PNNL-11734
UC-721

EM-50 Tanks Focus Area
Retrieval Process Development and Enhancements
FY97 Technology Development Summary Report

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September 1997

Prepared for
U.S. Department of Energy
Under Contract DE-AC06-76RLO 1830

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Authors' Note

The purpose of this report is to describe and summarize the conclusions that resulted from the FY97 Retrieval Process Development and Enhancements technology testing. The detailed final FY97 testing reports from the various Retrieval Process Development and Enhancements technology development subtasks are referenced at the end of this document.

Summary

The Retrieval Process Development and Enhancements (RPD&E) activities are part of the U.S. Department of Energy (DOE) EM-50 Tanks Focus Area, Retrieval and Closure program. The purpose of RPD&E is to understand retrieval processes, including emerging and existing technologies, and to gather data on those processes, so that end users have requisite technical bases to make retrieval decisions.

RPD&E activities support the need for multiple retrieval technologies across the DOE complex. Technologies addressed during FY97 include enhancements to sluicing, the use of pulsed air to assist mixing, mixer pumps, innovative mixing techniques, confined sluicing retrieval end effectors, borehole mining, light weight scarification, and testing of Russian-developed retrieval equipment. Furthermore, the Retrieval Analysis Tool was initiated to link retrieval processes with tank waste farms and tank geometric to assist end users by providing a consolidation of data and technical information that can be easily accessed.

The main technical accomplishments of RPD&E, based upon FY97 DOE activities include:

Oak Ridge Site - Gunite and Associated Tanks Treatability Study
Two waste retrieval end effectors were designed, fabricated, and tested for the Oak Ridge National Laboratory (ORNL) Gunite and Associated Tanks-Treatability Study (GAAT-TS). The Sludge Retrieval End Effector (SREE) was successfully deployed at the ORNL Tank W-3 with an integrated retrieval system consisting of a long-reach manipulator (the MLDUA), a remotely-operated vehicle with a teleoperated arm (the Houdini), a conveyance system and cable-management arm, and a multiple-camera vision system.

Pulsed Air Mixing
A Pulsed-Air Mixer was deployed inside the simulant holding tank at the GAAT test facility in December 1996. The simulant holding tank was used to collect simulated gunite tank waste used in testing the integrated GAAT retrieval system. After several retrieval system tests, the simulant collected in the holding tank needed to be transferred back into the test bed in preparation for the next test series. A means of mixing the simulated waste was needed to facilitate this transfer. Pulsed-Air Mixing was selected for this purpose. Additionally, RPD&E designed a full-scale Pulsed-Air Mixer for deployment into ORNL Tank W-9 in FY98. This required not only developing a mixer deployment concept and preparing the design drawings, but addressing specific operation issues as well.

Oak Ridge Site - Old Hydrofracture Facility
An Extendible-Nozzle Water-Jetting System was designed, constructed, and delivered to the ORNL to remediate five horizontal underground storage tanks containing sludge and supernate at the ORNL Old Hydrofracture Facility (OHF) site. The OHF tanks range in diameter from 2.4 to 3.2 m (8 to 10.5 ft) and length from 7.1 to 13.7 m (23 to 45 ft). The tanks contain up to 46 cm (18 in.) of sludge covered by supernate. The tanks will be remediated in FY98. This deployment will be the first radioactive demonstration of the Extendible-Nozzle Water-Jetting System. The extendible-nozzle design is based on existing borehole miner technology used to fracture and dislodge ore deposits in mines. The system includes the extendible nozzle deployed from within the mast, the support platform, and high-pressure liquid and hydraulic hoses.

Hydraulic Testbed Relocation

At the end of February 1997, the Retrieval Process Development and Enhancements program completed relocation of the Hydraulic Test Bed (HTB). The HTB supports DOE/EM programs, industry, and academia by providing key testing capabilities to support high-pressure waterjet end effector development. The HTB includes a large gantry robot, pumps, air blower, and other test equipment to support long duration mining strategy tests needed to evaluate steady state performance of end effectors. Through FY96, the HTB resided in the Hanford 337 Building's High Bay. In late FY96, the program was notified that the Fast Flux Test Facility (FFTF) legacy sodium removal program had plans to close the 337 Building's High Bay so that the sodium could be removed. The HTB had to be moved to continue retrieval end effector development and testing for Idaho National Engineering Environmental Laboratory (INEEL) and ORNL. The relocation task included securing a new test site, moving the equipment, setting up the equipment, and providing resources for site rental.

Cooling Coil Cleaning End Effector

An end effector was developed by researchers at the University of Missouri, Rolla (UM-R) and Pacific Northwest National Laboratory (PNNL) to meet INEEL site needs for cleaning the cooling coils and removing the particulate waste in the High Level Liquid Waste (HLLW) tanks. The end effector design was developed from functional requirements and size constraints identified by INEEL. Where possible, the cooling coil cleaning end effector also made use of proven technologies from the confined sluicing end effector that was developed for the ORNL site. The end effector was tested extensively in the HTB at PNNL to assess the end effector's performance in a mockup of the HLLW coiling coils. The Cooling Coil Cleaning End Effector was tested to evaluate the effectiveness of waterjets for direct cleaning of the top and indirect scouring of the bottom surfaces. The testing program showed that although the high-pressure waterjets were effective in directly removing the simulated waste from the tops of the tubes, they were ineffective in removing waste from the undersides of the tubes. The waterjets at pressures up to 35-mPa (5,000-psi) did not provide sufficient energy to entrain the 7.6-cm (3-in.) deep sand bed beneath the cooling coils to scour the undersides of the coils.

Light Weight Scarifier (LWS)

RPD&E completed bench scale testing of the Light Weight Scarifier (LWS) at Waterjet Technology, Inc. (WTI). Retrieval testing of the LWS was completed at the Hydraulic Test Bed at PNNL. Additionally, proof-of-principle integrated testing was conducted with the LWS deployed by the Light Duty Utility Arm (LDUA). The LWS was attached to the LDUA gripper and the system was used to retrieve simulants representing dried sludge and granular saltcake waste types. The LWS was selected as a featured technology for the Hanford Tanks Initiative (HTI) and was tested with the Grey Pilgrim EMMA manipulator at the National Institute of Science and Technology.

Innovative Tank Mixing (ITM)

RPD&E investigated commercial alternatives to jet mixer pumps for double shell tank (DST) sludge mobilization and slurry mixing. Over 100 vendors of mixing equipment were contacted in order to find innovative and applicable methods to mobilize sludge in DSTs. Several recognized academic and industrial tank mixing experts were contacted in order to identify applicable innovative mixing technologies. No viable, previously unidentified alternative to jet mixer pumps was found.

Advanced Design Mixer Pump (ADMP)

Recommendations were provided to the Savannah River Site (SRS) test program for test data to be taken to ensure Hanford W211 project requirements can be evaluated. A review of SRS test plans was conducted. The advanced design mixer pump (ADMP) testing needs to ensure it provides results that potential end users can use for evaluating the ADMP. One potential end user is Hanford W211 project, which plans to meet its mixer pump requirements using the W151 mixer pumps. The W151 pumps have not been extensively tested and there are concerns regarding their ability to meet the needs of waste tank retrieval projects.

Enhanced Sluicing

RPD&E completed the characterization of the Hanford Nozzle including determination of coefficient of discharge. An estimation of pressure and force fields generated by the impact of the waterjet emanating from the Hanford Nozzle, at various distances from the jet exit, and with geometrical orientations comparable with those expected during the sluicing operations in Hanford Tank C-106 was initiated. Qualitative tests of sluicing were conducted in a 9-m (30-ft) diameter tank at the UM-R. Near prototypic pressures, flow rates, and distances were used in conjunction with a Hanford Nozzle.

Russian Retrieval Equipment Testing

The pulsating pump and pulsating monitor from Russia were tested to provide an initial evaluation of the equipment for possible deployment in DOE waste tanks. The evaluation of potential end users was conducted to determine whether the conceptual design of the equipment could be adapted to their needs. The equipment was tested in the DST 1/4 Scale Test Facility using water and simulated tank waste. Pump operation was tested with water, kaolin clay slurries of varying concentration, and mixtures of kaolin clay and varying size aggregate.

Retrieval Data Analysis and Correlation

RPD&E completed dynamic force analyses for the Confined Sluicing End Effector (CSEE). Additionally, High-Pressure Waterjet Scarifier retrieval data was analyzed and incorporated into the Retrieval Analysis Tool and pneumatic conveyance data was analyzed to determine the maximum solids transport rate for retrieval of wet and dry solids from waste tanks.

Simulant Development

RPD&E provided simulant specification, makeup, and disposal support for testing of the INEEL End Effector, ORNL Gunite Scarifier, extendible nozzle, Light Weight Scarifier, Russian retrieval equipment, and enhanced sluicing equipment.

Retrieval Analysis Tool (RAT)

The Retrieval Analysis Tool, designed as a retrieval technology information source, was implemented using a relational database and was constructed using an Internet website. Retrieval information was compiled and the tool was implemented as a part of the HTI's solicitation to industry for retrieval of radioactive waste.

Acknowledgments

The RPD&E team consists of a core team of scientists and engineers from the Pacific Northwest National Laboratory, Waterjet Technology, Inc., University of Missouri-Rolla, University of Washington-Applied Physics Laboratory, and Pulsair Systems, Inc. This team exhibited their continued leadership in the retrieval process arena through presentations and participation at the Waste Management and Environmental Restoration Education and Research Consortium, Russian Retrieval Workshop, American Nuclear Society Topical Meeting on Robotics and Remote Systems, and American Chemical Society Conference. The team hosted several technical demonstrations, including the ORNL Confined Sluicing End Effector, INEEL End Effector, ORNL OHF Extendible Nozzle, Pulsed Air, Russian Retrieval Equipment, and LDUA/LWS Tank Waste Retrieval. Additional assistance was extended during the design review process to ORNL GAAT-TS, ORNL Old Hydrofracture Facility extendible nozzle design review process, data analysis and incorporation to the HTI Retrieval Analysis Tool.

Glossary

Acronym/Term	Definition
ACTR	Acquire Commercial Technology for Retrieval
ADMP	Advanced Design Mixer Pump
APL	Applied Physics Laboratory
comminution	process of reducing a material to powder
CSEE	Confined Sluicing End Effector
DC	direct current
DOE	U.S. Department of Energy
DST	Double Shell Tank
EM	Environmental Management
F&R	functions and requirements
FY	Fiscal Year
GAAT-TS	Gunite and Associated Tanks - Treatability Study
GSEE	Gunite Scarifying End Effector
Gunite	trade name for material used in waste tank construction
heel	hard, solid waste layer found on the bottom of some underground storage tanks
HLW	High Level Liquid Waste
HTB	Hydraulic Test Bed
HTI	Hanford Tanks Initiative
Hz	Hertz - a unit of frequency equal to one cycle per second
INEEL	Idaho National Engineering and Environmental Laboratory
LDUA	Light Duty Utility Arm
LPI	Lawrence Pump Incorporated
LWS	Lightweight Scarifier
MHZ	megaHertz
MLDUA	Modified Light Duty Utility Arm
MPa	Mega Pascals
NIST	National Institute of Standards and Technology
OHF	Old Hydrofracture Facility
ORNL	Oak Ridge National Laboratory
PTFE	polytetrafluoroethylene
PNNL	Pacific Northwest National Laboratory
psi	pounds per square inch
RAT	Retrieval Analysis Tool
RL	Richland Operations Office
ROV	remotely operated vehicle
RPD&E	Retrieval Process Development and Enhancements
rpm	revolutions per minute
scarifier	instrument used to prepare sludge or saltcake for retrieval
slipring	electrical coupling which allows rotary motion
SPAR	Spar Aerospace
SREE	Sludge Retrieval End Effector

Acronym/Term	Definition
SRS	Savannah River Site
SST	Single Shell Tank
TFA	Tanks Focus Area
THS	Tether Handling System
TRIC	Tank Riser Interface and Containment
UM-R	University of Missouri-Rolla
UW	University of Washington
WD&C	Waste Dislodging and Conveyance
WHC	Westinghouse Hanford Company
WTI	Waterjet Technology, Inc. (formerly the Waterjet Systems Division of Quest Integrated, Inc.)

Contents

Figures

1.0 Introduction

The purpose of this report is to provide a summary of the Retrieval Process Development and Enhancements (RPD&E) activities conducted during FY97 and funded by the U.S. Department of Energy (DOE) EM-50 Office of Science and Technology Tanks Focus Area (TFA), through Technical Task Plan RL3-6-WT-51. Based upon development and testing, recommendations for ongoing and new work have been provided, including input from end users through a series of needs assessment meetings conducted by the TFA at each site. This report does not replace the detailed reports prepared by the individual investigators within the RPD&E system. The individual reports listed in the references provide further detailed information.

The overall purpose of RPD&E is to continue to lead the DOE TFA national effort in the basic understanding of waste retrieval. In this process, waste is mobilized in such a way that it can be transferred out of the waste tanks in a cost-effective and safe manner. From this basic understanding, data is provided to the end users that will assist them in decision-making tasks. These activities also will transfer the retrieval process to fielded, deployable systems that have been identified by end users across the DOE complex. The retrieval process includes waste dislodging, mixing, sluicing, and conveyance (in general) and is not specific to various deployment systems.

The safe and cost-effective retrieval of waste from underground storage tanks is a major challenge throughout the DOE complex. Within the complex underground, waste storage tanks contain approximately 400,000 cubic meters (106-million gallons) of highly radioactive legacy waste from the DOE weapons programs. In various tanks, it is expected that some or all waste will need to be removed for remediation efforts. Also, each site has distinct differences in tank construction, tank materials, amount of in-tank hardware, waste forms, and tank integrity, as well as differing regulations and clean-up criteria. The RPD&E system addresses these issues in support of end users at Oak Ridge National Laboratory (ORNL), Idaho National Engineering and Environmental Laboratory (INEEL), Hanford Site and Savannah River Site (SRS). The tank waste problem further is described in the RPD&E FY96 report entitled, "*Tanks Focus Area Retrieval Process Development and Enhancements FY96 Technology Development Summary Report*," PNNL-11349 by Michael Rinker et al.

2.0 Technical Accomplishments

Technical achievements by the Retrieval Process Development and Enhancement (RPD&E) team in FY97 include providing technologies that address specific retrieval needs for the U.S. Department of Energy (DOE) sites. They include the Confined Sluicing End Effector (CSEE) for ORNL Gunite and Associated Tanks (GAAT), the Extendible Nozzle for Oak Ridge National Laboratory (ORNL) Old Hydrofracture Facility (OHF), and the Cooling Coil Cleaning Retrieval End Effector for Idaho National Engineering Environmental Laboratory (INEEL). Detailed reports on site-specific activities and the other retrieval technology processes are listed in the references. Technical conclusions and accomplishments of the RPD&E team activities are summarized in this section.

The main technical accomplishments of RPD&E, based upon FY97 activities include:

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RPD&E staff completed a dynamic force analyses for the CSEE. Additionally, high-pressure waterjet scarifier retrieval data was analyzed and incorporated into the Retrieval Analysis Tool (RAT), and pneumatic conveyance data was analyzed to determine the maximum solids transport-rate for retrieval of wet and dry solids that were removed from waste tanks.

Simulant Development
RPD&E project provided simulant specification, makeup, and disposal support for testing of the INEEL End Effector, ORNL Gunite Scarifier, Extendible Nozzle, Light Weight Scarifier, Russian retrieval equipment, and enhanced sluicing equipment.

Retrieval Analysis Tool (RAT)
The Retrieval Analysis Tool, designed as a retrieval technology information source, was implemented using a relational database and was constructed using an Internet website. Retrieval information was compiled and the tool was implemented as a part of the Hanford Tank Initiative's (HTI) solicitation to industry for retrieval of radioactive waste.

3.0 FY97 Technical Summary

Summary descriptions of the FY97 accomplishments of each of the Retrieval Process Development and Enhancement tasks are given in this chapter. Additional information can be obtained from the detailed year-end reports prepared by each of the testing development tasks. These reports are listed in references.

3.1 Oak Ridge National Laboratory (ORNL)

3.1.1 ORNL - Gunite and Associated Tanks Treatability Study

End Effectors

Two waste retrieval end effectors were designed, fabricated, and tested for the ORNL Gunite and Associated Tanks Treatability Study (GAAT-TS). The Sludge Retrieval End Effector (SREE) as shown in Figure 1 has been successfully deployed at the ORNL Tank W-3 with an integrated retrieval system. This system consists of a long-reach manipulator (the MLDUA), a remotely operated vehicle with a teleoperated arm (the Houdini), a conveyance system and cable-management arm, and a multiple-camera vision system. The retrieval system has retrieved the bulk of the sludge waste in Tank W-3 and the SREE is operating as expected.

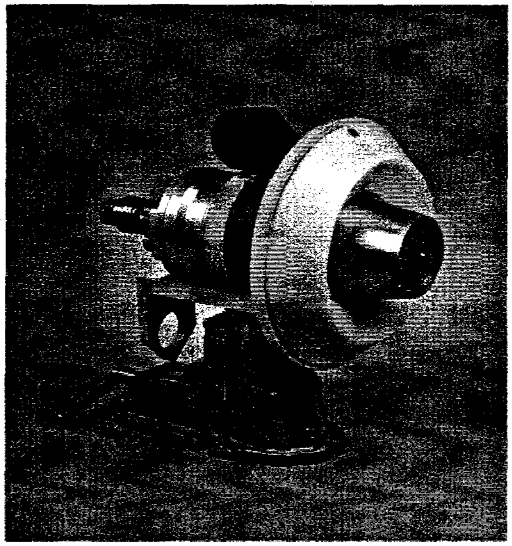

Figure 1. Sludge Retrieval-End Effector.

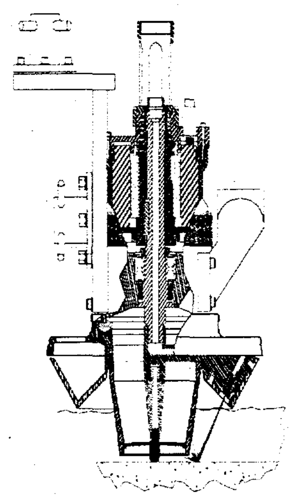

Figure 2. SREE Section View.

The SREE (Figure 2) uses a rotating array of three waterjets operated at 1.7 - 70 mPa (250 - 10,000 psi) to fragment and mobilize the waste. It is coupled to a jet-pump powered conveyance system, which aspirates the waste via a screened inlet nozzle in the center of the waterjet array. It is intended primarily for retrieval of sludge wastes and decontamination of hardware and tank surfaces. The Gunite Scarifying End Effector (GSEE) is a variant of the SREE, using the same main chassis and motor. It has a similar array of waterjets, aimed outward instead of in, and a large standoff hub in place of a conveyance inlet. It is designed to operate at up to 207 mPa (30,000 psi) to scarify gunite tank surfaces, hard waste deposits or contaminated concrete. It can remove more than 6 mm (0.25 in.) of fine-aggregate concrete at 60 cm^2/sec. (9 $in.^2$/sec.) when fitted with 0.0225 nozzles, consuming 20 L/min (5.25 gal/min) of process fluid at 207 mPa (30,000 psi). The GSEE is awaiting hot deployment at ORNL, following completion of the sludge retrieval operations.

The Waste Retrieval End Effectors were designed and fabricated at Waterjet Technology, Inc., (WTI) per design guidance and oversite from Pacific Northwest National Laboratory (PNNL), based on the prototype Confined Sluicing End Effector (CSEE) built by the University of Missouri-Rolla (UM-R) and tested at the Hydraulic Test Bed (HTB).

Tether Handling Systems (THS)

Two Tether Handling Systems (THS), as shown in Figure 3, were designed and fabricated for ORNL GAAT-TS under this task. One was for the Gunite Scarifying End Effector (GSEE) (Figure 4) and one for the Characterization End Effector (CEE) built by Sandia National Laboratory. The THS were the last major pieces of equipment to be delivered for the GAAT-TS. They include rotary slip rings to pass multiple channels of power and signals, and swivels to pass air and water supplies (207 mPa to the GSEE) from the balance of plant equipment to 100-ft (30-m) umbilical tethers serving the end effectors. The work scope included design and procurement of the tether for the CEE. The THS can mate to the Tank Riser Interface and Containment (TRIC) for deployment of the end effectors on the MLDUA, or to the Houdini Containment Bezel for deployment with the remotely operated vehicle (ROV).

The THS were designed and fabricated at WTI per design guidance furnished by PNNL.

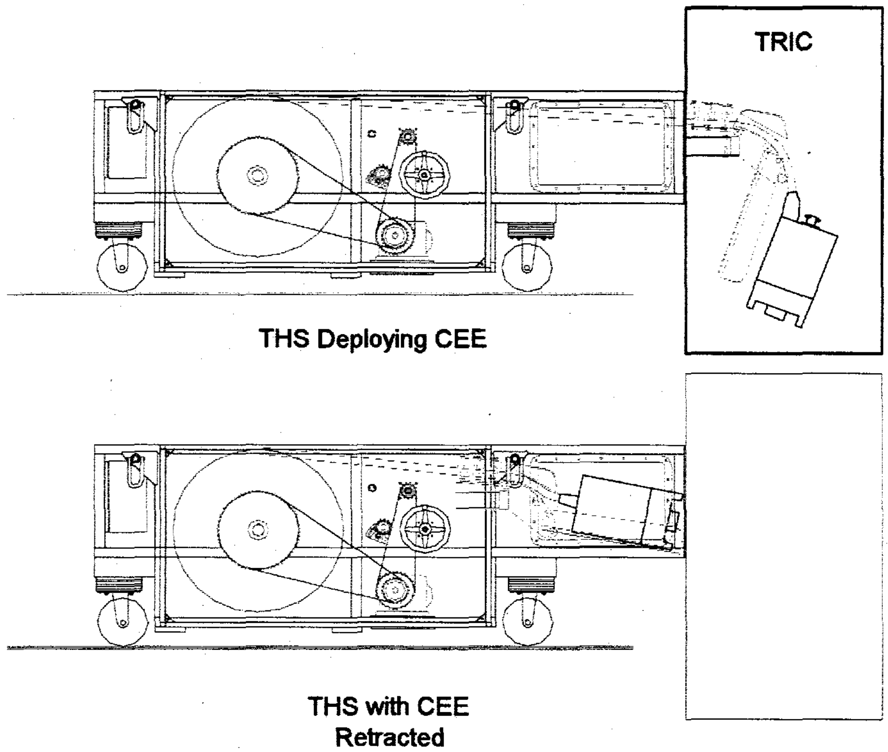

Figure 3. Tether Handling.

Jet Pump Development
The commercial jet pump (Figure 5), incorporated by ORNL in the GAAT-TS Conveyance System, has proven inefficient when operating in three-phase flow, as is the case for a significant portion of a retrieval operation, and not very durable when subjected to abrasives entrained in the flow, which was clearly demonstrated during testing. This task has directed baseline characterization testing, endurance testing, and some initial developmental testing of the commercial pump and two experimental articles designed by researchers at UM-R. Students at UM-R have conducted the testing. The parameters of mixing section-length, operating-pressure, and flow-phase compositions are being evaluated with the intent of improving overall efficiency. Abrasion-resistant ceramics are being tested for the mixing-section liner to improve durability.

Conclusive results and significant improvements on the commercial pump design will continue in FY98, with the expectation an alternative jet pump, which will be delivered to the GAAT program.

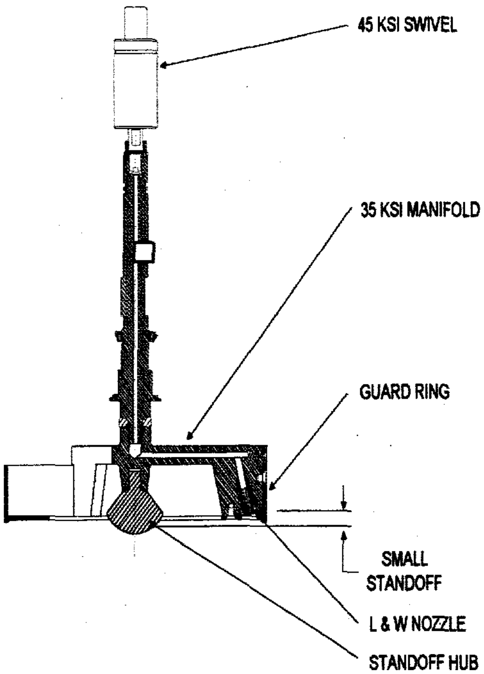

Figure 4. Gunite Scarifier Parts.

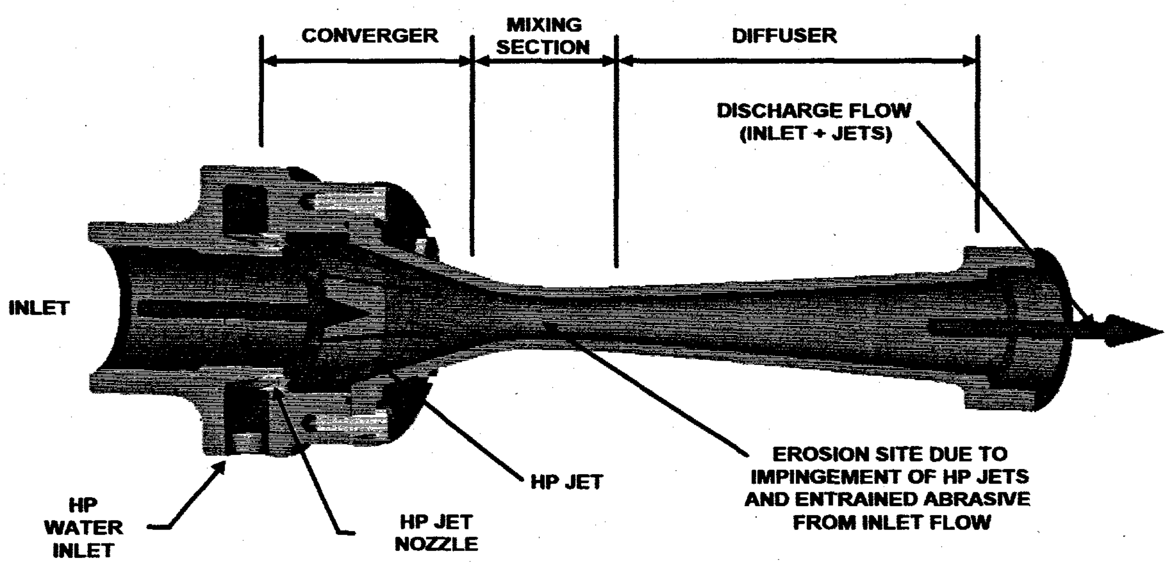

Figure 5. Jet Pump Principles.

3.1.2 ORNL Old Hydrofracture - Extendible-Nozzle Deployment

An Extendible-Nozzle Water-Jetting System, shown in Figure 6, was designed, constructed, and delivered to the ORNL to remediate five horizontal underground storage tanks containing sludge and supernate at the ORNL Old Hydrofracture Facility (OHF) site. The OHF tanks range in diameter from 2.4 m to 3.2 m (8 to 10.5 ft) and length from 7.1 m to 13.7 m (23 to 45 ft). The tanks are submerged at depths up to 1.2 m (4 ft) below grade. The tanks contain up to 46 cm (18 in.) of sludge covered by supernate. The tanks will be remediated in FY98 to remove >95 per cent of the waste. This deployment will be the first radioactive demonstration of the Extendible-Nozzle Water-Jetting System.

The extendible-nozzle design is based on existing borehole miner technology, which was used to fracture and dislodge ore deposits in mines. Borehole miner technology includes both dislodging and retrieval capabilities. Dislodging using the extendible-nozzle water-jetting system and retrieval using a jet pump located at the base of the mast can be deployed as an integrated system through one borehole or riser. The Extendible-Nozzle System for ORNL remediation only incorporates the dislodging capability.

The system shown in Figure 7 includes the extendible-nozzle deployed from within the mast, the support platform, and high-pressure liquid and hydraulic hoses. The extendible-nozzle has an extension length of 3 m (10 ft) from the center of the mast and extends outward horizontally to downward to three degrees from the Vertical, and rotates 360 degrees about the mast. The extendible-nozzle can operate at water pressures up to 20.7 mPa (3000 psi); however, for deployment at ORNL, the maximum operating pressure is 10.3 mPa (1500 psi). The extendible-nozzle configuration was improved over the prototype during the design phase. The revised design enhanced and simplified system operation by moving the arm actuator from beneath the elbow to above the elbow, thereby shortening the lower mast length by about 0.76 m (2.5 ft) and increasing the spray area to include the 30 degree cone directly beneath the mast. The new design simplified construction and operation considerably. The nozzle spray now 1) cleans the entire area beneath the nozzle from vertically downward to horizontal, 2) eliminates the additional piping to supply fluid to the spray nozzles beneath the mast and the valves and controls associated with operation of these separate spray nozzles, and 3) allows the nozzle to operate along the horizontal tank centerline because the mast extension length was decreased.

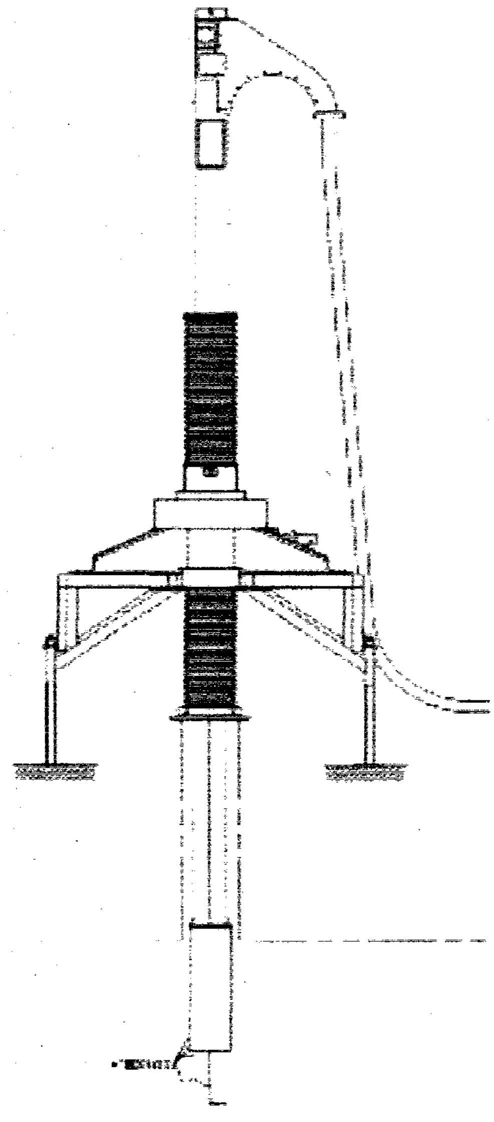

Figure 6. Extendible-Nozzle Water Jetting System for ORNL OHF Tank Remediation.

RPD&E is providing ORNL a complete Extendible-Nozzle System; ORNL will provide the balance-of-plant equipment to support the tank remediation. The Extendible-Nozzle-Operating System includes a high-pressure pump and pump skid to power the nozzle, valving and instrumentation and a control system to monitor pump performance, hydraulic power unit to control the extendible-nozzle's motion, and an extendible-nozzle that includes the mast and support platform. These components are being integrated and provided to support extendible-nozzle operation. In addition, a Visualization System developed at Sandia National Laboratory and PNNL to track nozzle location in the tank in real-time

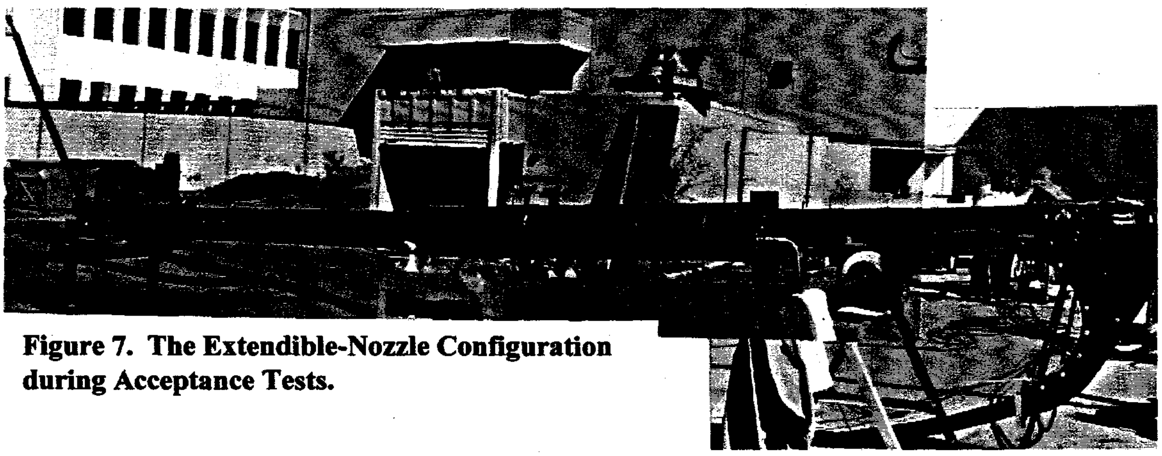

Figure 7. The Extendible-Nozzle Configuration during Acceptance Tests.

during operation is also being supplied. The Extendible-Nozzle Visualization System, shown in Figure 8, is an operator aid to be used during extendible-nozzle operation in tank. In the tank, the operator cannot view the nozzle position because in-tank cameras may cloud from mist generated during extendible-nozzle operation. The Extendible-Nozzle Visualization System provides the

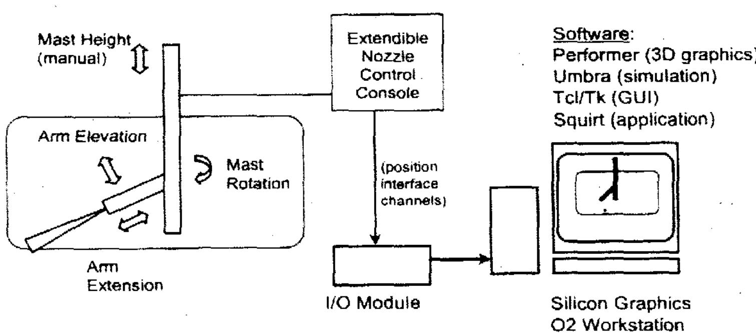

Figure 8. Visualization System Diagram.

operator visual guidance on nozzle position relative to the tank. The Visualization System consists of a Silicon Graphics O2 low end workstation, an input/output model that interfaces with the Extendible-Nozzle Control System, and software that provides a three-dimensional (3D) animated model of the extendible-nozzle and the tank in which it is deployed. Position and orientation information from the extendible-nozzle is fed to the software via the I/O model so that the 3D model accurately depicts where the extendible-nozzle and its spray stream are in relation to the tank. The software can also warn of any impending collisions between the nozzle and the tank infractructure ,or any modeled items included in the tank model.

Extendible-Nozzle Horizontal Tank Performance Assessment

Nozzle-spray tests using the prototype extendible-nozzle, shown in Figure 9, were conducted in a full-diameter, half-length model of a horizontal tank at PNNL to characterize the ability of the Extendible-Nozzle System to dislodge wastes similar to and more challenging than those at ORNL OHF. Tests were conducted using sludge simulants with shear strengths ranging from 2.5 kPa (0.363 psi) (modeling the OHF tank sludge) to 150 kPa (21.9 psi) using a cured plaster-kaolin clay mix (strong enough to walk on). The extendible-nozzle successfully dislodged these simulants using a 6,890-kPa (1000-psi) jet through both 7.137 and 7.874-mm (0.281 and 0.310 in.) diameter nozzles. Tests with a bed submerged with up to 46 cm (18 in.) of water and tests with a dry bed showed similar results. The dislodging and retrieval tests were conducted over a 30-40 minute period.

Extendible-nozzle testing during FY96 and FY97 included single-nozzle tests that investigated jet properties of dispersion, force, and ability to dislodge hard saltcakes and sludges at standoff distances up to 15.2 m (50 ft) and integrated dislodging tests, which investigated the jet's ability to dislodge saltcakes and sludges by traversing the jet across the simulant layer. These tests showed that the extendible-nozzle had the ability to function over very large standoff distances and also to erode saltcake simulants with shear strengths up to 21-mPa (3,000-psi). These saltcake simulants were developed to bound Hanford waste properties. Additional tests to quantify the nozzle coefficient of discharge were conducted over the nozzle diameter and pressure range. These tests provided data to correlate pressure at the nozzle with a flow rate. Now that this relationship has been quantified, extendible-nozzle performance can be more accurately predicted.

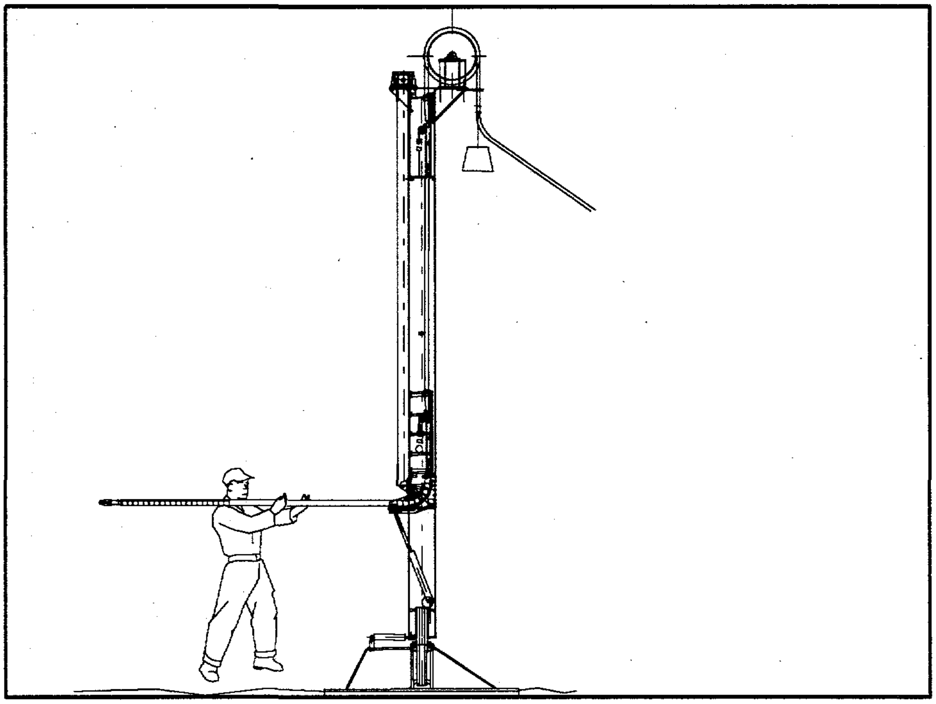

Figure 9. Floor Mounted Extendible-Nozzle Prototype.

3.2 Pulsed-Air Mixing

Pulsed-Air Mixer development during FY97 focused on designing a full-scale mixer for deployment into ORNL Tank W-9 in FY98. This required not only developing a mixer deployment concept and preparing the design drawings, but also addressing specific operation issues as well. A Pulsed-Air Mixer was deployed inside the simulant holding tank for the GAAT test facility in December 1996. The simulant holding tank was used to collect simulated gunite tank waste that was used in testing the integrated GAAT Retrieval System. After a series of retrieval system test, the simulant collected in the holding tank was transferred back into the test bed in preparation for the next test. A means of mixing the simulated waste was needed to facilitate this transfer. Pulsed-air mixing was selected for this purpose.

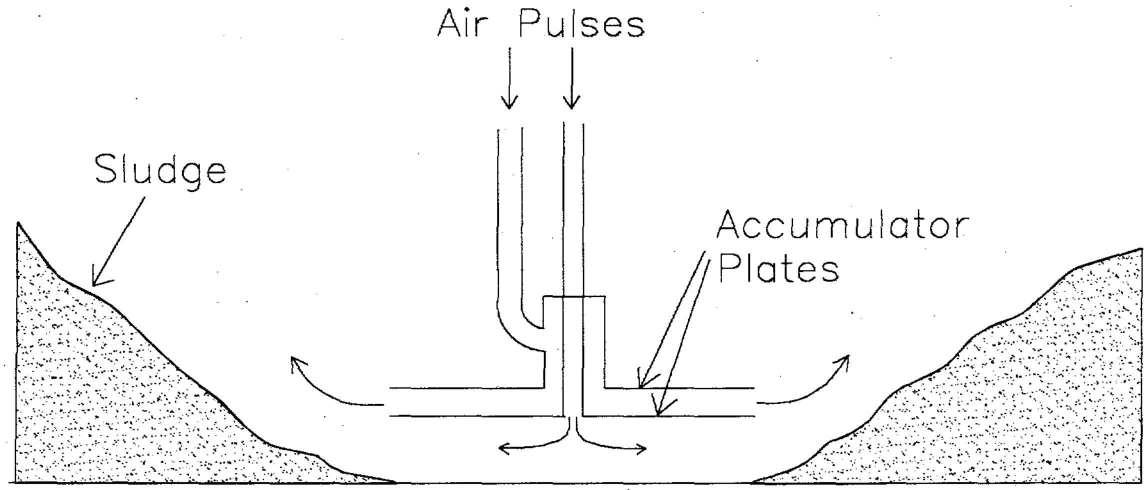

Figure 10. Dual Plate Accumulator Arrangement.

Approximately 18 m^3 of settled, simulated ORNL tank sludge was inside the simulant holding tank when the Pulsed-Air Mixer was installed. A dual-plate accumulator arrangement, shown in Figure 10, was selected for this application. Air pulses can be applied either to the underside of the bottom plate or between the plates. Pulsing air under the bottom plate clears away sludge and allows the mixer to work its way down to the tank floor. Once the mixer reaches the floor, air pulses are applied only between the plates. This eliminates the tendency of the plates to lift with each pulse, as is the case when pulsing under both plates.

The ORNL simulant was successfully mixed using the dual-plate mixer by periodically moving the plate to different regions of the tank. Once all the simulant was adequately mixed, it was transferred back into the GAAT Retrieval System's test bed. Figure 11 shows the mixer operating inside the simulant holding tank at ORNL.

The successful use of pulsed-air mixing in the simulant holding tank generated increased interest in using a Pulsed-Air Mixer in ORNL Tank W-9, which is the waste receiver tank for the Gunite Tank Waste Retrieval project. ORNL personnel decided that a Pulsed-Air Mixer would be installed inside Tank W-9 to mix waste solids in preparation for pipeline transfer to the Melton Valley Storage Tanks. Based on the FY96 Pulsed-Air Mixer's test data and on the constraints imposed by tank geometry, a 13-plate Pulsed-Air Mixer Deployment System was designed through a cooperative effort involving PNNL, Pulsair Systems, Inc., and the University of Washington Applied Physics Laboratory.

Figure 11. Pulsed Air Mixer Operating in ORNL Simulant Holding Tank.

Two different mixer deployment concepts were evaluated. One concept involved bending the air pipe leading to each plate such that each plate/pipe combination could be maneuvered down through the Tank W-9 riser sleeve and into position. The other concept involved lowering down through the riser a self-deploying assembly that unfolds like an inverted umbrella once contact is made with the tank floor. A full-scale mockup of an ORNL tank riser sleeve and a bent pipe/plate combination was assembled to evaluate the ease of deployment and retrieval for the bent pipe concept. Removal of the bent pipes from the tank was found to require the coordinated use of two cranes. This was judged by ORNL to be prohibitive because of the space restrictions surrounding Tank W-9. Thus, the inverted umbrella approach was selected. Figure 12 shows a sketch of the inverted umbrella mixer in Tank W-9. The inverted umbrella mixer design was finalized in preparation for construction and deployment in FY98.

As part of the Tank W-9 mixer design work, two issues had to be addressed. First, concerns were raised over the rate of aerosol generation from the pulsed-air mixer. Second, it was unknown whether the air-pulse shock wave and fluid motion near the plates might adversely affect the tank gunite. To address the aerosol generation concern, a review of the existing aerosol generation rate test data for similar systems (e.g., gases sparged through liquids) was performed. This review established that the aerosol generation rate in the Tank W-9 application is estimated to be no greater than 50 mg of wet aerosol per cubic meter of air used by the mixer. This aerosol generation rate is well within the capabilities of the existing Tank W-9 Ventilation System.

The potential for tank damage from the pressure wave generated by the sudden gas pulse was determined to be insignificant based on the calculated pressure wave decay and attenuation. The pressure loading on the tank walls resulting from each pulse was estimated to be less than 700 pa (0.1 psi), which is insignificant when compared to the expected gunite compressive strength, which is likely in excess of 3000 mPa (3000 psi). Erosion of the tank floor near the accumulator plates was also evaluated and determined to be insignificant provided that a slab of concrete can adequately model the erosion resistance of the tank floor gunite. Approximately 300,000 air pulses were applied to an accumulator plate positioned on top of a concrete slab, which was submerged in abrasive sand/water slurry (Figure 13). No significant erosion of the concrete was observed

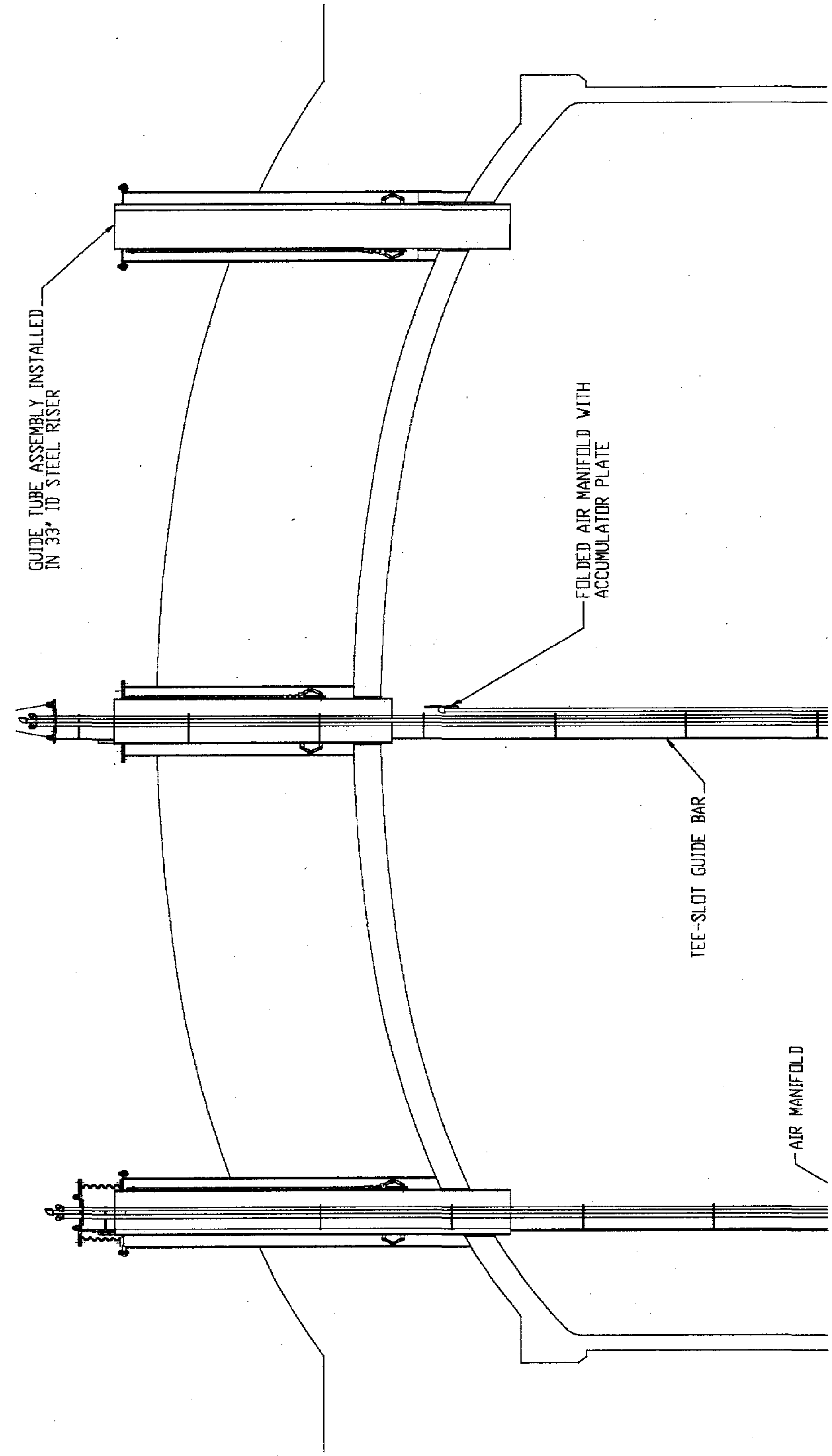

Figure 12. Sketch of Inverted Umbrella Pulsed Air deployed in the ORNL Tank W-9.

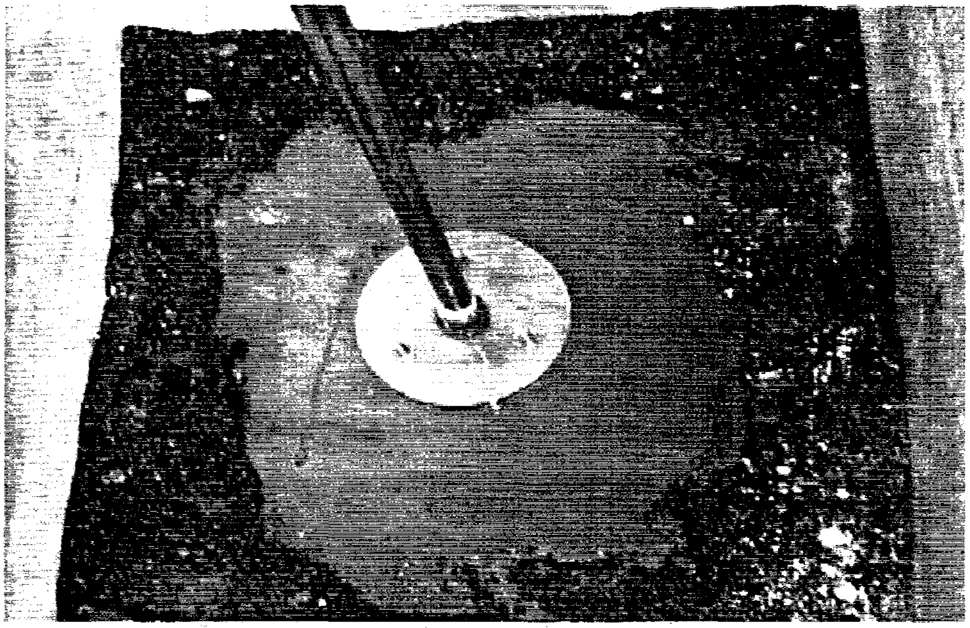

Figure 13. Post-test Concrete Surface Showing no Evidence of Erosion.

3.3 Hydraulics Test Bed

At the end of February 1997, the Retrieval Process Development and Enhancements program completed relocation of the Hydraulic Test Bed (HTB). The HTB supports DOE-EM programs, industry, and academia by providing key testing capabilities to support high-pressure waterjet end effector development. The HTB includes a large gantry robot, pumps, air blower, and other test equipment to support long duration mining strategy tests needed to evaluate steady state performance of end effectors. Through FY96, the HTB resided in the Hanford 337 Building's High Bay. In late FY96, the program was notified that the Fast Flux Test Facility legacy sodium removal program had plans to close the 337 Building's High Bay so that the sodium could be removed. The HTB had to be moved to continue retrieval end effector development and testing for ORNL and INEEL. The relocation task included securing a new test site, moving the equipment, setting up the equipment, and providing resources for site rental.

After a lengthy site survey, alternate lab space was secured in the Hanford 338 Building's Engineering Development Laboratory. Through deliberate efforts by PNNL project and facility staff and Fluor Daniel construction forces, the equipment was moved into the 338 Building. Conveyance lines were designed and installed to support testing of the INEEL Cooling Coil End Effector testing and Light Weight Scarifier. The gantry robot, a complicated computer-controlled robotic device, was installed, restarted, and operated with minimal problems. Controls and instrumentation wire was routed as required, and the data acquisition system was set up in the control station. The Conveyance Line Management System (CLMS) was reassembled and checked out. In addition, new brackets were fabricated for the high-pressure valves and jet pump and a weatherproof utility shed was constructed for the high-pressure pump. A steel conduit was installed between the pump house and the gantry to safely route high-pressure lines.

3.4 INEEL Cooling Coil End Effector

The Retrieval Process Development and Enhancement project has developed a prototype end effector to dislodge and convey waste from the high-level liquid waste (HLLW) storage tanks at the Idaho National Engineering and Environmental Laboratory (INEEL). Remediation of the HLLW tanks is driven by a Consent Order between the State of Idaho, the U.S. Department of Energy, and the Environmental Protection Agency that requires cleanup and closure of the tanks by the year 2009. Currently, requirements for removal of the waste are unclear, and retrieval decisions will be made after the waste is characterized.

The HLLW tanks, 15.2 m in diameter and 9.7 m high (50 ft diameter and 32 ft high) contain a maze of cooling coils covering the walls and floor at a standoff distance of 15.2 cm (6 in.), see Figure 14. The waste, ranging from 7.6 cm to 30.5 cm (3 to 12 in.) in depth, consists of supernate liquid covering a sedimentary layer. A black, tar-like material has also been found clinging to a radio frequency probe inside one tank. The complexity of in-tank hardware plus the waste clinging to the cooling coils and settled beneath them provides a challenging environment for surface cleaning and waste retrieval.

Figure 14. Cooling Coils Lining the Walls and Floor of the High Level Liquid Waste Tanks at INEEL.

The cooling coil cleaning end effector (Figure 15) was developed at the High Pressure Waterjet Laboratory of UM-R. This design benefits greatly from previous work in developing the prototype confined sluicing end effector for ORNL at UM-R. The cooling coil cleaning end effector contains high-pressure waterjets mounted on a rotating manifold within a fixed suction shroud (Figure 16). The end effector will fit through the 30.5-cm (12-in.) risers of the HLLW tanks. The prototype weighs 16.7 kg (37-lb) compared to the 11.3-kg (25-lb) target weight of the field-deployable unit.

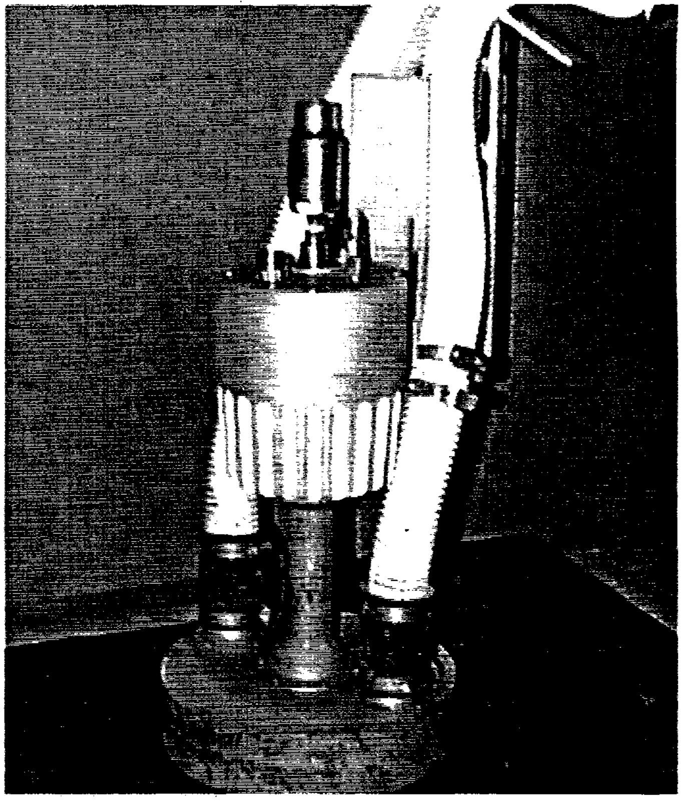

Figure 15. The Cooling Coil Cleaning End Effector Developed by the University of Missouri-Rolla for Performance Testing in a Mockup of the HLLW Tank Configuration.

Functional testing was performed at UM-R before shipping the end effector to PNNL. Testing in Pacific Northwest National Laboratory's HTB focused on evaluating long duration mining strategies using waste simulants and cooling tube structures typical of the INEEL storage tanks. A multi-stage cleaning strategy was tested where the rotating waterjets were first used to suspend the sediment and scour tube surfaces. In the second pass, the end effector was positioned close to the floor to remove the bulk of the particulate waste. In the third pass, the suction shroud was positioned beneath the coils to suction the remaining waste that was directly beneath the cooling coils (Figure 17).

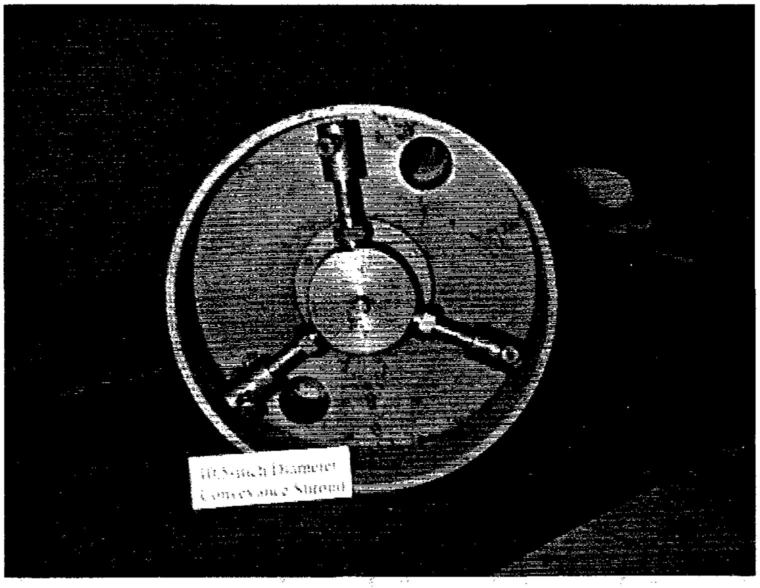

Figure 16. Rotating Waterjet Manifold within the Fixed Suction Shroud.

The testing program showed that although the high-pressure waterjets were effective in directly removing a fully cured roof sealing paint and a soft wax simulant from the surface of the cooling coils, they were ineffective in removing either of these waste simulants from the undersides of the coils (Figure 18). Therefore, the waterjets at pressures up to 35 mPa (5,000-psi) did not provide sufficient energy to entrain the 7.6 cm (3-in.) deep sand bed (the maximum estimated depth of particulate waste in the HLLW tanks) to scour the undersides of the tubes.

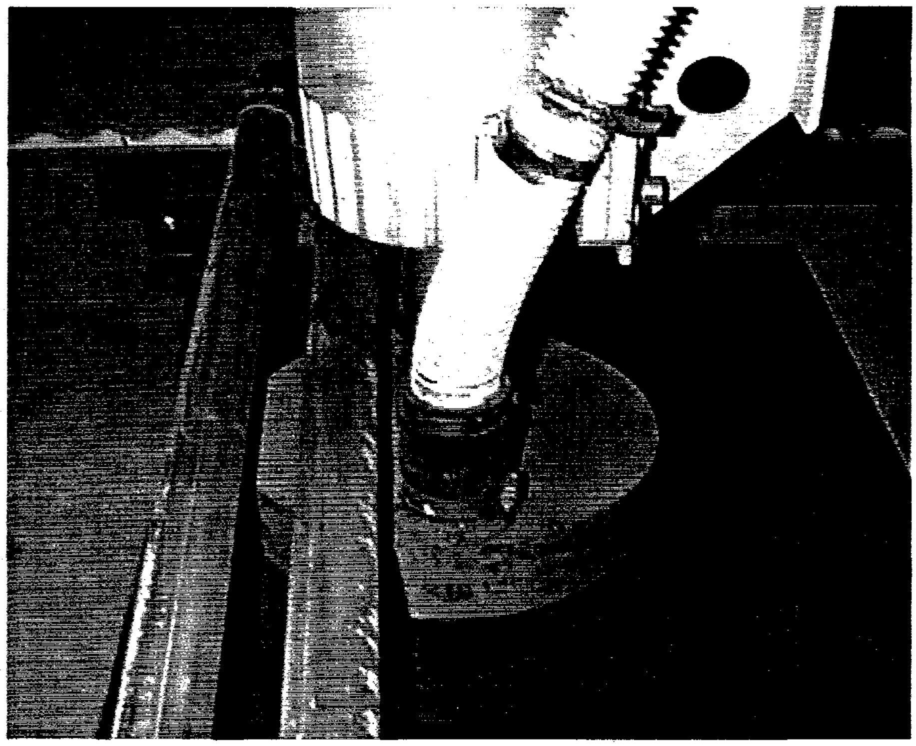

Figure 17. End Effector Positioned beneath the Cooling Coils to Suction Debris from the Floor of Tanks.

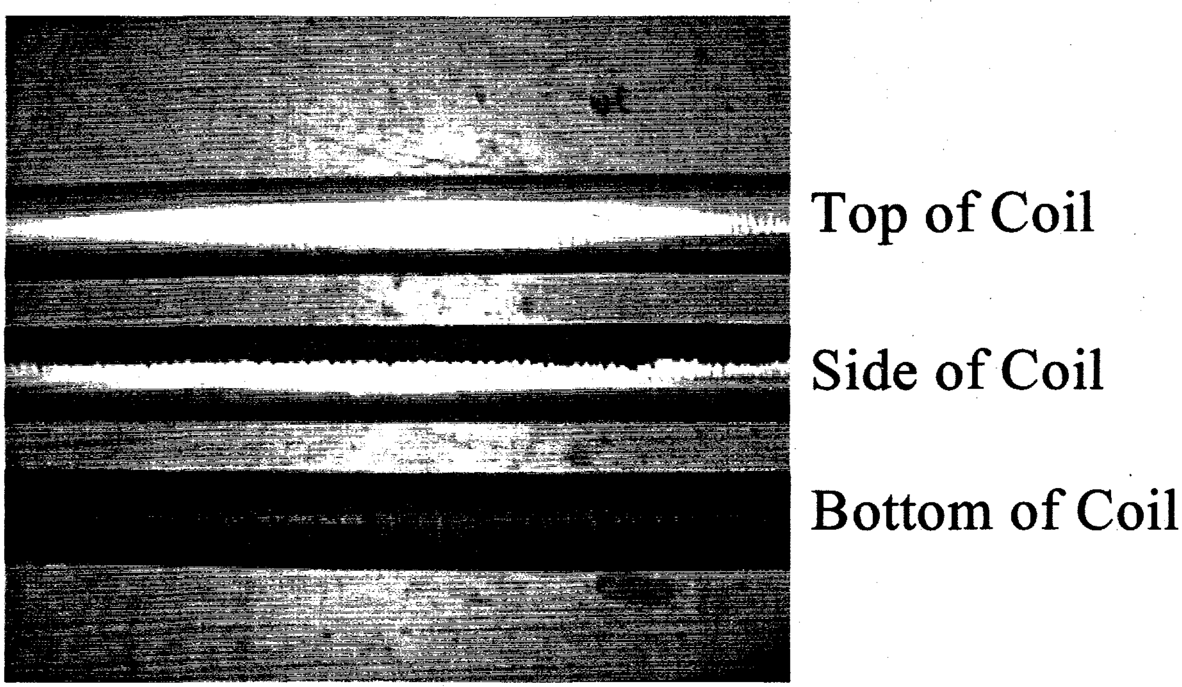

Figure 18. Photo Showing Effectiveness of Waterjets directly cleaning the Tops of CoolingCoils, but Ineffectiveness of Waterjets Mobilizing Sand to Scour the Bottom of Coils.

The end effector was also tested for bulk retrieval of sand from the tank floor beneath the cooling coils. Retrieval tests were run with the suction shroud in a flooded condition, showing that the end effector was able to remove most of the sand. Small ridges of sand remained in the corners where the cooling coils intersect with the support cross members (Figure 19).

In summary, this task has directly supported the INEEL waste retrieval program by providing prototype testing to support the future specification of a field-deployable end effector if required. Completion of this task closes out the development phase of retrieval end effectors for cleanup of the HLW tanks at INEEL.

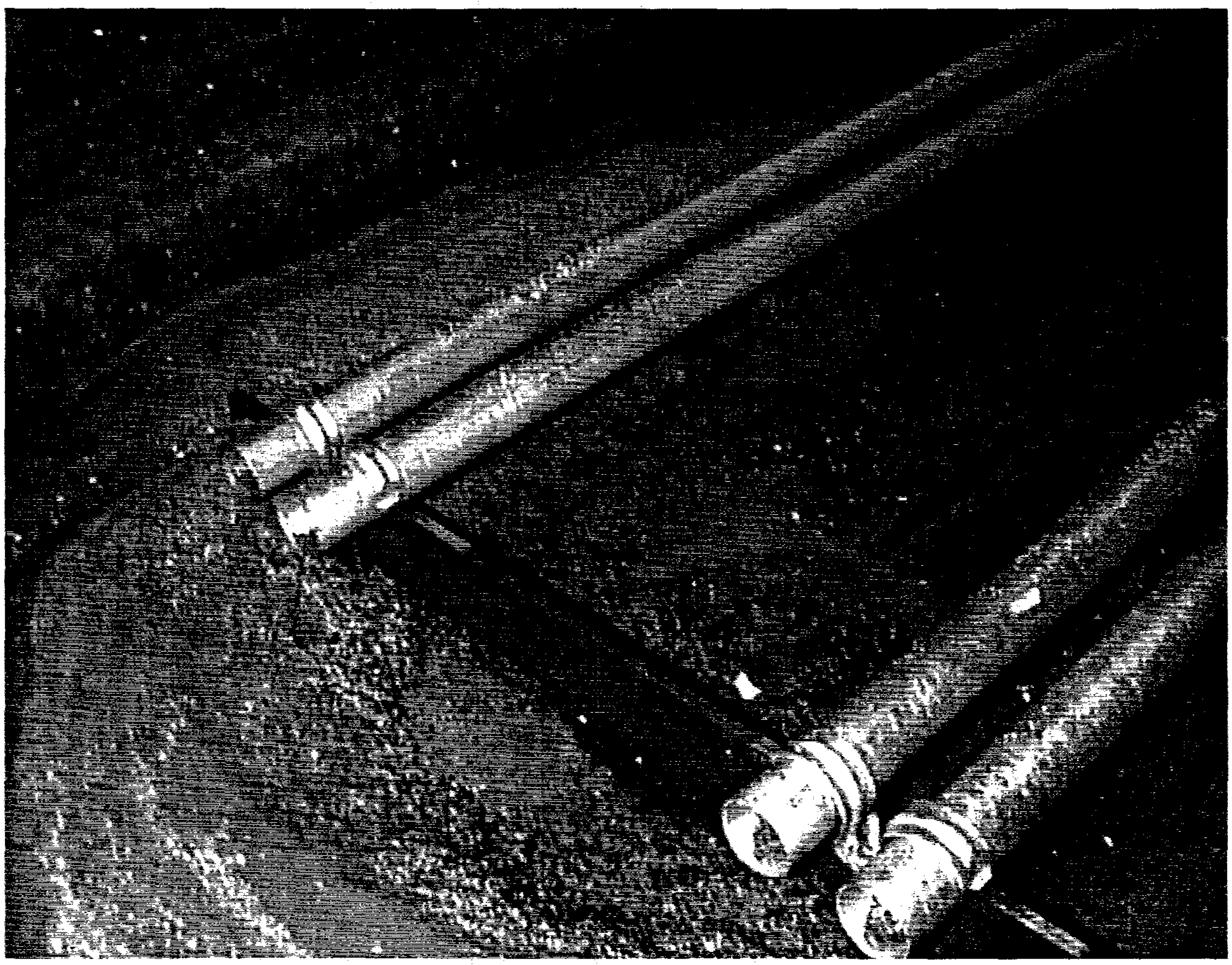

Figure 19. Photo showing Effectiveness of End-Effector in Removing Sand from Beneath the Cooling Coils.

3.5 Engineering Development of the Light Weight Scarifier

The Light Weight Scarifier (LWS) was developed for the remediation of tanks containing soft to extremely hard wastes, tanks that leak and cannot be safely sluiced, applications where significant waste dilution is not acceptable, and for wall scarification and surface decontamination applications.

The LWS uses ultra-high-pressure water jets up to 379 mPa (55,000-psi) to fracture and dislodge the waste. The ultra-high-pressure waterjets provide extreme power densities on the target and remove material at low water consumption rates. The LWS is coupled with an air conveyance system to pneumatically remove the dislodged waste and water that is used as the cutting fluid. Two waterjets are mounted on a manifold and are rotated by an electric motor to mill a channel in the waste material as the LWS is moved across the surface. At the end of FY95, the design layout of the LWS was developed to incorporate the features of the original scarifier in a smaller, lighter end effector, which retains the pressure capacity of its predecessor. The LWS, weighing 22.7 kg (50 lbs), can be deployed inside an underground storage tank by a number of platforms, including an extendible arm, such as the Light Duty Utility Arm (LDUA) or a remote crawler. During FY96, the designs of the LWS and an associated control module were completed and two prototype systems were fabricated and assembled. The LWS was featured in four testing and demonstration activities in FY97, including bench scale testing at WTI, retrieval testing at the PNNL HTB, integrated testing at the National Institute of Standards and Technology (NIST) for the Hanford Tanks Initiative (HTI), and integrated testing with the LDUA. The activities are described below.

The objectives for the work performed at WTI were to verify design concepts and determine the performance of the LWS using a matrix of simulants. Small scooping tests were performed to determine the range of applicability of the LWS to establish successful operating pressures, rotational speed, and traverse speeds for each simulant type. Testing was conducted with a full suite of test materials identical to those used by the Hanford HTI program (Powell, 1996) so that the LWS could be evaluated against competing retrieval technologies. Test variables included nozzle diameter (0.45 to 1.02 mm or 0.018 to 0.040 in.), pressure (68.9 to 379.2 mPa or 10,000 to 55,000 psi), stand off distance (1.27 to 8.89 cm or 0.5 to 3.5 in.), scarifier rotational speed (600 to1200 RPM), and traverse rate of 17.8 to 1524 cm/min or 7-600 in./min. A total of 40 tests on saltcake were performed.

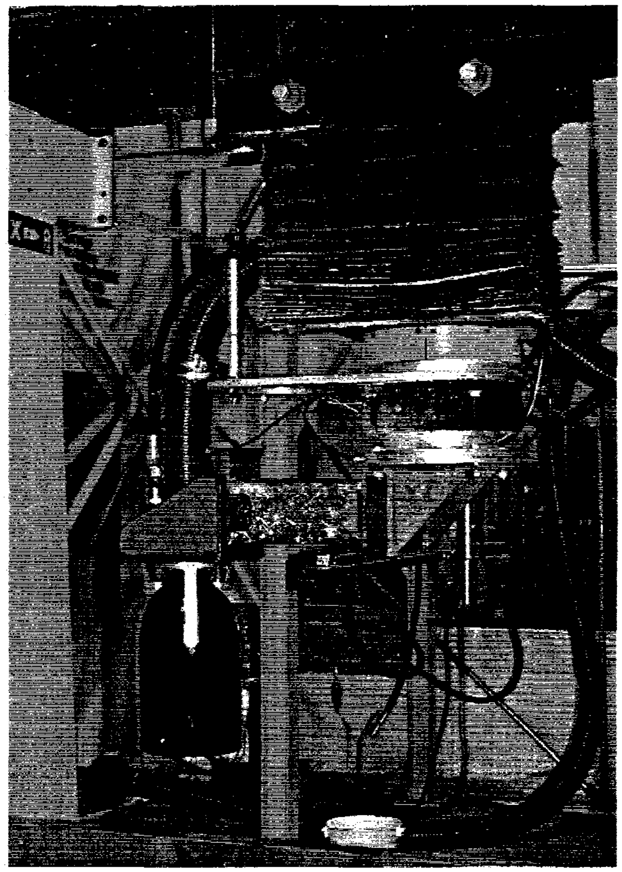

Figure 20. Light Weight Scarifier with Gantry Robot.

Peak efficiencies (measured as volumetric removal rate/water flow rate) in the range 0.8 to 0.9 were achieved with a small stand-off distance (1.27 cm or 5 in.) and high traverse rate of 762-cm/min (300 in./min) or larger stand-off distance of 5.1 cm (2 in.) and lower traverse rate (381 cm/min). Testing with granular rock salt simulant yielded efficiencies in the range 7 to 8 at 206.8 mPa (30,000 psi) nozzle pressure and a traverse rate of 1524 cm/min. Hardpan simulant was also retrieved at high efficiencies using 68.9 mPa pressure. These tests demonstrated that while the LWS was capable of dislodging material at high rates, the ability of the retrieval system to scavenge dislodged particles and water needed to be improved either by altering the way in which the LWS was used, or by modifying its design.

The objectives of the retrieval tests at PNNL were to determine long duration retrieval performance, to evaluate the LWS for alternate uses (including boring holes for instrument insertion), to measure steady state and dynamic reaction forces, and to evaluate alternate mining strategies for material removal. Prior to testing at PNNL, WTI recommended a set of near-optimum operating pressures, rotational speeds, and traverse speeds for each simulant type, based on their bench scale testing. This information greatly accelerated the progress of the testing program. The LWS has maneuvered through the waste with a large robotic gantry (Figure 20). A passive two-link arm was used to support the conveyance line and high-pressure hoses in the vicinity of the LWS.

A wide range of materials, ranging from sticky sludge to hard saltcake, was successfully retrieved by the LWS, demonstrating the versatility of the system. The retrieval goal for the LWS was 28.3 liters/min (1 ft^3/min) with a 2.54 cm (1 in.) depth of cut; this goal was reached for sludge, hardpan, and granular saltcake simulants. Test parameters and initial test results are provided in Table 1. The maximum capacity of the LWS may be even higher; however, the budget for the task limited the number of iterations that could be attempted. Retrieval of hardpan was made more difficult because the material tends to fragment into clumps, which sometimes were too large for the retrieval inlet and were pushed around by the waterjets. This problem was minor, but would have to be dealt with before deployment. Saltcake was also retrieved, although at a very slow rate. Pumping pressures were limited to 68.9 mPa (10,000 psi) at the testbed, and prior testing has validated that at least 206.7 mPa (30,000 psi) is required for adequate saltcake dislodging rates. Rather than focus on bulk retrieval of saltcake, the test engineers focused on water containment during retrieval, which is a critical issue for deployment in leaky tanks.

TABLE 1. Light Weight Scarifier Test Parameters and Retrieval Results.

Simulant	Test Parameters	Volume Retrieved, liters (ft^3)	Retrieval Rate, liters/min (ft^3/min)
Sludge Shear Strength 3.5 kPa	Rotation Speed: 750 RPM Traverse Speed: 762 cm/minute Water jet pressure: 8.27 mPa (1200 psi) Path width: 17.8 cm (7 in.)	357 (12.6)	28.3 (1)
Hardpan/Dried Sludge Composition #2 Shear Strength 200 kPa	Rotation Speed: 750 RPM Traverse Speed: 762 cm/minute Water jet pressure: 20.7 mPa (3000 psi) Path width: 17.8 cm (7 in.)	357 (12.6)	28.3 (1)
Granular Saltcake Compressive Strength 55 kPa	Rotation Speed: 750 RPM Traverse Speed: 762 cm/minute Water jet pressure: 8.27 mPa (1200 psi) Path width: 17.8 cm (7 in.)	357 (12.6)	28.3 (1)

It was found that, even at 68.9-mPa (10,000-psi) waterjet pressure, containment of the process water was a challenge for the retrieval system. The traverse speed and dwell time were modified to reduce the amount of water lost, and it was found that using a short dwell time followed by a rapid traverse could minimize the amount of water lost. During this process, a ridge is created by the waterjets that serves to deflect the water up into the conveyance line.

These and other test results have been evaluated and published in a PNNL report entitled "*Engineering Development of a Lightweight High-Pressure Scarifier for Tank Waste Retrieval*" (PNNL 11736) dated September 1997. Prior to the completion of testing, a demonstration of the LWS and other retrieval systems being developed and tested by the RPD&E team was held for personnel from DOE-RL. The demonstrations focused on technology development and "paper to product" site support that is the key to successful deployment and were very well received.

The LWS was also featured in integrated retrieval tests with remote manipulators. The LWS was selected as a featured technology for the HTI and was tested with the prototype, Grey Pilgrim EMMA manipulator, at the National Institute of Science and Technology Facility. Using this first-of-a-kind cable-driven deployment system, saltcake and sludge simulant were successfully dislodged and conveyed with the LWS. Proof-of-principle integrated testing was also conducted to evaluate the performance of the LDUA/LWS retrieval system at PNNL. The LWS was attached to the LDUA gripper and the system was used to retrieve simulants representing dried sludge and granular saltcake waste types. The LDUA was operated remotely through the use of two video cameras. Tests were conducted using manual operation and by executing programmed trajectories, which was necessary to precisely remove a pattern in the waste. These tests confirmed that the LDUA has the structural capacity to maneuver the LWS during waste retrieval while managing the conveyance and high-pressure hoses. From these tests, it is clear that maintaining minimal standoff distance throughout the retrieval process is critical if the material is to be scavenged efficiently.

These tests measured the performance of the LWS and validated its compatibility with existing long reach manipulators. Although there are no planned hot deployments of the LWS at this time, it is believed that the LWS has strong applications at Hanford for hard heal retrieval and at ORNL for gunite removal.

3.6 Tank Mixing

3.6.1 Innovative Tank Mixing

The objective of Double Shell Tank (DST) retrieval is to remove the sludge material from the tanks by mobilizing the sludge, forming a slurry with the salt supernate solution, and pumping the slurry out of the tank. In this application, both the sludge and supernatant are highly radioactive. The current baseline approach for sludge mobilization is through the use of a long-shaft mixer pumps, which are submersible pumps that produce a liquid jet parallel to the tank floor to disturb the sludge. Mixer pumps have been used before at both the Hanford and Savannah River nuclear reservations. Mixer pumps are not necessarily the ideal method of mobilizing sludge in DST since mixer pumps:

1. Are expensive to purchase and install,
2. Add heat to the tank waste,
3. May require frequent maintenance,
4. Are difficult to dispose,
5. May not be able to mobilize all of the solids inside a DST, depending on the waste characteristics, and
6. Have high operational costs at SRS for salt slurry due to multiple crane lifts.

Previous engineering studies at the Hanford site considered sluicing or recirculation with a transfer pump. In general, sluicing was found to drastically increase the waste volume because of excess dilution, and re-circulation of the waste through the transfer pump was thought to have a limited cleaning radius. Given the constraints of the mixing waste within a DST (radiation, volume, and limited access to the contents through risers), mixer pumps seemed to be the best alternative for mobilizing sludge.

In FY94, however, a commercial mixing technology was identified in which large air bubbles introduced through plates near the tank floor induce slurry mixing. The mixing technology, marketed by Pulsair Systems, Inc., was evaluated at PNNL in FY96, and shown to be effective at mobilizing sludge simulants. While the Pulsair mixing technology has several advantages over mixer pumps, e.g., no moving parts, it would be infeasible to install a large number of plates required at the bottom of a DST to completely mobilize the sludge. Because the Pulsair system was identified serendipitously, the question remained as to whether other commercial mixing systems could be applicable for double shell tank (DST) retrieval.

The objective of the innovative mixing task was to document a thorough literature search for applicable commercial alternatives to mixer pumps. If applicable, commercial technologies were identified for the mobilization and mixing of DST waste, a demonstration could be commissioned (a commercial mixing technology is defined here as a currently available system for sale by an industrial company). An applicable technology is defined as a technology that is able to mobilize sludge and/or mix a slurry solution in a 3,800 m^3 (1 million-gallons) DST. Sludge mobilization and mixing in a DST is non-trivial since there is limited access to the tank (the maximum size riser diameter is 1.1 m or 42 in.) and the DST sludge typically has a high yield stress.

At the conclusion of this task, no viable commercial alternatives to the baseline jet mixer pumps were identified. The task did not seek to discern differences between mixer pump technologies from different vendors or proposed changes to nozzle design and/or placement within the DST, since this research was viewed as outside the scope of the innovative mixing task.

The search for alternate sludge mobilization and mixing techniques was thorough. The following resources were used to search for innovative mixing technologies:

- Previous Hanford searches for alternative mixing technologies
- Textbooks on mixing and chemical engineering unit operations
- Research articles and chemical engineering magazines
- Expert consultation
- Trade publications and advertisements
- Internet WWW pages and news groups
- Mixing conferences
- Mixing classes
- National Technical Information Service (NTIS) published documents
- Thomas Register

Over 100 vendors of mixing equipment were contacted in order to find innovative and applicable methods to mobilize sludge in DSTs. Several recognized academic and industrial tank mixing experts were contacted or consulted in order to identify applicable innovative mixing technologies.

Over one hundred attendees of the 1997 North American Mixing Forum received a DOE presentation about their tank mixing needs. This forum allowed the needs of the innovative mixing task to be communicated to industrial and academic leaders throughout the international mixing community.

The mixing technologies that were identified generally fell into the following categories:

1. Conventional mechanical mixers (propeller, impeller, etc.)
2. Jet mixers
3. Positive displacement pumps (to suck-up the sludge at one point in the tank)
4. Crawlers
5. Pulse air and air lances
6. Air lift circulators
7. Sluicing
8. Wave generators

Of these mixing technologies, no previously unidentified technology was truly applicable for sludge mobilization or mixing in DSTs. Either the technologies were already identified, e.g., jet mixer pumps, pulse air, sluicing, mechanical propeller mixers, etc., or the tank geometry (riser diameter and/or sludge properties) limited their effectiveness. In addition, the SRS Flygt mixer test results should be reviewed closely to determine if Flygt mixers could be used as less expensive alternatives to jet mixer pumps in the Hanford DST(s).

3.6.2 Advanced Design Mixer Pump

The goal of the RPD&E FY97 support to the Advanced Design Mixer Pump was to provide technical support during pump tests to be held at the SRS TNX facility. Specifically, the EM30 testing program was to address long-term wear of the pump, and EM50 support was to try to capture as much performance data as possible that would assist users for operation of similar pumps. The RPD&E effort was de-scoped after the mixer pump experienced several technical problems, delaying testing until FY98. The following is a brief discussion of the history and current status of the Advanced Design Mixer Pump (ADMP).

The ADMP program was initiated by EM30 at Hanford and Savannah River in 1993, with the intent of producing a mixer pump design that could be used in radioactive waste tanks throughout the U.S. Department of Energy's complex. The main objective of the program was to develop and demonstrate a pump design for mobilizing and mixing settled-sludge in the waste tanks that was more reliable and maintainable the pumps currently employed. The majority of pumps being used are water-filled column line shaft pumps. A secondary goal of the program was to achieve higher mobilization and mixing performance.

A procurement specification (WHC-S-0211) was generated and sent out as part of a request for proposals. Two vendors, Westinghouse Electromechanical Division (WEMD) and Lawrence Pump, Inc., (LPI) with different design concepts were selected from the process. The WEMD design consists of a submersible electrical motor mounted internal to the tank and directly coupled to the pump. The LPI design is a more conventional long shaft design with the electric motor mounted external to the tank.

The design phase for both pumps was April through September of 1995. In FY96, budget cuts and vendor quotes for fabrication costs resulted in only the LPI design being selected for fabrication. In February of 1996, LPI was contracted to fabricate, assemble, and test their design of the ADMP for delivery in February of 1997.

Upon completion of vendor testing by LPI, the ADMP was to be shipped to the SRS for performance testing. Testing of the ADMP at SRS was to begin in April of 1997 and be completed by September of 1997. A number of technical problems associated with the fabrication and successful operation of the ADMP have delayed the delivery of the pump to SRS. At the end of FY97, these problems appear to be resolved; however, final vendor testing has not been performed. A letter report entitled, *"Advanced Design Mixer Pump Fiscal Year 1997 Status Report"* (HNF-SD-TWR-PRS-001) details the vendor and program activities for FT97.

The fabrication of the test facility at SRS for the ADMP performance testing has been completed. SRS has verbally committed to continuing their involvement in the ADMP program and conducting the performance testing of the pump in FY98. The initial test plan for the performance tests was reviewed in FY97, but a final test plan has not been released.

The LPI design for the ADMP is based on a major redesign of the LPI long length shaft design (motor external to tank) that is currently installed in tank AZ-101 on the Hanford site and referred to as the Hanford Project W-151 Mixer Pump design. Some of the major design advantages of the ADMP over the W-151 pumps are:

1. A gas-filled versus liquid-filled shaft column eliminates the addition of liquid (increase in waste volume) to the tank in the event of a failed seal. The gas-filled column results in a lower pump weight reducing bearing loads on the tank, and eliminates the need for freeze-protected water lines.

2. Tangential versus radial discharge nozzles are intended to provide for a more coherent discharge jet, which is anticipated to result in better mobilization and mixing for a given pump power.

3. The electric motor is designed to "Group B" hydrogen National Fire Protection Association (NFPA) standards, which allows for the operation of the pump in hydrogen watch-list tanks.

4. The ADMP is built to "Safety Class 1" standards to which the W-151 pump is not built.

5. Improved mechanical design features such as roller bearings, shaft coupling alignment joints, shorter shaft sections, etc., are all aimed at significantly increasing the operating life of the ADMP.

The W-151 pump is the current pump design slated for deployment in future Hanford Retrieval Operations. There are currently three W-151 pumps at the Hanford site. Two of these pumps have been installed in tanks but not operated, and the third is presently considered a spare.

Project W-211, at Hanford, is a future retrieval program with the potential to employ the ADMP. The W-151 pumps are currently the base-line pumps to which Project W-211 at Hanford wants to compare the ADMP when evaluating it for acceptance. The W-151 pump, however, has never been operated in a slurry under simulated waste tank conditions nor has its hydraulic performance or jet characteristics been determined. If W-151 is to be the benchmark pump, then base-line performance data should be obtained through testing.

It has been recommended to the Disposal/Retrieval program, at Hanford, that the spare W-151 mixer pump be shipped to SRS and tested in the ADMP test facility. The results of testing the W-151 pump would provide comparison data for projects like W-211 to base their evaluation of the ADMP. Tests of the W-151 hydraulic performance would also aid in evaluating the proposed design improvements made to create the ADMP and in resolving design issues that may arise as a result of the performance testing of the ADMP.

Mixer pumps currently in use with designs similar to that of the W-151 pump, such as those at West Valley and SRS, are operating with water leakage from the column. West Valley has reported leak rates of 14.5 gpm (54.9 liters/min) of water to the waste during pump operation. The operational life of these pumps in waste tanks has been several hundred hours.

Testing of the ADMP is necessary to evaluate the hydraulic performance and life span of the pump. The initial plans called for endurance testing the ADMP for 2000 hours of run time including speed variations, shut downs, and startups. It would be beneficial to test the pump to failure or an excess run time such as 5000 hours, and then perform a detailed post test inspection.

Hydraulic performance testing should include profiling the jets produced by the pump. Careful consideration should also be given to the simulants used for testing the pump to ensure meaningful results will be obtained under conditions that are similar to or bounding those anticipated to be encountered in the waste tanks.

Cost savings associated with mixer pumps can also be obtained by improving pump performance through pump operation. The ability to predict the pump power required to mobilize sludge in a tank or to maintain a specified suspension for transfer to a feed stream could greatly increase a pump's life span and efficiency. Experiments were conducted and data collected related to tank mixing via mixer pumps. This data should be used to develop models for predicting the maximum concentration of solids suspension as a function of flow rate through the mixer pump. The development of correlations for optimizing the operation of mixer pumps would result in a more efficient operation, criteria for sizing pumps, reduced heating of the waste due to excessive pump operation, and increased control of the solids concentration introduced to process feed streams.

The ADMP currently has no committed end users. Potential end users such as Project W-211 have not had the opportunity to influence the objectives of the performance testing. Approximately $270,000 of total funding has been requested by Hanford and SRS for FY98 to support the continuance of the ADMP development program. The bulk of the requested funds are for conducting performance tests at SRS.

The continuance of the ADMP program should include linking potential end users to the test program. The program should ensure testing is conducted at conditions applicable to the potential end users, e.g., with representative simulants and obtains data/information determined to be necessary by the end users for making a proper evaluation. Funding should also be secured for analyzing the test data and publishing the results and evaluation for potential end users. The ADMP development needs to be influenced by and reported to the end users if it is to become a useful retrieval tool for deployment.

Despite being delayed, the ADMP program has the potential to dramatically increase the operational life of mixer pumps while providing a pump with increased efficiency that does not posses the potential for leaking water to the waste. Increases in pump life can have significant benefits due to the cost of deploying, retrieving, and disposing of mixer pumps. The ADMP coupled with applicable models for tank mixing via mixer pumps will greatly reduce the costs associated with mixer pump operations in radioactive waste tanks.

3.6.3 Enhanced Sluicing

Enhanced sluicing is a broad field that encompasses many engineering disciplines. These include remote positioning of sluicing nozzle, visual or ultrasonic aiming control, mixing for effective slurrying of mobilized solids, estimation of formed slurry concentrations, and the fluid dynamics of sluicing nozzle design required to optimize the sluicing jet characteristics.

The end user client for this task is Hanford Project W-320, which involves the retrieval by sluicing of waste in single-shell Tank C-106 and transferring it to DST AY-102 late in FY98. The objective of transferring waste from Tank C-106 to Tank AY-102 is to resolve the high-heat safety issues in Tank C-106 and to demonstrate single shell tank waste retrieval technology.

No significant changes to the existing sluicing/retrieval operational plan are anticipated for Project W-320, due to budgetary limitations and the short time that would be available to implement any major changes. The thrust of the effort within the RPD&E project was focused on providing as much information as possible to clarify and predict the outcomes of the various planned operations and processes that will be utilized during sluicing, mobilization, retrieval and transport. It was hopped that such information would lead to 1) some optimization of the process control plans for Project W-320; and 2) justify the implementation of some relatively simple changes that could significantly enhance the sluicing process and, at the same time, not interfere with the project schedule. Operators will benefit from improved understanding of what to expect from the planned sluicing, retrieval, and transfer operations.

Based on the available background information, two main tasks were considered relevant to the sluicing and retrieval problems for Tank C-106. These two tasks are summarized bellow with indications on performance location, progress to-date and probability of completion before the end of FY97.

Characterization of the Hanford Nozzle

The nozzle's coefficient of discharge was obtained during tests at PNNL, and a detailed experimental plan to be followed in performing experiments to obtain water jet's performance as to sluicing effectiveness was designed. Installation of the Hanford Nozzle along with all the necessary support equipment was installed at UM-R where tests were to be conducted. Support equipment includes:

- Electric power for the pump and/or motor assembly
- Nozzle mount with height and yaw and pitch angles controls
- Rigid mount for the instrumented pressure plate
- Movable vehicle in which a pressure plate will be installed
- Computer connections for data recording
- High volume low-pressure pump
- Large water storage tanks to supply the Hanford Nozzle

Analysis and comparison with predictions of the pressure and force fields generated by the water jet produced by the Hanford Nozzle at different nozzle orientations was completed.

Figure 21. Hanford Nozzle Directed at Instrumentation.

It was found that, even at 68.9 MP waterjet pressure, containment of the process water was a challenge for the retrieval system. The traverse speed and dwell time were modified to reduce the amount of water lost, and it was found that using a short dwell time followed by a rapid traverse could minimize the amount of water lost. During this process, a ridge is created by the waterjets that serves to deflect the water up into the conveyance line.

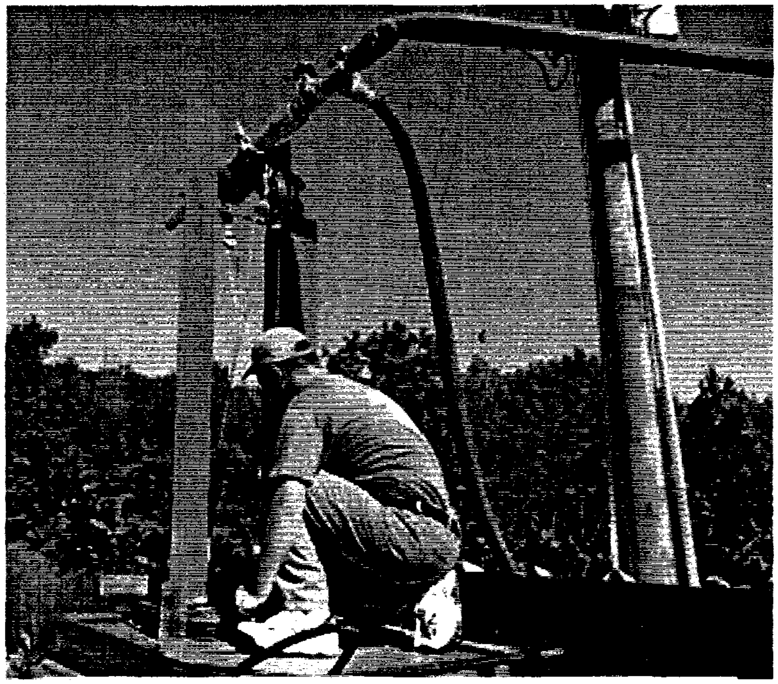

Figure 22. Hanford Nozzle on Mounting Stand.

These and other test results have been evaluated and published in a PNNL report entitled "Engineering Development of a Lightweight High-Pressure Scarifier for Tank Waste Retrieval" (PNNL 11736) dated September 1997. Prior to the completion of testing, a demonstration of the LWS and other retrieval systems being developed and tested by the RPD&E team was held for personnel from DOE RL. The demonstrations focused on technology development and "paper to product" site support that is the key to successful deployment and were very well received.

Development of an idealized mathematical model to describe and demonstrate the systematic solid particles dislodging and slurrying by sluicing as a function of the sluicing jet position and orientation in a set-up (Figure 21) similar to that in Tank C-106 was completed.

A detailed experimental plan was completed for experiments to obtain data of a single jet (Figure 22) sluicing operation similar to that which will be carried out in Hanford Tank C-106. Recommendations for necessary equipment and measurement schemes to carry out the experiments at UM-R were completed.

Construction of a model circular tank to be filled with a reasonably representative waste material in order to perform the above mentioned experimental program was completed.

3.7 Russian Retrieval Quarter-Scale Equipment Testing

Russian specialists from Radiochemservice Company and Krasnoyarsk-26 have developed, tested, and deployed several retrieval technologies for waste removal within Russia. Several of these technologies may have application to certain waste forms within the DOE Complex. The TFA in conjunction with EM International programs sponsored the design, fabrication, and testing of Russian Retrieval Equipment supernate and sludge retrieval. The Russian specialists designed, fabricated, and cold tested scaled models of this equipment prior to shipping it for experimental evaluation for potential deployment. The equipment includes a pulsating pump, hydroelevator, hydromonitor, and a pulsating monitor. The TFA RPD&E team and the Russian specialists conducted performance testing and demonstrations of the pulsating pump and the pulsating monitor at the Hanford site 336 Quarter Scale Test Facility to present them to interested potential users and to assess their viability for U.S. applications.

The Pulsating Pump and Pulsating Monitor both show promise of applicability in the DOE tanks; however, there are significant technical issues to be addressed before they are ready for deployment. The equipment has the advantages of having minimal moving parts in the tank, presenting explosion hazards, and being compact and inexpensive in-tank apparatus. Issues to be addressed in further development work would include:

- Making the check valves more tolerant of granular materials,
- Devising means to deal with hazards like wires, rags, gloves, etc.,
- Providing means to back flush and decontaminate all the wetted parts,
- Separation of the aerosols from the vacuum-side gas stream,
- Providing more flexibility in the control of valve cycling, and
- Allowing automatic rotation of the monitor without stopping the cycle, engineering fully remote operation of the valves and monitor rotation.

Pulsating Pump

The Pulsating Pump (see Figure 23) consists of an upright cylindrical reservoir, a foot check valve with an inlet screen, a working gas supply pipe, a discharge pipe, and a back flush/check valve at the riser head. In operation, the supply pipe is valved to a vacuum source, and the waste is drawn into the reservoir through the foot check valve. The supply pipe is then valved to a pressurized gas source to expel the waste up the discharge pipe through the check/back flush valve and into the downstream balance of plant pipe.

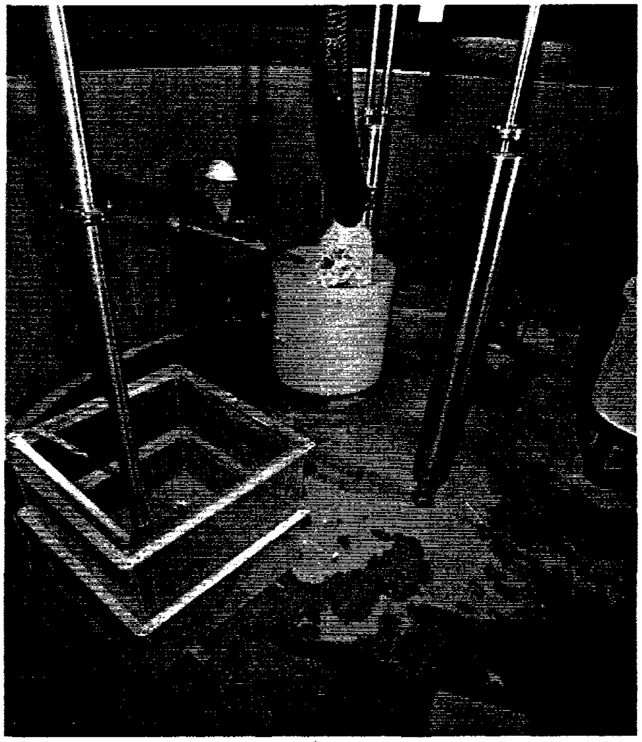

Figure 23. Pulsating Pump.

The foot check valve is a captive metallic ball (Tungsten or TiN - coated stainless) in a conical metal seat. The inlet screen is a short cylinder with side ports, extending beyond the base of the reservoir. It is removable for access to the check valve.

The upper check/back flush valve is a captive ball valve riding in a cage including the conical check valve seat. The entire check valve assembly can be lifted off a secondary seat so water introduced via the discharge port will: 1) agitate and flush the upper check valve and back flush the discharge pipe, 2) wash and agitate tot check valve, and 3) re-suspend any particulate that may have settled in the reservoir.

Pulsating Monitor

The Pulsating Monitor consists of an upright cylindrical reservoir, a foot check valve without (on the test article) inlet screen, a working gas supply pipe, a discharge manifold and nozzle head. In operation, the supply pipe is valved to a vacuum source and the waste is drawn into the reservoir through the foot check valve. The supply pipe is then valved to a pressurized gas source to expel the waste through the manifold and nozzles. There is no provision made for back flushing the foot check valve.

The Pulsating Monitor is supported by a riser cover plate on a swivel bearing/seal that allows operators to manually turn it to direct the nozzle jets in different directions. The working gas supply is delivered by a hose connected to a swivel 90-deegree elbow fitting at the top of the monitor. The swivel fitting must be loosened to swivel interrupting operations; but if the installation is planned well and four nozzles are used, hose flexure may accommodate the 90 degrees of rotation required.

The test article was fitted with only two jet nozzles. There are four ports in the head. The preliminary drawings showed a fifth nozzle directed axially downward on the centerline, but the port for that jet was not present on the test article. The foot check valve is a simple captive ball in a replaceable seat. The ball and seat were coated with titanium nitride for hardness and corrosion resistance.

Pulsating Equipment Controller
Both the Pulsating Pump and the Pulsating Monitor are controlled by the same controller, which delivers alternating pulses of gas pressure and vacuum to the Pulsating equipment. The controller consists of a motor-driven rotary valve, motor speed control, and a distribution manifold. As furnished, the rotary valve working parts were two polytetrafluoroethylene (PTFE) discs, one having a single round port open to the working gas delivery manifold and the other having a pair of elongated ports positioned over the working gas/vacuum supply ports in the valve body. The angles spanned by the elongated ports define the dwell times and open times for the valve, and the rotating plate with the single port governs the frequency of operation. The vacuum supply to the pulsating equipment was provided by an axial-jet eductor furnished with the equipment. The air compressor powered it, with the air source at 800-kPa (~100-psig) throttled to control the vacuum delivered. For most tests the vacuum was set at ~78-88-kPa (10-12psia).

Hydromonitor
The hydromonitor is a sluicing device comprising two diametrically opposed 10-mm jet nozzles inclined at 30° down from horizontal. The nozzles are mounted in the end of a vertical pipe stem above the tank floor. The pipe stem is inserted through a small riser and can be rotated about the vertical axis. The working fluid connection is made to a 90-degree elbow swivel fitting. The unit delivered is designed for operation at 1.2 mPa (175 psia). This system was not tested.

Hydroelevator
The hydroelevator is a fairly conventional axial jet pump, albeit neatly packaged. With a large axial motive jet, it would be categorized as a high volume – low-pressure pump. The rated output of combined water and slurry, for slurry of SG = 1.4, is 8–12 m^3/hour while consuming 6–9 m^3/hour of water; so unless supernate is used as the working fluid, the dilution ratio is unattractive. The decision was taken to set up the hydroelevator for an optional demonstration, but it was not tested at the Hanford 336 Building.

3.8 Retrieval Data Analysis and Correlation

Significant testing of retrieval processes was completed during past years by the RPD&E team. Since the Retrieval Analysis Tool (RAT) needs to incorporate data pertaining to various retrieval technologies, it is important that this data is analyzed and correlations are developed. During FY97, analyses were conducted for high-pressure scarification, pneumatic conveyance of wet and dry solids, jet pump conveyance, and confined sluicing dynamic reaction forces. This analysis, summarized below, contains detailed technical information to assist industry in the design of deployable systems and communicated lessons learned and open issues.

The objectives of high-pressure scarifier data analysis were to determine retrieval rate performance operational data, such as simulant composition, standoff distance, or traverse speed. In addition to operational performance, dynamic reaction forces were analyzed to determine the compatibility of the scarifier with remote deployment systems, such as the Light Duty Utility Arm. This data can be used to support decisions regarding the application of the scarifier (or similar) technologies and will allow design and validation of deployment system design and actual in-tank components. Since high-pressure scarifiers are being considered for remediation of Hanford Tanks, there was keen interest in this information from several industrial vendors wishing to propose retrieval concepts to the Hanford Tanks Initiative. The entire scarifier data analysis package was converted to an Internet web site to to not only industry, but lab technologists, project teams, regulatory agencies, and DOE management. Web-based publishing also helped ensure data commonality and accuracy.

The objectives of the pneumatic conveyance data analysis was to determine the pressure drop that occurs during steady pneumatic conveyance of liquid, solids and solid-liquid mixtures in vertical, horizontal and incline pipelines. Correlations describing pressure drop during very wet pneumatic conveyance over large vertical and horizontal distances do not currently exist. The data generated from this analysis can be used to determine the maximum solids transport rate for retrieval of wet and dry solids removed from waste tanks. This analysis attempted to provide process information to resolve the following issues concerning the use of air conveyance for retrieval of waste:

TABLE 2. Analysis of Air Conveyance Unresolved Issues and Their Impact.

Unresolved Issues	Impact of Information
Can pneumatic conveyance achieve the minimum required conveyance rates to remove waste efficiently from tanks?	This information will enable engineers to determine the minimum pipe diameter and blower capacity to achieve a target solids and liquid mass flow rate.
Will pneumatic conveyance be stable, resulting in minimal fluctuating forces on tank components?	This information can be used to assess whether or not the system could damage a tank or tank components.
What is the minimum required diameter of a conveyance line to convey waste from the tank?	Data will enable engineers to select pipe diameters, blower flow rates and maximum pressure drops during transport. This information can be used to determine whether a pneumatic conveyance line can fit through a riser, particularly when other equipment is occupying a portion of the riser.

The results of the conveyance analysis were documented in a test report. In addition, air conveyance theory was used to develop a spreadsheet to calculate the entrance Mach number for the conveyance system. This entrance Mach number will dictate the maximum possible flow rate through the system and can be achieved when the pump capacity is sufficiently large. The spreadsheet can be used to size the conveyance line and blower required achieving the desired flow rate and lifting for an air conveyance system.

The objective for jet pump data analysis was to develop correlations for jet pump retrieval of underground storage tank waste. Jet pump performance affects waste volume generation, system reliability, and retrieval throughout. Many sites are considering the use of jet pump for retrieval (ORNL, INEEL, Hanford). The ultimate goal of this task will be to determine jet pump performance and erosion rates as a function of inlet pressure and flow for a variety of waste types. During the course of jet pump testing in FY96, it was determined that entrained air decreases jet pump life and retrieval rate. During FY97, jet pump data analysis generated air flow and pressure data with the jet pump to support jet pump endurance tests at UM-R. Jet pump correlations are being develop based on continued testing at UM-R to predicted retrieval performance and erosion rates for a variety of jet pump designs.

Dynamic force analyses were also completed for the Confined Sluicing End Effector based on testing completed in FY96 for ORNL. A large amount of reaction force data was examined to determine the effect of waste type, motor speed, and waterjet pressure on end effector reaction forces. Two analyses were performed on each data set. First, a moving average filter was applied to verify that the average values were representative. Second, a spectral analysis was performed using the Mathcad™ implementation of real-data fast Fourier transforms. The average forces and peak forces were found to be well within the static load capacity of the MLDUA. Summary plots were generated to aid the visualization of changes in parameters and included in the final CSEE report entitled, "*Engineering Development of Waste Retrieval End Effectors for the Oak Ridge Gunite Waste Tanks*" (PNNL-11586) Mullen, 1997.

3.9 Simulant Development

Waste simulants are used in the development and testing of proposed waste retrieval systems. The simulant development task provides simulant recipe development, preparation, and disposal support to the other RPD&E tasks involved in testing with waste simulants. After discussions with the key personnel involved in the testing, simulant recipes are developed based on the existing waste characterization data and a consideration of which waste properties are thought to be most relevant for process being tested. Simulant procurement, preparation, characterization, and disposal were all performed by the simulant development task.

Simulant support was provided for the testing of the gunite scarifier, the OHF Extendible-Nozzle, the INEEL End-Effector, the Light Weight Scarifier, and the enhanced sluicing equipment at the University of Missouri-Rolla.

A rapid-curing gunite simulant, which contained fast-setting Portland cement, fine sand, and a cure accelerant, was developed to support testing of a high-pressure scarifier system planned for use in the ORNL gunite tanks. WTI performed testing of this simulant.

Three types of simulants were specified, prepared, and disposed for the OHF extendible-nozzle testing. A relatively low-strength sludge simulant was formulated to mimic the strength expected from the OHF tank waste. Four tests were performed using this simulant. Several tests were performed using a modeling clay simulant that has a shear strength roughly five times higher than that expected from OHF sludge. One test was performed using a strong hardpan simulant that is about 60 times stronger than the OHF sludge.

Testing of the INEEL end-effector involved simulating both the calcine particles and a tar-like substance, which is thought to be present on some of the INEEL tank components. Appropriately sized sand was used to simulate the calcine, and tubes coated with wax and sprayed with paint were used to simulate the tar-like coating.

Light Weight Scarifier testing utilized four different waste simulant types: wet sludge, hardpan, soluble saltcake, and hard saltcake. These simulants were previously developed as part of the Hanford Tanks Initiative program (formerly ACTR) and are documented a report entitled, "*Initial ACTR Retrieval Treatment Evaluation Test Material Recommendation*" (PNNL-11021) Powell, 1996.

Along with the simulant preparation/disposal work, a short series of tests were performed to improve the defensibility of sludge and saltcake waste simulants. A variety of sludge simulants were subjected to an impinging waterjet to determine the susceptibility of sludge simulants to sluicing-based retrieval methods. The shear strength was found to be a reasonable predictor of the impact pressure required to induce mechanical failure in the sludge simulants. These data will be used to support future enhanced sluicing work. Saltcake simulants were similarly tested except that high-pressure waterjets were used. Waterjet cutting performance was correlated with a variety of saltcake simulant physical properties.

Salt dissolution studies were also performed to improve the defensibility of soluble saltcake simulants. A methodology was developed for accounting for dissolution rate and solubility differences between the non-hazardous salts used as simulants (e.g., sodium chloride) and the hazardous tank saltcake constituents (e.g., sodium nitrite and nitrate). Using this method, the dissolution rate of a non-hazardous saltcake simulant can be used to predict the dissolution rate of tank saltcake provided that grain size and pore size data can be obtained for saltcake waste.

The simulant development task also prepared a document that describes many of the waste simulants that have been used to support retrieval system development and testing at Hanford. This document, entitled , "*Retrieval Process Development and Enhancements Waste Simulant Compositions and Defensibility*" (Powell et al. 1997), is being incorporated into the Retrieval Analysis Tool. The report describes the relevant properties and applications for sludge, hardpan, and saltcake simulants. Sludge and saltcake waterjet cutting tests and salt dissolution rate studies are also described in this report.

3.10 Retrieval Analysis Tool

During FY97, the RAT was initiated, and relevant retrieval information was collected primarily for the Retrieval Analysis Tool's first client, the Hanford Tank Initiative. User profiles were constructed, concluding that industry and laboratory retrieval specialists would be the primary decision-makers using the tool.

Using these profiles, a public Website was constructed on the Internet, with the domain name www.tanks.org. Using active server pages and a relational database structure, the tool will query documents and information sources pertaining to retrieval of waste in underground storage tanks across the DOE complex. The sources include relevant technical reports, test summaries, lists of vendors with applicable technologies, and tank/waste information for each site.

The first tests of the tool were used by the Hanford Tank Initiative to provide necessary information for retrieval technology decisions by industry, as a part of the August 8, 1997, solicitation *#WA31512 C-106 Waste Retrieval Demonstration*. In this solicitation, industry will be required to remove the radioactive hard heel waste from Hanford Single Shell Tank C-106 using methods of their choosing. The tool was accepted by Hanford Tank Initiative and incorporated into the solicitation on July 21, 1997.

A final accomplishment for this year will be the incorporation of initial technology and waste information from other sites, in preparation for expansion of the tool in FY98.

3.11 Chronological Summary

RAT efforts for FY97 are divided into two parts:

Establishing the Baseline. Through mid-January 1997, user profiles and available information were assembled so that the data needs and sources could be understood.

Assembling and Testing the Tool. Production of the database elements supported the May and July Milestones from HTI through task-level internal milestones, contributing technical results from ongoing EM research, in context, and results from retrieval projects across the complex. Using commonly available commercial software, primary database information regarding tank conditions and retrieval solutions was collected from each source, and published outside the firewall on the Internet. The completed information set has been published so that industry and all user sites can readily access it through the Internet.

Development elements include:

- Completion of the database of tank conditions and retrieval solutions.
- Development of an intelligent search and constrained selection capability.
- Development of an evaluation and risk assessment capability.
- Validation of the information against ongoing retrieval projects.

The finished product allows industry and DOE complex users to review work to date, pose high-level queries, and participate in development of the tool during FY97, to encourage their ownership.

The RAT was initiated in FY96 to provide a tool for end users concerned with the selection and use of systems to retrieve waste from underground storage tanks. These are complex decisions that require knowledge of Industry and DOE Laboratory work in progress, physical characteristics of the waste itself and other tank specific and external constraints. The Technical Work Plan, Revision No. 0, December 11, 1996, received final approval on December 29, 1997.

RAT has been in operation externally on the web since its Alpha release on May 31, 1997. This release included:

- Bringing a new Hanford site external web server online.
- Creating up-to-date web pages by extracting information from a various databases that are continually updated.
- Defining, collecting, assembling, and publishing waste retrieval data.
- Obtaining release approval for unlimited public distribution.

The Beta release on July 25, 1997, has the following enhancements from the Alpha release:

- Navigation within the web site has been simplified and expanded,
- Significant quality checks have been done on the web site operation and data and corrected where needed.
- Document information related primarily to the Hanford site has been greatly expanded and is almost up to date.
- Vendor information has been expanded and vendor data has been mostly verified to be up to date.
- Tank information related primarily to the Hanford site has been added.
- Feedback features have been added including the ability for outside vendors to file data correction notices.

Validation of the Beta version of RAT consisted of three steps:

1. A structured review of Retrieval Analysis Tool's functions, including a systematic review of the various features of the RAT website, assures that each feature was working properly, correct data was being returned, and documenting the capability of RAT.
2. To judge completeness, a series of keyword queries, believed to be typical of a RAT user, were examined to evaluate the responses and to recommend enhancements.
3. Verify user acceptance consisted of documenting Retrieval Analysis Tool's performance in support of its first client, the HTI project in the HTI "C-106 Waste Retrieval Demonstration REQUEST FOR PROPOSAL (RFP). While the initial focus of the work has been mostly HTI, the broader scope is clearly to serve the entire DOE complex. HTI assistance has encouraged other sites to openly contribute their technologies, tank data, and lessons learned; more of other site's data will be included in FY98.

The RAT has undergone some changes in focus from its initial concept of being a high-level decision tool for defining technologies for waste retrieval based on various parameters from the user. Creating an accurate and user-accepted decision "engine" proved extremely difficult when it was realized that the required data to make the decision logic was not available and to create the data would be highly subjective and may lead a user to the "wrong" decision. This effort was refocused to provide a repository of information related to a wide-range, tank waste retrieval data with tools to allow the user to make those decisions.

The RAT website currently brings together two databases that were created exclusively for the RAT task, a document database and a vendor database. RAT uses a document database, containing references to five categories of documents:

Category 1 - Very relevant, most all are recently published, full text is available.

Category 2 - Relevant, majority are recently published, Abstract and Table of Contents available.

Category 3 - Less relevant, generally older publications, most have Abstracts and Table of Contents available.

Category 4 - Reviewed as not relevant, list not viewed externally.

Category 5 - Documents in queue for review or awaiting release, list not viewed externally.

Only the Category 1, 2, and 3 document list is viewable publicly and all these documents have information on where hard copies of the document can be obtained or read. The vendor database includes company listing, addresses, and contact information. Tank data is currently extracted from other Hanford databases that are maintained by other groups.

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