION

RH TRU waste operations have been underway for over 5 years. Over this time frame the work scope has expanded causing a change in hazards and a change in needed facility space and equipment. The successful use of lessons learned, involving workers in planning and design changes in the process, and careful planning led to the low doses recorded. The outstanding safety record and control of dose during operations contributed directly to the added work that was funded by the ARRA program, as well as other work scope added by other agencies at the INL Site. As the result of an aggressive radiation protection and management program, throughout the changes, personnel protection has remained a top priority. Being able to integrate worker feedback into the planning process, utilizing lessons learned from prior experience in the management of RH TRU waste, and the use of a facility better suited for processing of highly radioactive waste has allowed for the safe and efficient repackaging of RH TRU waste for shipment to WIPP. To date, the project has:

- Processed 675 original containers of RH TRU and completed 207 shipments to WIPP
- Produced 189 drums from processing 105 additional larger, higher radiation dose containers and completed 24 shipments to WIPP
- No recordable injuries in over 3 years
- No loss of contamination
- No worker exposures above the annual administrative control limit of 700 mrem
- No overexposures
- No skin or clothing contaminations
- No compromise of High Radiation Area controls
- No WIPP compliance issues and have met all shipping schedules

With continued focus on personnel protection, this record should continue, paving the way for even more difficult waste processing activities in the future.