ORNL/TM-2004/75

Nuclear Science and Technology Division

Development of a Remote Long-Reach Retrieval Tool for Use at the Fernald Silos

V. K. Varma
B. E. Lewis
C. P. McGinnis

Date Published: April 2004

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6283
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

CONTENTS

LIST OF FIGURES

ABSTRACT

A long-reach tool was developed to remove discrete objects from the silos at the Fernald Environmental Management Project in Ohio. If they are not removed, these objects can potentially cause problems during the retrieval and transfer of waste from the silos. Most of the objects are on top of the Bentogrout cap inside the silos at or near the primary opening into the tank and will therefore require only vertical lifting. The objects are located about 20 ft from the top of the silo. Although most of the objects can be retrieved from 20 ft, the long-reach tool was designed to for a reach up to 40 ft in case objects roll towards the walls of the tank or need to be removed during heel retrieval operations.

This report provides a detailed description of the tool that was developed, tested, and demonstrated at the Tanks Technology Cold Test Facility at Oak Ridge National Laboratory. Scaffolding was erected over two experimental cells to simulate the 40-ft maximum working depth anticipated in the silos at Fernald. Plastic bottles and plastic sheeting simulated the debris that could be encountered during waste retrieval operations.

1. BACKGROUND

Operable Unit 4 at the Fernald Environmental Management Project near Cincinnati, Ohio, includes two domed silos that contain almost 10,000 tons of radium-bearing low-level waste. The waste, known as K-65 waste, consists primarily of solids of raffinates remaining after the processing of ores from the former Belgian Congo to recover uranium. The silos are 80 ft in diameter, 36 ft high at the center of the dome, and 26.75 ft to the top of the vertical sidewalls. The silos were constructed in 1951 and 1952 of concrete wrapped with steel post-tensioning wires, and the sides were covered with gunite. The floor of each silo slopes toward a 4×4 x 1 ft sump located near the center. Decant ports (50 per silo), consisting of a series of 3-in.-diam pipes, are located vertically on the wall of the silos at opposite sides. The silos also have an underdrain system and decant sump tank to collect any potential leakage. Earthen berms have been formed around the outside silo walls, and a radon collection system has been installed to reduce exposure levels to workers and releases to the environment.

Waste materials were originally transferred to silos 1 and 2 via pumping in the form of a slurry. The waste solids settled, and the supernatant was removed by overflowing from the decant ports, with the lowest port located 1 ft from the bottom of each silo. Silo 1 contains 115,900 ft^3 of K-65 waste and 12,600 ft^3 of bentonite clay. Silo 2 contains 100,400 ft^3 of K-65 waste and 11,100 ft^3 of bentonite clay (Bentogrout). The bentonite clay in both silos was added in 1991 in a layer over the existing K-65 waste to reduce the potential for radioactive emissions to the environment. The average thickness of the bentonite clay is estimated to vary between 6 in. and 2 ft. The average moisture level of the waste in silos 1 and 2 is approximately 30% and increases with depth.

Discrete objects in the silos are not well characterized and may consist of personal protective equipment, manway gaskets, hand tools, plastic sample bottles, metal pipes, drums, and cables. Sample bottles, screwdrivers, wrenches, and plastic tents (approximately 6 x 6 x 6 ft with glove ports) were observed on the surface of the waste before the Bentogrout cap was placed in the silos in the early 1990s.

The Accelerated Waste Retrieval (AWR) Project will retrieve the majority of the K-65 waste from silos 1 and 2, transfer the material to interim storage tanks for staging before final remediation, reduce the radon concentration in each silo headspace, provide radon control during retrieval and material storage, clean the silos and equipment in preparation for system closure, and handle the secondary waste generated during the project. The AWR Project will use sluicing technology in conjunction with a submersible sludge removal pump to retrieve the K-65 material down to a heel approximately 20 in. deep. The remaining waste will then be retrieved during the Heel Retrieval Project. The residual waste must be removed to the point of “no visible material” to allow for the planned demolition of the silos.

2. DESIGN CONSIDERATIONS FOR THE LONG-REACH TOOL

The long-reach tool retrieval process is designed to remove discrete debris objects that lie inside the silo on top of the K-65 material immediately beneath the Bentogrout cap. Because the objects in the silo include a variety of materials such as plastic bags, wrenches, pipes, and plastic sampling bottles, a well-designed gripper tool is needed for their removal. The location and the conditions under which the tool will be deployed determined the overall approach to the tool design.

Initially the AWR Project will deploy a submersible sludge pump along with two articulated nozzles to sluice and loosen the clay to facilitate retrieval operations. Because a layer of Bentogrout is on top of the waste, the pump must operate for some depth before it encounters any of the discrete debris in the silo. The following is a list of objects and scenarios that may be encountered during sludge retrieval:

1. *Plastic bags*: The plastic bags inside the silos have probably not moved far away from the position where they were dropped. If the bags are not removed, they may choke the sludge removal pump. If the bags are not significantly deteriorated, the long-reach tool should be able to remove them with a vertical pull after they are exposed. Directing the sluicing nozzles near the area of the bags should be sufficient to expose the bags entirely. Once the bags are exposed, the long-reach tool can easily remove them from the silo.

2. *Wrenches and other heavy metallic objects*: These objects are likely to be in the area where they were dropped. The long-reach tool can easily grip any exposed pieces and remove them from the tank.

3. *Plastic bottles*: Plastic bottles dropped on the K-65 layers may not have stayed in the area where they were dropped. In fact, it is highly likely that these bottles rolled and moved away from the riser location toward the sides of the tank. Although vertical lift can remove the exposed bottles near the opening to the silo, it cannot be used to reach areas near the tank walls without some degree of articulation. Furthermore, if the sweeping of the sluicing nozzles is not uniformly controlled during waste retrieval operations, a slope toward the sides of the silo will likely be formed in the bentonite clay, causing lightweight objects to move toward the outer wall of the silo. To retrieve objects that have rolled towards the silo wall, Sthe long-reach tool will require the incorporation of a joint in its design.

4. *Headroom inside the pump containment module*: Because the headroom inside the pump containment module is limited, the long-reach tool must be constructed in sections. To obtain the desired depth of operation, the sections are assembled as the long-reach tool is inserted into the silo.

5. *Cleaning pump inlet*: During waste retrieval operations, debris that becomes lodged at the inlet of the submersible transfer pump can choke the pump and reduce the waste transfer efficiency. If this occurs, either the pump must be brought into the pump containment module for hands-on maintenance or the long-reach tool must be deployed to remove the debris from the inlet while the pump is suspended by an overhead crane. A 90° or 135° elbow on the long-reach tool will enable it to remove objects that are lodged in the pump inlet. Use of the long-reach tool will (1) considerably shorten the time needed to remove debris from the pump inlet, and hence shorten the retrieval process, and (2) reduce radiation exposure to workers by minimizing contact with contaminated equipment if and when removal of debris from the pump is needed.

3. ANTICIPATED DEPLOYMENT APPROACH

This section describes the approach for deploying the long-reach tool to remove discrete debris objects. It is anticipated that this tool will be deployed at various stages during the waste retrieval process. Possible operating scenarios associated with these stages are as follows:

- *Stage I:* Currently, all loose objects are assumed to be on top of the K-65 material under the Bentogrout clay layer (Region I, Fig. 1). During the bulk removal process, the sluicing jets can be initially directed on top of the Bentogrout layer to expose the discrete objects (Region II, Fig. 1). Through the use of the long-reach tool, the objects can be removed by a vertical lift. After all the visible discrete objects are removed, the submersible transfer pump can be installed.

- *Stage II*: Once the transfer pump is installed, sluicing and pumping operations will begin to remove as much of the K-65 and Bentogrout clay as possible until any obstruction at the pump inlet chokes

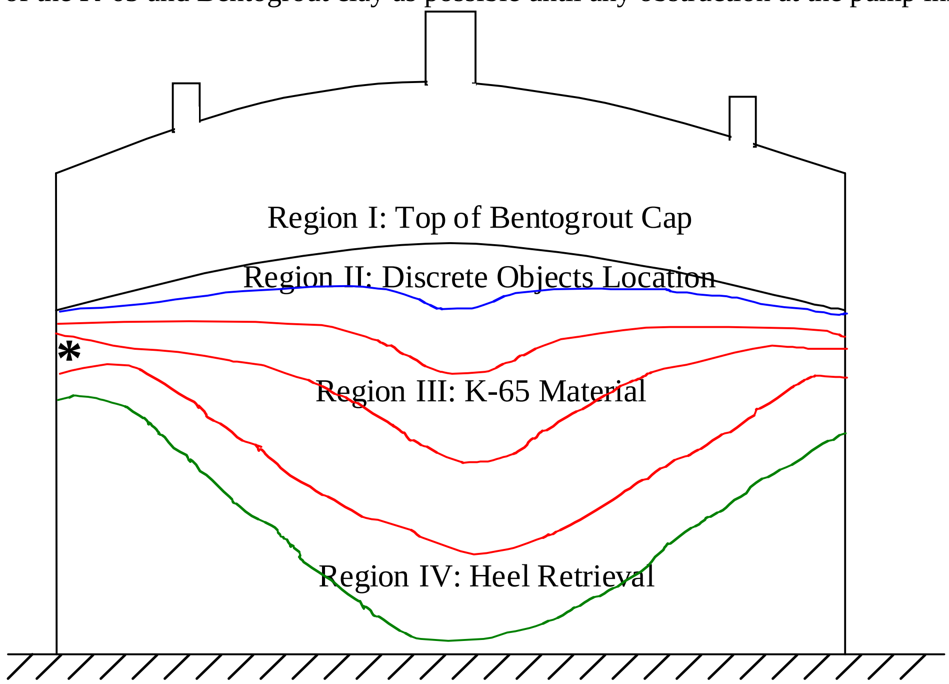

Fig. 1. Cross-sectional view of the silo, illustrating the profile of the contents inside as a function of material removal.

the flow (Region III, Fig. 1). At this stage, the pump can be partially retracted and the long-reach tool deployed to remove the debris near the inlet. The asterisk **(*)** in Region III of Fig. 1 depicts objects that might become stuck near the wall of the silos if sluicing is not performed uniformly. If debris is found near the walls of the silos, it is prudent to remove it immediately with the long-reach tool rather than waiting for it to migrate toward the pump and choke the feed. Because obstructions are likely to occur and the long-reach tool will need to reach the sides of the silos, the tool has been equipped with an articulated reach capability, apart from its normal vertical orientation.

- *Stage III*: When approximately 20 in. of waste is left in the tank, the efficiency of the transfer pump will significantly decrease. At this point a remotely operated vehicle may be deployed inside the tank to assist in the retrieval of the remaining material. Any discrete objects that are observed at this stage can also be removed by means of the long-reach tool (Region IV, Fig. 1).

4. TEST FACILITY AND TOOL DESIGN

4.1. TEST FACILITY DESIGN

To simulate the 40-ft working depth of the Fernald silos, 22.5-ft-tall scaffolding was erected over two experimental cells around the uncommissioned Experimental Gas-Cooled Reactor at the Tanks Technology Cold Test Facility at Oak Ridge National Laboratory (ORNL). Each experimental cell is 18.5 ft deep and, when combined with the scaffolding, provides the required 40-ft working depth (see Fig. 2). To simulate the pump containment module, a small room was constructed of wood and plastic sheeting on a work platform on top of the scaffolding.

Fig 2. Test platform for long-reach tool at ORNL.

4.2. TOOL DESIGN

To ensure that the long-reach tool does not bend excessively while operating, it is constructed from 1.25-in.-diam schedule 40 aluminum pipe. The tool is composed of five 8-ft-long pipe sections, one 4-ft-long pipe section, and a gripper assembly, with pipe sections attached by 0.5-in.-diam bolts with at least 1 in. of thread engagement. After each pipe section is attached, a setscrew arrangement is used to prevent any inadvertent loosening of the pipes during operation. The angle at which the setscrew is engaged inhibits any relative motion between the mating pieces of pipe.

The tool is lowered into the silo through the top plate as shown in Fig. 3. A quick-release cam-lock mechanism locks the tool in place while additional pipe sections are screwed together to extend the reach of the tool. The cam-lock mechanism allows the operator to release the tool and not be required to support the load during the entire duration of the retrieval operation. When the tool is in operation with the cam-lock released, a spring balancer is also used to minimize the weight carried by the operator to about 10 lb. To allow the long-reach tool to have sufficient room to work inside the tank, the top plate is supported by three springs (see Fig. 3). The springs not only support the weight of the tool but also allow for angular alignment of the tool inside the silo in the range of 10 to 15°.

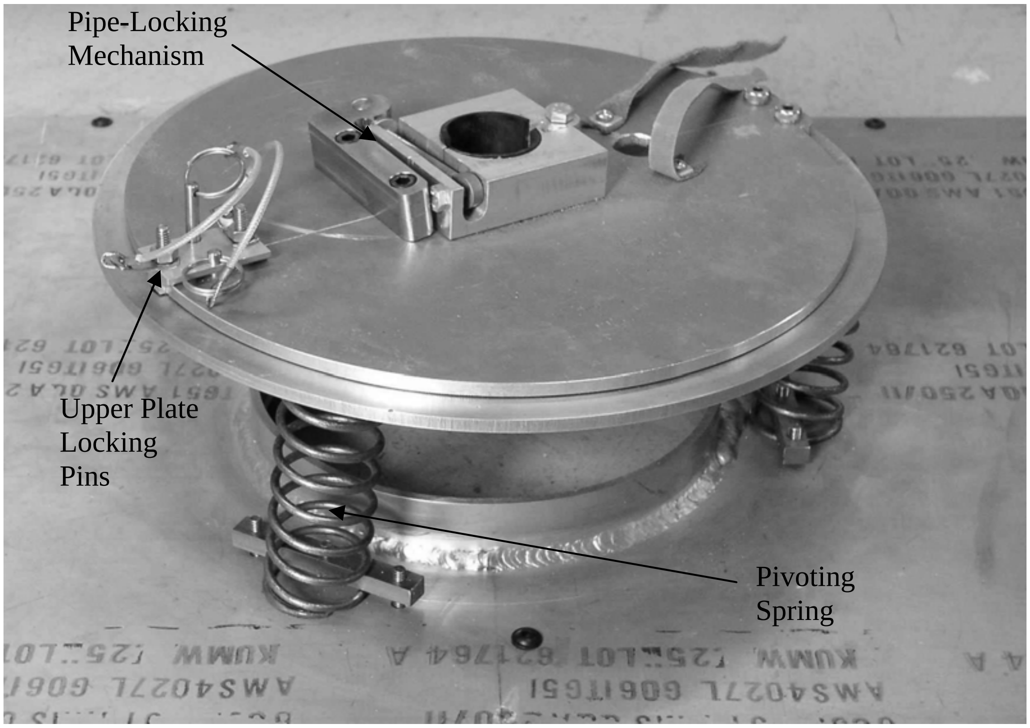

Fig. 3. Top plate assembly for the long-reach tool.

The end effector of the long-reach tool must be versatile enough to securely grasp the various sizes and types of debris expected to be inside the silo. Thus, as shown in Fig. 4 the end-effector gripper has been designed with opposing fingers. A stepper motor actuates the gripper, while limit switches restrict the gripper movements to a preset range. To provide additional flexibility, an alternate parallel-jaw gripper was also integrated into the tool design. Figure 5 shows the end-effector assembly of the long-reach tool with the parallel-jaw gripper. A camera is mounted on the actuator to provide the operator with a close-up view of the objects that are being grasped. The electric motor used to actuate the gripper has a brake that is normally closed and is turned off only when the motor is energized. The ability of the gripper to hold objects within its grasp without losing them will allow discrete debris to either be placed into a collection box inside the silo or to be brought to the platform area outside the silo, depending on the requirements. Most of the debris will likely be placed in a collection box, which is placed near the end effector, and lifted out of the silos by means of a cable connected to a winch inside the transfer pump containment module.

To retrieve objects such as plastic glove bags, the parallel-jaw gripper will be used to attach hooks to parts of the bag that are exposed during sluicing operations. Use of multiple hooks will prevent tearing of the glove bag. Each hook has a lanyard with a ring at the end to permit the hooks to be lifted by a winch inside the pump containment module. When sufficient portions of the glove bag have been exposed, it can be lifted out of the silo.

Fig. 4. Gripper design with opposing fingers.

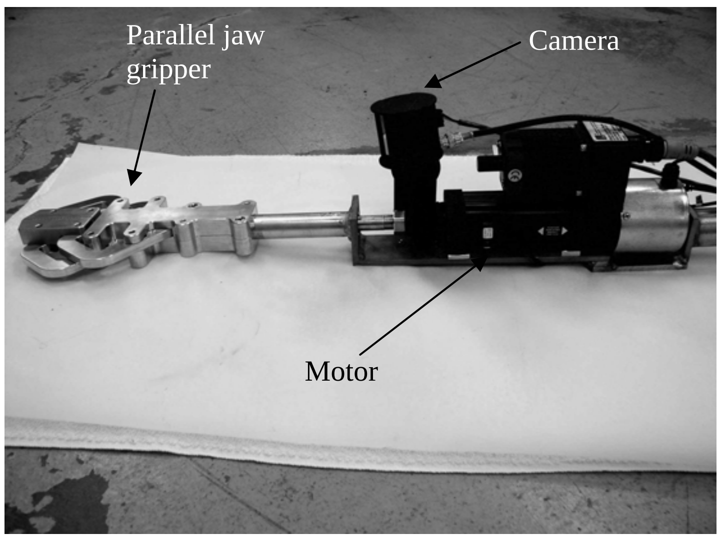

Fig. 5. Parallel-jaw gripper assembly.

The long-reach tool can also be used for cleaning the inlet port of the centrifugal pump if it becomes choked with debris that was not removed prior to pumping. To facilitate cleaning, the second section of the tool (the first section being the end-effector assembly and the motor) is equipped with an actuator. The positioning of the endeffector is achieved by turning a lead screw that actuates the linkages holding the gripper assembly (see Fig. 6). The endeffector can be positioned at any angle from 20 to 135° from the vertical (pointing downward). All tool operations have been designed to accommodate an operator who wears personal protective equipment, such as contamination control clothing and a respirator, while handling the tool.

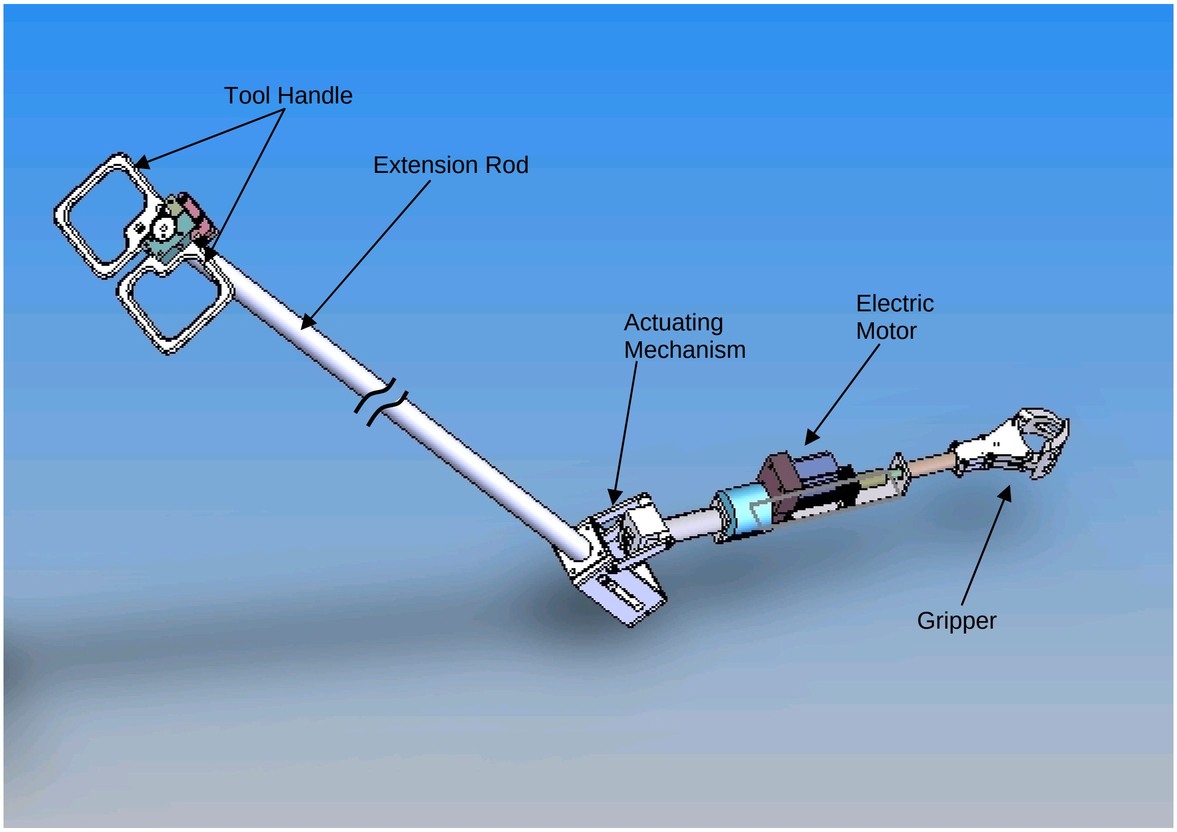

Fig. 6. Long-reach tool with actuating joint.

During initial testing, the weight of the tool prevented the operator from easily positioning it. The tool with the endeffector attached can weigh as much as 45 lb depending on the number of pipe extensions that have been added. To reduce the load supported by the operator, spring balancer will be attached to the I-beam on the pump containment module and then to the last section of the extension pipe. The tension of the balancer can be adjusted to be slightly greater or less than the weight of the long-reach-tool assembly based on operator preference. To tighten or loosen the balancer tension, the worm gear on the balancer is turned either clockwise or counterclockwise, respectively. At a 48.6-lb spring setting, the balancer tension is slightly greater than the total weight of the long-reach-tool with 40 ft of working depth.

5. LONG-REACH TOOL DEMONSTRATION AT ORNL

The operation of the long-reach tool was demonstrated at the ORNL Tanks Technology Cold Test Facility. Plastic bottles of varying sizes and a plastic bag were used to simulate discrete debris objects, and sand was used to simulate the K-65 material inside the silos. A small sandbox was located on the floor of the experimental cell to contain the simulated debris for the demonstration, with simulated collection box placed nearby. Various operators, including both ORNL and Fernald personnel, participated in the demonstrations.

For each demonstration, the long-reach tool was assembled in sections, and the operator was positioned inside the simulated pump containment module on top of the scaffolding. Existing cameras inside the experimental cells provided an overall view of the simulated silo interior. A close-up camera mounted on the end effector was used successfully in conjunction with the existing overview cameras to guide the process of picking up and placing the objects into the simulated collection box. The operators used the long-reach tool to pick up a 4-ft-long, 0.5-in.-diam nylon rope and a towel at the bottom of the scaffolding, a process that simulated a 20-ft working range of the tool. At the 40-ft range, the operators retrieved several 3- and 4-in.-diam plastic bottles. The operators also used the parallel-jaw endeffector to attach hooks to a plastic bag, which was used to simulate a glove bag. Use of wireless controls for opening and closing the gripper provided an easier way for the operators to actuate the gripper. The spring balancer was set at 48.6 lb to provide an upward force, which canceled slightly more than weight of the tool and required the operators to pull down on the tool to lower it and perform debris removal tasks. Applying a force as small as 5 lb was sufficient to position the tool within the workspace. This feature will greatly enhance comfort and reduce fatigue for the operators, who will be wearing full protective clothing during debris removal operations at Fernald.

6. OBSERVATIONS

Observations from two demonstration tests of the long-reach tool resulted in significant improvements to the initial tool design. Discussions with the sponsor and interactions with Fernald operations personnel provided the input necessary for the selection of the modifications for implementation in the final tool design as described in Sect. 4.2. The observations from the demonstration tests included the following:

1. The long-reach tool gripper with opposing fingers demonstrated the ability to grasp plastic containers of up to 4-in. diam.
2. The parallel-jaw gripper can be used to successfully install hooks in plastic sheeting to facilitate retrieval.
3. A cable management system is essential to the successful implementation of the tool.
4. A load-bearing-assistance system (spring balancer) is essential to minimize operator fatigue during tool deployment and debris retrieval operations.
5. In-tank overview camera views are essential to the efficient operation of the long-reach tool.
6. A grommet was needed to minimize cable wear during deployment and retrieval of the long-reach tool.
7. The remote control for the gripper end-effector actuator performed well in the simulated silo environment.
8. The onboard camera view provided the necessary close-up views of the debris objects to allow the operators to grasp and release the objects.
9. The setscrew locking system successfully prevented the pipe extension sections from loosening during deployment and operation of the long-reach tool.
10. Due to the physical exertion required, the long-reach tool should only be operated for limited periods of time by operators wearing full personal protective equipment.
11. The clam-shell pipe-locking mechanism on the top plate provided the necessary clamping force and friction to hold the tool in place during deployment.
12. Tool deployment and withdrawal requires assistance from two people.
13. Larger handles provided easier handling of the long-reach tool.

7. CONCLUSIONS

A long-reach tool was developed to remove discrete debris objects from the silos at the Fernald Environmental Management Project in Ohio. Although most objects can be retrieved from a distance of 20 ft, the long-reach tool was designed for a reach of up to 40 ft to retrieve objects that may have rolled and positioned themselves near the walls of the silos or to remove objects during heel retrieval operations. The long-reach tool was successfully demonstrated at the ORNL Tanks Technology Cold Test Facility. Various operators were able to use the tool to pick up and release objects such as plastic sample bottles, ropes, and plastic sheeting, which were used to simulate the debris expected to be present in the Fernald silos.