

Preparing, Loading and Shipping Irradiated Metals in Canisters Classified as Remote-Handled (RH) Low-Level Waste (LLW) From Oak Ridge National Laboratory (ORNL) to the Nevada Test Site (NTS)

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ABSTRACT

Irradiated metals, classified as remote-handled low-level waste generated at the Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee, were containerized in various sized canisters for long-term storage. The legacy waste canisters were placed in below-grade wells located at the 7827 Facility until a pathway for final disposal at the Nevada Test Site (NTS) could be identified and approved. Once the pathway was approved, WESKEM, LLC was selected by Bechtel Jacobs Company, LLC to prepare, load, and ship these canisters from ORNL to the NTS. This paper details some of the technical challenges encountered during the retrieval process and solutions implemented to ensure the waste was safely and efficiently overpacked and shipped for final disposal. The technical challenges detailed in this paper include: 1) how to best perform canister/lanyard pre-lift inspections since some canisters had not been moved in ~10 years, so deterioration was a concern; 2) replacing or removing damaged canister lanyards; 3) correcting a miscut waste canister lanyard resulting in a shielded overpack lid not seating properly; 4) retrieving a stuck canister; and 5) developing a path forward after an overstrained lanyard failed causing a well shield plug to fall and come in contact with a waste canister. Several of these methods can serve as positive lessons learned for other projects encountering similar situations.

INTRODUCTION

Canisters were historically placed/removed in the 7827 facility wells using either the High Radiation Level Examination Laboratory (HRLEL) shielded carriers or the OD-2 (source of acronym is unknown) shielded carriers. The shielded carriers were equipped to raise/lower the canister using a retrieval lanyard threaded through a small opening in the top where the retrieval lanyard would connect to the waste canister. The carriers were equipped with a bottom door that would be closed when transporting the canister and opened to retrieve/remove the canister from the shielded carrier. The carrier provided necessary shielding from the canister to facilitate transfer operations of the remote-handled (RH) low-level waste (LLW) waste. Canisters stored

in the 7827 wells processed during this work basically consisted of different sizes ranging from 1.5 meters (4.8 feet) in diameter by 10.6 meters (34.9 feet) in length, to 3.5 meters (11.4 feet) in diameter by 10.2 meters (33.5 feet) in length. The larger diameter canisters were retrieved using the OD-2 shielded carrier (having the largest inner opening diameter with thicker sidewalls) while the smaller diameter canisters were retrieved using the HRLEL shielded carrier equipped with an 'autohandler' feature.

The current canister design utilized a setup called an 'autohandler' which basically consisted of a cusp mounted on top of the canister. A retrieval device with a sensor would be lowered from inside the HRLEL shielded carrier, until it engaged the cusp which then allowed for retrieval of the waste canister. The retrieval device was lowered/raised from inside the carrier using a manually operated winch located on the outside of the HRLEL shielded carrier. The autohandler was designed to require two repetitive motions of lowering/raising and lowering/raising again before it would disconnect from the canister's cusp. This feature proved valuable during the retrieval operations when a canister became stuck in the well. The autohandler prevented the canister from becoming dislodged which could have resulted in the canister falling over 3 meters (10 feet) prior to hitting the bottom of the well (Refer to **Retrieving a Stuck Canister**).

The older historic canisters were lowered and retrieved from a lanyard that was attached to the top of the canisters. The lanyard was a one-piece stainless-steel wire rope cable that looped through a bolted connection pin (i.e., a clevis) mounted on the top lid of the canister. This setup generated a two-legged lanyard with each end requiring connection to the retrieval lanyard used to extract the canister from the well. This setup was a little more crude since the canister's lanyards would require remote retrieval from the top of the well, requiring a shepherd's hook from above, to fish the staged lanyard from within the well in order to pull the canister's lanyards to the top of the well. A shielded carrier was staged a few centimeters (inches) over the well with the retrieval lanyard threaded through the top opening to hang past the carrier's opened bottom door. The retrieval lanyard was then pulled from the bottom of the carrier to the side for connecting to the canister lanyard, which was then pulled through the carrier until threaded through the top opening of the carrier in preparation for retrieval. At this point, the shielded carrier could then be laid to rest on the interface plate on top of the well in preparation of retrieval. Handling the canister's lanyard in reverse order also proved to be a very cumbersome process. To reduce the surface dose rates, some of the higher concentrated waste canisters had concrete well shield plugs, sometimes stacked three high on top of the canister, prior to closure of the well. The shield plugs would require retrieval/removal prior to staging the shielded carrier on top of the well for retrieval/addition of a waste canister.

Prior to fabricating shielded overpacks utilized to help ensure the canisters were shipped in accordance with Department of Transportation (DOT) and Nevada Test Site (NTS) receipt requirements for disposal, every waste canister underwent a preliminary radiological survey to determine existing surface dose rates and isotopic information. These recent canister survey records showed that most of the canisters were emitting high surface dose rates, with the highest survey registering 215 Gy/hour (21,500 rads/hour) at a distance of 5 cm (2 inches) from the canister. In order to prepare, load and ship the canisters from Oak Ridge National Laboratory (ORNL) to NTS, the primary technical challenges consisted of maintaining employee

radiological exposures As Low As Reasonably Achievable (ALARA) and meeting DOT requirements.

Duratek Federal Services, under subcontract to Bechtel Jacobs Company, LLC, was responsible for the design and fabrication of the shielded overpacks used on this project. After several meetings, a shielded overpack design was selected that would house all the canisters while various inserts would be utilized to help provide added shielding (where applicable and feasible) and/or blocking/bracing for the smaller and higher surface dose rate canisters.

The process of transferring a canister from a donor well to the shielded overpack, then to the shipping cask can be summarized as follows:

1. An empty shielded overpack container was lowered into the loading-well framework (staged in an empty well).
2. A canister was then removed from a donor well by transferring it to a shielded carrier. The bottom door was closed on the carrier to help secure the canister inside the carrier, and to provide shielding along the bottom while the carrier was being relocated to another well.
3. The carrier was seated over the loading well. The bottom carrier door was opened, and the container was then lowered from the carrier into the shielded overpack.
4. After removing the carrier, the container's lanyard (where applicable) was cut using remote equipment so that it would not hinder placement of the overpack's shield plug lid.
5. The overpack shield plug with corresponding lid was installed and secured to the overpack container.
6. The shielded overpack was then placed inside a DOT shipping cask, in accordance with the DOT shipping cask's certificate of compliance, for shipment to NTS.
7. NTS would remove the shielded overpack from the shipping cask and dispose of the unit by direct burial in its permitted facility.

A crane was used for supporting very heavy, less sensitive operations. A specially designed hand-winch platform system utilizing a remote dynamometer was utilized when sensitive items and/or canisters with old existing lanyards required lifting. The dynamometer proved to be an excellent tool providing an early warning prior to excessive strain accumulating on the lanyard. Excessive strain was sometimes encountered when the canister would hang up on some of the well interface components. If excessive strain was measured, the canister could be lowered back into the well and a second retrieval attempt was performed without overstraining the older existing waste canister's lanyards. This same setup was eventually used to safely retrieve the well shield plugs.

TECHNICAL CHALLENGES

The following Integrated Safety Management (ISM) (1) and ALARA principles mentioned herein contributed to a positive work environment to resolve technical challenges while minimizing worker effective dose equivalents, and thus can serve as lessons learned to others encountering similar situations in other work environments.

The technical challenges detailed in this paper include: 1) how to best perform canister/lanyard pre-lift inspections since some canisters had not been moved in ~10 years, so deterioration was a concern; 2) replacing or removing damaged canister lanyards; 3) correcting a miscut waste canister lanyard resulting in a shielded overpack lid not seating properly; 4) retrieving a stuck canister; and 5) developing a path forward after an overstrained lanyard failed causing a well shield plug to fall and come in contact with a waste canister. During each event, work was stopped and the ISM process implemented to ensure the problem was properly evaluated. The basic functions of ISM consist of:

1. Defining the scope of work.
2. Analyzing the hazards.
3. Developing and implementing hazard controls.
4. Performing work within these controls.
5. Providing feedback and continuous improvement.

Details on each technical problem and its corresponding successful mitigation follow under each applicable subheading:

Canister/Lanyard Pre-lift Inspections

Some of the canisters being worked on during this project had not been moved in almost 10 years. There were concerns that deterioration may have occurred creating unsafe conditions. Due to the high radiation survey readings associated with several of the canisters, the option of physically looking down from the top of the well was not viable. A combination of mirrors mounted on poles, a camera equipped on a long-handled pole with a zoom feature, and a monitor setup at a distance and adjacent to the well pad, was utilized to perform visual inspections prior to retrieval of a canister. This proved useful to determine if a canister would require a high-efficiency particulate air (HEPA) filter-equipped vacuum to clean an area around the top cusp of the canister to ensure clear access for the autohandler device, or to determine if a lanyard was damaged beyond use. The camera/mirror setup proved useful during periods requiring corrective measures to help ensure tools utilized for this activity were in the proper location for implementing the corrective action (Refer to **Replacing or Removing Damaged Canister Lanyards and Miscut Waste Canister Lanyard**). This setup also proved to be a key tool in helping to ensure ALARA principles were applied adjacent to wells when visual confirmation was necessary for implementing or strategizing work processes.

The camera selected for this work was obtained from another project that required inspections inside dark vaults housing uranium oxide. The camera was purchased from Subseas Video™ and was designed for use in a dark underwater environment and came equipped with 12 light-emitting diodes (LEDs). The key problem encountered with this camera was during certain times of the day when the sun was directly overhead. The camera was not able to focus properly in very bright light. A light shield (e.g., piece of plywood) would sometimes be used to block the sun's illumination at the top of the well to obtain adequate video images. Furthermore, the work was performed during the peak of the summer, with some days reaching up to 37.8-degree C (100-degree F) temperatures. Since the case housing the monitor was black, it would become overheated and result in a blurred screen. Upon cooling, the monitor's picture

would return to normal. To correct this issue during extreme temperatures, the monitor was kept out of the sun and a cool, damp towel would be placed on the outer plastic housing. The monitor did not fail again after implementation of these practices.

Replacing or Removing Damaged Canister Lanyards

During the canister lanyard inspections, it was observed that one of the canisters had a lanyard that appeared to have been kinked, perhaps due to shield plugs, and another lanyard that had rusted and broken in half. Because of these conditions, retrieval of the canister using these lanyards was not considered a viable option. Also, the lanyard was damaged in a location that was far below the surface of the well, making installation of a Flemish eye (i.e., a type of knot) on the 'good' side impossible. The conclusion was that this lanyard required replacement.

The challenge was how to replace the lanyard remotely. The original lanyard was threaded through a clevis apparatus that screwed into the top of the waste canister lid that was located approximately 3.7 meters (12 feet) below the top of the well. The clevis had a rectangular body section that became the target for using an attachment to unscrew the clevis from the lid. Following several meetings with Duratek Federal Services and Apollo (subcontractor to Duratek), a long-handled tool was fabricated by Apollo with a crow foot-like fitting that could be used to unscrew the existing clevis. After about 3 hours of work from the surface, the existing clevis was finally loosened, unscrewed and removed from the waste canister. Besides trying to attach to the clevis remotely, another problem observed during this work was that the canister would spin which made unscrewing the clevis difficult. The use of shims to hold the canister in place was discussed but was only to be used as a last resort due to concern that this could lead to other problems (i.e., requiring a different tool to remove a canister from a well). The problem was ultimately resolved by having two people on each side of a T-handled tool device on the top of the well simultaneously hit the handle in the counter clockwise direction until the clevis was finally loosened and removed.

The long handled tool was equipped with a separate "end" fitting for screwing on a new lanyard fitting allowing for safe retrieval of the waste canister. The new fitting had a tapered screw head to help guide the tip into the lid's receiving connection. Care had to be taken to ensure enough threads remained on the tapered head such that it would engage and handle the load being lifted. The overall work was cumbersome and, even though it took over a half day to accomplish, the manual part of the work was performed to the side of the well opening using a combination of mirrors and the camera monitor, as discussed previously, to maintain ALARA.

A second waste canister was observed to have one damaged lanyard leg and one good lanyard leg. The damaged leg was kinked with a few broken strands while the good leg had no damage. Although the lanyard was installed as one continuous piece of wire rope, it was obvious from earlier retrieval processes that the lanyard did not 'slide' to equalize the weight on both legs of the lanyard. Typically, the shortest lanyard leg would pull the entire waste canister weight, with the longer lanyard leg not providing any support. To ensure this would be the case with this canister, a new Flemish eye was installed on the good lanyard leg and was designed to be shorter than the damaged leg. Both lanyards were pulled through the top of the shielded carrier with the longer, damaged leg connected to the retrieval lanyard and taped down in a manner that proved,

from a visual stance, that it was not carrying any load. The good leg was connected to the retrieval lanyard and was used to raise the waste canister off the well bottom to perform a static load test. When it was obvious that the damaged leg was neither carrying any weight nor sliding through the clevis, the canister was retrieved with plans to be lowered immediately should the lanyard reposition itself, or the damaged leg start carrying any weight. The damage leg never showed signs of carrying any load and the waste canister was retrieved safely and successfully using the good leg of the lanyard.

Miscut Waste Canister Lanyard

When a waste canister that was equipped with a lanyard was placed into the shielded overpack in preparation for transport, its lanyard would require cutting to a length short enough that would not interfere with installation of the shielded overpack's shield plug and corresponding lid. This was accomplished by utilizing some manually activated hydraulic cutters. The cutting head was designed such that it opened to allow access to go around a wire rope, and would then shut so that the wire rope was inside the cutting head opening and could not fall out. This would allow the user to feed the cutting head down into the well along the wire rope while holding onto the end of the wire rope lanyard that was extending beyond the well's upper casing. The user could continue to 'walk' the cutter head down the wire rope lanyard until it rested adjacent to or on top of the waste canister prior to cutting the wire rope. The cutter head's pump would be at the top of the well to allow for remote operations for cutting the wire rope once the hydraulic cutting head was in proper position. Mock runs were proven to be successful prior to attempting this process in the field.

However, a problem arrived when cutting the wire rope lanyard on the second overpacked waste container. The video footage showed the cutting head on top of the waste canister with the wire rope going through the cutting head and the other end at the surface of the well. After making the cut and pulling away the cutting head and a spliced section of wire rope, it was determined that approximately 1.5 meters (5 feet) of wire rope remained connected on the canister and was laying under the cutter head. The cause was failure to pull the cable tight to ensure all the wire rope available for cutting was pulled through the cutting head. Future wire rope cuts were performed in a manner to ensure such an oversight did not occur again.

The remaining piece of wire rope proved to be a problem in that it would not allow the shielded overpack's top shield plug to seat properly, thus preventing proper seating of the shielded overpack's top-locking cap. The crew attempted to retrieve the remaining section of lanyard and tried to thread the cutting head around it, but the section was cut just short enough that it fell below the surface of the well. Remote threading of the cutting head proved difficult if not impossible to complete the activity. The only other option was to remove the lanyard from the waste canister. The long-handled tool designed for replacing the damaged lanyard was equipped with an extension to be used in a 4.6-meter (15-foot) deep well, but the overpack was staged only 1.5 meters (5 feet) from the top of the well making this tool too long for this application. Shorter-handled, remotely-operated tools were developed onsite with the crow foot-like attachment to facilitate removal operations. Being on a slick newly-painted surface, the canister would spin easily making loosening of the lanyard's clevis difficult. Ultimately, the clevis finally released and the lanyard was removed. The next problem was removal of the stainless

steel clevis from within the shielded overpack. Using mirrors and various hooking devices, the piece was finally retrieved and removed from the overpack.

Retrieving a Stuck Canister

Interface plates were used to house the carriers for removal/addition of canisters that included a guide tube assembly. The guide tube is basically a sleeve that extends from a seated position at the surface, covered and held in place by the shielded carrier, and then extends into the well housing where the waste canister is stored. Due to the lip of the guide tube being inside the well casing, canisters being retrieved from the well can sometimes get stuck on the inside lip of the guide tube. To minimize the chance of the retrieval lanyard becoming overstressed and failing, instructions required the operator to lower the canister back into the well when the retrieval lanyard was under excessive stress.

During the retrieval of a particular waste container, the lanyard was obviously in a position where it was becoming stressed so the operator did what he was trained to do and lowered the canister back into the well. However, instead of traveling back into the well as usual, the canister did not budge from its current location causing the autohandler device to click into a secondary mode of operation. This meant that if the operator lowered the retrieval cable again, the autohandler would automatically release the canister and it would free fall back into the well. Operations were stopped and an all-hands meeting was held to discuss the problem and determine a solution. Based on historic experiences with the operators, this was not the first time a canister had become 'stuck' inside the well. It was believed the canister was partly inside the guide tube and the other part was on the well liner, angled such that it did not move up or down. Historically, the crew had lifted the shielded carrier to 'loosen' the guide tube setup to free up canisters. After reviewing various options, it was determined that this might be the most feasible option. To prevent radiation streaming from the base of the shielded carrier during such operations, additional lead blankets were installed around the base of the shielded carrier as an extra precaution. The shielded carrier was lifted using a crane, just enough to lighten the load on the guide tube to free the canister. The canister was then successfully retrieved and transferred from within the well into the shielded overpack for final processing.

An investigation was performed to determine the root cause for the stuck canister. The 7827 facility wells were relined prior to long-term storage of the waste canisters processed during this work. The relining process basically involved grouting of some well sleeves inside the original well casings to help minimize infiltration problems. During the installation process, apparently the sleeve on the well, previously contributing to a stuck canister, was not centered at the top, with the inner sleeve contacting the original well casing at one location. This resulted in the well casing being slightly skewed. Since the shielded carrier's interface plates and guide tube are aligned on the level surface at the top of the well, this resulted in a non-linear pathway for the waste canister, causing it to become jammed during retrieval once it was partly inside the guide tube. Once the weight of the carrier was reduced on the guide tubes recessed top lip, the guide tube was realigned with the well casing liner, allowing the waste canister to then pass freely through the assembly setup. The wells are not slated for future work, but should they be reused, any well with a skewed liner sleeve should be removed from service. This could also prove

valuable to those planning to sleeve existing wells to ensure spacers or other control methods are implemented to properly seat the sleeve into its designed and intended alignment.

A Dropped Well Shield Plug Comes in Contact with a Waste Canister

Due to the hazards associated with this work, a readiness review was performed and primarily focused on the 'new' work activities with historic activities accepted as proven techniques to accomplish work safely. Part of the historic operations included removal/addition of shield plugs staged on top of the waste canisters to help reduce the dose-rate survey readings at the wells. Such shield plugs were historically added/removed using a crane after the shielded carrier's interface plates (including well guide tubes) were installed. The shielded plugs vary in weight with the heaviest being approximately one hundred kilograms (i.e., a few hundred pounds). A lanyard with twice the safe working load limit capacity was used to retrieve/replace shield plugs during this work. During retrieval of a shield plug using a 90-tonne (100-ton) capacity Grove® crane, the plug became lodged on the well guide tube, bending it and ultimately stressing the lanyard until failure. The shield plug fell onto the top of the waste canister, and then came to rest at the bottom of the well. The area was immediately evacuated and checked to determine if an airborne radioactivity release had occurred. Radiological surveys from before and after the drop were compared and verified the absence of any airborne radioactivity or surface contamination. The crew retrieved the shield plug successfully the second time, but this time using a winch setup with a dynamometer to easily see when/if the lanyard was becoming strained so the load could be repositioned until cleared from any obstacles. A camera was used to inspect the top of the waste container, which appeared intact and free of damages that would hinder retrieval operations. The waste canister was successfully retrieved and overpacked for disposal.

During the readiness review, it was known that the waste canisters would sometimes hang up during retrieval and, thus, justified installing a dynamometer in the waste canisters with lanyard setups. This prevented overstraining and possible failure of the lanyard, similar to what occurred with the well shield plugs. The well shield plugs were curved at the edges and had been removed hundreds of times historically without occurrence. However, looking back, it would only make sense that the same type of hang-up that often occurred with the canisters could occur with the shield plugs. Process knowledge from historic operations prevented this hazard from being readily recognized and proves that new activities could impose similar hazards and, thus, should be evaluated accordingly.

IMPLEMENTATION OF ISMS & ALARA PRINCIPLES

The hazards associated with these projects were controlled and mitigated through implementation of specific work processes using the ISM approach. Work would be stopped and reevaluated when field conditions changed. Any changes to the defined scope of work were then reevaluated to verify the appropriate controls were in place, and to ensure that work was performed safely and efficiently. An ALARA review was performed prior to initiating work activities to evaluate the maximum expected total effective dose equivalent to determine stay times in high dose-rate areas. The work area was also surveyed at various distances (e.g., at the top of well surface, adjacent to the well, various distances outside of a loaded shielded overpack, the crane operator's seat, etc.) and compared to calculated exposure rates using MicroShield™

that incorporated isotopic source term concentrations for each canister. Differences between actual field survey measurements and calculated exposure rates were attributable to the survey location on the canister, thus accounting for radiation buildup and self-shielding from the irradiated metals inside the canisters.

The work activities yielded significantly lower overall effective dose equivalents to the workers than what was estimated and permitted from the ALARA review. The work activities yielding the highest effective dose equivalents occurred when employees had to remove the miscut well canister lanyard, and during relocation of the loaded shielded overpacks from the staging wells to the transportation casks. Those using similar approaches should consider this and compensate accordingly. Recommendations consist of taking field measurements on more than one side of the RHLLW canister or perhaps assume a maximum survey value over the entire waste stream volume for estimating maximum radiation field results.

The ISM process generated several safety highlights to help ensure employees performed work using time, distance, and shielding (i.e., ALARA) concepts. Some examples include:

- The maximum effective dose equivalent rates associated with loading the shielded carriers occurred along the base when a canister was being added/removed from a carrier (where the carrier rested on interface plates over the well casing). Personnel in the immediate area were elevated above the interface plates to be out of direct pathway from any radiation streaming. Additionally, the interface plates were lined with lead blankets to reduce the amount of streaming exiting from the area.
- Lanyards attached to the canisters would have to be 'fished' out of the well to retrieve the canister. An improvement in the work process consisted of staging the lanyards on top of well shield plugs to reduce employee exposure while fishing the staged lanyard out of well. Additionally, the lanyard would be long enough to be pulled outside of a well top casing while pulling the retrieval lanyard to the side in similar manner. Employees could then connect or disconnect lanyards in a low effective dose equivalent rate work area adjacent to the well.
- Some lanyards were considered old and suspect. Use of cameras and mirrors proved useful to inspect the lanyards and canisters and prevented the need for personnel to look directly into the well.
- Long-handled tools used to work on the canisters/lanyards were designed in a manner to protrude up and over the side of the well, such that personnel and their extremities did not need to make contact with the radiation streaming through the top of the well.
- MicroShield™ was used to generate estimated exposure rates and effective dose equivalent rates for the various work activities. This information was used to identify and establish low-exposure work areas (e.g., crane operator, ironworkers supporting taglines guiding the load). As an additional precaution, non-essential personnel, including neighboring subcontractors working on separate projects, were removed from the area during high dose-rate activities, such as when a shielded overpack having a thin-lined bottom was lifted high enough to facilitate being loaded into the shipping cask.

CONCLUSION

Several routine and unforeseen technical challenges were encountered prior to shipping irradiated metals in canisters from ORNL to the NTS. The work was successfully performed using DOE's ISM process that WESKEM, LLC incorporates into all of its work control processes. The ISM process is designed to ensure the hazards are analyzed and mitigated according to the defined scope of work, and to incorporate employee feedback. This process ensures that work is performed in a safe and efficient manner. Also, the ISM process includes documenting lessons learned associated with the work, which is the primary reason for this paper. The technical challenges from this project were successfully resolved without injury and without exceeding allowable effective dose equivalent limits as defined in the ALARA reviews. Furthermore, the lessons learned should prove useful to others handling RH LLW, especially when stored in an underground well environment.

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