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Development of Mechanical Systems for Dry Retrieval of Single Shell Tank Waste at Hanford

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ABSTRACT

There are currently 177 underground single-shell tanks (SST) storing 53 million gallons of semi-solid nuclear and chemical waste on-site in Hanford. Although historically the U.S. Department of Energy (DOE) has managed the waste within the Hanford tank farms as High-Level Waste (HLW) as a matter of operations management policy, DOE has long maintained that, based on origin, process history, and radiological characteristics, the wastes in any specific tank may be HLW, Transuranic Waste (TRU), Low Activity Waste (LAW), or Low Level Waste (LLW). This study proposes and evaluates a mechanical conveying system in collaboration with an In-Tank Vehicle (ITV) for dry retrieval of LLW, LAW, or TRU waste from Hanford's SSTs. Working with existing risers, the In-Tank Vehicle will mechanically dislodge and mobilize the waste towards the inlet of the auger conveyor to be transported out of the tank to meet the Tri-Party Agreement residual waste volume goal for 100-series and 200-series leaking tanks.

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TFA	Tank Focus Area
ORP	Office of River Protection
TRU	Transuranic
SST	Single-Shell Tank
DST	Double-Shell Tank
WIPP	Waste Isolation Pilot Plant
HLW	High-level Waste
LLW	Low-level Waste
LAW	Low-activity Waste
BPP	Bismuth Phosphate Process
SNF	Spent Nuclear Fuel
RH-TRU	Remote-handled Transuranic Waste
CH-TRU	Contact-handled Transuranic Waste
VR	Vacuum Retrieval
MRS	Mobile Retrieval System
MS	Modified Sluicing
CWC	Central Waste Complex
WRAP	Waste Receiving and Processing Facility
nCi	Nanocuries
ITV	In-Tank Vehicle

1. INTRODUCTION

The Hanford Site was constructed in 1943 during World War II as part of the Manhattan Project to produce plutonium for the manufacturing of atomic weapons. Less than three years after the first workers arrived, the Fat Man Bomb was dropped on Nagasaki, Japan in August 1945 using plutonium produced at Hanford that consequently ended the war. Plutonium production at Hanford did not end, however, until 1987. Almost half a century of production accumulated 56 million gallons of radioactive waste stored in 177 underground tanks on site. Seven decades after its construction during World War II, Hanford is the most contaminated site in the U.S. and is engaged in the largest cleanup effort ever undertaken in human history.

Since 1981, 67 of 149 single-shell tanks have been identified as leaking tanks or tanks with questionable integrity. An estimated 600,000 to 1,060,000 gallons of waste have leaked over the past 50 years. These leaks have resulted primarily from general corrosion, stress corrosion cracking, and mechanical damage in various locations in the tanks.

Once waste retrieval is completed, the tanks at Hanford will have exceeded their design life by about 50 years. Identifying and developing technologies applicable for remediation of leaking tanks was selected by the U.S. Department of Energy (DOE) Environmental and Waste Management (EM) Tanks Focus Area (TFA) as a strategic initiative. Concern over the leak integrity of SSTs resulted in the need to address retrieval methods that minimize leakage and use minimal water in a more controlled manner.

Regulatory requirements for SST waste retrieval and tank farm closure are established in the Hanford Federal Facility Agreement and Consent Order (HFFACO). The HFFACO was signed by the DOE, the State of Washington Department of Ecology (Ecology), and the U.S. Environmental Protection Agency (EPA) and requires retrieval of as much waste as technically possible, with waste residues not to exceed 360 ft^3 in 530,000 gallon PP or larger tanks; 30 ft^3 in 55,000 gallon or smaller tanks; or the limit of waste retrieval technology, whichever is less. If residual waste volume requirements cannot be achieved, then HFFACO Appendix 1.1 provisions can be invoked to request Ecology and EPA approval of an exception to the waste retrieval criteria for a specific tank.

2. EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science & Technology Workforce Development Program, an initiative designed by the US Department of Energy's Office of Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC) to create a "pipeline" of minority engineers and scientists specially trained and mentored to enter DOE-EM's workforce. During the summer of 2012, DOE Fellow, Ximena Prugue, spent 10 weeks doing a summer internship at Washington River Protection Solutions under the supervision and guidance of Leo Thompson. Ms. Prugue's project was initiated in June 3, 2012, and continued through August 10, 2012 with the objective to review options for dry retrieval of solid waste from Hanford's SSTs and evaluate alternatives and process improvements to gather an understanding of existing and future constraints.

3. RESEARCH DESCRIPTION

This study proposes and evaluates a mechanical system for dry retrieval of Hanford single-shell tank (SST) waste. Waste retrieval using modified sluicing and saltcake dissolution has typically reached the "limit of technology" prior to meeting the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989) (Tri-Party Agreement) waste residual goal of 360 cubic feet or less. Experience to date has shown these retrieval technologies typically leave approximately ten percent of the initial waste volume, which is commonly referred to as the hard-to-remove heel or "hard heel". These technologies also risk the possibility of leaking waste into the surrounding soil for leaking tanks.

Retrieval technologies that can work in tanks that are assumed leakers are needed to either supplement or replace modified sluicing and saltcake dissolution to achieve the waste retrieval goal without exacerbating the leak and retrieve both saltcake and sludge. This system can also be used to retrieve waste from tanks with obstructions, where a telerobotic arm would not be possible, and TRU waste.

Within the 16 tank farms at Hanford, there are 67 of the 149 SSTs that are confirmed or suspected of leaking waste into the environment listed in Table 2. The estimated volume of leaked waste ranges from approximately 600,000 to 1,060,000 gallons.

Tri-Party Agreement (TPA) Milestone M-45-08 addresses the mitigation of tank leakage during waste retrieval operations. Previous technologies deployed at Hanford introduce significant amounts of liquids to SSTs. In order to assure Minimal Achievable Leakage (MAL) during waste retrieval, dry technologies that utilize mechanical end effectors and conveyance systems need to be addressed.

3.1 Single-Shell Tank Description

Single-Shell Tanks consist of a carbon steel liner inside a reinforced concrete shell. They are classified as 100 series and 200 series. There are sixteen 200 series and 133 100-series SSTs in 12 tank farms containing 4 to 18 tanks each. The 100 series tanks are 75 ft in diameter, a nominal 530,000 to 1,000,000 gallon storage capacity, and have a below-grade invert elevation of 37 to 50 feet. The 200 series tanks are 20 ft in diameter, and a nominal 55,000 gallon storage capacity.

3.2 Waste Properties

The Hanford Site in Washington State manages 177 underground storage tanks containing approximately 250,000 m^3 of waste generated during past defense reprocessing and waste management operations. These tanks contain a mixture of sludge, saltcake and supernatant liquids.

Sludge

The insoluble sludge fraction of the waste consists of metal oxides and hydroxides and contains the bulk of many radionuclides such as the transuranic components and ^{90}Sr. Hanford sludge as a whole is predominantly aluminum.

Saltcake

The saltcake, generated by extensive evaporation of aqueous solutions, consists primarily of dried sodium salts and an iron compound. Saltcake waste forms represent some different challenges from sludge waste forms in both physical and chemical characteristics.

Supernatant

The supernatant liquid consists of concentrated (5-15 M) aqueous solutions of sodium and potassium salts.

Hard Heel Waste

"Hard heel" is the name given to the residual waste that is left when the modified sluicing or saltcake dissolution processes have reached the "limit of technology." It is short for "hard to retrieve heel" and is not meant to imply anything about the physical characteristics of the heel. The hard heel can be cobble left as the softer layers are sluiced away. The cobble could have been at any elevation in the original matrix in a sludge tank prior to modified sluicing. The specific characteristics of residual waste vary depending upon the type of waste, its specific chemical compositions, storage conditions (temperature, moisture, time, etc.), and retrieval process conditions.

Single-shell tank waste has high concentrations of sodium and aluminum, much of it insoluble. For example, the waste in the 241-C farm tanks contains 31 percent sodium and 30 percent insoluble aluminum. The supernatant liquid used in modified sluicing contains a high concentration of sodium and does a poor job of dissolving the low-soluble salts in hard heel waste. As a result, hard heel waste left after sluicing contains a high concentration of aluminum compounds and low-soluble sodium compounds.

Sample results from SST 241-C-108 show the waste to be about 60 percent by volume sodium fluoride phosphate, a low solubility salt. The larger chunks in the sample were crystalline forms of this material. The remaining material is mostly gibbsite, a mineral form of aluminum hydroxide. Preliminary analyses from samples collected from SST 241-c-109 in March 2011 indicate that the residual waste composition is about 50% ferrous compounds and 50% aluminum compounds.

3.3 Waste Characterization

Hanford tank wastes are far more chemically complex and heterogeneous than tank wastes at other DOE production sites. The Hanford tank wastes also tend to have substantially lower average radionuclide concentrations than other DOE tank wastes because of the inefficient recovery processes initially used (BPP), and the more than one hundred million curies of radionuclides [particularly cesium-137 (^{137}Cs) and strontium-90 (90Sr)] that were removed from the Hanford tanks forty years ago.

Hanford waste characterization data are used to engineer safe storage, retrieval, transport, and processing operations. Whenever waste is stored or handled, it is important to anticipate its behavior and understand the physical phenomena behind its behavior.

High-Level Waste (HLW)

The high-level waste (HLW) stream will be a much smaller volume slurry containing most of the solids, which have the high-activity isotopes, including ^{137}Cs and long-lived radioisotopes.

Low-Level Waste (LLW)

Low-level waste is the least dangerous radioactive waste. It consists of all radioactive waste that is not high-level, TRU, spent nuclear fuel, or by-product material, and may be disposed of in a near-surface facility. Hanford LLW is characterized by high nitrate and nitrite concentrations. Its constituents also include sodium aluminate, sodium hydroxide, and heavy metals and radionuclides among the trace constituents no longer highly radioactive.

Low-Activity Waste (LAW)

Low-activity waste consists of waste that remains following the process of separating as much of the radioactivity as is practicable from high-level waste. When solidified, low-activity waste may be disposed of as low-level waste in a near surface facility. The low-activity waste (LAW) stream is characterized as a high-volume, low-activity liquid process stream stripped of most solids and high-activity radioisotopes. Low Activity Waste is the fraction of the tank waste that is mostly chemicals and from which key radionuclides have been removed to the maximum extent technically and economically practical to render the waste not highly radioactive.
Given the derivation of the waste from tank wastes, DOE applies the term LAW to avoid confusion with wastes that are LLW at the point of generation. Because the Hanford tank wastes are regulated under the RCRA, LAW wastes are mixed LLW.

TRU Waste

There are eleven tanks that meet the definition of TRU waste as set forth in the Waste Isolation Pilot Plant (WIPP) Land Withdrawal Act of 1996 containing wastes from the Bismuth-Phosphate Process (BPP). The BPP was the first production-scale Spent Nuclear Fuel (SNF) reprocessing process ever used and was deployed during the Manhattan Project to separate plutonium from SNF. The BPP was a batch process that allows ORP to clearly distinguish where SNF existed within the process.

The wastes in these eleven tanks are not high-level waste (HLW), and contain more than 100 nCi of alpha-emitting TRU isotopes per gram with half-lives greater than 20 years. The fact that the wastes are not HLW is confirmed by waste fission product concentrations that are orders of magnitude less than those the U.S. Nuclear Regulatory

Commission requires to be disposed of in a geologic repository (10 CFR Part 61, Low-Level Radioactive Waste Disposal).

There are four SSTs with TRU waste in B-Farm: B-201, B-202, B-203, B-204. The remaining seven tanks are located in T-Farm: T-201, T-202, T-203, T-204, T-104, T-110, T-111. Four of the tanks, B-201, B-203, B-204, and T-111, are assumed leakers. The total waste of these tanks consists of 1408 Kgal of sludge, 158 Kgal of drainable liquid, and 0 Kgal saltcake. In order to meet the criteria for WIPP, the liquid cannot exceed 1 percent of the total volume of the waste. Table 1 lists the TRU waste tanks and current Best Basis Inventory as of February 2012.

Table 1. TRU Tank Waste Inventory

Tank	Tank Bottom Configuration	Tank Diameter (ft)	Tank Integrity	Total Waste	Supernatant Liquid (Kgal)	Drainable Interstitial Liquid (Kgal)	Drainable Liquid Remaining (Kgal)	Sludge (Kgal)	Saltcake (Kgal)
B-201	dished	20	ASMD LKR	29	0	5	5	29	0
B-202	dished	20	SOUND	28	0	4	4	28	0
B-203	dished	20	ASMD LKR	50	1	5	6	49	0
B-204	dished	20	ASMD LKR	50	1	5	6	49	0
T-201	dished	20	SOUND	30	2	4	6	28	0
T-202	dished	20	SOUND	20	0	3	3	20	0
T-203	dished	20	SOUND	36	0	5	5	36	0
T-204	dished	20	SOUND	36	0	5	5	36	0
T-104	dished	75	SOUND	317	0	31	31	317	0
T-110	dished	75	SOUND	370	1	48	49	369	0
T-111	dished	75	ASMD LKR	447	0	38	38	447	0

The *WIPP Land Withdrawal Act (LWA) of 1992, P.L. No. 102-579, 106 Stat. 4777, as amended by the WIPP LWA Amendments of 1996, P.L. 104-201, 110 Stat. 2422),* defines TRU wastes as:

> *The term "transuranic waste" means waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for:*
>
> *(A) High-level radioactive waste;*
>
> *(B) Waste that the Secretary has determined, with the concurrence of the Administrator, does not need the degree of isolation required by the disposal regulations; or*
>
> *(C) Waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with part 61 of title 10, Code of Federal Regulations.*

According to "Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement" (DOE/EIS-0189), August 1996, page S-3:

> ***TRU waste*** *is material contaminated with radioactive elements with atomic numbers greater than uranium. This waste does not require the same degree of isolation as high-level waste; however, it cannot be disposed of in a near-surface facility.*

Transuranic waste is itself divided into two categories based on its level of radioactivity.

- **Contact – handled TRU waste** (CH-TRU) accounts for about 97 percent of the volume of transuranic waste currently destined for WIPP. CH-TRU waste is primarily packaged in 55 gal metal drums or in metal boxes, although a variety of container types and sizes are included, and can be handled under controlled conditions without any shielding beyond the container itself. The maximum radiation dose at the general surface area of a CH-TRU waste container is 200mr/hr.
- **Remote-handled TRU waste** (RH-TRU) has a higher surface dose rate than CH waste. Surface radiation levels of remote-handled transuranic waste exceed 200mr/hr. The WIPP does not currently accept RH waste.

3.4 Current Retrieval Methods

There are four basic retrieval technologies deployed in Hanford tanks for retrieval: Modified Sluicing, Vacuum Retrieval System, Mobile Retrieval System, and the Mobile Arm Retrieval System. Table 3 lists the technologies and the outcome of retrieval.

Several factors influence the choice of a retrieval method, including:

- The degree to which water will be allowed for retrieval efforts in SSTs; this is perhaps the most important factor, since it may eliminate one of both proposed methods immediately.
- The preferred retrieval rate for operational considerations.
- Cost.
- Viability and effectiveness.

Modified Sluicing

Modified sluicing uses high pressure water or recycled supernatant to dissolve crystallized salt and to mobilize sludge waste in sound SSTs. This method has been effective in bulk retrieval, but has been unsuccessful in reaching the waste residual volume goal of 360 ft^3, leaving behind hard heel waste. Dilution water may be used to aid in the retrieval process by diluting the slurry to the appropriate specific gravity conducive to waste transfer. While dilute transfer of slurries will prevent pipe plugging, it increases waste volume and the burden on waste evaporators.

Modified sluicing in a saltcake tank versus a sludge tank differs only in the manner in which the waste responds to the sluicing. Generally in a saltcake tank, soaking for a period of a few days to a few weeks can improve retrieval efficiencies. This soaking may have little impact in a sludge tank. Retrieval of waste from a saltcake tank involves various water introduction and management devices, along with a progressive cavity pump for waste removal. Water is introduced to the tank through various sources and allowed to soak in the tank for a period of time.

Vacuum Retrieval System

The Vacuum Retrieval System consists of an articulating mast with a vacuum head, vacuum pump, slurry vessel, and a slurry transfer pump. While vacuum retrieval has been successful in reaching the residual waste volume goal, wastes on the tank walls and in equipment are not accessible by the vacuum retrieval system and it is not very efficient.

Mobile Arm Retrieval System

The Mobile Arm Retrieval System (MARS) has two modes: sluicing and vacuuming. For the purpose of this report, MARS-V will be evaluated for retrieval of leaking tanks.
The MARS-V is designed to accomplish retrieval per regulatory requirements in leaking tanks, potentially leaking tanks, and tanks of questionable integrity. It uses a fluid driven educator system in an end-effector at the end of a telescoping arm to mobilize SST waste. The MARS-V, however, is ineffective in tanks with significant in-tank obstructions, such as the AX tanks. It also requires the installation of a new riser to accommodate its robust, telescoping mast.

CH-TRU Waste Retrieval

The DOE’s plan for TRU wastes is to retrieve the waste, dewater, package, certify, and then dispose at WIPP. Once dewatered and packaged, wastes from these eleven tanks will meet all shipping and disposal requirements imposed by WIPP. Waste from nine of these eleven tanks will be contact-handled TRU waste and waste from the other tanks will be remote-handled TRU waste. CH-TRU waste will be transferred directly from the SST to the CH-TRU treatment plant located nearby. TRU waste retrieval plans were placed on hold due to budgetary constraints in February 2008.

The T-Farm and B-Farm CH-TRU waste will go directly to a CH-TRU processing facility. Facilities that are capable of accepting CH-TRU waste are the Central Waste Complex (CWC), the T-Plant Complex, and the Waste Receiving and Processing Facility (WRAP). Previous planning assumed this waste was retrieved using a Vacuum Retrieval (VR) system or Mobile Retrieval System (MRS). This SST retrieval plan assumes B-202, and T-200 tanks, T-104, and T-110 will be retrieved using Modified Sluicing (MS) with recycled supernate. Recycling liquid from the CH-TRU facility back to the SST undergoing retrieval will require a change to the existing conceptual design for this facility, but this change should not significantly alter the planned facility design.
The CH-TRU draft conceptual design currently assumes the incoming waste is only passed through a low-temperature vacuum dryer. The CH-TRU facility liquid/solid separation stage could be redesigned to handle MS slurries rather than VR/MRS slurries, and the SST retrieval system designs can be scaled back from those normally used for MS, or the MS shift operating schedules can be cut back to meet the CH-TRU waste throughput rates.

3.5 Disadvantages

- Water usage can lead to leakage during retrieval for tanks B-201, B-203, B-205, and T-111.
- The available height inside some tanks, i.e., the distance between the tank roof and the sludge surface, is less than the distance sometimes required to deploy a main arm member.
- Free jet sluicing nozzle has a lower sludge recovery efficiency; would use more water and time.
- When sludge levels drop, submergence requirements of the pump inlet would eventually prevent all pumps from removing the sludge and slurry heels in the tank. Therefore, large quantities of water and long operating times would be needed to insure very dilute heels (and effective retrieval of the sludge) if a pump were solely relied on for slurry removal.
- Heavy duty slurry pump would require a large-diameter central riser for deployment.

4. RESULTS AND ANALYSIS

4.1 Technology Development

Prioritizing technology development by weighing need, expected benefit, cost, and schedule needs to be established to ensure the completion of RPP mission goals. The TOC has set priorities for technology development as High Priority, Medium Priority, and Low Priority. Figure 1 illustrates the logic for prioritizing technology development.

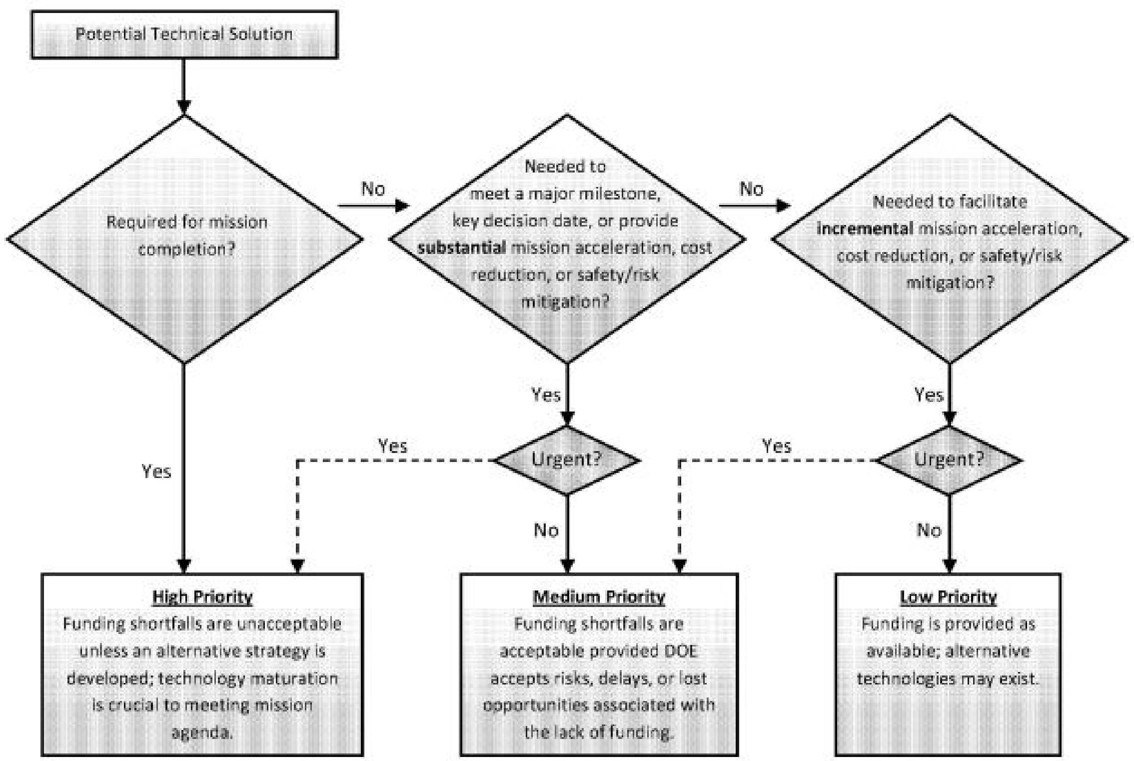

Figure 1. Mission-Driven Technology Development Prioritization Logic

Technologies that can be deployed in leaking tanks without exacerbating the leak and in tanks with significant tank obstructions are considered a medium priority because although there are other retrieval technologies available, they have not been successful in reaching the residual waste volume goal and they have the potential of leaking waste into the surrounding soil.

4.2 Vertical Screw Conveyor Concept Description

Shaftless screw conveyors benefit from high capacities and a resistance against tangling materials. They are ideally suited for difficult, sticky or wet materials, which may vary in flow rate, consistency or content, such as saltcake and sludge.

Lengths of over 50 m are possible utilizing only a single drive. Eliminating intermediate and end bearings reduces maintenance work. It also allows efficient and direct transfer into another conveyor – horizontal, inclined or vertical. With few moving parts, reliability is high and can convey a wide variety of materials efficiently.
Screw conveyors can be totally enclosed allowing fully contained waste transfer from SSTs to waste containers for packaging. There is no spillage of the material being conveyed and odors are completely contained. Direct-drive design allows a clean and efficient transmission without the maintenance required with belt and chain drives.
Single-shell sludge that has not been rehydrated will not readily flow into the inlet of an immersed pump, but screw conveyors are self-filling with auto shut-off when full. Also, pumps become unsuitable to remove sludge once sludge levels drop due to submergence requirements of the pump inlet. Therefore, large quantities of liquid and extended operating times would be needed to ensure very dilute heels (and effective retrieval of the sludge) if a pump were solely relied on for slurry removal.

4.3 Concept Generation

The screw conveyor for dry retrieval was based on the concept of positive displacement pumps used in the past for tank waste retrieval at Hanford, such as the Moineau pumps. Screw conveyors are simple and robust in design, versatile and easily maintained. They are self-feeding and are able to transport material in a continuous flow without any loss of materials. The use of a vertical screw conveyor allows for space minimization without sacrificing throughput.

The contact surface between the screw and the pipe does not need to be perfectly watertight, as long as the amount of water being scooped at each turn is large compared to the amount of water leaking out of each section of the screw per turn. Water leaking from one section leaks into the next lower one, so that a mechanical equilibrium is achieved.

Of the 146 SSTs, 80 do not have a large-diameter central riser. However, many of these do have 12-in diameter risers at or near center, which would be adequate for the installation of a vertical screw conveyor system.

Components

The screw conveyor would be entirely enclosed in double encasement with leak detection. A rock crusher/pulverizer can be installed above the inlet to reduce particle size and prevent blockages from debris found in SSTs.

The size of the screw and segmental flights are set to standard or special requirements dependent on two factors: the capacity of the conveyor and the lump size of the material to be conveyed (the maximum dimensions of the particle).

The drive consists of a geared motor, chain & sprockets on a fabricated mounting. Drive arrangements are oriented to meet site requirements. The inlets and outlets are made to requirements and are factory fitted or assembled on site.

Configuration

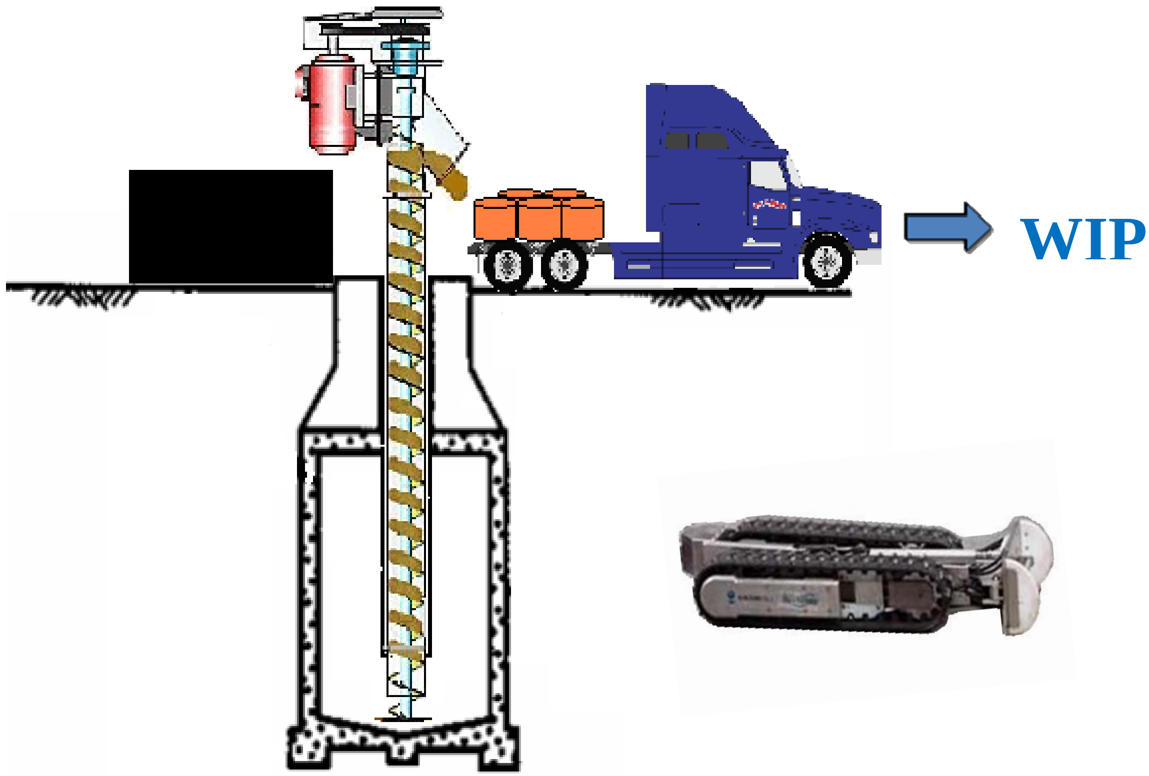

Figure 2. Vertical Screw Conveyor Configuration

The proposed configuration for a vertical screw conveyor in a CH-TRU waste tank is shown in Figure 2.

For hard heel retrieval, an In-Tank Vehicle (ITV), such as the Mobile Retrieval System crawler, would be used to help break up and push waste into the inlet of the conveyor. Dryers and de-watering skids can be configured into the system to ensure that the volume of water is less than one percent of the total waste volume.

Once the waste is conveyed upwards and out of the tank, the waste can be horizontally transported to appropriate waste containers dependent on waste type.

Commercial Availability

Several engineering companies design vertical conveying systems in a variety of materials and sizes for several applications. Most companies offer customizable options depending on bulk material to be conveyed. Appendix B lists a few commercially available screw conveyor designs that can be customized to meet retrieval configuration requirements for the Hanford underground waste storage tanks.

5. CONCLUSION

With success in similar applications of sludge transport packaging, a screw conveying system is a plausible method to consider for mobilization and retrieval waste in leaking SSTs. The physical characteristics of SST sludge cannot be pinned down to a single description. They vary considerably from candy, hard chunks to thick, dark brown paste. Being able to handle varying flow rates with a variety of materials, including sticky and wet waste such as sludge, a vertical screw conveyor with the assistance of an ITV can potentially successfully retrieve all of the waste from the tanks, including hard heel, with minimal amounts of water or caustic chemicals compared to previous methods used at Hanford.

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APPENDIX A.

Table 2. Leaking Single Shell Tank Data

LEAKING SINGLE-SHELL TANK DATA						
Tank	Waste Type	Total Volume Leaked[1] (gal)	Watch List	Year Stabilized[2]	Year Declared Leaking[3]	Removed from Service[4]
A-103	DSSF	5,500		1988	1987	1980
A-104	NCPLX	500 to 2,500		1978	1975	1975
A-105	NCPLX	10,000 to 277,000		1979	1963	1963
AX-102	CC	3,000		1988	1988	1980
AX-104	NCPLX			1981	1977	1978
B-101	NCPLX			1981	1974	1974
B-103	NCPLX		organic salts	1985	1978	1977
B-105	NCPLX			1984	1978	1972
B-107	NCPLX	8,000		1985	1980	1969
B-110	NCPLX	10,000		1984	1981	1971
B-111	NCPLX			1985	1978	1976
B-112	NCPLX	2,000		1985	1978	1977
B-201	NCPLX	1,200		1981	1980	1971
B-203	NCPLX	300		1984	1983	1977
B-204	NCPLX	400		1984	1984	1977
BX-101	NCPLX			1978	1972	1972
BX-102	NCPLX	70,000	ferrocyanide	1978	1971	1971
BX-108	NCPLX	2,500		1979	1974	1974
BX-110	NCPLX			1985	1976	1977
BX-111	NCPLX			N.A.	1984	1977
BY-103	NCPLX	<5,000	ferrocyanide	N.A.	1973	1973
BY-105	NCPLX		ferrocyanide	N.A.	1984	1974
BY-106	NCPLX		ferrocyanide	N.A.	1984	1977
BY-107	NCPLX	15,100	ferrocyanide	1979	1984	1974
BY-108	NCPLX	<5,000	ferrocyanide	1985	1972	1972

LEAKING SINGLE-SHELL TANK DATA						
Tank	Waste Type	Total Volume Leaked[1] (gal)	Watch List	Year Stabilized[2]	Year Declared Leaking[3]	Removed from Service[4]
C-101	NCPLX	20,000		1983	1980	1970
C-110	DC	2,000		N.A.	1984	1976
C-111	NCPLX	5,500	ferrocyanide	1984	1968	1978
C-201	NCPLX	550		1982	1988	1977
C-202	EMPTY	450		1981	1988	1977
C-203	NCPLX	400		1982	1984	1977
C-204	NCPLX	350		1982	1988	1977
S-104	NCPLX	24,000		1984	1968	1968
SX-104	DSSF	6,000	hydrogen	N.A.	1988	1980
SX-107	NCPLX	<5,000		1979	1964	1964
SX-108	NCPLX	2,400 to 35,000		1979	1967 (1962)	1967
SX-109	NCPLX	<10,000	hydrogen - vents other tanks	1981	1965	1965
SX-110	NCPLX	5,500		1979	1976	1976
SX-111	NCPLX	500 to 2,000		1979	1974	1974
SX-112	NCPLX	30,000		1979	1969	1969
SX-113	NCPLX	15,000		1978	1962 (1958)	1958
SX-114	NCPLX			1979	1972	1972
SX-115	NCPLX	50,000 (sodium nitrate solution, 40 kCi)		1978	1965	1965
T-101	NCPLX	7,500		1993	1992	
T-103	NCPLX	<1,000		1983	1974	1974
T-106	NCPLX	115,000		1981	1973	1973
T-107	NCPLX		ferrocyanide	N.A.	1984	1976
T-108	NCPLX	<1,000		1978	1974	1974
T-109	NCPLX	<1,000		1984	1974	1974
T-111	NCPLX	<1,000		N.A.	1974	1974

LEAKING SINGLE-SHELL TANK DATA

Tank	Waste Type	Total Volume Leaked[1] (gal)	Watch List	Year Stabilized[2]	Year Declared Leaking[3]	Removed from Service[4]
TX-105	NCPLX		organic salts	1983	1977	1977
TX-107	NCPLX	2,500		1979	1984	1977
TX-110	NCPLX			1983	1977	1977
TX-113	NCPLX			1983	1974	1971
TX-114	NCPLX			1983	1974	1971
TX-115	NCPLX			1983	1977	1977
TX-116	NCPLX			1983	1977	1969
TX-117	NCPLX			1983	1977	1969
TY-101	NCPLX	<1,000	ferrocyanide	1983	1973	1973
TY-103	NCPLX	3,000	ferrocyanide	1983	1973	1973
TY-104	NCPLX	1,400	ferrocyanide	1983	1981	1974
TY-105	NCPLX	35,000		1983	1960	1980
TY-106	NCPLX	20,000		1978	1959	1959
U-101	NCPLX	30,000		1979	1959	1960
U-104	NCPLX	55,000		1978	1961 (1956)	1951
U-110	NCPLX	5,000 to 8,100		1984	1975	1975
U-112	NCPLX	8,500		1978	1980	1970

CC — concentrated complexant - concentrated product from the evaporation of dilute complexed waste

DC — dilute complexed waste - characterized by a high content of organic carbon including organic complexants: ethylenediaminetetra-acetic acid (EDTA), hydroxyethyl-ethylenediaminetri-acetic acid (HEDTA), citric acid, and iminodiacetate (IDA)

DSSF — double-shell slurry feed - waste concentrated just before reaching the sodium aluminate saturation boundary in the evaporator without exceeding receiver tank composition limits.

N.A. — not applicable (not yet interim stabilized)

NCPLX — noncomplexed waste - general waste term applied to all Hanford site liquors not identified as complexed.

NOTES:

(1) The total volumes leaked do not include (except for some tanks) (1) cooling or raw water leaks, (2) infiltrating precipitation, (3) leaks within the tank farm from sources other than the tanks (pipelines, joints for overflow and fill lines, etc.), and (4) leaks from diversion boxes, catch tanks, encasements, etc.

(2) This is the year when the tank underwent interim stabilization.

(3) This is the year the tank was determined to have begun leaking if different from year declared leaking.

(4) This is the last year a tank was capable of receiving waste. The date of the last waste received may have been earlier.

Table 3. Technologies Deployed at Hanford

Tank	Primary Waste Type	Retrieval Technology(ies) Deployed	Residual Waste Volume (ft^3)
C-103	Sludge	Modified Sluicing	338
C-104	Sludge	Modified Sluicing/Hot Water Dissolution	657
C-106	Sludge	Past Practice Sluicing, Acid Dissolution	370
C-108	Sludge	Modified Sluicing	1029
C-109	Sludge	Modified Sluicing	1150
C-110	Sludge	Modified Sluicing	2300
C-111	Sludge	Modified Sluicing	4300
S-102	Saltcake	Modified Sluicing	12400
S-112	Saltcake	Modified Sluicing, Remote Water Lance, Caustic Addition	319
C-201	Sludge	Vacuum Retrieval	19
C-202	Sludge	Vacuum Retrieval	19
C-203	Sludge	Vacuum Retrieval	18
C-204	Sludge	Vacuum Retrieval	18

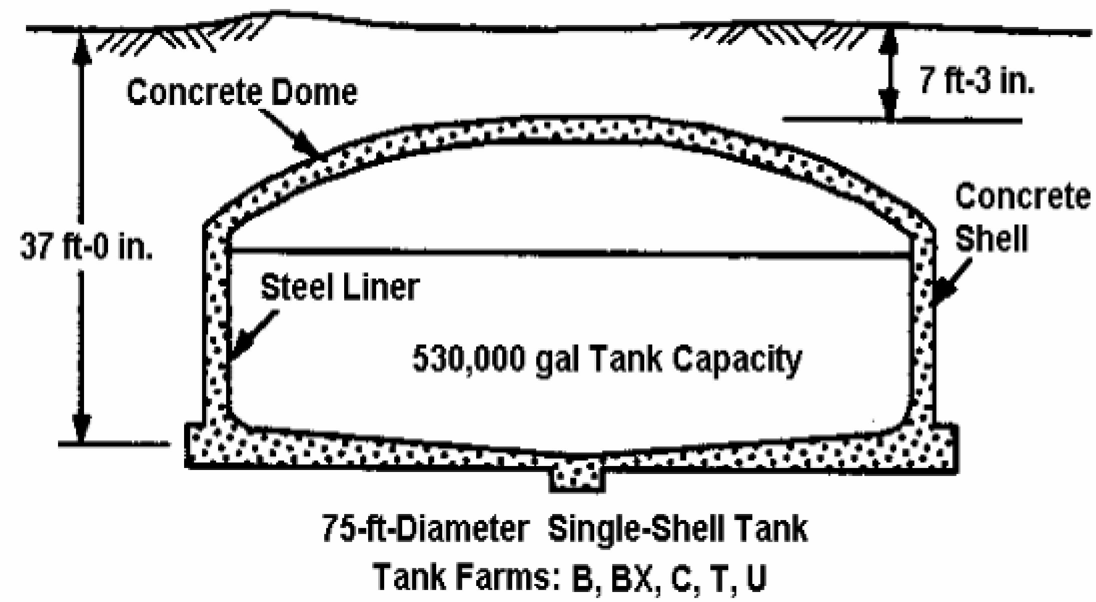

Figure 3. 200 Series SST

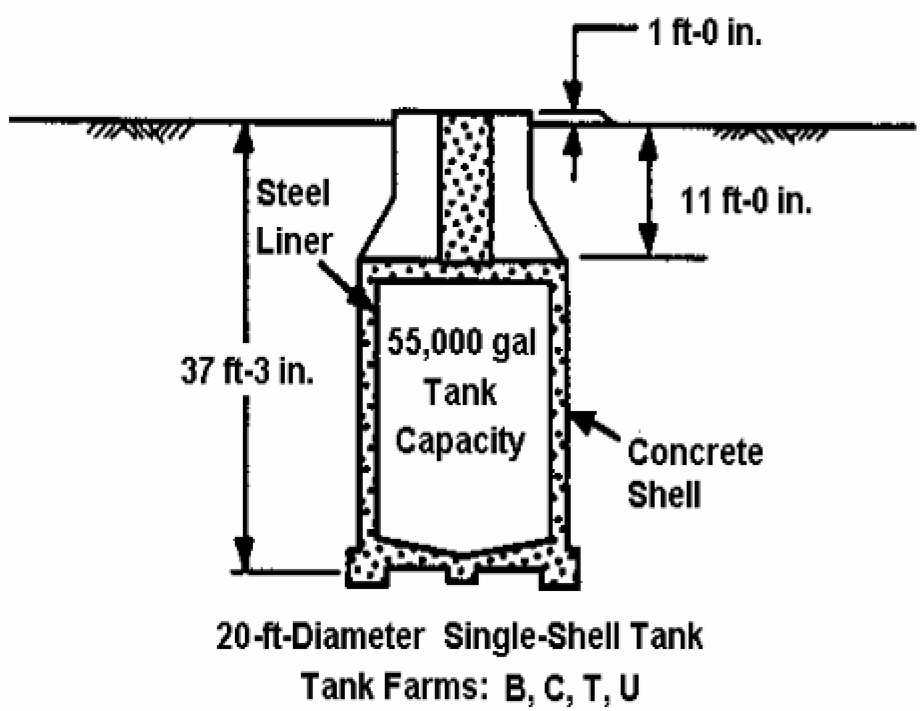

Figure 4. 100 Series SST

APPENDIX B

Figure 5. KWS Manufacturing Company Ltd. Vertical Screw Conveyor

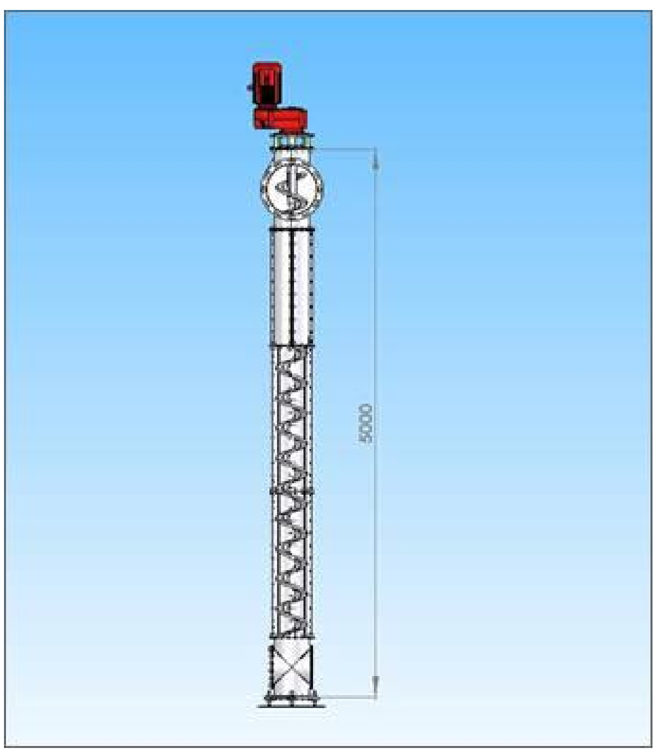

Figure 6. Huning Maschinenbau Vertical Screw Conveyor