Vertical Extraction Process Implemented at the 118-K-1 Burial Ground for Removal of Irradiated Reactor Debris from Silo Structures – 12431

Douglas B. Teachout*, Clinton J. Adamson**, Ames Zacharias**
*Vista Engineering Technologies, LLC, Richland, Washington, 99352
**Washington Closure Hanford, LLC, Richland, Washington, 99352

ABSTRACT

The primary objective of a remediation project is the safe extraction and disposition of diverse waste forms and materials. Remediation of a solid waste burial ground containing reactor hardware and irradiated debris involves handling waste with the potential to expose workers to significantly elevated dose rates. Therefore, a major challenge confronted by any remediation project is developing work processes that facilitate compliant waste management practices while at the same time implementing controls to protect personnel. Traditional burial ground remediation is accomplished using standard excavators to remove materials from trenches and other excavation configurations often times with minimal knowledge of waste that will be encountered at a specific location. In the case of the 118-K-1 burial ground the isotopic activity postulated in historic documents to be contained in vertical cylindrical silos was sufficient to create the potential for a significant radiation hazard to project personnel. Additionally, certain reported waste forms posed an unacceptably high potential to contaminate the surrounding environment and/or workers. Based on process knowledge, waste management requirements, historic document review, and a lack of characterization data it was determined that traditional excavation techniques applied to remediation of vertical silos would expose workers to unacceptable risk. The challenging task for the 118-K-1 burial ground remediation project team then became defining an acceptable replacement technology or modification of an existing technology to complete the silo remediation.

INTRODUCTION

The Department of Energy (DOE) Hanford Site 118-K-1 burial ground is an inactive solid waste site that operated from 1955 to 1973. This burial ground is located just outside the east perimeter fence of the 100-K Area, which contains the 105-KE and 105-KW Reactors. These reactors constitute two of the Hanford Site's nine plutonium production reactors and were the primary source of waste and reactor debris placed in the 118-K-1 burial ground. This burial ground contains radioactively and chemically contaminated soil, buried waste, demolition debris, and irradiated reactor hardware.

Along with the disposal trenches dispersed throughout the 118-K-1 Burial Ground are six underground vertical silos, each a 3 m (10 ft) diameter and 7.6 m (25 ft) long cylinders. Review of historical documents indicated one function of the silos to be interim storage for highly irradiated hardware undergoing radiological decay. Co-60 was the predominant isotope of concern in the historical reports. The vertical configuration of the silos and the potential for significant personnel exposure presented a unique waste and hazard management challenge.

METHOD

Remediation of the six cylindrical silos challenged the viability of using standard excavation techniques because of the depth of the silos and the susceptibility of the waste inside the silos to contain highly irradiated reactor debris and components. The engineering decision to deviate from normal remediation methods and techniques invoked several considerations for determining an acceptable substitute technology or technique. These considerations included but were not limited to:

1. Gaining a better understanding of the source term contained in the silos.
2. Configuring the remediation design to provide maximum protection of project personnel when remediating highly irradiated reactor debris and other materials with a high probability of loose surface contamination.
3. Determination of the safest and most effective method operational method for removing waste from a ten foot diameter cylinder that is twenty-five feet deep.
4. Incorporation into the remediation process a method to pre-determine waste form and hazard prior to removal of the waste from the silos and exposure to the environment.
5. Defining the necessary set of engineering controls to support safe implementation of an alternative technology.

To ensure a logical and informed decision a thorough review of documents and interviews with previous site workers was conducted. Concurrent with reviews of historic documents and evaluation of alternative remediation techniques, an in-situ characterization campaign was implemented at the 118-K-1 burial ground in an effort to qualitatively and quantitatively characterize the source term associated with the reactor debris and miscellaneous radioactive waste in the silos.

Characterization

Characterization was performed using a multi-detector probe (MDP) containing a suite of gamma-ray detectors, neutron detectors, and a gross radiation detector.

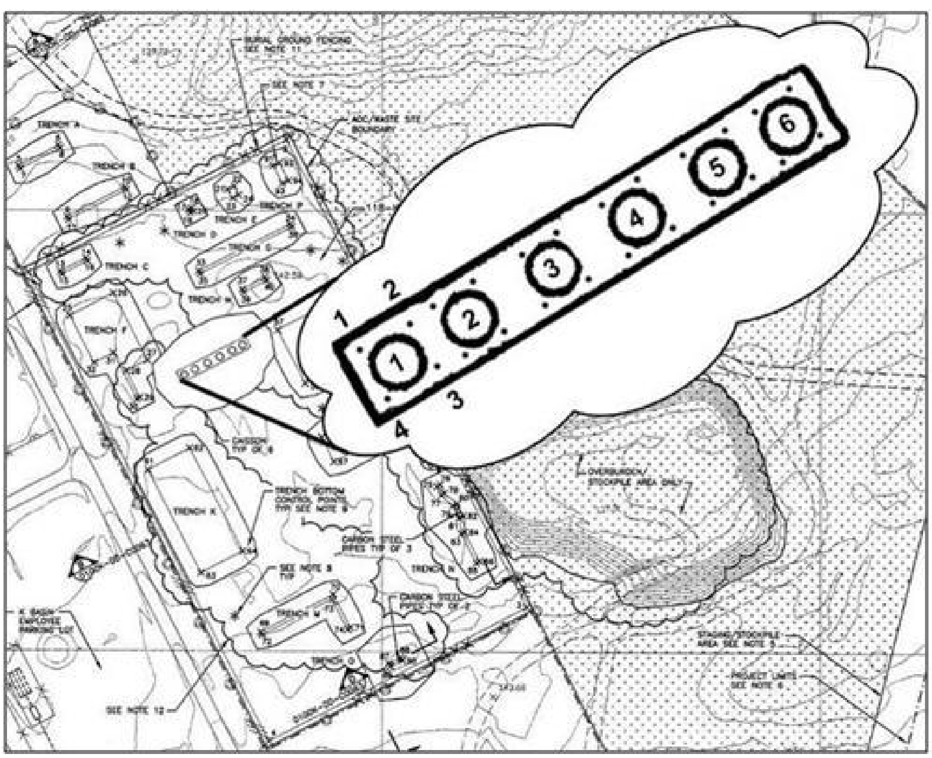

Fig. 1. Casing and Silo Identification

Steel cone penetrometer casings measuring two inches in diameter and thirty two feet in length were inserted around each silo as shown in Fig. 1. The casings were equally spaced approximately twelve inches from the outer edge of the silo.

Characterization proceeded by inserting the MDP instrumentation string to the full depth of each casing, performing a three minute count, then withdrawing the string one foot and repeating until the entire length of the casing had been counted. This process continued for each casing positioned around the silos. A minimum of twenty-six data measurement locations were logged for each casing installed around the silos. In addition to insertion of the MDP instrumentation string, a gross gamma meter was inserted into each casing to obtain a rough estimate of dose rates in the tubes.

Analysis of the MDP measurements provided baseline data sets to support characterization summaries for each of the six silos within the 118-K-1 burial ground. Included in this characterization summary was a graphic presentation of the location of sources in each silo. Fig. 2 illustrates a typical graphical presentation of the axial MDP and dose rate measurements. The primary objective of these measurements was to accurately and precisely determine the radionuclide activities (curie content) and their location inside the silos.

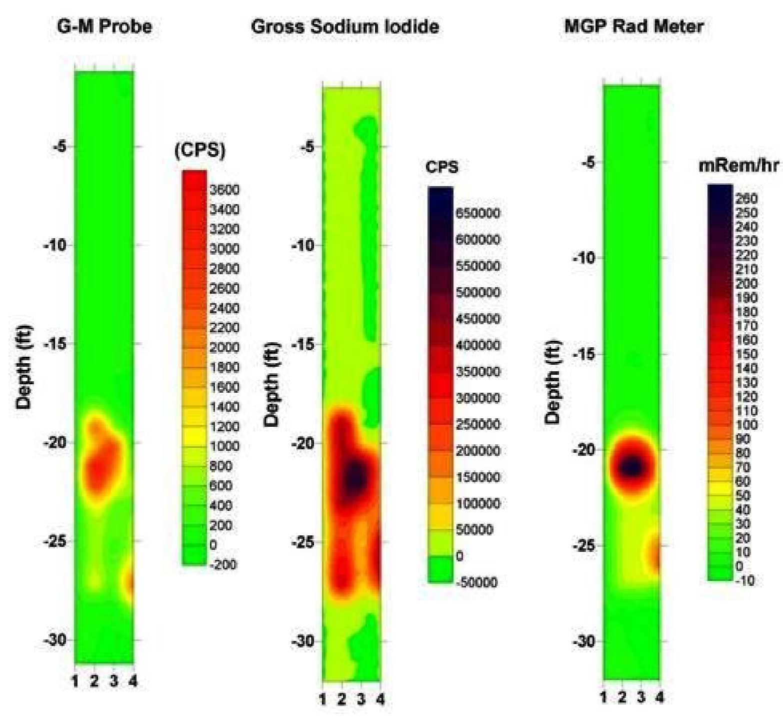

Fig. 2. Graphical Presentation of Axial Activity Distribution

Analysis of characterization data identified a diverse radionuclide presence in the silos. The primary radionuclides identified were Cs-137, Eu-152, and Co-60. Several curies of both Cs-

137 and Co-60 were reported in the lower region of three of the six silos, which solidified the decision to find an alternate remediation technique for the silos.

Site Preparation

Completion of characterization activities removed the necessity for penetrometer casings. The casings were removed as a site preparatory step for remediation of the silos. A growing concern for potential contamination spread to the environment resulted in the decision to construct a three-tier ecology block wall around the silos to provide a contamination control measure as waste is removed. An additional benefit of the concrete barrier is that the wall provides a shield between extracted silo waste and workers.

While construction of the ecology block wall had demonstrable benefits, an operational limitation was imposed by the presence of a structure adjacent to and surrounding the silos. It was now required to maintain the soil around the silos intact (no trenching to remove the silo walls and contents) and the newly adapted remediation method had to be capable of reaching over the wall and into the silos.

Modification of Existing Remediation Method

With consideration given to cost, schedule impacts, operational constraints, and process viability the decision was made to modify a standard excavator to give it the capability of digging in the vertical plane. The modification was necessary because a standard excavator boom configuration, like that shown on the excavator in Fig. 3, is not capable of digging straight down to the depth required for full remediation of a silo's contents. In this case the excavator shown in the figure is a Komatsu PC 400 prior to its conversion into a machine fully capable of digging to a depth up to thirty five feet in the vertical direction. Modification of the excavator presented unique challenges to the project staff and focused on four central configuration changes: (1) main hydraulic piston orientation, (2) boom length, (3) addition of a long vertical extension tube, and (4) conversion to a more practical bucket type.

Fig. 4 shows the same Komatsu PC 400 as that shown in Fig. 3 except the excavator is now pictured in its fully converted state.

Main hydraulic pistons are attached toward the middle of the excavator boom in a manner that facilitates positioning of the stick. The stick is the component to which the bucket is attached. Boom movement in the vertical direction is limited because of this orientation; therefore, the pistons were not configured properly to support a vertical pushing movement. Consequently, the main hydraulic pistons were re-located to custom mounts on the underside of the boom as shown in Fig. 4.

Even with the main hydraulic pistons now able to push the boom is a vertical direction, the boom and stick configuration was not yet capable of lowering a bucket into a cylindrical silo and perform remediation activities. Two components were added to overcome this shortcoming. An additional stick was attached to the excavator's main stick and then a twenty five foot vertical extension attached to that. These components are visible in Fig. 4.

The last mechanical modification was the attachment of a hydraulically operated clamshell bucket to the extension tube. Changing out the bucket was necessary because working inside the cylindrical silo was not possible with a standard excavator bucket that scoops with a sweeping motion. The clamshell jaws can be lowered into the silo, opened, positioned over the waste pile, and then clamped shut to retrieve the waste. Integrated into the clamshell bucket coupling was the capability for the bucket to rotate 270 degrees. This modification was a significant design modification because the clamshell bucket could be re-positioned (through rotation) for optimum extraction efficiency without having to physically move the excavator itself.

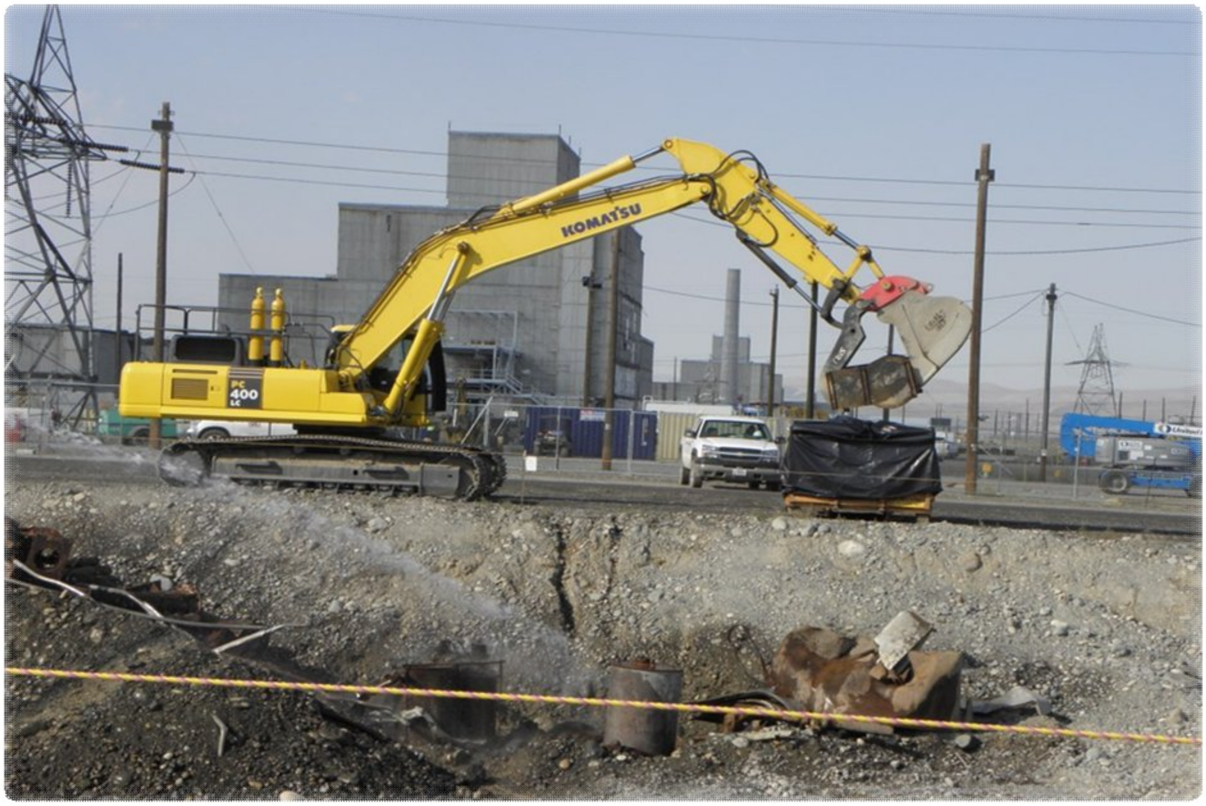

Fig. 3. Komatsu PC 400 Pre-Conversion Configuration

Fig. 4 shows the post-modification configuration of the Komatsu PC 400. In this photograph the machine is supporting removal of the previously cone penetrometer casings, which can be seen protruding from the ground in the vicinity of the clamshell bucket. It becomes obvious looking at the modified configuration that with the boom and main stick pushed high the additional stick and extension tube can be operated in the vertical direction (e.g., lowered into a cylindrical silo).

Fig. 4. Komatsu PC 400 Post-Conversion Configuration

Engineering Controls

While construction of a three-tiered ecology block wall around the silos provided shielding and a positive means of contamination control, a new hazard was introduced in the form of restricted operator visibility. As a control measure to mitigate this hazard, three very high resolution cameras were mounted on the excavator. Two of these cameras were mounted on the added stick (just behind the diamond logo on the stick in Fig. 4), one on the left side and one on the right side. The third camera was mounted between the jaws of the hydraulically operated clamshell bucket. Output from the cameras was viewable on a monitor inside the excavator cab as well as on a laptop at a remote location. Boom mounted cameras were used by the operator as a means of visualizing the overall environment when maneuvering the excavator and bucket into position for vertical extraction of waste materials. The camera mounted between the clamshell bucket jaws provided detailed observation of the ground for “fine control” of bucket movement. However, the most significant advantage of the clamshell bucket mounted camera was the very detailed picture of waste prior to removing material from the silo. Remote monitoring was provided by the Resident Engineer and experienced project support personnel, which enhanced the process knowledge and experience level in making decisions pertaining to handling of observed waste forms. Multiple observers providing input to the Resident Engineer prevented single point decision making by the excavator operator.

As previously discussed the most substantial hazard to workers was the radiological environment and the potential to extract intact, highly irradiated reactor components. During standard remediation practices an excavator has mounted near the bucket an onboard AMP-

100 probe. The AMP-100 is a Geiger-Mueller tube based rate meter designed to be continuously used in areas where high exposure rate levels exist. This detector configuration provides real time exposure rate information to the operator but does not, as configured, provide data to a remote location. It also is not a good indication of radiological conditions away from the bucket. For a more thorough understanding of conditions as silo remediation progressed, a wireless remote monitoring (WRM) system consisting of several strategically placed electronic dosimeters was installed and monitored by experienced Radiological Control Technicians (RCTs). Detector output was displayed on a laptop located adjacent to the laptop displaying camera output. With this arrangement a visual picture was coupled to detector readings, which aided in understanding the source of any elevated readings. The AMP-100 was coupled to a telemetry system as well so that the exposure rate indicated in the operator's cab could be monitored by the RCTs. Implementing the WRM system engineering control provided an early detection capability in determining whether or not higher dose rate items were extracted from the silos.

Contamination control was achieved by designing a directional water application system that was engineered to fit over the concrete barrier (wall) and connect to a water truck as a source of water. Configuring the nozzle of the application system adjacent to a silo provided a very controllable water stream that was aimed directly into the desired silo internal cavity. Water flow was controlled from the tanker truck, which kept personnel well away from the work area and associated hazards. Magnesium chloride was mixed with the water to provide more binding capability than would be achieved with plain water spray. When more aggressive binding capability was needed DustBond™ was mixed with water at a 1:7 mixture sprayed sparingly into the silos. Care had to be exercised in using DustBond™ near the jaw-mounted camera because of the potential to coat the camera lens with a film that would disrupt visual observations. DustBond™ was used much more aggressively on material initially extracted from the silos and during a waste segregation and sorting process. DustBond™ was also lightly sprayed into silos on an as-needed basis.

RESULTS

Trench I-Silos remediation was completed successfully, with the personnel involved receiving 64% of the estimated dose for the job (see Table I). The successful remediation campaign was enhanced by early characterization activities, which facilitated informed job planning by providing a graphical display of the location of sources that yield higher exposure rates.

Table I. ALARA Summary for Silo Waste Retrieval

Task	Estimated Dose (mRem)	Actual Dose (mrem)	% of Estimate Received
Retrieval, sorting, and loadout of silo waste	486	309	64%

The use of engineering and administrative controls was instrumental in preventing the spread of contamination, airborne radioactivity, and personnel exposure. With the unknown hazards and high risk associated with the Trench I-Silos, the conservative approach that was implemented from the beginning of the job proved to be invaluable and greatly helped with maintaining keeping personnel exposures as low as reasonably achievable (ALARA).

DISCUSSION

Early characterization data provided a good tool for evaluating the location of potential high exposure rate items in the silos. Quantitative characterization was a different case and proved difficult because of the large diameter of the silos and the potential for variable density of attenuating soils and waste forms in the silo. Consequently, the most relevant information supporting job planning and understanding of the conditions was the data obtained from the gross gamma meter that was inserted into each casing to provide a rough estimate of dose rates in the tubes. No added value was realized in attempting to quantify the source term and/or associate the isotopic activity with a particular actual waste form (e.g., sludge).

Implementing the WRM system allowed monitoring of worker and boundary exposure rates from a distance, maintaining compliance with ALARA principles. This system also provided the project team early knowledge of items being removed that had high exposure rates associated with them, thus creating an efficient method of acknowledging an issue and arriving at a solution prior to having an upset condition.

An electronic dosimeter with telemetry capability replaced the excavator mounted AMP-100 system approximately half way through remediation of the silos. Much higher connectivity efficiency was derived from this configuration. Increasing the data feed efficiency additionally led to less interruption of the remediation effort.

Early in system testing process a process handicap on the excavator operator was acknowledged. A loss of depth perception resulted when maneuvering the excavator and bucket using the camera feed to an in-cab monitor. Considerable practice and mock-up testing allowed this handicap to be overcome.

The most significant equipment failures involved the cable connection to the camera mounted between the clamshell bucket jaws and the video splitter in the excavator cab. Rotation of the clamshell bucket was identified as the cause of cable connection failures because of the cyclic twisting motion and continuous mechanical jarring of the connection. In-cab vibration was identified as the culprit in causing connection failures of the video splitter. While these failures were repaired, substantial production time was lost. Ultimately, the decision was made to purchase a second cable and higher quality video splitter eliminate the down time. An engineering improvement for future operations would be inserting cable pig tails at more stressed cable connection points to facilitate rapid change out of the cable should that be required.

Overall, the system performed better than expected in a safe and efficient manner.

REFERENCES

1. Akers, D., Smith, B. P., and Riess, M. J. (2008). 118-K-1 Burial Ground Source Term Characterization Report, Richland, Washington.