INNOVATIVE TECHNOLOGY
Summary Report

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Advanced Waste Retrieval System

Tanks Focus Area

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Innovative Technology Summary Report

Advanced Waste Retrieval System

Tech ID 2948

Tanks Focus Area

Demonstrated at
West Valley Demonstration Project
West Valley, New York

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine whether a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that prospective users consider a technology.

Each report describes a technology, system, or process that has been developed and tested with funding from U.S. Department of Energy's (DOE) Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, worker safety, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

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SECTION 1
SUMMARY

Technology Summary

Background

The West Valley Demonstration Project (WVDP) is located on the site of the only commercial nuclear fuel reprocessing plant to have operated in the United States. The plant is located at West Valley, south of Buffalo, New York. The site is home to four underground storage tanks, two of which are 21-m (69 ft) in diameter, 8.2 m (26.9 ft) tall, and contain grid work located on the bottom of each tank. These tanks were constructed in the 1960s to contain radioactive waste generated during spent fuel reprocessing operations at the site. During retrieval campaigns between July 1996 and December 1999, long-shafted mobilization (jet mixer) pumps were used to mobilize the bulk waste in these two storage tanks. Transfer pumps were used to move 96% of the HLW to the WVDP Vitrification Facility, where it was immobilized (vitrified) in glass (Hamel, McMahon, and Meess 2000). The storage tanks now contain residual solids from tank sludge and zeolite ion-exchange medium from vitrification operations. West Valley Nuclear Services (WVNS) currently operates WVDP.

Problem

Retrieval campaigns are using existing jet mixer pumps and a sluicing wand to mobilize waste. For effective mixing, the mixer pumps require about 35 cm (14 in.) of liquid in the tank. As a result, less waste is retrieved with each batch removed from the tank. This results in an increased cost per unit mass of waste retrieved. Alternative waste retrieval equipment may be needed if cost to retrieve the residual waste becomes excessive or the existing waste retrieval methods are unable to meet tank cleanup goals. In particular, technologies are needed for retrieval of waste from tanks with obstructed access (due to tanks' internal configuration and the presence of internal structures).

Solution

The Advanced Waste Retrieval System (AWRS) provides increased solids removal and transfer capability over the baseline method. This increased capability is the result of using a telescopic arm to place the suction pickup within an inch of the tank floor and coupling the suction system to the existing transfer pumps for delivery of retrieved waste from the tanks to the Vitrification Facility. The ability to move the suction pickup to the waste eliminates the need to mobilize the waste with a mixer pump or sluicing wand. Figure 1 shows the AWRS telescopic arm and suction pickup line deployed in a test tank.

Figure 1. AWRS telescopic arm deployed in a test tank.

How It Works

The complete AWRS consists of a mast tool delivery (MTD) assembly, telescopic arm and jet pump assembly, modified G-012/G-012A transfer pump assembly, grinder-separator assembly, booster pump assembly, and remote-control skid assembly (WVNS 2000).

The MTD assembly is a deployment system that uses electric winches to raise and lower carriages along a central mast. For WVDP, two camera systems located on different carriages are part of the MTD assembly. The camera systems provide illumination in the tank and a view for remote operation of the equipment located on the telescopic arm and jet pump assembly. Control of the MTD assembly and telescopic arm and jet pump assembly is provided by instrumentation located in the remote-control skid assembly.

The telescopic arm is used to connect the suction pickup line to a new transfer pump column (new column and in-tank connection are part of the modified G-012/G-012A transfer pump assembly) and to move the suction pickup to various locations in the tank. Once the suction pickup line is connected to the new transfer pump column, a steam jet pump is used to create suction for retrieval of waste material.

Retrieved waste is drawn through the new transfer column to a grinder-separator assembly. A cyclone separator diverts small (<50-µm) particles and about 90% of the water around the grinder. Large particles are size-reduced in a vibratory-kinetic energy (VKE) grinder. The small-particle stream (from the cyclone separator) and size-reduced particle stream (from the grinder) are combined at the outlet of the grinder and then transferred to the WVDP Vitrification Facility with the assistance of the booster pump assembly.

Potential Markets

The AWRS was developed specifically for application at WVDP; however, components such as the MTD assembly, the telescopic arm and jet pump assembly, and the grinder-separator assembly may have application for tanks at other U.S. Department of Energy (DOE) sites.

Advantages over Baseline

The AWRS has been designed to provide improved methods for in-tank viewing, waste retrieval, and waste handling.

- Cameras procured and installed on the MTD assembly are equipped with four 250-watt flood/spot lights to improve in-tank viewing.
- Telescopic arm and jet pump assembly provide remote positioning capability and mobility that enable the telescopic arm to position the suction pickup head within an inch of the tank floor, much closer than baseline retrieval methods can get.
- The suction pickup arm is capable of picking up and transferring larger particles, rust, and scale than possible with the existing G-012/G-012A transfer pump.
- Grinder-separator assembly provides means to size-reduce the retrieved particles to meet site requirements for transfer to the WVDP Vitrification Facility.

Demonstration Summary

Selected full-scale system components were demonstrated at the Specialty Maintenance and Construction, Inc. (SMCI) test facility located in Lakeland, Florida. Five specific activities were performed at the SMCI cold-test facility:

- installed the MTD assembly in a tank riser,
- evaluated the remote coupling operation and performance,
- demonstrated placement of the suction pickup arm to target areas of the test tank,
- evaluated the suction pickup operation and performance, and
- evaluated the operation and performance of the grinder-separator assembly.

Key Results

All of the tested AWRS components performed satisfactorily and met criteria established prior to fabrication and testing:

- Electric winches and actuators met performance specification. The original MTD assembly used a hydraulic system. The change to an electric system will reduce the amount of hose management required in the tank and enclosure above the tank.
- Telescopic arm and jet pump assembly provided remote positioning capability and mobility.
- Use of the jet pump with the suction head at the tank bottom eliminated the need for a mobilization pump to suspend particles in solution for retrieval. Particle sizes up to 0.5 cm (0.2 inch) were removed from the test tank.
- The grinder-separator assembly successfully met the requirement that 90% of the particles passing through the grinder outlet be smaller than 200 µm. In fact, sampling results showed that 99% of the solids were reduced below the required 200-µm size.

Parties Involved in the Demonstration
The following organizations participated in the fabrication and testing of the AWRS and components:

- DOE Office of Science and Technology, Tanks Focus Area
- West Valley Nuclear Services
- Specialty Maintenance and Construction, Inc.
- West Metal Works (grinder system development and testing)
- R. S. Corcoran (booster pump manufacturer)

Commercial Availability and Readiness
With the exception of the modifications for the G-012/G-012A transfer pump assembly, all of the AWRS components were procured and delivered to WVDP. The equipment is ready for deployment should the existing retrieval method utilizing mobilization pumps and transfer pumps prove unable to meet target tank cleanup levels.

The MTD assembly is based on a proven design that has been deployed in WVDP tanks. Core equipment for the grinder-separator assembly and the booster pump assembly are commercially available. Designs for the as-built grinder-separator, booster pump, telescopic arm and jet pump, and remote-control skid assemblies have been tested and can be used as a basis for similar systems at other DOE sites.

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Other
All published Innovative Technology Summary Reports are available on the Office of Science and Technology (OST) Web site at www.em.doe.gov/ost under “Publications.” The Technology Management System, also available through the OST Web site, provides information about OST programs, technologies, and problems. The Tech ID for the Advanced Waste Retrieval System is 2948.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

The AWRS consists of an MTD assembly, telescopic arm and jet pump assembly, modified G-012/G-012A transfer pump assembly, grinder-separator assembly, booster pump assembly, and a remote control skid assembly. These components are described below.

MTD Assembly

The MTD assembly is a second-generation system based on lessons learned from previous deployments of MTD assemblies in WVDP Tanks 8D-1 and 8D-2. The MTD assembly comprises a fabricated 16.5-m- (54-ft)-long stainless steel mast inserted into a riser. When fully deployed, the mast, which is similar to a 20-cm- (8-inch)-wide flange beam, extends to within 30 cm (12 inches) of the bottom of the tank. The mast comprises seven individual sections, which are assembled in the vertical position during installation.

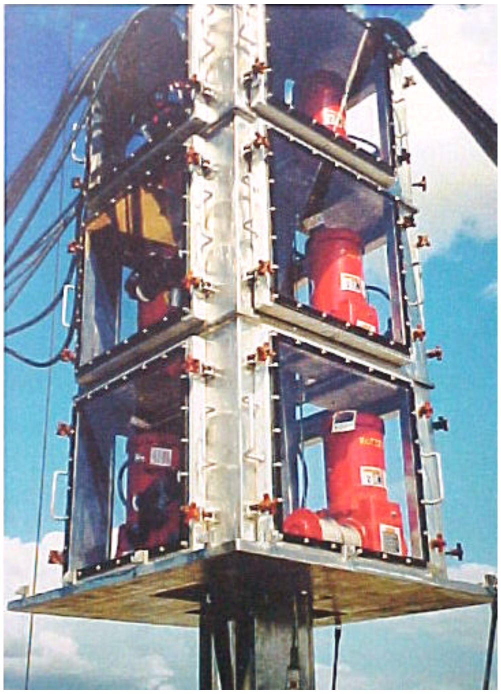

Figure 2. Winch stand assembly.

The top of the mast extends out of the riser and is mounted to a rotary bearing unit (moving like a turntable) connected to an electric gear motor. Mounted to the mast, above the rotary bearing unit, are six variable-speed electric (480-volts alternating current [VAC]) winches located in a winch stand assembly (see Figure 2). Each winch has a lifting capacity of 454 kg (1,000 lb). These winches raise or lower carriages down both sides of the vertical mast. The carriages serve as platforms to lower various tooling and equipment into the tank.

Two camera arm assemblies are mounted to the mast via carriages for remote viewing within the tank (see Figure 3). Each assembly contains a radiation-resistant, black and white video camera equipped with four variable-intensity 250-watt flood/spot lights and a pan/tilt unit. The camera assemblies are each mounted on a retractable arm, which is deployed with a 120-VAC linear actuator.

One camera arm assembly mounts to one side of the mast and deploys straight out from the mast. The other assembly mounts to the opposite side of the mast and deploys to the side of the mast (90º offset from the first camera). This offset installation provides redundant viewing capability, as well as 360º viewing capability, within the tank. The remote-control skid assembly governs the rotary bearing unit, winches, camera arms, and video equipment.

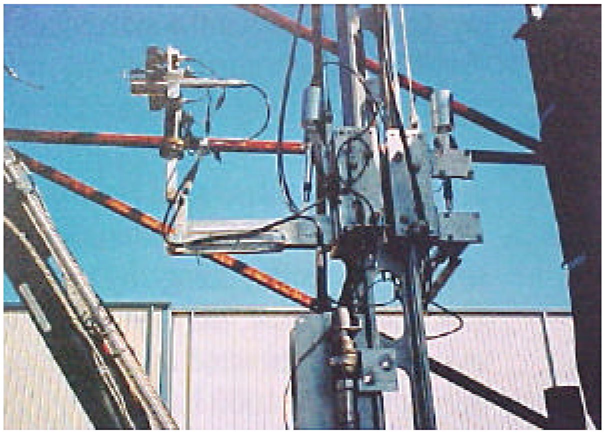

Figure 3. Camera assembly installed on mast.

Telescopic Arm and Jet Pump Assembly

The telescopic arm and jet pump assembly mounts to the beam of the MTD assembly via a rolling carriage. The arm is mounted to the carriage vertically and parallel to the beam to enable it to be inserted into a 61-cm (24-inch) riser. Once inserted and clear of the riser, a single-stage hydraulic cylinder is used to unfold the telescopic arm outward to the horizontal position.

The telescopic arm comprises two sections of

rectangular tubes, one inside the other. The inner tube telescopes outward on bronze bearings using a single-stage hydraulic cylinder. The arm is about 3.4 m (11 ft) long before extension and about 5.8 m (19 ft) long when fully extended. At the end of the telescopic arm is a remote coupling. Two single-stage hydraulic cylinders provide the vertical movement of the
0.9-m-(3-ft)-long suction arm with swivel joint. A fixed steam jet is located at the end of the telescopic arm. When the hydraulic cylinders are actuated, the swivel joint on the suction arm rotates from the horizontal to the vertical position. The suction arm is designed to reach within 1.3 cm (0.5 inch) of the bottom of the tank and to operate in the tank liquid.

The remote in-tank coupling feature of the AWRS consists of two mating components. A spring-loaded flexible hose connection is located on the end of the telescopic arm. The mating connector block is mounted to the end of a line that will be added to the existing transfer pump assembly. A flexible, braided stainless steel transfer line is used for the connection between the steam jet pump and the existing transfer pump. At the end of the flexible line is a 15-cm- (6-inch)-diameter flange with double O-ring seals. The flange seals against the mating connector block internal sealing face.

A series of stainless steel Bellville-type springs is mounted between the flange and a 15-cm- (6-inch)-diameter collar on the new transfer line. The springs and collar are compressed toward the sealing flange by two hydraulic cylinders on the end of the telescopic arm. Once compressed, the assembly is installed in the connector block. The hydraulic cylinders are retracted, and the assembly is clamped within the block by the resultant spring force of 4.5 kN (1,000 foot-pounds). Once the connection is made, the telescopic arm is allowed to rotate away from the block, leaving the connection and flexible hose attached. Figure 4 shows the remote coupling box being tested.

Modified G-012/G-012A Transfer Pump Assembly
Modifications to the existing G-012/G-012A transfer pump assembly include the installation of a 5-cm- (2-inch)-diameter transfer line adjacent to the existing transfer pump column. This new line provides a means for retrieving waste material from the tank. At the bottom of the transfer line is a remote coupling box that enables connection to the telescopic arm and jet pump assembly. An access port will be installed in the existing pump flange and the line/remote coupling unit will be lowered into the tank and attached to the pump flange.

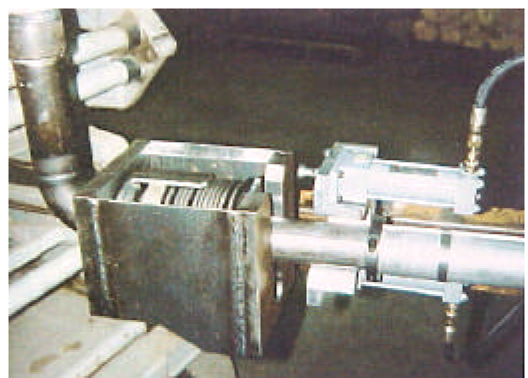
Figure 4. Testing of the remote coupling assembly.

Grinder-Separator Assembly
A VKE rod mill was selected for the AWRS grinder-separator assembly. The selected grinder unit was a commercially available design from MicroGrinding Systems, Inc. An advantage of the VKE mill is the generation of much higher impact, or grinding forces, than ball mills or other similar mills, which are based on the gravity force generated by falling balls or rods impacting the material to be size-reduced. Vibratory mills generate greater impact forces through the rapid vibration of a motor-driven grinding chamber, described below.

The VKE grinder design consists of a 51-cm- (20-inch)-diameter by 200-cm- (80-inch)-long grinding chamber, which contains hardened steel rods. A tuned-spring system completely suspends the grinding chamber within a rigid steel frame. A 5.6-kW (7.5-hp), 480-VAC vibratory motor is mounted directly to the grinder chamber. With the motor attached directly to the grinding chamber, there is no power train to maintain, thus increasing reliability. Figures 5 and 6 show the interior of the grinding chamber with rods and the exterior of the grinder, respectively.

During operation, the grinder is optimized using lower flow rates through the chamber. The lower flow rates increase the grinding time within the chamber, thereby maximizing the size-reduction. To accomplish this, the liquid/solid waste being delivered to the grinder is first sent through a separator, which uses a cyclone action to separate the larger particle sizes along with a small percentage of the water and delivers them to the grinding chamber. Smaller (<50-µm) particles bypass the chamber along with approximately 90% of the water. The two lines are reconnected at the discharge of the grinding chamber for further transfer.

Booster Pump Assembly

The original design of the AWRS required transfer of the waste from Tank 8D-1 to Tank 8D-2. The steam jet on the telescopic arm provided the required head to deliver the retrieved waste. An added requirement to transfer waste from Tank 8D-1 directly to the WVDP Vitrification Facility required the addition of a booster pump.

The requirements for the booster pump were 230 L/min (60 gpm) with 30 m (100 ft) of head. A Cocoran Model 5400 stainless steel centrifugal pump was selected for the application based on its ability to meet the back-pressure and flow requirements and to operate within the high-radiation field of the Waste Tank Farm at WVDP. The pump is mounted to a stainless steel frame with flexible steel jumpers at both the inlet and outlet.

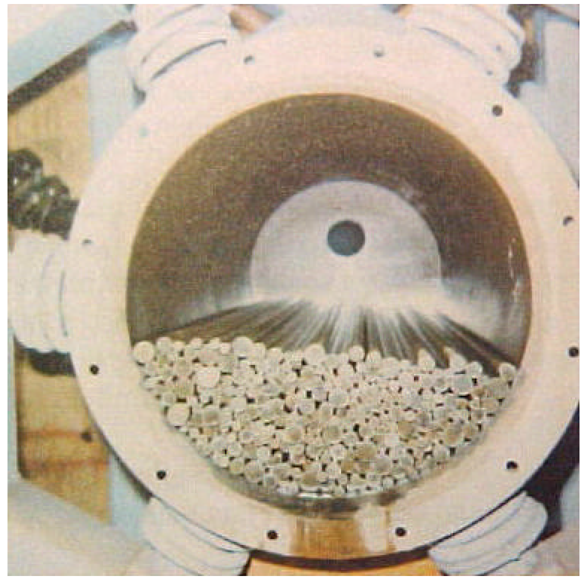

Figure 5. Grinder chamber interior with rods.

Figure 6. Grinder exterior.

Remote-Control Skid Assembly

For the existing MTD assembly installed at WVDP, the controls are based in a control trailer with all cabling hard-wired within fixed cable trays. The original control console did not allow for the flexibility of adding different components. For the AWRS, the skid assembly enables placement of the skid in locations as required for tank cleanout and inspections. The skid allows for the flexibility of adding a multitude of equipment and tooling for accomplishing various tasks.

The remote-control skid assembly is a weather-tight 2.4 m by 2.4 m (8 ft by 8 ft) enclosure with its own lights and heating, ventilation, and air conditioning unit. The assembly contains an overhead lifting frame for placement with a crane. A forklift can also be used to move the assembly. Power required for the assembly is 480 VAC, which is internally distributed to the various control functions.

The skid provides control of the six winches on the MTD assembly, the rotating bearing unit, the two in-tank camera arm assemblies, and the hydraulic power supply and manifold. A portable control panel is provided which can be located up to 30 m (100 ft) away from the skid, if required.

System Operation

The AWRS was designed and fabricated for future installation into WVDP tanks should waste removal criteria not be met using the current mobilization and retrieval methods. Existing retrieval efforts utilize a combination of mobilization and transfer pumps along with a sluicing arm deployed on the first-generation MTD assembly. Operation of AWRS will build on lessons learned from the first-generation MTD assembly and those learned from the acceptance testing of the full-scale AWRS components.

Special Operational Parameters

Special operating parameters are not anticipated for the AWRS.

Materials, Energy, and Other Expendable Items

- MTD assembly requires power for six 480-VAC electric winches, two 120-VAC linear actuators for the camera assemblies, and the electric gear motor for the rotary bearing.
- Hydraulic cylinder pressure for remote coupling on telescopic arm and jet pump assembly is 5,500 kPa (800 psi), far below the WVDP 20,500-kPa (3,000-psi) maximum.
- The telescopic arm and jet pump assembly requires a steam jet for sized for 230 L/min (60 gpm) with 30 m (100 ft) of head.
- The grinder-separator assembly requires power for a 5.6-kW (7.5-hp), 480-VAC vibratory motor.

Personnel Requirements

Installation and operation of AWRS will use many of the same skills currently used for retrieval operations at WVDP. Full-scale testing of equipment prior to delivery to WVDP, with oversight and participation of staff from WVNS, provided operators an opportunity to become familiar with the full-scale system. Training for remote operation is anticipated to be similar to existing training for operation of the MTD sluicing arm. Special training for operation of the remaining components of the AWRS is not anticipated.

Secondary Waste Stream

Operation of the AWRS is not anticipated to create a secondary waste stream that is greater than that currently generated from the baseline retrieval operation. Since the use of the jet pump with the suction head at the tank bottom eliminates the need for a mobilization pump to suspend particles in solution for retrieval, the amount of water required for retrieval may be decreased.

Potential Operational Concerns and Risks

Components of the AWRS have been designed to use as much of the existing WVDP tank infrastructure as possible. Relative to other systems currently used, the grinder-separator assembly is the most different (the current in-line grinder is more of an emulsifier). Experience with actual waste material from a tank is needed to fully define the operating parameters for this AWRS component. Application of AWRS or any of its components at other DOE sites may require modifications to meet site-specific requirements, such as load limits above a tank.

SECTION 3
PERFORMANCE

Demonstration Plan

Many of the individual components for the AWRS are either available commercially or based on previous designs. To ensure that components would meet the needs for WVDP, many of the individual components and AWRS systems were fabricated and tested as prototypes. Demonstrating prototypes prior to release of detailed design documents ensured the design would meet all requirements at completion, thereby minimizing risk. This approach led to two sets of testing for the AWRS components: individual component testing by the vendor and/or developer and full-scale system testing. Both sets of tests and their results are described below.

Component Testing

Grinder Performance Tests
Initial development and testing was performed at West Metal Works in Buffalo, New York. Testing was performed with a commercially available VKE grinder that was modified to meet space constraints in the WVDP tank farm. Once development testing was completed in October 1999, final modifications were made to the unit and the unit was shipped to SMCI for final testing.

For the grinder performance tests at the SMCI facility, a test tank was set up with zeolite particles spread throughout the tank. Various zeolite piles and layers of differing depth were used to simulate conditions in the WVDP tanks. A centrifugal pump connected to a suction pickup head was used to draw zeolite particles into the grinder. The suction head was manually moved through the zeolite particles at a rate of approximately 1.2 cm (0.5 inch) per second. This speed was representative of the movement rate selected for operation of the telescopic arm and jet pump assembly.

Approximately 40 tests were performed using different zeolite layer configurations and an average particle size of 700 µm (WVNS 2000). The goal was to demonstrate that the grinder was capable of size-reducing 90% of the particles to less than 200 µm. After testing, samples of the liquids and solids were collected and analyzed by a certified lab. Results indicated that 97% of the solids were smaller than the 200-µm maximum size limit for the tests performed.

Telescopic Arm and Jet Pump Vendor Acceptance Testing
The completed telescopic arm and jet pump were fully acceptance tested at the SMCI facility after final fabrication by SMCI. The testing was divided into three basic areas: bench testing of the remote coupling, testing of the arm, and recovery and redundancy testing.

Bench testing involved both the spring and hydraulic portion of the arm and the coupling block planned for the G-012 transfer pump assembly. Pressures up to 1,300 kPa (190 psi) were demonstrated with no sign of leakage. This pressure is well above the maximum pressure requirement of 680 kPa (100 psi). Hydraulic cylinder pressures were noted at 5,500 kPa (800 psi), which is below the maximum allowable pressure of 20,500 kPa (3,000 psi).

The completed arm assembly was tested through all ranges of motion, which included the arm in the full collapsed position, full horizontal position, positioning the suction pickup head, and the remote coupling operation. All ranges of motion for the telescopic arm were adequately tested and were shown to perform as required. Additionally, hydraulic hoses and service loops for the hydraulic cylinders were checked, and no pinching occurred. All hydraulic cylinders were monitored for pressure during operation. Pressures exceeding the maximum allowable pressure of 20,500 kPa (3,000 psi) were not observed.

Testing was performed to document the recovery from failure of a single cylinder during the remote coupling operation. It was demonstrated that remote coupling to the coupling block connection (compressing the collar spring) could be made using only one cylinder instead of the two cylinders used for installation or removal. The pressure required to perform this operation approached the maximum allowed pressure of 20,500 kPa (3,000 psi) but did not exceed it.

MTD Assembly Acceptance Testing

Testing of the MTD assembly was performed at the SMCI facility in Lakeland, Florida. Bench testing of the two camera assemblies was completed prior to assembling the MTD assembly to determine the correct working parameters of the units. Bench testing demonstrated that the electric actuators on each camera assembly were sufficient to deploy the camera arm from its collapsed position to the full horizontal position but were not capable of collapsing the arm back to the vertical position for removal from the riser. The original (3:1) actuators were replaced with large (20:1) ones, which performed successfully.

Also prior to assembling the MTD assembly, load test activities were conducted. Each of the six winches in the winch stand assembly were load tested separately to 900 kg (2,000 lb), with each load test successfully passed. The winch stand assembly was load tested to 5,400 kg (12,000 lb) to verify the full load of the winches. Additionally, the assembled mast was load tested to verify beam joint capability. No problems were identified during the load testing.

Installation of the system into the test riser and platform was accomplished using an overhead crane and manually positioning the MTD assembly sections. The trolley assembly—an adapter between the rotary bearing unit and mast—was held in place by the crane and bolted to the rotary bearing. The trolley assembly enables the mast to be moved to either side of riser, enabling additional carriages to be mounted on the open (free) side of the mast. The mast was installed vertically through the center of the trolley assembly, with each of its seven sections bolted together in sequence. Next, the winch stand assembly was lowered into position using the crane and mounted to the top of the mast.

With the mast and winch stand in place, the two camera assemblies were installed. Each assembly was lowered by crane to a position adjacent to the mast and riser. Winch cables were rolled out and attached to each assembly. The camera assemblies were then manually guided into position and mounted to the carriages on the mast. All connecting cables were then plugged into the camera assemblies and functionally operated through all required motions via the remote-control skid assembly. After verification that the camera assemblies worked satisfactorily, the camera assembly arms were folded vertical, parallel to the mast, for lowering through the riser. Once at the desired location, the assemblies were unfolded from vertical to the horizontal operating position. No interferences were encountered during camera assembly testing.

Booster Pump Assembly Acceptance Testing

Testing of the booster pump was performed at R. S. Corcoran, the pump manufacturer, prior to shipment to WVDP. The inlet to the pump was connected to a test tank filled with water. The 480-VAC pump motor was connected to a variable-frequency drive controller and operated through a range of speeds to verify flow, head, and motor horsepower. Pump outlet flow and pressure were monitored. After testing, a graph was developed that verified pump performance at 0–60 Hz. The pump achieved 230-L/min (60-gpm) flow and 30 m (100 ft) of head at 5.6 kW (7.5 hp). At the full range of 7.4 kW (10 hp), the pump achieves 480 L/min (125 gpm) with 27 m (90 ft) of head. Figure 7 shows the booster pump that was tested.

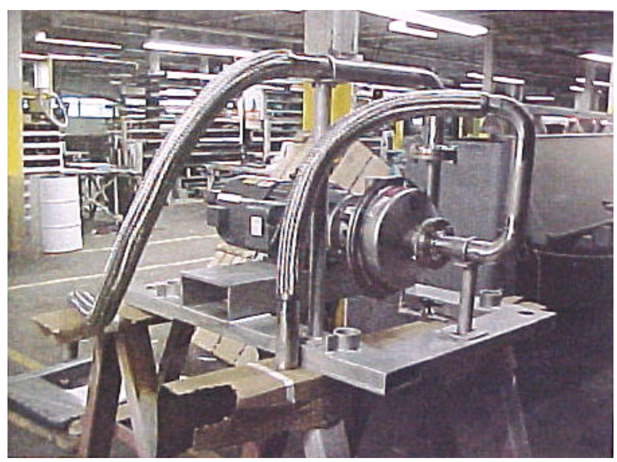

Figure 7. Booster pump assembly.

Full-Scale System Testing

Test Facility

Figure 8. SMCI test platforms.

Full-scale system testing and demonstration was performed at the SMCI test facility in Lakeland, Florida. The facility was set up in 1998 as part of the test program for the original MTD assembly. A 12.8-m- (42-ft)-high platform that incorporates a full-scale tank riser with a 61-cm- (24-inch)-diameter opening enables testing of the full-length MTD assembly. Figure 8 shows the platforms and test tank at the SMCI facility. The distance between the bottom of the tank riser and the floor of the installed test tank is about 8.2 m (27 ft).Below the platform is a 4.6-m by 4.6-m (15-ft by 15-ft) carbon steel test tank that is representative of Tank 8D-1. The grid work, support beams, foot pads, and columns are in the exact configuration of the waste tank as determine by the original tank drawings (WVNS 2000). The test tank was also representative of the area at the low point of Tank 8D-1, including a tilt in the actual tank of about 15 cm (6 inches) from center. Figure 9 shows an aerial view of the test tank.

The test facility also includes a second platform for the grinder-separator assembly that was 10.7 m (32 ft) high to simulate the distance between the 8Q-1 pit floor and the bottom of Tank 8D-1.

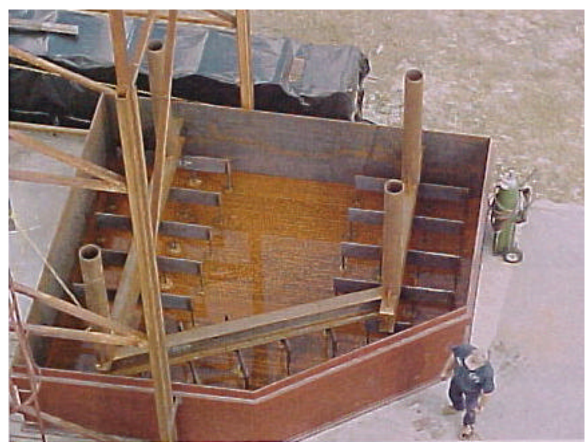

Figure 9. Aerial view of the test tank.

Utility services for testing included a 690 kPa (100-psi) diesel-operated steam generator, a 480-VAC diesel electric generator, a remote water supply (for filling the test tank), and a holding tank for the steam generator.

Installation and Deployment

The MTD assembly mast and winch stand assembly were left in place after the acceptance testing performed prior to full-scale testing. Camera assemblies had been removed to enable for the installation of the telescopic arm and jet pump assembly. Installation of this assembly onto the mast required an overhead crane to lower it into position. Once in position, the assembly was slowly lowered until the lower and upper rollers could be engaged onto the MTD assembly mast.

Once fully engaged on the beam, the winch cable was attached to the carriage and the crane was disconnected. The winch then lowered the carriage and telescopic arm and jet pump assembly down into the riser until the top of the telescopic arm cleared the winch stand. The telescopic arm was then actuated back to the collapsed configuration for installation down through the riser. As the arm was lowered through the riser, several areas were observed to be close to causing interference. In actuality, these areas did not cause any interference during installation of the arm assembly, but some minor components, such as mounting blocks, carriage brackets, a suction arm mounting bracket, and a grease fitting, were subsequently modified to increase clearances.

After the telescopic arm and jet pump assembly was installed through the riser, the two camera assemblies were installed on the mast and lowered through the riser. After the cameras were lowered through the riser, all operations were performed using only the two in-tank cameras. Installation of components on the MTD assembly mast was performed a number of times with no problems noted.

Remote Coupling Operation and Performance

After all components were installed and lowered down the MTD mast, the telescopic arm was positioned horizontally using the hydraulic tilt mechanism. The arm was then extended to a position just above the site of the remote coupling block on the modified G-012/G-012A transfer pump assembly mock-up. The actual coupling block that would be installed at WVDP was used for this test.

Once in position, the two hydraulic cylinders were actuated to compress the spring arrangement on the remote coupling line. The telescopic arm was then slowly rotated sideways, using the rotary bearing control, until the spring assembly contacted the touch-off pads on the connector block. Using the rotary bearing provided the most accurate positioning of the arm due to the arm's slight swaying motion. The telescopic arm was then extended outward until the second touch-off pad was in contact. Once in place, the arm was slowly lowered using the winch controls until the unit was fully seated within the block.

Once fully seated, the telescopic arm was rotated away from the block, leaving the coupling line attached to the block. The only issue identified during the testing of the remote coupling operation was the deformation of a bracket supporting the spring arrangement during initial operations. The bracket configuration was revised to incorporate stiffening flanges and then reinstalled. No further issues were identified after the modifications. A single remote coupling operation took less than 10 minutes.

Deployment to Low Point of Tank

After the remote coupling was engaged, the telescopic arm was folded back into the collapsed position, parallel with the mast. The rotary bearing unit then rotated the mast about 180º to the area that approximated the low point of the test tank. The two in-tank cameras provided all the necessary viewing capability to enable positioning of the mast.

Once in the desired area, the telescopic arm was again deployed to the horizontal position and extended outward as required. The suction pickup was moved from its horizontal position, parallel to the telescoping arm, using the hydraulic actuating cylinder. No binding or unwanted movement occurred during positioning and operation of the telescopic arm or the suction pickup.

Suction Pickup Deployment and Performance

The telescopic arm and jet pump assembly was lowered using the winch controls until the suction pickup was 2–5 cm (1–2 inches) below the water level of the test tank. The offset camera was used to zoom in on the suction pickup, while the overhead camera provided an overall view of the operation. The elevation of the offset camera was adjusted based on the suction head location.

With the suction pickup located between the mast and grid work, the optimal position for the offset camera was about 3 m (10 ft) above the tank floor. With the suction pickup on the opposite side of the grid work near the tank wall, both cameras were required to be positioned about 1.5 m (5 ft) below the tank roof, enabling both cameras to "see" over the beams.

With the suction pickup in position, steam was supplied to the steam jet to provide the energy needed to create suction to lift the liquids and solids off the tank bottom. Once stabilized, the telescopic arm and suction pickup were lowered slowly into a zeolite pile using the winch controls. Using the cameras for viewing, the suction pickup was lowered until it was approximately 1 cm (0.5 inch) above the tank floor. The zeolite pile was removed, and a cleared area was visible. To clear large open areas between tank obstructions, the rotary bearing unit was used to move the telescopic arm and suction pickup sideways in an arc until coming close to an obstruction. The telescopic arm was then extended outward about 8 cm (3 inches), and the rotary bearing unit was again used to move the telescopic arm sideways in the opposite direction. This motion was repeated to clear a large area of solids accumulation.

When cleaning between the grid work plates and around the standoff disks on the tank floor, the movement of the rotary bearing unit, telescopic arm, and suction pickup was similar but was performed in short sweeps. The suction pickup was maneuvered through, and vacuumed up, piles of zeolite over 8 cm (3 inches) deep. For deeper piles of zeolite, the motion of the arm was slowed from its usual speed of 1 cm (0.5 inch) per second to enable clearing of the material before moving the telescopic arm to another location.

The suction pickup contains a screened inlet and back-flush line to remove accumulated solids buildup. During the testing, no blockage occurred, therefore the back-flush line was not tested. At the end of every test run, the suction pickup was lifted up above the zeolite to enable the tank liquid to flush the system. The remote coupling unit was disconnected periodically to check for solids accumulation and blockage. There was no buildup of solids in the coupling block or transfer lines.

Grinder-Separator Operation

The grinder-separator assembly performed satisfactorily throughout the full-scale system testing. The back-pressure at the outlet to the grinder was set at 70 kPa (10 psi) to represent the predicted line loss between the WVDP 8Q-1 to 8Q-2 transfer pump pits. The grinder was operated during all tests with varying percentages of solids delivered for grinding.

The discharge at the grinder outlet was sampled several times during each test run. Test runs lasted approximately one-half hour, with sampling performed at intervals of 10 minutes. The resultant samples were sent to a certified test lab to have the particle sizes analyzed. The requirement to have 90% of the particles smaller than 200 µm was satisfied: over 99% of the solids were reduced to less than 200 µm.

After each test run, the grinder was flushed with water from the steam jet for about 15 minutes. The grinder was disassembled numerous times to determine whether there was any buildup of solids. These inspections verified that the grinder was free of any significant solids buildup.

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Technology Applicability

The baseline method used for retrieving HLW waste from WVDP tanks includes jet mixer pumps and sluicing wands to mobilize waste material. Once mobilized, waste is kept in suspension with the jet mixer pumps and then removed from the tank using centrifugal transfer pumps. The baseline method has been effective for the bulk removal of 96% of the waste but may not be effective in achieving a waste retrieval goal of greater than 98%. An innovative technology was needed in case WVDP was unable to meet the target retrieval goal with existing equipment. The baseline retrieval method used at WVDP is also used for HLW waste retrieval at Hanford and the Savannah River Site (SRS) (Cuta et al. 2000; Poirier, Powell, and Gladki 1998; Daymo 1997).

The AWRS was designed to provide a waste retrieval capability for residual waste in the event that the existing baseline system was ineffective in achieving the target cleanup goal. Competing retrieval technologies were not selected because WVDP had the baseline system in place that could be upgraded to deploy innovative technology less expensively than installing a new technology never demonstrated at WVDP. Important advantages of using AWRS were that AWRS components were designed to use existing tank infrastructure, thereby achieving significant cost savings, and that the AWRS incorporated lessons learned to develop a second-generation MTD assembly. The lessons learned from testing individual AWRS components suggest that individual components may be an option for application at other DOE sites. The following section briefly discusses selected AWRS components and competing technologies.

Competing Technologies

The AWRS can be divided into four functions for comparison with competing technologies: (1) equipment deployment system (MTD assembly), (2) retrieval method (telescopic arm and jet pump assembly), (3) particle size reducer (grinder-separator assembly), and (4) waste conveyance (booster pump assembly). The grinder-separator and booster pump assemblies consist of commercially available equipment and can be compared with other commercial systems. Note that all AWRS components have been tested at full scale and were designed for conditions in the WVDP HLW tanks. No scale-up or waste compatibility issues are expected for the application of AWRS components at other DOE sites.

The MTD assembly is a mast deployment system. Deployment of mast-based technologies such as the Borehole Miner (OST 1999a) may be possible using the MTD assembly. Direct comparison of the MTD assembly with an arm-based deployment system such as the Light Duty Utility Arm (LDUA) is application specific (tank size, tank contents, riser limitations, retrieval goals, etc.). However, some general comparisons between the MTD assembly and LDUA (OST 1998a) can be made for initial screening:

Feature	MTD assembly	LDUA
Minimum riser diameter	61 cm (24 inches)	30 cm (12 inches)
Vertical reach	16.5-m (54-ft) mast	15-m (50-ft) mast plus arm
Horizontal reach	Depends on system deployed	4.1 m (13.5 ft)
Camera system	Deployed on mast	Deployed in separate riser
Deployable systems	Three demonstrated on one mast (two cameras and telescopic arm and jet pump assembly)	One end effector at a time

Another deployment option for in-tank equipment is a remotely operated vehicle system such as the Houdini II (OST 1999b) or Scarab III (OST 2001). Application of these systems may be complicated by the presence of in-tank obstructions, such as the grid work found in the WVDP tanks. Houdini II was used as part of the waste retrieval system for the Gunite and Associated Tanks (GAAT) at the Oak Ridge Reservation (ORR) in combination with the LDUA and a number of end effectors. Application of Scarab III has been for sampling activities in ORR Tank T-14. Deployment of a remotely operated vehicle system for waste retrieval has not been performed to date in the large-diameter tanks (21 m [69 ft] or greater) located at Hanford and SRS.

The telescopic arm and jet pump assembly component of the AWRS is similar to the LDUA equipped with the Confined Sluicing End Effector (CSEE) except that the CSEE is designed to dislodge waste in addition to retrieving it (OST 1998b). For WVDP, the telescopic arm and jet pump assembly was designed to have a horizontal reach of 5.8 m (19 ft). For application in the GAAT tanks, the CSEE deployed on a modified LDUA had a horizontal reach of 4.5 m (15 ft) (OST 1998a). The telescopic arm and jet pump assembly is designed to interface with a tank's existing transfer pump, while the CSEE used a separate pump for conveying waste from the GAAT tanks.

Patents/Commercialization/Sponsor

The Tanks Focus Area sponsored the design, fabrication, and testing of the AWRS. The system is available for installation should the current mobilization and retrieval methods fail to achieve the goal of removing greater than 98% of the original sludge radioactivity.

SECTION 5
COST

Methodology

With the exception of the new transfer line for the existing G-012/G-012A transfer pump assembly, all components of the AWRS were procured, tested, and delivered to WVDP. Cost estimates provided in this section represent the cost for the design, fabrication, and testing of AWRS components. Data to estimate deployment costs for WVDP have not been developed.

Combined capital and development cost estimates presented for competing technologies are based on published information and are provided for an order-of-magnitude comparison between a competing technology and AWRS components. The list of competing technologies is intended not to be inclusive but to highlight the types of systems that should be considered when evaluating components of the AWRS for a specific application. A more detailed cost analysis would be required to evaluate cost-effective, tank-specific waste retrieval options. Elements to consider include waste retrieval goals, tank infrastructure limitations, waste type, presence of in-tank obstructions, and time constraints.

Cost Analysis

Table 1 contains information provided by WVNS staff based on historical procurement information. No effort has been made to adjust the estimated costs for inflation.

Table 1. Estimated cost for AWRS components

Component	Cost ($K)
MTD assembly (mast, winches, trolley support, and camera assemblies)	200
Telescopic arm and jet pump assembly*	280
Grinder-separator assembly	100
Booster pump assembly	50
Full-scale testing	200
Total	830

*Includes design and fabrication. Fabrication alone costs about $100K.

Relative to the baseline method using jet mixer pumps, transfer pumps, and sluicing wands, the AWRS represents increased capital cost. However, if AWRS is implemented, it will be because the baseline method is not capable of meeting cleanup goals or because the baseline method has reached a point of diminishing return for the amount of waste retrieved per retrieval campaign. Operating costs for AWRS are estimated to be the same as or lower than those for the baseline since the jet mixer pumps will not need to be used. Waste retrieval efficiency is anticipated to be higher for AWRS than for the baseline because the suction pickup point will be moved to the location of the waste rather than relying on movement of the waste to the fixed suction points of the transfer pumps.

Table 2 provides estimated combined capital and development costs for competing technologies discussed in Section 4. The reference source for the cost and further information on the competing technology is provided. Capital costs based on demonstrated designs and potential future development costs for a new application should be discussed with the developer of the competing technology.

Table 2. Estimated costs for competing technologies

Technology	Cost ($K)	Reference
Light Duty Utility Arm (LDUA)	1,900	OST 1998a
Modified LDUA	2,000	OST 1998a
Confined Sluicing End Effector	200	OST 1998b
Houdini I and Houdini II	5,000	OST 1999b
Scarab III	850	OST 2001

Cost Conclusions

The AWRS was developed as a backup system in the event that current retrieval methods are not sufficient to meet target cleanup goals for WVDP Tanks 8D-1 and 8D-2. If cleanup goals are met with the existing systems at WVDP, then the cost to achieve this goal will include the $830K invested in the AWRS backup system. If AWRS is deployed at WVDP, then AWRS will incur installation costs and operating costs for residual waste retrieval.

Lessons learned from the development and demonstration of AWRS reduce technical and programmatic risk associated with WVDP waste retrieval by providing a backup system that can be implemented in a timely manner if needed. In addition, components of the AWRS can provide the basis for similar systems at other DOE sites to address residual waste retrieval needs.

SECTION 6
REGULATORY AND POLICY ISSUES

Regulatory Considerations

The AWRS was designed, fabricated, and acceptance tested by WVNS. The system provides increased solids removal and transfer capability over the existing transfer pumps, which require that small particles be suspended in solution for adequate pickup and transfer. Because the system was designed to use as much of the existing WVDP tank infrastructure as possible and to be based on lessons learned from current equipment, no barriers are envisioned for the deployment of the AWRS at WVDP.

Secondary Wastes
Operation of the AWRS is not anticipated to create a secondary waste stream that is greater in quantity than that currently generated from the baseline retrieval operation. Since the use of the jet pump with the suction head at the tank bottom eliminates the need for a mobilization pump to suspend particles in solution for retrieval, the amount of water required for retrieval may be decreased.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Evaluation
This section summarizes how the AWRS addresses the nine CERCLA evaluation criteria.

1. *Overall Protection of Human Health and the Environment*
   Use of the AWRS is envisioned to result in a greater percentage of material being retrieved from waste tanks with minimal additional worker exposure.

2. *Compliance with Applicable or Relevant and Appropriate Requirements*
   The AWRS has been designed to be compatible with current equipment and operating conditions at WVDP. Compliance issues with the deployment of the system at WVDP are not anticipated.

3. *Long-Term Effectiveness and Permanence*
   Use of the AWRS is envisioned to result in a greater percentage of material being retrieved from waste tanks, thus reducing the long-term risk from residual tank waste material.

4. *Reduction of Toxicity, Mobility, or Volume Through Treatment*
   Use of AWRS is envisioned to result in a greater percentage of material being retrieved from waste tanks, thus reducing the quantity of residual tank waste material. The reduction of the quantity of residual tank waste material should therefore improve the performance of a tank closure method for reducing toxicity and mobility of residual waste.

5. *Implementability*
   Full-scale testing of AWRS components has been completed and showed the equipment capable of meeting performance requirements. Full-scale testing of equipment prior to delivery to WVDP ensured that the equipment operated properly. Designs for the modified G-012/G-012A transfer pump assembly have been developed to provide in-tank remote connection capability. As a cost savings measure for the initial development and testing work, these modifications were not made, but they would be required prior to installation of the AWRS.

6. *Cost*
   Relative to the baseline method using jet mixer pumps, transfer pumps, and sluicing wands, the AWRS represents increased capital cost. However, if AWRS is implemented, it will be because the baseline method is not capable of meeting cleanup goals or because the baseline method has reached a point of diminishing return for amount of waste retrieved per retrieval campaign. Operating costs for AWRS are estimated to be the same as or lower than those of the baseline since the jet mixer pumps will not need to be used. Waste retrieval efficiency is anticipated to be higher for AWRS than for the baseline because the suction pickup point will be moved to the location of the waste rather than relying on movement of the waste to the fixed suction points of the transfer pumps.

7. *State and Community Acceptance*
   No issues are anticipated for state and community acceptance of the AWRS because the system would not significantly alter the facilities at WVDP. In addition, the deployment of the AWRS would enable the site to meet tank cleanup criteria should the baseline methods be shown inadequate.

Safety, Risks, Benefits, and Community Reaction

Topics for this area are covered under Regulatory Considerations. Installation and deployment issues were not identified during the fabrication and testing phases of the AWRS development project.

SECTION 7
LESSONS LEARNED

Design and Implementation Considerations

Most elements of the AWRS system were fabricated and tested as prototypes, including the grinder-separator and the remote coupling feature of the telescopic arm and jet pump assembly. The design was ensured to meet all requirements at completion, thereby minimizing risk, by employing the practice of prototype demonstrations prior to the release of detailed design documents.

Full-scale testing of equipment prior to its arrival on site ensured that equipment operated properly. Full-scale testing also provided operators an opportunity to become familiar with the system, thereby minimizing training time. Operators were given the opportunity to participate in the design development and suggest design improvements before the final system was delivered.

Using existing proven designs such as the MTD assembly as the starting point of development, the AWRS worked successfully and minimized the amount of time necessary for design development. Reviewing commercially available technologies in regard to pumps, vibration grinders, and steam jets expedited the AWRS development process. This approach was used to select the booster pump and steam jet for the AWRS, equipment that performed as expected during testing and is projected to have a high degree of reliability in a radioactive environment.

Technology Limitations and Needs for Future Development

The MTD assembly was designed for WVDP and fits through a 61-cm (24-inch) riser. Application of this system at other DOE sites will require evaluating the load limit above the tank and may also require the construction of a support platform.

Designs for the modified G-012/G-012A transfer pump assembly have been developed to provide in-tank remote connection capability. As a cost savings measure for the initial development and testing work, these modifications were not made, but they would be required prior to installation of the AWRS.

Technology Selection Considerations

The AWRS was developed specifically for application at WVDP; however, components such as the MTD assembly, telescopic arm and jet pump assembly, and the grinder-separator assembly may have application for tanks at other DOE sites.

APPENDIX A
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APPENDIX B
ACRONYMS AND ABBREVIATIONS

AWRS	Advanced Waste Retrieval System
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSEE	Confined Sluicing End Effector
DOE	Department of Energy
GAAT	Gunite and Associated Tanks
HLW	high-level waste
LDUA	Light Duty Utility Arm
MTD	mast tool delivery
ORR	Oak Ridge Reservation
OST	Office of Science and Technology
SMCI	Specialty Maintenance and Construction, Inc.
SRS	Savannah River Site
VAC	volts alternating current
VKE	vibratory-kinetic energy
WVNS	West Valley Nuclear Services
WVDP	West Valley Demonstration Project