Deactivation and Decontamination of Extraction Cell – 1 at the West Valley Demonstration Project, New York, USA – 11127

Joseph W. Ebert* and Cynthia Dayton*
*West Valley Environmental Services LLC

ABSTRACT

Extraction Cell-1 (XC-1) is the first in a series of three extraction cells in the Main Plant Process Building (MPPB) at the West Valley Demonstration Project (WVDP). Formerly used as a commercial nuclear fuel reprocessing facility, in 2010, areas of the MPPB still contained original reprocessing components and high levels of contamination and residual radionuclides associated with those past activities. XC-1 is the only extraction cell to still contain its original reprocessing equipment.

A major element of the 2007-2011 West Valley Environmental Services, LLC (WVES) workscope at the WVDP is to prepare the five-story MPPB for demolition. Three cells in the facility, two “Head End” cells where fuel was prepared for chemical dissolution and XC-1, the first phase of the fission product separation process, contained approximately 13,400 Ci, or 60 percent of the total curies, in the facility. Removing the remaining equipment from XC-1 and removing residual contamination from the Head End Cells[1] is key to successfully preparing the MPPB for demolition.

In mid-2010, WVES, prime contractor to the U.S. Department of Energy at the WVDP, initiated piping removal activities in XC-1. Using a modified, fully-robotic arm deployed through a ceiling hatch in the cell, operators began cutting away the mile of process piping inside the cell to gain access to the vessels. This paper will provide insight into the development and use of robotic tooling in this application, radiological controls for the extreme environment and lessons learned during the fully robotic dismantlement evolution.

INTRODUCTION

Dismantlement of XC-1 is a technologically and radiologically challenging project, complicated by its limited access and limited infrastructure support. The components in the cell were not designed for remote disassembly and separating the vessels from the process piping required precise engineering and planning and the use of specialized equipment. Although two other extraction cells were previously disassembled and decontaminated at the WVDP, many of the techniques used during those dismantlement projects are not applicable in XC-1 dismantlement because the radiological dose rates in the cells allowed hands-on decontamination in those cells. Due to XC-1’s high dose rates, this work would be a first-of-a-kind endeavor for the WVDP and would be groundbreaking work for the U.S. Department of Energy’s Environmental

[1] WM2011 Conference, Nitrocision®, Chilson, Winkler, 11221

Management complex. As the top-down piping removal work progresses in XC-1, WVES is gaining valuable insight into the dismantlement of rigid components in a fully remote, highly radioactive environment. As of mid-November 2010, the initial phase of pipe cutting was completed and the first vessel was removed from the cell. The second vessel was removed in mid-December 2010. Completion of this workscope is scheduled for mid-2011.

HISTORICAL USE OF XC-1

XC-1 contained equipment for the partition cycle of the Nuclear Fuels Services (NFS) spent nuclear fuel reprocessing, and was the first of three extraction cells used in a two-step solvent extraction process to separate uranium (U) and plutonium (Pu) from chemically dissolved irradiated nuclear fuel. The MPPB facility operated as a commercial fuel reprocessing venture from 1966 to 1972, and in 1972/73 was extensively decontaminated to prepare for enhanced facility operations. The facility did not reopen and fuel reprocessing activities were never resumed at West Valley. In 1982, the U.S. Department of Energy (DOE) took over control of the facility to solidify residual liquid high-level radioactive waste at the site and decontaminate the facilities used during nuclear fuel reprocessing.

Historical records indicate that NFS used a number of different decontamination solutions and water flushes which were transferred through all of the major equipment in XC-1, with the resulting effluent either flushed further through the plant systems or to waste processing. Line plugging and other operational problems were reported and noted in some of the tanks and columns, and the material plugging the lines was flushed to the floor of the cell.

DETERMINING THE RADIOLOGICAL CONDITIONS OF XC-1

WVES’ predecessor West Valley Nuclear Services Company, Inc. conducted a radiation survey of XC-1 in March 2000 using a shielded probe deployed through the small “man hatch” in the ceiling of the cell. The probe was lowered near the center of the cell, passing approximately .5 meters (18 inches) from the three largest vessels. Radiological survey readings obtained as a result of the survey ranged from 200 mR/hr gamma at the ceiling of the cell to 100R/hr gamma near the cell floor level. An increase in dose levels was observed as the probe passed by each vessel, with tank 4D-2, the bottom most vessel, exhibiting the highest dose readings. The information obtained during this initial survey was used to develop reliable and conservative curie estimates for twelve of the vessels in the cell using dose-to-curie computer modeling. Similar screening conducted on the remaining vessels associated with spent nuclear fuel radioisotopes resulted in overly conservative estimates and the use of available information for the floor provided unreliable information, therefore additional radiological analysis of the cell was required to more accurately determine the radiological conditions inside XC-1.

In April 2003, a video inspection of XC-1 was performed to verify equipment configuration inside the closed cell. This inspection confirmed the presence of an additional pot not present in available drawings of the cell, which was subsequently added to the list of cell components.

In June 2003, a mast mounted mechanical arm was deployed through the small man hatch as part of a more extensive radiological characterization effort to obtain additional dose readings for the vessels, cell and floor. A lead shielded radiation probe was deployed on the end of the mechanical arm to obtain surveys inside the cell. Due to obstructions at the floor level of the cell that prevented free movement of the mast mounted arm, the probe was removed from the arm and re-deployed on a wheeled cart at the floor level of the cell. The overall height of the cart was approximately 30.5 cm (12 inches), while the front face of the probe rested 3 cm (1.25 inches) from the floor of the cell. The cart was controlled from above to move around pipes and other interferences in the bottom of the cell to obtain ambient radiation levels directly in front of the detector.

Sampling of material from the floor and segments of four pipe sections was also conducted in 2003. An air sampler modified with a wire brush mounted on a vacuum head was used to loosen floor particulate, which was then drawn into a two-inch diameter sample cartridge for collection on a piece of filter paper. A composite sample was obtained in this manner collecting samples from three locations on the cell floor. In each location where a sample was obtained, the brush sampler removed the deposited material to the extent that the stainless steel floor liner was left in a bright and shiny condition. Pipe samples were also obtained by first tell-taling the horizontal section of the pipe to confirm there was no liquid present in the pipe section and then by cutting four one-inch sections of pipe using a portaband saw.

Using the sample data obtained, dose-to-curie modeling of the floor and piping was conducted using MicroShield™ software. The modeling was performed using a dose rate that was attributed solely to Cs-137, the primary gamma emitter present in the cell. For the purpose of modeling, contamination was assumed to be evenly distributed across the surface of the cell floor. A similar approach was taken in modeling the vessels, which were divided into two categories: those with internal structures and those without.

Based on the characterization and modeling data obtained in 2000 and 2003, XC-1 was determined to be one of the three most radioactive cells in the MPPB. All cell dismantlement activities require the use of fully remote equipment and additional shielding for operators in the control room while debris is being removed from the cell. Tank 4D-2, at the base of the cell, was the single most radioactive vessel in the MPPB when dismantlement of XC-1 began.

EXTRACTION CELL-1 CONFIGURATION AND COMPONENTS

XC-1 is constructed of reinforced concrete and the bottom of the cell is lined with 304L stainless steel that extends up the walls .5 meters (18 inches). The cell is similar in configuration to an elevator shaft, with the primary point of access to the cell being through a centrally located ceiling hatch that opens into the extraction cell chemical room (XCR), which is accessed by roof hatches that correspond to the ceiling hatches for each of the three extraction cells. A smaller “man hatch” is also present in the ceiling of the XC-1.

Approximately one mile of process piping three tanks, fifteen pots, and one exchanger were in place in XC-1 at the start of dismantlement activities. The 16.4 cubic meters (580 cubic feet) of material weigh approximately 11.16 metric tons (12.3 tons). In addition to the existing intact contaminated process equipment, a previously deployed mast mounted mechanical arm and camera system remained in the cell and also required removal. The arm, which was deployed through the man hatch and used to obtain vessel dose readings to support a characterization study of the cell conducted in 2003, was left in place for retrieval during cell dismantlement.

Approximately 100 penetrations exist in the walls and ceiling of XC-1 to accommodate process and utility piping. The cell is ventilated through the Main Plant ventilation system and receives airflow from the lower warm aisle via connecting pump niches.

GAINING ACCESS TO THE CELL

A series of four existing concrete ceiling hatches secured the main hatch opening into XC-1. They were original equipment for the cell that was installed when the MPPB was constructed in the mid-1960s. Removal of the hatches and replacement with more readily moveable hatch system was one of the preparations made to gain physical access to the cell.

A series of three tapered concrete covers were set in the hatch opening of XC-1, with the innermost hatch cover being a side-by-side thicker split concrete cover. Considerable corrosion had taken place on the steel lifting devices and removal of the hatches involved installation of new anchor lugs and lifting devices. Due to the depth of the opening, configuration and confines of the opening when the split hatch was reached, removal of the lowest hatch cover proved to be the most challenging. Following successful removal of the existing ceiling hatches, a new 7.6 cm (3 inch) thick rolling steel cover was installed over the hatch that provides ready access to the cell and enabled deployment of the new robotic arm on a mast tool delivery system that workers can access from the XCR.

In the XCR above XC-1, a number of infrastructure improvements were made to support dismantlement activities in XC-1. A portion of the MPPB’s existing monorail rail system was removed to enable construction of an extension on the XCR to cover the XC-1 hatch. A new gantry system was installed in the XCR addition to provide lifting capacity for XC-1 and allow crane travel along a track system that extends past the Extraction Cell-2 ceiling hatch. The new gantry crane augments an existing XCR crane that is capable of travel over the hatches for Extraction Cells 2 and 3 and the adjacent Product Purification Cell. The cranes may either be engaged along the track system or “parked” at the ends of the XCR.

Visual access was gained to the cell after a number of core borings were made to install in-cell cameras in XC-1. Six remotely-controlled in-cell GE Inspection Technologies Ca-Zoom® cameras with tilt, pan, and zoom capability were installed in the cell to provide full visual access to all areas for inspection and dismantlement. In the XCR, an additional six cameras were installed to monitor “ex-cell” during manned entries in the XCR above the cell.

The existing mast mounted mechanical arm was retrieved from the man hatch opening in the XC-1 ceiling. The arm was decontaminated and packaged for possible future reuse in the Waste Tank Farm. The mounting mast was also recovered, decontaminated, and prepared for redeployment in sections through the central ceiling hatch. It serves as the primary delivery system for the NuVision Artisan™ robotic arm.

WORK PLAN FOR DISMANTLEMENT OF XC-1

With more than one-mile of process piping connecting the vessels in XC-1, there were significant obstacles to removing the tanks from the cell. Based on experienced gained during hands-on dismantlement of the other two extraction cells, the most expedient way to remove piping to free vessels is to cut it and allow it to fall to the bottom of the cell until floor debris impedes work and must be collected and removed. In the case of XC-1, however, because all work was being conducted remotely and the bottom-most tank rested only 23 cm (9 inches) from the floor of the cell, it had to be cut free before any debris had collected on the cell of the floor. Further complicating this operation was the fact that the NuVision Artisan™ arm could not reach under the vessel to make those cuts, so an alternative method of cutting the tank free would have to be devised.

WVES engineers designed a remote-deployed saw cart that was fabricated by an off-site vendor to cut the bottom vessel free from the piping before deployment of the NuVision Artisan™ arm. Following the initial cuts, the centrally located robotically controlled arm would be deployed on a mast to conduct the remainder of the pipe and structural member cutting inside the cell.

Once cut free from the process piping and their structural supports, the three large tanks, which were positioned directly below the ceiling hatch, would be lifted through the ceiling hatch and roof hatch using a mobile crane positioned behind the MPPB. Each vessel would be hoisted through the ceiling hatch into the XCR, set onto a transfer cart and moved to the ceiling hatch for Extraction Cell-2 (XC-2) where a shielded waste box would be already staged in position to receive it. The crane would then be repositioned over the XC-2 roof hatch opening, reattached to the tank to lift it from the cart allowing the cart to be moved out of position, enabling the tank to be lowered into the waiting waste container. This simultaneous pipe cutting, tank freeing, lifting, and packaging evolution will be repeated for the three major vessels, clearing the center pathway of XC-1.

After removal of the bottom most tank (4D-2), the first waste removal campaign would be conducted in XC-1. A grapple will be used to collect the piping and structural support debris that was cut during the initial phase of dismantlement, clearing the cell for access to outer edges of the cell.

Removal of the two tall, column shaped vessels and one shorter column on the south side of XC-1 would be accomplished by a similar method, with the process piping being cut away first and the columns moved to the hatch opening for removal. Due to their length, the columns would be sectioned into pieces and packaged into waste containers as they are removed through the ceiling hatch.

The dedicated work crew for XC-1 dismantlement is made of a Project Manager, four shift Supervisors, and 16 operators. A portion of the labor, including the labor costs for 14 of the operators, is funded by the American Recovery and Reinvestment Act. Engineering resources are provided through a combination of WVES engineers, supplemented by specialized subcontracted engineers from RJR Engineering to support this workscope. WVES electricians and mechanics are also an integral component of this project, working closely to set up the robotic arm, perform regular maintenance on it, and be involved in the change of the end effectors for the arm.

NU-VISION® ROBOTICS ARM AND END EFFECTORS

The work plan for dismantling the equipment in XC-1 called for a fully robotic dismantlement of the equipment inside the cell, necessitated by the high radiological dose readings and suspected airborne contamination levels. The NuVision Artisan™ robotic arm, the central piece of equipment for the dismantlement of XC-1, is based on a mast tool delivery system that was installed in the high level waste tank 8D-2 for 1999-2000 sluicing, inspection, and characterization of the underground vessel. The design was modified to provide maximum travel capability for the robotic arm on the vertical mast, which is also rotatable on a pivot to reach all corners and levels of the cell. The arm features three rotary joints and three pivot joints, giving it six degrees of freedom during operation. This tooling was determined to offer the most versatility for removing the piping material from XC-1 and cutting the tanks and vessels free from the process piping and structural supports. The system also offered multiple opportunities for rapid tool changes with the ability to travel all levels and directions in the cell and to bring it to a “parked” position in the XCR, where workers can make tooling changes and perform maintenance on the equipment as needed while the rolling hatch is closed and radiological exposure from the cell is minimized.

Working with nuclear dismantlement vendor Mega-Tech Services LLC, existing tooling was modified for use with the robotic arm to create a reasonably quick interchangeable system of tools capable of completing the vast number of different dismantlement operations required in the cell. This is accomplished with a series of six separate end effectors, including two shears (one for cutting pipe less than two inches in diameter and the other for cutting pipe two to four inches in diameter), a grinder, a guillotine saw, an impact wrench, a reciprocating saw, and a portaband saw. In most situations, changeout of an end effector can be completed in less than one hour.

Figure 1: The NuVision robotic arm undergoes pre-deployment testing in the test tower at the WVDP.

WVES engineers and engineering support subcontractor RJR Engineering worked closely with NuVision Engineering and Mega-Tech Services LLC through the design, modification, fabrication, testing, and deployment of the 408 kilogram (900 pound), 480-volt, three-phase hydraulically-operated robotic arm and modified end effectors to ensure the features needed were designed and integrated into the final product and the operators and maintenance mechanics using the equipment were fully versed on its use, maintenance, and limitations. That close working relationship included multiple vendor/client visits between the arm vendor and WVDP facilities, including a two-week training evolution during which all 16 operators, four supervisors, and the engineering team involved in the XC-1 dismantlement project were trained on the operation and maintenance of the equipment at the vendor's location. In addition to shop training, all personnel involved in the arm's operation were required to be adept at picking and placing a 5 by 10 cm (2 by 4 inch) block, grabbing an object inside a barrel, cutting a pipe, and hydraulic shear operations. This vendor testing evolution provided an opportunity to make adjustments to the equipment before the arm left the vendor's facility. Once on site at the WVDP, the arm was again extensively tested, this time in the WVDP's test tower that was used formerly for practicing operations in the underground waste tanks. This close working relationship continues through the working phase of the arm's deployment and is instrumental in recovering from any operational issues that occur during in-cell deployment of the equipment.

Figure 2: The robotic arm is lowered into the XCR through the roof hatch while an operator inside the XCR maintains radio contact with the mobile crane operations crew outside the MPPB.

The arm performed as expected during pre-deployment testing, with no major problems or deficiencies noted. The hydraulic cables that operate the arm's end effectors were subject to cable handling issues during pre-deployment, and testing the equipment before it was installed provided an opportunity to observe the cable tracking tendencies and make the necessary adjustments in a non-radiological environment before the arm was deployed.

INITIAL PHASE OF PIPING AND VESSEL REMOVAL

Following successful testing in a full-scale mockup, WVES deployed the low-profile robotic saw cart on wheels it designed and fabricated to the floor of XC-1 in mid June to make the initial six cuts in the process piping. Per design, the cart was directed by a line feed from above to the designated pipe sections, the clamping mechanism was engaged to hold the cart firmly in place while cutting was underway, and a reciprocating saw was engaged to complete the pipe cut. This operation was completed successfully four times, however, on the fifth attempt, the saw blade broke, requiring retrieval of the cart and replacement of the blade. This operation was completed successfully, the cart was redeployed, and the remaining pipe cuts were completed. The saw cart was subsequently retrieved, decontaminated, and is stored for possible future reuse.

Simultaneous testing of the robotic arm was well underway, and the cell was prepared to commence full-scale pipe cutting activities after the saw cart was retrieved from the bottom of XC-1. Following successful completion of pre-deployment testing and resolution of cable handling adjustments, a mobile crane was used to move the arm from the test tower and lower it through the roof hatch into XC-1 on July 28, 2010. The arm was then connected to the hydraulic cabling, hydraulic power unit, and the control station and subsequently underwent operational checkout. Pipe cutting operations inside the cell commenced after successful checkout in early August.

Figure 3: Operators inside the XC-1 command center monitor operations inside XC-1 and the XCR using the camera system installed inside and outside the cell. The command station for the robotic arm is in front of the operator seated at left.

An operations center was established for the NuVision Artisan™ control center terminal in the extension adjacent to the XCR. In addition to operating the arm in the cell and maintaining radio contact with personnel during manned entries in the XCR, personnel in the operations center can monitor and record operations within the XCR and XC-1 using the six in-cell cameras and six cameras located in the XCR. A series of lead blankets was installed along the base and ceiling levels of the wall separating the XCR from the XC-1 operations center to shield personnel from radiation exposure during vessel removal. This area serves as a staging and deployment area for personnel.

After the initial pipe cuts at the base of the cell were completed using the saw cart, all subsequent piping cuts were made using the NuVison® robotic arm. Within the first week of using the robotic arm, more than 100 pipe cuts were made using the equipment and the equipment performed as expected. The next several weeks were spent cutting access to the first vessel, Tank 7D-1, a cylindrical vessel situated directly below the main hatch.

By early November, 20 percent (approximately 305 meters [1,000 linear feet]) of the in-cell piping had been removed, gaining free access to the vessel. Initial plans had been to rig lifting devices to the outside of the vessel to pull it through the opening, but as more of the piping was cleared from the cell and better visual access was obtained, it became apparent that the external structure of the vessel prevented safe external rigging. Due to the inadequate size of the existing external anchors on the cylindrical tank, fabrication of an internal lifting device was required to remove the vessel from the cell. An internal lifting device was designed and fabricated while other preparations for the vessel's removal proceeded.

Prior to removal from the cell, the tank was flushed with a water rinse that drained to the floor of the cell to remove any loose internal debris. Access holes drilled into XC-1 from the adjoining operating aisle to decontaminate and apply fixative to the outside of the vessel before it was removed from the cell. Three coupon samples were taken from the tank wall and internal dose readings and an internal camera inspection were conducted to prepare for vessel removal. The lifting device was placed in the vessel and the tank was gradually lifted using a mobile crane. While suspended, the vessel was slowly raised while a fixed spray wand applied paint to the exterior of the tank to fix any loose external contamination in place. A shielded gamma probe inserted in the top of the tank recorded internal dose readings ranging from 300-400 mR/hr at the top of the tank to a “hot spot” reading near the bottom of the tank registering 14R/hr.

With the vessel fully prepared for removal from the cell, a mobile crane was used to lift tank 7D-1 through the hatch of XC-1 into the XCR. Once in the XCR, a transfer cart was rolled into place over the hatch, and the tank was lowered so the tank’s supports came to rest on the transfer cart frame. The mobile crane was then disengaged from the tank, the cart powered on rails to XC-2 where a waste box was staged for the vessel, and the mobile crane was reconnected to the vessel through the XC-2 roof hatch. A crane was used to lift the vessel from the transfer cart, the cart was rolled out of position, and the crane safely lowered the vessel into the waste box.

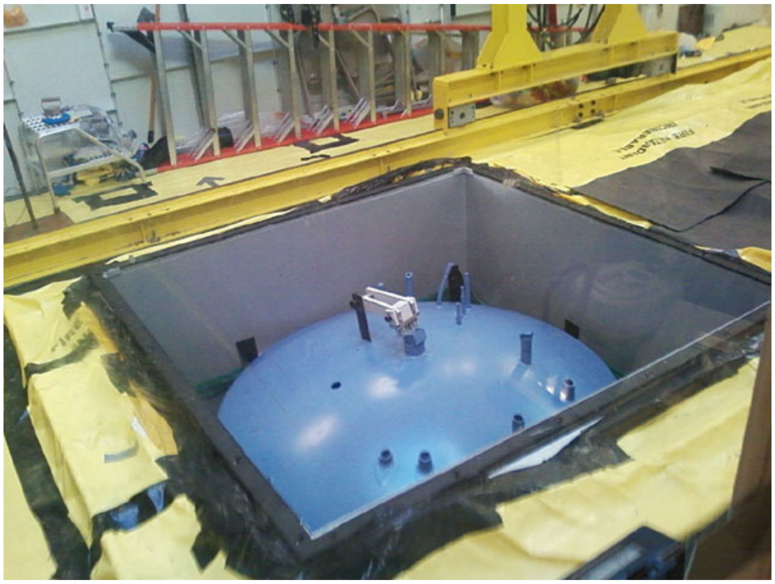

Figure 4: Tank 7D-1, the first vessel removed from XC-1, was safely removed from cell and placed in a staged waste container in the hatch opening of XC-2 in early November 2010. The top of the vessel is shown above.

Following removal of the first vessel, a maintenance outage was taken to modify the end of the robotic arm to encompass more compliant end effector use. Pipe removal then resumed in the cell to gain access to the second vessel, Tank 4D-1. During this evolution of piping removal, approximately 750 feet additional feet of process piping was cut to gain access to the second vessel and obtain extra working room to enable the installation of additional sections of mast on the robotic arm delivery system. Deployment of the next section of mast was necessary to allow deeper access into the cell to reach the bottom of the vessel, where installation of a plug in the drain line in the bottom of the vessel was required prior to vessel removal from the cell. The tank was then decontaminated externally with wash water that was allowed to drain to the floor of the cell and samples were taken from the inside of the vessel for radiological characterization. Based on radiological sample data obtained from the vessel inside the cell, the vessel was preliminarily characterized as low-level waste, enabling it to be handled and packaged in a less restrictive manner than the first vessel removed from the cell.

To prepare for its removal from the cell, Tank 4D-1 was lifted from the top and rotated within the cell while fixative was applied to its external surface. Due to lower radioactivity levels in the vessel, packaging of Tank 4D-1 required less stringent measures than the first vessel removed from the cell. An area outside the Main Plant was prepared to receive the vessel, with a waste box staged on the ground outside the building. The vessel was then lifted from the cell, sleeved as it was removed from the cell's ceiling hatch to prevent the spread of contamination, and lifted through the roof hatch. It was then lowered into the staged waste container on the ground below.

PREPARING FOR FOLLOW-ON VESSEL REMOVAL

As 2010 came to a close, the XC-1 project realized success at removing approximately one-third of the process piping and two of the three large vessels from the highly contaminated cell. With just two tanks removed from the cell, it had become evident that though the vessels were similar in appearance, structure, and application, no conclusions about the vessels' similarities could be made without thorough investigation and characterization. Planning for removal of the third vessel from the base of the cell was well underway in late 2010 to support in-cell characterization to determine the best method to remove it. Preliminary indications suggest that it will have the highest dose readings of the three large vessels. Extraction Cell-1 is scheduled to be completed by mid-2011.