LESSONS LEARNED DURING REMOTE TOOLING DEVELOPMENT FOR THE CLEANUP OF THE HEAD END CELLS AT THE WVDP

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PROJECT DESCRIPTION

Cleanup efforts at the West Valley Demonstration Project (WVDP) have shifted from the focus on high-level radioactive waste processing to decontamination and dismantlement (D&D) of the former nuclear fuel reprocessing plant. A portion of these D&D efforts are being focused on cleanup of the Head End Cells (HECs).

The HECs were originally used between 1966 and 1972 to mechanically prepare spent nuclear fuel (SNF) for chemical processing to recover uranium and plutonium. The HECs are heavily shielded hot cells that were used to size reduce and store the sheared SNF prior to chemical processing, and receive the leached SNF hulls for eventual transfer to an on-site disposal area. Decontaminating these facilities required the repair and replacement of failed equipment, and retrieving, characterizing, processing, packaging, and storing loose debris. Engineering work began in 1996 to plan the cleanup effort for these cells.

The Head End Cells consist of two main cells: the Process Mechanical Cell (PMC) and General Purpose Cell (GPC). Through historical reports and upon an initial radiological survey of the cell, it was found that the HECs contain a significant quantity of loose debris generated during SNF recovery operations. As a result, the HECs were heavily contaminated with spent fuel, activation products, and fission product radio nuclides. Radiation levels in the HECs range from general area dose rates of 100 R/hr to hot spots of 2,000 R/hr. Both alpha and beta/gamma removable contamination levels are on the order of billions of disintegrations per minute. Therefore, all the cleanup work in the HECs must be performed remotely.

The significant amount of loose debris discovered in the PMC and GPC consisted of general contaminated equipment and scrap from fuel and waste handling, fuel assembly hardware, leached fuel hulls, fine particles, miscellaneous fuel-bearing objects, and waste from the Analytical Cells. In addition to debris, water had infiltrated the GPC due to its below-grade location and created further damage to the cell and its equipment.

The primary consideration for cleaning up the HECs is ensuring the radiological protection of workers and the environment. The WVDP=s policy is to maintain radiation exposure of workers As Low As Reasonably Achievable, (ALARA) and the most effective way to achieve this goal is to perform operations remotely. Unfortunately in the case of the HECs, much of the remote operations equipment, including the shielded viewing windows, the GPC shield door that shielded an adjacent Crane Maintenance Room, and all the remote handling capabilities, had deteriorated to an unusable condition. Replacement and repair of the equipment was necessary before debris retrieval and packaging could begin.

In parallel with these physical facility changes, the safety and waste management bases for performing the expected work activities were reviewed and new approaches to cleanup were developed. Since the chief consideration for safe completion of cleanup work was limiting radiological exposure to workers, it was important to evaluate the criticality potential of the SNF-related debris and arrive at the most effective and efficient way to collect and package it.

The Head End Cells Project team was formed to ensure integration between the various aspects of the project. The core team consisted of a project manager and various project leads. Each of the project leads was assigned an area of specific responsibility. To aid the project leads, support personnel were matrixed into the project. The support personnel included Radiation Protection, D&D Operations, Waste Management, Design Engineering, Industrial Health and Safety, Procurement Services, Project Controls, Construction Projects, and Quality Assurance.

DECIDING THE PATH FORWARD

The HEC Engineering and Operations team discussed its options for the remote cleanup of the HECs. The cleanup of the cells required the collection of materials from all points in the cells and size reduction/packaging of an array of various sized and shaped components. The lack of any floor space and proper ground floor access points, ruled out any use of track-mounted robotics or vehicles. Each cell had access by their respective crane maintenance rooms through a shielded access door. Several options were discussed for companies supplying specific-use, crane-mounted robotics and end effector tooling. The decision was made to purchase a generic-use robotic arm deployed from a crane bridge with a trolley hoist. This robotic arm, the Bridge-Mounted Manipulator System (BMMS), and the specific tooling needed for each task would be developed by on-site personnel. It was also decided that although the GPC and PMC have different dimensions and depths, a standard mast/robotic arm should be used in both cells, allowing for shared spare parts and engineering methodology. These requirements, along with a basic set of capabilities of the BMMS were developed, including reach envelope capacity, allowable deflections and life-cycle maintenance. The BMMS was then purchased on a design-build basis. During the fabrication of the two cell bridges and mast delivery system, it was decided to purchase a third mast/robotic arm both for a mock-up and as spare parts for the in-cell units. In this way, a tooling mock-up platform was available, as well as any parts that were not separately purchased.

SHIELD WINDOW REFURBISHMENT

All the shielded viewing windows in the PMC and GPC had deteriorated to the point where they no longer provided visual access to the cells. Each of the shield window assemblies consists of leaded shield glass in a concrete/cast iron shot-filled window assembly. The spaces between the shield glass panes are filled with mineral oil. In the PMC, the total window assembly weighs approximately 15 tons (13.6 metric tons); each piece of shield glass weighs between 800 to 1,500 lbs (299 to 560 kilograms). The windows needed to be pulled from the window cavity into the operating aisle to allow for removal and replacement of the glass and fluid, but the floor in the operating aisle could not support the weight of the window assembly. To help distribute the 15-ton (13.6-metric ton) weight of the window assembly and to facilitate its removal, a structural steel extraction table was designed and installed in the aisle.

To protect the workers and control the spread of contamination during the removal process, a containment tent was erected in the operating aisle to facilitate the refurbishment work. Airborne radioactive contamination was managed by ventilating the containment tent back to the PMC through an empty manipulator port, eliminating any external local filtration system that could potentially release radioactive contamination into the operating aisle. Radiation exposure to personnel was reduced by installing temporary steel shielding around the window opening while a temporary shield door was slid into place in front of the window cavity.

Lessons learned from refurbishment of the first windows were incorporated by the project team into the field work for subsequent windows, resulting in a reduction of the time needed for refurbishment of the later windows by almost 75 percent. These radiological protection measures allowed personnel to perform the refurbishment work in radiation fields of less than 5 mR/hr and resulted in no personnel contaminations. The design and use of the table, ventilation, and sliding shield door were the main contributors to the very low exposure for the job.

GPC SHIELD DOOR REPAIR

The repair of the GPC shield door was required to allow personnel entry in the GPC Crane Room (GCR) to support removal of failed equipment. The 50-ton (45.3-metric ton) shield door had been left in a half-open position when the facility was shut down in 1972, and the drive mechanism located in the GCR had failed. The drive mechanism was further damaged from periodic flooding of the GCR from surface water infiltration. General area dose rates in the GCR were 30 to 150 mR/hr, with hot spots of greater than 300 mR/hr gamma. There was also a large amount of dirt and debris covering the floor. Removable contamination levels exceeded 1 million dpm beta/gamma. An engineering evaluation was performed with significant input from Radiation Protection and Maintenance personnel. From the evaluation it was determined that replacement of the failed components, rather than a new design and equipment fabrication, would best ensure the maximum degree of radiological protection and cost-effectiveness.

Due to the complexity of the repair work, the project team decided to construct a full-scale mock-up of the GCR. This full-scale mock-up then allowed Operations and Maintenance personnel to review each step of the repair process and develop the necessary tools and techniques to accomplish the repair. This mock-up resulted in several innovative ideas. The crane room was extremely cramped for space and did not allow for hydraulic equipment to lift and hold the 50-ton (45.3-metric ton) shield door. Two manually operated semi-trailer jacks were purchased, modified and tested to lift and hold the door in position during repair and were extremely effective. The door screw jacks and motors weighed in excess of then 400 lbs (149 kilograms) each, so they could not be manually moved or placed in the area without overhead lifting capabilities. A unit with four expanding unistrut legs and a light unistrut beam with trolley was engineered and fabricated. The unit was light enough to carry through the tents and airlock, yet it could expand and be set up as a tool positioning system for the gear boxes and motors.

The refinement and execution of the repair approach for the shield door project resulted in a personnel exposure reduction of greater than 65 percent, from the original 2,980 person millirem estimate to the actual 1,037 person millirem exposure. This can be attributed to the use of the mock-up and the tools developed.

REMOTE-HANDLING EQUIPMENT REPLACEMENT

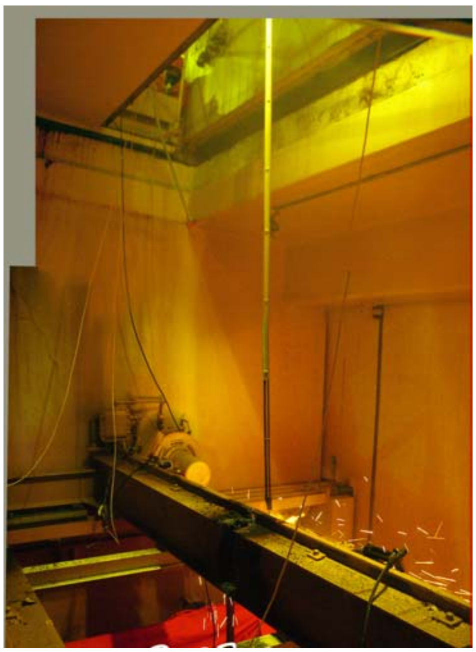

Fig. 1. Oxy-gasoline Torch Used to Size-Reduce a Crane.

Removal of the failed bridge-mounted cranes and power manipulators posed a significant contamination control challenge. New hard-walled enclosures were constructed over the existing PMC Crane Room (PMCR) and GCR to serve as buffer areas during removal and replacement of the crane bridges. Concrete roof hatches weighing up to 25 tons (23 metric tons) were removed or relocated from the ceiling of each crane room to provide ready access to the cranes during the removal process, and lighter steel covers were installed in their place.

The crane bridges were constructed of carbon steel, measured 16 feet (4.9 meters) rail-to-rail, and were 9 feet (2.7 meters) wide; each weighed approximately 7 tons (6.3 metric tons). Initial radiological data on the existing crane bridges showed high contamination levels and dose rates of 30 to 80 mR/hr, with hot spots of up to 650 mR/hr. The initial dose estimate, based on hands-on mechanical size-reduction, was 1,600 person millirem. Due to this high potential personnel exposure, the project team conducted an evaluation of alternative cutting methods. An oxy-gasoline cutting technology was found through a technology sharing program with the Fernald Environmental Management Project. The oxy-gasoline technology offered the advantages of cutting much faster and providing several safety features not found with oxy-acetylene torch cutting. In addition, a greater standoff distance between the material and the torch head was allowable, and the particulate generated was larger than that associated with plasma cutting techniques. Working directly with the torch vendor, a first-of-its-kind, 13-foot-long (4-meter-long) cutting tool was fabricated. This specially designed torch allowed operations personnel to size-reduce the PMC crane bridges while standing in the enclosure located above the PMCR.

Before using the oxy-gasoline torch, a full-scale mock-up of the bridge girder was fabricated and constructed. The mock-up provided a means to train Operations personnel on the use of the torch and refine the tools and techniques to be used. As an added measure to control the spread of contamination during cutting, a strippable coating was sprayed on the bridges and other miscellaneous pieces of equipment. The entire evolution, from setup to crane bridge removal, lasted seven weeks for the first of two PMC crane bridges. The project team reviewed the work done on the first crane bridge and implemented improvements for removal of the second bridge.

By factoring in the lessons learned, the time to complete the removal of the second crane bridge was reduced to two weeks.

The new single bridge, having both the crane and the power manipulator, was then installed through the PMCR enclosure onto the rails in the PMCR.

Because the existing GPC crane bridge was of lighter construction and thermal cutting created airborne contamination challenges, mechanical cutting was used to size reduce the bridge. The crane bridge and power manipulator bridge were moved to the GCR. Personnel entered the room and performed hands-on, size-reduction of the bridges using a special large-capacity band saw. Similar to work done in the PMC, the new GPC BMMS was installed through the GCR enclosure onto the crane rails in the GCR, then moved into the GPC.

SAFETY BASIS

A fire hazards analysis (FHA) was conducted for proposed HEC operations. The presence of combustible material and potentially pyrophoric metal (zircalloy fuel cladding) in the cells was evaluated in terms of the likelihood and consequence of fires occurring in the HECs. Fire protection measures were then devised based on the recommendations in the FHA, and included packaging combustible material first in the debris retrieval sequence, restricting and controlling the use of Athermal@ methods of debris size-reduction, and prohibiting the use of decontamination methods that would remove the oxide layer present on zircalloy fuel cladding. The physical facilities were also modified for fire protection purposes. A spark arresting screen, similar to a stove ventless hood was placed over the open hatch between the PMC and the GPC to reduce the amount of particulate sent downstream to the ventilation system filters during a fire. The screen also reduced the amount of airborne particulate that was filtered during normal operations. A supply of Class D fire extinguishing agent was placed in the PMC and GPC for delivery by the remote-handling equipment to provide fire response capabilities in case of a metal fire. A 300-pound (136-kilogram) fire extinguisher was also modified; in a fire situation the hose could be pushed through an unused manipulator port and held by the in-cell BMMS while the control valve was still in the operating aisle.

WASTE MANAGEMENT BASIS

In addition to the characterization and packaging issues for highly radioactive waste common throughout the DOE Complex, the WVDP also has some unique problems. The former spent fuel reprocessing activities at the Western New York Nuclear Service Center (WNYNSC), which includes the 220-acre (0.81-square kilometer) WVDP, were considered a commercial operation and, therefore the WVDP was not included as a defense-related facility in the legislation that created the Waste Isolation Pilot Plant (WIPP). As such, the WVDP=s transuranic (TRU) waste cannot be shipped to WIPP for disposal at this time. However, in the absence of any other disposal facility for TRU waste and recognizing that most, if not all, the debris to be packaged in the HECs would likely be categorized as TRU waste, waste packaging plans were developed using WIPP=s established contact-handled (CH) and proposed remote-handled (RH) TRU waste acceptance criteria (WAC).

There are two key factors for planning to satisfy the WIPP WAC during D&D operations: having information on the chemical, physical, and radiological composition of the debris; and using containers that either meets the WAC or containers that can later be placed into WIPP-acceptable disposal containers. However, the characterization information existing prior to cleanup was limited to only in-cell radiation measurements and partial radiological analysis from 1986. Therefore, a sequential characterization approach was taken.

An innovative in-situ gamma spectroscopy unit was deployed in the HECs. This unit aided in identifying and quantifying gamma-emitting radionuclides in debris and equipment, and targeting specific areas for sampling.

Thirty-gallon (132-liter) containers were selected for packaging debris based on the size constraints of the HECs and to allow for the greatest degree of flexibility for packaging into the final disposal containers. The hatches between the hot cells had been sized to accommodate the transfer of 30-gallon (132-liter) containers, which are essentially the same as the scrap drums used during spent fuel reprocessing operations. The 30-gallon (132-liter) container also offers more options for over-packing and shielding than are available with larger containers. The container can be placed readily into the proposed RH-TRU waste canister, or other not yet identified containers.

THE DAY-TO-DAY TOOLING

In parallel with the major equipment and program activities, a myriad of other tasks were completed prior to cell cleanup operations and included providing specific tools for remote operations, ensuring that essential spare equipment was in place and that repair capabilities existed.

The HEC projects cleanup scope of work began with the cleanup of the combustible materials to reduce the immediate potential for a sustained fire in the HECs. Materials including wood, plastics and rubber were packaged and size reduced using shears/bolt cutters that were modified for remote use.

Tools of this category were welded to steel base plates that were light enough to be picked up with the in-cell equipment, but heavy enough to not slide on existing tables while being cut. Another early remote tool developed was grips that could be attached to a safety blade cutting knife and easily handled by a remote manipulator. This knife was capable of slicing old tarps and vinyl coverings into sizes that were more conveniently handled. During this time, tooling was being developed for future size reduction activities. Due to the nature of the ventilation of the cells, any cutting technology that produced large airborne particulate or large quantities of smoke had to be ruled out. Engineers chose to take the simple approach, using off-the-shelf hand tools that hobbyists would use to cut materials and perform maintenance tasks, rather then implementing complex designs.

A bench-top band saw was modified and lowered into the cell from a crane hook. This saw was very successful in cutting up broom and mop handles, and pieces of pipe that were used during cell operations. Additional hand-held band saws were modified to cut the 8-inch-diameter (20-

centimeter) manipulators that were broken and abandoned in the cell. These saws were modified by removing the blade guards and welding in Afinger@ style guides on the non-cutting portions of the band saw rotation to allow for alignment of the saw blades during blade changes. Drill press quick clamps were modified to allow for materials to be held, or the in-cell BMMS arm would hold the piece while MSMs operated the table saws.

As the cell cleanup efforts progressed, the dose rates of the packages began to increase. Initial drums were loaded with general combustible waste using the small tooling that was readily available. These drums were low dose (<500mR/hour) and could have been packaged using hands-on methods. Engineers developed methods to minimize contamination by covering the initial waste packages (30-gallon drums [132 liter]) with a remotely removable covering. When it was time to bring the package out, the covering was removed while the drum was suspended in the air, and the drum was then immediately removed. The drums were being removed from areas where contamination levels are in the billions of counts per minute (CPM) and the resulting contamination levels on the packages removed was minimal.

Additional efforts to allow for the project=s overall dose reduction ALARA strategy were investigated in the area where the drums were weighed, measured for radiation dose, and overpacked in 55-gallon (242 liter) drums or shielded containers. The SRR was refurbished and allowed for drums to be brought out in a lower background radiation level area. Engineers developed a method to remotely take weights and dose readings, then place drums in shielded containers using a 55-gallon (242 liter) drum with pre-positioned radiation probes on it. This Aradiation drum counter@ was mounted on a standard floor scale. This allowed waste drums to be lifted from the GPC through the hatchway, where their contamination covers were removed. Next, the waste drums were placed in the radiation drum counter where weight and dose readings were transmitted to an indicator panel outside the cell. Finally, the drum was placed in a shielded container without exposing the operators to radiation. The workers now only had to enter a low-dose, low-contamination zone and bolt the final lids on the drums to remove them.

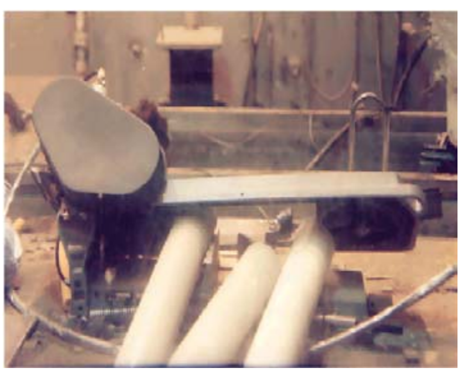

Fig. 2. Tabletop Band Saw Cutting Pipes Remotely.

The WVDP explored other areas to help reduce exposure to workers while handling waste. The Chemical Process Cell (CPC) had been cleaned out and racks installed in support of the high-level waste (HLW) vitrification project. When the vitrification process was completed and all of the available rack space had not been used, WVDP engineers reestablished the flow path between the GPC and the CPC to allow for temporary waste storage of higher-dose waste drums. This process allowed remote storage of the waste drums and ensured worker safety for storage for the TRU waste drums until the disposal path for this waste is determined.

For ease in removing some components from their mounts, impact wrenches were remotized by attaching manipulator-friendly handles on the base of the wrenches and attaching telerobotic manipulator quick disconnect for the air lines. Air was throttled by using a valve exterior to the cell and sockets could easily be handled by the manipulators. Several brands were tested to find the wrenches with proper torquing, but minimal reactionary forces.

Tool development continued with the remotizing of an off-the-shelf saw with counter rotating cutoff saw blades. The advantages of the counter rotating blades is that they produce no kickback to the BMMS and do not require the piece being cut to be clamped. The saw was modified by adding a hex bar as a handle to allow for the BMMS to grip it. The blade changeout method was experimented with and the engineers developed a method to place small, high-powered magnets in the arbor so that the blades stayed properly in place without being held. This allowed for the manipulators to position and replace blades efficiently.

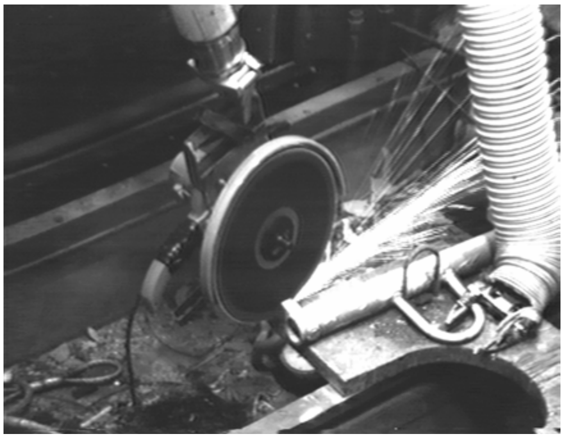

Fig. 3. An Impact Wrench Modified with Manipulator Handle and Quick-disconnect.

Engineers wanted to use shear mechanisms in-cell to help size reduce some of the materials, but the safety basis for packaging the waste did not allow for the waste to become moderated; this precluded the use of hydraulic equipment in the cells because of the probability for a leak. The team purchased an off-the-shelf, battery operated, auto rescue tool and modified it for use. The battery charging module was modified with a plug that was easily operated by a manipulator and the switches were extended for easy access. The rescue tool was deployed and could be used to quickly cut through various loose piping and rods.

Fig. 4. The Remotized Cutoff Saw Being Operated by BMMS.

When larger items started to require size reduction, the project team began developing more aggressive cutting methods. The initial cleanup efforts removed the majority of the flammable materials, and therefore spark producing tools were evaluated and tested. Two of these saws were generic cutoff saws with 9-inch and 14-inch blades and different brands of hand-held metal circular saws. The metal circular saws were found to be effective for stainless of up to 1/4 inch thick and were easy to use on large flat plate and smaller pipes. The abrasive cutoff saw was developed to cut larger diameter pipe and thicker materials. On these saws, the handles were again replaced with hex bars for use with the BMMS and the arbors were redesigned and welded into a one piece unit. A socket was welded to the arbor and allowed for the remote impact wrenches to remotely remove and replace the blades.

Visual access and lighting were issues throughout the project. Several innovative designs were used to come up with an overall acceptable means to get acceptable views and visual access to areas being worked. Traditional radiation-hardened cameras proved to be expensive, and spare parts were sometimes hard to find. The project team developed a way to install cameras that were not radiation hardened through penetrations to the cells. The cameras were pushed into the cells to get the required views, then drawn back into the walls when not in use to shield them from the cell radiation fields. Also inexpensive Aspy@ cameras were used to get looks into areas by being held by the robotic arms. These cameras gave very sharp pictures and would last for days to weeks at a time.

SUMMARY

It was decided very early in the Head End Cell project to buy a centralized, general-use robotic system and develop the tooling from that system. This path allowed for development of simple tools and one-time use tools that were inexpensive and disposable. Other, more complex designs were reviewed, but did not have the flexibility of easy changeout of specific-use tools. Another decision that was made early in the project that paid large returns was the purchase of the spare unit. This unit allowed for quicker development of tools that could be tested with remote conditions, and was available to use for spare parts that were known to operate correctly and be replaced on the in-cell units. This allowed for quicker repair turnarounds and guaranteed spare parts. The Akeep-it-simple@ principle was used throughout the project and proved to be cost-effective and efficient for all phases of the operation.

FOOTNOTE