# The Retrieval Knowledge Center Evaluation of Low Tank Level Mixing Technologies for DOE High Level Waste Tank Retrieval - 10516

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## ABSTRACT

The Department of Energy (DOE) Complex has over two-hundred underground storage tanks containing over 80-million gallons of legacy waste from the production of nuclear weapons. The majority of the waste is located at four major sites across the nation and is planned for treatment over a period of almost forty years. The DOE Office of Technology Innovation & Development within the Office of Environmental Management (DOE-EM) sponsors technology research and development programs to support processing advancements and technology maturation designed to improve the costs and schedule for disposal of the waste and closure of the tanks.

Within the waste processing focus area are numerous technical initiatives which included the development of a suite of waste removal technologies to address the need for proven equipment and techniques to remove high level radioactive wastes from the waste tanks that are now over fifty years old. In an effort to enhance the efficiency of waste retrieval operations, the DOE-EM Office of Technology Innovation & Development funded an effort to improve communications and information sharing between the DOE's major waste tank locations as it relates to retrieval. The task, dubbed the Retrieval Knowledge Center (RKC) was co-lead by the Savannah River National Laboratory (SRNL) and the Pacific Northwest National Laboratory (PNNL) with core team members representing the Oak Ridge and Idaho sites, as well as, site contractors responsible for waste tank operations.

One of the greatest challenges to the processing and closure of many of the tanks is complete removal of all tank contents. Sizeable challenges exist for retrieving waste from High Level Waste (HLW) tanks; with complications that are not normally found with tank retrieval in commercial applications. Technologies currently in use for waste retrieval are generally adequate for bulk removal; however, removal of tank heels, the materials settled in the bottom of the tank, using the same technology have proven to be difficult.

Through the RKC, DOE-EM funded an evaluation of adaptable commercial technologies that could assist with the removal of the tank heels. This paper will discuss the efforts and results of developing the RKC to improve communications and discussion of tank waste retrieval through a series of meetings designed to identify technical gaps in retrieval technologies at the DOE Hanford and Savannah River Sites. This paper will also describe the results of an evaluation of commercially available technologies for low level mixing as they might apply to HLW tank heel retrievals.

## INTRODUCTION

The Department of Energy's Office of Environmental Management (DOE-EM) is responsible for the risk reduction and cleanup of the environmental legacy of the nation's nuclear weapons program. The DOE-EM Office of Waste Processing is the office within the Office Technology Innovation & Development (EM-30) responsible for developing the technologies, tools and techniques needed to safely stage and remove waste from aging waste tanks and process the waste for final disposition. The Office of Waste Processing technology development and deployment program has several key technical focus areas including storage, waste retrieval, tank closure, pretreatment and immobilization based on a 2008 report to congress [1].

In August of 2008, the DOE-EM Office of Waste Processing began an initiative to develop a Retrieval Knowledge Center (RKC) to provide the DOE, high level waste tank farm operators, and technology developers with a core team of knowledgeable expertise to move waste retrieval technologies forward. The RKC is also designed to facilitate information sharing across the DOE Complex of waste tank sites through workshops, and a searchable database of waste retrieval technology information. The Retrieval Knowledge Center core team was assembled from laboratory and site expertise to identify waste retrieval requirements and technical gaps that would benefit from technology advancement. To assemble the data and develop plans for addressing the gaps, the RKC hosted four technical meetings in 2008 and 2009. The DOE Hanford and Savannah River Sites are home to most of the DOE waste tanks so the majority of the retrieval challenges to be addressed are expected to originate from these sites, although, other DOE sites with waste storage tanks contributed significantly to the development of the challenges.

In mid-2009, the Office of Waste Processing requested further support from the RKC to develop a plan to evaluate adaptable commercial technologies that could assist with the removal of waste material in the bottom (heel) of waste tanks.

## DEVELOPMENT OF THE RETRIEVAL KNOWLEDGE CENTER

Over the past several years, tank waste retrieval technologies have been deployed on a tank by tank basis across the Department of Energy's (DOE) complex with little synergy and sharing of information to assist with future retrieval activities. Commercial technologies do not offer "off-the-shelf" deployable packages for waste tank retrieval. The Office of Waste Processing within the DOE-EM Office of Technology Innovation & Development commissioned work in August 2008 to begin an initiative to develop a centralized location of available data and expertise for tank waste retrievals. The concept was to provide the DOE, waste retrieval operators, and technology developers with a focused working-level forum to share knowledge, experience and expertise and provide a technical resource that could address technology challenges in waste retrieval across the DOE complex.

To encourage this collaboration between DOE waste tank sites, the core team was formed around co-leadership from the Savannah River National Laboratory (SRNL) and the Pacific Northwest National Laboratories (PNNL). The resulting objective was to add complex-wide expertise in retrieval that could assess, gather and share information that would aide in addressing technical gaps in retrieval; dubbed the Retrieval Knowledge Center (RKC). The goal was for the RKC to provide a centralized location for sharing detailed technical information related to retrieval deployments at Hanford, Savannah River, Idaho and Oak Ridge. The RKC was also envisioned to facilitate information sharing through working meetings, workshops and through the development of a searchable database of waste retrieval technology information. Ultimately, the RKC would provide the venue for assembling information on new retrieval technologies and assessing state-of-the-art technologies applicable to retrieval needs within the complex.

A two-pronged approach to address the need for improved communications and information sharing was developed by the core RKC team. The first step was to gather and provide existing information available for all potential retrieval technology users. The second step was to assemble an expanded team to develop a framework of technical challenges to wastes tank retrieval and begin developing plans to address the challenges.

**Web Based Technical Information on Retrieval**

The core RKC team developed a concept for a virtual retrieval center that would house experience and information related to tank retrievals within the DOE Complex. The Retrieval Knowledge Center was to develop an information library related to the remediation of radioactive wastes from underground storage tanks throughout the DOE complex, but with emphasis on the most technically challenging in the Complex; the Hanford and Savannah River Sites. The information was to be categorized into various functional attributes which were to have the ability to be queried individually or as a group by searching or browsing. The goal was to provide users with easy access to the information and documents.

SRNL and PNNL, in collaboration with NuVision Engineering, developed a test version of the Retrieval Knowledge Center web site and database in 2008. The goal was to collect available information on retrieval efforts within the Complex into a searchable database. The website concept allowed provisions for users to submit technical information and reports, and includes a number of attributes attached to each entry (i.e. document) for an easy to use but fairly robust search engine (see figure 1). The website features the retrieval database that the initially imported documents from the Retrieval Technology Guide that was previously developed but had not been maintained since 2002. The database is useable to research effective technology approaches for specific retrieval tasks and lessons learned from previous operations. It is also an effective tool for users to remain current with the state of the art in retrieval technologies and with ongoing technology development within the DOE complex. The core team completed two beta tests of the web site and database in 2008 and a significant upgrade in 2009. The website, located at http://rkc.pnl.gov, contains over fourteen hundred retrieval related documents.


Fig. 1. The Retrieval Knowledge Center developed and released a web based document database in 2009 highlighting over 1400 tank retrieval related documents.

**Working Meetings on Retrieval Functions and Challenges**

The RKC also hosted and facilitated two working meetings in the fall of 2008 designed to define top-level waste retrieval functional areas, exchange lessons learned, and develop a path forward to support a technical plan focused on addressing technology needs for retrieval. At Hanford, there have been several retrieval campaigns over the past several years, and the waste feed requirements for the Waste Treatment Plant are beginning to result in formidable flow down requirements to tank farm and treatment plant operations. At SRS, tank retrieval challenges could limit subsequent immobilization processing plants from reaching full capacity. The first two working meetings engaged tank farm operations and engineering personnel, and national laboratory researchers and commercial industry, and resulted in technical challenges in each of the major high level retrieval functions. The meetings also demonstrated the value of discussing the similarity of technology gaps between the sites, and provided recommendations on which of the technology gaps would hold the highest value when resolved. [2]

The meetings demonstrated that while industry has many commercial systems based upon applications in other industrial areas; these "off-the-shelf" technologies historically require significant testing, evaluation, and fairly involved modifications prior to being deployed into HLW tank systems. It was found that over the last several years, waste retrieval technologies have been typically deployed on a tank by tank basis across the DOE Complex but lacked synergy and consistency. Successful deployments (and in some cases, less successful deployments) have lacked timeliness of detailed information sharing to assist with future retrieval development activities. The foundation of the Retrieval Knowledge Center was formed around an approach of using shared knowledge and experience to aid in communicating and addressing technical gaps in retrieval technology efforts, and build consensus on a generalized set of technical retrieval challenges between the two primary sites performing on-going HLW tank retrieval operations.

The first two RKC hosted meetings were designed to capture and evaluate the functions related to high-level waste tank retrieval as a means of determining specific technology focus areas as input to the larger DOE-EM Technology Development Program. The meetings ultimately described technical challenges in the five primary functions of retrieval (characterization of tank waste, access to the waste, dislodging & mobilizing the waste, convey and transport the waste). A simplified diagram of the functions related to retrieval is shown in figure 2. The information generated from these meetings and serve as a foundation for building technology roadmaps and development plans to address the noted technical gaps in the various functions. The two meetings successfully accomplished RKC goals to identify the high-level gaps, but also resulted in the need to investigate specific technical challenges within the various functions of retrievals, namely heel retrievals.

**Complexities of Tank Heel Retrievals**

Stemming from the high-level discussion of challenges related to the functions of retrieval, the team hosted a third review of the technology gaps specifically related to tank heels. A third meeting of the core RKC team was held in mid-2009 to develop further details of the technical challenges facing the retrieval of tank heels. The RKC assembled a team of technical personnel broadly representing tank waste retrieval knowledge at Hanford, Savannah River, Idaho and Oak Ridge for a working meeting on June 3, 2009 at the Savannah River Site in Aiken South Carolina to discuss what has been attempted within the DOE Complex and across industry for retrieving tank heels. The team reviewed recent site heel retrieval deployments, such as: SRS Tanks 18 and 19 robotic crawler deployments, and modified sluicing on Tank C-103 at Hanford. The facilitated meeting reviewed specific technologies and lessons on successful and less-than successful deployments. The meeting also discussed needs and gaps in technologies for retrieving tank heels relative to what might be the next step in high-level waste tank technology (e.g. through similar applications in commercial industry) and what would be needed to make new options available. Areas such as: keeping solids suspended at low tank levels, moving tank solids to, into and through pumps, and characterization were just three of the nine gaps that were reviewed.

The team concluded that identifying equipment to effectively mix waste tanks at low levels will be of value to tank closure processes within the DOE Complex. Savannah River Site will be preparing to employ an Enhanced Chemical Cleaning process over the next several years that would clearly benefit from improve acid contact time at low levels. The undertaking of an evaluation of low level mixing would also provide options to retrieval efforts where the large submersible mixer pumps become increasingly ineffective at moving solids at tank levels less than 1.2 meters (4 feet). The ability to mix or suspend solids at low tank levels could be expected to support several on-going initiatives at both the Savannah River Site and Hanford sites. Effective, low cost, low level mixing options would be expected to add to the complement of tools needed to retrieve high-level waste tanks prior to final cleaning and closure. Minimizing secondary waste is another advantage of low level mixing since successful mixing and retrieval was predicted to be achievable using considerably less water than previous efforts. Low level mixing pumps are also expected to be physically smaller than typical mixing pumps, and relatively inexpensive; the majority of the cost wrapped up in installation costs. However, a small mixing pump with a close coupled motor would not require significant above tank structures or extensive plant modifications which should minimize installation and usage costs. Multiple low level mixing pumps were predicted to be necessary to effectively mix a tank heal since they are not as powerful as the long shaft mixing pumps currently in use. [3]

### Evaluation of Low Level Mixing to Address Stubborn Heel Removal

Based on the RKC meeting in June of 2009, the team received approval to proceed with a plan to evaluate commercially available technologies for low level tank mixing to address removal of heels. Since most waste transfer systems employ pumps to transport wastes out of the tank in slurry form, maintaining the insoluble waste particles in suspension, particular in the lower tank levels is key to removing them from a tank. The low level mixing concepts were initially targeted for use in Savannah River Site waste tanks which are seventy-five to eight-five feet in diameter, although this concept will be applicable to other large waste tanks across the DOE Complex.

## LOW LEVEL MIXING EVALUATION

The RKC led program to evaluate low level mixing was designed to comparatively evaluate high potential candidate commercial technologies. Derived from discussions in the third RKC meeting, the concept was well supported by the SRS tank farm contractor, who had previously investigated possible commercial technologies for the same application. The approach was funding limited, but centered on a two-tiered down select based on simple comparison of the technologies. The initial criteria for selecting up to three technologies for a side-by-side comparison was 1) cost of a single unit, 2) magnitude of modifications (vendor and local), 3) availability, and 4) form, fit and function. The form, fit and function parameter included consideration of general pump configuration and handling (e.g. easily manipulated using standard tank installation tools) and the services required, as well as, the pump system's ability to fit through a standard 22 ½" riser.

The second tier comparison was performed on the technologies resulting from the first tier and was more oriented on engineering aspects of the candidate technologies. The selection criteria for the second tier centered on measured axial velocities at varying liquid levels. Table I shows the test matrix for the second tier comparison.

Table 1. Overall test matrix for comparative evaluation of low level mixing technologies.

| Pump | Nozzle height, cm (in)[1] | Tank level, m (ft)[2] | Axial velocity positions, m (ft) |
|---|---|---|---|
| Centrifugal | 30.5 (12) | 1.2 (4) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Cavity | 61 (24) | 1.2 (4) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Cavity | 30.5 (12) | 1.2 (4) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Cavity | 7.6 (3) | 1.2 (4) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |

| | | | |
|---|---|---|---|
| Cavity | 45.7 (18) | 0.9 (3) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Cavity | 30.5 (12) | 0.9 (3) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Cavity | 7.6 (3) | 0.9 (3) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Centrifugal | 30.5 (12) | 0.9 (3) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Centrifugal | 30.5 (12) | 0.6 (2) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Cavity | 30.5 (12) | 0.6 (2) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Cavity | 7.6 (3) | 0.6 (2) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Cavity | 30.5 (12) | 0.3 (1) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Cavity | 15.2 (6) | 0.3 (1) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Cavity | 7.6 (3) | 0.3 (1) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Centrifugal | 30.5 (12) | 0.3 (1) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Centrifugal | 7.6 (3) | 1.2 (4) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Centrifugal | 7.6 (3) | 0.9 (3) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Centrifugal | 7.6 (3) | 0.6 (2) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |
| Centrifugal | 7.6 (3) | 0.3 (1) | 1.8(6), 3.6(12), 5.4(18), (9) 30 |

[1] Nozzle positions were to be achieved by elevating the entire pump for this test matrix.

Notable evaluation parameters for the second tier included motor voltage, current and frequency. Pump speed correlated to pressure and flow at the discharge nozzle was to provide another data point to be evaluated. Instrumentation to measure flow and directional movement of the test fluid at various distances from the discharge nozzle was also investigated and was expected to be used to characterize test fluid movement. The low level mixing systems were to be tested in tank levels ranging from one to four feet at varied discharge nozzle heights. Water was to be used for test fluid to help manage test costs and to provide comparative data for this evaluation. The data and analysis is expected to demonstrate which system(s) stands out for further, more rigorous technical evaluation using tank heel simulants and to develop an initial determination of technology readiness to feed a proposed point of insertion into baseline heel retrieval strategies.

**Results of Initial Evaluation**

The team found a total of three technologies that warranted further investigation. Due to funding limitations, the selected two of the commercial technologies for further comparison against the second tier selection criteria. The two technologies, a progressive cavity type pump and a centrifugal pump were evaluated against the first tier selection criteria in mid-2009, just before funding for the project was discontinued. Table II shows (without vendor or technology nomenclature) how twelve candidate technologies were down selected to three. It is notable that although twelve vendors were initially included, several dropped quickly from further review because of either cost or disinterest. It is also notable that twelve vendors were selected for evaluation of only five varying technologies, with the most prominent commercial technologies being progressive cavity and centrifugal pumps. Ultimately, the team did select a single progressive cavity pump and single centrifugal pump for further evaluation.

Table II. General parameters and results of an initial selection of commercial technology candidates to further evaluate for low level mixing applicability.

| **Criteria** | **Parameter** | **Result (of twelve candidate vendors)** |
|---|---|---|
| (1) Cost | <$25,000/unit | 6 of 12 |

| | | |
|---|---|---|
| (2) Magnitude of Modifications<br>a. vendor mods<br><br><br><br>b. local mods | High – Medium-Low<br>High > 2x unit cost<br>Med. < 2x unit cost<br>Low no cost difference<br><br>High – Medium-Low<br>High > 1,500 hrs per unit<br>Med. < 750 hrs per unit<br>Low no hours needed | a. 6 of 12<br><br><br><br>b. 4 of 12 |
| (3) Availability | < 14 weeks ARO[2] | 4 of 12 [1] |
| (4) Form, Fit, Function | manageable with 22 Ton Crane<br>57.2 cm (22-½") Riser Fit<br>Submersible | 4 of 12<br>3 of 12<br>3 of 12 |

[1] Four commercial technologies remained after the initial evaluation, but one of the technologies was removed later based on significant cost increases reported to reengineer bearing housing for material compatibility.

2 After receipt of order

## CONCLUSION

The Retrieval Knowledge Center provided needed review of technology gaps in retrieval of DOE high level waste tanks. This ultimately led to an initial evaluation of commercially adaptable technologies for potential use in heel retrieval through low level tank mixing to support missions at both the Savannah River Site and Hanford site in Washington. With the aggressive Savannah River schedule to close as many as twenty-two tanks within the next eight years, and the introduction of Enhanced Chemical Cleaning, options for mixing at low tank levels becomes a significant technology enabler. Further evaluation and a rigorous engineering test program to quantify nozzle velocity relationships to effective solids suspension and mixing is needed to fully evaluate low level mixing technologies before insertion into tank waste retrieval baselines.

## REFERENCES

[1] "Engineering & Technology Roadmap Reducing Technical Risk and Uncertainty in the EM Program", U.S. Department of Energy – Office of Environmental Management (2008).

[2] A.P. FELLINGER, M.W. RINKER, et.al. "EM-21 Retrieval Knowledge Center: Waste Retrieval Challenges," SRNL-STI-2009-00231/PNNL-18356, Savannah River National Laboratory (2009).

[3] A.P. FELLINGER, M.W. RINKER, R.L. MINICHAN, K. AIRHART, and J. STEIMKE "EM-21 Retrieval Knowledge Center Meeting Report: Mobilize and Dislodge Tank Waste Heels," SRNL-STI-2009-00535 (Draft), Savannah River National Laboratory (2009).