Fernald Silos Remote Retrieval Tool Development

VENUGOPAL K. VARMA , BENJAMIN E. LEWIS
varmavk@ornl.gov, lewisbejr@ornl.gov
Nuclear Science and Technology Division
Oak Ridge National Laboratory

and

JACK HUGHES
Jack.Hughes@fernald.gov
Fluor Fernald, Inc.

ABSTRACT- *A long-reach tool was developed to remove discrete objects from the silos at the Fernald Environmental Management Project in Ohio. If not removed, the 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 in case the objects need to be removed during heel retrieval operations.*

This document provides a detailed description of the tool that was developed, tested, and demonstrated at the Oak Ridge National Laboratory (ORNL) Tanks Technology Cold Test Facility. Scaffolding was erected over two experimental cells to simulate the 40-ft maximum working depth anticipated in the silos at Fernald. Plastic bottles and a plastic sheet simulated the debris that could be encountered during waste retrieval operations. This paper describes the functionality of the tool and proposed modifications to improve its operability.

I. BACKGROUND

Operable Unit 4 at the Fernald Environmental Management Project (FEMP) 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 left over from processing 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 x 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 opposing sides. The silos also have an underdrain system and decant sump tank to collect any potential leakage through the base of the silos. 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 by pumping them 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 varies between 6 in. and 2 ft. The average moisture level of the waste in silos 1 and 2 is ~30% and increases with depth.

Discrete objects in the silos are not well characterized and may consist of personal protective equipment, man-way gaskets, hand tools, plastic sample bottles, metal pipes, drums, and cables. Sample bottles, screwdrivers, wrenches, and plastic tents (~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 AWR 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. Then the Heel Retrieval Project will retrieve the remaining waste. The residual waste must be removed to the point of "no visible material" to allow for the planned demolition of the silos.

II. LONG-REACH TOOL DESIGN CONSIDERATIONS

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 taken for 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 will need to 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:

a) Plastic bags: Bags probably have not moved far away from the position where they were dropped. If the bags are not removed, they likely will choke the sludge removal pump. If the bags are not 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.

b) Wrenches and other heavy metallic objects: These objects will likely stay mainly in the area where they were dropped. The long-reach tool can easily grip any exposed pieces and remove them from the tank.

c) Plastic bottles: Plastic bottles dropped on the K-65 layers might not have stayed in the area where they were dropped. It is highly likely that these bottles rolled and moved away from the riser location as far as the sides of the tank. A vertical lift could remove the exposed bottles near the opening to the silo but cannot be used to reach areas near the tank walls without some degree of articulation. 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. This slope would cause light weight objects to move toward the outer wall of the silo. To reach the silo walls and retrieve objects that rolled toward them, the long-reach tool will need a joint incorporated in its design.

d) Head room inside the pump containment module: Because the head room 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.

e) 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 will need to be brought into the pump-containment module for hands-on maintenance, or the long-reach tool will need to be deployed to remove the debris from the pump 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 considerably shorten the time needed to remove debris from the pump inlet and hence shorten the retrieval process. Use of the long-reach tool will also reduce radiation exposure for workers by minimizing contact with contaminated equipment.

III. APPROACH

The approach for deploying the long-reach tool to remove discrete debris objects is explained in this section. We anticipate that this tool will be deployed at various stages during the waste retrieval process. These stages and possible operating scenarios are as follows:

a) 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

b) 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 the flow (Region III, Fig.1). At this stage, the pump can be partially retracted, and the long-reach tool can be deployed to remove the debris near the inlet. The asterisk (*****) in Fig.1 region III 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 with the long-reach tool as soon as the debris is discovered rather than waiting for it to migrate towards the pump and choke the feed to the pump. Because obstructions are likely to occur and the long-reach tool will need to reach the sides of the silos, the tool has an articulated reach capability apart from its normal vertical orientation.

c) 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 can 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).

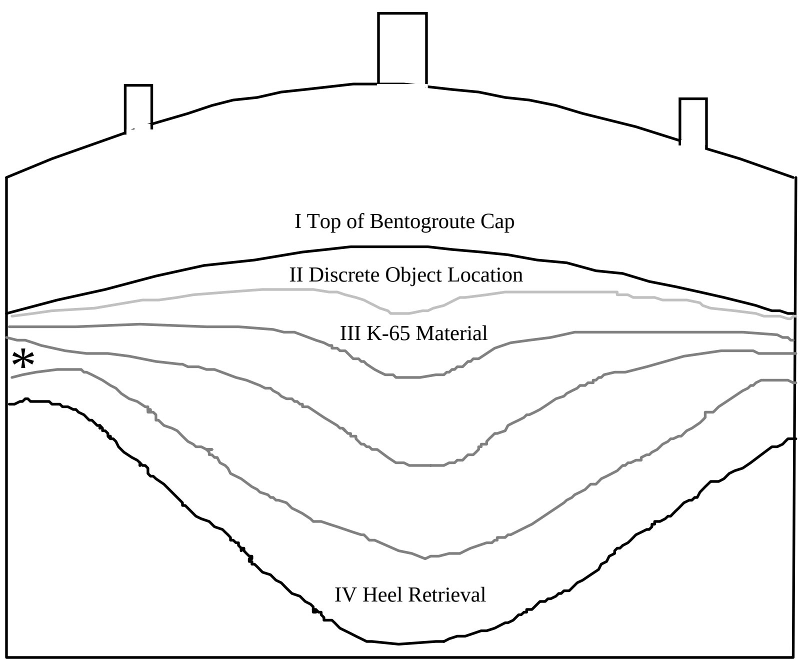

Figure 1. Cross-sectional view of the silo, illustrating the profile of the contents inside as a function of material removal.

IV. TEST FACILITY AND TOOL DESIGN

IV.A. 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 ORNL Tanks Technology Cold Test Facility. Each experimental cell is 18.5 ft deep; when combined with the scaffolding, they provide 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.

IV.B. 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 long-reach tool is composed of five 8-ft-long pipe sections, one 4-ft-long pipe section, and a gripper assembly. The pipe sections are attached by 0.5-in.-diam bolts with at least 1 in. thread engagement. After each pipe section is attached, a set-screw arrangement is used to prevent any inadvertent loosening of the pipes during operation. The angle at which the set screw 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 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 lbs. To allow the long-reach tool to have sufficient work area 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°.

Figure 2. Long-reach tool test platform at ORNL.

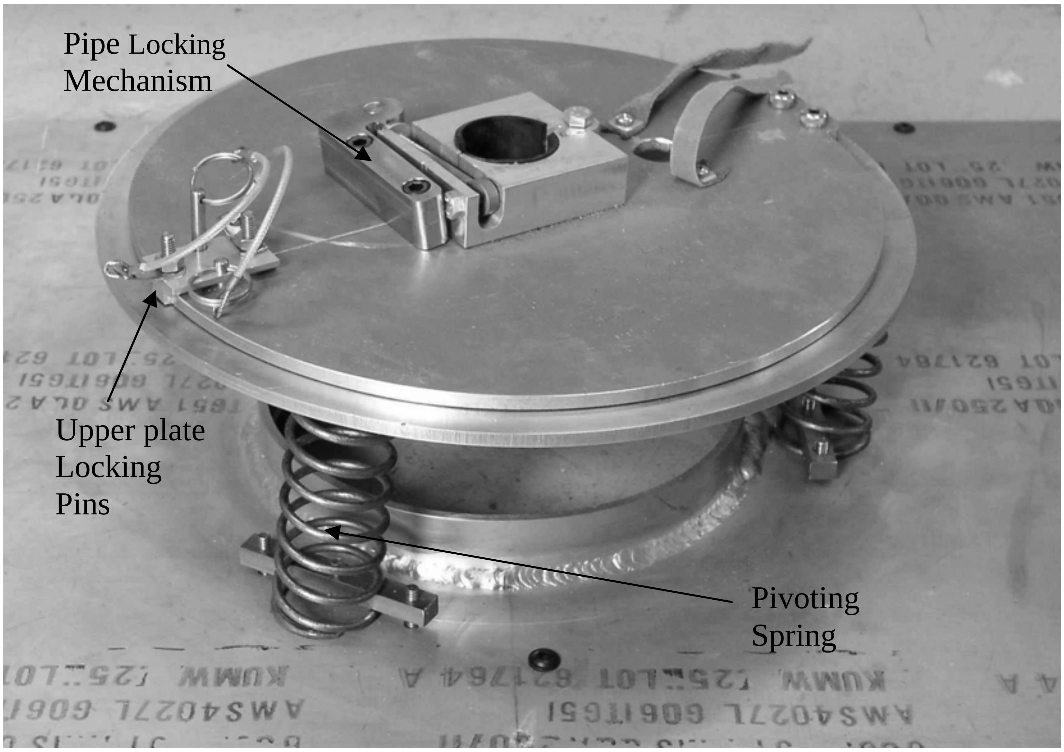

Figure 3. Top plate assembly for the long-reach tool.

The end effector of the long-reach tool needs to be versatile enough to have a secure grasp around the various sizes and types of debris anticipated to be inside the silo. Thus the end-effector gripper has opposing fingers as shown in Fig. 4. A stepper motor actuates the gripper. 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 gripper 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 in actuating the gripper has a brake that is normally closed. The brake is off only when the motor is energized. Ability of the gripper to hold objects within its grip without loosing it will allow the discrete debris to be either 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 likely will be placed in a collection box, which is suitably placed near the end effector, and lifted out of the silos by means of a cable connected to a wench inside the transfer pump containment module.

To retrieve the plastic glove bag, the parallel jaw gripper attaches 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 so the hooks can 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.

Figure 4. Gripper design with opposing fingers.

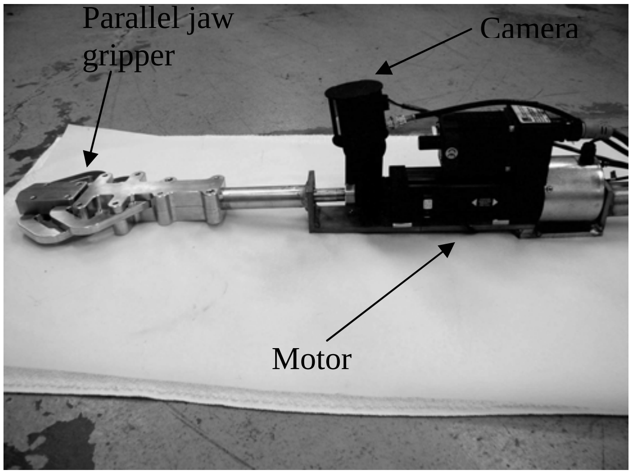

Figure 5. Parallel-jaw gripper assembly.

The long-reach tool can also be used for cleaning the inlet port of the centrifugal pump if it gets choked with debris that was not removed prior to pumping. To facilitate cleaning, the second section of the tool (first section being the end-effector assembly and the motor) is equipped with an actuator. The positioning of the end-effector is achieved by turning a lead screw that actuates the linkages holding the gripper assembly (see Fig. 6). The end-effector can be positioned at any angle from 5° from the vertical (pointing downward) to 135°. All tool operations have been designed to accommodate an operator wearing personal protective equipment, such as contamination control clothing and a respirator, while handling the tool.

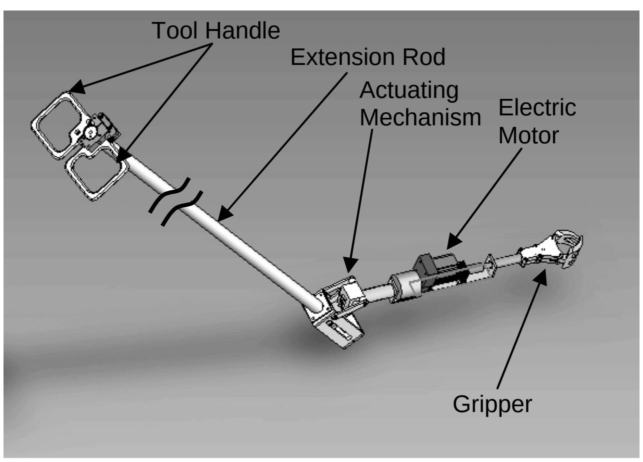

Figure 6. Long-reach tool with actuating joint.

V. LONG-REACH TOOL DEMONSTRATION AT ORNL

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 sand box was placed on the floor of the experimental cell to contain the simulated debris for the demonstration. The simulated collection box was placed on top of the sand box.

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 of the long-reach tool was used successfully in conjunction with the overview cameras to guide the process of picking up and placing the objects into the simulated collection box . The operator 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, which simulated a 20-ft working range of the tool. At the 40-ft range the operator retrieved plastic bottles 3 in. and 4 in. in diameter. The operator also used the parallel-jaw end-effector to attach hooks to a plastic bag, which simulated a glove bag.

VI. 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 20 ft, the long-reach tool was designed for a reach of up to 40 ft in case objects roll and position themselves near the walls of the silos or in case objects need to be removed during the heel retrieval operation. The long-reach tool was successfully demonstrated at the ORNL Tanks Technology Cold Test Facility; it was able to pick up and release objects such as plastic sample bottles, ropes, and plastic sheeting, which simulated debris in the silos.

VII. ACKNOWLEDGMENTS

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