Operating Experience from RH-TRU Processing at the Argonne National Laboratory Building 205 K-Wing Hot Cell Facility

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INTRODUCTION

This paper describes the operating experience derived from processing Transuranic (TRU) waste at the Argonne National Laboratory Building 205 K-Wing nuclear facility, a small quantity TRU waste generating site. The objective of the project is to remove (de-inventory) sufficient quantities of radioactive materials from the facility to reclassify it as a less than Hazard Category 3 nuclear facility. The high hazard category contributing materials are primarily the remote-handled transuranic (RH-TRU) waste. The project contains many unique challenges and substantial time constraints.

The facility had been used for performance of experiments with irradiated test specimens and consists of three shielded cells, an operating area, and a laboratory/service area. The waste material in the hot cell facility includes both liquid and solid waste. The waste is primarily RH-TRU and contact-handled transuranic (CH-TRU) waste that requires treatment and handling prior to disposal at the Waste Isolation Pilot Plant (WIPP). Additionally, as part of the project, the facility was required to upgrade its safety basis to a Basis for Interim Operations (BIO) per DOE-STD-3011-2002 to provide controls for the de-inventory.

De-inventory activities have been accomplished through the execution of work control documents (WCDs) designed to characterize, handle, package, and/or remove specific radioactive materials from the facility.

Project challenges include:

- Development of a method to adequately process the liquids into solid form acceptable for packaging and shipment to WIPP. A process was developed to solidify the aqueous acidic waste using sorbent material and was validated by a third party consultant.

- The WCDs developed for this project had to be approved by the U.S. Department of Energy-Office of Science (DOE-SC) in Washington, D. C.

- The WIPP Acceptable Knowledge (AK) resources were not dispatched to the site until the project was five months from its imposed deadline date.

- Solid processing required the design and construction of special equipment to minimize the spread of contamination and radiation dose to workers, including an alpha control barrier to minimize the spread of contamination and a remote-operated gated drum shield (GDS) for minimization of worker dose.

- Part of the material to be dispositioned consisted of higher activity fuel examination waste remaining from previous separation science experiments. At the start of the project the disposition path was undetermined.

Liquids inventory consisted of approximately 175 liters of aqueous nitric acid waste liquids. The basic process for treating the liquids included identifying, staging, and bulking like liquids. Aqueous acidic liquids were then planned for solidification using NoChar N940 sorbent. Multi-phase (organic/aqueous) solutions were to be separated, the aqueous nitric acid waste liquids to be solidified with Nochar N940 sorbent, and the organic waste streams to be transferred out of the cell for subsequent treatment as low-level waste (LLW).

The basic process for processing solids included sorting the waste and identifying and segregating and/or remediating any prohibited items. In order to complete this process, several pieces of special hardware were designed and fabricated. An alpha barrier with a drop chute was designed and fitted into the C-Cell that allowed for dropping material into the packaging drum from B-Cell and also provided a barrier to prevent the spread of contamination from B-Cell to C-Cell. A special GDS was developed that fit around a standard 55-gallon drum that provided for shielding while closing and moving the drums from the facility. Also, a special closure device was designed that allowed for easy, remote closure of the drums, helping to minimize personnel exposure. After materials were size reduced, they were loaded into drums through the drop chute in the alpha barrier. When drums were filled they were transferred to another facility for staging prior to further characterization and subsequent shipment offsite to WIPP.

This paper summarizes the experience and lessons learned from this project.

Argonne National Laboratory / Facility Description

Argonne National Laboratory's (Argonne) mission is to serve DOE and national security by advancing the frontiers of knowledge, by creating and operating forefront scientific user facilities, and by providing innovative and effective approaches and solutions to energy, environmental, and security challenges to national and global well-being. Argonne's work is supported by DOE-SC.

Argonne is one of 23 DOE national laboratories and technology centers. Argonne is located on 1,508 acres in DuPage County, IL, 25 miles southwest of downtown Chicago. Argonne's campus includes some 105 buildings and 109 other structures.

The Chemical Technology Building (Building 205), containing the K-Wing, was built during the 1949 to 1950 time period. The K-Wing kilocurie hot cell complex was designed to conduct metallurgical research on radioactive fuel materials. The facility consists of three heavily shielded cells, an operating area, and a laboratory/service area. The shielded cells are designed to handle up to 10,000 curies of 1 MeV gamma activity in Cells A and B and 10 curies in Cell C. A series of five remotely operated manual manipulators service Cells A and B. These manipulators operate in the x, y, and z planes and have a hand that can rotate 360^{o} around the z-axis as well as pivot 180^{o}. These manipulators can lift loads of up to 15 lbs. Cell C has a PaR 3000 arm that is electrically operated. A similar device previously existed in Cell B but has been removed. Cells

A and B also have a hoisting mechanism that can lift heavier objects. The floor plan of the Facility is included as Figure 1. Specific experimental activities in the facility involved the development of pyroprocessing techniques, aqueous biphasic extraction studies, long-term testing of radioactive waste forms, and experimentation with the Uranium Extraction (UREX) solvent extraction process and separation sciences chemistry. Programmatic operations in the Building 205 K-Wing were suspended temporarily in July 2007. Subsequently, Argonne decided to make that suspension permanent and to de-inventory the facility.

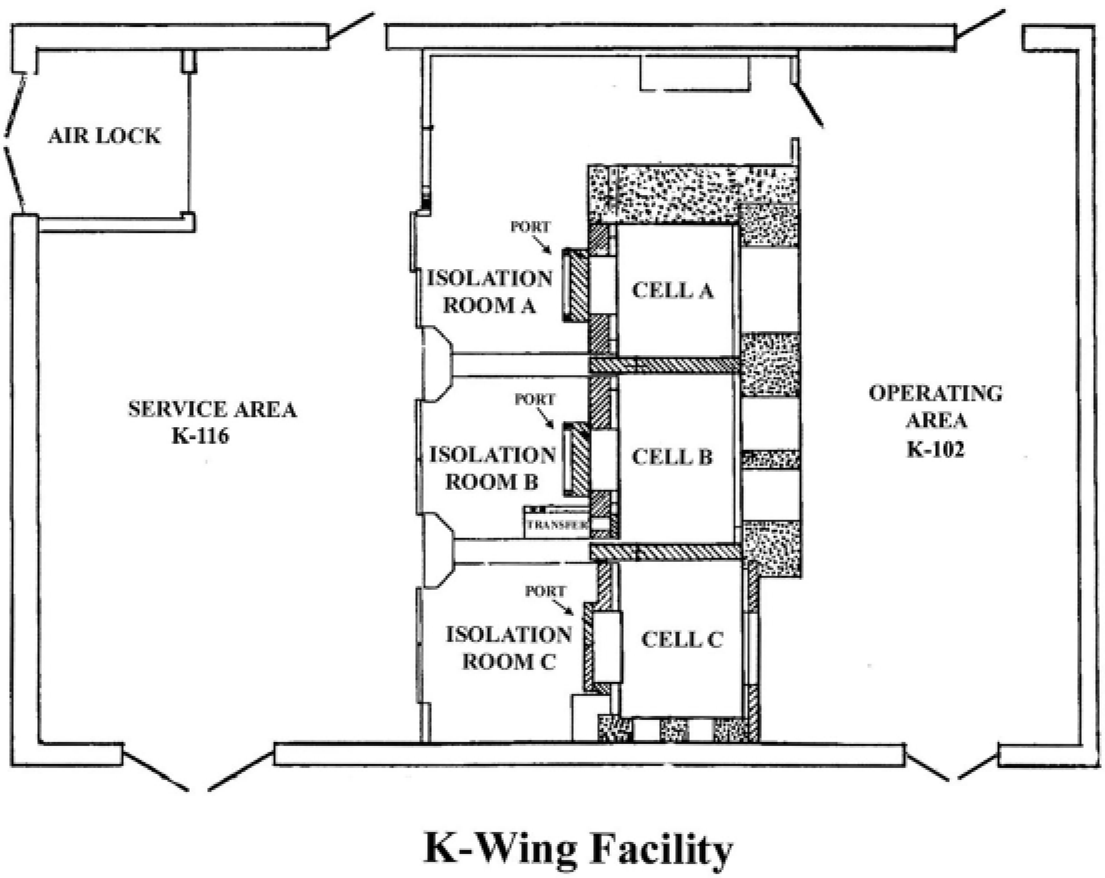

Figure 1 Floor plan of Building 205 K-Wing

205 K-Wing Waste Materials

Solid materials in the Building 205 K-Wing facility with a high Hazard Category (HazCat) contribution are predominantly fuel examination waste (FEW), i.e., source-derived irradiated test specimens contained in various intermediate containers such as jars, stainless steel capsules, paint cans, etc. and/or inside of temporary shielding. The contaminated in-cell equipment / debris also contribute to a lesser degree to the radioactive material inventory. This material is being sorted, compiled, and packaged to meet certification and shipping requirements. The facility inventory also includes aqueous and organic solutions containing various dissolved FEW source materials in a variety of plastic and glass containers. The technical approach for the majority of the waste in the facility is to prepare the material for disposal at WIPP as primarily RH-TRU waste with a smaller subset of CH-TRU and also low-level and mixed waste.

PROJECT DESCRIPTION

The Building 205 K Wing nuclear facility is a HazCat 2 nuclear facility per DOE-STD-1027-92. The objective of this project is to remove sufficient quantities of radioactive materials from the facility to reclassify it as a less than HazCat 3 nuclear facility.

The scope of the deactivation project is:

1. To implement the DOE-approved safety basis document:

    a. A deactivation BIO developed in accordance with DOE-STD-3011-2002 to provide controls for de-inventorying the facility (including hot cells) to less than HazCat 3 is currently under DOE for review.

2. De-inventory activities will be accomplished through the execution of work packages designed to characterize, handle, package, and/or remove specific radioactive materials from the. Work packages are comprised of work clearance permits that integrate job hazard analyses, radiological work and industrial health permits, and detailed job instructions. This allos the work to be performed safely and in accordance with Argonne environmental, safety, and health standards while ensuring compliance with the approved safety basis. The work to be performed as described in the BIO and Deactivation Plan includes:

    a. FEW encapsulation/packaging

    b. liquids processing, packaging, and removal, and

    c. residual solid material removal including material in hot cells (RH-TRU certification and packaging activities are integrated into this activity).

NEW AND IMPROVED PROCESSES

As the project began to plan the process for accomplishing the goals, previous site experience with packaging RH-TRU waste drums in the Building 212 Alpha Gamma Hot Cell Facility (AGHCF) was leveraged to the maximum extent possible. The project utilized lessons learned from previous projects and improved in other areas. For example, contamination control lessons learned led to the design of the alpha barrier and previous personnel radiation exposure analysis led to the design of GDS and the 55-gallon Closure Ring and Preuss Device. Unique to this project, however, was the need to solidify liquids to meet WIPP packaging requirements. Development of these items is described below.

Liquid Processing Sorbent Selection

In the Building 205 K-Wing hot cells, both aqueous and organic liquid wastes are contained in plastic or glass bottles mostly ranging in size from one- to four-liters. Most of the liquids in the hot cells are aqueous waste composed of nitric acid (HNO3) with a concentration in the range of 1-6 M. Lesser quantities of aqueous wastes containing guanidine carbonate (GC) or lactic acid (LA) are also present in the hot cells. Because of their lower radioactivity, organic liquid waste will be solidified and handled outside the hot cells as LLW. There are also multi-phase liquids, those having both the aqueous and organic phases, in the hot cells that will be separated before the aqueous phase is solidified. A WCD was developed to identify tasks and activities necessary to safely perform effective solidification of these aqueous liquid wastes so that they could be properly packaged for inclusion in the RH-TRU waste stream. This work is scheduled to be performed in March of 2010.

The project planned to originally utilize AcidBond (A660), a polymeric absorbent manufactured by Nochar, Inc., for solidification of aqueous acidic waste solutions. As an alternative, the project also evaluated AcidBond (N940), a mixture of A660 and soda ash that neutralizes while solidifying. A variety of radioactive liquid wastes at DOE sites have been successfully solidified using A660/N940. The project performed initial testing with simulated liquid wastes that were based on actual waste compositions of 6M HNO3, 100 g/L GC and 1.5 M LA in the hot cell inventory. Based on visual observation, no free liquid was present; however, no standard analysis or environmental stability tests had been conducted on the solidified waste liquids.

To support development of the WCD, a treatability study was conducted by an independent subcontractor to confirm the effectiveness of A660/N940 to solidify the above waste streams at a dose ratio of absorbent to liquid recommended by the manufacturer. For an additional safety margin against the release of free liquid, the absorbent dose was increased by 20%. Effectiveness of solidification was initially based on the solidified liquids passing the SW-846 Method 9095 Paint Filter Test (PFT). The corrosivity and reactivity of the solidified liquid was based on pH as measured using SW-846 Method 9045D.

Three environmental stability tests were conducted to examine the potential for solidified liquids to release free liquid under adverse conditions of pressure, temperature, and vibration occurring during transport or interim storage. The solids were subjected to three freeze/thaw cycles (25 – 90^{o} F) over 3 days. In the pressure test the solids were subjected to a vacuum (260 mm Hg) representing an altitude of about 26,000 feett above sea level for 4 hours. In the vibration/heat test the solids were subjected to vibration at 1,700 cpm and a temperature of 115^{o}F for 24 hours.

The testing indicated the following conclusions:

1. The Nochar absorbent A660 without neutralization generated nitric acid solids having a pH well below 2.0. These solids could be considered highly corrosive.

2. The Nochar N940 absorbent effectively neutralized and solidified simulated nitric acid waste at the manufacturers recommended dose of 1:1. The resulting solids also passed all three environmental stability tests. Because of the varying densities of nitric acid, it was

recommended that the absorbent dose be set at 1.4 g N940 to 1 mL nitric acid waste (1.4:1). This ratio is adequate for dilute nitric acid up to a 6.7 M concentration.

3. Effective contact between the absorbent and the liquid was obtained either by adding the liquid to the absorbent or by adding the absorbent to the liquid. However, inadequate dispersion and poor contact between the absorbent and the liquid resulted when the liquid layer in a given container had a thickness exceeding one-half inch.

Gated Drum Shield

A remote operated GDS was designed and fabricated at Argonne for performing RH-TRU waste packaging operations. RH-TRU waste is highly radioactive and poses a significant exposure risk to workers who must handle the waste containers. This innovation was aimed at reducing radiation exposure to workers assigned to package and load out RH-TRU waste associated with the Building 205 K-Wing Deactivation Project.

There are several features associated with the remote-operated 55-gallon GDS, as well as the outload procedures, that have ensured RH-TRU drums generated during de-inventory operations have kept kept worker radiation exposure as low as reasonably achievable (ALARA). The following general features were designed into the equipment and processes:

- Three inches of lead shielding around a 55-gallon drum.
- Split closure lid with hinges to minimize spatial requirements when opened.
- Robust casters to allow workers to move the cask into position under the alpha barrier drop chute located inside of C-Cell.
- Attachment of GDS to a power pusher to be used to move the cask into and out of the work area.

The following additional functional features were designed into the equipment and processes:

- Overall size allowed maneuvering the gated cask into the 205 K-Wing C-Cell where RH-TRU packaging operations were to take place.
- Pneumatic controls located outside of C-Cell with cable passing through the hot cell shield wall to allow hot cell operators to remotely operate the gated cask closure lid.

Figure 2 shows the remote-operated GDS as built and in the open position.

Figure 2 GDS in Open Position

Alpha Barrier

The project needed to develop a system that would minimize the contamination in the C-Cell during outloading operations. To accomplish this goal, an alpha barrier was designed, fabricated, and installed in the C-Cell just outside of the B/C gamma shield wall. The following were design features of the alpha barrier during conceptual design:

- Easy to assemble from readily attainable materials (Lexan, Unistrut, Herculite, etc.)
- Required no permanent modifications to the hot cell structure
- Accommodated pouches up to the size used in 55-gallon drums
- Allowed the use of the PaR manipulator and hoists
- Compatible with the GDS

- Useable from the B-cell side with the current manipulator configuration when the B/C shield door was opened
- Transparent in areas where visual confirmation is needed to ensure waste conformance and for ease of operations
- Equipped with a remotely operated hatch that allowed pass-through of items (rather than pouching)
- Equipped with a small hoist to lower heavier items into the drum/pouch assembly
- Included a camera that would show the drum/pouch interior from above

Figures 3 shows the alpha barrier as built.

Figure 3 Alpha Barrier Mock-up As-Built

55-Gallon Closure Ring and Preuss Device

A 55-gallon drum bolt-on closure ring was designed and fabricated for performing RH-TRU waste packaging operations. RH-TRU waste is highly radioactive and poses a significant exposure risk to workers who must handle the waste containers during loading and shipment. This innovation was aimed at reducing radiation exposure to workers assigned to package, load out, and ship RH-TRU waste associated with the Building 205 K-Wing Deactivation Project.

There are several unique features associated with the 55-gallon drum bolt-on closure ring with inboard closure lugs that are not found on standard 55-gallon drum bolt-on closure rings. They are discussed below:

- The closure ring design allows for direct loading of RH-TRU waste into a 55-gallon drum rather than into a 30-gallon drum that had been used on previous RH-TRU campaigns.

- The closure ring design was tested as a U.S. Department of Transportation (DOT) Type A package with >900 lb payload and successfully passed all performance tests.

- The closure ring design will continue to result in a significant reduction in the number of containers that must be loaded (30-gallon drum = 4.0 ft^3 vs. 55-gallon drum = 7.5 ft^3), resulting in a reduction in exposure during packaging and out-load operations. The reduction in the number of containers to be loaded into a Removable Lid Canister (RLC)/RH-72B shipping container will also reduce exposure during shipping operations and will result in less risk/exposure to the public due to the reduced number of shipments from Argonne to WIPP.

The closure ring design allows the closure ring to be expanded using a mechanical device that attaches to the closure ring with locking pins. Once this remote closure device, named the Preuss device, is installed, closure ring is expanded so that the ring fits smoothly over the drum closure lid. The closure ring and Preuss device are staged inside of the hot cell along with the waste drum and lid.

The closure ring design allows the closure ring assembly to be placed on the waste drum remotely using a PaR 3000 manipulator. Once the drum is filled, the closure ring is remotely placed on the drum and properly seated. Figure 4 shows the drum closure ring and Preuss device expanded.

Figure 4 Drum Closure Ring with Preuss Device "Expanded"

Once the closure ring is in position, the operator releases the lever-actuated device with the PaR manipulator allowing the closure ring to constrict and snugly fit around the drum closure lid and chime. Next, using the PaR manipulator, the operator tightens the closure bolt and jamb nut in accordance with manufacture instructions and the Preuss device is removed. Closure of the RH-TRU drum is completed remotely with minimal radiation exposure to the operator.

The closure ring design allows a 55-gallon RH-TRU drum to be safely loaded directly into the RLC because its design has inboard closure lugs. Typically, the outside diameter of a 55-gallon drum with standard ring installed is greater that the inside diameter of a RLC. The Argonne-designed ring positions the lugs on the inside of the ring, thus reducing the overall diameter of the drum. Before the new ring was developed, 55-gallon drums could not be used for direct loading of RH-TRU waste because the standard ring had to be replaced with a lever lock ring. This did not meet the same DOT performance standards as the bolt ring and therefore reduced the margin of safety associated with the container. The Argonne ring design meets the same DOT performance standards as the standard bolt-on ring and permits a 55-gallon drum to be directly loaded into an RLC.

PROJECT CHRONOLOGY AND CHALLENGES

Schedule and Resources

In December 2008, Argonne submitted a Nuclear Footprint Reduction and Deactivation Plan to DOE. As part of this plan, Building 205 K-Wing was to be deactivated to less than Hazard

Category 3 by March 2010. This plan called for implementation of a new safety basis in addition to Fuel Examination Waste Encapsulation, Liquids Processing, and Solid RH-TRU Material Processing.

The DOE responded to this plan in February 2009 requiring that 205 K-Wing be downgraded to a radiological facility (less than HazCat 3) by December 31, 2009. Argonne submitted a revised plan on March 9, 2009.

Initially, project funding was received from Laboratory overhead accounts. Facility and project staffing was minimal. Facilities resources consisted of a facility manager, an assistant facility manager, and a relatively new hot cell operator. Project resources initially consisted of only the project manager. By the time American Recovery and Reinvestment Act (ARRA) money was approved and available to the project, only six months remained until the project deadline. Some additional project resources were added, however, there remained insufficient time to hire and train new facility personnel that would accomplish the hands on work. In September 2009, two additional qualified hot cell operators were loaned from other facilities to assist with the hands-on work.

Implementation of New Safety Basis and Work Packages

On March 24, 2009, the DOE approved the 205 K-Wing BIO. As part of this approval, DOE required that work could not be conducted in Hot Cell A or Hot Cell B without DOE Headquarters approval. This required that all work packages for work inside the Hot Cell portions of the facility be forwarded and approved in Washington.

In May 2009, the new BIO was fully implemented by the facility. This was the first safe harbor-compliant safety basis approved and implemented for an Argonne facility.

The work package and the activity-specific hazards analysis (AHA) for Liquids Processing was submitted in June 2009 and approved by DOE. After an internal Management Assessment of readiness, work was conditionally authorized for start-up in August 2009. Full start-up was authorized in September 2009. The Solids Processing AHA work package was submitted in July 2009 and approved by DOE in September 2009 and full start-up was authorized in November 2009.

Solids Process Refinement

Once the prototype equipment cited in the previous section was in place, the fundamental process needed to be proven through mock-ups. The GDS was delivered to the facility in September 2009, at which time procedural practice with the actual equipment commenced. A series of mock-ups was conducted first in K-116 to walk through the process. During these sessions several modifications to the procedure and equipment were made. Of particular concern was the pouch sealing operation. Initial attempts took over 20 minutes to seal the pouch using the radio frequency (RF) pouch sealer. Since the project anticipated that the radiation dose rate might be as much as 1 Rem/hour during the operation, a time reduction was sought. By reducing the amount of pouch material between the drum and the chute and by stretching the remaining material flat, the pouch sealing was reduced to about 8 minutes in mock -up operations.

After fabrication of the first drum closure rings, the need for a device to squeeze the ring to achieve the proper torque became apparent. Project engineering resources were engaged to design such a device. The mechanism needed to both squeeze the ring and lift the drum at the same time. This device was fabricated by Argonne's Central Shops organization and delivered to the facility for use during the second drum sealing and outload iteration in November 2009.

WIPP Packaging Requirements

Initially, the project plan was devised to clean out the cells and package the RH-TRU into drums "at risk" for storage until the disposition path could be clearly determined. In May 2009, project personnel met with DOE-Carlsbad Field Office (CBFO) / WIPP-Central Characterization Project (CCP) to discuss the accelerated 205 K-Wing schedule and inclusion of the 205 K-Wing waste into the existing Argonne RH-TRU waste stream and AK Report.

During July 2009, WIPP-CCP AK support personnel visited Argonne to initiate the 205 RH-TRU waste stream data collection. This visit was extremely successful as the decision was made to include the 205 K-Wing waste in the current AK Summary Report debris waste stream, because of the similarities between the 205 K-Wing waste and the AGHCF RH-TRU waste. This approach saved considerable effort by WIPP-CCP to establish a new AK report. A draft report was issued in early September 2009 and the final report was approved in early October 2009.

WIPP-CCP radiological characterization personnel engaged in conference calls in September 2009. Their review of the data supplied to them by Argonne indicated that it was insufficient for radiological characterization purposes. Radiological characterization personnel visited Argonne in early October 2009 for a first hand view of cell conditions. Based upon this visit, sampling and analysis plans (SAPs) for both liquids and solid were initiated. The first draft of the solids SAP was issued in late October 2009 and final approval was received in early December 2009. The liquid SAP was received as a draft for comment in late October 2009.

The liquids SAP required a significant change in the planned process for handling liquids. Instead of solidifying liquids in small batches from the various sources, the sampling plan required the liquids be consolidated into several very large batches to perform sampling of more homogenous batches. The solids sampling required taking smear samples of approximately 50 surfaces in the cell and grouping those into 19 samples for analysis. The results of the samples provided input to a radiation characterization model that determined the radiological constituents of the RH-TRU drums to meet regulatory requirements. The final solids SAP was approved in early December.

Milestone Extension

Based upon the time required to finalize and approve the AK requirements and the changes in the process that it required, on November 6, 2009, the DOE granted an extension of the deadline to reduce the 205 K-Wing inventory to below Hazard Category 3. The deadline was extended until

June 30, 2010, with an interim milestone to have the facility below Hazard Category 2 by December 31, 2009. The interim milestone was accomplished on December 18, 2009.

Solids Processing Initiation

Upon approval to start, the project initiated solids processing on November 5, 2009, with the first drum being outloaded from the facility on November 9, 2009. Soon after drum packaging operations began in the hot cell, the limitations of the manipulators and hoisting mechanism became apparent. The manipulator arms are limited to lifting objects of no more than 15 lbs. The hoisting mechanism, which could lift much heavier objects, could not position objects above the drop chute in C-Cell. Project engineering resources were engaged to design a hoisting mechanism that could lift heavier objects in B-Cell, transfer them into C-Cell, and position them over the drop chute for packaging into the 55-gallon drums. They devised a rail mechanism that mounted to the installed alpha barrier over the top of the shield door into B-Cell to which a hoist mechanism was mounted. This hoist was tested up to a capacity of 250 lbs., which allowed for lifting and packaging of heavy items while reducing wear on the manipulators. This mechanism was delivered to the facility and installed on December 12, 2009.

FEW Packaging

Prior to the start of the project, there was not an approved waste disposition path for the FEW. In the previously cited trip to WIPP by project personnel the determination was made that FEW would be acceptable at WIPP. The challenge then became how to package this waste to meet transportation and WIPP requirements. The FEW consisted of high activity source-derived solid pieces of various sizes. A previously designed inner ALARA shield was deemed too heavy to be used with the manipulators in the hot cells. A smaller, less costly design was developed. The first of these inner ALARA shields were delivered on November 30, 2009, to the facility and used to shield the first FEW into RH-TRU Drum #6.

LESSONS LEARNED / CONCLUSIONS

The Argonne Building 205 K-Wing Deactivation Project continues. While the project has experienced many challenges, much has been safely accomplished in a short period of time. The facility has implemented a BIO. Also, the facility nuclear material inventory has been reduced to below Hazard Category 2 levels by visually examining, packaging and outloading nine drums of RH-TRU waste. The sampling and analysis to characterize the solid and liquid wastes has also been completed.

Many innovations and prototype equipment were designed, fabricated, and successfully implemented in the facility to support project goals. Without a creative, persistent, and motivated project team with strong facility, operations, and project management, and programmatic scientific, and engineering support, the project could have been mired in delays resulting from inadequate existing equipment and possible contamination/dose issues. Also, the WIPP-CCP AK support was timely and their project integration was seamless. The project contained many unique challenges and time constraints but was able to protect workers and maintain their dose ALARA. The project continues with most of the challenges successfully overcome.