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1. Title for Conference or Meeting Waste Management 2003
2. Group Sponsoring WM Symposia, Inc.
3. Date of Conference Feb 23-27, 2003
4. City/State Tucson, AZ
5. Will Information be Published in Proceedings? [ ] No [x] Yes
6. Will Material be Handed Out? [x] No [ ] Yes

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RPP-14340-FP
Revision 0

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Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

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Richland, Washington

Contractor for the U.S. Department of Energy
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EDC-	FMP-
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Document Type: RPT	Page Count: 15

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Abstract		Summary		Full Paper	X	Visual Aid	
Conference Name:	Waste Management 2003						
Conference Date:	February 23, 2003						
Conference Location:	Tucson, AZ						
Conference Sponsor:	Waste Management Symposia, Inc.						
Published in:	Proceedings of Waste Management 2003 Symposia						
Publication Date:	February 2003						

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RETRIEVAL OF HANFORD'S SINGLE SHELL NUCLEAR WASTE TANKS USING TECHNOLOGIES FOREIGN AND DOMESTIC

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ABSTRACT

Significant progress has been made on the Hanford single shell tank (SST) retrieval projects since they were initiated as part of the modified Hanford Federal Facility Agreement and Consent Order (Tri-party Agreement) in 2000. Four of the 149 SSTs at the U.S. Department of Energy (DOE) Office of River Protection (ORP) Hanford facility are being retrieved to meet Tri-Party Agreement commitments. An additional tank is being retrieved to demonstrate an alternate technical approach. As the Hanford Site transitions to an accelerated retrieval and closure mission, these methods will be the baseline methods for SST retrieval. The five SSTs are located within the Hanford 200-Area tank farms operated by CH2M HILL Hanford Group (CH2M HILL) for ORP. Included in this paper will be discussions on the technologies selected for retrieval of each tank; electrical resistance technologies that are being evaluated for ex-tank leak detection and monitoring; and the Cold Test Training Facility (CTTF) used for testing of and training on the different retrieval systems.

INTRODUCTION

The Hanford Site is accelerating its SST retrieval mission. One aspect of this acceleration is the identification of new baseline retrieval technologies that can be applied to all tank conditions that include salt and sludge wastes in both sound and leaking tanks. The five SST retrieval activities discussed here relating to tanks U-107, S-102, S-112, C-104, and C-106 will be accomplished by implementing three different retrieval technologies that have broad applicability to the remaining tanks. These technologies are retrieval alternatives to past practice sluicing which employs large volumes of liquid to remove the waste, resulting in greater potential for tank leakage than the selected methods and a leak detection alternative to liquid-level monitoring which is less viable when used with low water level retrieval methods. The technologies associated with the retrieval of each tank will target three broad waste classifications at Hanford and other

DOE sites, i.e., saltcake (soluble) waste, sludge wastes (low solubility to insoluble), and a combined sludge-saltcake waste. The five tank retrieval activities will demonstrate low water-volume saltcake dissolution in tank U-107, bulk sludge retrieval that would be acceptable for leaking tanks in tank C-104, removal of a sludge heel in tank C-106, and will combine removal of salt and salt mixed with sludge with the removal of insoluble residual heel materials in tanks S-112, S-102, and U-107. Each category represents a range of technical challenges for the retrieval processes and achievement of the Tri-Party Agreement retrieval goal of 99% volume reduction. This goal represents a volume of less than 100.8 m^3 of residue in a 22.88-m diameter tank. The CTTF has been constructed to test new retrieval equipment, develop operating procedures and train Operations staff on the use of the equipment. The chosen retrieval systems use a controlled depth of water and shorter duration operations to mitigate the effects of any potential leakage. Low-water retrieval methods reduce the effectiveness of water-level leak detection methods that depend on measuring a free liquid surface to detect a drop in level or comparing the levels in sending and receiving tanks for a mass balance. New ex-tank soil resistivity methods adapted from the petroleum industry are being evaluated.

U-107 DISSOLUTION RETRIEVAL

The first phase of tank U-107 retrieval, a saltcake tank, will be accomplished by low volume dissolution of the wastes utilizing water as the solvent. Retrieval operations started in December 2002 (1, 2, 3) and are planned to continue through March 2003. Preliminary results indicate that tank U-107 salt upper surface readily dissolves in the path of the water jets. This process is integrated with tank interim stabilization equipment where a low capacity (15 – l/min) jet pump is used to remove any pumpable (leakable) liquids from stored waste (4). All Hanford SSTs have been or are currently being interim stabilized. Low volume dissolution uses a set of spray nozzles, three fixed and one moving in a pattern, to apply water to the surface of the salt. The water seeps down through the salt cake dissolving salt and is removed as brine by the jet pump. At all times, the liquid level is maintained below initial tank liquid levels so as not to increase leakage head pressure. As a follow-on or supplement to Interim Stabilization Operations the only additional infrastructure needed is the water addition system. After the dissolution demonstration of tank U-107 waste, bulk modified sluicing retrieval (discussed below) will remove solids with a residual waste volume goal of less than 10.8-m3 or 99.5% of tank contents retrieved

Fury 400 ™ Tank Cleaner

The primary spray system is a Fury 400 ™ automatic tank cleaner produced by Breconcherry, Ltd. of the United Kingdom. This is a compact cleaning unit with a piston-operated mechanism. It produces high impact, long-range jets which oscillate through 90° while indexing around the central axis powered by the wash water. Commercial applications include process vessels, storage tanks, and transport containers for food, pharmaceutical, chemical, and nuclear industries.

C-104 BULK SLUDGE RETRIEVAL

Tank C-104, a sludge tank, has been selected to demonstrate a retrieval method that will be acceptable for use in leaking waste tanks. The Mobile Retrieval System consists of an Articulating Mast vacuum retrieval system (see Figure 2) and a remote controlled In-Tank Vehicle (see Figure 1). The Articulating Mast will lift waste into a batch vessel, where water will be added and mixed into slurry for pipeline transfer to the destination tank. A retrieval tool, mounted at the end of the mast's boom, can clear waste from a 9 m diameter area at the center of the tank. The In-Tank Vehicle will be used to dislodge waste from the rest of the tank and move the waste to within range of the retrieval system. Non Entry Systems, Ltd. (NESL) of the UK provides these technologies that are adapted form those used by European petroleum and mining industries. This combination of technologies minimizes water required to mobilize the waste within the tank thus reduces the potential for liquids to leak. The system will also function with more liquid in the tank, which would facilitate retrieval in a sound tank. The retrieval system incorporates ultrasonics to both decontaminate hardware and to breakup precipitates vacuumed to the surface vessels prior to pumping the slurry to the receiving tank. The vehicle and mast systems were delivered to the CTTF in August and November 2002, respectively, for acceptance testing. The system is scheduled for use in tank C-104 in 2005. Additional vacuum retrieval systems of similar design are being considered for use in retrieval of the 16-200 series SSTs (6-m diameter) beginning in FY 2004.

In-Tank Vehicle

The C-104 In-Tank Vehicle (see Figure 1) is a rugged, 600-kg NESL crawler that can fold to a width of 68.5-cm to allow passage through a 91-cm tank access riser. It then unfolds to a width of 101.6-cm for the stability to maneuver over uneven waste surfaces. An on-board water jet and pump/nozzle combination can throw waste toward the central vacuum retrieval system in conjunction with the plow blade. For a dryer (less liquids) retrieval campaign, the pusher blade can be used alone. Also, the sheer weight of the vehicle will crush harder sludge deposits, mobilizing waste in the process of moving around the tank. An umbilical line connects the crawler to aboveground deployment and control equipment. The line provides services and control to the crawler and is the recovery tether.

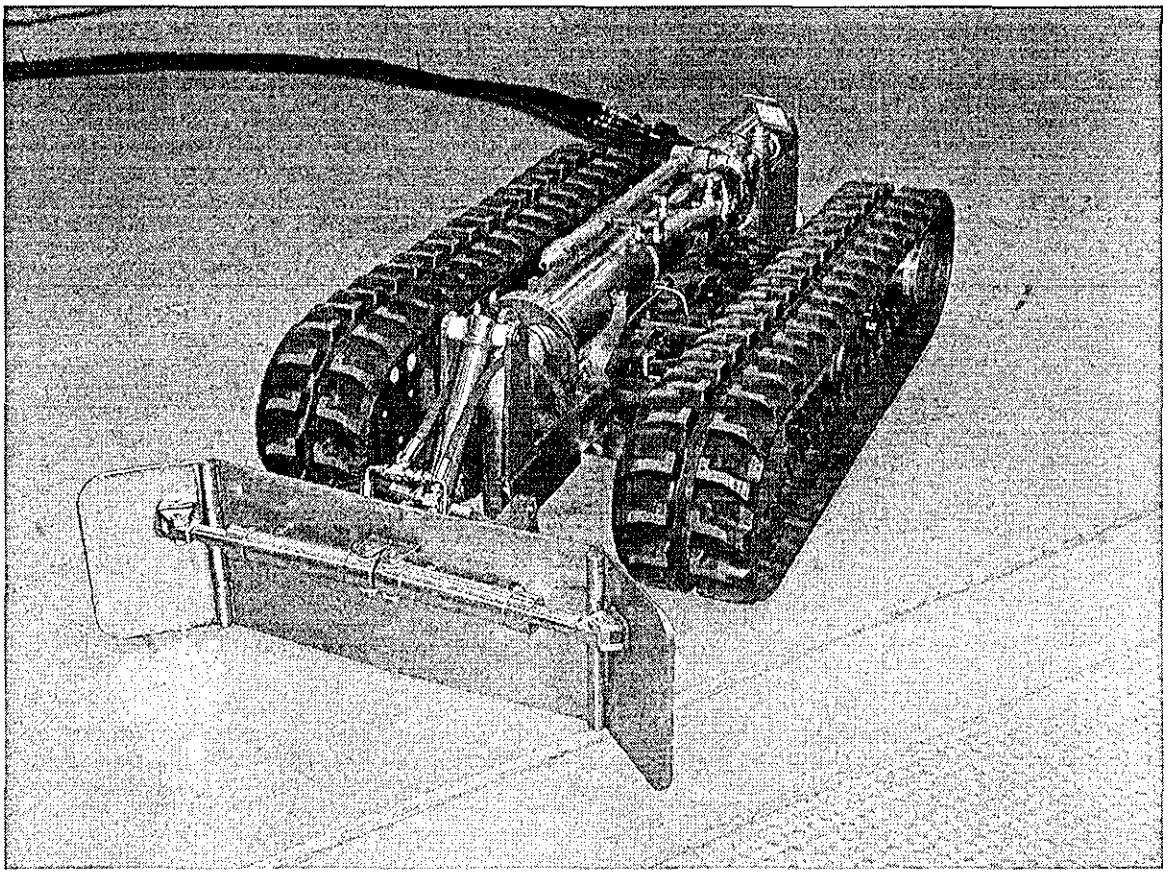

Figure 1. C-104 NESL In-Tank Vehicle -- Folding Crawler System

Articulating Mast

The Articulating Mast (see Figure 2) is supported from the 30-cm diameter tank access riser located in the center of tank C-104. The vacuum/air conveyance retrieval line passes through a pivoted boom extending from the fixed mast. This is the vertical pipe shown at the side of the larger mast. Hydraulic actuators swing the boom to reach 4.6-m from the mast. Once the boom is swung out, the boom support can be lowered within the mast to allow the boom retrieval tool to reach waste down to the tank floor. The boom can be equipped with a water/air injected Tore™ (Merpro Ltd., Bristol, UK) fluidic agitator at the lower end or other tools to help mobilize waste for pick up.

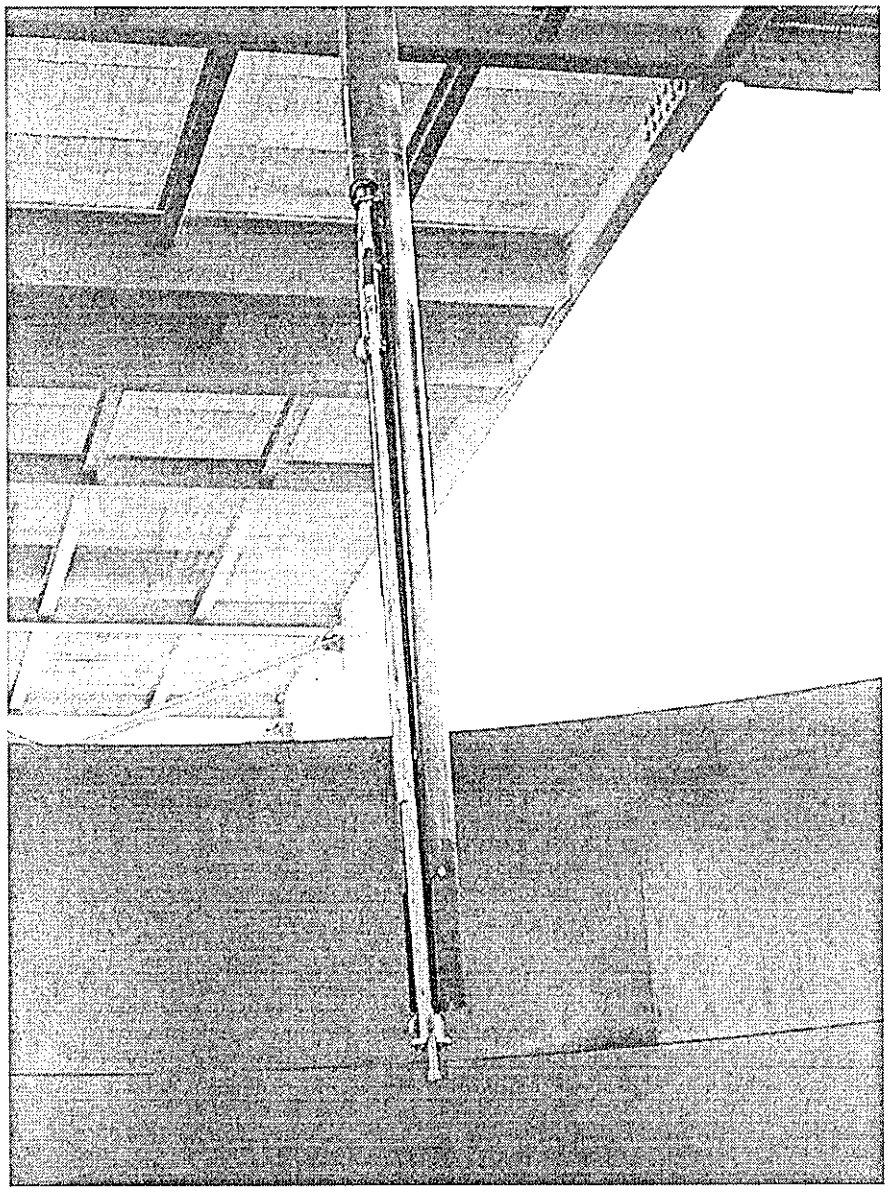

Figure 2. C-104 NESL Articulating Mast Retrieval System deployed in the CTTF

Vacuum Receiver System

The vacuum/air conveyance receiver system consists of a vacuum skid housing the blowers that maintain the vacuum and a batch vessel skid. The batch vessel catches the air-entrained waste, dropping it to the bottom of the vessel. Here the waste is mixed into slurry using a water injected Tore ™ unit for pipeline transfer. This skid-mounted system is designed to be readily moved from tank to tank.

C-106 SLUDGE HEEL

Tank C-106, a sludge tank, was initially retrieved in 1999 using past practice sluicing (5), leaving a residual sludge heel of solids and liquids. A final retrieval campaign to remove these residuals is scheduled for spring 2003. Past practice sluicing used supernate liquid from the waste receipt tank as the sluicing medium. The retrieval pump then moved the waste slurry along the parallel transfer line to the receipt tank. There, solids would settle and the liquids would be pumped back to tank C-106. As the amount of waste to be retrieved now is much less, waste will be sent to the receipt tank but liquids will not be returned. A closed cycle, in-tank, recirculation sluicer plus a fresh water sluicer will be used to mobilize the solids. A 750-l/min-retrieval pump will transfer slurry batches to the receipt tank. This method allows the use of a temporary, single 5-cm diameter over-ground transfer (OGT) line resulting in economy over using the original pair of 13-cm diameter steel underground transfer lines.

Recirculating sluicer/pump

One of the challenges for Hanford SST retrieval is tank access. Tank C-106 has one 30-cm access riser near the center of the tank, which will be occupied by the transfer pump. The float pump for the recirculating sluicer needs to be installed through a riser located 1.5-m from the tank wall. It is designed to unfold once in the tank, placing the floating suction head near the center of the tank. This liquid pumping system can discharge either to the two sluicer nozzles for mobilization of difficult sludge or to the transfer line for dewatering the tank. This unit can reduce the liquid level to one inch after a campaign. It is not, however, powerful enough for solids transfer which the transfer pump must do. Recirculation will reduce the estimated water usage from 2.8 Million liters to approximately 1.1 Million liters.

Fresh water sluicer/transfer pump

The primary source of water to be used for sluicing and slurry transfer will come from fresh water, pressurized by a booster pump to 700 to 1400-kPa, introduced through the two sluicing nozzles. The nozzles are located at opposite sides of the tank and can be used in tandem to move waste to the transfer pump. The 750-l/min-transfer pump is capable of pumping slurry down to a depth of 15-cm and is equipped with a beater to break up large waste solids that might accumulate on the suction strainer. The challenge

of removing these residual solids will be typical of completing retrieval of virtually all salt and sludge tanks.

S-112, U-107, AND S-102 BULK SALT/INSOLUBLES RETRIEVAL

Bulk retrieval of the combined sludge-saltcake waste tanks S-112, U-107, and S-102 will be performed through the operation of fresh water sluicing to mobilize salts and high-flow rate pumping systems. When soluble salts have been removed the sluicers will be used to mobilize the solids into slurry for pumping out of the tanks. This method is expected to remove wastes from a tank within two to three weeks of active retrieval time minimizing the time at risk for increased leakage potential. Water levels will be maintained below a level where the tanks have not been shown to be leaking. Retrieval will begin at the center of the waste and progress outward to the tank walls. Between campaigns free liquids will be pumped out to further minimize leakage potential. This is typical for all retrieval operations using water for retrieval. S-112 retrieval activities are scheduled to be completed by fall 2003. U-107, and S-102 will be completed in FY2004.

Fresh water sluicer/transfer pump

Tank S-112 retrieval, which will be typical of any salt retrieval activity, uses up to three directional sluicing nozzles and an automatic tank-cleaning device. A dual tank nozzle Fury™ tank cleaner similar to the single nozzle unit selected for tank U-107 was selected for tank S-112 after testing in the CTTF in June 2002. The sluicers and tank cleaner can be operated separately or together as conditions dictate. Fresh water is supplied to the nozzles at up to 550 kPa with 375-l/min through the nozzles and 75 l/min through the Fury™. The transfer pump will be a 375-l/min progressive cavity or vertical turbine pump directed through a 5-cm OGT to the destination tank. In addition, the transfer pump can be used to circulate the brine through a distributor at the tank top to increase dissolved solids content, if needed.

Bulk Retrieval

Bulk retrieval will focus on dissolution of salt waste. Fresh water will be added at a rate resulting in the desired saturation level of brine being removed from the tank. This will use the Fury™ tank cleaner for general distribution and the peripheral nozzles to assist and focus the retrieval. The retrieval pump will be operated in coordination with the sluicers to maintain the proper water level during retrieval and transfer. The pump is capable of dewatering the tank at the rate of 5-cm/hr.

Heel retrieval

Heel retrieval will consist of mobilizing the insoluble solid remaining after salt dissolution is complete. This will be done by using the peripheral sluicers to move solids to the pump and slurry them once there, for transfer out of the tank. The technique used will build on the experience of tank C-106 heel retrieval. As these systems have no

recirculating sluicing mode, if any consolidated sludge forms are present, additional water will be needed to complete retrieval.

COLD TEST TRAINING FACILITY

Due to the complexity of the equipment used for the retrievals, and the technologies being adapted from other industrial applications, significant testing must be performed to accomplish the following: 1) determination of the robustness of the technical hardware, evaluate the "infant mortality" of the equipment, and allow modifications during cold deployment and testing; 2) performance of full scale deployment to train the construction crafts in a non-radiological environment; and 3) providing a training environment for the operators prior to initiating hot operations and performance of complete system testing. To accomplish this challenge, CH2M HILL hired Los Alamos Technical Associates under a firm fixed price performance contract to construct the CTTF. Actual construction was completed in less than a year.

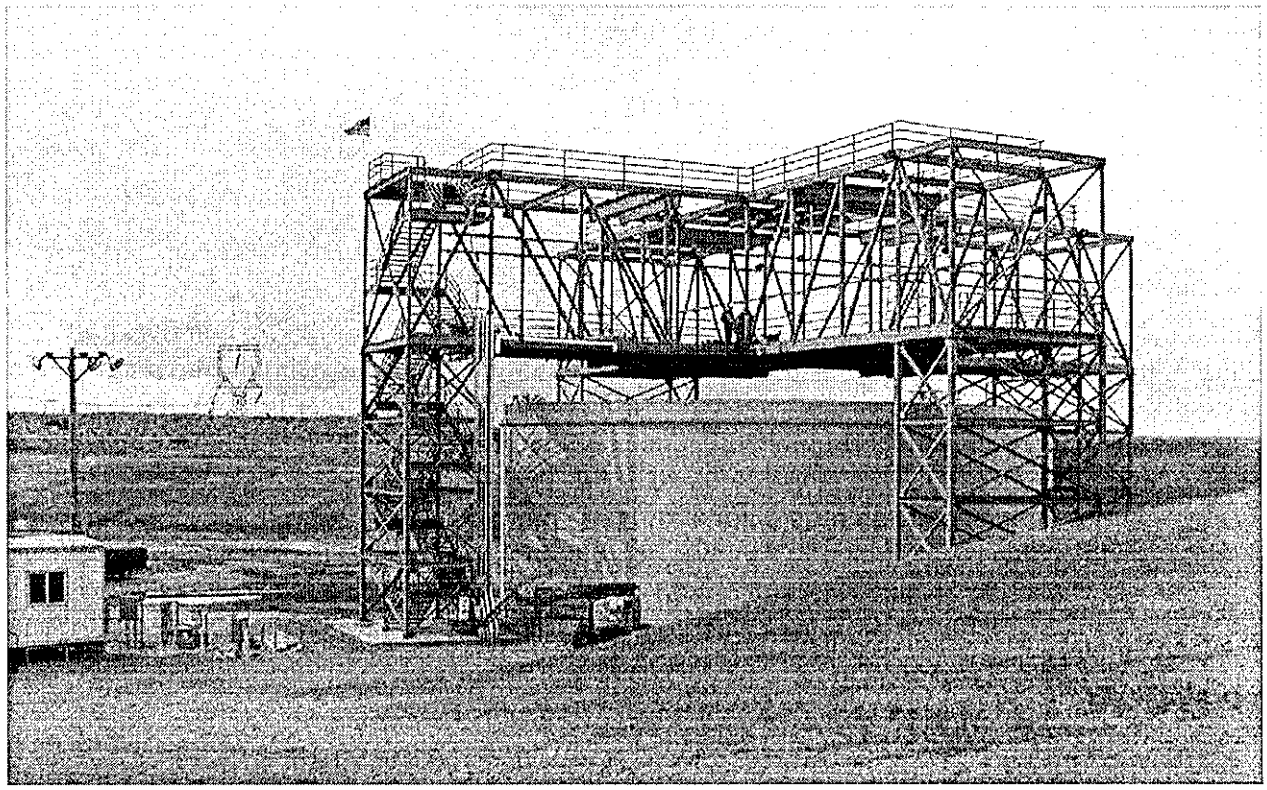

Figure 3. Cold Test Training Facility, 600 Area, Hanford Site, Richland, Washington

Cold Test Training Facility

The 8-m tall open-top steel tank is the same width (22.8-m) as a large (1.9M-, 2.8M- and 3.8M -liters) Hanford SST (see Figure 3). A superstructure (decks) simulates the access

to Hanford tank at ground level. Two levels represent 1.9M-liter SSTs (10.7-m high) and 3.8M-liter SSTs and double-shell tanks (16.7-m high). The tank holds up to 3M liters of reusable, non-hazardous and non-radioactive simulated waste. A staging pond area provides a retrieval receipt destination. A test control center and storage facilities are included.

Cold Testing to date

The first equipment to be tested in CTF was the Fury™ tank cleaner selected for Tank S-112. Testing was completed in July 2002. The tank C-104 NESL crawler was received and initially tested in summer 2002. Tank C-104s Articulating Mast was received in November 2002. In addition to acceptance testing both the crawler and the articulating mast have worked well maneuvering in and retrieving a dense loam mud test material. The crawler was not deterred by coveralls inserted between the tracks and rollers, but was able to keep moving with out difficulty.

LEAK DETECTION, MONITORING, AND MITIGATION

The SSTs on the Hanford Site will not be leaking at the start of retrieval operations. Those suspected of leaking have first priority to be interim stabilized. During retrieval operations, the possibility of leakage is again present because of adding new water or possibly disturbing previously trapped interstitial liquids. Leak Detection Monitoring and Mitigation (LDMM) is a systematic approach to minimizing the chance of a leak event and to minimize the severity of a leak should one occur. This is Mitigation. Part of mitigation is Detection of a leak and assessing the volume of the leak (Monitoring). Detection and volume determination drive the response to the leak. For example: Is it better for the environment to stop retrieval activities for a small leak or to complete the work in a short time? This question is not easily answered, but accurate monitoring and detection methods look for an answer. CH2M HILL invested in cold field tests of several ex-tank leak detection and monitoring technologies in 2001 and early 2002. Following those tests, three resistivity methods were selected for further demonstration at the Hanford 105-A Mock Tank Site. This is a cold test facility, located in the 200 East Area of Hanford, designed specifically for ex-tank underground leak detection technology testing. Test injections and resistivity measurements were completed in November 2002 and though the results have not yet been fully analyzed, it appears that resistivity methods show promise of being more reliable and accurate than baseline methods.

Resistivity Leak Detection and Monitoring

Resistivity leak detection and monitoring are currently used in the petroleum industry. It is based on the proposition that any leak from a tank will create a plume in the subsurface that is more electrically conductive than the native soil. With an appropriate measurement of the resistivity of the soil below a tank, this conducted plume can be detected and the presence of a leak inferred (6). Once baseline values are determined, a change in resistance due to a moisture plume intruding in the area between the electrodes

will be measured. This is especially true for brine-containing conductive salts. One result of the test at the Mock Tank Site has been the observation that the change in resistivity over time is proportional to the total volume of material leaked. This could lead to a method for monitoring the total volume of a leak.

Resistivity Testing at Hanford's Mock Tank Site

The three resistivity-methods tested were Electrical Resistivity Tomography (ERT) -- Point electrode (ERT-PET); ERT-long electrode (ERT-LET); and High Resolution Resistivity (HRR) (7, 8). The ERT-PET method requires the installation of a number of electrode arrays where each electrode is sensed individually with the object of determining the shape of a plume within the array. The ERT-LET simulated the use of existing Hanford tank farm monitoring dry wells as the electrodes and focused on finding changes in bulk resistivity. HRR is similar to ERT-LET in that it uses the dry wells as electrodes. HRR also used a series of short (1.2-m) surface electrodes; a distant reference electrode and, in some cases, the leak plume itself as an electrode. All three methods used the same off-the-shelf geophysical transmitter/receiver to get resistivity readings.

A significant innovation was the use of the internet to give the ERT Principal Investigator (PI) from Lawrence Livermore National Laboratory in California and the HRR PI from hydroGEOPHYSICS, Inc. in Arizona the ability to control the test parameters and gather the data remotely, saving much in reduced travel to the Hanford Site. Each method had its own protocol and allotted time window for controlling the transmitting equipment. All three methods, when looking at bulk resistivity gave good indication of decreasing resistivity that corresponded with the total leaked test volume. HRR, using the waste plume as an electrode had the greatest acuity. Using a waste plume (should one occur) as an electrode requires sensing the potential of the tank waste via installed equipment such as a thermocouple tree. If the tank leaks, the tank no longer electrically isolates the waste and a dramatic change in signal can be seen. This was simulated at the mock tank site by placing an electrode in the test "leak site" (see Figure 4). Using the known leak rates and volumes at the leak site, the methods promise a good evaluation for a similar site. The remaining question is: How does this translate to an actual tank within a tank farm? The consensus of the PIs is that it would provide viable leak detection information. The data gathered from this test are currently being evaluated to determine Probability of Detection and Probability of False Alarms for such a system.

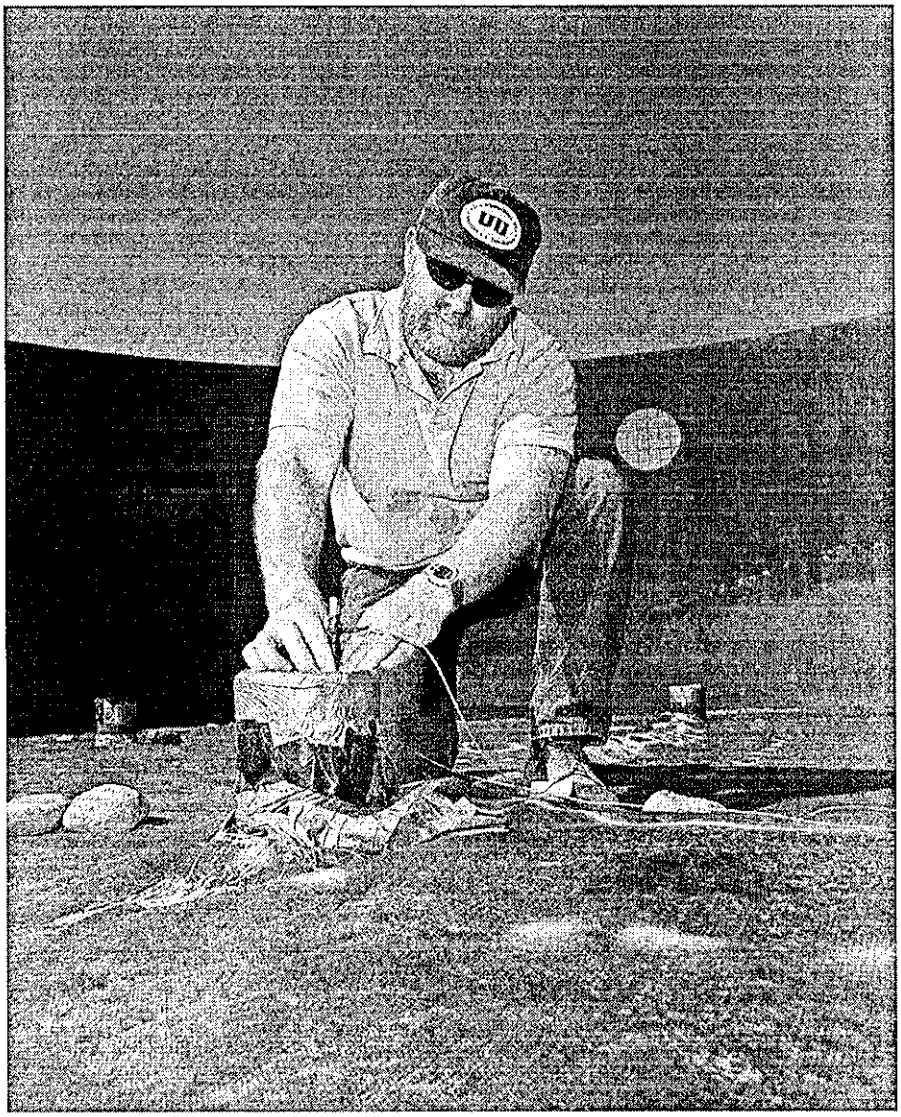

Figure 4. "Leak" Electrode in Mock Tank Test of Resistivity Leak Detection

These leak detection technologies are being adapted from the petroleum and environmental engineering industries.

CONCLUSION

CH2M HILL and ORP are making significant progress at Hanford in preparing to retrieve radioactive wastes from the SSTs through the utilization and adaptation of proven commercial technologies, both foreign and domestic. Retrieval methods that use standard equipment under standard regulatory agreements will enable accelerated tank cleanup at a significantly lower cost. The retrieval of the 149 SSTs, of which greater then 40% have been declared leakers, will be achievable by deployment of these technologies. These methods are being developed and tested to verify that they will

protect workers, the public, and the environment during retrieval. Use of CTTF for performing equipment and process testing in a simulated tank, will be key in the effort to safely clean up millions of liters of highly radioactive and hazardous waste stored in 177 large underground tanks within a few miles of the Columbia River.

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