AN INNOVATIVE WASTE RETRIEVAL SYSTEM FOR DEEPLY BURIED, RESTRICTED ACCESS TANKS

J.A. Faldowski, M.C. Williams, S.A. Taylor
AEA Technology Engineering Services, Inc.

ABSTRACT

An innovative pumping and retrieval system has been designed and built, demonstrating an engineered approach to solving the difficult problems associated with waste recovery from deeply buried radioactive waste storage tanks with limited and/or difficult access. The system, which incorporates novel technology applicable to a wide array of tank retrieval applications, was manufactured specifically to retrieve the waste from the Decant Sump Tank (DST) on the Fernald Closure Site.

The DST presented a challenging retrieval problem because of its unique access configuration. The DST is a 9-feet diameter, 18-feet long carbon steel cylindrical horizontal direct buried tank. It is located under the earth berm currently supporting Silos 1 & 2 and is connected to the surface via a 30-inch diameter corrugated galvanized steel riser. The riser terminates approximately 33 feet below grade, where the interface with the DST is via a 20-inch diameter man way located in the center of the corrugated riser, but off tank center. Further complicating entry into the tank is a bend or bow in the corrugated riser due to earth movement during berm construction.

The innovative pumping and retrieval system designed and built to retrieve waste from the DST utilizes a modular design comprising a Power Fluidic™ Pumping Module deployed into the tank. The operating and control systems including pipework, valves, instrumentation, and operator station for this module are housed in two 20-foot ISO Containers located above the corrugated riser. The Pumping Module is a compact unit, measuring 18-inches in diameter, designed to navigate around the bow in the riser and be self-guiding into the 20” man way connected to the tank. The module is equipped with cameras that provide remote 360^{o} viewing of the inside of the tank during retrieval operations.

The Power Fluidic™ Pumping Module directs the free liquid in the tank through articulated nozzles to remove waste from the walls and mobilize the sludge in the tank. The system recycles the free liquid already in the tank thereby minimizing water additions and secondary waste generation.

INTRODUCTION

The Fernald Closure Site is working to an aggressive accelerated closure schedule. A major milestone on the schedule is the retrieval and packaging of waste from Silos 1 & 2. This project comprises retrieving the sludge waste from two earthen-berm silos, transferring it to a purpose-built waste treatment and packaging facility and transporting it off site. Following waste retrieval from Silos 1 & 2, they will be decommissioned and removed. Clean out and removal of The Decant Sump Tank (DST), installed to accept the decanted liquid from the Silos, presented an obstacle on the critical path not only to the Silos 1 & 2 cleanup project but to the Fernald Site closure plan.

The DST presented a challenging retrieval problem because of its unique access configuration. The DST is a 9-feet diameter, 18-feet long carbon steel cylindrical horizontal direct buried tank. It is located under the earth berm currently supporting Silos 1 & 2 and is connected to the surface via a 30-inch diameter corrugated galvanized steel riser. At the bottom of the riser, approximately 33 feet below grade, the interface with the DST is via a 20-inch diameter man way located in the center of the corrugated riser but off tank center. Further complicating entry into the tank is a bend or bow in the corrugated riser due to earth movement during berm construction. The bow has been estimated by site personnel to be 22^o and located 22’ below the top of the corrugated riser.

Although the liquid waste in the DST has been retrieved at regular intervals using a mechanical pump, a layer of sludge has built up in the tank over many years. This waste must be removed prior to final tank disposition. This layer of sludge could not be retrieved using the conventional mechanical pump currently installed in the tank. AEA Technology designed and fabricated a Power Fluidic™ system to mobilize the tank contents and clean visible waste from the inside surfaces of the tank. The system is also required to retrieve the sludge from the DST and transfer it to the Site Remediation Facility. The Power Fluidic™ Pumping Module is custom engineered for deployment into the tank via cable including by navigating around the bend in the corrugated riser and remotely self-centering into the 20” tank manway at the bottom.

Track Record Of Tank Retrieval using POWER Fluidics ™

Power Fluidics™ is the generic name for a range of maintenance free equipment built around the common principle of using one medium, most commonly air, to move fluids (Reference 1). In radiological applications, these fluids are mainly radioactive liquids or sludge. Fluidic devices generally have no moving parts in contact with process fluid and therefore require no maintenance of contaminated equipment. Significant cost and safety benefits are achieved by using Power Fluidic devices in place of their mechanical equivalents.

Since the mid 1990’s AEA Technology (AEAT) has successfully deployed Power Fluidics™ Tank Waste Mixing and Retrieval Equipment for mixing and retrieval of waste from tanks and silos across the United States Department of Energy (US DOE) complex, with an inventory ranging up to 100,000 gallons. Systems have also been developed to retrieve waste from facilities with storage capacities up to 1 million gallons. This technology has demonstrated numerous and significant advantages over “past practice sluicing” and other alternative retrieval technologies. Power Fluidics™ Tank Waste Mixing and Retrieval Equipment has been successfully used to remove the bulk of the waste from the following tanks: Oak Ridge National Laboratory (ORNL) BVEST Tanks W21, W22, W23, C1, C2, T-

1, T-2, Capacity Increase Tanks at Oak Ridge, and Pump Tank 1 at Savannah River. In each case, the projects were performed below the baseline costs and ahead of the baseline schedules.

Tank waste retrieval operations using fluidic equipment have recently been completed at Los Alamos National Laboratory, Idaho National Engineering Laboratory, Oak Ridge National Laboratory and a prototype 1 million gallon tank fluidic retrieval system deployed at the Hanford Site Cold Test Facility in late 2003.

Principles of Power Fluidic™ Technology

Power Fluidics™ pumps have been operating in UK nuclear plants since 1970. The technology is proven across a range of fluidic devices and applications and is standard technology in UK nuclear facilities.

Power Fluidics™ pump systems mobilize waste via a three phase process:

- Suction phase
- Drive phase
- Vent phase

The main elements of a Fluidic Pump are a Charge Vessel, Jet Pump Pair (JPP), Reverse Flow Diverter (RFD), and a Control System.

All fluidic pumping systems use compressed air, regulated by standard valves and instrumentation, as the motive force for the movement of the process liquid. Each system features a pressure vessel, called a Charge Vessel, which is a fluid reservoir that is filled or discharged by the evacuation or pressurization of the void space above the liquid level. The control of the air into and out of the Charge Vessel is accomplished using the Jet Pump Pair (JPP), designated the fluidic system Primary Controller. The JPP comprises two back-to-back ejector elements. Its purpose is to:

- Produce a partial vacuum in the charge vessel during the suction phase
- Supply a positive air flow and pressure to the Charge Vessel during the drive phase
- Provide a vent path for the air during the vent phase

The internal geometry of the device is specially designed for each installation to fulfill these roles.

The RFD is an engineered component designed as a passive (i.e. no moving parts) valve which allows material to be drawn from the waste tank into the Charge Vessel and subsequently discharged from the Charge Vessel into the transfer line.

The equipment upstream of the Jet Pump Pair is designated the fluidic system Secondary Controller. Its purpose is to:

- Control the duration of the drive phase and supply compressed air to the "drive" part of the JPP during this phase
- Control the duration of the vent phase and switch off the air supply to the JPP during this phase

- Control the duration of the refill phase and supply compressed air to the "suction" part of the JPP

The compressed air on/off control is accomplished using conventional actuated valves, which handle only clean air and are installed in an accessible position so that maintenance can be performed.

The sequencing of the valves and setting of phase durations are regulated electronically by AEAT’s PRESCON™ controller[a]. The PRESCON™ computer both analyzes the input from the process instrumentation and controls the sequencing and operation of the plant. It determines when the charge vessel is full and sets the datum point for the start of each cycle. It accomplishes this by analyzing the pressure signals from the compressed air line and is thus totally non-intrusive.

The controller automatically compensates for variations in the system (e.g., changes in liquid level and specific gravity) and so maintains the fluidic system operation at optimum efficiency. In addition, the enhanced software monitors process loops, checking for drift of pressure transducers, integrity of signal loops and other input, and provides a continuous health check on the system.

DST Bulk Waste Retrieval System Principal Components

The mobile fluidic system deployed in the DST consists of the following modules, or skids:

- In-Tank Module (Power Fluidic™ Pumping Module)
- Control Skid
- Jet Pump Skid

The Control skid and Jet Pump skid are located above ground adjacent to the tank, connected by the requisite electrical and instrument cables, and flexible hoses for air, water, and slurry/sludge. The system is controlled using a control system housed in one half of the control skid. As Radon generated by the silo waste is a major concern, ventilated air from the system is discharged into the Site Radon Control System, or RCS.

The in-tank module includes the Charge Vessel, RFD, two wash nozzles, and two waterproof, LED-Lighted, pan and tilt cameras. The charge vessel is designed to be deployed into the DST rather than above ground to overcome the limitation of maximum liquid lift with a vacuum. That is, a full vacuum at atmospheric pressure can lift a column of water 10.2m, which is less than the distance from the top of the riser to the bottom of the DST. Specific design features of the module are discussed in more detail below.

In-Tank Module

The charge vessel module is designed to navigate around the bow in the 30" corrugated riser and self-center into the 20" diameter manway on the tank and consists of:

- A Charge Vessel: This is an ASME Section VIII U stamped vessel.

- The RFD element connected to the bottom of the charge vessel; this is mounted in the system such that the inlet for the RFD is ½" above the base of the module

- Two AEAT designed wash nozzle assemblies, each with a linear actuator for vertical positioning and a rotary actuator for horizontal positioning. Each nozzle has a horizontal "sweep" of approximately 220^{o}; one nozzle covers the west end of the tank, the other the east end.

- The supporting framework with feet at the bottom. The unit is intended to sit on the base of the tank. All pipes and the framework at the bottom of the module are contoured to assist in locating the module within the 20" manway during installation.

- The interconnecting pipework; the air-link pipe which supplies the compressed air to the charge vessel, the delivery pipes connected to the RFD outlet and the wash nozzle feed lines. Each pipe terminates in a quick-disconnect coupling at the top of the module, for connection to the hoses which pass down the riser.

- Two LED-lighted cameras, each with pan and tilt control; one is used primarily for the west end of the tank, the other for the east end. Camera feeds are connected to a monitor and video recording equipment in the control skid.

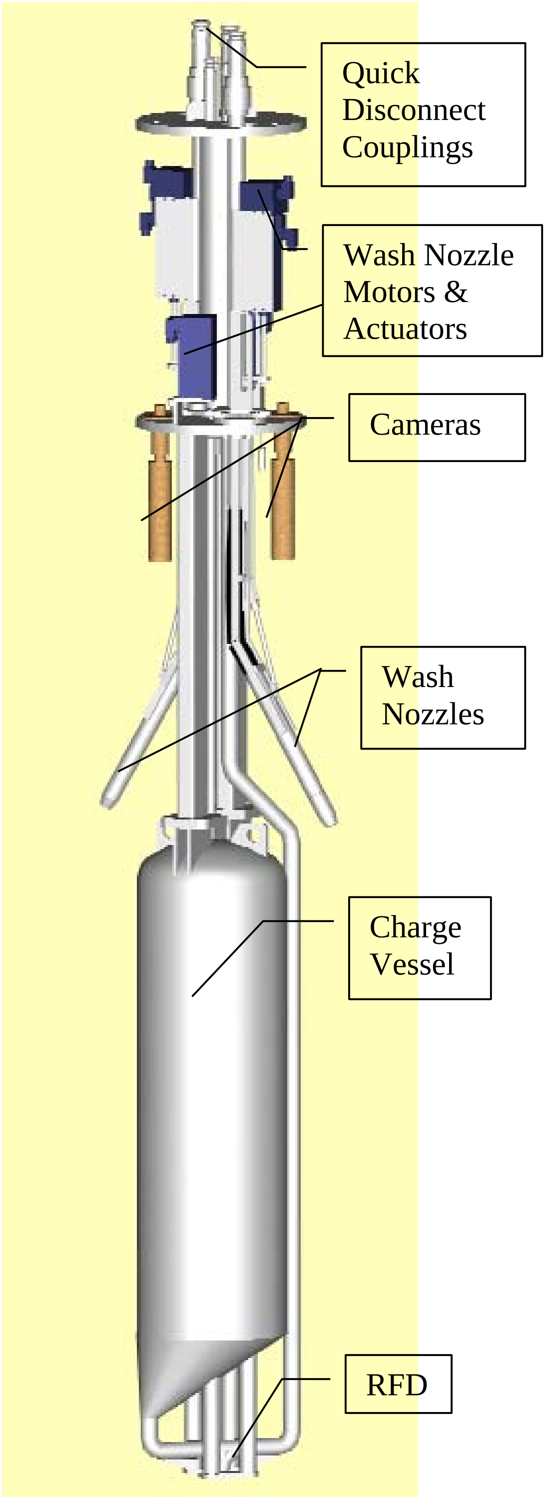


Fig. 1. Charge Vessel Module

The unique design of the in-tank module has several key features enabling efficient waste retrieval from the DST, including:

- All equipment mounted on the assembly is located within an 18" diameter
- The articulated nozzles can be oriented down for installation and removal of the module and rotated up for capability to wash all tank internal surfaces
- Greater than 360o coverage of sweep with the wash nozzles

- Greater than 360o viewing angle with the cameras

Flexible hose connections enable deployment around the bow in the corrugated riser.

In the design and engineering of the In-Tank Module, extreme care was taken to ensure that the module could be remotely deployed and removed from the DST without becoming ‘snagged’ at any point within the corrugated riser or tank itself. In addition to preparation of AutoCAD interference diagrams and 3-D computer modeling prior to manufacture, the deployment of the completed module assembly was tested at the AEAT facility using a crane and full scale mock-up of the riser and tank entry. All possible orientations and angles that the module may adopt during deployment were investigated and if interferences or clashes were identified appropriate modifications to the equipment were made.

Control Skid/ Operator Station
The Control Skid/ Operator Station (Fig. 2) is installed in a 20’ ISO type container and is divided into two sections; the valve skid and the operator station. The Valve skid contains all of the process valves and instrumentation which handle the “clean” compressed air and flush water supplies upstream of the jet pumps. The operator station contains the system’s controller.

The main compressed air and water feeds to the mixing system are connected to this skid. The compressed air and water lines emerging from this skid are connected to the Jet Pump skid via flexible hoses. The skid interconnecting water line is trace heated and insulated for freeze protection.

The operator station contains the system’s controller; a PC based control system connected to each skid mounted marshalling cabinet via a network cable. The control system sends and receives signals via the network enabling the remote operation of actuated valves and data collection from field mounted instruments. The control software interfaces with the remotely mounted control components via a 12Mbit Profibus DP network.

An independent hard-wired trip circuit follows the network cable linking all the cabinets together. The activation of the hard-wired trip circuit shuts the system down in to a fail-safe state.

Jet Pump Skid
The Jet Pump Skid (Fig. 2) is housed in a 20’ ISO type container and contains:

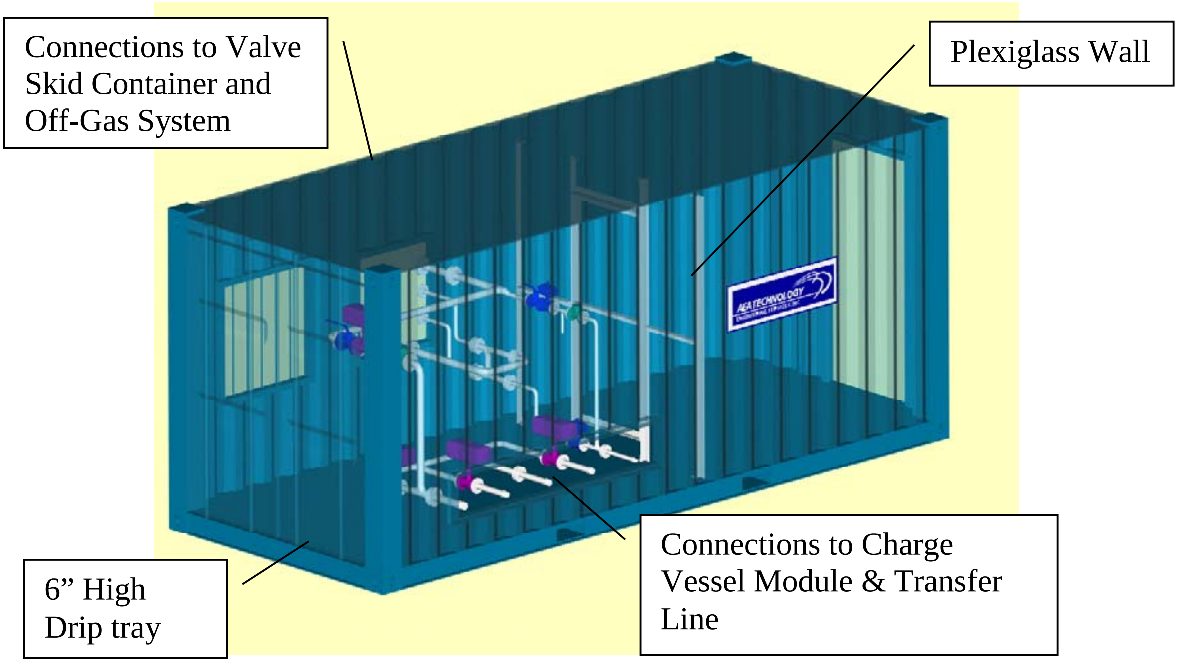
- The Jet Pump Pair: A fluidic component used to handle the airflow to and from the Charge Vessel thereby evacuating or pressurizing the charge vessel dependent upon the current phase in the process.
- Process Valves: Automated valves which direct the slurry delivered from the RFD pump to either the transfer line or back down into the tank via one of the wash nozzles.
- Flush Water Valves: Automated valves which distribute the flush water either to the Charge Vessel or into the transfer line

The skid is housed in one end of the container and is located within a 6” high drip tray. A Plexiglas “splash protection” wall separates the skid from the other end of the container which houses the all of the electrical equipment associated with the Jet Pump Skid and the

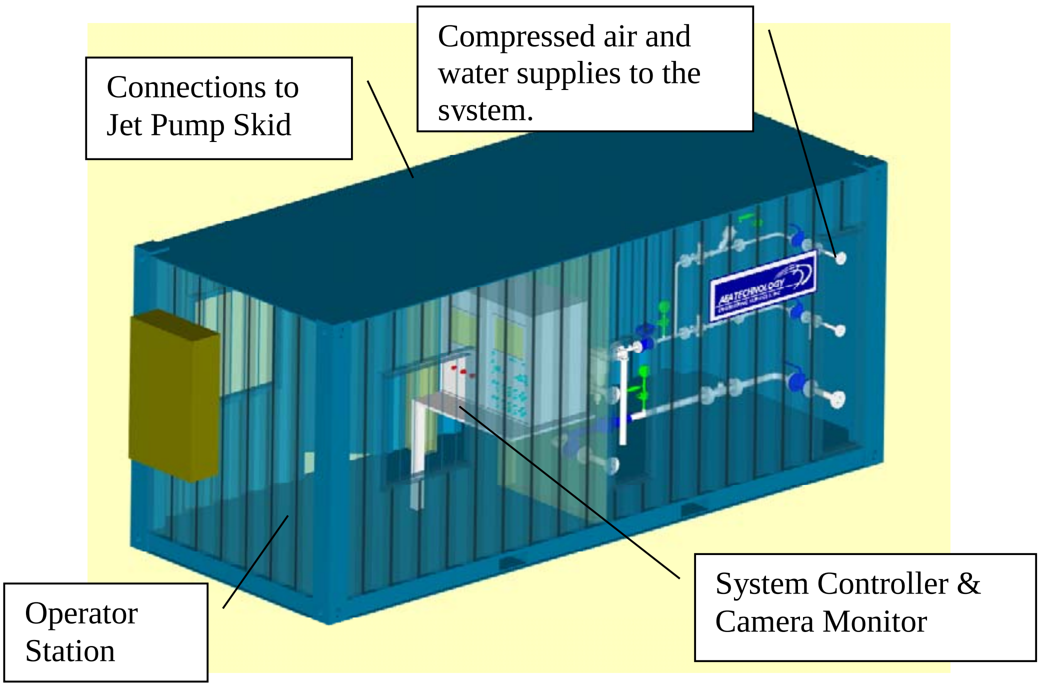
Charge Vessel Module including the servo drives which drive the linear and rotary actuators used to steer the articulated wash nozzles.

A flexible hose connects this container to the existing transfer line to the treatment facility. All hoses running from this skid to the transfer line and the charge vessel module are double-contained.

All connection points for Air, Water, Tank Waste and Electricity are located on the exterior of the container.



Jet Pump Skid



Control Skid/ Operator Station

Fig. 2. ISO Container mounted process skids for DST bulk waste retrieval.

DST System Installation

The fluidic equipment is supplied in modular form as described in the preceding section and installed as depicted in Fig. 3. Each module is designed to be readily handled for positioning using a mobile crane or forklift truck.

Upon arrival at the tank site, the modules are set on a base prepared and leveled with gravel. After the tank riser is made accessible, the in-tank module is lowered into the tank using a three point, braided steel lifting cable. A steel beam, load-bearing gantry is employed to span the riser and support the weight of the hoses and cables running vertically down to the in-tank module.

Following completion of skid placement and interconnection, the system is subjected to a series of basic functional tests to demonstrate satisfactory integrity and operation prior to mixing or retrieval of active tank contents.

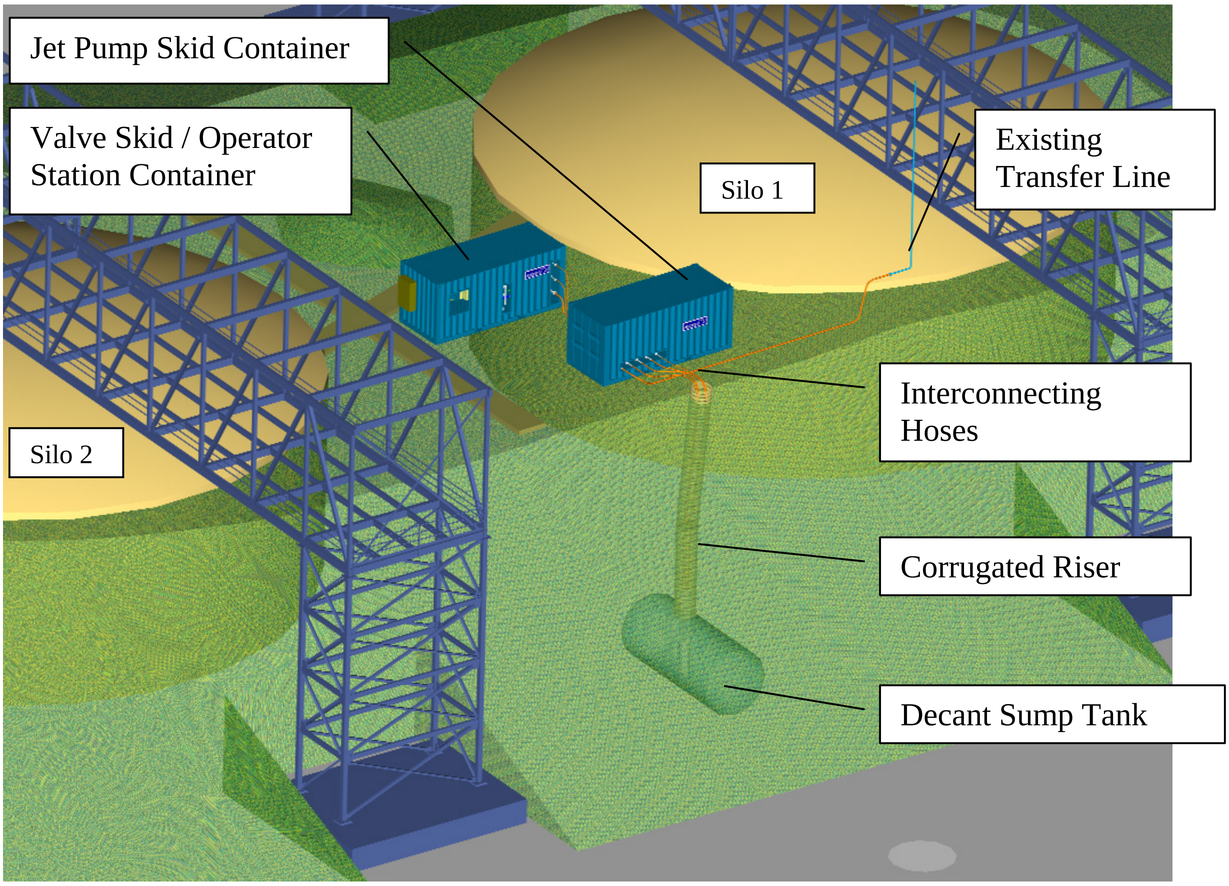


Fig. 3. Fernald Site Installation

DST System Operations

The fluidic system is designed to mobilize and retrieve waste from the DST in a controlled and versatile manner. The system can operate in a number of modes dependent upon prevailing conditions at any given stage of the retrieval operations. These modes of operation are described below.

The pump system remobilizes the sludge contained within the waste tank by first drawing liquid out of the tank into a pressure vessel in the suction phase. This liquid is then driven back into the tank through either of two articulated wash nozzles deployed near the top of the waste tank in the drive phase, thereby gradually re-hydrating the sludge into a slurry. Alternatively, the wash nozzles may be used to wash encrusted solids from the walls or roof of the tank by directing the jet in the desired location. Finally, during the vent phase pressurized air remaining in the pressure vessel is allowed to vent to an air handling system.

During operation of the DST bulk waste retrieval system, the pressurized air is vented through the jet pumps into the existing Radon Control System (RCS). The mixing process is repeated until the sludge and free liquid in the waste tank are well mixed. Once this occurs, the mobilized sludge/liquid is pumped out of the tank, through the existing 500’ long transfer line to the purpose-built treatment facility. Tank emptying is achieved by filling the charge vessel from the waste tank and then discharging the charge vessel to a delivery line, instead of back into the waste tank through the wash nozzles.

Fig. 4 depicts the basic system outline for the mixing and transfer system in each of its primary operating modes.

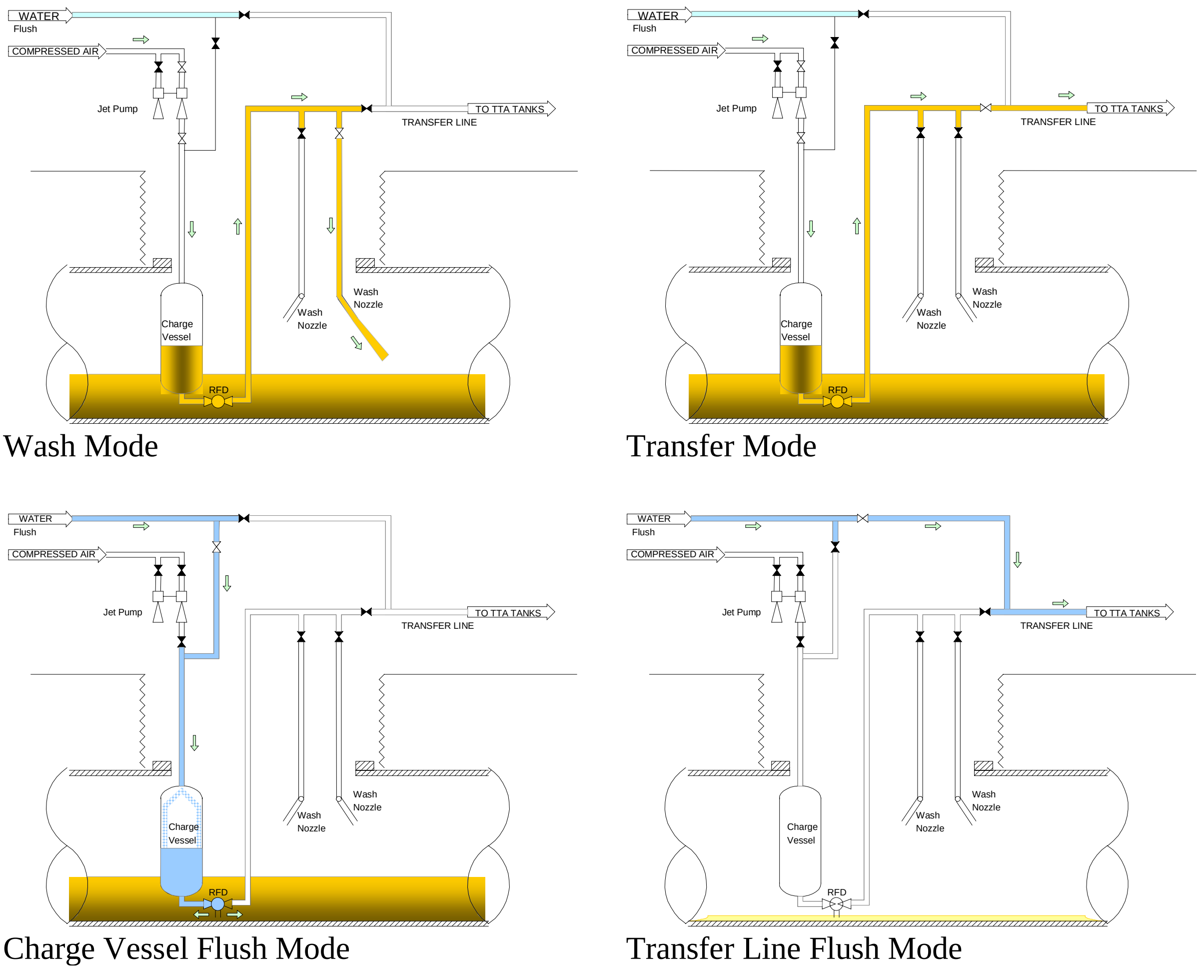


Fig. 4. DST fluidic bulk waste retrieval system operating modes

The operating modes for the system are outlined in Table I below:

Table I. DST Bulk Waste Retrieval System Operating Modes

• Wash		-	To direct the contents of the charge vessel through either of the wash nozzles in order to mobilize the contents of the tank. One wash nozzle operates towards the West end of the tank; the other operates towards the East end.
• Transfer		-	To direct the contents of the charge vessel along the transfer line.
• Flush:	C. Vessel Flush	-	To flush the Charge vessel / RFD using the flush water supply
	Transfer Line Flush	-	To forward flush the contents of the transfer line into the treatment facility

The following sections highlight the main operating features of each mode.

Wash Mode

The objective of this phase of operation is to direct the wash nozzle jets to mobilize the sludge in the tank and create a slurry suspension which is ready for transfer to the treatment facility. The waste or sludge in the tank is settled and compacted due to the length of time it has been left undisturbed. The first part of the retrieval operation is to "re-hydrate" the sludge. This is achieved by the operation of the charge vessel system and associated wash nozzles.

The RFD operates in its normal suction-drive-vent operating cycle. During the suction phase, fluid is drawn out of the tank to fill the charge vessel. During the drive phase, the contents of the charge vessel are discharged along the RFD's transfer pipe and back into the tank through one of the wash nozzles.

The articulated nozzles are also used to direct a jet of liquid against the walls of the tank, removing adhered residual sludge. The pressure of the jets is regulated to 60 PSI. At this pressure, sufficient mass of liquid strikes the wall for effective washing while the impact force on the tank structure and internals is negligible.

It should be noted that in this mode of operation the system provides all the effectiveness of "past practice sluicing" but with the significant added benefit of only utilizing a fixed, small volume of free water in the tank and thereby minimizing secondary waste generation. Virtually all operations can be controlled from the control skid, which is a radiologically clean environment and is located so as to minimize operational dose uptake for workers.

The operator selects which nozzle is used in any cycle, via the pump's control system interface. Each wash nozzle can be rotated both up and down and around a vertical axis to enable the operator to direct the jet. Each wash nozzle has a horizontal "sweep" of approximately 220^{o}; one nozzle covers the west end of the tank, the other the east end.

Transfer Mode

The objective of this phase is to transfer the slurry along the transfer line. The decision of when to transfer the slurry is normally made when the mobilization operations have reached "steady state" whereby continued operation would not suspend any more sludge. During operations, the time taken to fill each charge vessel is monitored; the duration of the suction time provides a useful indicator of when a steady state is reached.

During this mode, the RFD operates in its normal suction-drive-vent operating cycle and the contents of the charge vessel are directed along the transfer line via remotely operated valves.

The RFD pump's control system operates a valve located in the transfer line: during the drive phase the valve is opened, during the suction phase the valve is closed in order to prevent the contents of the transfer pipe flowing back into the tank.

Flush Mode

There are 2 types of flush operations related to the system, Charge Vessel Flush and Transfer Line Flush.

The objective of a Charge Vessel Flush is to flush the inside of the Charge vessel and RFD using the flush water supply. This mode of operation occurs infrequently; before a prolonged shutdown of the system or as part of final cleaning / decontamination processes.

The Transfer Line-Flush involves the introduction of water into the transfer line to flush the remaining fluid from the line after an RFD transfer operation.

FOOTNOTES

[a] The PRESCON™ (PRESsure CONtrol) system is the AEAT patented method of sensing liquid levels remotely and non-intrusively and is used for the control of Power Fluidic pumping and mixing systems.

REFERENCES

1. Williams, Martin C. and Murry, Paul A. 2003. A Review of Power Fluidics™ for Nuclear Waste Mobilization, ICEM03-4605, Proceedings of ICEM '03, The 9th International Conference on Radioactive Waste Management and Environmental Remediation Examination School, Oxford, England.