INNOVATIVE TECHNOLOGY
Summary Report

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PITBULL ä Pump

Tanks Focus Area

Prepared for
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INNOVATIVE TECHNOLOGY
Summary Report

PITBULLä Pump

Tech ID 2372

Tanks Focus Area

Demonstrated for
Savannah River Site
Aiken, South Carolina

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine whether a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that prospective users consider a technology.

Each report describes a technology, system, or process that has been developed and tested with funding from U.S. Department of Energy's Office of Science and Technology. Each report presents the full range of problems that a technology, system, or process will address and its advantages to site cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, worker safety, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the Office of Science and Technology Web site at www.em.doe.gov/ost under "Publications."

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SECTION 1
SUMMARY

Technology Summary

Problem
At the Savannah River Site (SRS), the target waste residual level for Tank 19 at the completion of retrieval operations is less than 1,000 gallons (WSRC 2001). This corresponds to residual less than 0.3 inch deep across the 85-foot-diameter floor of Tank 19. Conventional centrifugal pumps cannot lower the tank liquid level below 6 inches.

Solution
The PITBULL™ pump has been demonstrated to remove simulated waste material from a tank to a liquid level of 1 inch (Hatchell et al. 1998). When combined with a system such as the disposable crawler (Nance et al. 2000b) to move residual slurry to the PITBULL™ pump at a tank floor's lowest spot, an average of 0.3 inch of residual across the entire tank floor may be achievable.

Figure 1. PITBULL™ pump mounted to mast.

How It Works
The PITBULL™ pump is an air-operated, positive-displacement pump comprising a pump chamber, two check valves, and an air pressure/vacuum control system. The pump uses two distinct cycles, fill and discharge, to perform its pumping action. During the fill cycle, vacuum is applied to the pump chamber, which draws liquid into the chamber. When the liquid level inside the chamber reaches a sensing tube, the chamber is pressurized with compressed air to discharge the liquid out of the pump chamber and into the discharge line. Check valves are used at the pump chamber inlet and outlet to control the direction of flow. An air-powered vacuum pump at the control panel generates a vacuum in the airline. Maximum air pressure and discharge time are set at the control panel and can be adjusted depending on the liquid being pumped and discharge conditions. Deployment of the pump into a tank requires a mast (Figure 1).

Potential Markets
Retrieval systems that remove the last few inches of waste in a waste tank are needed at the Hanford Site and SRS. The PITBULL™ pump was installed in SRS Tank 19 in August 2000.

Advantages over Baseline
In addition to the ability to operate with a lower liquid level than conventional centrifugal pumps, the PITBULL™ pump has other advantages, including (1) the ability to discharge at a constant rate regardless of pumping demand; (2) the ability to self-prime; (3) the ability to ingest air without losing prime; and (4) a moderate degree of tolerance for debris.

Demonstration Summary

Testing performed at the Pacific Northwest National Laboratory between December 1997 and February 1998 evaluated the operating performance of a full-scale PITBULL™ pump under a variety of conditions and determined the likelihood of failure in extreme conditions (Hatchell et al. 1998). Waste simulant material used for the testing was selected to provide a range of both specific gravity and particle size to encompass the anticipated operating conditions in SRS Tank 19.

Key Results

Based on tests at a discharge head (elevation) of 43 feet, the pump can transfer slurries with a specific gravity between 1.0 and 1.2 and can transfer slurries with a specific gravity as high as 1.5. Fine and coarse sand with a particle size of 0.01–0.08 inch did not affect the pump performance. The addition of pea gravel with a particle size of 0.12–0.38 inch significantly degraded average pump performance in terms of average mass flow or volumetric rate. Trapped pea gravel eventually caused the discharge check valve to stick open, which caused most of the pumped material to flow back into the tank during the fill cycle.

Extreme condition tests sought to create blockages in the system that might occur by ingesting a large amount of solid material or by a flow interruption in which solids were allowed to settle in the pump chamber and discharge line. Solids settling in the chamber prevented the inlet check valve from opening. Solid accumulation in the discharge line was never a problem, even when blockages were created to test the flushing system. Flushing with water or compressed air through the air pressure and discharge lines was helpful in dispersing solids in the chamber and, to some extent, clearing the check valves.

During pump tests using kaolin clay, some clay migrated into the air line and was released into the air by the air ejector vacuum system jet. This problem will need to be addressed for similar radioactive service.

Commercial Availability and Readiness

The PITBULL™ pump is commercially available from the Chicago Industrial Pump Company. Demonstration testing was conducted using a full-scale pump specifically configured by the manufacturer for deployment through a 24-inch riser. This adaptation involved replacing the in-pipe suction check valve with a flapper check valve mounted in the bottom of the vessel.

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Other

All published Innovative Technology Summary Reports are available on the Office of Science and Technology Web site at www.em.doe.gov/ost under “Publications.” The Technology Management System is available at the same Web site under “Tools.” The Technology Management System contains information about Office of Science and Technology programs, technologies, and problems. The Tech ID for the PITBULL™ Pump is 2372.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

The PITBULL™ pump is an air-operated, positive-displacement pump comprising a pump chamber, two check valves, and an air pressure/vacuum control system (Figure 2). The pump chamber is designed with spacers, or feet, which hold the pump chamber an inch above the tank floor. The pump inlet is located in the center of the bottom of the pump chamber, an inch above the tank floor. This is a nonstandard configuration provided by the manufacturer. Two distinct cycles, fill and discharge, are used to perform the pumping action. During the fill cycle, vacuum is applied to the pump chamber, drawing liquid into the chamber. When the liquid level reaches a sensing tube, the chamber is pressurized with compressed air to discharge the liquid out of the pump chamber and into the discharge line. Check valves are used at the pump chamber inlet and outlet to control the direction of flow. An air-powered vacuum pump generates a vacuum in the air line. Maximum air pressure and discharge time are set at the control panel and can be adjusted depending on the liquid being pumped and discharge conditions.

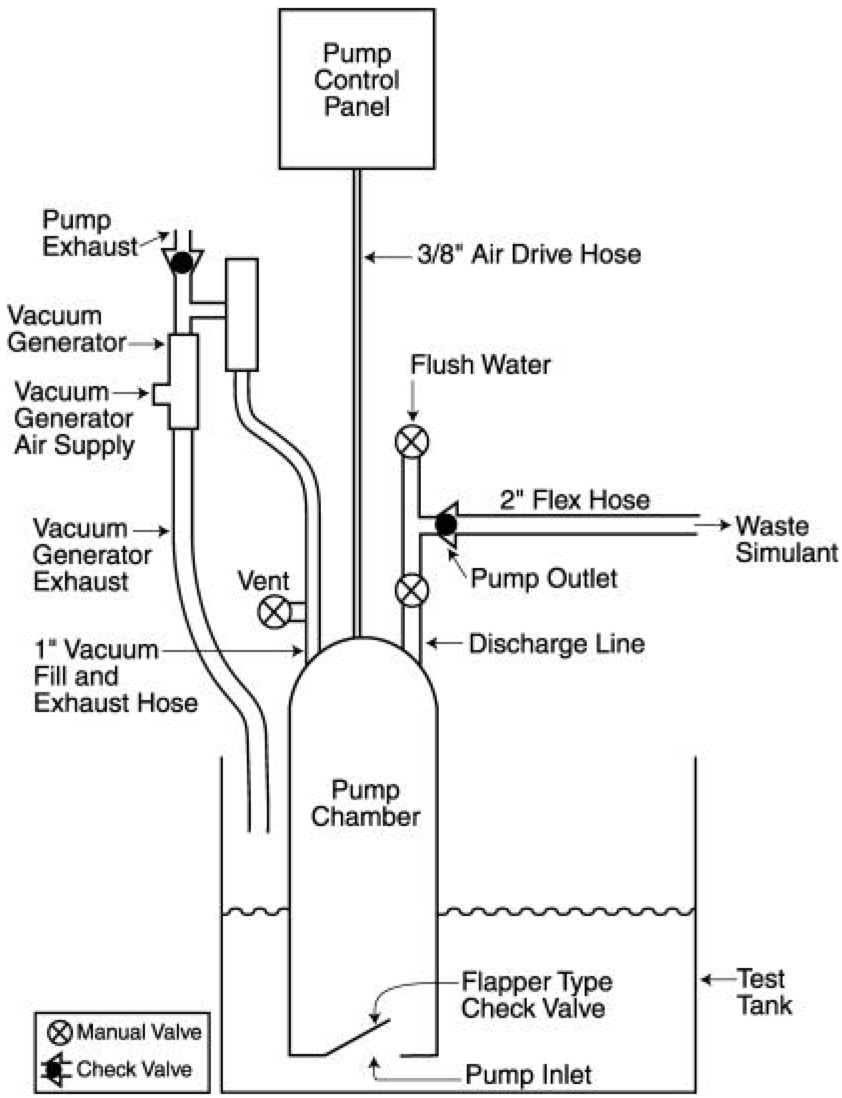

Figure 2. PITBULL™ pump schematic.

System Operation

The pump settings that can be varied are discharge pressure and discharge cycle duration. The vendor-recommended setting for the discharge pressure is 15 pounds per square inch above the calculated dynamic head required. The optimal setting will vary from site to site.

Special Operational Parameters
A clear landing zone is required to ensure that the pump inlet on the bottom of the pump chamber is unobstructed. Because the pump suction is not sufficient to affect a significant radius around the pump, another in-tank system is needed to move sludge to the pump inlet.

Materials, Energy, and Other Expendable Items
The air requirement for the pump depends on the discharge head and desired flow rate. For the conditions tested for SRS (100 gallons per minute flow rate at 43- and 100-foot discharge heads), an air supply between 30 and 60 standard cubic feet per minute is required. The inlet air pressure is regulated between 60 and 100 pounds per square inch.

Personnel Requirements
Installation of the PITBULL™ pump requires many of the same skills used for the placement of such in-tank equipment as jet mixer pumps, sluicing nozzles, and transfer pumps. Initial training is required for selecting and adjusting pump settings at the control panel to ensure smooth operation.

Secondary Waste Stream
Cleaning the check valves generates a small amount of liquid waste. Decontamination of the unit for use in a subsequent tank generates secondary liquid with some solids. Solid secondary waste may be generated from equipment maintenance as well as by carryover through the air exhaust.

Potential Operational Concerns and Risks
The pump has been designed and tested for conditions anticipated in SRS Tank 19. Different waste properties, waste chemistry, and configuration of the residual waste after current retrieval operations have been completed may impact the ability of the pump to reduce the residual waste liquid level.

Operational testing of the pump identified reliability concerns associated with the pump control system. Several instances of clogged tubing and leaks in the control system components resulted in improper cycling times, poor pump performance, and the inability to transfer waste during testing at the full-tank test facility.

The vacuum system used for the pump should be evaluated for the potential for waste to be inadvertently transported through the vacuum line. The pump eductor located inside a tank may generate aerosols in the tank being retrieved. Aerosols may also be a concern in the receiving tank. Aerosol generation is of concern due to the potential to overload a tank's ventilation system.

SRS evaluated the potential for airborne releases resulting from operation of the vacuum generator. Accidents associated with inadequate vertical separation between the waste and eductor, a plugged discharge line, or a leaking check valve in the discharge line have the potential to push waste into the suction line up to the level of the eductor. Authorization basis safety controls may be needed to protect against these potential accidents.

SECTION 3
PERFORMANCE

Demonstration Plan

Between December 1997 and February 1998, testing of the PITBULL™ pump was performed in a 1:12-scale test tank at Pacific Northwest National Laboratory's Fluid Dynamics Laboratory, located in the 336 Building at the Hanford Site (Hatchell et al. 1998). This cylindrical tank is 75 inches in diameter and 41 inches tall and has a maximum capacity of 790 gallons. When the pump was in the tank, the tank's capacity was reduced by 28 gallons. The pump was initially tested with water and slurry simulants. To evaluate the effects of large particles, sand and pea gravel were added to the slurry. The test matrix included closed-loop, steady-state tests to evaluate pumping rate and drawdown tests to evaluate the effect of low liquid levels. The pump and discharge lines were flushed as required with water and compressed air to clean internal pipe surfaces, dislodge blockages, and clear check valves. The test equipment, configuration, and simulants are discussed in the following sections.

Test Equipment

The pump used for testing was a custom unit developed by the Chicago Industrial Pump Company with input from SRS personnel. The chamber of this custom pump is 14 inches in diameter, 49 inches tall, and cylindrical to facilitate insertion through a tank riser (Figure 3). Located at the bottom of the pump is a 5-inch-diameter inlet equipped with a check valve. A 2-inch-diameter discharge check valve is located above the pump chamber. The pump chamber has spacers which rest on the tank floor. The spacers hold the pump chamber and inlet 1 inch above the tank floor. The discharge check valve is oriented horizontally to prevent solids from settling into the valve.

Figure 3. PITBULL™ pump.

Test Configuration

The pump was placed at the bottom of the 1:12-scale tank with the discharge located 43 feet above the inlet of the pump to simulate the head expected in Tank 19. The discharge line included connections to enable back and forward flushing. Flushing water or air could be introduced prior to the discharge check valve through the air pressure line and at the end of the slurry test pipeline. The pump control panel and air supply were located on the first floor, just above the top of the 1:12-scale tank (Figure 4).

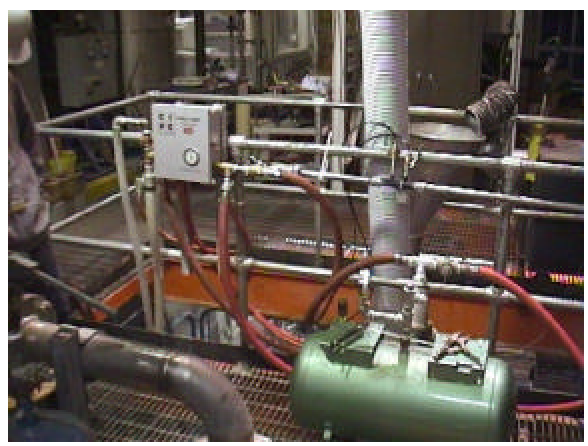

Figure 4. Pump controller and air supply.

Data collected during testing included supply air pressure, air pressure for drive phase, drive phase air flow rate, discharge pressure, and discharge slurry flow rate and density. The slurry receipt tank, used for the drawdown tests, was mounted to three load cells, which were used to calculate mass flow rate. This data was compared to the mass flow output data from the instrumented slurry test pipeline.

Materials Tested

Table 1 shows the composition of the materials prepared to evaluate the impact of specific gravity on pump performance. The range of specific gravity was based on the anticipated property for waste slurry in Tank 19. Residual material may contain sludge and zeolite particles. The zeolite particles were reportedly added to the tank as 20–50 mesh particles. However, it is possible that the zeolite may have undergone some consolidation and/or reactions that yielded larger particles.

Table 1. Materials prepared to test impact of specific gravity

Test materia l	Material components	Component specific gravity	Component weight percent	Calculated mixture specific gravity
1	Water	1.00	100.0	1.0
2	Water Silica	1.00 2.65	85.4 14.6	1.1
3	Water Silica Kaolin	1.00 2.65 2.64	70.5 25.8 3.7	1.2

Silica was chosen as a test component because the fine particle size reduces the rate of particle settling and the addition of silica creates a low-viscosity slurry that reduces the likelihood of air retention. Pump recirculation and air lances were used to suspend the silica in solution. As the specific gravity was increased to 1.2, it was necessary to add a small amount of kaolin to reduce the hardness of the settled material and to minimize the settling rate. The mixture specific gravity was a calculated value.

Testing the pump with hard, fast-settling solids represented the greatest challenge for the pump, as solids tended to jam the check valves or create blockages in the discharge line. To determine the ability of the pump to handle coarse materials, fine sand, coarse sand, and pea gravel were successively added to test material #3. The size of the fine sand was 0.01–0.03 inch in diameter and was similar to unreacted zeolite. The size of the coarse sand ranged 0.04–0.08 inch, while the size of the pea gravel ranged 0.12–0.38 inch. Prior to pump tests, the solids were dumped in small piles on both sides of the pump inlet, submerged under a layer of slurry, and then introduced into the pump with air spargers during pump operation.

Demonstration Summary

A total of 39 data sets were collected during the testing to measure the expected operating performance of the pump under a variety of conditions and to determine the likelihood of failure in extreme situations (Hatchell et al. 1998). Results from the testing are provided in the following sections that discuss pumping rate, pumping solid materials, and considerations for remote operation.

Pumping Rate

Based on vendor information, the recommended setting for the discharge pressure was 15 pounds per square inch above the calculated dynamic head required for the application. For the configuration tested, this corresponded to a setting of 45 pounds per square inch. Test results showed the maximum mass flow increased with greater pressure setting, although the average mass flow was not significantly affected. A pressure setting of 55 pounds per square inch was found to provide a modest improvement in average flow rate. For each discharge pressure, the discharge cycle duration required adjustment to provide a smooth discharge flow profile. Note that the setting for the discharge cycle duration is dimensionless. The time for the discharge cycle is a function of the properties of the material being pumped. For example, a control panel discharge setting of 25 corresponds to 5.1 seconds for water.

Continuous, closed-loop pump tests were conducted to determine the effect of specific gravity on pump performance. Table 2 shows the average pump performance data during steady-state operations for the three materials tested. In addition, performance data is shown in Table 2 for tests involving test material #3 and the added larger-particle material. The average mass flow rates were identical for test materials #1 and #2 and decreased slightly for the denser test material (#3). This effect was likely due to the presence of the small amount of kaolin, which increased the viscosity of test material #3 relative to the other two. As expected, the volumetric flow of slurry decreased with increasing specific gravity. The results for tests with sand and pea gravel are discussed in the next section.

For pump drawdown tests using test materials #1, #2, and #3, data indicated that (1) pump performance decreased rapidly for tank liquid levels below 2 inches due to air ingestion and (2) high liquid levels did not improve pump performance. The final liquid level in the tank was approximately 1 inch for each of the three materials tested. Because the pump is intended to be operated for significant periods of time with minimal liquid in a tank, it is important to note that vortexing of liquid at the pump inlet and air ingestion will decrease pump performance at low liquid levels.

Table 2. Average pump performance data during steady state operating conditions

Data	Units	Test material #1 (water)	Test material #2 (water, silica)	Test material #3 (water, silica, kaolin)	Test material #3 with fine sand and coarse sand	Test material #3 with fine sand, coarse sand, and pea gravel
Specific gravity	Average	0.997	1.077	1.180	1.177	1.041
Discharge time	Setting	25	25	25	25	25
Discharge pressure	Setting, psi	55	55	55	55	55
Supply air pressure, gauge	Max, psi Min, psi Ave., psi	96 84 91	94 84 89	97 88 93	94 83 89	95 85 91
Air flow	Max, SCFM	NA	103	110	109	125
	Min, SCFM	NA	47	50	47	47
	Ave., SCFM	NA	72	73	70	69
Period	Ave., sec	9.1	15.3	12.2	12.3	17.5
Fill time	Ave., sec	4.0	7.1	6.1	5.9	11.5
Discharge time	Ave., sec	5.1	8.1	6.1	6.3	6.0
Mass flow	Ave., lb/min	583	583	530	544	320
Volumetric flow	Ave., gpm	70	65	54	56	37

psi = pounds per square inch
SCFM = standard cubic feet per minute
gpm = gallons per minute

Pumping Solid Materials

Addition of fine sand to the test material #3 did not affect pump performance, as the results were almost identical to those for test material #3 without fine sand. Average results for the addition of coarse sand and pea gravel to test material #3 are shown in Table 2. Results using test material #3 with added fine and coarse sand did not degrade pump performance in terms of mass and volumetric flows. However, the presence of coarse sand did cause the discharge check valve to take longer to close and to audibly chatter. During a 4-hour endurance test, vibration from the check valve attempting to seat was enough to cause hose fittings to loosen. Flushing the check valve with water was effective at clearing the sand from the check valve, eliminating the chatter.

The presence of pea gravel in the slurry mixture significantly degraded the average pump performance in terms of average mass and volumetric flow. The discharge check valve oscillated during the fill cycle, which resulted in significant slurry backflow. Check valve blockage also caused fluctuations in the discharge flow rate. Flushing with water was not an effective means for clearing pea gravel from the check valves. The pump in the configuration tested did not reliably pump slurry containing pea gravel. Alternative seal materials for the check valve (rubber was used for testing) such as urethane or aluminum may be needed when pumping slurries containing harder materials such as pea gravel.

Considerations for Remote Operations

During initial tests with water/silica slurries, water vapor condensed and froze in the pump exhaust valve. As icing occurred, the time required to fill the chamber increased, while the average flow rate decreased. Replacement of the stainless steel exhaust valve with a larger aluminum valve eliminated the icing problem. For the aluminum valves, rubber seals were installed for the joints between the valve body and flange connections to address leakage observed for these areas during operation.

During most of the pump tests, the pump chamber was secured to the test tank with straps to prevent it from moving or tipping. For one test, the straps were removed to determine whether the pump would tend to topple during operation due to surging of material into the discharge line. The pump was operated for 10 minutes and showed no tendency to move or tip over.

The pump chamber exhaust was routed through the exhaust valve, vacuum generator, and a long hose (to attenuate sound) and directed back into the tank. During pumping, the exhaust contained up to 2.5 liters per minute of water. Silica was found inside the exhaust valve, indicating the presence of solids in the aerosols as well. The amount of aerosols appeared to increase with discharge pressure. For the installation of the pump in SRS Tank 19, the exhaust line was directed back into the tank. Follow-on work at SRS quantified the performance of the pump vacuum system under off-normal conditions. Tests showed that 88–95% of liquid drawn through the eductor would be returned to the tank, leaving 5–12% assumed to be atomized (Duignan 2000). The concern is whether or not aerosols will be sufficient to justify a condenser, demister, and heater in the ventilation system to protect the operational integrity of the HEPA filter.

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Technology Applicability

The PITBULL™ pump is well suited for in-tank operation and can transfer slurry with a range of specific gravity and solid loadings without any adjustments. The unit has few moving parts, is easy to control, and operates on vacuum and compressed air. The ability to monitor discharge flow rate, pump chamber pressure, and slurry specific gravity was useful in diagnosing problems encountered during testing. Measurement of these parameters should be considered for deployment of the pump.

Testing showed that pump performance was significantly reduced by the presence of pea gravel in the slurry mixture. Applications with hard and/or large-particle waste material may require further testing to ensure adequate pump performance. Multiple pumps may be needed for a given application if the method used for pushing waste to the pump uses a water flow rate greater than the pump capacity. An average volumetric flow rate of 70 gallons per minute was measured using water to push solid waste.

The pump was successfully operated with initial liquid levels of 18 inches and was capable of reducing the liquid level to approximately 1 inch. Use of the pump may be possible with deeper initial liquid levels. However, the relatively low volumetric flow rate of the PITBULL™ pump compared to other transfer pumps makes the use of this pump for deeper liquid levels less attractive.

To be effective, the pump needs to rest at or near the tank bottom due to the small suction zone of influence the pump has for waste solids. Consequently, this technology should be used only in tanks without cooling coils on the tank bottom.

Baseline Technologies

Three types of transfer pumps are used within the Department of Energy complex for waste retrieval activities: vertical turbine pump, submersible pump, and eductor pumping system. A brief discussion of each type and its limitations is provided below.

Vertical Turbine Pump
A vertical turbine pump unit consists of a motor mounted on the top of a long drive shaft that turns a series of impellers located at the bottom of the pump assembly and along the drive shaft. The impellers are mounted in bowl assemblies commonly referred to as “stages.” Multiple stages can be used to deliver the desired flow rate and meet head requirements. The vertical turbine pump used in the large waste tank at the West Valley Demonstration Project (West Valley) in New York has 13 stages (Hamel, McMahon, and Meess 2000). A vertical turbine pump is capable of removing liquid down to the point where the bottom impeller or stage is uncovered. Once the liquid level falls below the midpoint of the bottom impeller, the pump is unable to remove additional liquid. At Hanford, the pump inlet and height of the bottom impeller are typically greater than 7 inches. At West Valley, the transfer pump was operated at a typical volumetric flow rate of 100 gallons per minute.

Submersible Pump
A submersible pump consists of a compact pump and motor assembly entirely submerged in, and cooled by, the liquid being pumped. The pump bearings are lubricated and cooled during normal operation by the pumped media. A suction screen is located on the bottom of the pump to prevent solids greater than 0.25 inch in diameter from entering the pump. The submersible pump can be installed within 2 inches of the bottom of the tank and is capable of drawing down the tank volume to a level of uncovering the pump suction without damage to the pump assembly. However, if the liquid level in the tank is drawn down to a level between the first stage impeller (typically 7-inch depth) and the pump suction (2-inch depth) and the pump operation is shut down, the pump will not be able to restart. The pump does not have the ability to create its own suction lift unless the first stage impeller is submerged in liquid. This limitation would require the addition of material to the tank to a level above 7 inches. At Hanford, a submersible pump was designed and

deployed for use in tank 241-SY-101 for retrieval operations conducted December 1999 to April 2000 (Mahoney et al. 2000). The typical transfer volumetric flow rate was between 100 and 120 gallons per minute for the 241-SY-101 project.

Eductor Pumping System

An eductor operates by passing a motive fluid (typically water or air) under pressure through the eductor inlet to a nozzle that converts the motive fluid into a high-velocity stream. The increase in fluid velocity through the eductor creates a decrease in pressure in the suction chamber part of the eductor. Material is drawn into the suction chamber and mixed with the motive fluid. The mixture of motive fluid and material is discharged through the eductor outlet. A recirculating eductor relies on a closed loop to recirculate the motive fluid/material mixture repeatedly through the eductor. A valve downstream of the recirculating pump is used to bleed material out of the loop at the rate that material is recovered. The saltwell pumping system used as the Hanford baseline for the Single-Shell Tank Interim Stabilization Project (Ross et al. 1998) is an example of a recirculating eductor pumping system. Solids larger than 0.05 inch in diameter are screened from entering the saltwell pumping system. The suction inlet is typically located 7 inches from the tank bottom. A volumetric flow rate of 2–4 gallons per minute is typical for existing Hanford saltwell pumping units.

Competing Technologies

Remediation of the Gunite and Associated Tanks at Oak Ridge Reservation (ORR) in Tennessee used a number of technologies to successfully clean eight underground storage tanks (Roeder-Smith 2001). One of the technologies successfully deployed was the tank waste dislodging and conveyance system, which included a confined sluicing end effector (OST 1998a), a hose management system, and a flow control equipment and containment box. The dislodging and conveyance system was designed for deployment with either a long-reach manipulator like the Modified Light-Duty Utility Arm (OST 1998b) or a remotely operated vehicle system such as Houdini™ (OST 1999). An in-line, radial jet pump located inside the deployment mast for the hose management system sucks waste from the end effector and pumps it to a flow control box located on the surface of the tank. The jet pump is an axial-flow, water-powered eductor that utilizes 4,000–8,000 pounds per square inch water to produce a vacuum for removing waste from the tank.

For the gunite tank remediation project, the tank waste dislodging and conveyance system was most efficient at removing sludge when the waste material was deep enough to partially submerge the end effector, thus avoiding three-phase (solid, liquid, gas) pumping (Lloyd et al. 2001). For the last 1–3 inches of tank waste, the most productive method of operation was to have the Houdini™ crawler plow “waves” of waste to the end effector (held by the Modified Light-Duty Utility Arm). The residual waste volume remaining in the tanks, which were either 25 feet or 50 feet in diameter, was about 0.5% for each tank.

Patents/Commercialization/Sponsor

The Tanks Focus Area provided funding for the development and performance testing of the PITBULL™ pump technology. Testing performed at the Pacific Northwest National Laboratory involved correspondence with the Chicago Industrial Pump Company, the commercial vendor for the PITBULL™ pump. The SRS operations contractor provided functional requirement input. The performance test utilized a full-scale prototype and commercially available components.

SECTION 5
COST

Methodology

The PITBULL™ pump is intended for use after bulk waste removal from a tank using baseline methods such as jet mixer pumps for waste dislodging and mobilization and centrifugal transfer pumps for waste removal. Based on this anticipated application, it is not appropriate to compare the costs of the PITBULL™ pump with the baseline waste-retrieval methods. A more appropriate cost comparison is with the waste conveyance portion of the tank waste dislodging and conveyance system used for the Gunite and Associated Tanks remediation project at ORR because it can remove the last few inches of residual waste from the floor of a tank.

Cost Analysis

Information provided by SRS indicates a capital cost for the PITBULL™ pump of less than $10,000. Costs for a deployment mast and aboveground support equipment, such as a generator, air compressor, and trailer to house control equipment, were not readily available. If wet sludge must be pushed to the PITBULL™ pump, a disposable crawler would add approximately $100,000 to the overall cost, providing that lights and cameras were already installed (Nance et al. 2000a).

Using information for systems used at Hanford, the following capital costs were estimated for each of the three baseline technologies: vertical turbine pump—$300,000, submersible pump—$750,000; and eductor pumping system—$20,000. Cost information for support equipment necessary for the operation of the three baseline systems was not identified.

The capital cost for a competing technology, the waste dislodging and conveyance system used at ORR, is less than $750,000 (Lloyd et al. 2001). The waste conveyance portion includes the following three primary hardware subsystems: the hose management system including a jet pump for waste conveyance, the confined sluicing end-effector (cost about $100,000), and the flow control equipment and containment box. In addition, a decontamination spray ring and a control system were developed for the ORR application. The waste dislodging and conveyance system was designed for deployment in conjunction with either a long-reach manipulator like the Modified Light-Duty Utility Arm (cost about $1,900,000) or a remotely operated vehicle system such as the Houdini™ crawler (cost about $1,200,000). These separate deployment systems provide the ability to reach a greater portion of the tank floor (OST 1998b, OST 1999).

Cost Conclusions

The PITBULL™ pump is a commercially available, low-cost, off-the-shelf technology. Relative to the baseline technologies, the pump is significantly lower in cost than the large-flow pump systems (vertical turbine and submersible pumps). Capital costs for the PITBULL™ pump are similar to those for the eductor pumping system. The advantage of the PITBULL™ pump over the eductor pumping system is the ability to handle solids. The simple design of the PITBULL™ pump results in a significantly lower cost than for competing technologies like the waste dislodging and conveyance system deployed in ORR tanks.

The role of a PITBULL™ pump is to transfer waste out of a tank. If the waste is only liquid, the liquid will naturally flow to the PITBULL™ pump for transfer out of the tank. If the waste is a sludge layer, another technology, such as the disposable crawler, must be deployed to move the sludge close enough to be pumped by the PITBULL™ pump. Another option is to use mixers to slurry the sludge into a mobile liquid phase, which will then flow within suction range of the PITBULL™ pump.

For each future application, the cost advantage of the PITBULL™ pump will be a function of the dislodging and mobilization method selected to move the waste to the transfer pump location. If the waste dislodging and mobilization method needed requires a long-reach manipulator arm and end effectors with a transfer pump (e.g., confined sluicing end effector), then that technology can be used to reach all parts of the tank floor. In that scenario the PITBULL™ has no cost advantage. However, if a floor-level spray system such as the disposable crawler will meet the waste dislodging and mobilization needs for a tank, then the PITBULL™ pump becomes a more attractive option because of its simple design and corresponding low cost.

SECTION 6
OCCUPATIONAL SAFETY AND HEALTH

The baseline methods for removing waste from large-diameter underground storage are vertical turbine pumps, submersible pumps, and eductor pumping systems.

Comparison with Baseline Operating Safety

The typical tank configuration for waste retrieval involves the use of a single transfer pump, usually located at the center or low point of the tank. At West Valley, one long-shafted, vertical turbine transfer pump is installed in Tank 8D-2 (Hamel, McMahon, and Meess 2000). This pump has a shaft approximately 40 feet long, driven by a 20-horsepower motor located in a remote, shielded pump pit. The pit houses the pump head, discharge piping, motor, and transfer lines. Also located in the pump pit is an in-line grinder to size-reduce waste material and its motor and cooling water lines. Installation of the pump required a crane.

Installation of the PITBULL™ pump will also require a crane in a similar manner as for baseline transfer pumps. The pump itself is mounted to a mast that is of sufficient length to enable the pump to be lowered to the bottom of a tank. In addition to the at-tank support for the mast, support equipment for the PITBULL™ pump includes the control panel and a vacuum source. For the projected conditions at SRS, 100-gallon-per-minute flow rate with 43- and 100-foot discharge heads and an air supply capable of 30–60 standard cubic feet per minute are required. The inlet air pressure is regulated 60–100 pounds per square inch.

Comparison with Baseline Maintenance Safety

Maintenance requirements for the in-tank portion of the PITBULL™ pump are anticipated to be less than for the baseline transfer pump. The in-tank portion of the PITBULL™ pump has few moving parts and does not use impellers. The only moving parts are two check valves, which require occasional cleaning by a remote flush procedure. Maintenance of the at-tank components such as the control station, vacuum supply, and flushing system include unplugging control system lines, repairing line leaks, and replacing seals in the vacuum-line shutoff valve. As an example of baseline maintenance experience, the postulated cause for the failure of the original West Valley vertical turbine transfer pump was either severe bearing wear in the region of the 13-stage impeller section or damage to one of its impellers.

Required Safety and Health Measures

During the PITBULL™ pump demonstration, the pump chamber exhaust was routed through the exhaust valve, vacuum generator, and a long hose (to attenuate sound) and directed back into the tank. During pumping, the exhaust contained up to 0.65 gallons per minute of water. Silica was found inside the exhaust valve, indicating that solids were present in the aerosols as well. The amount of aerosols appeared to increase with discharge pressure. For the installation of the pump in SRS Tank 19, the exhaust line was directed back into the tank. Follow-on work performed at SRS quantified the performance of the pump vacuum system under off-normal conditions to evaluate potential waste loading of the tank ventilation system (Duignan 2000). Authorization basis safety controls were established to protect against potential waste aerosolization accidents in off-normal conditions. Additional precautions associated with the mechanical movement of equipment and pressurized lines on top of the tank should be reflected in operating procedures and operator training.

Safety Lessons Learned from Demonstration of Technology

Based on the results of tests performed at the Pacific Northwest National Laboratory, the following recommendations were identified to improve the PITBULL™ pump and prepare the system for deployment:

- Replace the original stainless steel exhaust valve with a larger aluminum valve to reduce the likelihood of icing. Consider adding gaskets between the valve body and mating flanges.

- Make improvements to the check valve to improve the ability to pump slurries containing hard solids.

- The discharge cycle is terminated by a timer and not by a level sensor. In situations where the pump is operated for long periods without surveillance, it appears likely that the pump will inject air into the discharge line, which could result in a water hammer effect. If this is undesirable, a low-level bubbler could be added to the pump.

- The vendor recommends aluminum sealing surfaces, rather than the specified nitrile used on the pump for the SRS application, for pumping slurries containing harder materials.

- To reduce the accumulation of solids in the pump chamber, consideration should be given to reducing the distance between the discharge pipe and the chamber bottom (the current distance is 2.5 inches). Alternatively, air nozzles could be incorporated into the chamber to suspend solids.

SECTION 7
REGULATORY AND POLICY ISSUES

Regulatory Considerations

Regulatory acceptance of the PITBULL™ pump is not considered a potential issue. This expectation is based on the extensive commercial use of similar pumps to perform a variety of commercial applications. Results from the performance testing are most applicable for SRS, but are also useful for the Hanford underground storage tanks.

Secondary Wastes
Operation of the PITBULL™ pump is not anticipated to create a significant secondary waste stream. Solid and liquid secondary waste may be generated if the pump requires decontamination to perform maintenance prior to completion of a retrieval operation. The quantity of secondary waste generated from the operation of the PITBULL™ pump is not anticipated to be greater than that generated from other in-tank systems.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Evaluation

Note that only ORR is remediating underground storage tanks under CERCLA. Hanford and the Idaho National Environmental Engineering Laboratory are satisfying Resource Conservation and Recovery Act requirements, while SRS is satisfying state wastewater requirements.

This section summarizes how the PITBULL™ pump addresses the nine CERCLA evaluation criteria.

1. *Overall Protection of Human Health and the Environment*
   Use of the PITBULL™ pump is envisioned to result in a greater percentage of material being retrieved from waste tanks with minimal additional worker exposure.

2. *Compliance with Applicable or Relevant and Appropriate Requirements*
   The pump was designed to meet SRS requirements. Compliance issues with deployment of the unit in Tank 19, or other tank, are not anticipated. Further evaluation is needed for application of the unit for waste with properties different from those tested.

3. *Long-Term Effectiveness and Permanence*
   Use of the PITBULL™ pump is envisioned to result in a greater percentage of material being retrieved from waste tanks, thus reducing the long-term risk from residual tank waste material by minimizing the quantity of material left in a tank.

4. *Reduction of Toxicity, Mobility, or Volume Through Treatment*
   Use of the PITBULL™ pump is envisioned to result in a greater percentage of material being retrieved from waste tanks, thus reducing the quantity of residual tank waste material. The reduction of the quantity of residual tank waste material should therefore improve the performance of a tank closure method for reducing toxicity and mobility of residual waste.

5. *Short-Term Effectiveness and Permanence*
   SRS evaluated the potential for airborne releases resulting from operation of the vacuum generator. Accidents associated with inadequate vertical separation between the waste and eductor, a plugged discharge line, or a leaking check valve in the discharge line have the potential to push waste into the suction line up to the level of the eductor. Authorization basis safety controls may be needed to protect against these potential accidents. Secondly, follow-on work performed at SRS quantified the performance of the pump vacuum system under off-normal conditions to evaluate potential waste loading of the tank ventilation system (Duignan 2000). Authorization basis safety controls were established to protect against potential waste aerosolization accidents in off-normal conditions.

6. *Implementability*
   Performance testing of a full-scale prototype of the PITBULL™ pump showed that the unit is capable of meeting performance requirements for the SRS Tank 19 application. Further evaluation is recommended to ensure the compatibility of equipment with tank-specific requirements and appropriateness of equipment for a specific tank waste.

7. *Cost*
   The PITBULL™ pump represents a low-cost method to increase the amount of waste that can be retrieved from a tank.

8. *State Acceptance*
   No issues are anticipated for state acceptance of this pump system because similar systems have been used commercially for nonradioactive underground storage tanks. In addition, the deployment of the PITBULL™ pump would enable a site to meet tank cleanup criteria should the baseline methods be inadequate.

9. *Community Acceptance*
   No issues are anticipated for community acceptance of this pump system because similar systems have been used commercially for nonradioactive underground storage tanks.

Safety, Risks, Benefits, and Community Reaction

These topics are addressed earlier in this section and in Section 6, Occupational Safety and Health. Site- and tank-specific requirements will dictate any necessary modifications to the PITBULL™ pump prior to deployment.

SECTION 8
LESSONS LEARNED

Design and Implementation Considerations

Based on the results of tests performed at the Pacific Northwest National Laboratory, the following recommendations were identified to improve the PITBULL™ pump and prepare the system for deployment (Hatchell et al. 1998).

- Replace the original stainless steel exhaust valve with a larger aluminum valve to reduce the likelihood of icing. Consider adding gaskets between the valve body and mating flanges.

- Make improvements to the check valve to improve the ability to pump slurries containing hard solids.

- The discharge cycle is terminated by a timer and not by a level sensor. In situations where the pump is operated for long periods without surveillance, it appears likely that the pump will inject air into the discharge line, which could result in a water hammer effect. If this is undesirable, a low-level bubbler could be added to the pump.

- The vendor recommends aluminum sealing surfaces, rather than the specified nitrile used on the pump for the SRS application, for pumping slurries containing harder materials.

- To reduce the accumulation of solids in the pump chamber, consideration should be given to reducing the distance between the discharge pipe and the chamber bottom (the current distance is 2.5 inches). Alternatively, air nozzles could be incorporated into the chamber to suspend solids.

The above tests demonstrated the presence of liquid carryover in the pump exhaust. During pumping, the exhaust contained up to 0.65 gallons per minute of water. Although the pump exhaust for the Tank 19 installation at Savannah River was directed back into the tank, there was a concern regarding aerosol generation.

Tests at the Savannah River Technology Center revealed that 5–12% of liquid passing through the eductor was atomized. Future applications need to consider the generation of aerosols and the ability of the ventilation system to remove aerosols with demisters and condensers prior to HEPA filtration.

Technology Limitations and Needs for Future Development

A clear landing area is required for optimum performance in reducing the residual waste level to less than 1 inch in depth. If the feet of the pump chamber rest on objects or a buildup of hard sludge, the residual waste level will be the height of the pump inlet, which could be inches above the tank floor in such circumstances. Compatibility of pump parts with waste properties needs to be evaluated for individual tank applications.

Technology Selection Considerations

The PITBULL™ pump provides a waste conveyance method that can operate with minimal liquid in a tank. This piece of equipment also provides a means for pumping out the contents of a tank with a minimal residual liquid level. However, the pump must be combined with a waste dislodging and mobilization method that is capable of moving waste to the pump inlet.

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APPENDIX A
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APPENDIX B
ACRONYMS AND ABBREVIATIONS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
ORR	Oak Ridge Reservation
SRS	Savannah River Site