

# **Hanford Tanks Initiative Vehicle-Based Waste Retrieval Demonstration Report Phase II, Track 2**

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

Project Hanford Management Contractor for the  
U.S. Department of Energy under Contract DE-AC06-96RL13200

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# **Hanford Tanks Initiative Vehicle- Based Waste Retrieval Demonstration Report Phase II, Track 2**

Prepared by  
Environmental Specialties Group, LLC

Prepared for  
Lockheed Martin Hanford Corporation  
Contract Number MSH-SLD-A31518

Date Published  
July 1997

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July 29, 1997

Re: Purchase Order MSH-SLD-A31518

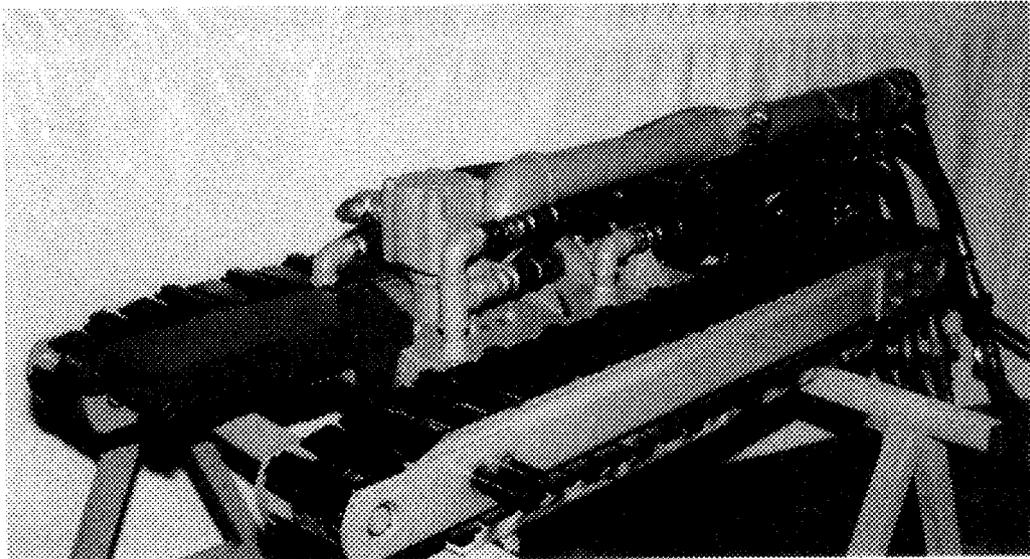
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*Eddy L. King*

*for*  
Richard H. Smith  
President  
ESG, L.L.C.



**Hanford Tanks Initiative  
Vehicle-Based Waste Retrieval  
Demonstration Report  
Phase II, Track 2**

Prepared for:  
Lockheed Martin  
Hanford Company  
P.O. #:MSH-SLD-  
A31518

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July 15, 1997

## EXECUTIVE SUMMARY

Using the versatile TracPump™, Environmental Specialties Group, LLC (ESG) performed a successful Phase II demonstration of a Vehicle-Based Waste Retrieval System (VWRS) for removal of waste material and residual liquid found in the Hanford Underground Storage Tanks (USTs). The purpose of this demonstration was to address issues pertaining to the use of a VWRS in USTs. The demonstration also revealed the waste removal capabilities of the TracPump™ and the most effective techniques and equipment to safely and effectively remove waste simulants.

ESG successfully addressed the following primary issues:

1. Dislodge and convey the waste forms present in the Hanford USTs;
2. Access the UST through tank openings as small as twenty-four inches in diameter;
3. Traverse a variety of terrains including slopes, sludges, rocks and hard, slippery surfaces without becoming mired;
4. Dislodge and convey waste within the confinement of the Decontamination Containment Capture Vessel (DCCV) and with minimal personnel exposure;
5. Decontaminate equipment to acceptable limits during retrieval from the UST;
6. Perform any required maintenance within the confinement of the DCCV; and
7. Maintain contaminate levels "as low as reasonably achievable" (ALARA) within the DCCV due to its crevice and corner-free design.

The following materials were used to simulate the physical characteristics of wastes found in Hanford's USTs: (1) *Hardpan*: a clay-type material that has high shear strength; (2) *Saltcake*: a fertilizer-based material that has high compressive strength; and (3) *Wet Sludge*: a sticky, peanut-butter-like material with low shear strength. Four test beds were constructed of plywood and filled with a different simulant to a depth of eight to ten inches. Three of the test beds were of homogenous simulant material, while the fourth bed consisted of a mixture of all three simulant types.

Various types of tool packages were tested on the waste simulants. Early in the testing, it became clear that water-jetting techniques offered the best performance, versatility, and control in waste retrieval operations. Consequently, a significant amount of energy and budget were allocated to define the combination of pressure and flow rate required to achieve the best overall waste retrieval rates. While the water-jet tool proved to be the most effective, tests were also conducted with grinders and mills.

A full scale containment, or Decontamination Containment Capture Vessel (DCCV), was constructed to evaluate the methodology for ingressing and egressing the UST. The DCCV houses the Umbilical Control System (UCS), a complete Decontamination Washdown System (DWS) for use during TracPump™ retrieval, and glove ports for maintenance operations. It also isolates the UST from personnel and the outside environment. The DCCV prototype was used to conduct time and motion studies designed to determine maintenance cycle times (for tool

changes, expected maintenance, etc.), optimize the ergonomics of the DCCV design (e.g. simplify maintenance, maximize access to TracPump™ parts, eliminate maintenance pitfalls), and for operators to practice hot work.

Once designs were finalized and tooling constructed, testing confirmed waste retrieval rates that would allow UST waste to be retrieved safely and effectively. Waste was dislodged at rates from 0.2 cubic feet per minute in Saltcake to more than 3 cubic feet per minute in the Hardpan and Wet Sludge simulants. The waste was pumped to a height of seventy feet with flow rates of more than seventy gallons per minute. The TracPump™ Assembly passed easily through a thirty-six-inch riser, similar to the riser on tank 241-C-106 in Hanford's Area 200, and will fold to fit through a twenty-four-inch riser.

The Phase II demonstration proved the TracPump™ to be a tough, durable, versatile tool for removing waste in the challenging environments of the Hanford USTs. The TracPump™ is reliable, easily maintained, inexpensive and decontaminable. Given the large scale of these tests and their successes, ESG is ready to provide equipment, personnel and engineering for UST waste retrieval operations.

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## ACKNOWLEDGMENT

Cox-Walker & Associates, Inc., a consulting engineering firm based in Baton Rouge, Louisiana, provided the engineering expertise for tool development and architectural and mechanical development of the Decontamination Containment Capture Vessel and Quality Assurance oversight.

Cox-Walker has two decades of experience providing engineering services to clients in industry and government. These services include chemical, mechanical, civil, structural and environmental engineering.

## GLOSSARY

air-bag seal	A remotely-inflated seal fitted to the DCCV stinger to prevent a release of UST contaminants.
bend radius	The minimum radius to which a hose can be wrapped without kinking or the minimum radius the Umbilical can be bent to under power of the TracPump™ Assembly (TA).
Borrow-pit Method	A method of calculating excavated volumes by dividing an excavated area into squares and measuring the depth in each square.
bundle hose	A hose system consisting of one large core hose surrounded by secondary hoses, which are helically wrapped around the core hose.
cabling	The process of manufacturing a bundle hose in which small secondary hoses are helically wrapped around a larger core hose.
Claw Tracks	Tracks with replaceable carbide-tipped spikes welded at intervals.
complex waste field	A random mixture of waste simulant materials.
Decontamination Containment Capture Vessel (DCCV)	A vessel that isolates personnel from radiation exposure, while enabling access to the Hanford USTs. The DCCV will house all equipment required for waste retrieval operations, except controls and power supply for the TA.
Decontamination Washdown System (DWS)	A series of nozzles located in the DCCV stinger that clean the TA as it is retrieved.
dish radius	The radius of a dished tank head.
Downtime ( $T_D$ )	Any time not engaged in pumping or mining, i.e., maintenance, decontamination, retrieval/deployment of the TA, mobilization/demobilization, etc.
Downtime Coefficient, ( $\epsilon_D$ )	Downtime experienced per unit of waste retrieved.
Dragon Box	A device used to determine the particle size of solids contained in a slurry.
Face Mill	A roller with carbide tips propelled at high speed to grind into hard material.
folding mechanism	A system of hydraulic cylinders that folds the TracPump™ pontoons allowing it to pass through a twenty-four-inch port.

## GLOSSARY

glove ports	Ports lined with leaded-gloves that allow for maintenance of the TracPump™, while protecting personnel from radiation exposure.
Hardpan	A clay-type material that has a high shear strength.
High Pressure Water Lance (HPWL)	A backflush system for cleaning a clogged hose. A small nozzle uses high pressure water to travel through a flexible hose to the clogged point. The water pressure is also used to dislodge the obstruction in the hose.
HIPRESS tool	A high-pressure water tool package consisting of an oscillating header with various types of nozzles. The HIPRESS tool is actuated by hydraulic cylinders so that it can discharge water directly down or in a horizontal direction.
Hougen Bit	An impeller-type bit with the sharp, hardened tips designed to cut into hard material.
make-up water	Water added to dislodged waste in order to suspend solid particles, thus creating a slurry that can be pumped.
Mining Rate (MR)	The rate solids waste simulants are dislodged.
Mining Time Coefficient ( $\epsilon_m$ )	Time spent mining per unit of waste retrieved.
Nipple-up Procedure	The procedure used to connect the DCCV to the UST and seal the UST from the outside environment.
Pinch Rollers	A system of two rollers with external surfaces designed to match the outside diameter of the Umbilical. The rollers are driven with a hydraulic motor and provide positive control of the Umbilical.
pontoon	The part of the TracPump™ around which the tracks rotate.
Power Unit (PU)	A diesel engine and hydraulic pump that supplies power via hydraulic fluid to the various motors and cylinders of the TA.
processing	The degree to which waste material is ground or crushed by a dislodging tool.
pump operating point	The intersection of the system curve and pump performance curve. The operating point specifies the flow and head of a pump in the given piping system.
pump performance curve	An expression of the flow generated by a pump as a function of its head.
Pumping Time Coefficient ( $\epsilon_p$ )	Time spent pumping per unit of waste retrieved.
Repad	A reinforcing pad of steel used in locations under high stress.

## GLOSSARY

Saltcake	A fertilizer-based material that has high compressive strength.
simulated Umbilical	A five-inch tank-car hose used to model the Umbilical. It has roughly the same flexibility characteristics and is stiff enough to model the Umbilical without being full of liquid. It does not, however, have similar surface characteristics or jacket toughness.
Sludge Pump	The solids handling pump installed on the TracPump™, as part of the TA.
Smith's Auger	A roller with replaceable carbide tips, installed in an auger configuration, that grinds hard material and feeds the cuttings to the pump section.
solids concentration	Volume of saturated solids per unit of total volume.
stinger	Part of the DCCV which stabs into the UST riser allowing a simpler Nipple-Up Procedure. The stinger will be fitted with a remotely-inflated air-bag seal to prevent a release of UST contaminants.
system curve	An expression of the head required for a given flow in a piping system.
tank head	The top or bottom of a vertical tank; the sides of a horizontal tank. Heads are usually elliptical, hemispherical or flat.
tank-car hose	Hose used to load and unload rail cars. It consists of an elastomer jacket and is reinforced with a steel spring.
test beds	Plywood structures sixty-feet long by four-feet wide filled ten-inches deep with waste simulant materials.
TracPump™	A remotely-controlled pumping system that excavates and dislodges waste and pumps sludges and slurries from tanks, basins, lagoons, cisterns, pipelines and sewers.
TracPump™ Assembly (TA)	The TracPump™ and components that make up the fully functional waste retrieval unit. Additional components include the HIPRESS tool for dislodging waste and the Umbilical which supplies the pump with hydraulic fluids for operating power.
TracPump™ Assembly Retrieval Winch (TRW)	A component of the UCS that supports the load of the TA during retrieval/deployment operations.
turn radius	The minimum radius of a circle through which the TA travels when making a 180° turn.

## GLOSSARY

Umbilical	A system of hoses that supplies fluids required by the TracPump™ and conveys waste discharged by the TracPump™. These hoses include hydraulic fluid supply, high pressure water supply and the Sludge Pump discharge hose.
Umbilical Apron	Part of the DCCV used to store the retrieved Umbilical.
Umbilical Control System (UCS)	The system which is responsible for deploying and retrieving the Umbilical as well as controlling the Umbilical during TA operation. It must operate in conjunction with the TA and the TRW.
V-Notch Weir	A “V” shaped plate through which water flows. The flow rate through the weir is a function of the depth of flow allowing the weir to be used as a flow measurement device.
Volume of Waste Retrieved ( $V_{WR}$ )	Volume of waste actually removed from the UST.
Waste Simulants	Materials selected to reproduce the characteristics of the actual UST wastes.
Wet Sludge	A sticky, peanut-butter-like material with low shear strength.

## ACRONYMS

$\epsilon_D$	Downtime Coefficient
$\epsilon_M$	Mining Time Coefficient
$\epsilon_P$	Pumping Time Coefficient
ALARA	As Low As Reasonably Achievable
BWRT	Batch Waste Retrieval Time
DCCV	Decontamination Containment Capture Vessel
DWS	Decontamination Washdown System
ESG	Environmental Specialties Group, LLC
HPWL	High Pressure Water Lance
HTI	Hanford Tanks Initiative
MR	Mining Rate
NFPA	National Fire Protection Association
OSVS	Overview Stereo Video System
OVS	Overview Video System
PNL	Pacific Northwest Labs
PU	Power Unit
TA	TracPump™ Assembly
$T_D$	Downtime
TRW	TracPump™ Assembly Retrieval Winch
UCS	Umbilical Control System
UST	Underground Storage Tank
$V_{WR}$	Volume of waste retrieved
VWRS	Vehicle-Based Waste Retrieval System

# INTRODUCTION

## HANFORD TANKS INITIATIVE, PHASE II, TRACK 2

Environmental Specialties Group, LLC (ESG) was contracted to perform a Phase II demonstration of a Vehicle-Based Waste Retrieval System (VWRS). The purpose of this demonstration was to test waste retrieval techniques and equipment proposed by ESG with waste simulants that reflect the physical characteristics of waste forms found in the Underground Storage Tanks (USTs) at Hanford. This report presents the data collected from the Phase II testing.

## TRACPUMP™ VEHICLE-BASED WASTE RETRIEVAL SYSTEM (VWRS)

### *System Capabilities*

The TracPump™ and containment systems constitute a solution to the technical issues of the Hanford Tanks Initiative (HTI). The TracPump™ Assembly (TA) and Decontamination Containment Capture Vessel (DCCV) will provide the following capabilities that specifically address the issues of the HTI:

1. Dislodge and convey the waste forms present in the Hanford USTs;
2. Access the UST through tank openings as small as twenty-four inches in diameter;
3. Traverse a variety of terrains including slopes, sludges, rocks and hard, slippery surfaces without becoming mired;
4. Dislodge and convey waste within the confinement of the DCCV and with minimal personnel exposure;
5. Decontaminate equipment to acceptable limits during retrieval from the UST;
6. Perform any required maintenance within the confinement of the DCCV; and
7. Maintain contaminate levels as low as reasonably achievable (ALARA) within the DCCV due to its crevice- and corner-free design.

### *Equipment*

ESG's TracPump™ is the foundation of the proposed VWRS. It is the platform for mounting various tools and monitoring equipment included in the Phase II testing program. The TracPump™ and DCCV systems provide a significant step forward for the retrieval of single shell tank waste.

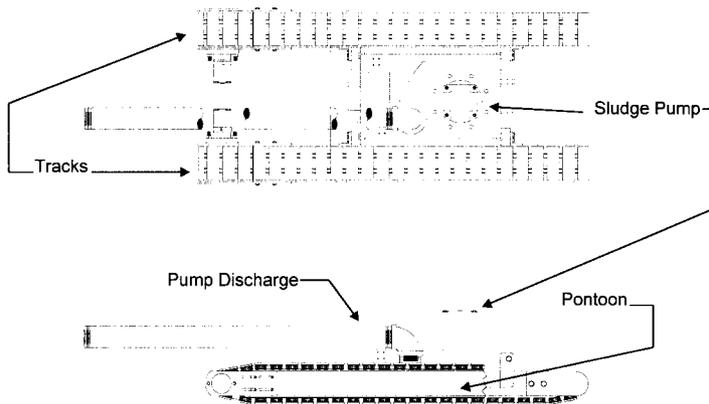
For more than five years, the TracPump™ has been used successfully in numerous waste and environmental cleanup projects worldwide and has established a history of reliability, adaptability and maneuverability in a variety of terrains. The TracPump™ has been employed for hazardous waste conveyance in the petrochemical and nuclear industry and has achieved extraordinary commercial success and a reputation for toughness and reliability. It has been

## INTRODUCTION

fabricated in stainless steel, aluminum and carbon steel to suit specific applications. The unit has proven to require little maintenance, even in concentrated chemical waste environs.

TracPump™ is a remotely controlled pumping system that excavates or dislodges waste and pumps sludges and slurries from tanks, basins, lagoons, cisterns, pipelines or sewers. The system consists of:

- A motorized, track-driven carriage with a submersible hydraulic pump sized for the specific application, see Figure 1.
- A base unit manufactured to fit through a thirty-six-inch diameter port.
- The track pontoons hydraulically linked to the carriage platform. The track pontoons can be folded underneath the unit to allow access into manways or risers twenty-four inches in diameter.
- A pump platform supporting a variable speed sludge pump.
- Carriage pontoons housing the track drive assemblies.



**Figure 1. TracPump™**

The waste forms in the Hanford Tanks present a great challenge for any VWRs. The rough terrain, stickiness and slipperiness of the material will cause most VWRs to become mired. ESG's Claw Tracks (patent pending) provide the additional tractive power needed to maneuver in the difficult waste of the Hanford Tanks. Claw Tracks have replaceable, carbide-tipped spikes attached in a pattern specifically designed for this application.

## INTRODUCTION

The motive power for the tracks is provided by hydraulics. The hydraulic power unit for the TracPump™ system is trailer mounted and equipped with all controls to operate the motive system.

The Power Unit (PU) system can easily be adapted to operate from a remote control room, allowing operators to be stationed at a safe distance from high radiation doses. The TracPump™ is equipped with a variable-speed hydraulic sludge pump, designed and manufactured to convey slurries with high solids content. It will provide 150 gpm of flow to a height greater than seventy feet through 210 linear feet of three-inch hose.

The unit discharges waste through a flexible discharge hose. The discharge hose, hydraulic control hoses and water supply hoses are contained within a single unit called the Umbilical. The Umbilical has a protective jacket constructed of a chemical-resistant material with a smooth surface finish to provide for easy decontamination. See ESG TP-002A Umbilical/UCS Design Review for more information about the Umbilical.

The in-tank system consists of the TracPump™ and assorted interchangeable tooling designed for specific applications. This in-tank system is called the TracPump™ Assembly (TA). Tool systems are designed for dislodging waste, removing foreign objects, or deploying waste sampling and characterization systems. The platform may be fitted with a variable height grinding tool, water-jetting assemblies or rotating cutter heads. The high-pressure water tool package (HIPRESS tool) consists of an oscillating header with various types of nozzles. Oscillation of the header is propelled by hydraulic motors, and positioning of the tool is controlled by hydraulic cylinders. The HIPRESS package is capable of dislodging the Hardpan, Salteake and Wet Sludge wastes.

The out-of-tank systems are housed in the DCCV. The TracPump™ and Umbilical are deployed into and retrieved from the tank by hydraulic winches located in the DCCV. For these tests, a full scale mock-up was fabricated from carbon steel. The DCCV is equipped with an Umbilical Apron for storing the Umbilical after waste retrieval or during TracPump™ maintenance. Spray jets designed to operate at over thirty gallons per minute and twenty thousand psi are installed at numerous locations on the DCCV shell interior. This is the primary decontamination technique to be utilized in preparation for maintenance. These jets will be used to wash the TA as it is retrieved into the DCCV.

While the primary purpose of the DCCV system is to house the TracPump™ and support systems, the DCCV provides an enclosure that contains contaminants and returns them to the UST. In the event of a leak or spill, the DCCV high pressure wash down system will be employed to remove and channel the contaminants into the UST for later retrieval. In the event the tank discharge hose is clogged, the DCCV will facilitate backflushing. HEPA exhaust ports for controlled ventilation and control of the containment atmosphere are available. The height of the system above the riser pit is the result of a conscious decision to expand the distance above the riser pit to maintain exposure rates ALARA while performing maintenance on the TracPump™ or Containment System. For more information about the DCCV, see ESG TP-002 Evaluation of Decontamination Containment Capture Vessel (DCCV).

## INTRODUCTION

### ENVIRONMENTAL SPECIALTIES GROUP (ESG)

Environmental Specialties Group, LLC (ESG), was formed with the support of Numanco, LLC and H&H Pump and Dredge Company, Inc. The objective of ESG is to offer world class experience in pumping and dredging of hazardous chemical wastes, nuclear decontamination, health physics, engineering and mechanical design to the Defense Weapons Complex and the Hydrocarbon Production Industry.

ESG shares the extensive technical and management resources that are available to both Numanco, LLC and H&H Pump and Dredge Company. These resources include a complete engineering, design, fabrication and testing facility, with over 150,000 square feet under roof, located on over 50 acres. Notable abilities and experience follow:

1. Our personnel are experienced in management of large environmental restoration and waste management projects, as well as the important environmental and regulatory issues facing Defense Weapons Complex facilities. Management has experience in compliance with and implementation of DOE regulations and orders governing Environment, Safety and Health (ES&H), Quality Assurance, Design, and Project Management and Control.
2. We have the ability to provide personnel, with comprehensive experience, to handle the technical and administrative issues in strict compliance with all applicable regulations, DOE requirements and Lockheed Martin Hanford Company (LMHC) policies and procedures.
3. ESG has the resources to support a full array of environmental compliance and restoration services including decontamination and decommissioning services, hazards characterization, hazardous and mixed waste management, compliance audits and radiological and environmental engineering.
4. The ESG approach to all of our projects is to carefully plan the project to minimize cost through use of appropriate proven technologies, and adequate preparation for contingencies. The requirement to ensure the health and safety of our project personnel and the strong desire to implement and execute a successful project are the foremost concerns of our teams. These careful considerations result in an obvious minimization of risks.

### TESTING

ESG built all necessary facilities for the Phase II Track 2 contract testing at the ESG plant in Holden, Louisiana. Eight tests were conducted in accordance with the proposal and some newly identified design issues. Table 1 summarizes these tests.

## INTRODUCTION

**Table 1. Summary of Phase II Tests**

Test Phase	Objectives
ESG TP-001	Determine the waste retrieval rates and level of processing for a variety of TracPump™ tools.
ESG TP-002a	Evaluate available materials, hose construction, surface finish, chemical resistance, strength, and flexibility (bend radius) of the proposed Umbilical design. Also, review the Umbilical Control System design.
ESG TP-002b	Test the maneuverability of the TracPump™ Assembly in a simulated Underground Storage Tank (UST) environment.
ESG TP-003	Assess the components, materials and fabrication of the Phase II Decontamination Containment Capture Vessel (DCCV) prototype.
ESG TP-004	Analyze the requirements of Remote Surveillance Equipment for the UST environment.
ESG TP-005	Verify the efficacy of a High Pressure Water Lance (HPWL) backflush system for unclogging the pump discharge hose.
ESG TP-006	Confirm the minimum penetration size for ingress/egress of the TA.
ESG TP-007	Determine conveyance rates of TA with dislodged waste simulants.
ESG TP-008	Establish a schedule of expected maintenance for TA components.

### WASTE SIMULANTS

To conduct the proposed tests, the following waste simulants were used: (1) *Hardpan*: a clay-type material that has high shear strength; (2) *Saltcake*: a fertilizer-based material that has high compressive strength; and (3) *Wet Sludge*: a sticky, peanut-butter-like material with low shear strength. The simulants were blended according to formulas prescribed by Pacific Northwest Labs (PNL). Two samples of each waste simulant type were sent to an independent laboratory to determine compressive strengths. The results are presented in Table 2.

**Table 2. Waste Simulant Compressive Strengths**

Simulant	Units	Sample 1	Sample 2
Salt	psi	3,464	3,075
Cake	kN/m <sup>2</sup>	23,883	21,201
Hard	psi	2,214	2,663
Pan	kN/m <sup>2</sup>	15,265	18,360
Wet	psi	50	53
Sludge	kN/m <sup>2</sup>	344	365

### TESTING SUMMARY

Various types of tool packages were tested on the waste simulants. Early in the testing, it became clear that water-jetting techniques offered the best performance, versatility, and control in waste retrieval operations. Consequently, a significant amount of energy and budget were allocated to define the combination of pressure and flow rate required to achieve the best overall waste retrieval rates. While the water-jet tool proved to be the most effective, tests were also conducted with grinders and mills.

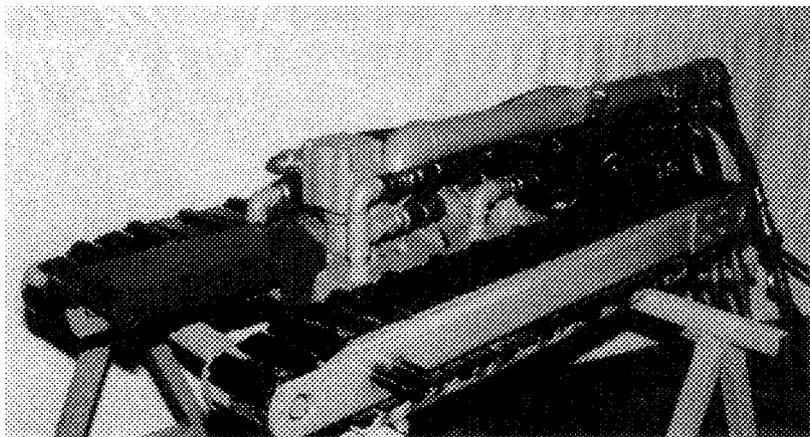
A full scale containment, or Decontamination Containment Capture Vessel (DCCV), was constructed to evaluate the methodology for ingressing and egressing the UST. The DCCV

## INTRODUCTION

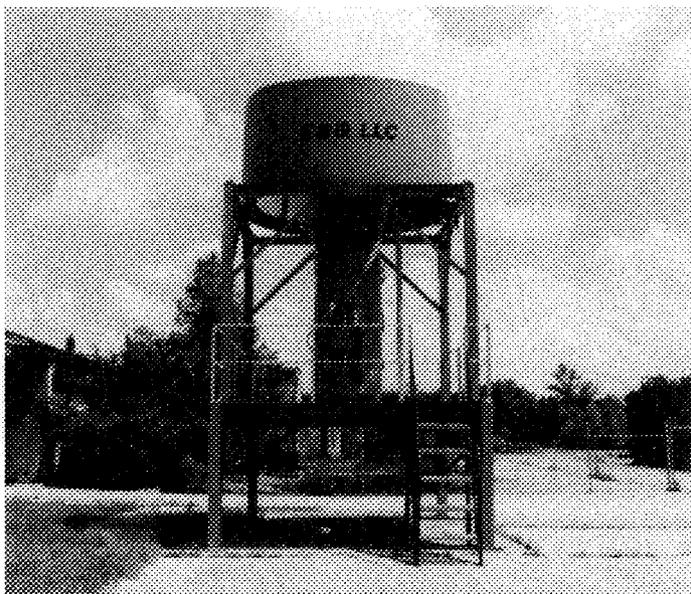
houses the Umbilical Control System (UCS), a complete Decontamination Washdown System (DWS) for use during TracPump™ retrieval, and glove ports for maintenance operations. It also isolates the UST from personnel and the outside environment. The DCCV prototype was used to conduct time and motion studies designed to determine maintenance cycle times (for tool changes, expected maintenance, etc.), optimize the ergonomics of the DCCV design (e.g. simplify maintenance, maximize access to TracPump™ parts, eliminate maintenance pitfalls), and to allow operators to practice hot work.

Data collected from testing with the simulant materials were used to evaluate the tools, equipment and containment designed and fabricated by ESG. Several design improvements were identified on the basis of these tests. Some were implemented immediately, while others have been presented in this report and can be implemented in Phase III.

INTRODUCTION



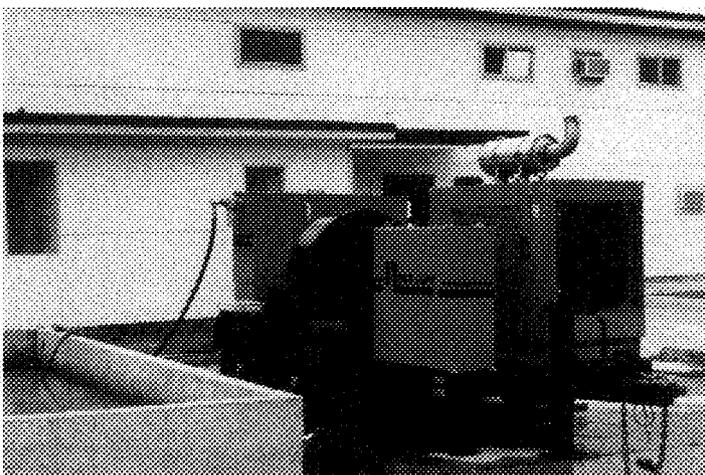
Photograph 1. TracPump



Photograph 2. Decontamination Containment Capture Vessel (DCCV)



Photograph 3. Power Unit



Photograph 4. High Pressure Water Supply Unit

## ESG TP-001 DETERMINATION OF WASTE RETRIEVAL RATES

### OBJECTIVES

The objective of these tests was to evaluate the performance of various tool packages in the three waste forms. The waste retrieval rate and the processing capability of each tool were determined. A series of relations was established based on the Mining Rate, total waste retrieval time for a UST batch, pumping rate, and down time. The relations are presented below.

$$BVRT = \frac{\text{Batch Retrieval Time}}{\text{Volume of Waste Retrieved}}$$

$$BVRT = \epsilon_p + \epsilon_M + \epsilon_D, \text{ where}$$

$$\epsilon_p = \frac{V_{PUMPED}}{V_{WR}} \cdot \frac{1}{Q}, \quad \epsilon_M = \frac{V_{MINED}}{V_{WR}} \cdot \frac{1}{MR}, \quad \epsilon_D = \frac{T_D}{V_{WR}}$$

BVRT = Batch Waste Retrieval Time; BVRT is the time required to remove a unit volume of waste for a given waste batch.  $\epsilon_p$  = Pumping Time Coefficient;  $\epsilon_p$  is the unit pumping time required for removal of a given waste batch.  $\epsilon_M$  = Mining Time Coefficient;  $\epsilon_M$  is the unit mining time required for removal of a given waste batch.  $\epsilon_D$  = Downtime Coefficient;  $\epsilon_M$  is the unit downtime experienced during removal of a given waste batch.  $V_{WR}$  = Volume of Waste Retrieved;  $V_{WR}$  is the volume of waste retrieved from the test bed.  $V_{PUMPED}$  = Total Volume Pumped;  $V_{PUMPED}$  is the total volume of fluid pumped during the retrieval of an amount of waste equal to  $V_{WR}$ .  $Q$  is the volumetric flow rate of the sludge pump.  $V_{MINED}$  = Volume Mined;  $V_{MINED}$  is the volume of waste simulant material dislodged from the test bed.  $MR$  = Mining Rate;  $MR$  is the rate solids were dislodged from the waste simulant in a test bed. Note that  $MR$  will vary with each tool and with each waste simulant.  $T_D$  = Downtime;  $T_D$  is the total downtime experienced during removal of a given waste batch. Downtime is defined as any time not engaged in pumping or mining, i.e., maintenance, decontamination, retrieval/deployment of the TA, etc.

Note that the coefficients defined here are valid only for a given waste batch, and must be recalculated for each batch they are applied. However, it should be possible to extrapolate from one batch to another when certain conditions are similar, i.e., waste characteristics, tank geometry, and ingress/egress requirements. In some cases, some of the coefficients may have to be recalculated to extrapolate from one batch of waste to another. In summary, the coefficients calculated are not universal and should only be applied with a thorough understanding of their meanings and of the methods used to calculate them.

The TracPump™ Assembly (TA) for these tests consisted of the 3x25 Sludge Pump, Claw Tracks, hydraulic lines for all hydraulic motors and cylinders, and four-inch discharge hose. A

wooden electrical spool was elevated twelve feet in the air with a forklift to model the geometry of the thirty-six-inch riser UST access. The hydraulic lines were extended over this spool to simulate the expected resistance of the hydraulic lines during operation of the TA. Additionally, some tests were performed with the TA dragging all the hoses along the ground.

Several tools were evaluated during the test procedures. Each of the tool assemblies is described below. Data collected from testing were used to select the best tool package for each given waste type.

#### *HIPRESS Tool*

The HIPRESS tool is a high-pressure-water tool package consisting of an oscillating header with various types of nozzles. The tests will evaluate the waste retrieval rate for different nozzle types at varying water flow and pressure. The oscillation of the header is propelled by hydraulic motors, and positioning of the tool is controlled by hydraulic cylinders.

#### *Face Mill*

The Face Mill is a roller with carbide tips propelled at high speed to grind into hard material. The positioning of the tool is controlled by hydraulic cylinders. This tool is interchangeable with the HIPRESS tool.

#### *Smith's Auger*

Smith's Auger is a roller with replaceable carbide tips, installed in an auger configuration, that grinds hard material and feeds the cuttings to the pump suction. The roller is driven by hydraulic motors and positioned with hydraulic cylinders.

#### *Hougen Bit*

The Hougen Bit is an impeller type bit with sharp, hardened tips designed to cut into hard material.

### TEST PROCEDURES

A series of tests was performed with the HIPRESS tool to determine its performance limits. The tests were designed to determine: (1) The working pressure limit of the HIPRESS tool oscillating header; (2) The oil flow rate and pressure to the positioning hydraulic cylinders required to maintain the tool position against the force generated by the water flow through the HIPRESS tool nozzles; (3) The optimum mix of water flow, water pressure, and nozzle type that would produce the highest waste retrieval rate.

#### *ESG TP-001A HIPRESS Tool/Hardpan And ESG TP-001B HIPRESS Tool/Wet Sludge*

The TA was positioned inside the bed filled with Hardpan simulant. After tracking to the edge of the material, the HIPRESS tool was engaged to begin dislodging material. The TA was advanced at a velocity determined by the material retrieval rate. As water accumulated to the level of the pump suction, the slurry was pumped to a holding container. The container was used as a settling basin for final disposal of the material. Samples were collected from the test bed and from the settling container to determine the percentage of solids contained in both slurries. Dislodging and conveyance activities were timed for determination of waste retrieval rates.

During waste retrieval, the TA moved into and over the Hardpan material under its own power to identify any conditions where the unit might become inoperable. The same procedures were followed with the Wet Sludge simulant.

#### *ESG TP-001C HIPRESS Tool/Saltcake*

The TA was positioned inside the bed filled with Saltcake simulant. The TA was then advanced to the simulant and the tooling engaged to begin dislodging of the material. The TA advanced at a velocity determined by the material retrieval rate. Water from the HIPRESS tool and dislodged solids were collected in the low point of the test bed. When mining of a section of the simulant was complete, the TA was moved into the low point of the test bed. The HIPRESS tool agitated the slurry to suspend the solid particles before the slurry was pumped to a Roll-on Roll-off Box. The RoRo box was used to collect material for determining the size of the dislodged particles. Waste dislodging and retrieval were timed for determination of rates, and the mined area was measured to determine the volume of waste mined.

#### *ESG TP-001C Face Mill and Hougen Bit/Saltcake*

The TA was positioned inside the bed filled with Saltcake simulant. The Face Mill tool was engaged and lowered into the simulant to begin mining. Hydraulic pressure was recorded and the TA advanced as allowed by the mining rate. Waste dislodging and retrieval were timed for determining rates. The procedures were also followed with the Hougen Bit.

#### *ESG TP-001C Smith's Auger/Saltcake*

The TA was positioned inside the bed filled with Saltcake simulant. The Smith's Auger tool was engaged and lowered into the simulant to begin mining. Hydraulic pressure was recorded and the TA advanced as allowed by the mining rate. Waste dislodging and retrieval were timed for determining rates and a sample of the dislodged material was taken.

#### *Face Mill, Smith's Auger, And Hougen Bit/Hardpan And Wet Sludge*

Testing of the other tools with the Hardpan and Wet Sludge simulants was canceled. This decision was based on the materials caking on tools, rendering them ineffective.

### TEST RESULTS

The results of waste retrieval tests are presented in Tables 3, 4, and 5. The coefficients presented in the tables are described in the OBJECTIVES section of this test report.  $V_{\text{MINED}}$  was determined using the Borrow-pit method for calculating excavated volumes.  $V_{\text{PUMPED}}$  was estimated by summing the volume of water added through the HIPRESS tool to the volume  $V_{\text{MINED}}$ . MR was determined by  $V_{\text{MINED}}$  by the time spent mining. Once these values were determined, the relations described in the OBJECTIVES section were used to determine the coefficients presented in the tables below.

ESG TP-001  
Determination Of Waste Retrieval Rates

**Table 3. ESG TP-001A Waste Retrieval Rates in Hardpan Simulant**

Description	Units	HIPRESS Tool	Face Mill	Smith's Auger	Hougen Bit
Simulant Average	psi	2438.5	2438.5	2438.5	2438.5
Compressive Strength	kN/m <sup>2</sup>	16812	16812	16812	16812
High Pressure	psi	10,000	X	X	X
Supply Rate	bar	689.5	X	X	X
High Pressure Water	gpm	28.2	X	X	X
Flow Rate	l/min	106.8	X	X	X
Pumping Time	min/gal	0.1220	X	X	X
Coefficient, $\epsilon_P$	min/l	0.0322	X	X	X
Mining Time	min/gal	0.0114	X	X	X
Coefficient, $\epsilon_M$	min/l	0.0030	X	X	X
Downtime	min/gal	0.1000	X	X	X
Coefficient, $\epsilon_D$	min/l	0.0264	X	X	X
BWRT/1000 $V_{WR}$	hours/gal	2.060	X	X	X
	hours/l	0.544	X	X	X
Max Water Level	inches	4.0	X	X	X

X - Test canceled because tool was ineffective in Hardpan simulant

**Table 4. ESG TP-001B Waste Retrieval Rates in Wet Sludge Simulant**

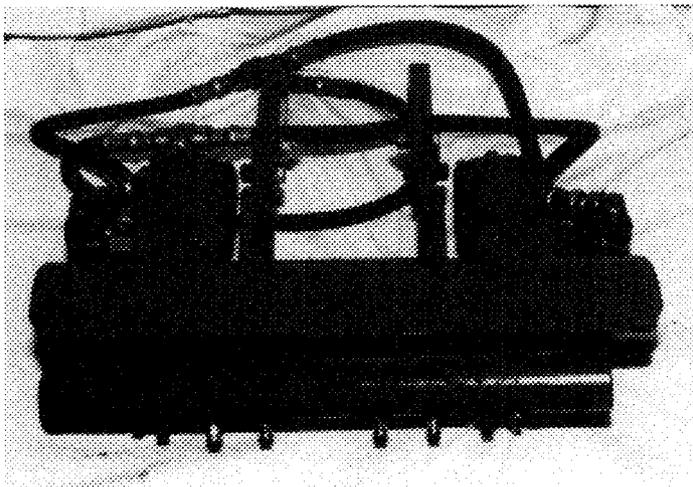
Description	Units	HIPRESS Tool	Face Mill	Smith's Auger	Hougen Bit
Simulant Average	psi	51.5	51.5	51.5	51.5
Compressive Strength	kN/m <sup>2</sup>	354.5	354.5	354.5	354.5
High Pressure	psi	10,000	X	X	X
Supply Rate	bar	689.5	X	X	X
High Pressure Water	gpm	28.2	X	X	X
Flow Rate	l/min	106.8	X	X	X
Pumping Time	min/gal	0.0143	X	X	X
Coefficient, $\epsilon_P$	min/l	0.0038	X	X	X
Mining Time	min/gal	0.0114	X	X	X
Coefficient, $\epsilon_M$	min/l	0.0030	X	X	X
Downtime	min/gal	0.1000	X	X	X
Coefficient, $\epsilon_D$	min/l	0.0264	X	X	X
BWRT/1000 $V_{WR}$	hours/gal	2.090	X	X	X
	hours/l	0.552	X	X	X
Max Water Level	inches	4.0	X	X	X

X - Test canceled because tool was ineffective in Wet Sludge simulant

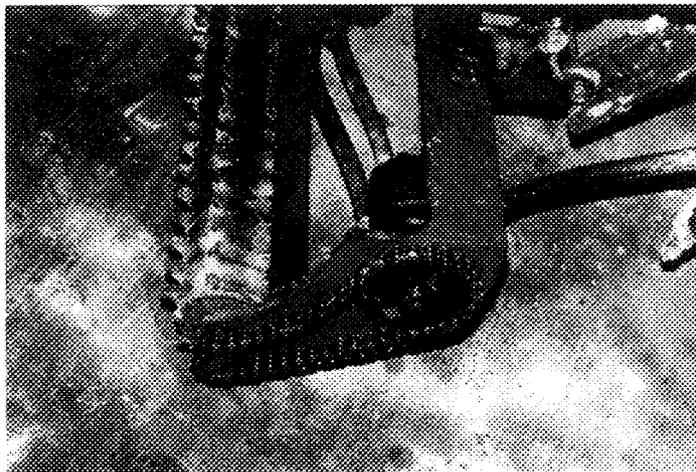
ESG TP-001  
Determination Of Waste Retrieval Rates

**Table 5. ESG TP-001C Waste Retrieval Rates in Saltcake Simulant**

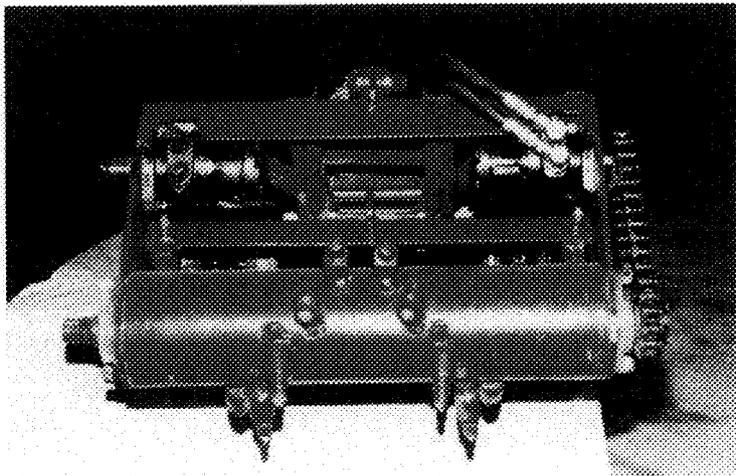
Description	Units	HIPRESS Tool	Face Mill	Smith's Auger	Hougen Bit
Simulant Average	psi	3269.5	3269.5	3269.5	3269.5
Compressive Strength	kN/m <sup>2</sup>	22542	22542	22542	22542
High Pressure	psi	15,000	NA	X	X
Supply Rate	bar	1034.2	NA	X	X
High Pressure Water	gpm	65	NA	X	X
Flow Rate	l/min	246	NA	X	X
Pumping Time	min/gal	0.0714	0.0714	X	X
Coefficient, $\epsilon_p$	min/l	0.0189	0.0189	X	X
Mining Time	min/gal	0.3333	0.8333	X	X
Coefficient, $\epsilon_M$	min/l	0.0880	0.2201	X	X
Downtime	min/gal	0.1000	0.1000	X	X
Coefficient, $\epsilon_D$	min/l	0.0264	0.0264	X	X
BWRT/1000 V <sub>WR</sub>	hours/gal	8.40	16.74	X	X
	hours/l	2.219	4.422	X	X
Max Water Level	inches	0.0*	0.0	X	X
X - Test canceled because tool was ineffective in Wet Sludge simulant					
* Water accumulated only in localized areas where waste was being mined					



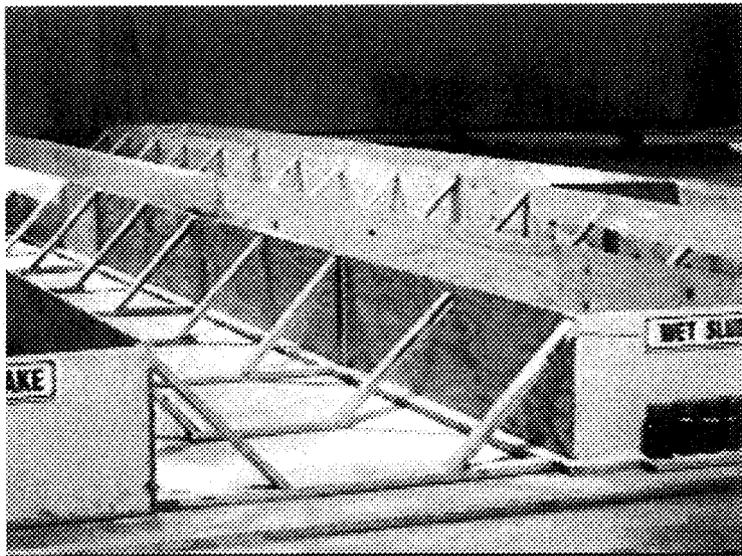
Photograph 5. HIPRESS Tool



Photograph 6. Face Mill Tool



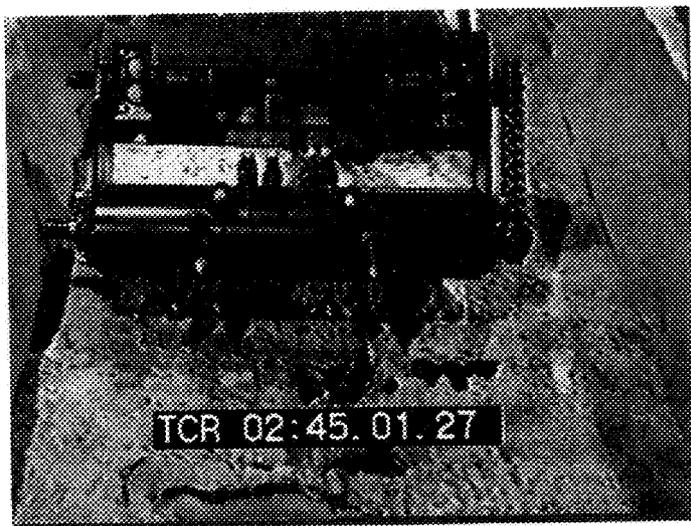
Photograph 7. Smith's Auger



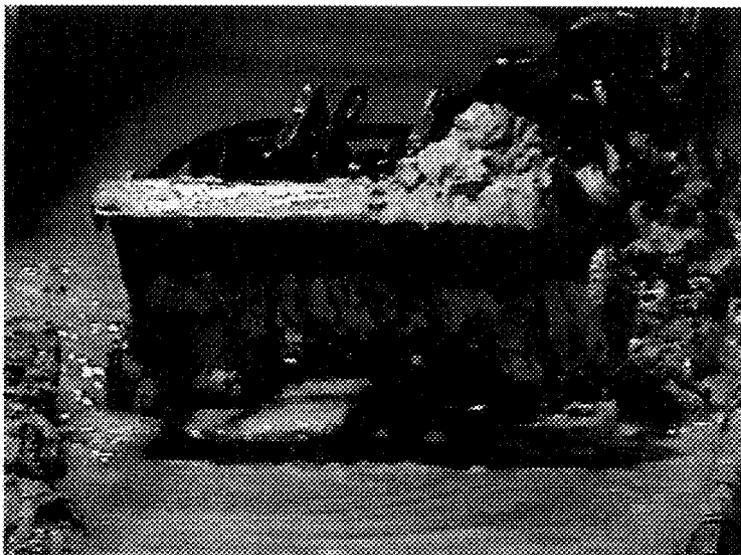
Photograph 8. Waste Simulant Test Beds



Photograph 9. HIPRESS Tool Dislodging Mixed Waste



Photograph 10. Smith's Auger Dislodging Hardpan



Photograph 11. TA Equipped with HIPRESS Tool Dislodging and Pumping Wet Sludge

## ESG TP-002A UMBILICAL/UCS DESIGN REVIEW

### INTRODUCTION

The Umbilical and UCS are critical components of the TracPump™ based VWRS. The Umbilical facilitates remote operation of the TracPump™. Table 6 lists the hoses which must be included in the Umbilical.

**Table 6. Umbilical Requirements**

Quantity	Description	Function
1	3" Pump Discharge	Self explanatory
14	½" Hydraulic Lines	Provide power and control to various hydraulic motors and cylinders used by the TA
1	½" High Pressure Water	Provide water to the HIPRESS tool

The UCS enables the pump to be deployed from, and retrieved into, the DCCV.

### UMBILICAL DESIGN

#### *Umbilical Design Objectives*

The following objectives were established for design of the Umbilical.

1. *Provide a means of delivering the fluids required for TA operation.* These requirements are detailed in Table 7.
2. *Maximize the Umbilical's life in the UST working environment.* The Umbilical will withstand temperatures up to 200°F, normal pH of 9.5 with peaks greater than 12, and radiation levels up to 500 rad/hr.
3. *Allow for storage within the DCCV.* The Umbilical must be contained within the DCCV and be stored neatly to allow repeated deployment and retrieval of the TA. The Umbilical must also be compatible with the UCS.
4. *Maximize the maneuverability and retrievability of the TA.* The Umbilical will be flexible enough to allow the TA to maneuver around obstacles, i.e., risers located inside a UST. It will be clear of the moving parts of the TA and also allow for easy retrieval and deployment of the TA.
5. *Support the weight of the TA.* The Umbilical will be capable of supporting the weight of the pump. This load is estimated to be 1,800 lb.

#### *Umbilical Design Criteria*

The design criteria in Table 7 were identified on the basis of the design objectives.

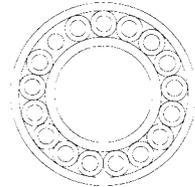
**Table 7. Umbilical Design Criteria**

Criterion	Requirement
Temperature Limit	Withstand minimum of 200°F
Chemical Resistance	Resist constant pH of 9.5 with peaks greater than 12
Radiation Resistance	Withstand 500 rad/hr without significant embrittlement
Flexibility (Minimum Bend Radius)	Contained within a DCCV and maximize maneuverability of TA
Surface Characteristics & Permeability	Exterior and interior smooth and non-permeable to avoid harboring contaminants
Toughness (abrasion/puncture resistance)	Resist damage by UST internals and UCS
Control	Sufficient to maximize maneuverability of TA
Geometry	Simplify decontamination, and maximize maneuverability of TA
Strength	Exceed 1,800 lb.
Cost	Minimize with acceptable performance

**Alternatives Analysis - Umbilical**

There were two Umbilical alternatives to consider: (1) the use of a bundle hose; and (2) separating the pump discharge hose, hydraulic lines, and water line. The remainder of this section details why the bundle hose design was selected.

The bundle hose is constructed by helically wrapping the secondary hoses (½" water and hydraulic lines) around the primary, or core, hose (3" pump discharge). This process is called *cabling*. The bundle of hoses is packaged inside a jacket which holds the bundle together and protects the interior hoses. Figure 2 shows a cross section of the bundle hose design. This design has several advantages that address the design criteria previously identified.



**Figure 2. Umbilical Cross Section**

Advantages of Bundle Hose Design

1. Compared to separate lines, this design offers much greater maneuverability and eliminates the chance of entanglement with UST obstacles.
2. The bundle hose will result in lower friction forces as it is pulled by the TracPump™ along the UST floor. This will lead to greater maneuverability of the TA.
3. The number of lines directly exposed to contaminated material is reduced to one, the jacket. This geometry minimizes hose contact with contaminated material resulting in simpler decontamination.
4. Only one exterior surface must be cleaned of contaminants as the Umbilical is retrieved into the DCCV. This geometry eliminates the enclosed spaces created by multiple hoses, further simplifying decontamination.
5. The exterior jacket will protect the interior hoses from chemical attack, radiation, abrasion, and puncture. This addresses the toughness design criterion.
6. Single hoses cannot be subjected to the entire load of the pump. By utilizing a bundle hose, the weight of the Umbilical will be carried primarily by the jacket which is not directly related to TA operation. Therefore, in a sense, this design offers greater strength.

7. Containing all hoses within the bundle minimizes the amount of equipment required in the DCCV for retrieval. This simplifies the UCS required.
8. The flexibility of the bundle hose is somewhat less than the individual hoses that make up its components. Discussions with vendors indicate that, in their experience, bundling does not drastically reduce the flexibility of the hose components. The cabling process provides for a very flexible unit. Essentially, the bundle hose is as flexible as its stiffest component. It should be noted that this rigidity is desired to keep the Umbilical clear of moving parts of the TA.
9. Bundle hoses are a proven technology. They have been used on offshore oil platforms, in smaller sizes, for many years.

#### *Selection of Materials - Umbilical*

This section concentrates on selection of the Umbilical jacket material. All of the design criteria previously established are applicable to the jacket, and it will be subject to the most strenuous service. The hoses contained within the Umbilical jacket were selected on the basis of temperature and pressure requirements as well as consideration of the carried fluid. The following is an analysis of commercially available Umbilical jacket materials and their performance with respect to the established design criteria.

*Radiation Resistance* - Polyurethane is indicated as offering the best resistance to degradation by nuclear radiation. There is no available data.

*Flexibility* - In the experience of manufacturers, materials do not greatly affect the flexibility of bundle hoses (within the constraints of available materials and small wall thickness).

*Surface Characteristics and Permeability* - Both acceptable materials have smooth exterior and interior surfaces. For permeability data see Table 8.

*Control* - Materials are not pertinent to this criterion.

*Geometry* - Materials are not pertinent to this criterion

*Strength* - See UCS DESIGN.

*Cost* - There are no significant differences in the costs of the materials considered.

Table 8 provides a comparison of the materials considered with respect to the remaining design criteria.

**Table 8. Comparison of Commercially Available Jacket Materials**

Material	Manufacturable	Temperature Limit °F	Resistance to Alkalies	Water Resistance	Absorption % 24 hrs	Abrasion Resistance	Mechanical Resistance	Hardness Shore A
PVC	YES	220	F	G	0.10	U	F	85
EPDM/Polypropylene	NO	248	G	E	1.50	G	F	92
EPDM/Polypropylene (FR)	NO	266	E	E	0.30	G	G	87
<b>Polyurethane</b>	<b>YES</b>	<b>250</b>	<b>G</b>	<b>G</b>	<b>1.00</b>	<b>E</b>	<b>E</b>	<b>90</b>
Polyurethane (FR)	YES	180	G	G	1.50	E	E	75
LDPE	NO	150	G	E	0.10	G	G	50
PE (FR)	NO	150	E	E	0.03	G	G	90

E = Excellent G = Good F = Fair P = Poor U = Unsatisfactory  
 FR = Flame Resistant

Adapted from Parker Fluid Connectors "Multitube Data"

Only three of the materials can be manufactured without incurring unacceptable retooling costs. These materials are indicated in the *Manufacturable* column. Of these three, only two meet the minimum temperature requirement of 200 °F. These two are PVC and polyurethane. Polyurethane was chosen for its resistance to attack by alkalies, mechanical damage, abrasion damage, and degradation by nuclear radiation.

## UCS DESIGN

### *UCS Design Objectives*

The UCS was designed to retrieve a load equal to three times the weight of the Umbilical and TA. This design load provides extra capacity in case the TA becomes stalled.

Although the quoted maximum load for the bundle hose was 5,099 lb., the design load for the UCS was 5,400 lb. Additionally, creep would be significant in the jacket at the high UST temperatures. Since bundle hoses are not designed to be load bearing, it was decided that a TracPump™ Assembly Retrieval Winch (TRW) and cable should be used to support the pump load during deployment and retrieval operations. Note that the actual weight of the TA and Umbilical amounts to about 1,800 lb. The 5,400 lb. design criterion was established to allow extra pulling force in case the TA becomes stalled. Therefore, the bundle hose can serve as a redundant retrieval method. However, under normal operation the Umbilical will only support its own weight.

### *Alternatives Analysis - UCS*

Two major alternatives were considered for the UCS: (1) A hose reel assembly, and (2) A system of Pinch Rollers which would grab the hose by friction. Either alternative would be powered by hydraulic motors.

#### Alternative #1 - Hose Reel Assembly

Hose reels are the typical method for retrieving and storing flexible hose. Unfortunately, they are impractical for this bundle hose system.

The problem with hose reels is that the hose reel must rotate to retrieve the hose. The rotation occurs where the hose connects to a rotating fitting on the side of the hose reel. In a single-tube hose this presents no problem. But, with a bundle hose, this would result in twisting of the secondary hoses around the core hose; this effect would occur once for each revolution of the hose reel. This was judged unacceptable. Two means of eliminating this problem were identified.

The first requires that all the secondary lines be disconnected during retrieval or deployment of the pump. This idea was rejected because it requires frequent human intervention. This would result in increased personnel exposure and awkward operations.

The second requires a rotating hard-piped spool piece with rotating connections for each hose (one 3" and sixteen ½" hoses). The spool piece could connect at the side of the hose reel and at the DCCV wall. It would then accept the rotation of the hose reel, eliminating the problem of twisting. This idea was rejected because it involves a rotating connection at the DCCV wall that would require a dynamic seal and alignment with the axis of the hose reel. It was, therefore, deemed unreliable and overly complex. Without a solution to the twisting problem, the hose reel UCS was rejected in favor of the Pinch Roller mechanism.

#### Alternative #2 - Pinch Rollers

The Pinch Roller system consists of two rollers with external surfaces sized to match the outside diameter of the Umbilical. The urethane jacket, when wet, does not develop significant friction on any material. For this reason, the Pinch Rollers were designed with teeth to bite into the jacket. Several ideas were implemented to protect the Umbilical.

1. *Maximize the number of teeth in contact with the hose jacket to minimize the load carried by each tooth.* Each roller was designed with forty rows of eight teeth spaced so that sixteen teeth (thirty-two teeth considering two rollers) will always be engaged with the Umbilical jacket. Under normal operation, each tooth must support a maximum load of 19.3 lb. (Umbilical weight = 618 lb. / 32 teeth). This was judged to be acceptable.
2. *Ensure that both Pinch Rollers operate at the same speed.* This eliminates the possibility of tearing caused by different tooth speeds. Because hydraulic motors cannot be operated to precise speeds, it was decided that one hydraulic motor should drive both Pinch Rollers through a chain drive.
3. *Provide a means of adjusting the engagement depth of the teeth.* Preliminary testing indicated that the urethane jacket is highly resilient. By limiting the engagement of the teeth to approximately 3/32", only elastic deformation occurs in the jacket while considerable shear force can be supported by the tooth. Because of normal manufacturing tolerances applied to the Umbilical and the Pinch Rollers, a means of adjusting the engagement depth of the teeth was necessary. This ensures that the proper tooth engagement can be set such that the required shear forces are developed without damaging the jacket.

*Also note that the jacket material was selected on the basis of mechanical resistance, abrasion resistance, and hardness (measures of resistance to cutting and tearing).*

The Pinch Roller system does not provide storage for the Umbilical. For this reason an Umbilical Apron was designed into the DCCV. An acceptable torsion limit of three degrees was

established on the advice of manufacturers. With the Pinch Roller system, the hose is fixed (it cannot rotate) at the Pinch Rollers and at the discharge bulkhead of the DCCV. The result of fixing the hose on either end is that it will twist 360° each time it wraps around the Umbilical Apron. The DCCV inside diameter of twelve feet was selected so that the torsion in the hose would be limited to two degrees.

## SUMMARY

### *Umbilical Design*

The following design objectives were established for the DCCV Umbilical:

1. Provide a means of delivering fluids required for TA operation;
2. Maximize the Umbilical's life in its working environment;
3. Allow for storage within the DCCV;
4. Maximize the maneuverability and retrievability of the TA; and
5. Support the weight of the TA.

Ten design criteria were established on the basis of these objectives:

1. Temperature Limit
2. Chemical Resistance
3. Radiation Resistance
4. Flexibility (Minimum Bend Radius)
5. Surface Characteristics and Permeability
6. Toughness (Abrasion/Puncture Resistance)
7. Control
8. Geometry
9. Strength
10. Cost

Two alternatives were discussed for the Umbilical. The bundle hose design was selected over separated pump discharge and hydraulic lines for the following reasons:

1. Greater maneuverability because all hoses are contained inside the Umbilical jacket;
2. Greater maneuverability due to a lower friction load for the TA to pull;
3. Ease of decontamination through reduced number of hoses exposed to contaminants;
4. Ease of decontamination because only one exterior surface must be cleaned;
5. Better abrasion and mechanical resistance provided with the protective Umbilical jacket;
6. Greater strength because of the bundle hose cabled design; and
7. Minimal equipment (UCS) required for retrieval of the Umbilical.

An analysis of available Umbilical jacket materials was performed with respect to the applicable design criteria. Polyurethane was chosen for its resistance to attack by alkalis, mechanical damage, abrasion damage, and degradation by nuclear radiation.

### *UCS Design*

The UCS was designed for a load of 5,400 lb. This load is three times the weight of the TA and Umbilical. This design basis provides extra operating capacity.

A Pinch Roller system and a hose reel assembly were considered as options for the UCS. The hose reel assembly was rejected because it would result in twisting of the secondary hoses ( ½" hydraulic and water lines) about the pump discharge hose. No practical solution to this problem could be identified. The system of Pinch Rollers was selected as the most practical design concept.

Two design concepts were implemented with the Pinch Roller system. The Pinch Roller teeth were designed to be adjustable to ensure proper engagement depth with the Umbilical jacket. Also, an Umbilical Apron was designed into the DCCV to provide storage for the Umbilical.

## ESG TP-002B TRACPUMP™ AND UMBILICAL FUNCTIONAL TESTS

### OBJECTIVES

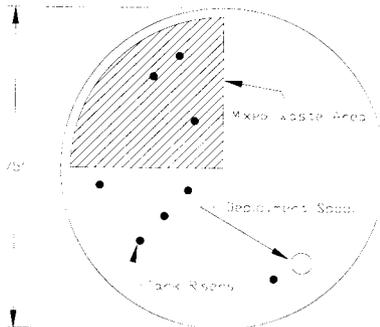
The purpose of this test procedure was to evaluate the effect of the Umbilical on maneuverability of the TA, the performance of the UCS, and the stability of the TA. The Umbilical should be flexible enough to allow the TA to maneuver around UST obstacles, while being rigid enough to prevent binding during sharp turns. This test was designed to prove the ability of the TracPump™, loaded with the Umbilical, to navigate multiple risers in a varied terrain environment.

### TEST PROCEDURES

Three separate tests were designed to achieve the test objectives:

#### *Maneuverability Test*

A full-scale mock-up of UST AY-104 was constructed, using HTI drawings, to replicate the worst-case conditions for maneuverability at the Hanford site. A portion of the mock-up was filled with a random mixture of the Hardpan and Salt Cake waste simulants.



**Figure 3. Schematic of UST AY-104 Mock-Up**

The TA was installed with 100 feet of five-inch tank-car hose attached to the pump discharge and four hydraulic lines attached for operation of the tracks. The HIPRESS tool was raised in its near-vertical orientation (spray nozzles aimed forward). The Claw Tracks (tracks with replaceable, carbide-tipped spikes welded at intervals) were installed for this test.

A wooden electrical spool was elevated twelve feet in the air with a forklift to model the geometry of the thirty-six-inch UST access riser. The hydraulic lines were extended over

this spool to simulate the expected action of the hydraulic lines during operation of the TA.

In this test, the TA was driven through the mock-up tank making appropriate maneuvers so that the actual turn radius could be determined. The Umbilical was intentionally dragged against the simulated risers to prove the ability of the TracPump™ to negotiate the riser obstacles, while dragging the Umbilical through those obstacles.

#### *Umbilical Control Test*

In this test, fifty feet of five-inch tank-car hose was inserted into the prototype UCS. The UCS was operated from the PU controls. The hose was retrieved and deployed three times to test the UCS and the Umbilical Apron of the DCCV.

The test was repeated with the TracPump™ connected to the Umbilical. The TA was retrieved and deployed by the TRW, while the hose was controlled with the UCS.

#### *Stability Test*

To test the stability of the TracPump™, a ramp was constructed at an angle of 11°. The TracPump™ climbed the ramp with one track on the ramp and one track on the ground, until tipping occurred.

## RESULTS

#### *Maneuverability Test*

Figure 4 below shows the path taken by the TA during the test. It easily negotiated the simulated obstacles on mixed waste at an incline, while pulling 100 feet of Umbilical hose. The actual minimum bend radius of the Umbilical (achievable under power of the TracPump™) was three feet. The turn radius of the TA was about eight feet.

One issue was identified during this test that was unrelated to the actual maneuverability test. The Camlock fitting used to attach the Umbilical to the pump discharge failed. A fitting capable of withstanding the load will be selected for Phase III.

#### *Umbilical Control Test*

Both tests of the UCS showed that the system operates as planned.

The Umbilical was retrieved and deployed successfully and could be stored in the

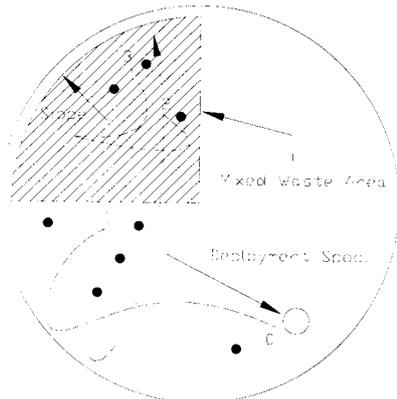
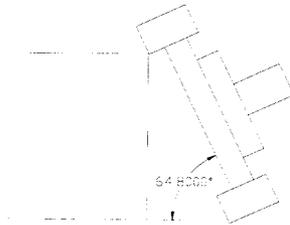


Figure 4. TracPump™ Maneuverability Test

Umbilical Apron of the DCCV (see last paragraph of this section). Additionally, operation of the TRW, in conjunction with the UCS, proved to be uncomplicated and provided adequate control of the Umbilical, while retrieving and deploying the TA.

Two issues were identified during this test. At times, during retrieval operations only, the Umbilical adhered to the DCCV shell and had to be forced down into the Umbilical Apron. This issue is attributed to two factors. The tank-car hose used to simulate the Umbilical has a significantly rougher surface than the urethane jacket specified for the Phase III Umbilical. The urethane jacket is very slick (especially when wet) and will be less likely to cling to the capsule shell. Also, the Umbilical was not full of pumped material during this test. The added weight of materials in the pump discharge hose will tend to force the hose into the Umbilical Apron. Further testing should be conducted with appropriate materials and a full Umbilical to prove the design completely. The second issue identified was that the Umbilical occasionally rubbed the chain drive of the UCS. Repositioning of the chain and sprockets or a guard rail will be used to protect the Umbilical.



**Figure 5. TracPump™ Stability Test**

### **Stability Test**

The TracPump™ climbed the ramp until it reached an angle of sixty-five degrees as shown in Figure 5. It did not tip, but ceased to climb the ramp because of the lack of contact between the tracks and either the ground or the ramp. Therefore, the actual tipping point is not known but is known to be greater than sixty-five degrees.

### **SUMMARY**

The TA performed well in the maneuverability, control, and stability tests.

Maneuverability testing showed that the actual turn radius of the TA with the Umbilical attached was approximately eight feet and the TA was able to negotiate the simulated tank AY-104 obstacles while pulling the Umbilical.

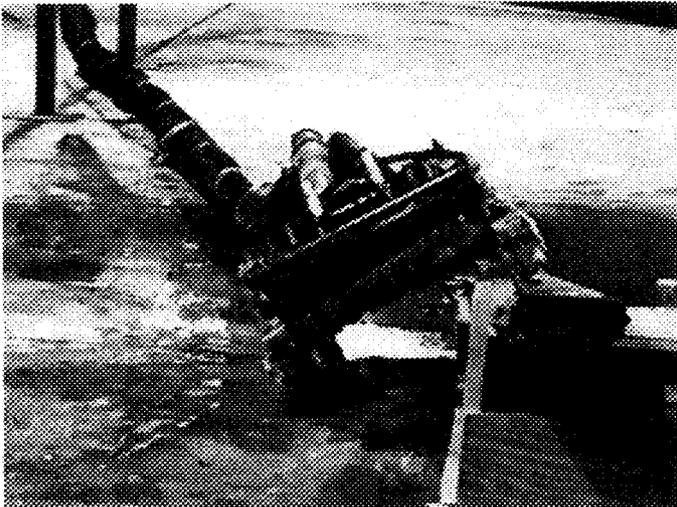
The Umbilical Control Test demonstrated the success of the UCS design. It proved that the operation of the TRW, for retrieving the TA load, in conjunction with the UCS, provides excellent control and maneuverability of the TA.

During the Stability Test, the TracPump™ climbed a ramp until it reached an angle of sixty-five degrees (as shown in Figure 5). At this point, the TracPump™ could not continue because of the lack of contact between the tracks and either the ground or the ramp. Therefore, the actual tipping angle of the TracPump™ is known to be greater than sixty-five degrees.

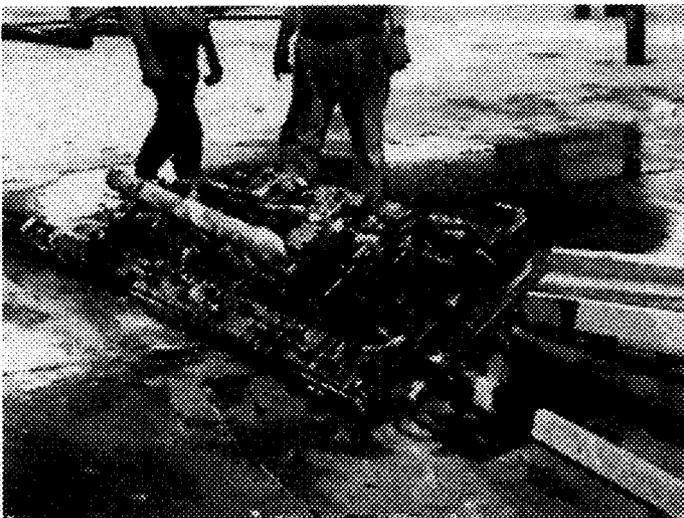
## LESSONS LEARNED/ACTION ITEMS

Several issues were identified during these tests that should be addressed in Phase III.

- The Camlock fitting used to attach the Umbilical to the pump discharge failed. One capable of withstanding the loads encountered will be selected.
- Some issues were encountered during Umbilical control operations. The Umbilical had a tendency to adhere to the shell of the DCCV instead of folding neatly into the Umbilical Apron. Several causes were identified that were unique to the testing procedure and it is felt that these issues will not be encountered in Phase III. However, further testing under actual expected conditions will prove that the Umbilical stores properly.
- The Umbilical occasionally rubbed against the chain drive of the UCS. Repositioning of the chain and sprockets or a guard will be used to protect the Umbilical.



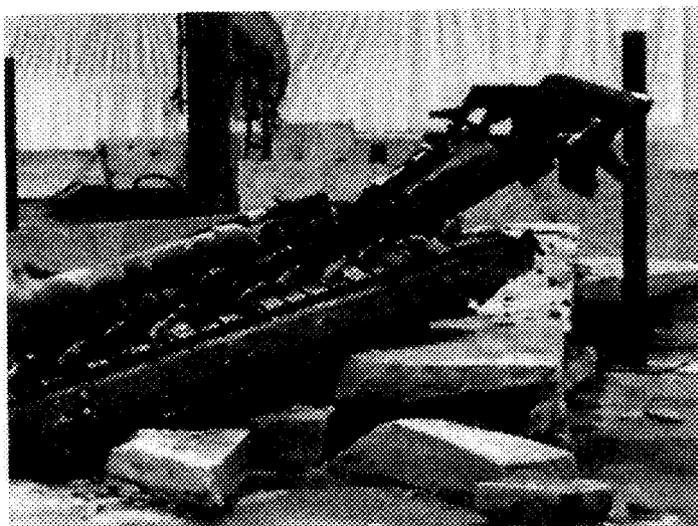
**Photograph 12. TA Climbing a Ramp in the Stability Test**



**Photograph 13. TA at Maximum Operating Angle in the Stability Test**



Photograph 14. TA Traversing the Mixed Waste Area



Photograph 15. Illustration of the Climbing Ability of the TA

## ESG TP-003

# EVALUATION OF DECONTAMINATION CONTAINMENT CAPTURE VESSEL (DCCV) DESIGN

### OBJECTIVES

The DCCV was designed to isolate personnel from radiation exposure, while enabling access to the Hanford USTs. The DCCV will house all equipment required for waste retrieval operations, except controls and power supply for the TA.

The following objectives were established for design of the DCCV:

1. Isolate personnel from exposure to contaminated waste;
2. Provide platform for operation of UCS; and
3. Provide easy access to TA for maintenance.

### DCCV DESIGN

#### *Isolate Personnel From Exposure To Contaminated Waste*

Four methods were identified to minimize exposure to contaminants. These methods were: (1) Shielding, (2) Simplify Decontamination, (3) Distance from Platform to UST, and (4) Structure Design for Simple Nipple-Up Procedure.

#### Shielding

Shielding will be provided by a 3/8"-thick stainless steel wall polished to a mirror finish. Although other materials (such as lead) offer better shielding characteristics, stainless steel was chosen for ease of decontamination, weldability, machinability, and mechanical properties. The stainless steel wall, in addition to the other methods to be discussed, should provide adequate personnel protection.

#### Simplify Decontamination

The polished stainless steel shell was selected because of its ease of decontamination. Spray nozzles will be installed to wash away any materials that cling to the Umbilical or TA. These nozzles will be located along the riser that connects the UST to the DCCV and should prevent contaminants from being introduced into the DCCV. Additional nozzles will also be provided, inside the DCCV, to wash away any contaminated material that does reach the DCCV and prevent it from collecting in recesses that may be present in the tank. Some of these nozzles will be directed specifically at problem areas of the DCCV, including vessel heads and the Umbilical Apron.

Vessel geometry was also designed to minimize the collection of contaminants (see Figure 6). ASME 80:10 heads were selected for each of the bottom heads because they have the smallest dish radius and they have a knuckle. The knuckle eliminates sharp corners, at the head's large end, where contaminants might collect. To eliminate sharp corners at the small end of the head, the small dish radius of the ASME 80:10 heads provides for the greatest slope at the intersection of the head and the reduced diameter section of the vessel. Repad at the intersection will allow for this intersection to be ground smooth and round to further simplify decontamination.

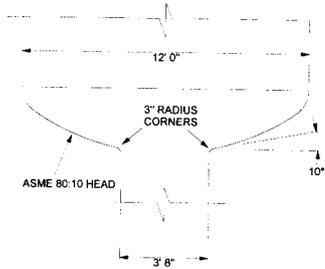


Figure 6. DCCV Cross Section

#### Distance from Platform to UST

The DCCV superstructure was designed to provide a distance of 14'-9" from the maintenance platform to the bottom of the UST pump pit. With this distance, dose rates at the superstructure floor will be 218 times less than the rate one foot above the pump pit bottom. This should provide adequate protection from exposure to radiation emanating directly from the UST.

#### Structure Design for Simple Nipple-Up Procedure

The DCCV was designed to eliminate personnel exposure when making the connection between the DCCV riser and the existing UST nozzle. This design does not require personnel to enter the pump pit. The DCCV has four pipe legs that mate to four pipe guides on the superstructure. This system will simplify positioning of the DCCV centerline so that it is aligned with the existing UST nozzle. Once the superstructure is constructed and the tank nozzle is open, the DCCV will be lowered onto the superstructure. The DCCV stinger will stab into the UST nozzle and the air-bag seal will be inflated remotely. Figure 7 illustrates the DCCV Nipple-Up procedure.

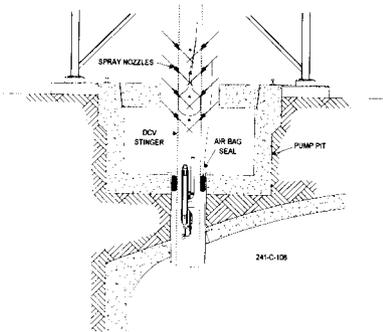


Figure 7. DCCV Nipple-Up Illustration

#### Provide Platform For Operation Of UCS

The DCCV inside diameter was tailored to the requirements of the UCS. To minimize the torsion in the retrieved Umbilical, an inside diameter of 12'-0" was required. This is discussed in greater detail in ESG TP-002 TRACPUMP™ AND UMBILICAL FUNCTIONAL TESTS.

Two C8x13.75 beams and a smaller substructure span the larger chamber of the DCCV to support the UCS. They were designed for loads in excess of the maximum TRW capacity plus the weight of the UCS components (approximately 12,000 lb.). An Umbilical Apron was also designed for storage of the Umbilical during retrieval operations. A drain will be provided to allow for any contaminants to be washed back into the UST.

#### *Provide Easy Access To TA For Maintenance*

The DCCV's lower section diameter was set to 3'-8". A wooden mock-up of the lower section was constructed to perform maintenance trials. On the basis of these trials, 3'-8" was found to be the optimum size for maintenance access. In addition to the DCCV diameter, leaded gloves and sight glasses will be provided for maintenance access.

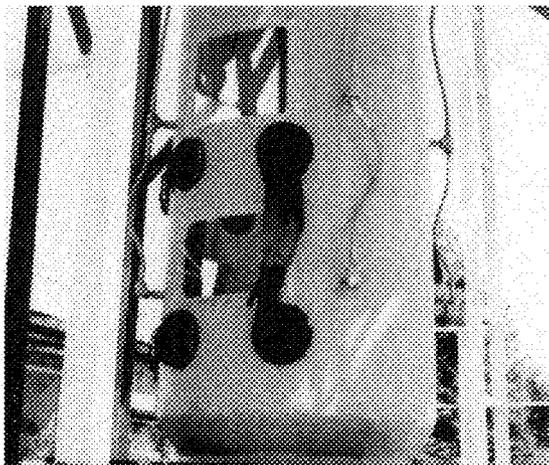
#### SUMMARY

The following DCCV design objectives and solutions were discussed:

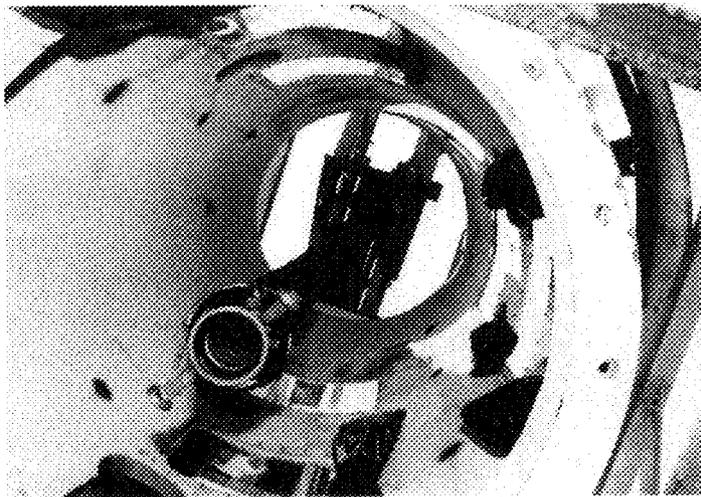
1. *Isolate Personnel From Exposure To Contaminated Waste.* Four methods were identified to achieve this objective: (1) The polished stainless steel shell was selected to provide radiation shielding and to simplify decontamination; (2) Spray nozzles and vessel geometry were used to simplify decontamination within the DCCV; (3) The DCCV superstructure height was specified to provide ample distance between personnel and the high dose rates near the UST nozzle; and (4) The DCCV and superstructure were designed with pipe leg supports to allow for a simple Nipple-Up procedure that does not require personnel to enter the pump pit.
2. *Provide Platform For Operation Of UCS.* The DCCV was tailored to the UCS in its size and accessories.
3. *Provide Easy Access To TA For Maintenance.* Testing was performed to determine the optimum lower-section diameter for ease of maintenance. Accessories were also mentioned that will provide maintenance access.



Photograph 16. Decontamination Containment Capture Vessel



Photograph 17. View Ports and Glove Ports



Photograph 18. Interior View of DCCV



Photograph 19. Decontamination Washdown System Operating

## ESG TP-004 REMOTE SURVEILLANCE EQUIPMENT

Current plans are to use the Overview Video System (OVS) or Overview Stereo Video System (OSVS) developed at the Savannah River and Hanford sites. Further study will be conducted to verify that these systems are capable of supporting the requirements of the TracPump™ based VWRS.

The primary issues that will be addressed are:

1. Verify that the VWRS's vigorous waste retrieval action does not create a contamination problem for the OVS.
2. Can the OVS system provide the depth perception, or multiple views, required for location of the TA or would the OSVS system be better suited for this application?
3. Ensure that there is no interference between the OVS and VWRS systems.

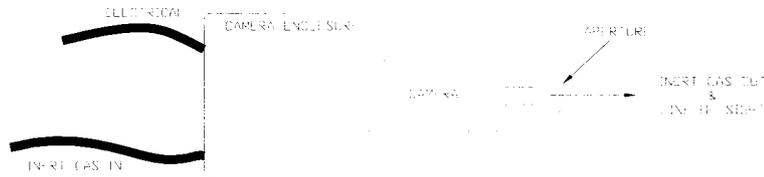
An alternative surveillance plan has also been investigated. It addresses the following issues:

- The tank environment including radiation, temperature, corrosive elements, humidity, dirt, and hazard classification;
- The need for a light source; and
- Camera placement strategy.

### TANK ENVIRONMENT

The humidity, dirt, and corrosive/hazardous elements present in the Hanford tanks can be handled with technology currently available on the market. Figure 8 shows a camera with the lens aimed through a small aperture in the camera enclosure. An inert purge gas flowing through the aperture will ensure that the undesirable elements are eliminated from the camera enclosure. This design addresses the following issues:

1. Dirt or condensation hindering the camera's view;
2. Fire or explosion potential from hazardous elements, i.e., hydrogen reaching the camera's electrical components; and
3. Corrosive materials damaging the camera itself.



**Figure 8. Camera with Inert Gas Purge**

Note that this type of purge is acceptable under NFPA 496 Class I Division I Group B for hydrogen service.

A non-browning lens will be used for its resistance to radiation damage. Additionally, the camera enclosure will be 316L stainless steel for corrosion resistance and ease of decontamination.

#### **CAMERA PLACEMENT**

Ideally, a single unit consisting of four cameras aimed at 90° intervals would be used to provide 360° visual coverage. Such a unit would require only one tank penetration and one source of light. However, the availability of a suitable tank riser or nozzle for this installation must be verified. Alternatively, multiple cameras aimed individually could be used. The placement strategy of cameras requires further investigation and must be specific to each tank.

## **ESG TP-005 BACKFLUSH SYSTEM FUNCTIONAL TEST**

### **OBJECTIVES**

The objective of this test was to evaluate the effectiveness of a High Pressure Water Lance (HPWL) backflush system for cleaning a clogged discharge hose. Waste samples will be intentionally used to clog the TracPump™ discharge line. Once the line is clogged, the HPWL will dislodge the clogged line.

### **TEST PROCEDURES**

The TA was driven into the complex waste field, a random mixture of all three waste simulant types. Waste retrieval operations commenced to verify proper tool performance, and test data was collected. Samples from the complex waste field, consisting of the three simulant materials, were collected to clog the discharge hose. The test section of discharge hose was twenty-feet long and four inches in diameter. Samples of each material were inserted in separate places along the hose. The material was packed into the hose using hand tools and allowed to harden for three days.

The HPWL was connected to the TA discharge manifold using the Flex Lance Guard. The HPWL was pressurized and fed into the discharge hose. An initial flowrate of 13 gpm and pressure of 2000 psi was used to begin the test. After test completion, the HPWL was withdrawn. Dislodging and conveyance operations were commenced again to validate the integrity of the system.

### **RESULTS**

The HPWL was pressurized and inserted into the discharge manifold. The flowrate was set to 13 gpm, and the pressure was set at 2000 psi. The HPWL broke through the first clogged section, which consisted of Saltecake, within one minute. The discharge water contained no sign of large particles, indicating that the Saltecake was dissolved by the HPWL. The HPWL continued along the discharge hose until it reached the second clogged portion, which consisted of Hardpan. The HPWL met some resistance, so the pressure was increased to 3000 psi. At this pressure, the HPWL passed the second clogged portion of the hose within three minutes.

### **SUMMARY**

The task of unclogging different complex wastes was easily completed using the HPWL. The HPWL broke through each of the clogged portions in minutes. The operation of the HPWL did not have any adverse effects on the TA, which operated normally after the test.

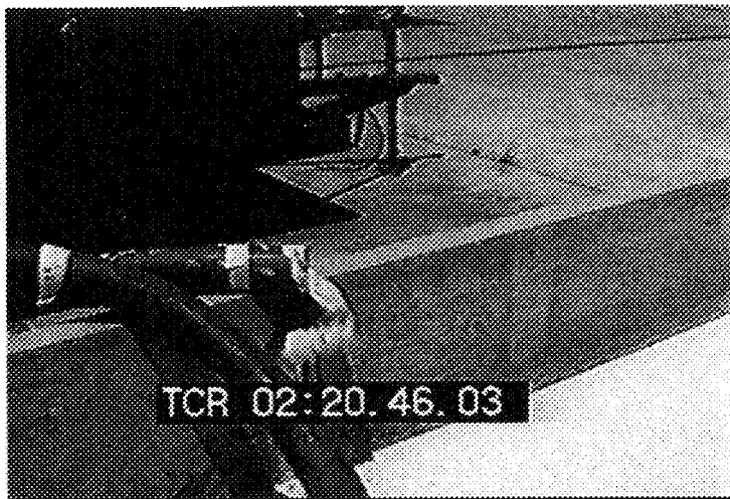
## LESSONS LEARNED/ACTION ITEMS

Several issues were identified during these tests that should be addressed in Phase III.

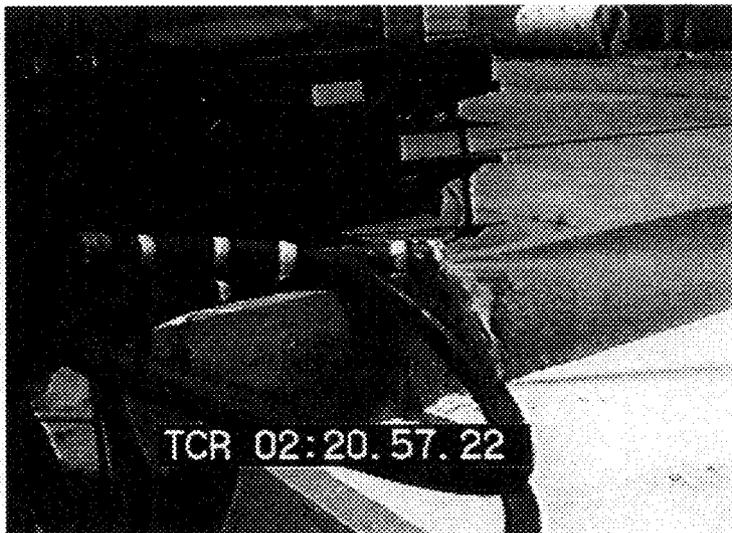
- Location of insertion point for the HPWL in the discharge line;
- Solid size of the unclogged Hardpan; and
- Procedures to eliminate potential clogging.



Photograph 20. Insertion of Water Lance into Plugged Line



Photograph 21. Plugged Material Discharging from Line



Photograph 22. Plugged Line Completely Cleared

## **ESG TP-006**

### **TRACPUMP™ ASSEMBLY (TA) INSERTION AND RETRIEVAL TEST**

#### **OBJECTIVES**

The purpose of this test was to demonstrate the TA's ability to ingress/egress the UST using the UCS.

#### **TEST PROCEDURES**

The TA was installed with the HIPRESS tool, 3X25 Sludge Pump, simulated Umbilical, Claw Tracks, and folding mechanism. The insertion and retrieval tests were performed with the TRW and UCS.

The testing described herein was conducted in conjunction with ESG TP-002B TRACPUMP™ AND UMBILICAL FUNCTIONAL TESTS. The following procedures were performed after the procedures of ESG TP-002B.

The TA was retrieved into the maintenance section of the DCCV. A twenty-four-inch pipe (23<sup>3</sup>/<sub>8</sub>" inside diameter) ten-feet long was placed underneath the DCCV to simulate a tank riser. The TracPump™ folding mechanism was engaged. Under control of the TRW and UCS, the TA was inserted into and retrieved from the simulated UST riser.

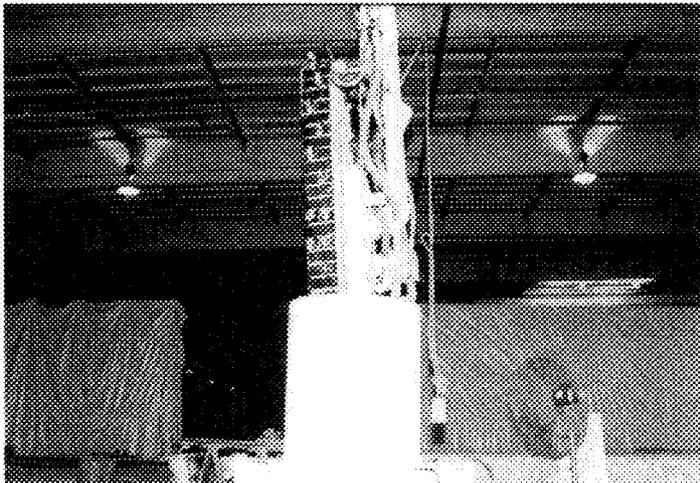
#### **TEST RESULTS**

The TA was successfully deployed into and retrieved from the simulated twenty-four-inch riser.

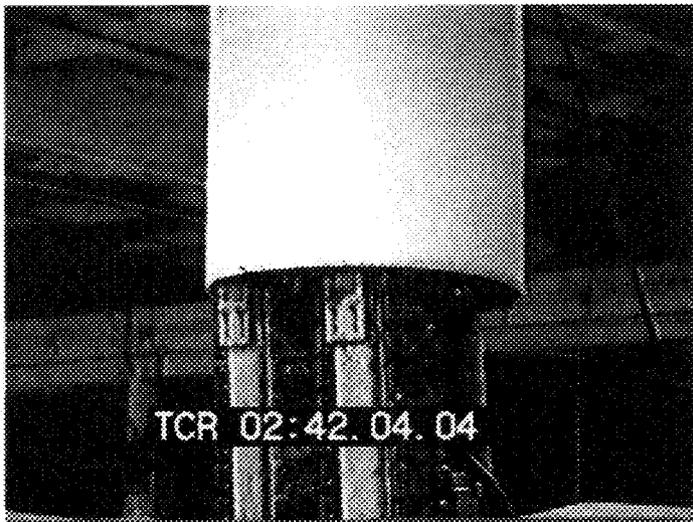
#### **LESSONS LEARNED/ACTION ITEMS**

Although the TA was able to pass through the 23<sup>3</sup>/<sub>8</sub>" port, more clearance should be provided to allow for movement of equipment. This will be accomplished in one of two ways:

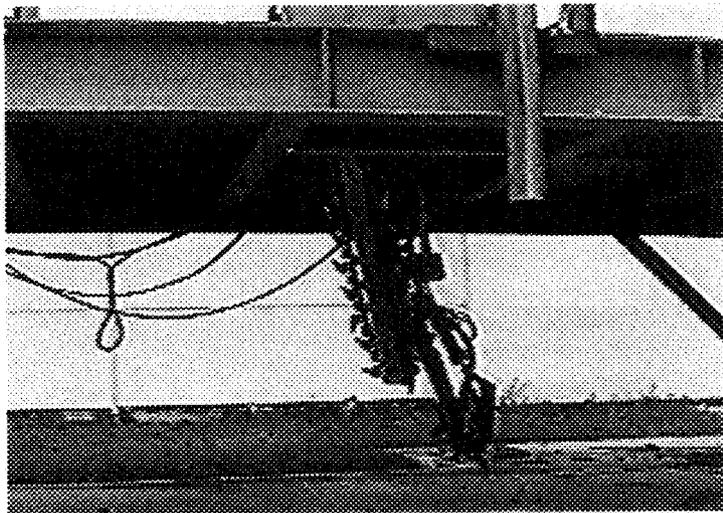
1. Decrease each pontoon width by two inches. This will provide ample clearance without affecting the performance of the TracPump™.
2. Make the pump base portion of the TracPump™ two inches narrower. This will be possible by integrating the pump base and the pump casing. This alternative will not affect the performance of the TracPump™.



Photograph 23. Insertion of TracPump™ into 24" Pipe



Photograph 24. Extraction of TracPump™ from 24" Pipe



Photograph 25. Extraction of TracPump™ from DCCV



Photograph 26. TracPump™ Leaving the DCCV

## ESG TP-007 DETERMINATION OF WASTE CONVEYANCE RATE

### OBJECTIVES

The objective of this test was to establish the rate and effectiveness of the TA in conveying dislodged waste material from a UST. The TA includes the TracPump™ equipped with a 3x25 H&H Sludge Pump, HIPRESS tool, and 210 linear feet of the three-inch discharge hose.

This test was performed using the Hardpan waste simulant. Note that all three waste simulant types were successfully dislodged during test ESG TP-001. Hardpan was selected for this test because it was denser and higher in solids concentration than the other simulant types. The solids concentration of the removed slurry was 58%.

### TEST PROCEDURES

The TA was set in the Hardpan test bed (see ESG TP-001 for details). Material was dislodged using the HIPRESS tool, and make-up water was added to lower the solids concentration below 30%. The dislodged material was pumped to a concrete holding pit, near the DCCV prototype.

Once the holding tank was full of Hardpan slurry, the TA was transferred to the holding pit. A three-inch hose was connected to the pump discharge. To simulate field conditions, the discharge end of the hose was attached to a pole, at the DCCV, to an elevation of seventy-one feet. The hose discharged to atmosphere and into a funnel. Liquid flowed through the funnel into four pipes and, by gravity, down to a tank equipped with a V-Notch Weir (this arrangement is described below). The weir discharged into a holding tank where a hydraulic pump was used to return the material to the concrete holding pit, where the TA was located.

The flow from the TA was recorded as the PU hydraulic pressure varied. The PU pressure was increased until the flow reached the maximum allowed by the configuration.

A sixty-degree Triangular V-Notch Weir was selected to measure the discharge flow of the TA. The V-Notch Weir plate was installed at the end of a three-foot-wide by ten-foot-long steel chamber. The following equation was used to determine the flow rate:

$$Q = 1.4076 \cdot (H / 12)^{3/2} \cdot 448.83.$$

Q is the flow rate, in gpm, and H is the depth of the liquid flowing through the V-Notch Weir, in inches. Table 9 was prepared for determining flow rates during the test. Figure 9 illustrates the measurements recorded.

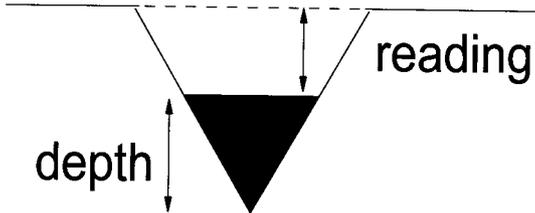


Figure 9. V-Notch Weir Measurements

Table 9. V-Notch Weir Calibration Chart

Reading		Flow		Reading		Flow		Reading		Flow	
Inches	Inches	GPM	l/min	Inches	Inches	GPM	l/min	Inches	Inches	GPM	l/min
11¼	0	0.0	0.0	7¼	4	40.5	153.4	3¼	8	229.3	867.8
11	¼	0.0	0.1	7	4¼	47.2	178.5	3	8¼	247.6	937.1
10¾	½	0.2	0.8	6¾	4½	54.4	205.9	2¾	8½	266.8	1009.8
10½	¾	0.6	2.3	6½	4¾	62.3	235.7	2½	8¾	286.8	1085.7
10¼	1	1.3	4.8	6¼	5	70.8	268.0	2¼	9	307.8	1164.9
10	1¼	2.2	8.4	6	5¼	80.0	302.7	2	9¼	329.6	1247.5
9¾	1½	3.5	13.2	5¾	5½	89.8	340.1	1¾	9½	352.3	1333.5
9½	1¾	5.1	19.4	5½	5¾	100.4	380.1	1½	9¾	375.9	1422.9
9¼	2	7.2	27.1	5¼	6	111.7	422.7	1¼	10	400.5	1515.9
9	2¼	9.6	36.4	5	6¼	123.7	468.1	1	10¼	426.0	1612.4
8¾	2½	12.5	47.4	4¾	6½	136.4	516.4	¾	10½	452.5	1712.6
8½	2¾	15.9	60.1	4½	6¾	149.9	567.5	¾	10¾	479.9	1816.3
8¼	3	19.7	74.7	4¼	7	164.2	621.5	¾	11	508.3	1923.8
8	3¼	24.1	91.3	4	7¼	179.2	678.5	0	11¼	537.6	2035.0
7¾	3½	29.0	109.9	3¾	7½	195.1	738.5				
7½	3¾	34.5	130.5	3½	7¾	211.8	801.5				

## RESULTS

Figure 10 shows the pumping rates calculated as a function of the PU pressure.

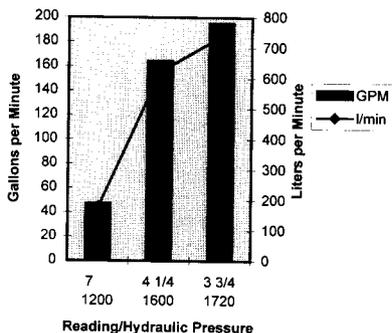


Figure 10. TA Pumping Rate vs. PU Pressure

Pumping rates for the other simulant types will be identical to the pumping rates with Hardpan, because the head developed by a centrifugal pump is independent of the specific gravity of the liquid pumped. The following is reprinted from *Cameron Hydraulic Data*, 18<sup>th</sup> edition, page 1-9:

*In a centrifugal pump the head developed (in feet) is dependent on the velocity of the liquid as it enters the impeller eye and as it leaves the impeller periphery and therefore is independent of the specific gravity of the liquid.*

The liquid density does, however, affect the power requirements of the pump. For this test, the Hardpan simulant was chosen because it has the highest density of the simulant types and, therefore, requires the highest power input.

To determine the operating point of a centrifugal pump, two curves are needed. *The system curve* specifies the head required for a given flow in a piping system. It is a function of the piping system only, i.e., pipe internal surface characteristics, pipe inside diameter, and the piping geometry. The liquid viscosity can affect the system curve, but the viscosity of the simulant types tested did not vary enough to be significant. *The pump performance curve* specifies the flow generated by the pump operating at a given head. The intersection of the pump performance curve and the system curve shows the operating point of the pump, i.e., determines the flow and head.

The test data was used to define the system curve. The system curve was plotted against the performance curve of the Sludge Pump used in the TA (see Figure 11). At 1800 rpm (22.5 gpm hydraulic oil supply), the system operates at 140 gpm.

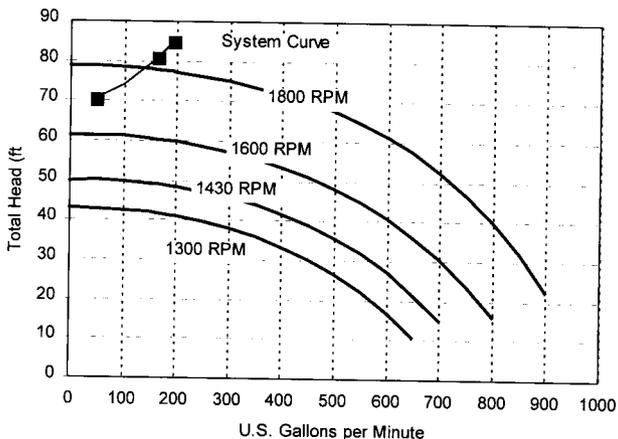


Figure 11. Sludge Pump performance curve and system curve

The conveyance test was considered successful. However, the final operation of the Assembly should consider recirculation of the material to increase the solids content of the discharged liquid to the maximum allowed by the owner's treatment capabilities. This will minimize the use of any sluicing or make-up water.

#### LESSONS LEARNED/ACTION ITEMS

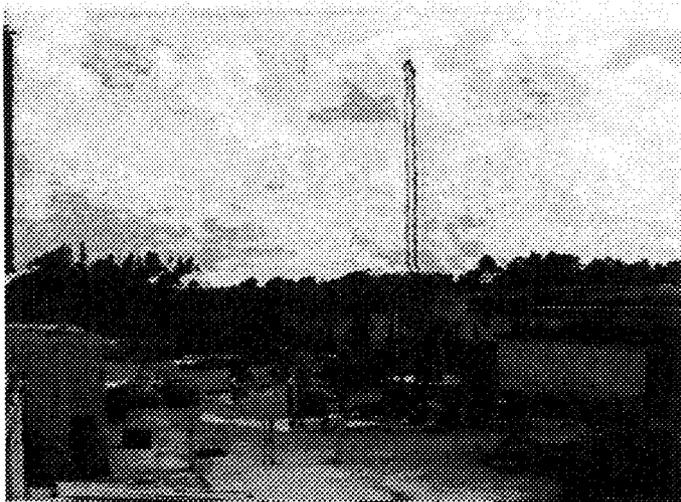
- The solids concentration of conveyed waste will determine the amount of make-up water required. Partial recirculation of the discharged slurry could be used to minimize the amount of make-up water usage. This issue should be discussed with Hanford Site management in Phase III.
- A secondary pump will be required to inject discharge slurry into the 140 psig recirculation loop. This pump could be an inline booster pump or a pump tank and secondary pump. A grinder type pump could be used as the secondary pump to further process solids.



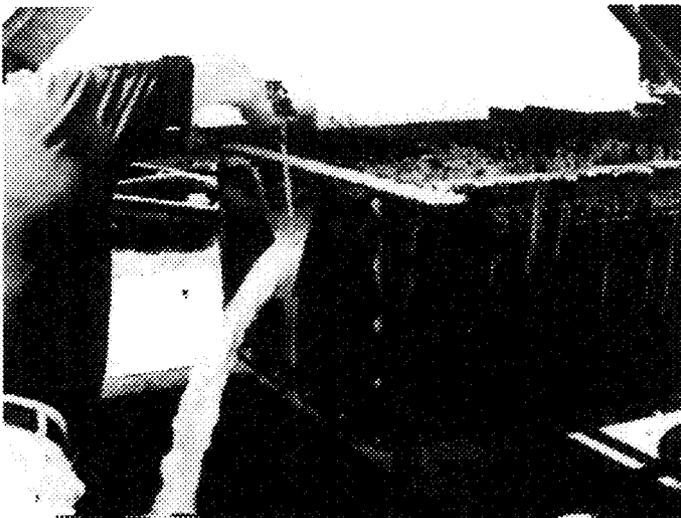
Photograph 27. HIPRESS Tool Dislodging Saltcake in the Complex Waste Test Bed



Photograph 28. HIPRESS Tool Dislodging Saltcake



Photograph 29. Test Configuration for Determination of Waste Conveyance Rate



Photograph 30. Measurement of Waste Pumping Rate Using a V-Notch Weir

## ESG TP-008

### TRACPUMP™ ASSEMBLY (TA) AND DECONTAMINATION CONTAINMENT CAPTURE VESSEL (DCCV) MAINTENANCE TEST

#### OBJECTIVES

This test was performed to establish a projected maintenance schedule and requirements for expected maintenance of the TracPump™ system components. The following tests were performed:

1. Remove and install track;
2. Remove and repair hydraulic line and pump motor; and
3. Find rotation limits of unit and accessibility from gloves location.

#### TEST PROCEDURES

For these tests, the TA was installed with the HIPRESS tool and the simulated Umbilical. The TA was retrieved into the maintenance position inside the prototype DCCV using the TRW and UCS. The tests described below were then performed.

##### *ESG TP-008A Remove and Install Track*

###### Remove Track

1. Reeled TracPump™ into place;
2. Removed track from pontoon;
3. Located chain separating pin and removed clips; and
4. Removed track.

###### Install Track

1. Installed chain on bottom sprocket;
2. Changed position;
3. Installed top sprocket;
4. Removed slings;
5. Rotated tracks;
6. Matched up the connecting tracks; and
7. Replaced pins.

##### *ESG TP-008B Remove and Replace Hydraulic Lines and Pump Motor*

1. Removed upper hydraulic line;
2. Removed lower hydraulic line;
3. Removed motor;
4. Replaced motor; and
5. Replaced hydraulic lines.

**ESG TP-008C Find Rotation Limits of Unit and Accessibility from Gloves Location**

Two mechanics rotated the pump, by hand through the glove ports, to its extreme positions, and the angle of rotation was measured. The mechanics also attempted to reach all mechanical parts of the TA.

**RESULTS****ESG TP-008A Remove and Install Track**

One mechanic removed the track in twenty-eight minutes. Tools required were: screwdriver, needle nose pliers, come-along chain, and adjustable wrench.

Two mechanics replaced the track in forty minutes. Tools required were: screwdrivers, needle nose pliers, come-along chain, and adjustable wrenches.

**ESG TP-008B Remove and Replace Hydraulic Lines and Pump Motor**

One mechanic removed and replaced the hydraulic lines and pump motor in fourteen minutes. Tools required were: screwdriver, needle nose pliers, and adjustable wrench.

**ESG TP-008C Find Rotation Limits of Unit and Accessibility from Gloves Location**

Two mechanics were able to rotate the unit more than 110° from the upper and lower gloves location. All mechanical parts on the TracPump™, except the HIPRESS nozzles and HIPRESS positioning cylinders, were accessible within the range of the glove locations. The mechanics were able to exchange tools and assist each other.

**SUMMARY****Table 10. ESG TP-008A Requirements to Remove/Install Track**

Man Hours Required	1.8
Tools required	2 screwdrivers 2 sets of needle nose pliers 1 come-along chain 2 adjustable wrenches

**Table 11. ESG TP-008B Requirements to Remove/Install Hydraulic Lines and Pump Motor**

Man Hours Required	0.23
Tools required	1 screwdriver 1 set of needle nose pliers 1 adjustable wrench

In test ESG TP-008C, mechanics were able to rotate the TA through 110° in its maintenance position. The only inaccessible parts were the HIPRESS nozzles and HIPRESS positioning cylinders.

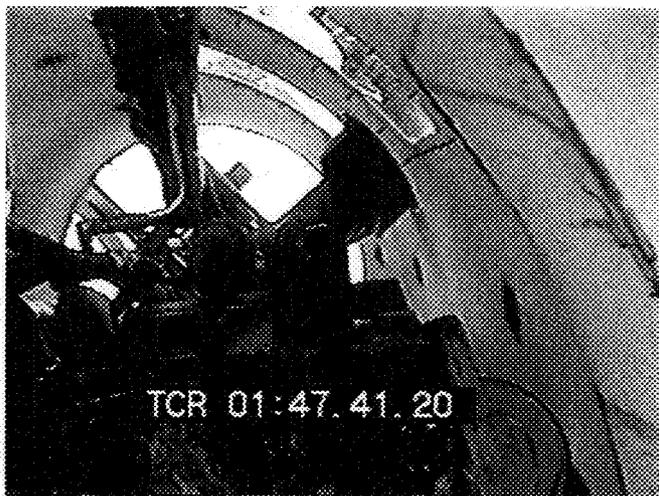
## LESSONS LEARNED/ACTION ITEMS

Several issues were identified during these tests that should be addressed in Phase III.

- A chain adjuster unit will make removal and installation of a track easier.
- Drill single holes into the track plates without spikes for use with the come along chain to secure the TracPump™ in position for maintenance. This will increase safety and ease of repair.
- Gloves should be bigger and not susceptible to tearing with the use of mechanic's tools.
- Need to raise the TracPump™ to a position where bottom gloves can allow mechanics to reach the lowest item of the unit from the bottom to the top.
- Chain clips on the side of the vessel would help to maintain the unit in any position desired.
- A projected maintenance schedule has not yet been developed.



Photograph 31. Mechanics Performing Maintenance on TracPump™ in DCCV



Photograph 32. Mechanics Replacing a Track



Photograph 33. Mechanics Replacing Hydraulic Lines

## CONCLUSION

ESG's Phase II demonstration of a VWRS addressed the following issues related to UST waste retrieval:

1. Dislodge and convey the waste forms present in the Hanford USTs;
2. Access the UST through tank openings as small as twenty-four inches in diameter;
3. Traverse a variety of terrains including slopes, sludges, rocks and hard, slippery surfaces without becoming mired;
4. Dislodge and convey waste within the confinement of the Decontamination Containment Capture Vessel (DCCV) and with minimal personnel exposure;
5. Decontaminate equipment to acceptable limits during retrieval from the UST;
6. Perform any required maintenance within the confinement of the DCCV; and
7. Maintain contaminate levels "as low as reasonably achievable" (ALARA) within the DCCV due to its crevice and corner-free design.

Once designs were determined and tooling constructed, testing confirmed waste retrieval rates that would allow UST waste to be retrieved within three months from initial tank access. Table 12 presents a summary of the testing results. Data collected from testing with the simulant materials were used to evaluate the tools, equipment and containment designed and fabricated by ESG. Several design improvements were identified on the basis of these tests. Some were implemented immediately, while others have been proposed in this report and will be addressed in Phase III.

**Table 12. Phase II Demonstration Summary**

Test Phase	Key Results	Key Lessons Learned/Action
ESG TP-001 Determination of Waste Retrieval Rates	HIPRESS tool effectively dislodged the three waste simulants. Retrieval rates ranged from 0.2 cfm in Saltcake to over 3 cfm in Hardpan.	Mills, grinders were ineffective in dislodging waste simulants.
ESG TP-002A Umbilical/UCS Design Review	Reviewed the design of the Umbilical/UCS	
ESG TP-002B TracPump™ and Umbilical Functional Tests	Demonstrated the TAs ability to traverse fields of waste simulants while pulling umbilical.  Turn Radius of the TA was approximately 8 ft.  Demonstrated operation of the UCS in coordination with the TA.	Umbilical rubbed against UCS chain drive. <b>Action:</b> Either reposition sprockets or install chain guard.  Umbilical occasionally adhered to DCCV shell. <b>Action:</b> Because test conditions did not conform to expected UST conditions, further testing required. Expectation is that under true conditions Umbilical will store without adhering.

## CONCLUSION

Test Phase	Key Results	Key Lessons Learned/Action
ESG TP-003 DCCV Design	Reviewed design of the DCCV.	
ESG TP-004 Remote Surveillance Equipment	Reviewed availability and potential designs for Remote Surveillance Equipment.	
ESG TP-005 Backflush System Functional Test	Demonstrated the ability of the HPWL to dislodge a pump discharge hose clogged with waste simulants	Locate the insertion point for the HPWL in the discharge line.  Add a pressure relief line to allow water to flow to the UST.  Establish procedures to eliminate clogging potential.
ESG TP-006 TA Insertion and Retrieval Test	Demonstrated insertion and retrieval of the TA through a 24 in. riser.	Provide more clearance to allow for movement of equipment. This will be accomplished with minor modifications to the TracPump™.
ESG TP-007 Determination of Waste Conveyance Rate	Demonstrated pumping rates of 140 gpm to 70 ft height through 210 lf. of 3 in. hose.	Recirculating discharge slurry to increase solids content could reduce make-up water usage.  Use a secondary pump to inject into recirculation loop and possibly to provide further solids processing.
ESG TP-008 TA and DCCV Maintenance Test	Demonstrated that expected maintenance can be performed inside the DCCV and established maintenance requirements.	Identified several equipment modification to simplify maintenance operations.  Establish projected maintenance schedule.

Testing of the TA and DCCV yielded conclusive documentation that commercial technology is readily available to begin UST waste retrieval with a VWRS. Given the large-scale of these tests and their successes, ESG is ready to provide equipment, personnel, and engineering for an actual UST waste retrieval operation.

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