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An Evaluation of Power Fluidics™ Mixing and Pumping for Application in the Single Shell Tank Retrieval Program

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Abstract: This document is being released for information only. It provides an explanation of fluidics pumping and mixing technology and explores the feasibility of using fluidics technology for the retrieval of S102. It concludes that there are no obvious flaws that would prevent deploying the technoloty and recommends further development of fluidics technology as a retrieval option. The configuration described herein does not represent the basis for project definition.

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An Evaluation of Power Fluidics™ Mixing and Pumping for Application in the Single Shell Tank Retrieval Program

March 2,2001

Prepared for
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Executive Summary

The Hanford Site has 149 Single-Shell Tanks (SSTs) containing radioactive solid and liquid waste produced from nuclearfuel reprocessing. The DOE Office of River Protection (ORP) is charged with retrieving the wastesfrom the Hanford tanks, treating it to immobilize contaminants. and providing safe long term storage or disposal ofthe treated tank waste. The currentplan is to treat the tank waste at an immobilization facility that will be constructed at Hanford. Several SSTs will be retrieved and will providefeedstock to theplant **for** treatment.

The Tri-Party Agreement M-45 series ofmilestones identifies three SSTs, 241-4112, 241-C-104, and 241-S-102, for retrieval. Schedule milestones are also applied to these future retrieval projectsfor the design. construction, and retrieval ofthe tanks.

Technologies havepreliminarily been identifiedfor thefirst two tanks to be recovered, 241-4112 and 241-C-104, as demonstration retrievalprojects. The remaining tank, 241-S-102, is to be retrieved as the "firstfull-scale retrieval". As such, the identijcation and evaluation of alternative technologiesfor the mobilization, recovery, and transfer of SST soluble solid waste has been initiated.

This report investigates one retrieval methodpreviously identified as warrantingfurther consideration, AEA Technology Power Fluidics™. **This** technology has **been** used to mobilize waste in radioactive storage tanks at other DOE sites and warrants additional engineering developmentfor application in the Hanford SST retrievalprogram. This preliminary engineering evaluation is an investigation ofthe technologies developed by AEAT to identify uncertainties andpotential utility in the Hanford SST Retrieval Project. Specifically, a preliminaryprocess and acquisition strategy are developedfor the retrieval of 241-S-102.

A technical evaluation along with the uncertuinties and items requiring resolution is included. This evaluation was conducted by interviewing equipment users, the technology vendor, and through engineering data provided by AEAT. Nofatal flaws

were found that would prohibit this technology from being deployed in a Hanford SST for the recovery of soluble saltcake waste. Several technical uncertainties, however, were identified that will require additional engineering development, including:

- *Mixing Capability;*
- *Transfer Flow and Velocity;*
- *Transfer Pressure;*
- *Debris Management;*
- *Ability io Reach Cleanliness Goal; and*
- *Double Shell Tank Space Availability.*

Based on this preliminary assessment, the uncertainties should be carried forward and addressed during conceptual design.

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List of Figures and Tables

Acronym List

AEAT	AEA Technology Inc
ASME	American Society of Mechanical Engineers
AUR	Air Utilization Process
BVEST	Bethel Valley Evaporator Service Tanks
CCTV	Closed-Circuit Television
CIP	Capacity Increase Project
DOE	Department of Energy
DST	Double Shell Tank
EPDM	Ethylene Propylene Diene Monomer (a.k.a. Rubber)
GAAT	Gunite and Associated Tanks
gal	Gallons
gpm	Gallons per Minute
HIC	High Integrity Container
HLW	High-Level Waste
HTI	Hanford Tank Initiative
IDLH	Immediately Dangerous to Life and Health
INEEL	Idaho National Environmental and Engineering Laboratory
kg	Kilogram
kgal	Kilogallons
kpsi	Kilopounds per Square Inch
LFL	Lower Flammability Limit
LLW	Low-Level Waste
mL	Milliliter
MVST	Melton Valley Storage Tanks
ORNL	Oak Ridge National Laboratory
PFD	Process Flow Diagram
psi	Pounds per Square Inch
psig	Pounds per Square Inch, Gauge Pressure
RFD	Reverse Flow Diverter
RPP	River Protection Project
SRS	Savannah River Site
SST	Single Shell Tank
TFA	Tank Focus Area
TPA	Tri-Party Agreement
WSRC	Westinghouse Savannah River Corp.

1.0 INTRODUCTION

The River Protection Program (RPP) mission includes the retrieval, immobilization, storage and disposal of Hanford Site tank waste (HNF-SD-WM-MAR-008). In order to immobilize the waste for subsequent storage and eventual disposal, both Single-Shell Tank (SST) and Double-Shell Tank (DST) wastes must be retrieved for processing. Because of concerns related to the liquid integrity of the older SSTs, waste from the SSTs will be retrieved and staged temporarily in the newer and more reliable DSTs. The current baseline reference technology for the retrieval of SST waste is "past practice sluicing." This technique has been used successfully at the Hanford Site to retrieve SST waste, and it is considered one of the primary tools available to support the programmatic objective of retrieving SST waste. However, sluicing is **an** expensive process, and a production that relies solely upon this technology establishes a prohibitive cost baseline for achieving the SST Retrieval Project objectives.

The SST Retrieval Project has initiated activities to identify and demonstrate in actual field conditions, alternative retrieval technologies that will provide adequate SST waste feed to support the RPP immobilization facility while reducing the overall cost for tank cleanup and closure activities. A recent technology search and evaluation of potential technologies applicable for retrieval of saltcake waste from Hanford's SSTs (Boes, et al. 2000) recommended the fluidic mixing and pumping systems (developed and patented by AEA Technology (AEAT)) as a preferred candidate for full-scale deployment to demonstrate dissolution retrieval of saltcake waste. It was noted in this evaluation that the fluidic mixing/pumping technology is not only capable of supporting recovery of soluble salt wastes, but it is also suited for mobilization and retrieval of insoluble solids (e.g., sludge waste).

Based on this recommendation and the successful experience in applying fluidic mixing systems to radioactive tank waste retrieval efforts at other Department of Energy facilities, the **SST** Retrieval Project Office has sponsored this additional technical evaluation of the fluidic mixing/pumping technologies.

1.1 Purpose

The purpose of this report is to document the technical investigation of the fluidic mixing and pumping technologies developed by AEAT. The evaluation is to determine if any fatal flaws exist with application of this approach for SST waste retrieval. A draft plan is developed for deployment of fluidic mixing/pumping systems in a SST to demonstrate its effectiveness in recovery of tank wastes. Preliminary tank selection activities have identified 241-S-102, located in the 200 West Area's 241-S Tank Farm, as the preferred tank for staging the fluidic mixing/pumping demonstration.

The current Tri-Party Agreement (TPA) M-45 series of milestones for the retrieval of Hanford SSTs, includes the recovery of 241-S-102. The proposed amendment (in comment phase, September, 2000) includes a schedule for the recovery of 241-S-102 as a full scale retrieval effort following the demonstration retrieval of 241-S-112. 'Xey elements of the proposed change include ... [t]ransfer of no less than 800 curies ...

[from] . . . S-112 and S-102' (U.S. DOE Office of River Protection, *Request for Public Comment*, 2000). These changes will likely be incorporated, requiring the determination of a suitable retrieval method to be employed on 241-S-102. This investigation of the available, viable retrieval technologies is paramount to meeting the intent of the TPA. This report will supplement the investigation and ultimate selection of a retrieval method for deployment on 241-S-102.

The proposed schedule for 241-S-102 retrieval is included in Table 1.

Milestone	Activity
October 30,2002	Submit Functions and Requirements Document
March 31,2004	Complete Design
November 30,2005	Complete Construction
September 30,2006	Complete Waste Retrieval

Table 1 Proposed **241-S-102** Retrieval Milestones

1.2 Scope

The scope of this effort is to investigate the AEAT fluidic mixing and pumping technologies for their potential application to support retrieval of Hanford SST wastes. A draft plan for deployment of these technologies in Tank 241-S-102 has also been developed. This work scope expands upon the previous pre-conceptual evaluation of fluidic mixing as a potential saltcake dissolution retrieval method (Boes, et al., 2000), and includes a compilation of relevant information resulting from the completion of the following activities:

- Perform a documentation search and conduct field visits and interviews of Hanford Tank Farm personnel as necessary to support the identification of critical interfaces associated with Tank 241-S-102 and associated facilities;

- Identify key input information necessary to design and deploy a fluidic mixing and pumping system into a Hanford single-shell tank (SST) for the purpose of demonstrating waste retrieval;

- Identify any significant technical issues, uncertainties or concerns relative to the deployment and operation of a fluidic mixing system in a SST to support retrieval of waste;

- Conduct off-site travel to ORNL to observe and collect data on an fluidic mixing systems previously and/or currently in use to support retrieval of high-level radioactive tank waste, and to conduct interviews of the ORNL technical and operations personnel relative to the performance of these systems;

- Conduct off-site travel to AEAT engineering and fabrication facilities to conduct technical discussions with engineers and other technical experts in the field of fluidic mixing;

- Prepare a description of the fluidic mixing and pumping processes as proposed for use in the Tank 241-S-102 retrieval demonstration activities, and a discussion of relevant past experience and system performance for in-tank applications of fluidic mixing technologies, particularly those performed in a nuclear environment;

- Prepare a summary-level project acquisition plan for deployment of the fluidic mixing technology into Tank 241-S-102;

- Analyze the fluidic mixing and pumping technologies for any fatal flaws that could jeopardize the successful application of these technologies to support waste retrieval in a Hanford SST; and

1.3 Synopsis of AEA Technology Power Fluidics™

AEA Technology has only been present in the DOE arena for a short time. While the company employs several thousand people worldwide, only a couple of hundred reside within the United States. The company (AEAT) specializes in the development of non-moving part technologies including pumps, mixers, valves, and ventilation systems for use across a broad range of industrial/commercial applications.

Within the US division of AEAT are numerous sub-divisions proposing methods and technologies with potential application at the Hanford site. The investigation was, however, restricted only to those technologies/methods applicable to the mobilization and recovery of tank waste, specifically, pulse-tube and pulse-jet mixing methods, and Reverse Flow Diverter (RFD) and diode pumps.

Application of specific AEAT systems to Hanford SST retrieval is dependent upon the tank constituents, retrieval goals, and project mission. RFD and diode pumps appear to have application for a variety of scenarios, while mixing application is more a function of retrieval goals, tank solubility, budget restrictions, etc.

AEAT experience and application in the United States for the DOE has been limited to tank mixing at *Oak* Ridge National Laboratory. Only one pumping applications has been used (past or present) in this circle; a sample pump at the Savannah River Site. More than 400 pumps (both RFD and diode) have been successfully deployed elsewhere, primarily in the United Kingdom. The RPP vitrification plant design baseline includes more than 500 fluidic mixers, pumps, and samplers.

While the relative lack of DOE experience using fluidic pumps adds to the uncertainty, the principles of operation are simple and the track record to date has been very good (see Section 2.5). These pump types are obviously inherently impervious to normal pump failure modes. The primary uncertainty will be the expected performance characteristics, not functionality. It is the author's recommendation that a demonstration of the system at Hanford be pursued.

2.0 AEA TECHNOLOGY POWER FLUIDICS™

AEA Technology Power Fluidics™ methods are used for mixing and pumping of liquids and solids in a variety of applications. The primary advantage of the AEAT system(s) when compared to more conventional retrieval methods is that no moving parts are employed in the primary system(s). This system simplicity reduces maintenance cost, down time, and worker exposure when deployed in a dangerous or hazardous environment. Within the power fluidic division of AEAT are both mixing and pumping systems with potential utility at Hanford. The system components and operation principles are described in detail within the subsequent sections of this report. The majority of the components employed for the various systems are similar if not identical. These common components include:

- Air compressor with or without accumulator,
- Off-gas (or ventilation) skid,
- Valve skid,
- Jet skid (or jet tower),
- Pipe bridge,
- Charge vessel, and
- Control cubical.

A simplified schematic showing the arrangement and interrelationship of these components, as they would be arranged for Hanford tank retrieval is provided in Figure 1.

As can be seen in Figure 1 only the charge vessel assembly, or portions thereof, is inserted into the tank. While the system does incorporate moving parts, none are introduced into the dangerous waste environment. Components that contain moving parts (i.e. those with potentially greater failure frequency, or requiring routine maintenance or surveillance) are installed away from the hazardous environment.

Cyclic pressurization and evacuation of the charge vessel is initiated by the continuous supply of air flowing from the air compressor to the valve skid. Solenoid valves on the valve skid direct the airflow to the jet skid. Depending upon the valve configuration, the air flows through one of two, or neither, of the eductors. A description of the jet assembly and the principles of operation are included in Section 2.4.1. By opening and shutting solenoid valves the airflow through the valve skid, pipe bridge, and charge vessel is modulated. Liquid is drawn into the charge vessel during the evacuation phase and expelled from the charge vessel during the drive phase. Air is removed from the charge vessel by routing the vent stream through the filters on the off-gas skid. Operations and monitoring of the system are performed within the control cubical located at or near the equipment deployment location.

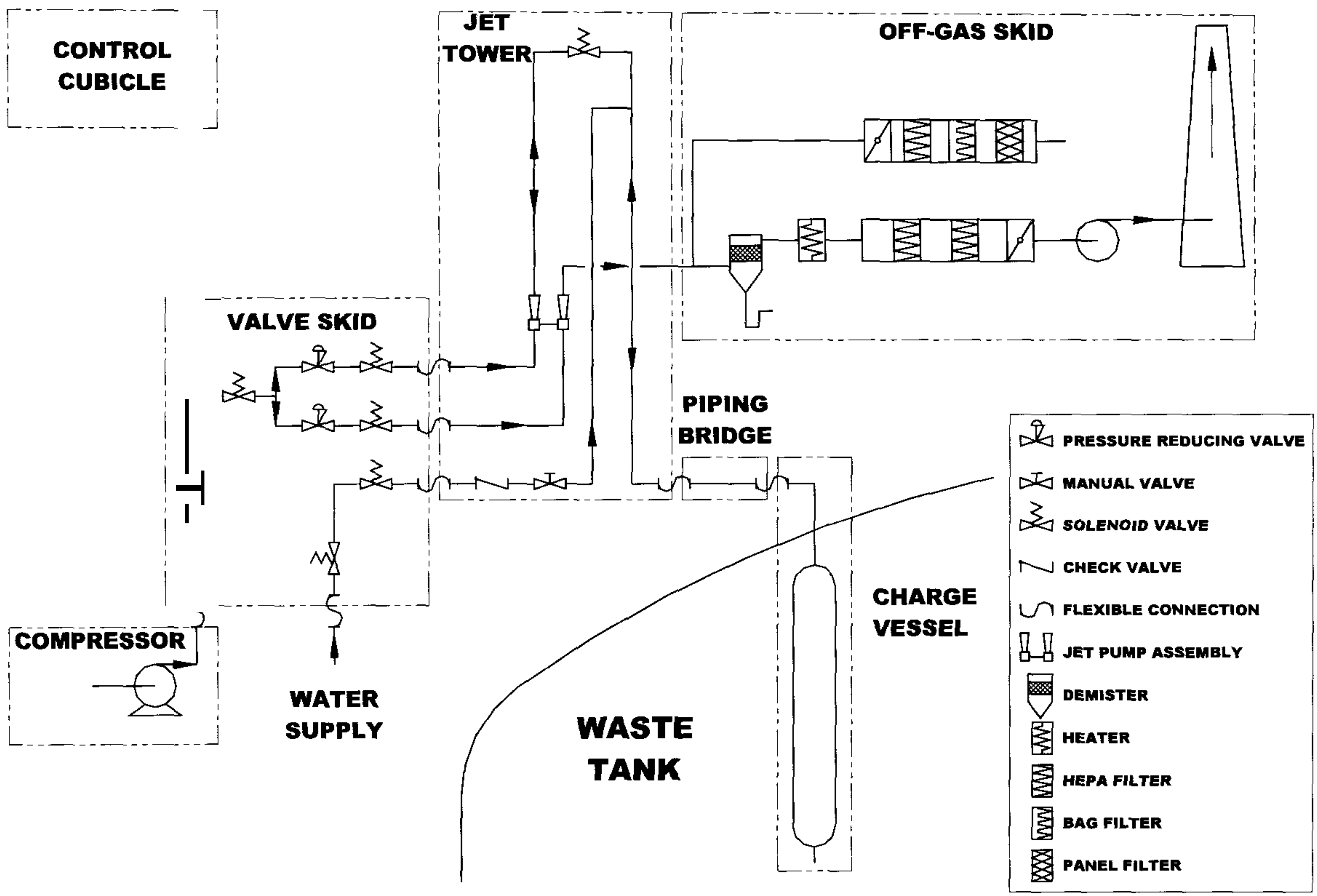


Figure 1 Power Fluidics™ Schematic

Compressor

The air compressor must be selected with sufficient flow capacity to support the pumping and/or mixing operations. Typical AEAT designs utilize air pressures on the order of 60 to 70 psig.

The flow capacity requirements for the compressor, termed "air consumption", are considered in terms of efficiency. The Air Utilization Ratio (AUR) is defined as the average airflow rate divided by the average liquid flow rate. The AUR can be estimated based upon the performance of similar systems. The compressor can then be sized based upon the estimated AUR and desired average flow rate.

Valve Skid

The compressed air and water supply are controlled by solenoids located on the valve skid. Airflow is directed from the compressor to either (or neither) of the two jet nozzles. Valves on the valve skid also regulate the introduction of water.

Pressure, flow, temperature, and valve position indication data are gathered from an array of instrumentation mounted in/on the valve skid piping. The signals are sent to the Control Cubical where the retrieval process can be monitored, controlled, and optimized. A picture of the Oak Ridge National Laboratory (ORNL) C Tank valve skid being staged for the Capacity Increase Project (CIP) tank installation is provided in Figure 2 as an example.

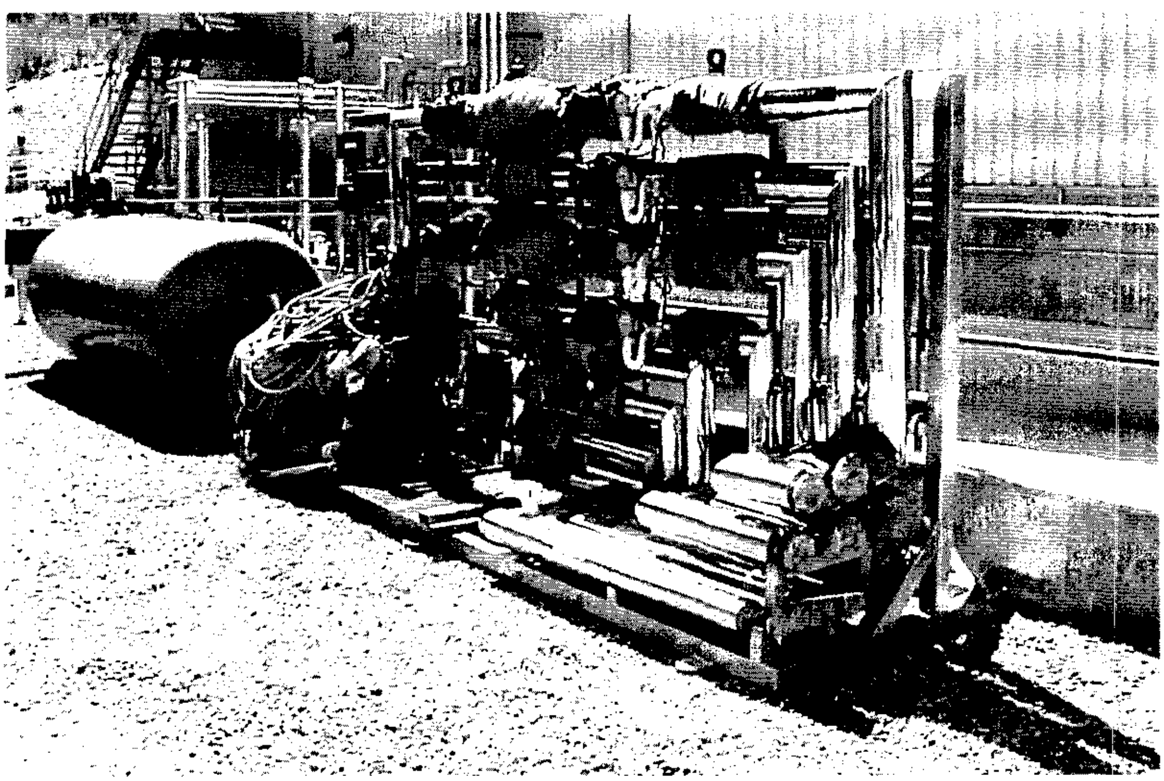


Figure 2 Valve Skid

Jet Skid/Tower

The jet skid incorporales the jet assembly (Section 2.4.1) and an anti-siplion feature to prevent drawing of liquid waste through tlic charge vessel and pipe bridge to the valve skid. The jet tower extends 35 feet vertically above the highest anticipated liquid waste level. This height exceeds tlrc height at which water can be "lifted", or siphoned. The maximum siphon height for water is 32 feet in the theoretical event that a perfect vacuum is drawn. The tower is generally qualified seismically and is considered a fail-safe system to prevent contamination of the upstream components and system:,.

A picture of a jet-tower installed at the ORNL Bethel Valley Evaporator Service Tanks (BVEST) site is included as an example in Figure 3 (right-hand side of photograph).

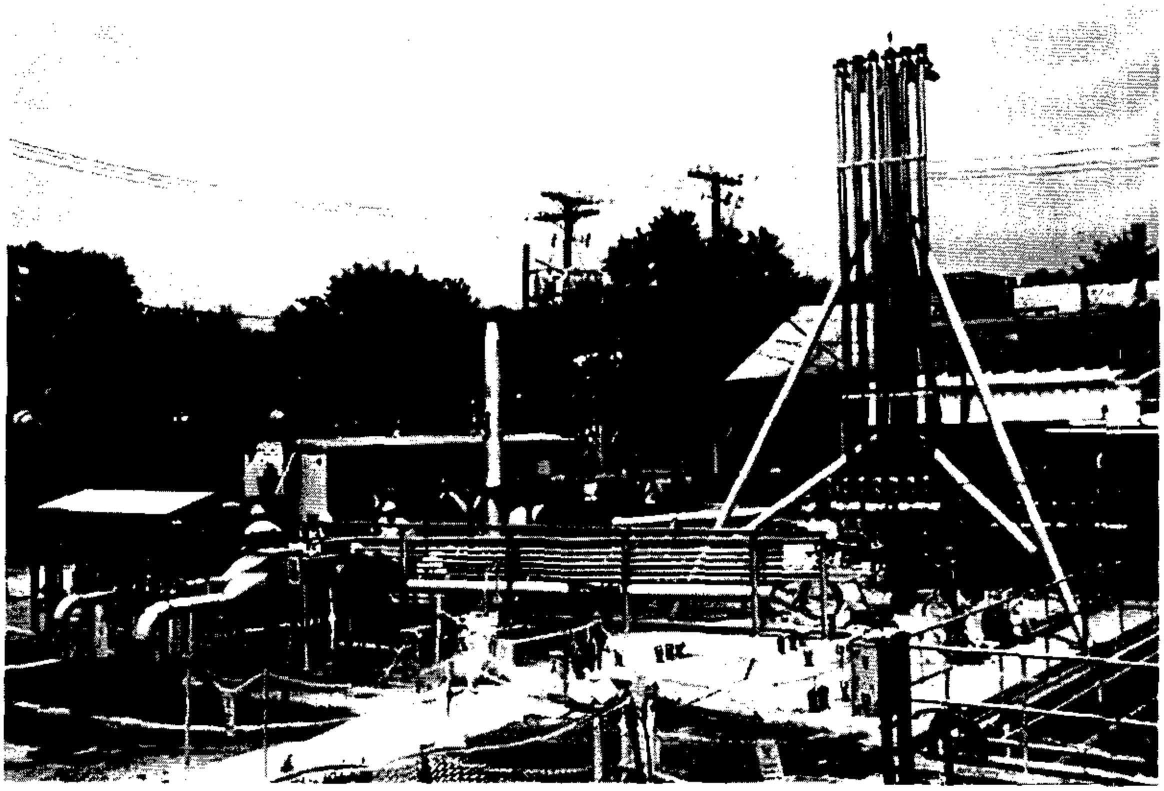


Figure 3 Jet Tower

Piping Bridge

The pipe bridge connects the jet skid to the charge vessel. It may be as simple as rolled up EPDM hoses with quick-disconnects or as complex a rolling rigid structure with hard pipe, flex hoses, and swivel fittings.

A picture of a piping bridge installed at the ORNL CIP site is included as an example in Figure 4.

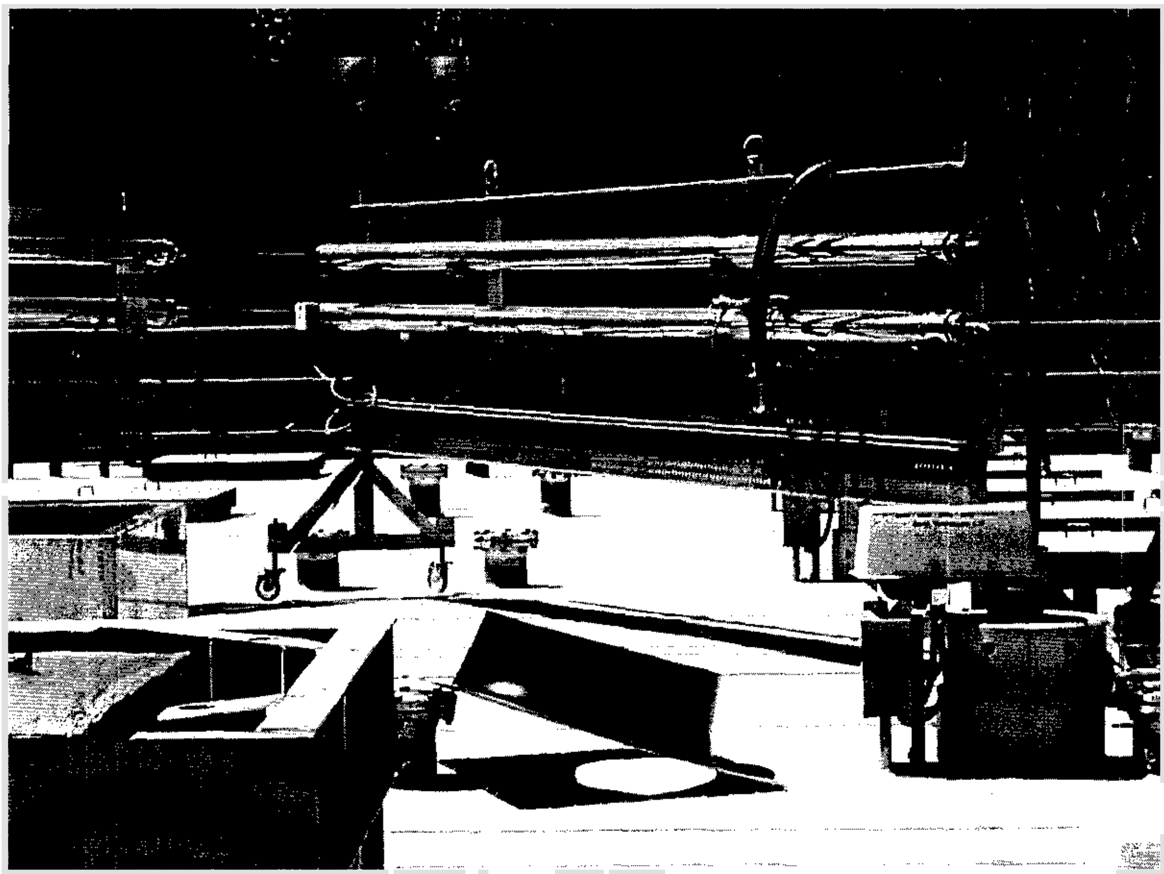


Figure 4 Piping Bridge

Off-Gas Skid

The off-gas, or ventilation, skid is used to filter contaminants from the charge vessel exhaust stream. The off-gas skid is simple in form and self explanatory in function. A demister and heater are generally installed upstream of the filter housing to prevent filter saturation. The demister drain is routed back to the recovery vessel. A picture of the off-gas skid installed at ORNL BVEST C Tank facility is shown in Figure 5.

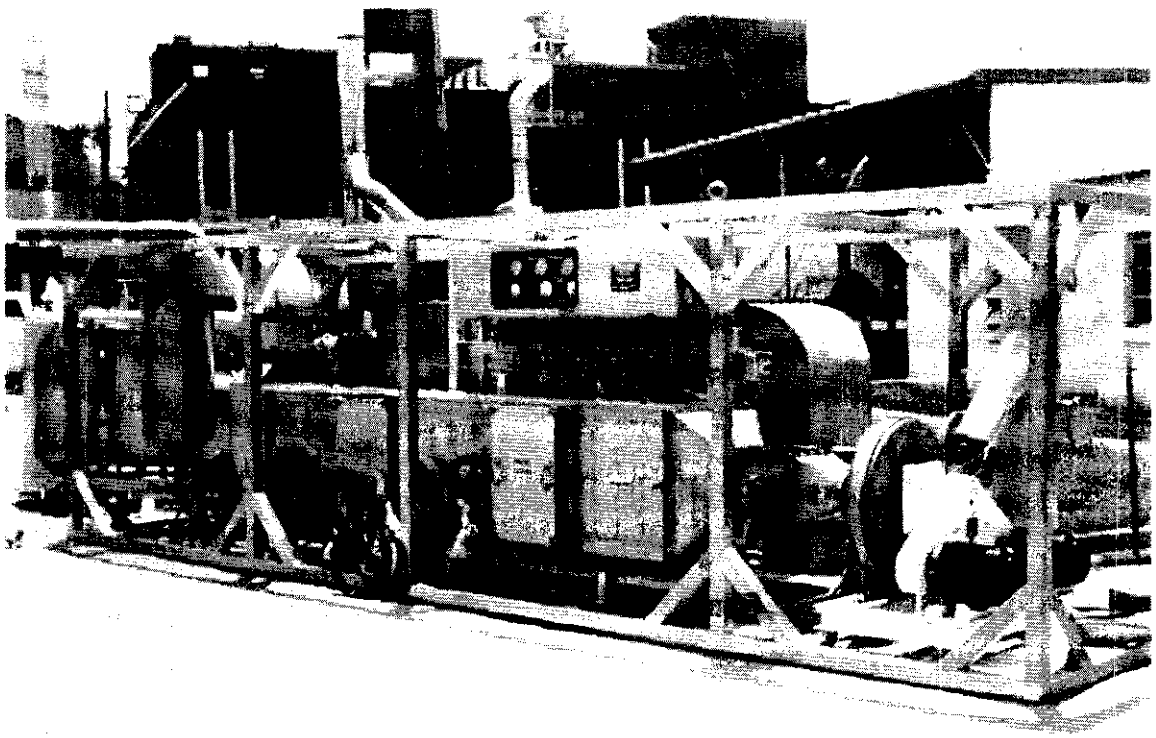


Figure 5 Off-gas Skid

Charge Vessel

The charge vessel rcccivcs and expels liquid waste from the recovery vessel. The charge vcsscl may be installed in, above, **or** adjacent lo tlrc recovery vessel. It is an ASME coded pressure vcsscl, which varies in size lo suit the particular application. The filling ofthe charge vcsscl is initiated by directing airflow from tlic compressor through the evacuation eductor on the jet skid. Several safeguards may be employed to ensure the charge vessel is not overfilled. Thcsc include:

- Establishing a set duration limit **for** tlic evacuation cycle,
- Tracking the previous evacuation durations and not allowing the subsequent evacuation cycle to exceed this time hy more than a predetermined percentage,
- Measuring the pressure on the evacuation line. When the liquid reaches the top of the charge vessel the flow accelerates as the Ilow cross-section reduces. This produces **a** momentary, yet perceptible, "blip" in tlic pressure,
- Establishing a maximum suction prcssurc limit, and/or
- Installing limit switches, conductivity sensors, or dip tubes within the charge vcsscl.

Over-filling the charge vessel during tlic drive or pressurization cycle may be of concern, depending upon the particular application. Over-tilling will inject air into the liquid waste potentially generating aerosols, waste foaming, **or** entraining air in the transfer line. Measuring the air pressure and flow, setting a pressure limit, and limiting the pressurization cycle duration all mitigate the possibility of over-filling.

For mixing operations, the charge vessel may be mounted on a bearing arid rotated by a stepper motor *to concentrate* mixing *on* a particular tank location *This rotation may be* controlled automatically by the PRESCON™ controller. manually by an operator, **or** have allowances ***for*** both. **A** picture of the top of a rotating charge vessel assembly (without shroud) is provided in Figure 6. This unit depicted was installed and successfully operated *in* the OKNI. BVEST C Tanks.

Figure 6 Charge Vessel Bearing and Gear

Generally, the charge vcssel is designed to fill the available space for installation. Up to a point. the larger tlic charge vessel, tlic better the system performance. The charge vessel may be installed in, above, or adjacent to the recovery vessel.

Figure 7 shows the installation of a charge vcssel in the ORNL CIP W-35 tank. This charge vcssel extended out of the top of the tank, hut was contained within ttic vault space.

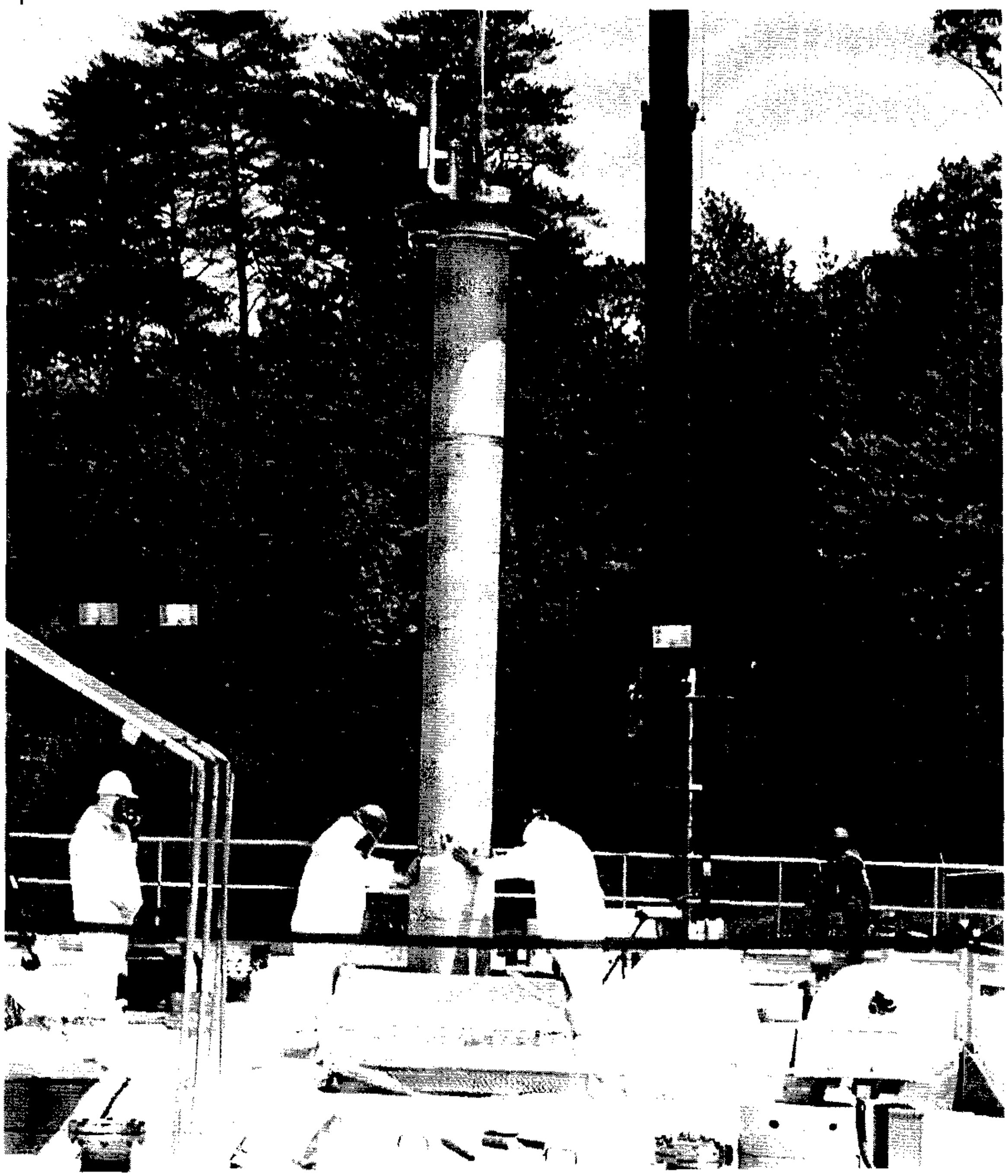


Figure 7 Charge Vessel Installation at ORNL CIP Facility

Control Cubicle

The operations and monitoring of the system are performed from a control module, cubicle, or office. A PRESCON™ (PRESsure CONtroller) control unit collects inputs, operates the solenoid valves, and initiates system responses. It is preprogrammed to function nearly independent of an operator's presence. Error and warning codes/messages are displayed on a television screen/monitor to allow the operator to track system performance.

The PRESCON controller may also be used to automatically index the charge vessel a nominal rotation (e.g. ±5°) after each cycle, if the vessel is designed for rotation.

Generally, a CCTV monitor and controls are also located within the control cubical. This allows for visual inspection and assessment of the in tank mixing/pumping operations and performance.

2.1 Fluidic Mixing Methods and Process Description

The AEAT power fluidics™ mixing offer **a** significant potential advantage over other mixing technologies. The system utilizes the existing recovery liquid (supernatant) to mix the waste. If an insoluble solids layer exists on the tank floor, the mixing vessel can use the overlying supernatant to mix and suspend the solids. As the solids are mobilized and eroded away the charge vessel can be lowered until the ideal vertical placement is reached.

Liquid is drawn into the charge vessel during the evacuation cycle and expelled from the charge vessel during the drive, or pressurization, cycle. The relative duration for these two cycles is generally in the range of three **or** four to one, respectively.

The two mixing methods offered by AEAT (i.e. pulse-jet and pulse-tube) are largely the same with only minor differences. The pulse-jet mixing alternative is generally the preferred method due to the increased ability to control the mixing process.

2.1.1 Pulse-Jet Mixing

The inlet to the charge vessel on a pulse-jet system is typically a **nozzle** directed parallel to the tank floor. Ideally, the charge vessel is installed on a large bearing and rotated between cycles by a stepper motor to optimize the mixing area of influence. **A** simplified schematic of the pulse-jet mixing method is included in Figure 8.

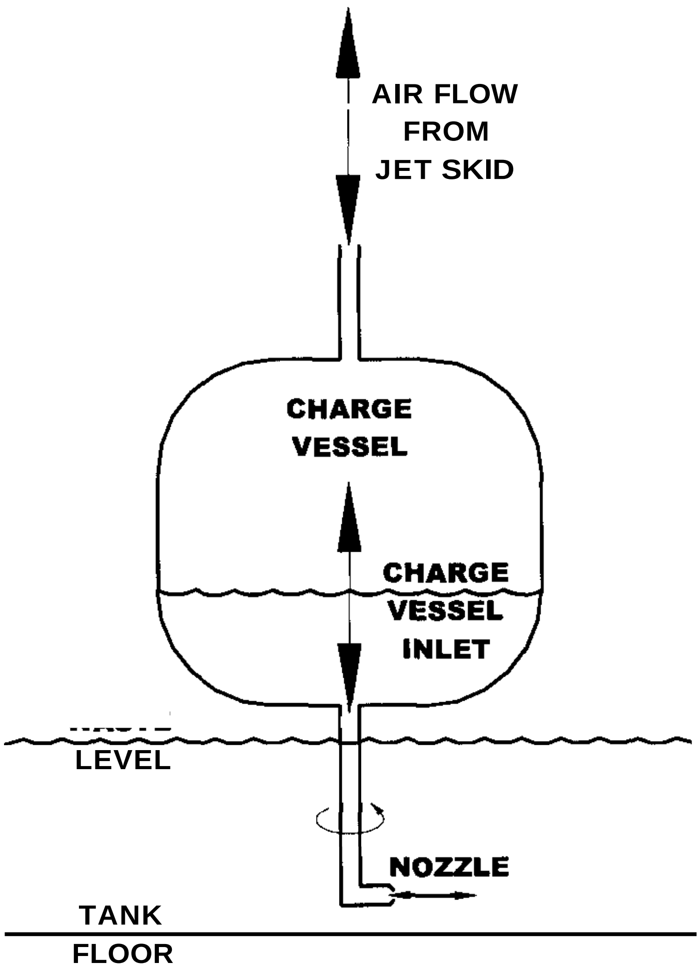


Figure 8 Pulse-Jet Mixing

The mixing is performed by evacuating tlic charge vessel until it is 95% full (as a target) then expelling tlic vessel contents back into the recovery vessel. The liquid expulsion fractures and mobilizes tlic solid waste constituents for recovery into the charge vessel. Flow into the charge vessel docs not require any suction head pressure to initiate lilling as an inherent function of the design. Further mixing of the recovered constituents occurs within the charge vessel as it is drawn in and again upon expulsion. Measures are taken to ensure that the charge vessel is not over filled and that the expulsion docs not result in over filling (a.k.a. over-blow) in the drive phase. These controls are discussed in Section 2.0.

As an example, a nozzle is shown in Figure 9 that was used in the ORNL CIP tank W-35.

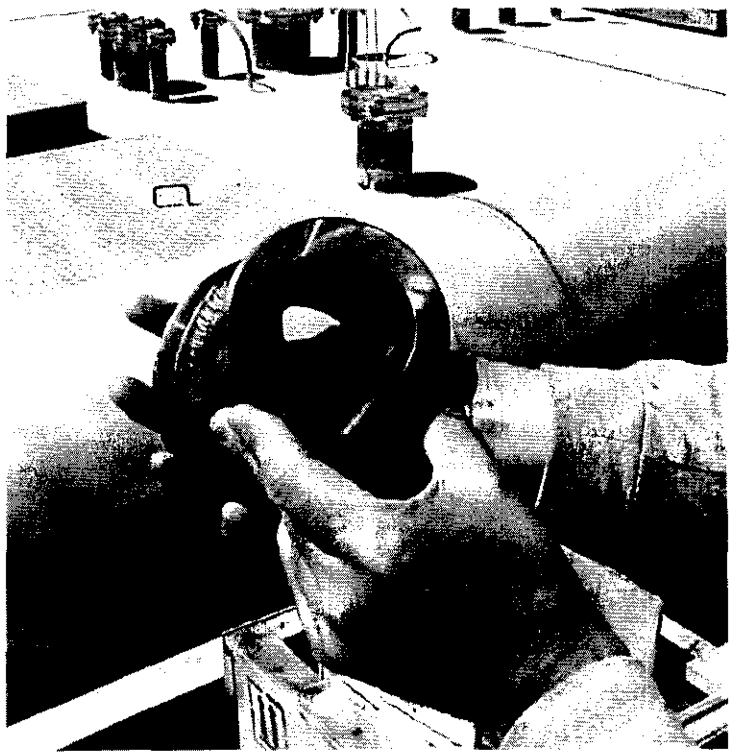


Figure 9 Pulse-Jet Nozzle

2.1.2 Pulse-Tube Mixing

The charge vessel inlet in a pulse-tube system is pointed vertically and directed at the tank floor. The expulsed liquid is projected against the tank floor under pressure or allowed to self-drain under the influence of gravity. **A** simplified schematic of the pulse-tube mixing method is included in Figure 10.

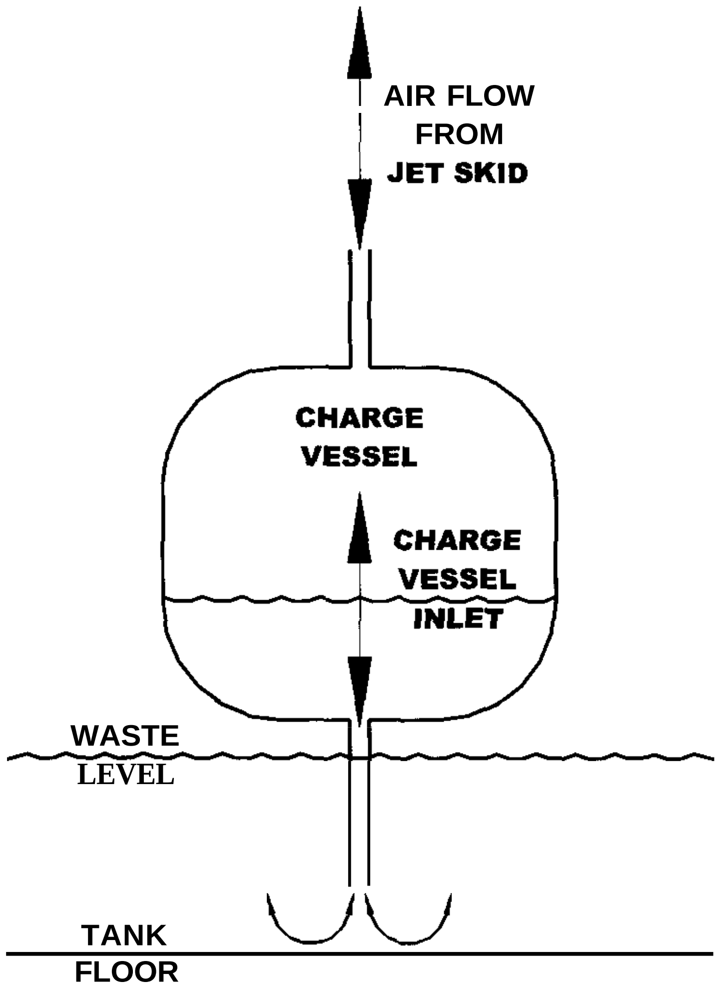


Figure 10 Pulse-Tube Mixing

The principle of operation for the pulse-tube mixing method is largely the same as **for** the pulse-jet mixing method. In pulse-tube mixing the drive phase is not necessarily incorporated. Liquid may be drawn into the charge vessel and allowed to drain under the force of gravity. In either case, the pulse-tube mixing method is generally not as efficient at mixing as the pulse-jet method. Even when the drive phase is utilized a significant fraction of the expelled liquid's kinetic energy is lost on the tank floor reducing the area of mixing influence. Additionally, the lack of ability to rotate and direct the liquid expulsion limits the pulse-tube method from localizing the mixing efforts on difficult areas.

2.2 Fluidic Pumping Methods and Process Description

AEA Technology utilizes and markets two different types/methods of "no moving parts" pumps. In order to understand how these unique pumps function, a description of the Fluidic Diode (diode) and Reverse Flow Diverter (RFD) is included in Section 2.3.

Power fluidic pumps provide intermittent flow injection to the transfer line as a "step" function. In general, the evacuation cycle is on the order of three to four time longer than the expulsion cycle. This results in an average flow rate from the recovery vessel one-third to one-fourth of the peak expulsion flow rate. Multiple fluidic pumps could in theory be operated out of phase to produce a near continuous flow. In addition to producing a constant flow velocity, this would allow the installation of a booster pump downstream of the fluidic pumps. Pump installation in this fashion has not, however, been previously demonstrated.

Each of the pumping methods has unique performance characteristics suiting them for different applications. Diode pumps can generally accommodate large solid particle size and operate more efficiently, while RFD's generate greater head pressure. Careful consideration of the project goals and mission should be made prior to the selection of the pump to be utilized.

The RFD pump was developed prior to the diode pump and has been employed for over 15 years in a variety of applications. Diode pumps have been around for less than ten years, with much less utilization compared to RFD pumps.

2.2.1 Fluidic Diode Pump

In a fluidic diode **pump,** two fluidic diodes (Section **2.4.2)** are incorporated. One diode is installed between the charge vessel inlet and the **pump** inlet (inlet diode), and the other between the charge vessel inlet and transfer line outlet (outlet diode). This arrangement is illustrated schematically in Figure 11.

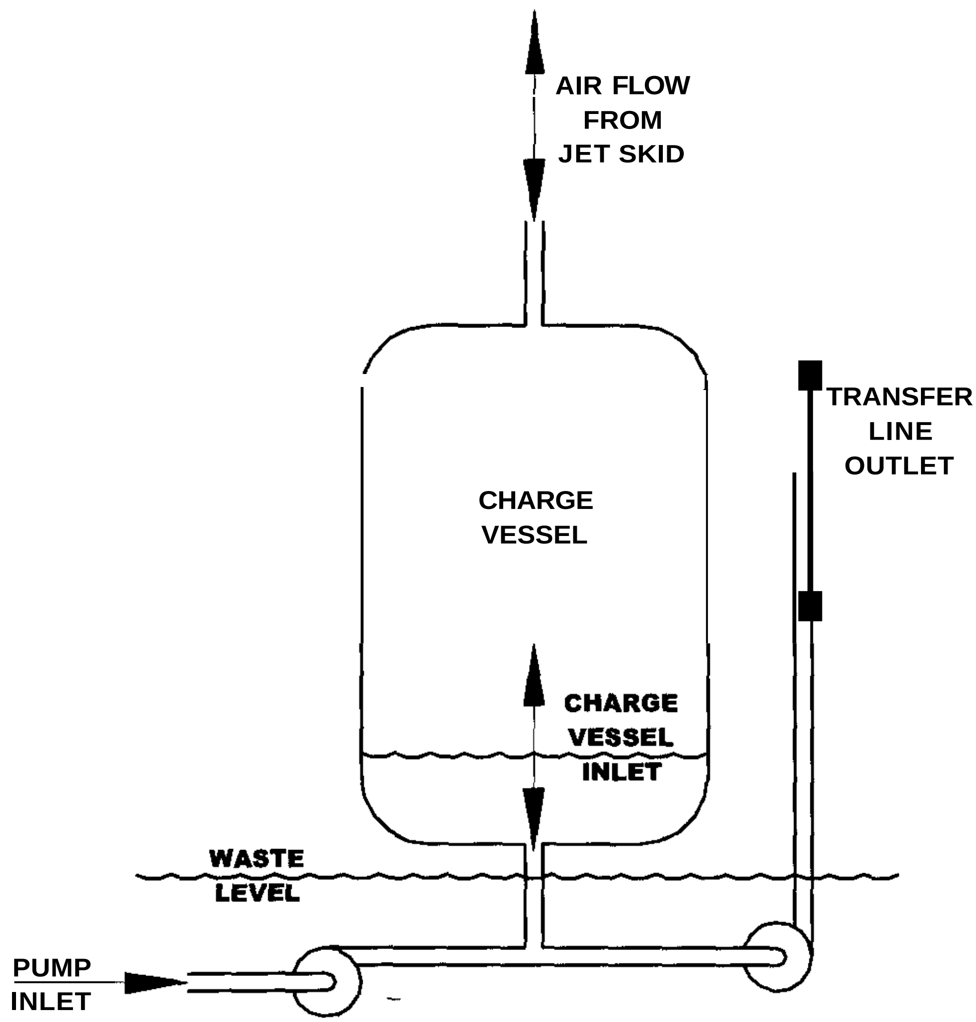


Figure 11 Diode Pump

As the charge vessel is evacuated, flow through the inlet diode is unrestricted allowing the charge vessel to fill with liquid from the recovery vessel. The outlet diode restricts flow from coming back down and out of the transfer line. When the charge vessel is pressurized, the diode roles are reversed; the unrestricted flow path is out of the charge vessel to the transfer line.

Because the diode impedes backflow from the transfer line, the charge vessel size can generally be smaller than that required for a RFD pump. The diode acts like a leaking check valve during the evacuation phase allowing only a percentage of the expelled volume to return to the tank.

Examples of applications where diode pumps have been employed are included in Table **2.**

Pump Type	Minimum Dimension in Fluidic Element (in)	Delivery Line			Process Fluid	SpG	Average Pump Rate (gpm)
		Lift (ft)	Length (ft)	Dia. (in)			
2-Diode	5/16	38	48	1	Water	1	3
2-Diode	5/16	38	48	1	Kaolin (25% w/w)	1.2	2
2-Diode	5/16	46	65	1	Water	1	2
2-Diode	5/16	46	65	1	Barium Carbonate	1.3	2
2-Diode	5/16	46	65	1	Water + 5-15% w/w sand	NR	2
2-Diode	5/16	46	65	1	Water	1	2
2-Diode	5/16	46	65	1	MAC1 Floc	1.1	1
2-Diode	5/16	46	65	1	MAC2 Floc	1.09	1
2-Diode	5/16	46	65	1	Water + Sand	NR	2
2-Diode	7/16	55	57	2	Water	1	7
2-Diode	7/16	55	57	2	Kaolin (25% w/w)	1.2	7
2-Diode	7/16	55	57	2	Water	1	7
2-Diode	7/16	55	57	2	Kaolin (25% w/w)	1.2	7
2-Diode	1 7/16	65	114	3	Water	1	70
4-Diode	5/8	65	2656	3	Water	1	13

Table 2 Fluidic Diode Pumping Applications

2.2.2 Reverse Flow Diversion Pumping

In a Reverse Flow Diverter (RFD) pump, the RFD functions as the liquid inlet and backflow inhibitor. The RFD and the principles of its operation are provided in Section 2.4.3. This arrangement **is** illustrated schematically in Figure 12.

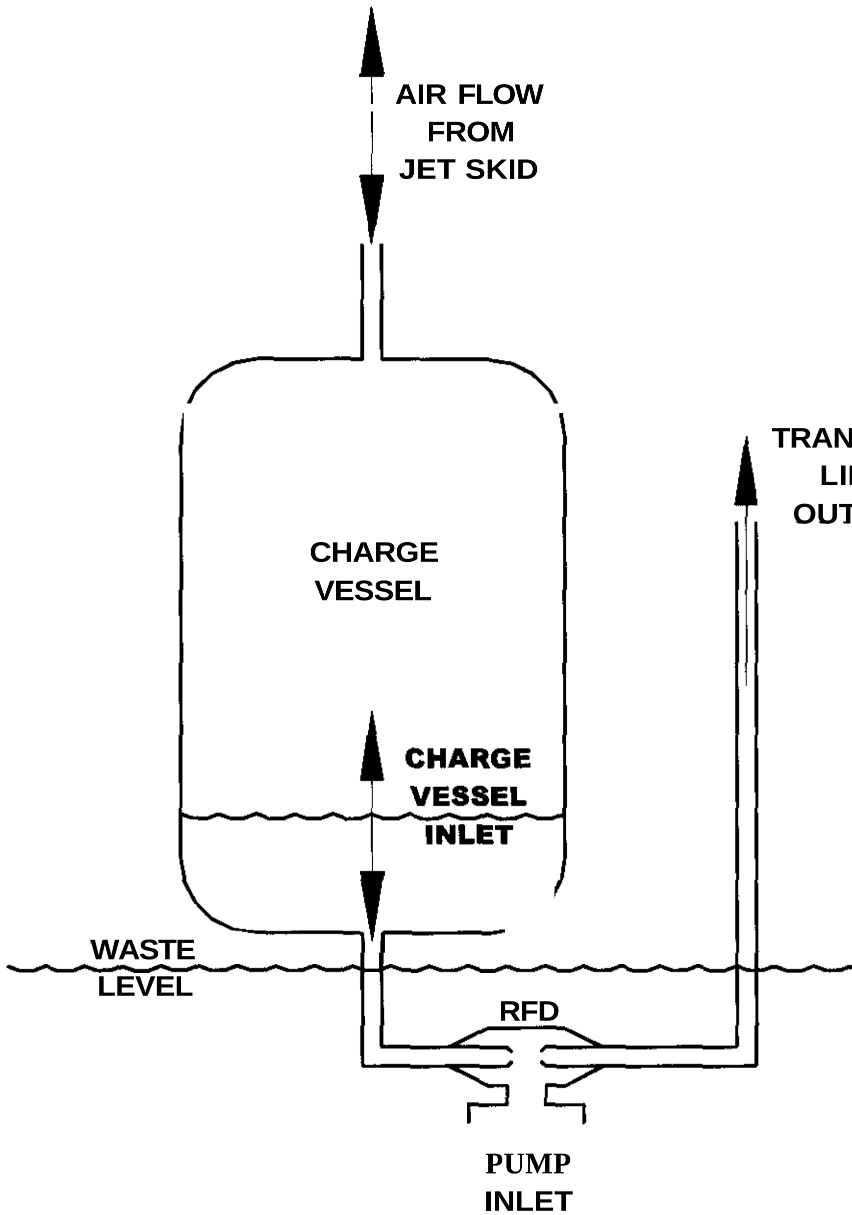


Figure 12 RFD Pump

The charge vessel is filled during the evacuation phase with liquid from the recovery vessel via the pump inlet and liquid back flowing out of the transfer line. When designed properly the least restricted flow path to the charge vessel will be through the pump inlet. When the charge vessel is pressurized, the path of least resistance for the expulsion stream is into the transfer line.

Unlike with a fluidic diode pump, the entire transfer volume is relatively unrestricted to backflow into the tank during the evacuation phase. This requires that the charge vessel be larger to overcome the line hold up until a means of backflow is reached outside the recovery tank.

Applications where RFD pumps have been employed are included in Table **3.**

RFD Size (in)	Delivery Line			Process Fluid	SpG	Average Pump Rate (gpm)
	Lift (ft)	Length (ft)	Dia. (in)			
7/32	100	147	1	Water	1	3
1/4	27	49	1	Ion Exchange resin	NR	2
1/4	9	16	1	3M Nitric Acid + 3g/l stainless steel shavings	NR	1
3/8	29	193	1	Ion Exchange resin	NR	1
3/8	13	29	½	Water	1	5
13/32	100	147	1	Water	1	8
7/16	14	49	1	Barium Carbonate	Up to 1.3	11
5/8	26	32	2	Floc	NR	3
5/8	27	98	2	Barium Carbonate	NR	2
5/8	100	147	2	Water	1	23
5/8	14	113	1-1/2	Barium carbonate + Filter precoat + magnetite	NR	7
3/4	16	111	2	Ferric hydroxide sludge	NR	15
13/16	49	1515	3	Water	1	7
13/16	100	147	2	Water	1	35
13/16	19	82	1-1/2	Floc	1.1	10
13/16	19	65	2	Floc	NR	11
13/16	19	65	2	MAC floc	NR	11
13/16	19	65	2	SEC floc	NR	11
13/16	16	131	3	Floc	1.1	47
13/16	16	131	3	BE7 Floc	1.08	18
13/16	16	131	3	MAC floc	1.1	31
13/16	16	131	3	SEC floc	1.1	26
13/16	16	131	3	Simulant2: China clay + bentonite	1.1	26
13/16	16	131	3	Simulant3: China clay + bentonite	1.1	26
13/16	16	131	3	Simulant4: China clay + bentonite	1.1	26
13/16	55	167	2	Water + Filter precoat + magnetite	NR	15
1	100	147	3	Water	1	44
1	9	16	1-1/2	Water + dicalite + sand	NR	8
1-1/8		98	3	Water	1	57
1-1/8	49	65	3	Uranyl Nitrate + Kieselguhr + Graphite	Up to 1.6	61

Table 3 Fluidic RFD Pumping Applications

2.3 Combination Fluidics Mixing and Pumping Method

The AEAT mixing and pumping systems can be combined to provide a "pure" power fluidics system or operated in conjunction with conventional pumping or mixing techniques. For example, a submersible transfer pump could be employed with a pulse-jet-mixer, or, a conventional mixer pump could be employed with a RFD pump.

A complete system relying solely on power fluidics to perform both the mixing and pumping functions can be accomplished in one of two ways. The simplest form would be to have separate charge vessels, one for mixing and a second for pumping. A more compact method, which may have greater utility at Hanford, would be to share a common charge vessel for both functions. The limited riser size and availability in the SST's at Hanford make this second option the most appealing. Deploying two charge vessels into a riser of limited size reduces the volume of each of the charge vessels. This in turn reduces the performance characteristics by reducing the cycle duration. The solution to this problem may be to utilize a system similar to that depicted in Figure 13.

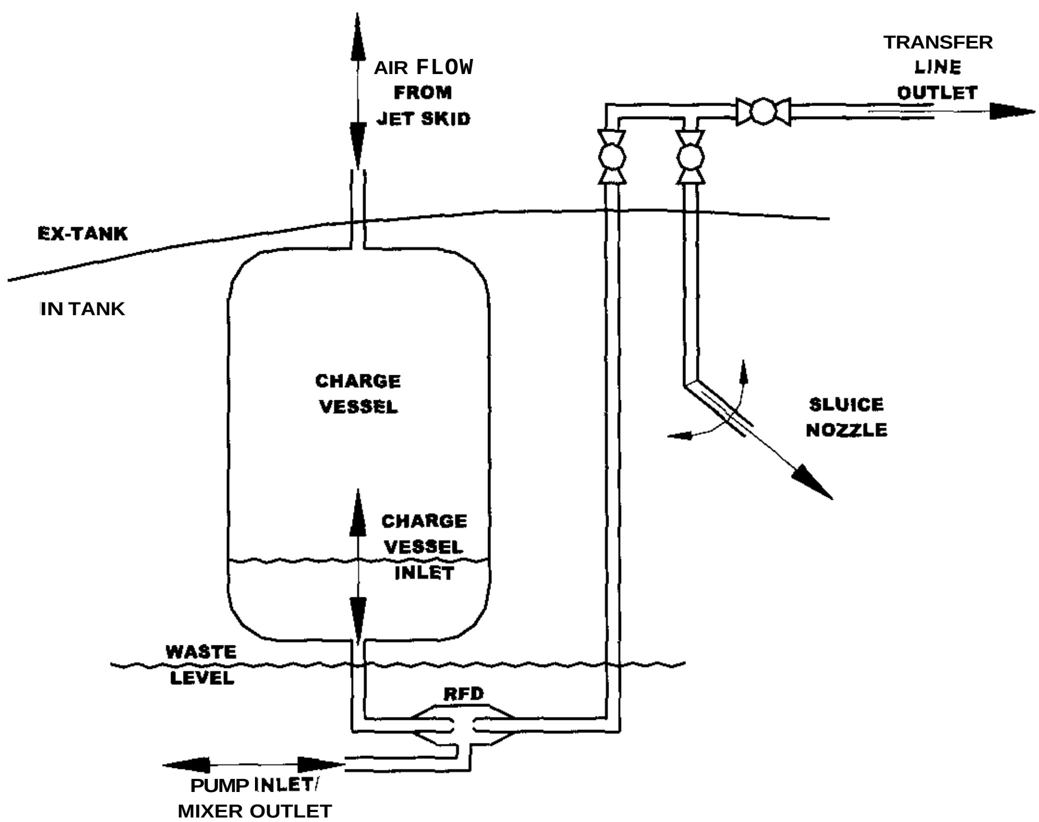


Figure 13 Combination Mixer and Pump

Depending upon the valve configuration shown in Figure 13 the expulsion of liquid from the charge vessel can be directed to 1) **a** submerged mixing nozzle, 2) *an* above waste sluicing nozzle, or **3)** into the transfer line.

2.4 Principles of Operation

To understand how the AEAT systems perform without the utilization of moving parts, a description of the means and principles of operation are included for several of the key components. The statement that no moving parts are utilized can be misleading. A compressor and valve skid outside of the immediate pumping/mixing location are utilized which do rely on moving components. These pieces of equipment can, however, be located at a considerable distance from the recovery vessel and in a non-radiological area. Maintenance and repair of this equipment would be relatively simple and inexpensive when compared to removal and repair of contaminated pumps typically used for waste retrieval.

2.4.1 Jet Assembly

The AEAT mixing, pumping, and sampling systems utilize many of the same primary components. In particular, the operations utilize an air compressor that supplies continuous flow through a "jet" assembly consisting of two eductors. One of the eductors is connected to a charge vessel, the other to either an off-gas skid (for pumping and mixing systems) or redirected into the recovery tank (for sampling systems). The charge vessel is evacuated by directing the airflow with solenoid valves through the evacuation eductor. Flow directed through the other eductor can be used to pressurize the charge vessel depending upon the application.

Utilizing the terminology of eductors for the jet assembly is somewhat of a misnomer. One of the jet assemblies functions as an eductor while the other does not. This second eductor looks and performs like a very poorly designed eductor, which actually overflows due to the relative nozzle/venturi diameters and configuration. The jet assembly is illustrated in Figure 14.

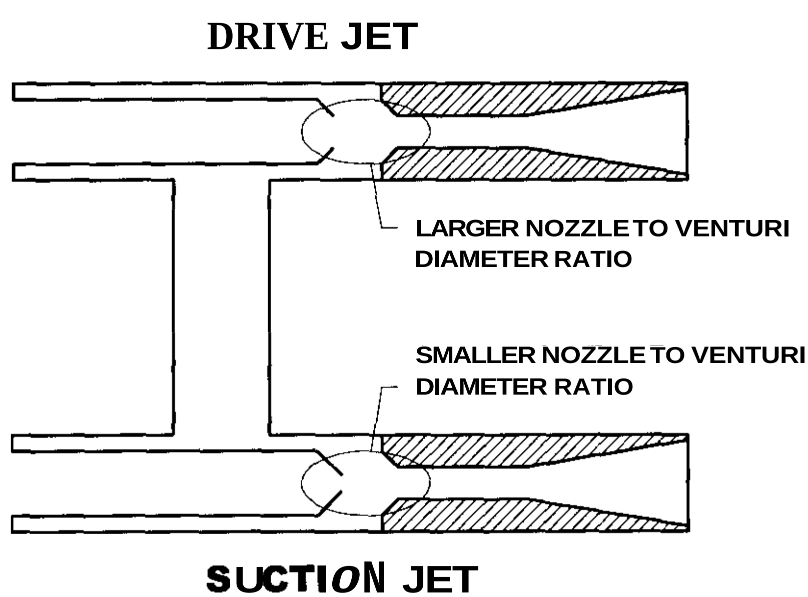


Figure 14 Jet Assembly

As illustrated in Figure **14** the drive jet is larger (relative to the venturi inlet diameter) than the suction jet. Flow directed through the suction jet to the off-gas skid, as illustrated in Figure 15, evacuates the charge vessel. This evacuation draws or vacuums liquid waste into a charge vessel. Once the charge vessel is full, solenoid valves redirect the flow through the drive jet as illustrated in Figure 16. This pressurization drives the liquid out of the charge vessel. In pumping applications the liquid is transferred out of the recovery vessel into a discharge line. In mixing applications the fluid is expelled back into the recovery/mixing vessel. In sampling applications, the expulsion stream is directed out of the tank to a sample station and then routed back into the tank. **A** third mode **of** optional operations is to vent the charge vessel. This mode is generally used to de-pressurize the charge vessel prior to "over-blow". Over-blow is when the charge vessel is pressurized for a duration exceeding that required to expulse the liquid. This results in air from the compressor leaving the nozzle, creating the potential generation of aerosols and waste foaming. Figure 17 illustrates the vent cycle.

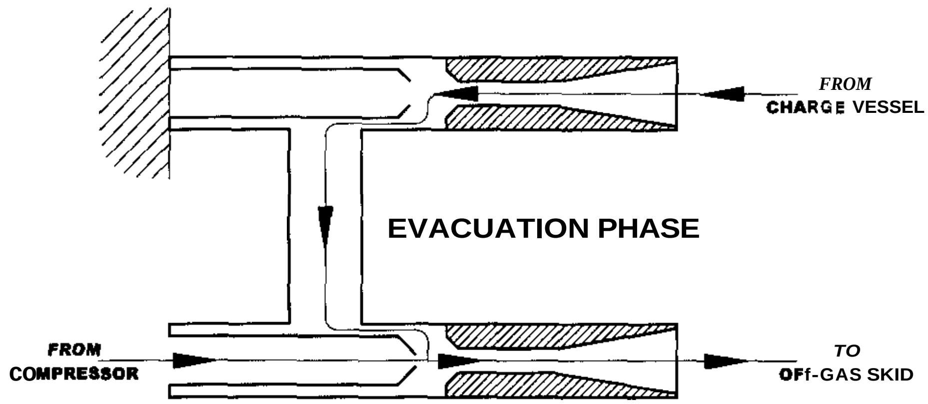


Figure 15 Evacuation Phase

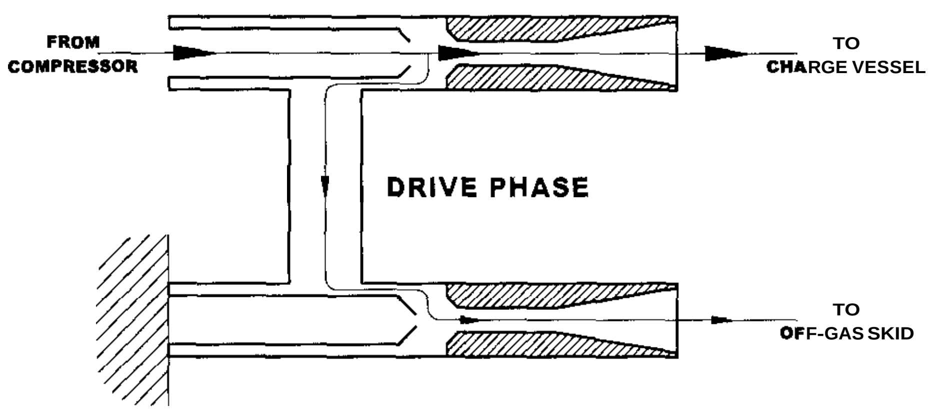


Figure 16 Drive Phase

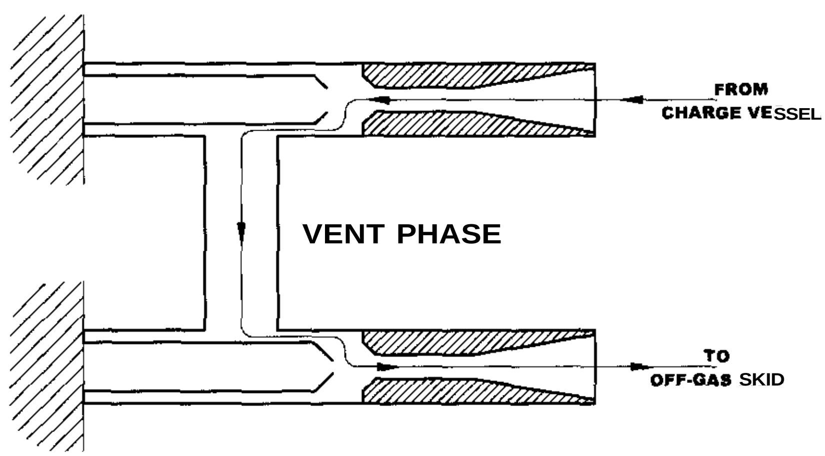


Figure 17 Vent Phase

2.4.2 Fluidic Diode

A Fluidic Diode is the fluid equivalent to **an** electric diode. **As** with an electric diode, flow in one direction is relatively unimpeded while flow in the other direction meets a high resistance. Fluidic diodes, if designed properly, can generate flow impedance on the order **of** 150 times greater in the reverse direction compared to the forward direction (Taylor et al. 1996) for the same flow rates. **A** standard check valve could be used in the place of a fluidic diode; however, this would incorporate moving parts into the system. **A** Fluidic Diode performs similar to a leaking check valve.

A Fluidic Diode works by creating a vortex when flow is introduced in the reverse direction, while flow in the forward direction has a relatively unrestricted flow path. Figure 18 provides ***a*** simple illustration of this phenomenon.

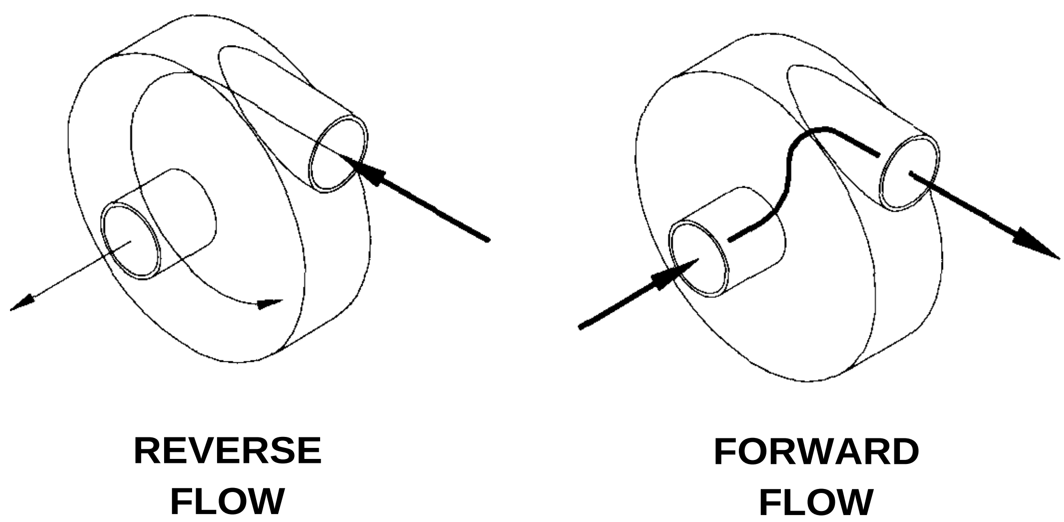


Figure 18 Fluidic Diode

2.4.3 Reverse Flow Diverter (RFD)

A Reverse Flow Diverter (RFD functions similar to a diode pump, however, the principles of operation are quite different. Figure 19 provides a simple illustration of **an** RFD.

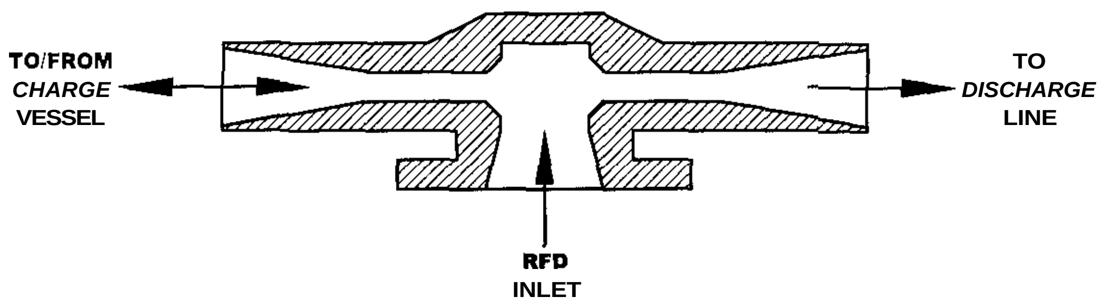


Figure 19 Reverse Flow Diverter

When the charge vessel is evacuated liquid flows either back out of the transfer line or from the recovery vessel. If properly designed, the majority of the liquid will flow to *the* charge vessel through the pump inlet. When the charge vessel is pressurized, the liquid is expelled from the charge vessel and directed from the first nozzle to the second. The liquid flow "shoots-the-gap" and is directed out of the tank through a transfer line. The RFD may be designed to function as an eductor (a.k.a. jet pump) to entrain additional liquid from the pump inlet during discharge. Compared to a fluidic diode pump this pump type has a great propensity to draw liquid back out of the transfer line and will completely drain the line if backflow prevention is not provided.

2.5 Historical Use and Applications

AEA Technology **Power** Fluidics™ methods and technologies have not been utilized extensively within the United States. The only current **or** future (planned) applications are within the DOE complex. A list of completed and in-process applications in the United States is summarized in Table 4. Additional activities that are in the proposal, design, and proof of concept phase, are not included.

Location	Project	Lead/Contact	Status
Oak Ridge National Laboratory	BVEST W-Tank Waste Mobilization for Retrieval	Tom Monk* INEEL	Tanks W-21 and 22 compleie. W-23 system in continued operation.
Oak Ridge National Laboratory	BVEST C-Tank Waste Mobilization for Retrieval	Tom Monk', INEEL	Tanks C-2 and 1 complete.
Oak Ridge National Laboratory	CIP W-35 Tank Waste Mobilization for Transfer	Tom Monk*, INEEL	Installation Complete, Not Yet Operated.
Oak Ridge National Laboratory	Small Tank Mixer for Retrieval	David Bolling, Bechtel	Tank 3003A complete.
Savannah River Site	HLW Sampler Systems	Bill McEvoy,	Complete, In Continued
Savannah River Site	Tank 1 Mixing for Retrieval	Gary Johnson, WSKC	Installation Complete, Not Yet Operated

Table 4 Power Fluidic™ Applications

<u>Oak Ridge National Laboratow. BVEST</u>

The most extensive application of AEAT power fluidics to date in the United States has been at Oak Ridge National Laboratory (ORNL). Mixing systems have been installed and operated in the Bethel Valley Evaporator Service Tanks (BVEST) W-21, W-22, and W-23 (Hunt, et al., 1998). These systems, primarily the W-23 system, continue to be operated in support of the Gunite And Associated Tanks (GAAT) retrieval and closure efforts. These systems exceeded the initial expectations and goal for tank cleanliness by mobilizing and removing (via the existing progressive cavity pumps) greater than 95% of the original tank sludge volume.

The three BVEST W-Tanks are collocated within a common vault. Each of these tanks contained six open-ended three-inch pipes, 12 inches above the tank floor, installed during the original construction, which were utilized as the mixing nozzles. The charge vessels, six total, were installed on a skid placed within the vault between W-21 and W-22. Flex hose jumpers with Camlock® fittings connected each charge vessel to one of the pipes. This arrangement required that the jumpers be manually reconnected to change the mixing/recovery tank. The control cubicle, compressor, valve skid, jet skid, piping bridge, and off-gas skid were also reused and common to each of the efforts.

Problems encountered during the deployment and operations were primarily attributed to the working relationships between AEAT, DOE-ORNL, MK Fergussen, Bechtel-Jacobs, and the facility owner, Lockheed Martin. The AEAT arrangement and contract were placed directly with the DOE. Some difficulties coordinating the procurement, commissioning (testing), installation, turnover, operations, and maintenance were encountered. AEAT is a wholly owned subsidiary to corporate AEA of the United Kingdom. Additional challenges were encountered resulting from the complexities and unfamiliarity with working under an international agreement. As a result of the lessons learned and additional work scope within the United State all future fabrications are planned internal to the United States and are to be performed to accepted US standards.

Normal, minor equipment issues were encountered during the commissioning and operations of this system. No design inadequacies, however, were identified which hindered system performance.

The initial ORNL tank retrieved, W-21, underwent activities in addition to mixing in an attempt to further reduce the solid sludge waste volume. Nine transfer campaigns were performed to recover approximately 7,100 of the initial 7,200 gallons of sludge. Table 5 contains the results of the mixing and transfer process. Campaigns 7 and 8 were performed in conjunction with the utilization of a mechanical sluicer. Campaign 9 was performed with mixing and the addition of nitric acid. It should be noted that additional water was added between transfers as a sludge diluent for all campaigns.

Transfer Number	Post Transfer Total Volume (gallons)	Post Transfer Sludge Volume (gallons)	Percent Recovered (Cumulative)
Initial Tank Conditions	40,000	7200	-
1	9500	4853	33
2	6900	1766	75
3	6100	1362	81
4	9000	1112	85
5	9000	919	87
6	1100	854	88
7	1350	604	92
8	4000	354	95
9	750	104	99

Table 5 Tank W-21 Retrieval Project

Similar results were obtained for W-22 and W-23 as for W-21. These tanks were only mixed, without manual sluicing operations or an acid wash. The tank W-23 retrieval was not pursued as rigorously as the previous two, as this tank is continuing to receive transferred waste (and sludge) from the GAAT. The sludge volume recovered from the W-22 tank was approximately 97 percent (7000 gallons initial to 202 gallons final).

The second project application of **an** AEAT mixing system was deployed in the BVEST C-Tanks, C-2 and C-1. These tanks were similar in construction to the BVEST W-Tanks; 12 feet in diameter, 61 feet 5 inches long with a total volume of 50,000 gallons and an operating volume of 47,500 gallons. The C-Tanks did not, however, contain pre-installed “mixing pipes”. Additionally, these two tanks contained cooling coils for the receipt of evaporator bottoms. Two charge vessels, one at either end, were installed on bearings with offset nozzles to fit between the cooling coils. A stepper motor was used to orient the nozzle direction and a camera was installed through the charge vessel to visually assess the process. The remaining Power Fluidics™ components, as described in Section 2.0, were the same in this application. After the mobilization and recovery of tank C-2 the charge vessels were moved to tank C-1. Recovery for these tanks was 99 and 95 percent, respectively.

Following completion of the C-Tank retrieval, the system was scavenged for parts *to* support the CIP Tank W-35 installation leaving only the charge vessel assemblies.

Oak Ridge, Capacity Increase Proiect (CIP)

Six 100,000-gallon tanks reside within the CIP vault. Tank W-35 was designated as the sludge receipt tank and selected for the installation **of** an AEAT Power Fluidics™ mixing system. This system has been installed and commissioned (tested and turned over), but not yet operated. Although the tanks are twice the size of the BVEST tanks, the fluidic mixing™ system design is nearly identical. In fact the majority of the components were acquired from the BVEST C-Tank mixing system.

Having learned from the BVEST mixing projects, the majority of the contract issues associated with these previous activities have been resolved. The most notable problem encountered with this project was during system installation. The charge vessel assemblies had been fabricated in pieces in the UK to save freight dollars. The unfamiliarity of the site construction forces (MK-Fergussen) and operating contractor (Lockheed Martin) led to significant confusion and delays in the installation in spite of AEAT representation. **As** future fabrications are to be performed within the US, this issue should now be resolved.

Oak Ridge. Small Tank Mixer

The last application of an AEAT mixing system at the *Oak* Ridge site was installed as a portable system in Tank 3003A. A dedicated nozzle assembly was installed with flexible jumper assemblies connecting to two portable mixing skids. The system was operated to mix and sample the resultant slurry prior to transfer for retrieval and ultimate tank closure.

The nozzle designs deployed clogged during the mixing campaigns due to the presence of unanticipated foreign matter in the tank (later determined to be pine-tree needles).

System performance continually degraded until the nozzles became completely plugged. While the system did not meet the "anticipated" performance expectations, the project goals were met (Appendix B Phone Interviews).

Savannah River Site. HLW Sampler
The SRS procured three sampling systems from AEAT to recover representative samples for waste characterization in their one million gallon storage tanks. One sampler is currently in operation with satisfactory results. The sample system configuration is essentially the same as for a small RFD pumping system. Instead of expelling the charge vessel volume into a transfer line, the waste is sent through **an** above-grade sampling station and recirculated back to the tank. No significant issues were identified for the system procurement, commissioning, or operations.

Savannah River Site. Tank 1 Mixer
A mixing system was designed and deployed in the SRS intermediate staging Tank 1. This tank is used during cross-site transfers and has demonstrated a propensity to collect solids during these transfers. An AEAT mixing system has been installed in this tank to operate ***during*** the transfers to eliminate the accumulation of solids. This system has been delivered, commissioned, and operated the week of September 13 through 18,2000. The residual waste heel was transferred (via a non-fluidic pump) to a High Integrity Container (HIC) for transport. No performance data is available for inclusion at this time.

2.6 System Requirements

A power fluidic pump and mixer can be deployed in situations where access is extremely limited. The charge vessel can be installed in, adjacent to, or above the recover vessel. For Hanford SST retrieval, however, there is no adjacent access and shielding requirements would generally dictate the charge vessel be installed internal to the tank (below grade).

While a system could potentially be installed through risers of very small diameter, there are practical limits. For example, mixing with a charge vessel having a volumetric capacity below 50 gallons would be slow and have a reduced mixing effectiveness and efficiency. For pumping applications, the minimum charge vessel size is specifically quantifiable.

Unlike mixing applications, fluidic pumping requires that the charge vessel be of adequate size to overcome line drain-back. The efficiency of pumping can be considered in terms **of** the expelled volume versus the transferred volume. The transfer line volume from the charge vessel to the transfer receipt vessel, or other backflow prevention means, must he less than the expulsed volume. For example, if the line volume from the charge vessel to the first solenoid valve is 20 gallons, the expulsion volume must exceed 20 gallons to result in a net positive transfer volume. This assumes that the entire transfer volume flows back to the recovery vessel during the vent and evacuation phases. In general, the pumping efficiency should be significantly greater than one (1). **As** for the preceding example, the charge vessel capacity should be at least 40 gallons and ideally would be on the order of 120 gallons.

Installation of a pump and mixer in the same riser will also decrease the potential or maximum size of each component. In any event, the mixing and charge vessels should be designed to utilize the available space. In general, the larger the mixer and pump charge vessel, the more effective and efficient the operations.

For a pulse-jet mixer deployment, the **riser** and/or mounting should be evaluated to withstand the torque produced by the expulsion nozzle. This is not a requirement for a pulse-tube mixer as the loads are along the vertical axis of the charge vessel and riser.

The power necessities for the system are predominantly determined by the air compressor requirements. The desired airflow rates are a function of the system design and desired pumping/mixing rates. As such, the specific power requirements are not immediately quantifiable. The compressor can be installed a significant distance from the recovery site. The air may be supplied by electric, or diesel compressors, or a facility air supply if available. Electric power is also required to control and operate the solenoid valves, monitor and control the system, and for the off-gas skid. These power requirements are, however, considered to be minimal.

Similarly, a source of water is required for system flushes and potentially to perform as a waste diluent. Again, the specific requirements are a function of the system design and application, but should be easily supported with minor modification to the SST infrastructure.

3.0 APPLICATION FOR HANFORD WASTE RETRIEVAL

The AEAT Power Fluidics™ system has potential application in the retrieval of both soluble and insoluble SST waste. The lack of moving parts on the "in-tank" portion of the system makes it intrinsically safe to operate in flammable gas atmospheres. The following sections discuss a *preliminary* system for deployment in 241-S-102.

3.1 241-S-102 Recommended System Configuration

The system proposed for deployment in 241-S-102 consists of two pulse-jet mixers and three RFD pumps. One **of** the pumps will have a recirculating loop from the transfer line feed. Expulsed liquid from this charge vessel can then be redirected to a "sluice" nozzle for final tank cleanout. A preliminary Process Flow Diagram (PFD) has been developed for this arrangement as discussed in Section **3.2** and depicted graphically in Figure 20. This arrangement is specific to 241-S-102 and presupposes that the majority of the waste constituents will be soluble in water and/or easily mobilized by mixing.

3.2 Process Flow Diagram

A recommended PFD for the recovery of waste from 241-S-102 is provided in Figure 20. This configuration was selected based upon the following considerations:

- **A** desired constant pumping recovery rate,
- Limited riser availability,
- Riser sizes and location,
- Minimization of unmixed zones/areas,
- Liquid waste minimization, and
- Potential capability to reach the tank closure cleanliness goal.

A complete description of this *preliminary* recommended system configuration, deployment, operation, and acquisition strategy are contained within the subsequent sections.

Multiple pumps operating and discharging 180° out of phase will provide a more constant delivery and flow velocity. While one pump charge vessel is being filled the other is expelling waste to the transfer line. Ideally, three **or** more transfer pumps would be employed, however, the limited number of available adequately sized (10 inch or bigger) risers makes this prohibitive. A reduction in the number of tank intrusive activities is achieved by combining the pump and mixer in a single assembly.

The installation of two mixers in diametrically opposed riser positions would not be enhanced by the addition of a third pump/mixer assembly only a short distance away. However, installation of a single mixer in an offset riser would not likely mobilize the solid constituents. Large "shadowed" areas would result from a single mixer considering the proximity of the 12-inch risers to the central riser and saltwell screen. The manhole locations would be a more suitable for mixing effectiveness and would accommodate much larger charge vessels. Consideration should be made to utilize these risers before the final design and deployment decision is made.

It is unlikely that the mixedpump assemblies alone **will** reach the tank cleanliness goal considering the location and method of agitation and pumping. **A** modified RFD pump with recirculating sluice nozzle is proposed to perform the final tank cleanout.

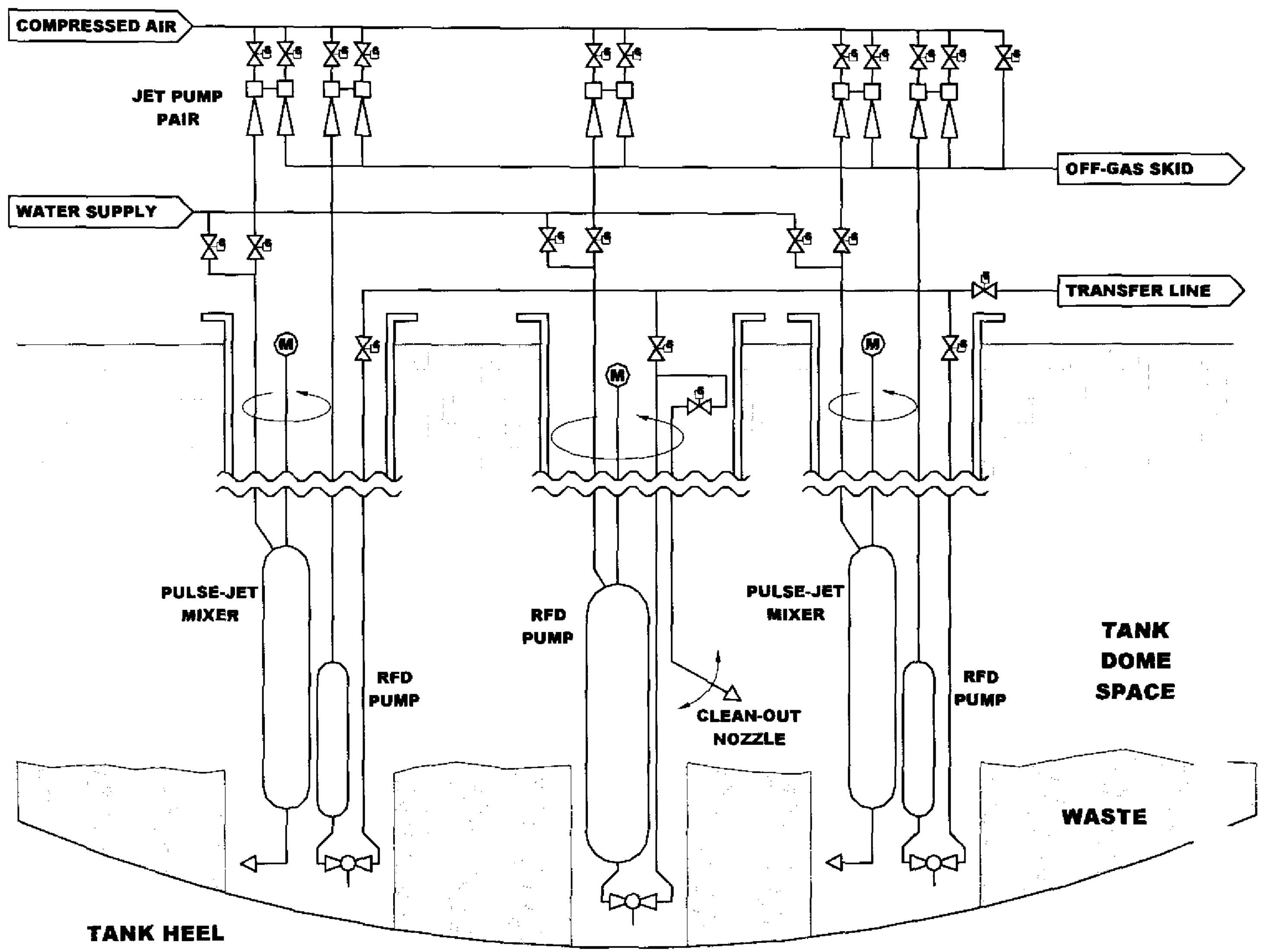


Figure 20 241-S-102 Process Flow Diagram

3.2.1 Primary System Components

The system configuration will consist of the following components previously described in Section 2.0:

- Air compressor with/without accumulator,
- Off-gas **(or** ventilation) skid,
- Valve skid,
- Jet skid (or jet tower),
- Pipe bridge,
- Charge vessel, and
- Control cubical.

3.2.2 Performance Expectations

A *preliminary* material flow and balance is developed and contained in Table ***6*****.** There will be four primary modes of operation; bulk waste mixing, bulk waste transfer, final tank washing, and heel waste removal. Within each of the primary modes are three subordinate modes of operation: the evacuation, drive, and vent phases as discussed previously in Section 2.4.1

Cycle	Vent Time (seconds)	Evacuation Time (seconds)	Drive Time (seconds)	Peak Flow Rate (gpm)	Average Flow Rate (gpm)
Bulk Waste Mixing	25	90	20	1600*	18
Bulk Waste Transfer	15	45	15	60	12
Final Tank Washing	45	180	60	300*	40
Heel Waste Transfer	45	180	60	150	40

* **Maximum attainable at *60* psig**

Table 6 241-S-102 Material Flow and Balance Estimates

3.3 Application of Power Fluidics™ Retrieval for 241-S-102

Two fluidic mixer/pump assemblies will initially be installed in opposing risers and near the tank floor by lancing through the waste in Risers ***6*** and 8 or 5 and 7. Existing supernatant, if available in sufficient quantity, will be vacuumed and expelled from the mixing charge vessel to mobilize the solid waste constituents. If insufficient drainable liquid is present in the tank after the conclusion of the interim stabilization process, water will be introduced into the mixing charge vessel. Both mixers will be operated simultaneously 180" out of phase. The mixers will automatically index 5" between cycles to effectively mix the largest possible area of influence. After the elapse of a predetermined interval, mixing operations will be suspended and pumping operations commenced.

The RFD pumps will operate 180" out of phase. While one charge vessel is being filled, the other is expelling solution into the transfer line. Solenoid valves will be operated to limit the transfer line back flow and redirection of process fluids to the other pump. Operation of two pumps out of phase will provide near continuous flow and a relative constant flow velocity in the transfer line. The pumping and transfer cycles will continue until the drainable liquid is recovered or the duration to refill the charge vessel becomes excessive.

This recommended system configuration and means of operation recovers waste in a "bottoms up" fashion. As in Interim Stabilization saltwell pumping, waste near the tank floor **is** recovered first. The overlying waste is allowed to settle/collapse to provide feed for subsequent pumping cycles. A "top down" retrieval does not control the liquid inventory during the recovery campaign. Water, or other solvent, that is added will permeate through the waste to the tank floor if not immediately recovered after introduction. The accumulation continues until the interstitial liquid level reaches the pump suction inlet.

After the initial drainable liquid has been recovered an additional ten to twenty charge vessel volumes of water will be introduced to the tank waste via the mixing charge vessels. A portion of this water volume may come from transfer line back flushing if the retrieval operations are extended for any duration. The mixing and pumping cycles will be performed repeatedly until the majority of the waste has been recovered. The automatic rotational indexing of the fluidic mixedpump assembly will cease and the remaining mixing operations will be directed manually with input from a radiation hardened in-tank CCTV camera.

Once the bulk of the waste has been recovered the mixing nozzles will be aimed/directed to clean the existing in tank hardware and saltwell screen in particular. The saltwell screen will be pulled from the tank, if possible, and the central RF'D pump with recirculating nozzle will be installed. If the saltwell screen cannot be removed, one of the previously installed mixer/pump assemblies will require removal to accommodate the recirculating pump.

The recirculating line on the clean-out RFD pump will terminate at a nozzle in the tank dome space. Liquid recovered from the tank heel will be expulsed from the nozzle and projected against the tank walls. Once the heel liquid is determined to contain a sufficient inventory of solids (by percent), the liquid/waste slurry will be recovered and transferred. Additional water will be introduced to the charge vessel and the cleaning cycle repeated. Rotating the charge vessel assembly and rotating the nozzle assembly in the vertical plane provide the nozzle direction control.

The mobilization, recovery, and transfer process will be controlled and monitored remotely from a mobile office located outside of the S Tank Farm. A remotely operated in tank CCTV camera will be installed in an available 12-inch tank riser and a display housed in the control office.

3.4 Deployment and Acquisition Plan

The recommendations of this pre-conceptual acquisition strategy are focused primarily on acquisition of the power fluidics systems described and evaluated within this report. Detailed planning, based on considerations that may have a direct influence on competition and design efforts by subcontractors, should be developed by the SST Retrieval Project for acquisition of architect-engineering services and other subcontracted functions needed to execute the project.

While power fluidic pumps and mixers are quite simple in nature, the operational control and optimization of system performance is not. AEA Technology holds a patent on the PRESCON control system, which manages the power fluidics operations. It is not recommended that an effort be undertaken to re-invent a power fluidic system at Hanford when the technology can be readily procured from a qualified supplier with years of experience devoted to the development and operation of these systems. AEAT is the sole proprietor of technically mature power fluidics systems, therefore the SST Retrieval Project should pursue this procurement as a sole source acquisition.

Based on the experience gained in the contracting model employed by DOE at the ORNL Site, the following acquisition approach is recommended for application at the Hanford Site. AEA Technology should be contracted to develop a preliminary (or conceptual) design for the SST retrieval system based upon an approved Functions and Requirements baseline and/or functional specification, and to conduct sufficient mock-up or simulation testing to confirm that the proposed system will function as required in the specific **SST** application. Based upon acceptable preliminary design results, additional contract options can then be exercised, at the discretion of the SST Retrieval Project. It is recommended that a technology demonstration contract be placed with AEAT. The contract should include provisions for technical and operations support during on-site system assembly/installation, commissioning (i.e., startup testing and readiness review) and subsequent retrieval operations.

Field installation and startup of the AEAT equipment should be performed either by plant forces or by Hanford construction forces, under the technical guidance of on-site AEAT representatives. The complex nature of the power fluidics control system, coupled with its limited operational utility (i.e., a one-time demonstration) at the Hanford Site, do not appear to warrant expenditure of significant resources on training Hanford Site personnel to maintain and operate the AEAT equipment without supervision.

As planning for the project matures, the acquisition strategy should evolve through an iterative process and become increasingly definitive in describing the interrelationship of the management, technical, business, resource and other aspects of the project. As demonstrated in the ORNL example, the chances for successful implementation of new retrieval technologies are enhanced by close collaboration and consensus among the key participants and stakeholders involved in executing and overseeing the work. The recommended acquisition approach, coupled with active involvement throughout the projects life cycle by SST program/project management, DOE, and regulatory personnel, can help to ensure that the project’s technical, cost and schedule objectives are satisfied.

4.0 241-S-102 BACKGROUND AND EXISTING CONDITIONS

4.1 Process History

The 241-S Tank Farm was constructed during 1950 and 1951 in the 200 West Area of the Hanford Site. According to Anderson (1990), 241-S-102 went into service in 1953. Figure 21 (Brevick et al. 1997) graphically depicts the 241-S-102 waste processes and fill history. During the third quarter of 1953, the tank received REDOX high-level waste (HLW) from **S** Plant. From the fourth quarter of 1953 to the third quarter of 1955, REDOX HLW cascaded from 241-S-101 to 241-S-102. Waste additions to 241-S-102 from 241-S-101 did not occur again until the fourth quarter of 1973 and continued intermittently until the second quarter of 1979.

Because 241-S-102 was the 242-S Evaporator feed tank from 1973 to 1976, frequent transfers were made to 241-S-102 from other tanks during this period. After 1976, 241-S-102 received mostly evaporator bottoms and evaporator feed from 241-SY-102, 241-T-101, 241-TX-102, 241-TX-104, and 241-TX-105. In 1979, additions of $HNO_3/KMnO_4$ were received from an unknown source. These receipts were probably associated with evaporator operations, which use $HNO_3/KMnO_4$ in the partial neutralization process. Large intermittent transfers of water were added to the tank from 1972 through 1976.

Tank S-102 was removed from service and labeled inactive in 1980. Tank S-102 was partially interim-isolated in 1982 and is awaiting the completion of interim stabilization (Brevick et al. 1997). Saltwell liquor waste was transferred from 241-S-102 to 241-AW-106 during the fourth quarter of 1992 as part of the interim-stabilization process. Approximately 549,000 gallons of waste was left in 241-S-102 after the final transfer from the tank in 1992.

Saltwell pumping of 241-S-102 was re-initiated in the fourth quarter of 1998. Difficulties with process flow and equipment failure have hampered the recovery effort. The tank remains un-stabilized and is not currently scheduled for repair and/or restart (fourth quarter 2000).

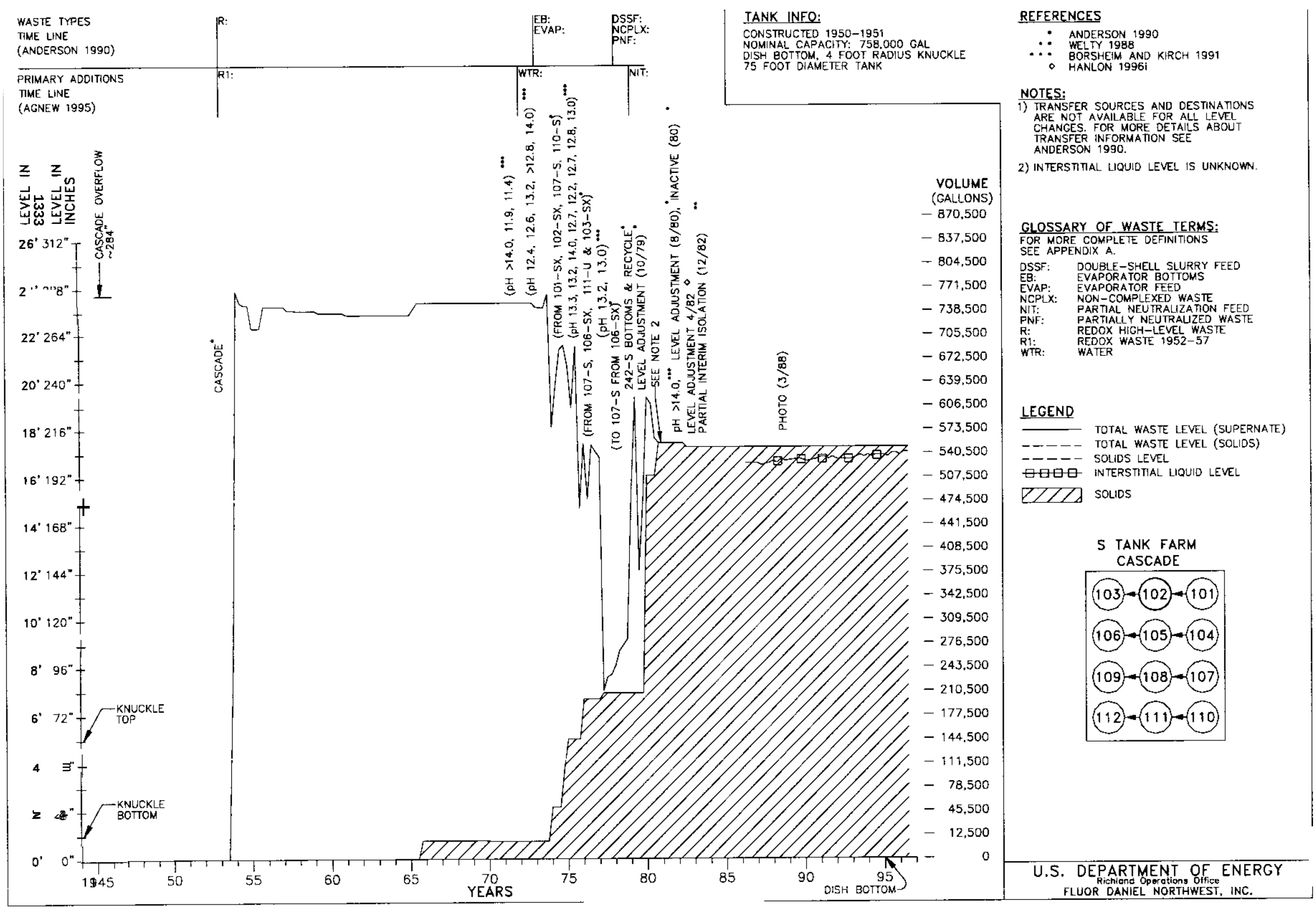


Figure 21 241-S-102 Process Flow and Fill History Diagram

4.2 Sampling and Inventory

Two push-mode core samples were taken between January and March 1996 to satisfy the requirements of the safety screening DQO (Dukelow et al. 1995), the organic complexant safety DQO (Turner et al. 1995), and the historical model evaluation DQO (Simpson and McCain 1997). The sampling and analysis were performed in accordance with the SAP (Eggers 1996). Before core sampling began in 1996, the tank headspace vapors were measured for flammable gas concentration as required by the safety screening DQO.

Twelve push mode core segments were taken between March 5,1998 and April 2,1998. Three grab samples were taken on October 27, 1998 from 241-S-102. Two liquid grab samples were taken on June 22, 1995 to support the waste compatibility issue. Extensive vapor sampling was performed between March 14, 1995 and February 11,1997.

4.2.1 Retrieval Safety Concerns

An assessment of potential safety problems involving the saltwell pumping recovery and transfer of waste from 241-S-102 into 241-SY-102 are documented in *Tank Safety Screening Data Quality Objective* (Dukelow et al. 1995). Of the issues identified and evaluated, only the classification of 241-S-102 as a Flammable Gas Watch-list Tank required further resolution. The flammable gas data quality objective (DQO) has been extended to apply to all tanks (Bauer and Jackson 1998). Analyses and evaluations will change according to program needs until this issue is resolved. Tank S-102 is on the flammable gas, safety issue Watch List (Public Law 101-510). Final resolution of the flammable gas safety issue is expected to be completed by September 30,2001 (Johnson 1997).

Flammable Gas

In accordance with the sampling **and** analysis plan (SAP) (Eggers 1996) and as required by the safety screening DQO (Dukelow et al. 1995), the 241-S-102 headspace was sampled and analyzed before core sampling in 1996 for the presence of flammable gases, using a combustible gas meter. This was crucial considering that 241-S-102 is on the Flammable Gas Watch List. The analysis indicated that the flammable gas concentration in the tank headspace was 6 percent of the lower flammability limit (LFL), which is below the safety-screening limit of 25 percent of the LFL. In addition, the concentration of oxygen gas, ammonia gas, and total organic carbon (TOC) vapors were determined. The ammonia concentrations were above the "immediately dangerous to life or health" (IDLH) notification limit of 300 p/m.

Retrieval of the remaining pumpable liquids by saltwell pumping scheduled to commence early in FY2001 will further mitigate the flammable and noxious gas safety concerns. Therefore, this is not considered a significant issue requiring any further consideration during the 241-S-102 retrieval.

Waste Compatibility

Tank S-102 was only partially interim stabilized in 1992. Saltwell pumping ofwaste from 241-S-102 (waste stream SST-99-02) into 241-SY-102 was reinitiated in 1998. At the onset of this pumping campaign, approximately 480,000 gallons of waste, including dilution and flush water were anticipated to be received into the double-shell tank (DST) system by saltwell pumping. Before pumping the waste liquids from 241-S-102, a waste compatibility assessment was performed by Process Control. Other wastes are scheduled to be received into 241-SY-102. Receipt of these other waste streams has also been considered in this assessment. The waste compatibility assessment ensures that the waste in 241-S-102 is compatible with the waste in the receiving DST, 241-SY-102. The *Datu Quality Objectivesfor Tank Farms Waste Compatibility Program* (Mulkey and Miller 1997, Fowler 1995 and 1999) directs the waste compatibility assessment.

A waste compatibility assessment (Fowler 1995 and 1999) recommended that 241-S-102 waste be transferred to 241-SY-102 provided requirements specified by the assessment were addressed. Seven requirements were specified in the waste compatibility assessment, with results indicating that no additional waste categories, waste codes, or tank safety concerns will be created as a result of transfemng 241-S-102 wastes into the DST system.

The assessments performed do not however, consider the addition of the solid salts or insoluble solids into 241-SY-102. **A** new compatibility assessment will have to be performed to consider the recovery **of** the entire 241-S-102 tank contents.

4.3 Sampling History

Recent core, vapor, and grab sampling has been completed for 241-S-102. A summary of the recent sampling events is contained in Table 7. Analyses performed on these samples were used as the basis for establishing the Best Basis Inventory and evaluating the safety concerns associated with the tank.

Sample/Date	Phase	Location	Segmentation	Percent Recovery
Vapor sample (3/14/95 - 2/1 1/97)	Gas	Tank headspace, Riser 7	N/a	N/a
Push core 125 (1/9/96 - 3/8/96)	Solidiliquid	Riser 11	11 segments	2-100
Push core 130 (1/9/96 - 3/8/96)	Solidiliquid	Riser **14**	11 segments	0-100
Push core 232 3/5/98 - 4/3/98)	Solidiliquid	Riser 16	11 segments	0-100
Grab (6/22/95)	Liquid	Riser 13	**N/a**	Two sample bottles
Grab (10/27/98)	Liquid	Riser 13	N/a	Three sample bottles

volumes for the saltcake solids and interstitial liquid were 519,000 gallons and 26,000 gallons, respectively. The sludge volume **used** in the inventory calculations was 4,000 gallons, which is the same as that predicted by Agnew et al. (1997) and Hanlon (1999). An evaluation of available chemical information for 241-S-102 was performed (Anantatmula and Wilmarth 1999), including the following:

- An inventory estimate generated by the HDW model (Agnew et al. 1997)
- A sample-based inventory estimate from two push cores from 1996
- Data from 1998 core 232 for ^{90}Sr and ^{137}Cs inventory estimates
- ***An*** engineering evaluation of sludge inventory based on comparisons developed by evaluation of 241-S-101, 241-S-104 and 241-S-107.

Based on this evaluation, a best-basis inventory was developed for 241-S-102. The sample-based evaluation inventories from 241-S-102, 241-S-101, 241-S-104, and 241-S-107 were used as a basis for the engineering evaluation. The two sample-based evaluations were combined to arrive at the engineering assessment, which is chosen as the best basis for the majority of non-radioactive analytes. The reported quantities of the non-radioactive constituents are included in Table 8.

Analyte	Total Inventory (kg)	Comment
[illegible]	49,500	
Bi	246	
Ca	1,360	
Cl	13,000	
TIC as CO_3	89,800	
Cr	9,700	
F	16,500	Upper bound estimate
Fe	2,880	
Hg	0	Simpson (1998)
K	3,090	
La	4.41	
Mn	1,320	
Na	6.62E+05	
Ni	106	
NO_2	1.25E+05	
NO_3	1.12 E+06	
OH_{TOTAL}	75,000	
Pb	189	
PO_4	1.51E+05	
Si	1,600	
SO_4	30,300	
Sr	36.3	Upper bound estimate
TOC	13,600	
U_{TOTAL}	2,860	
Zr	20.2	

Table 8 241-S-102 Best Basis Inventory of Non-Radioactive Constituents

The total alpha value from the 1996 core sample data for solids and the total uranium value were used to estimate inventories of the alpha contributing radionuclides and nuclides based on uranium. The same isotopic ratios listed in the HDW model were used for the calculations.

Best-basis tank inventory values are derived for 46 key radionuclides (as defined in Section 3.1 **of** Kupfer et al. 1998), all decayed to a common report date of January 1, 1994. Often, waste sample analyses have only reported ^{90}Sr, ^{137}Cs, $^{239/240}$Pu, and total uranium (or total beta and total alpha) while other key radionuclides such as ^{60}Co, ^{99}Tc, ^{129}I, ^{154}Eu, ^{155}Eu, and ^{241}Am, etc., have been infrequently reported. For this reason it has been necessary to derive most of the 46 key radionuclides by computer models. The Best Basis inventory of radionuclides is provided in Table 9, which includes those constituents with an inventory estimate greater than 20 curies.

Analyte	Total Inventory (Ci)	Comment
^{14}C	34.2	
^{60}Co	37.6	
^{63}Ni	237	
^{90}Sr	84,200	
^{90}Y	84.200	From ^{90}Sr
^{99}Tc	244	
^{106}Ru	0.00664	
^{113m}Cd	87.4	
^{125}Sb	161	
^{137}Cs	4.61E+05	
^{137m}Ba	4.36E+05	From ^{137}Cs
^{151}Sm	12,000	
^{154}Eu	611	
^{155}Eu	232	
^{239}Pu	241	Based on total alpha and HDW isotopic distribution
^{240}Pu	40.0	Based on total alpha and HDW isotopic distribution
^{241}Am	256	Based on total alpha and HDW isotopic distribution
^{241}Pu	438	Based on total alpha and HDW isotopic distribution

Table 9 241-S-102 Best Basis Inventory of Radioactive Constituents

4.5 Rheological Properties

Densities for the saltcake and interstitial liquid were averaged from the 1996 core sample data for the solid and liquid subdivisions respectively. The densities calculated are 1.68, 1.39, and 1.77 g/mL for saltcake solids, interstitial liquid and sludge respectively.

The extrusion reports from core samples taken in 1996 and 1998 indicated waste of varying consistency. Figure 1 graphically depicts the sample extruding technician's interpretation and classification **of** the waste upon extrusion. The legend used to apply the designations of "dry sludge", "wet salt'' etc. can be found in photo 96040468-1cnd.

Grab and core samples acquired in 1998 yielded waste salts ranging in color ***from*** white to gray. Drainable liquids were reported as clear with a yellow hue (Anantatmula and Wilmarth 1999). Density/specific gravity measurements were performed on all segments of the 1998 core sample. The subsegment-level results ranged from a high of 1.92 g/mL (from the upper half of segment 11, core 125), to a low of 1.274 g/mL (from the drainable liquid sample of segment 10, core 130), and yielded an overall mean of 1.64 g/mL. The saltcake, sludge, and saltcake/sludge composites yielded estimates of 1.69 g/mL, 1.67 g/mL, and 1.75 g/mL, respectively. These values were consistent with the 1996 core sample analytical results.

Shear and viscosity measurements for the saltcake acquired during the core sampling events could not be located.

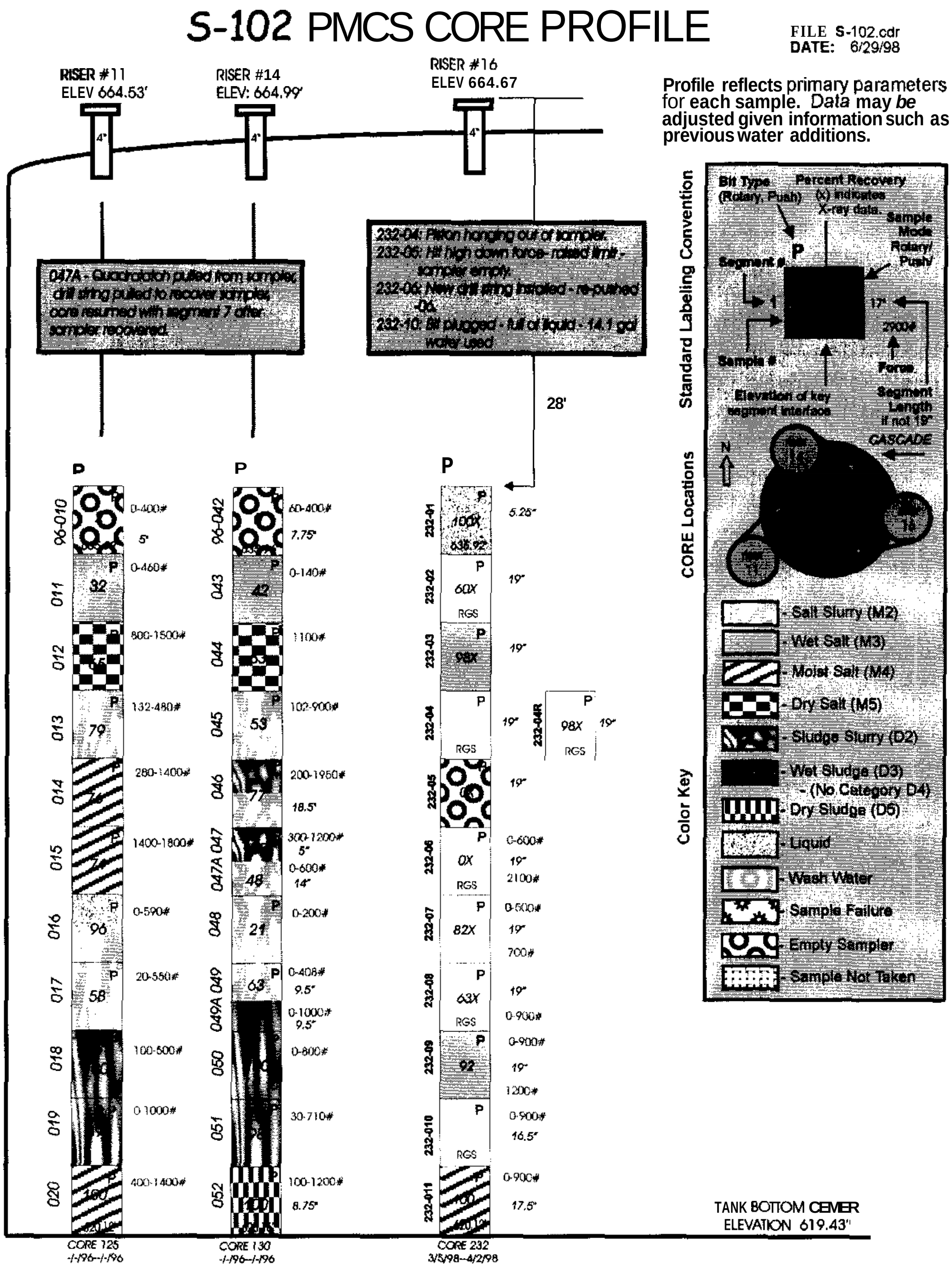


Figure 22 241-S-102 Core Sampling Waste Profile

4.6 Tank Configuration

Table 10 is a summary level description and status of 241-S-102. The tank **has a** nominal storage capacity of 758,000 gallons, and presently contains an estimated 549,000 gallons of double-shell slurry feed (Hanlon 1999). Figure 23 provides a plan view of SY Farm, a portion of **S** Farm, and the available transfer lines connecting 241-S-102 and 241-SY-102.

TANK DESCRIPTION	
Type	Single-Shell
Constructed	1951
In service	1953
Diameter	75 ft
Operating depth	23 ft
Capacity	758,000 gal
Bottom shape	Dish
Ventilation	Passive*
TANK STATUS (as of 12/31/98)	
Waste classification	Double-shell slurry feed
Total waste volume	549,000 gal
Supematant volume	0 gal
Saltcake volume	545,000 gal
Sludge volume	4,000 gal
Drainable interstitial liquid volume	262,000 gal
Waste surface level (12/31/98)	205.5 inches
Temperature (1/1/98 – 12/31/98)	72.9° - 145.7 °F
Integrity	Sound
Watch List status	Flammable gas
Flammable gas facility group	2
SERVICE STATUS	
Declared inactive	1980
Interim stabilization (partial)	1992
Interim isolation (partial)	**1982**

* Exhauster POR-004 is ducted to 241-S-102 and may be available for use.

Table 10 241-S-102 Description and Status

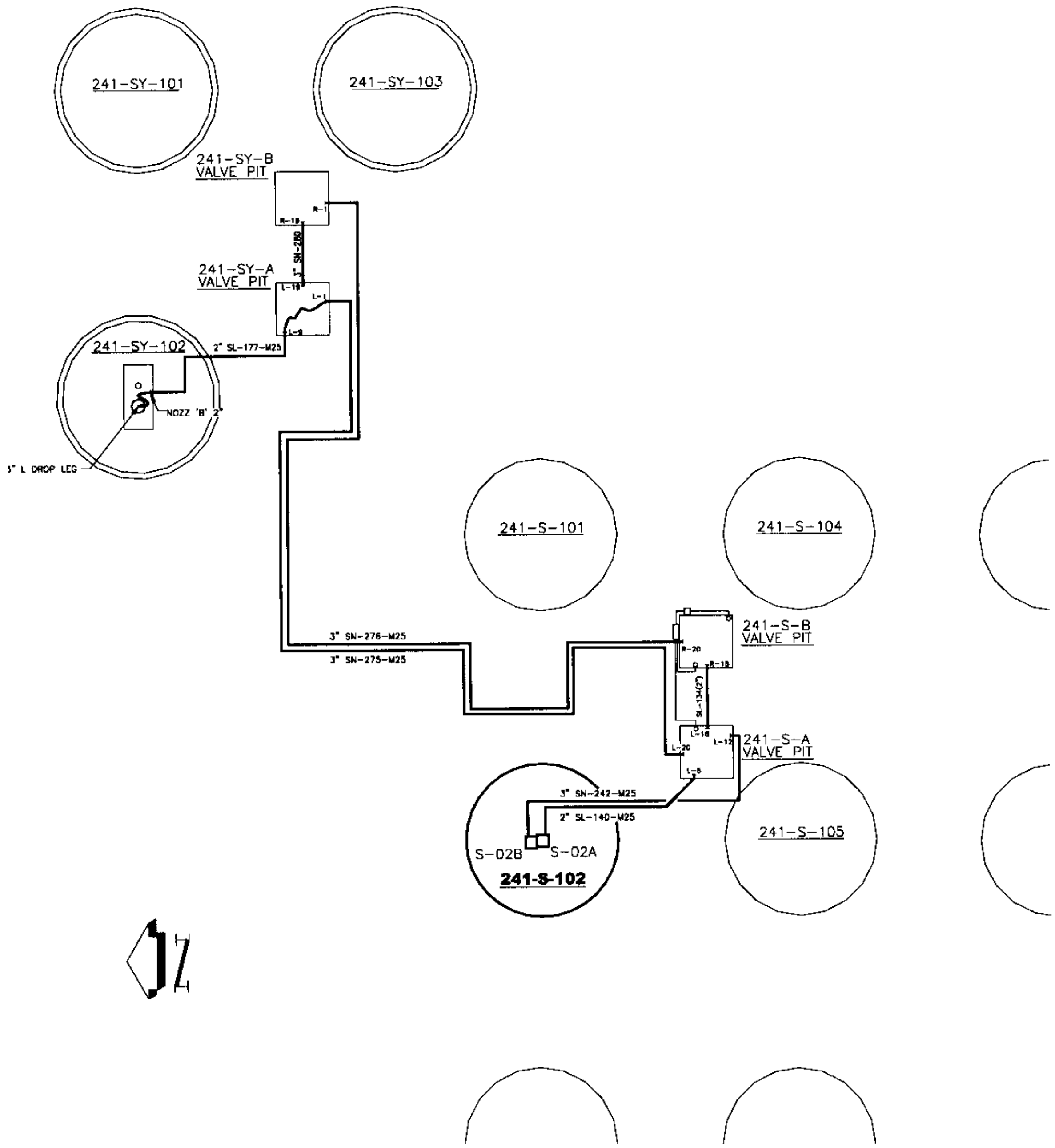
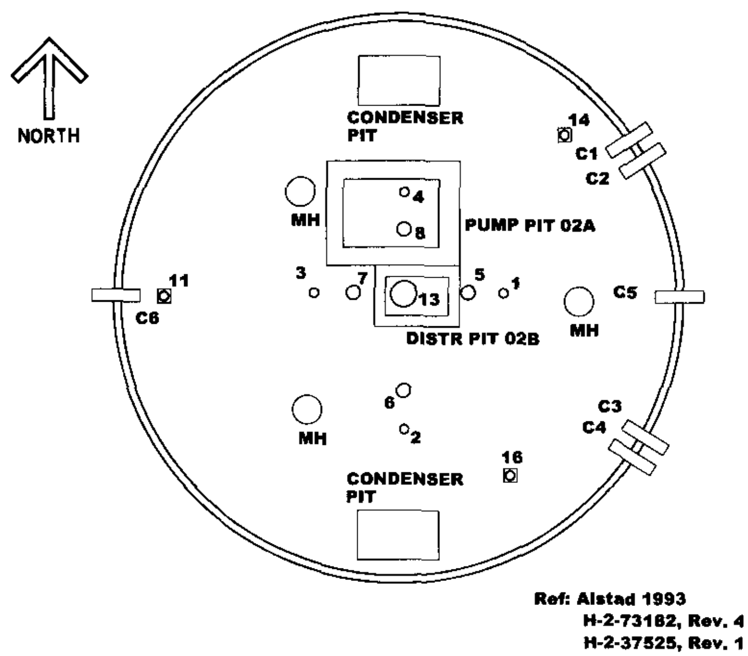


Figure 23 241-S and SY Farm Plan View

Numerous risers of various sizes are situated about the tank that may be utilized for the deployment of the fluidic pumping system. Figure 24 shows the tank and riser configuration in plan and elevation and Table 11 lists the current riser utilization. The risers are numbered 1 through 16. The cascade lines are designated C1 through C6.

241-S-102



TANK RISER LOCATION

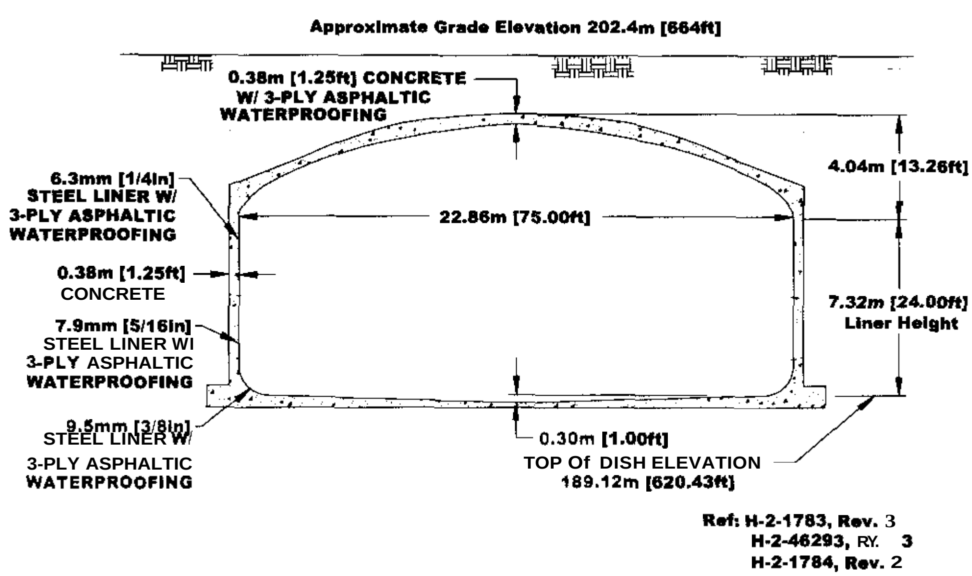


Figure 24 241-S-102 Plan and Elevation Views

RISER NUMBER	DIAMETER (Inches)	DESCRIPTION AND COMMENTS*
1	4	BLIND FLANGE [BREATHER FILTER CE0-41059 3/17/87] [HYDROGEN MONITOR / AIR FILTER ECN-W369-11 12/15/94]
2	4	ENRAF [ECN-620751 2/27/95]
3	4	B-221 TEMPERATURE PROBE
4	4	SPARE [UNUSABLE CE0-41059 3/17/87]
5	12	B-346 LOW [BM CEO-36910 12/11/86]
6	12	VENTILATION [BLANK CE0-41059 3/17/87] [DUCT REMOVED & RISER CAPPED ECN-706501 8/29/95]
7	12	B-222 OBSRV PORT [INSTALL MULTIPORT ADAPTER W/ HEATED VAPOR PROBE IN HIGHEST PORT ECN-628735 12/19/95]
8	12	PUMP MOUNT, WEATHER COVERED
11	4	SMP
13	42	SALTWELL SCREEN AND PUMP
14	4	SLUDGE MEASUREMENT PORT
16	4	SLUDGE MEASUREMENT PORT [BM CEO-36910 12/11/86]
C1	3	SPARE NOZZLE, CAPPED
C2	3	SPARE NOZZLE, CAPPED
C3	3	SPARE NOZZLE, CAPPED
C4	3	SPARE NOZZLE, CAPPED
C5	3	INLET, CASCADE OVERFLOW FROM 241-S-101
C6	3	OUTLET, CASCADE OVERFLOW TO 241-S-103
MH	-	MANHOLE

*Riser utilization per HNF-SD-WM-ER-611, Rev 1

Table 11 241-S-102 Riser Utilization

Two pipe-in-pipe encased transfer lines connect 241-S-102 to the S Farm valving system. Two-inch SL-140 connects the S-02B pit to the S-A valve pit, which is currently being utilized by the interim stabilization project. **All** of the tanks currently being pumped in S and SX Farm are routed through the **S-A** valve pit. Interim Stabilization activities in these farms are scheduled for completion in FY2003. **A** sister line, three inch SN-242, connects the S-02A pit to the **S-A** pit as well. Table 12 shows the encased piping route that could be used to transfer waste from 241-S-102 to SY-102 (272WA routing board, H-2-46524). The total transfer route volume, including pit jumpers, is approximately 290 gallons.

Transfer Line	Size (inches)	Length (feet)	Hold-Up (gallons)	From-To	Heat Traced
SL-140	2	103	18	S-02B to **S-A**	Yes
SN-275	**3**	470	180	S-A to SY-A	Yes
SL-177	2	86	15	SY-A to SY-02A	Yes
SN-242*	3			S-02A	Unknown

5.0 TECHNICAL EVALUATION AND UNCERTAINTIES

The preliminary evaluation of the AEAT Power Fluidics™ mixing and pump system warrants the systems further consideration for potential application for the retrieval of Hanford Single Shell Tank waste. Numerous areas of concern and uncertainties must be resolved during subsequent design phases prior to implementation.

5.1 Mixing Capability

The effective mixing volume and range of influence is a function of waste physical properties. In the case of solid suspension of "typical" Hanford sludge, an estimated 10,000 to 20,000 gallon charge vessel operating at 60 psi is required to homogenize the tank constituents (White Paper, AEAT to Numatec, ***Assessment of Pulse Jet Mixing in 75*** *Foot* ***Diameter Tanks*** *at* ***Hanford).*** The conclusions of AEAT were that the pulse jet system is "not suitable for mixing the million gallon Hanford tanks." This is not to say that SST retrieval necessarily requires the complete initial suspension of solids to initiate transfer. ORNL mixing and pumping campaigns retrieved on average, approximately 50% of the sludge volume per campaign. Similar results may be obtained for the application of Power Fluidics™; however, there is considerable uncertainty in the performance expectations on this large (75 foot) scale. Mock-up trials and cold testing would mitigate this uncertainty.

5.2 Transfer Line Velocity

Fluidic pumps produce intermittent flow as a function of the design. Multiple pumps 2 to 4 if designed properly and operated out of phase could potentially produce a relatively stable flow velocity. This type of pumping operations has not been attempted in cold or hot applications. Preliminary testing results at Florida International University (FIU) sponsored by the DOE, indicate that the AEAT systems are very effective at removing line blockages. Furthermore, the pulsating delivery is not prone to plugging in the fist place.

An additional uncertainty associated with the transfer of waste from 241-S-102, regardless of the technology/method, is the available transfer lines. The proposed route is comprised of both 2 and 3-inch lines. The pressures required to achieve the critical flow velocity (6 feet per second) in the 3 inch section is unattainable without exceeding the design pressure limits of the existing transfer lines.

5.3 Transfer Pressure

The existing transfer route from 241-S-102 to SY-102 is approximately 600 feet in length and elevates 9 feet from the S-02A pit to the SY-A valve pit (elevation 661.1 feet to 670.2 feet, respectively). The excessive transfer distance may be prohibitive for fluidic pumping methods. A booster pump, however, may be deployed with the application of multiple fluidic pumps operating out of phase to produce continuous flow. This type of pumping operations has not been attempted in cold or hot applications.

The excessive transfer distance will, at a minimum, require a means of backflow prevention on the transfer waste stream after exiting the tank. This is necessary to eliminate transfer line backflow and achieve a net positive transfer volume.

Multiple transfer pumps will require a manifold with remotely actuated valves be installed outside the tank, preferably in an appropriate pit. The valves would be cycled open and shut to introduce the process waste stream and prevent backflow to the other pumps. Installation and maintenance of actuated valves in a radiological environment has always been problematic. Careful consideration should be made in the design and selection of the manifold to not adversely impact the retrieval operations.

5.4 Debris Management

The ORNL Tank 3003A demonstrated the power fluidic™ systems susceptibility to failure due to unknown tank debris (see Section **2.5).** An assessment of anticipated debris as well as a video inspection should be performed prior to initiating retrieval operations. In order to effectively clean a 75 foot diameter tank the mixing charge vessel and nozzle size will be considerable larger than that employed on Tank 3003A and will be less vulnerable to plugging. Debris may also affect the performance of fluidic pumps. Debris management problems/uncertainties with fluidic pumps are, however, more easily mitigated. A screen is easily employed; while in mixing applications, a screen placed over the nozzle/inlet would dramatically reduce the kinetic energy of the expulsion stream. This would reduce the effective range of the mixing nozzle and reduce the energy transferred to the waste for solid suspension. Whereas flow through a fluidic pump inlet is unidirectional (excluding unwanted backflow). The pump inlet can be sized appropriately smaller than the diode and RFD element(s) to ensure that debris entering the pump will not become lodged.

Regardless of the debris consistency and size, it is unlikely that the transfer of miscellaneous tank debris is desirable. A screen could be placed over the pump inlet to eliminate all but the smallest particles. Pump screens, however, are symptomatically problematical. They can easily become clogged, result in unacceptable pressure drops, become the formation sites of crystalline salts growths, and are not easily cleared by flushing. The consequences of debris ingestion, and the effects on the down stream components, must be weighed against having a screen present. Conventional "Y" strainers have been employed successfully in other recovery efforts (ORNL, Tank W-9), yielding mixed results.

5.5 Ability to Reach Cleanliness Goal

The ***preliminary*** system configuration proposed (Section 3.0) considers the waste volume remaining after bulk retrieval may exceed the cleanliness goal of 360 cubic feet. The provision of a recirculating sluice nozzle will increase the likelihood of obtaining this goal, however, there is considerable uncertainty. The system should ideally be mocked-up full scale and tested to determine the effective range and cleaning capabilities prior to construction activities. The recovery efficiency (in terms of waste removed versus water added) will decrease exponentially for each of the final campaigns (based on the ORNL BVEST retrievals, see Section 2.5). **A** clear definition of the project end-state and the retrieval "limits of technology" should also be established early in the project cycle.

5.6 DST Space Availability

Based on the mixing and retrieval efforts seen at the ORNL facility, it can be expected that approximately 50% of the waste volume will be recovered during each mixing and transfer campaign. This, however, does not consider the solubility of the waste constituents. It is expected that a relatively accurate estimate for the solubility and the associated required water (as a solvent) for dissolution could be made. The volume of water required to reach the cleanliness goal and the retrieval "limits of technology" must be defined early in the project life cycle. The retrieval efficiency beyond retrieval **of** the initial bulk 80 to 90 percent is anticipated to decrease exponentially (based on ORNL observations in BVEST retrieval, see Section 2.5).

6.0 REFERENCES

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APPENDIX A SITE VISITATION NOTES

The following notes are as generated by Mr. Greg Bogen during his investigation of the AEA Technology Power Fluidics™ Mixing and Pumping systems.

The language used is provided in his own words. Opinions expressed, and his interpretation of the opinions expressed by his contacts, are his own. Mr. Bogen is not responsible for the accuracy of the information or material presented in his notes. In no event shall the verbiage prescribed be construed as an endorsement (or lack thereof) for the companies or systems investigated and/or mentioned.

Material and quotations from this section of the report shall not be made without the expressed written consent of Holmes and Narver/DMJM and Mr. Bogen.

9/13/00. Wednesday 8:00p/est
Ed Danfelt, AEA Technology Oak Ridge, TN

Went over Thursday itinerary
Discussions included the following:

- Application of AEAT at ORNL
  - o Only mixing applications currently used, no pumping for waste transfer
- Pumping at ORNL only for sampling
  - o ORNL sampler is predecessor to Hanford "Nested-Fixed Depth Sampler" being developed and managed by Mike Boger, CHG
- ORNL retrieval goal Of 95%. Actually 98% retrieved
  - o Mixed waste with AEAT Pulse Jet
  - o Pumped waste with existing progressive cavity pump (Moyno pump)
- Acquisition and deployment strategy
  - o AEAT under international agreement worked directly for DOE-ORNL
  - o System fabbed in UK then brought to site
  - o System commissioned (onsite acceptance tested)
  - o After commissioning system turned over as DOE property
  - o Consultants from AEAT remained during installation by onsite construction forces
  - o AEAT then operated system(s) without direct support from union forces due to the retrieval being called a "demonstration"
- At SRS the onsite union operators ran the system with supervision by AEAT consultants
- Mr. Danfelt provided two reports that I read that evening: BJC/OR-82 and BJC/OR-279. These reports are on the mobilization and retrieval of the 'W' and 'C' tanks respectively.

9/14/00, Thursday 8:00a/est
Ed Danfelt, AEA Technology Oak Ridge, TN

Discussions included primarily resolution of questions raised by reading the reports:

- W-21 was nearly recovered by mixing/pumping, but two additional actions were taken
  - o A manual sluicer was introduced to break-up "sand bars"
  - o Nitric Acid was added to remove sand bar
- Mr. Danfelt stated that sluicing was a disaster and the acid result accounts vary depending upon whom you talk to.
- Numerous methods to ensure that charge vessels are not over filled
  - o Target fill percent set at 95%
  - o Delta P observed as blip when vessel is full
  - o Pressure switches added in CIP tanks
  - o Previous time to fill is tracked
  - o Limit on fill time set point
  - o Barometric Protection (32 feet theoretical, 35 feet mast used)

9/14/00, Thursday 9:00a/est
Ed Danfelt, AEA Technology ORNL X-10, Oak Ridge, TN

Met with:
Jim Moore, Beehtel Jaeobs Design Engineer

Proceeded to CIP tanks (Capacity Increase Project) also known as "New MVST"

- CIP tanks are 100 kgal tanks a stones though south and up hill of older MVST (Melton Valley Storage Tanks)
- MVST are 50 kgal with 47.5 kgal operating capacity
- CIP tanks W-32, 33, 34, 35, 36, 37
- MVST W-24, 25, 26, 27, 28, 29, 30, 31
- CIP tanks are horizontal cylindrical shaped, above grade in a concrete building
- CIP became operational in December 1998
- Tanks are filled when at 90% capacity
- All tanks filled except one. This tank is maintained for emergency pumping

Met at MVST with:
Brian Oakley, Waste Management Federal Services Operations

- Examined AEAT system that was visible
  - o Large capacity (500 gal?) accumulator for compressor (no compressor)
  - o Off-gas skid [looks like large portable exhauster]
  - o Jet-Pump skid (aka tower) [35 foot vertical mast connecting valve skid to charge vessel. Mounted on side of building. Seismically qualified]
  - o Valve skid [valves, gauges, PRV's, etc]
  - o Everything was heat traced and insulated and installed as skids on concrete pads at the southeast comer of the building

- Walked stairs to top of building (approx 2 stones)
  - o Pulse-Jet system installed on W-35
  - o Two charge vessels installed (300 gal each?), one at each end
  - o "Piping bridge" on roof connected "tower" to CV
  - o Two connections on each CV, looked like EPDM hose
  - o A rolling bridge was on the South side. This was to keep the roof clear when AEAT system not in use.
  - o Stepper motor allows rotation of CV/nozzle ±180° in 5" increments
  - o Large shroud/shielding structure over assembly on roof
    - ▪ *6* inches thick, 5 A? diameter, 3ft? tall
    - ▪ weight of assembly supported from roof
    - ▪ Charge vessels were not within the tank, but were within the building. This was required to maintain the large CV size
- Control room inside building included:
  - o Heat trace cabinet
  - o Camera (not in or operating?)
  - o Control computer (HMI)
- System will use AEAT only for mixing of sludge transferred over from Bethel Valley over one mile away (7100 equivalent feet of pipe). Two inch in four inch encased line. Line does not drain or have COB's, Pits, Etc. The line goes over a hill and under a creek. Line is flushed with one volume following transfer and not blown out. It is cathodic protected.
- Progressive cavity pumps will move waste out of W-35 to the immobilization facility (not built yet).
- I spoke separately with Mr. Moore and Mr. Oakley. Both were pleased with system performance and reliability. Had difficulty recalling any AEAT system failures or maintenance problems. Only suggestion of Mr. Moore was to acquire the system assembled. BVEST systems bought complete, which were assembled in UK. The CIP system was brought over in pieces to save freight. Assembled on site, over tank. Not a pleasant experience according to either gentlemen. Ending up costing more time and $'s in long run.

Mr. Jim Moore went to a meeting and Mr. Danfelt, Mr. Oakley, and myself proceeded to BVEST

9/14/00. Thursdav 10:30a/est BVEST
Ed Danfelt, **AEA** Technology
Brian Oakley, Waste Management Federal Services

Bethel Valley Evaporator Service Tanks (BVEST)
W-21, 22, 23 approximately *50* yards? North of evaporator

- Looked at most of the same equipment on W-21 as was present on CIP tank.
- BVEST tanks also in vault. W-21 vault lid at grade. W-22 and 23 approx 20ft? below grade
- No accumulator for compressor. Compressor was electric.

- 3 inch pipes were installed in W-21, 22, and 23 at construction. Six in each tank. These pipes evidently had 90's at the bottom and were just above the tank floor. Open pipes were used as nozzles.
- Pipe bridge was not mobile
- Control Cubical was small mobile office
- No heat trace on lines. Used steam readily available, controlled manually.
- A CV skid with six CV's installed in vault. EPDM jumpers with camlocks hooked to tanks as required. One CV for each pipe/nozzle. This required manned entry into vault to change tank.
- Discussed Operations
    - Manual sluicing was "disaster" according to Mr. Oakley. Waste of time, money, and exposure. More exposure during sluicing than all else combined. Camera problems and confusion during sluice resulted in 1000's of gallons un-necessary water additions. Did not break-up sand bar. Cavity pump ran dry, etc, etc
    - Nitric Acid addition was unlikely very affective according to Mr. Oakley. It did reduce the sludge volume; however, an additional mixing campaign alone without acid may have produced similar results.
    - W-21 was first AEAT ORNL mixed tank. Done as demonstration. Precedence established and rest of tanks were also done with AEAT people.
    - AEAT folks would operate system and call WOCC (Waste Operations Control Center (shift office)) and tell them to transfer.
- Walked over to C tanks (spiting distance away) immediately adjacent to North wall of evaporator.
    - C-1 and C-2 in vaults, lid approx 3ft? above grade.
    - System scavenged for parts used on CIP tanks. Only remaining parts were CV's. Evidently charge vessels were swapped between tanks. All unused stuff D&Ded. Pipe extended through charge vessel for camera install.
    - C tanks did not have existing nozzles like W-21, 22, 23
    - Stepper motor used to rotate CV/nozzle like CIP W-35 tank
    - C tanks had cooling coils. I guess they received evaporator bottoms.

General Observation, Information, Summary
BVEST, MVEST tanks are all alike. 50 kgal, cylindrical shaped, and lying horizontal.
All in vaults, stainless steel, limited access
AEAT Systems installed (in order) on:

W-21, W-22, W-23, C-2 and C-1, W-35 (not operated yet)

None of the AEAT systems had transfer capability
Proposed MVST system will have capability to pump/transfer waste

9/14/00. Thursdav 11:00a/est Oak Ridge, TN (K-25?)

Ed Danfelt, AEA Technology
Gary Riner, DOE-ORNL TRU Waste Program Manager

- Discussed (at high level) satisfaction with AEAT system.

  - o Mr. Riner had nothing but good things to say about AEAT and their system
  - o Mentioned that they did not repeatedly submit change orders etc...
- Discussed W-2 1 retrieval, acquisition, deployment, ops, etc.
  - o Didn't think that the manual sluicing worked
  - o Did think that Acid was very affective. Thought we should consider at Hanford
  - o Did not have any problems with union claiming operations of mixing. Evidently it was his call not to train all the operators for a one-time demonstration. Subsequent tanks also called demonstrations. No grievances have yet been filed by union.
  - o Did receive EM-50 money for W-21 system
- Discussed "Russian System" with Mr. Riner
  - o Did not request the system, it was "given" to him
  - o System slated for TH-4
  - o Lots of problems in general. AEAT works to ISO-9001. Russians work to ??. Trouble qualifying system etc.

9/14/00. Thursdav 2:00p/est X-10
Mr. Marshall Johnson Engineer

Met Mr. Johnson at ORNL West Gate. He provided technical papers and a general tour of GAAT (Gunite And Associated Tanks)

North "Tank Farm" consisting of W-3 and W-4
W-1 and W-2 are evidently non-gunite little tanks located somewhere else
North TF smaller that average house lot. Maybe 10k square feet total. Immediately next to road

South Tank Farm consisting of W-5 thru W-10, just across street and several feet lower than North TF. Total pre-retrieval sludge volume south TF approximately 170 kgals. Vertical cylindrical tanks.
These tanks were retrieved using MLDUA (modified light duty utility arm) confined sluicer and Houdini crawler. Tanks were recovered to W-9? Then sent to W-23 then transferred cross-site to CIP.
South Farm probably 2-3 times larger than North (still very small)
Waste cascaded from North to South TF's then to two ponds (one higher than other)
Walked into farms for tour without suiting up.

Bridges spanned tank for recovery to support load
MLDUA installed
Confined sluicer (CS) installed
Houdini installed
MLDUA would reach over and pick up CS. *Arm* was too flimsy to be very effective.
Houdini (Red Zone) was used to bulldoze waste over to confined sluicer.

System was installed on W-9 at time of walk-down. Large vertical mast containing MLDUA, and another of similar height with UMS for CS. The Houdini recovery and maintenance structure was a Plexiglas glove box.

The general impression was that Mr. Johnson was not particularly impressed with the MLDUA. Evidently the design inadequacies I recognized on the LDUA here at Hanford have been carried forth into MLDUA. MLDUA performance degraded tank-to-tank. At some point they tried using a UHP **CS** (35 kpsi, 10 gpm) but ann could not handle torque. UHP pump just sitting there rotting. Suggested giving it to Hanford IS **Terry Hissong, CHG** to lance BY-105

Same "marginally adequate" performance observations for Houdini as MLDUA. Overall performance and reliability degraded from tank-to-tank. Evidently the crawler spent more time being maintained than operated. The hydraulic crawler arm did not work as designed, tracks loosened, etc.. Mr. Johnson recommended Ex- Red Zone employee **David Vesco, ORNL** be consulted for lessons learned and consultation if crawler is to be used at Hanford.

Transfer line from BVEST to MVEST is limited to 300 psi. Annulus is pressurized with nitrogen to 350 psi. If delta 50 psi? occurs over 8 hours, leak is declared (very different than Hanford leak detection)

W-1 1 thru W20 are other smaller "associated tanks" scattered around the site and within the facilities.

Saw TH-4 tank where Russian system is to be deployed. Tank farm/location very unimpressive. Not in zone, right next to road about 100 yards east southeast of South Farm.

9/14/00. Thursday 3:00p/est

Went to old reactor where "Russian" System is being cold-tested.

Not much to say:
PNL developed control of hardware that Russians shipped over.
4 nozzles on CV head
Sparge ring for cleaning screen over inlet.

The PFD for the crawler system is literally identical to the AEAT system.
It is not immediately evident who initially developed the concept.
System bugs seem to have been worked out. System is performing well according to John? Technical lead at cold-test site.

9/15/00, Friday 9:00a/est Mooresville. NC

Ed Danfelt, AEA Technology
Paul Murray, AEA Technology Business Development?

Discussed:

- Hanford applications of AEA Technology
  - o T-105 tank in 324 bldg (in proposal stage?)- ?
  - o Nested Fixed Depth Sampler- Mike Boger, George Janicek, Joe Cruz
    - Cogema design with consultation from AEAT?
    - Project now long in the works (2+ years?)
- Asked for list of other similar applications
  - o List of locals for DOE and contacts to be provided
  - o Over 400 pumps (RFD and Diode) used or in use (mostly UK)
  - o Only pump used in **US** is sampler pump at SRS

In summary, I expressed to Mr. Murray that I was primarily interested in additional information on pumping. Sufficient data had already been collected on mixing process and application. Investigation of power fluidic for retrieval of SST is the sole focus. AEAT has numerous divisions with potential applicability and capability to various Hanford projects, however, were not seen to be within scope.

Power Fluidic applications consist of mixing and pumping. They have **two** mixing systems: pulse-tube and pulse-jet. Additionally, they have two pumping methods: Reverse Flow Diverter and Diode Pumping.

Information was provided by myself to Mr. Murray on an example tank, S-102, and it was requested that a system be proposed for recovery of that tank. Mr. Murray to provide me with a PFD and material balance sheet for this high level proposal.

Technical information on pumping performance and capabilities were also discussed. Most of this information is available within the reports provided to me by Mr. Murray. To avoid redundant discussions, relevant information will be included within the report body.

APPENDIX B PHONE INTERVIEWS

9/21/00 10:30am PST
David Bolling, Bechtel-Jacobs ORNL
1-865-241-2424

- A small mixing system was deployed to recover waste from "Tank 3003A" behind building 3003A
- 12kgal gunite (concrete) containing approximately 300 gallons **of** sludge waste.
- 4 mixing pumping campaigns with the system recovered sludge to less than 100 gallons
- "Leaves and straw-like" debris in tank clogged the nozzle
- System deployed was a pulse-tube mixer
- A "dish" around the tube inlet/outlet directed the mixing out 360"
- Submersible pump used to transfer waste
- ORNL has recovered waste from 6 gunite tanks and 12? Smaller tanks. 18 to 20 total tank in FY2000.
- Retrieval in compliance with Federal Facility Agreement (FFA).
- Delivered system had one nonconformance
    - Small ("pinhole") leak in demister where a penetration repair had been made.
    - Relatively easily corrected.
- AEAT was a subcontractor to Allied Technology Group.
- ATG won contract **from** Bechtel-Jacobs

Mr. Bolling was inquired about any additional information, opinions, or impressions of the AEAT system and dealings with AEAT.

- General impression was that the system "worked well" producing "effective waste" mobilization
- System works well to mobilize [for recovery] the first "85 to 90 percent" of waste
- Beyond 90% recovery you enter the realm of diminishing returns
- System is very effective at bulk waste retrieval
- Would not recommend for retrieval efforts requiring recovery much beyond the 90% mark.

Mr. Bolling was then inquired to recommend system modifications from his lessons-learned.

- Recommended redesigning the discharge
- Opening size should be larger in one location to produce a nozzle
- System should be rotate-able to direct the expulsed waste stream

9/26/00 2:30pm PST
Gary Johnson, Westinghouse Savannah River Site
1-803-208-8026

Mr. Johnson returned my phone call from earlier the same day

An AEAT small mixer installed in SRS Tank 1
- Tank 1 is a interim storage tank (catch tank)
- Tank inside cell
- 10 foot in diameter
- Normal operating waste depth is about 4 feet
- Initially had approximately a 10 inch mound of sludge
- Last transfer to/from tank some decade ago

AEAT mixer system installed
- 80 gallon charge vessel
- Pulse-Tube system
- Installed through 6 inch nozzle (riser?)
- 8 millimeter annulus, 360" spray pattern
- Suction/outlet 3 inches above tank floor
- Vented directly back into cell
- Jet pump installed in existing piping in cell
- Commissioned during three days of continuous operations
- Resulted in spg 1.2 to 1.3 or approximately 15 weight percent solids
- Pulse tube effectively rolled-over waste
- Turned out to be very slow settle sludge
- Compressor operated at 300 scfin
- Drive pressure was 70 psig

Problems encountered during commissioning included:
- Insects plugging vent line
- Removal of components during testing were not re-installed properly allowing moisture infiltration
- Circuit board went bad? Replacement fixed problem
- Initial air hose (from compressor) were under sized

Mr. Johnson's general impression was that the system worked well for mixing and that the operations were extremely simple. He stated that once the system was set up, no operational input or intervention was required. It is a simple "push button" operation.