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United States Department of Energy
Office of Environmental Management

Waste Processing
Annual Nuclear Safety Related R&D Report
for CY2008

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EXECUTIVE SUMMARY

The Engineering and Technology Office of Waste Processing identifies and reduces engineering and technical risks associated with key waste processing project decisions. The risks, and actions taken to mitigate those risks, are determined through technology readiness assessments, program reviews, technology information exchanges, external technical reviews, technical assistance, and targeted technology development and deployment (TDD). The Office of Waste Processing TDD program prioritizes and approves research and development scopes of work that address nuclear safety related to processing of highly radioactive nuclear wastes. Thirteen of the thirty-five R&D approved work scopes in FY2009 relate directly to nuclear safety, and are presented in this report.

1.0 INTRODUCTION

The mission of the Office of Waste Processing is to reduce the technical risk and uncertainty of EM waste processing programs and projects through the timely development of solutions to technical issues. The Office offers guidance and technical assistance to EM's waste processing operations and is responsible for the development of technology needed to adequately and safely address waste processing problems. Additionally, the Office of Waste Processing provides technical direction and/or assistance to sites to address difficult technical problems, sponsors cross-site integration and technology information exchange efforts, and provides engineering and scientific expertise for external technical reviews and technology readiness assessments to address difficult technical problems or for resolution of issues identified by project managers.

The Office of Waste Processing identifies and reduces engineering and technical risks associated with key waste processing project decisions. The risks, and actions taken to mitigate those risks, are determined through technology readiness assessments, program reviews, technology information exchanges, external technical reviews, technical assistance, and targeted technology development and deployment. The Office of Waste Processing works with other DOE Headquarters offices, project and field organizations to proactively evaluate technical needs, identify multi-site solutions, and improve the technology and engineering associated with project and contract management. Participants in this program are empowered with the authority, resources, and training to implement their defined priorities, roles, and responsibilities.

2.0 WASTE PROCESSING PROGRAM and RELATIONSHIP TO NUCLEAR SAETY

The Department of Energy's Office of Environmental Management (DOE-EM) has over 80 million gallons of liquid waste stored in aging underground tanks. The DOE-EM's Office of Engineering and Technology is engaged in reducing programmatic and technical risks associated with safely processing this waste through research & development tasks over a broad range of initiatives within the waste processing technologies. The Office of Waste Processing has implemented a series of plans outlining the selection of programmatic focus areas, development of teams, and general governance of the program that recognizes efforts needed to ensure safely processing and dispositioning of this legacy nuclear material.

2.1 Engineering & Technology Roadmap

The *DOE-EM Engineering & Technology Roadmap* issued to Congress in 2008 outlines strategies of the EM Engineering & Technology Program to address technology gaps and risks within Waste Processing Program Area. The Roadmap further organizes waste processing into seven programmatic focuses; Waste Storage, Waste Retrieval, Tank Closure, Waste Pretreatment, and Stabilization, Challenging Materials and Spent Nuclear Fuels (these last two added late in FY2008); and a single cross-cutting initiative. This arrangement (known as the Work Breakdown Structure, or WBS) delineates the management approach to identify, fund and report on actionable research and development projects and tasks generated to address the technical risks associated with waste processing. One of the primary programmatic themes of the report addresses the need to develop technologies to safely process the environmental legacy (wastes) of the Nation's defense nuclear programs.

Within the eight Waste Processing programmatic focus areas, and eighteen supporting strategic initiatives , numerous programs, tasks and activities were outlined in the *DOE-EM Waste Processing Multi-Year Program Plan* (MYPP) to address the gaps. These tasks are updated and evaluated annually through a prioritization process that includes safety as an evaluation criterion.

2.2 Waste Processing Multi-Year Program Plan

The *Office of Waste Processing Multi-Year Program Plan* (MYPP) supports the goals and objectives of the *Office of Environmental Management Engineering and Technology Roadmap* by providing direction for technology enhancement, development, and demonstrations that will lead to a reduction of technical uncertainties and risks in EM waste processing activities. The MYPP summarizes the strategic initiatives and the scope of funded and proposed activities within each initiative over a five year period to improve safety and reduce costs and environmental impacts associated with waste processing. While scope execution is impacted by funding levels on a year-to-year basis, the plan outlines scope that is centered on safely treating, moving and dispositioning legacy nuclear wastes. The Waste Processing Program activities are described within the eight programmatic focus areas and the resulting eighteen strategic initiatives outlined in the E&T Roadmap. (Two new programmatic initiative areas--Challenging Materials (CM) and Spent Nuclear Fuel (SNF)--were established in the Office of Waste Processing during late FY2008.)

The strategic initiatives and proposed work scopes were developed with input from the appropriate DOE-EM sites, projects, and programs in order to ensure that the key waste processing needs throughout the DOE-EM Complex were fully represented in this effort. With DOE-EM leadership and National Laboratory representation, the MYPP defines Initiative Development Teams (IDTs) that have been established in the eight strategic initiatives under Waste Processing Programs.

These strategic initiatives and the associated scopes were developed by the Office of Waste Processing through these IDTs. The IDTs were formed around experts from national laboratories, industry, and academia intimately familiar with the EM sites and programs involved with waste processing. The IDTs conducted an analysis of the risks and an assessment of the impacts if the risks were not mitigated. The IDTs then performed a gap analysis against current efforts funded by the DOE-EM sites, DOE programs, and other entities to form proposed activities within each strategic initiative area. The result being a list of activities representing a balanced research and development portfolio designed to address both near-term project needs and the longer-term strategic needs in waste processing.

Within the MYPP, nuclear safety considerations continually influence the technical risk and high level challenges within the strategic initiatives. Therefore, proposed activities derived from the analyses within the IDTs and the MYPP inherently contain some basis in the nuclear safety aspect. Whether through worker and public safety, or environmental safety; the top challenges represent a waste processing R&D program goal that addresses safe storage, safe retrieval and safe and stable end state of these materials. In summary, the Waste Processing MYPP encompasses the technology development programs and scope deemed necessary to safely address treatment and disposition of high-level waste (HLW); the treatment, transportation, and disposal of low-level waste (LLW), transuranic (TRU) waste, and spent nuclear fuel (SNF); and the development of disposition pathways for DOE's "challenging materials"(CM).

2.3 Office of Waste Processing Prioritization

The Waste Processing portfolio of tasks generated through the IDTs and described in the MYPP was prioritized in FY09 according to the Cogentus Framework used in FY08. The application in FY09 drew upon the successful prioritization process from FY08, with improvements based on feedback at the conclusion of the FY08 prioritization cycle.

Process-wise, the prioritization was based on a format similar to that used in FY08; whereby initial meetings were held with a subset of the entire team to agree on the principles for the new analysis and refine the evaluation criteria. Datasheets containing questions to capture the costs, benefits, as well as other programmatic elements of each task were again compiled and distributed to the Team Leads for completion – such that each candidate project and task was represented in the analysis. Submitted datasheets were compiled into a database which formed the basis for the prioritization model.

Most of the elements that define the FY09 criteria selection remained unchanged from FY08; this refers mainly to the overall Problem Definition (drivers, constraints, success criteria etc). All the differences for the FY09 prioritization were centered on the criteria, the portfolio structures and the projects included.

In FY09, the process ultimately evaluated proposed projects and tasks on a set of five criteria based on the three core elements of *DOE-EM Engineering & Technology Roadmap*; namely

Effectiveness, Cost and Risk Reduction. On this premise, teams were formed to develop the resulting five specific evaluation criteria, the first of which was Environmental and Safety Risk. This criterion measured the ability of a proposed technology (project or task) to reduce the Environmental and Safety risks to the baseline. The criteria included consideration of:

- Releases on / off site
- Safety & Health risk to workers and public, which included aspects of:
  - Fire safety
  - Radiation safety
  - Nuclear safety
  - Industrial safety and hygiene

2.4 Relationship to Nuclear Safety

Several FY08 and FY09 funded tasks within the Waste Processing strategic initiatives were presented and discussed at the DOE/NNSA Nuclear Safety Research and Development Forum in February 2009. This participation in combination with this report summarizes the Office of Waste Processing Program elements in research and development tasks committed to advancing nuclear safety within the context of processing nuclear wastes.

This report compiles the technical progress on research and development activities associated with the applicable MYPP Initiative areas during calendar year 2008. Reports from 35 technical tasks are included and represent significant accomplishments toward reducing the technical risk associated within the Waste Processing arena.

3.0 ELEMENTS OF NUCLEAR SAFETY IN OFFICE OF WASTE PROCESSING TECHNOLOGY DEVELOPMENT PROGRAM

The Office of Waste Processing produces an annual report describing technical activity progress and plans. The following sections highlight activity summaries extracted from that annual report for their applicability to research and development work related to nuclear safety.

3.1 **Solid-Liquid Interface Monitor**

3.2 Pipeline Unplugging Technology Qualification

3.3 In-Line Solids Monitor

3.4 Large Scale Demonstration Testing of an Alternative Approach for the Retrieval of K-Basin Container Sludge Simulant

3.5 Evaluation of HEPA Filter Performance under Upset Conditions

3.6 Partnership for the Development of Next-Generation Simulation Tools to Evaluate Cementitious Barriers and Materials Used in Nuclear Applications (Cementitious Barriers Partnership Project)

3.7 Design and Delivery of a Fluidic Sampler for Tank 50 at the Savannah River Site

3.8 Remediation of Cooling Coils In Large Tanks

3.9 In-Tank Characterization for Closure of Hanford Waste Tanks

3.10 Aluminum Solubility

3.11 Advanced Mixing Models

3.12 Demonstrate HIP Process for INL HLW Calcine and DOE Legacy Waste

3.13 Direct Analysis of SRAT (Slurry Receipt and Adjustment Tank) Contents

3.1 Solid-Liquid Interface Monitor (SLIM)

Principal Investigator: David Roelant, ROELANTD@FIU.EDU, 305-348-6625, and Dwayne McDaniel of Florida International University

Collaborators: Ruben Mendoza, Washington River Protection Solutions (WRPS), Paul Bredt, Pacific Northwest National Laboratory (PNNL)

Project Duration: 2004-2010

Waste Processing Challenge

As Hanford tank waste retrieval operations transfer waste between tanks, it is imperative that engineers have an accurate method of estimating tank waste volume. The inability to monitor the actual solid-liquid interface leads to conservative estimates of the actual amount of solids in the tank so as to prevent exceeding the safe maximum solids level due to gas generation. Hanford site personnel identified a critical need for such an interface monitor, which is capable of detecting the interface between the settled solids and the supernate liquid in a tank. Existing commercial off-the-shelf (COTS) technology for imaging the solids layer level are not suited to the highly radioactive and caustic environment inside these tanks.

SLIM will assist site engineers by providing an understanding of the interface location between the supernate and the settled solids during the transfer of tank waste between tanks. Knowing this location will improve uncertainty in the transfer of the supernate, reducing the likelihood of plugging in the pumps and transfer lines and preventing excess cost and schedule delays related to the plugging. In addition, having an accurate determination of the amount of solid waste will assist in reducing the risk of gas generation build up.

Research Objective

The focus of 2008 work was to complete the design based on additional Hanford-defined needs, and prepare it for deployment at Hanford's Cold Test Facility (CTF) in 2009. In addition, FIU would evaluate an alternative sonar system that could improve shortcomings associated with the sonar head, primarily relating to the onboard electronics.

Research Progress

Based on final requirements from Hanford, the SLIM system design was completed during 2008, while fabrication was started for cold test at the CTF. The containment system design was completed by performing a finite-element analysis of the enclosure loading, and the effect of that load on the support jacks. Laboratory testing validated that the support jacks would not hold the tension load associated with an 85 mph wind load. Based on this finding, the system was modified to use a machine table (Figure 1). The table was selected so that the table top oversized the dimensions of the bottom plate of the enclosure box. The figure below shows the stress distribution of the support table. The maximum stress was determined to be 9,018 psi concentrated at the upper area of the downwind legs, well below the yield strength of the material in use.

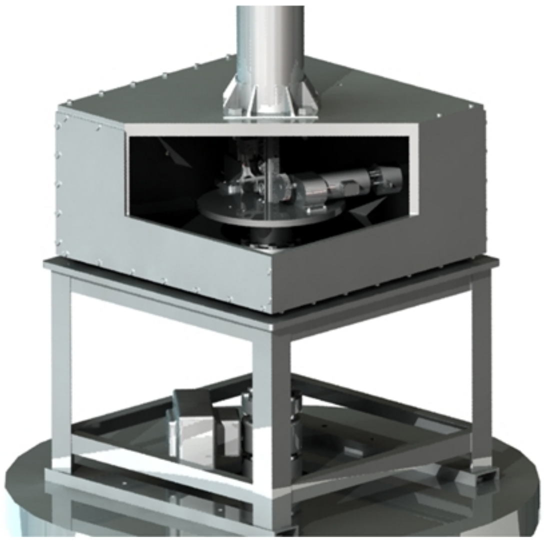


Figure 1. SLIM system with machine table

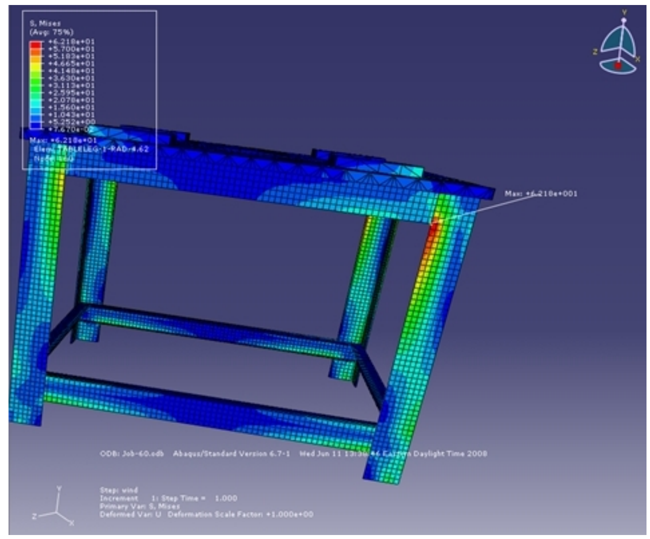


Figure 2. FEA of SLIM support table

At the initiation of 2008, FIU was informed by Hanford personnel that a lack of site funding would not allow the SLIM to be deployed at the CTF. Due to the costs and modifications required to perform cold testing at alternative facilities, FIU was forced to place cold testing on hold until Hanford’s CTF could support such an effort. On a parallel task, FIU began to evaluate sonar systems that could reduce system complexity, address longevity issues with on-board electronics, and map with the resolution provided by the current side-scan sonar. Based on this search and evaluation, candidate sonar was selected. The modified system provides a 3D profile of the mapping area from 1 m to 20 m. The sonar operates at 1 MHz frequency, providing a 15 mm resolution at 1 m. All electronics are located in a NEMA 4X enclosure that can be located up to 30 m from the sonar head. The system has a 3.5 in diameter, leaving 0.25 in tolerance for maneuvering the riser into the tank. The housing is titanium with a polyurethane boot for signal propagation. The system includes a software package that can be used for volume estimation, individual depth readings, and control of the system. This alternative sonar was procured for integration into the current SLIM platform and modifications to the SLIM deployment platform were initiated to allow for integration with the new sonar system.

Planned Activities

The planned activity for 2009 will focus on completing the development of the SLIM utilizing the improved 3D profiling sonar; The system modifications as a result of the 3D profiling sonar will reduce areas of operational complexity by minimizing the control system to only include the reel motor, and minimize installation issues with the removal of the 48 ft streetlight pole. The 3D profiling sonar will greatly improve longevity of the system by removing any electronics from the sonar head. In addition, FIU will perform verification testing of the system at FIU, develop manuals and have technology ready for deployment when the opportunity arises.

References

1. McDaniel, D., Awwad, A. Srivastava, R., Roelant, D., Varona, J., "Design and Testing of a Solid-Liquid Interface Monitor for High-Level Waste Tanks," Waste Management Symposia, February 2008.
2. Roelant, D., McDaniel, D., Awwad, A. Srivastava, R., Varona, J., Tachiev, G., "Chemical Process Alternatives for Radioactive Waste," Environmental Management Mid-Year Presentation, July 2008.

3.2 Pipeline Unplugging Technology Qualification

Principal Investigator: David Roelant, ROELANTD@FIU.EDU, 305-348-6625, and Dwayne McDaniel of Florida International University (FIU)

Collaborators: Ruben Mendoza, Washington River Protection Solutions (WRPS); Paul Bredt, Pacific Northwest National Laboratory (PNNL); Erich Kezsler, NuVision Engineering (NVE); Dawn Wellman, PNNL; Adam Poloski, PNNL; Robb Burk, Bechtel

Project Duration: 2006-2011

Waste Processing Challenge

Availability of pipeline unplugging technology is critical to the effort of cross-site tank-waste transfers through pipelines. In the past, some of the pipelines have plugged resulting in schedule delays and increased costs. Currently, there are no unplugging technologies qualified to be deployed at the site should the plugging of a transfer line occur. In the past, a number of plug locating, and pipe unplugging technologies were demonstrated at FIU, which identified the most promising technologies with potential for deployment at the site. The current project will build upon results of these demonstrations by qualifying the effectiveness, efficiencies and costs for deploying the most promising pipeline unplugging technologies for use at Hanford and other DOE sites.

Plugged tank-waste pipelines can be expensive to repair, add to schedule delays and potentially expose the environment and site personnel to hazardous conditions. Having unplugging technologies qualified and readily available to assist site engineers when a blockage occurs could assist in minimizing these issues.

Research Objective

The overall objectives of this project are to identify the functions and requirements of unplugging technologies for deployment and to conduct technology qualification testing on the most promising technologies. In order to achieve this goal, novel unplugging methods will be set up at FIU and experimental and numerical techniques will be used to provide details on the governing physics.

Research Progress

During 2008, experimental data collected during the evaluation of NVE's wave-erosion technique was completed. The operating principles of the wave-erosion method have been identified and the effects of various operating parameters such as drive time, suction and vent times and drive pressures on the unplugging effectiveness were investigated. A numerical model was developed to simulate the flow of the pressure transients in the pipelines with air trapped near the blockage. Results from the modeling were compared with the pressure distributions measured during the experiments with NVE.

In addition, a second pipeline unplugging method from AIMM Technologies was evaluated utilizing the FIU mock-up transfer pipeline with various unplugging scenarios. The pipeline at FIU was built in order to simulate the characteristics of tank-waste transfer lines and the total length of the pipeline was made adjustable (310 ft, 646 ft and 1822 ft) in order to understand the effects of plug distances on the technology parameters. Three different plugs were manufactured simulating clay and crystallized salt-type plugs. The plugs were made from Bentonite clay, potassium-magnesium-sulfate, sodium-aluminum-silicate and were placed in 4ft, 8ft and 12 ft pipe sections. The pipeline pressure distributions during the operation of the AIMM Technologies were recorded at 6 different locations at 1 kHz sampling rate using static and dynamic pressure sensors. In addition to this, internal fluid temperature and pipe wall vibration characteristics were also recorded. The experimental pipeline set up was able to investigate the effects of geometrical and configuration changes in pipelines such as constrictions, elbows and expansion joints. Results obtained after the analysis of the collected data during these experiments revealed crucial information on how the technology operates and what limitations and advantages it offers to site engineer

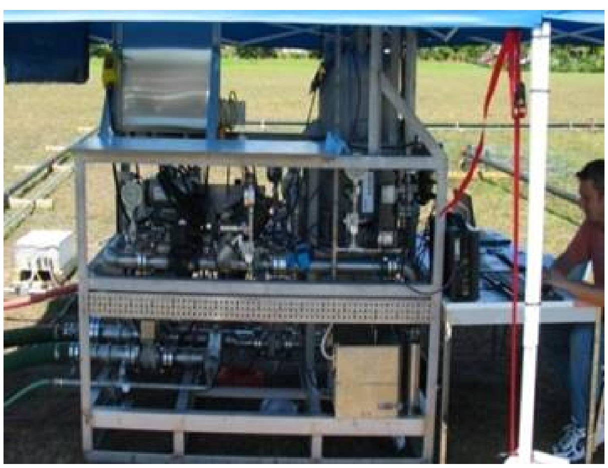


Figure 1. NVE's Wave-Erosion Method during Experiments at FIU in 2007

Figure 2. AIMM Technologies' Hydrokinetics Method during Experiments at FIU in 2008

Planned Activities

Future activities for 2009 will include completing the data analysis from the AIMM Technologies testing. Additionally, FIU will focus on evaluating alternative conceptual methodologies for pipeline unplugging. The task will initiate by defining the parameters for the additional concepts and conducting computer-aided modeling and simulations of the pipeline and plugged sections. The computational simulations will be used to evaluate if the new unplugging concepts offer improvements over commercially-available methods.

References

1. McDaniel, D., Gokaltun, S., Awwad, A. Srivastava, R., Roelant, D., Varona, J., "Qualification of Innovative Waste Pipeline Unplugging Technologies", Waste Management Symposia, February 2008.
2. Roelant, D., McDaniel, D., Awwad, A. Srivastava, R., Varona, J., Tachiev, G., "Chemical Process Alternatives for Radioactive Waste", Environmental Management Mid-Year Presentation, July 2008.

3.3 In-Line Solids Monitor

Principal Investigator: David Roelant, Florida International University (FIU), ROELANTD@FIU.EDU, 305-348-6625

Collaborators: Ruben Mendoza, Washington River Protection Solutions (WRPS), Paul Bredt, Pacific Northwest National Laboratory (PNNL)

Project Duration: 2008-2010

Waste Processing Challenge

During the past few decades there has been significant progress in moving two-phase tank waste from tank to tank within a single tank farm and across tank farms. At the DOE Hanford site some transfer lines have plugged as a result of these waste transfers. The chemical composition (phosphate levels), the amount of undissolved solids (percent by weight) and the ambient temperature (causing precipitation) have been identified as key plugging factors. To prevent further plugging problems, prior to removing waste from a tank, the composition is monitored and controlled. Heat tracing is added to new waste transfer lines to allow control of temperature during waste transfers. However, one critical parameter, the percent solids by weight entrained in a fluid, is missing because there are no commercial technologies able to measure this parameter.

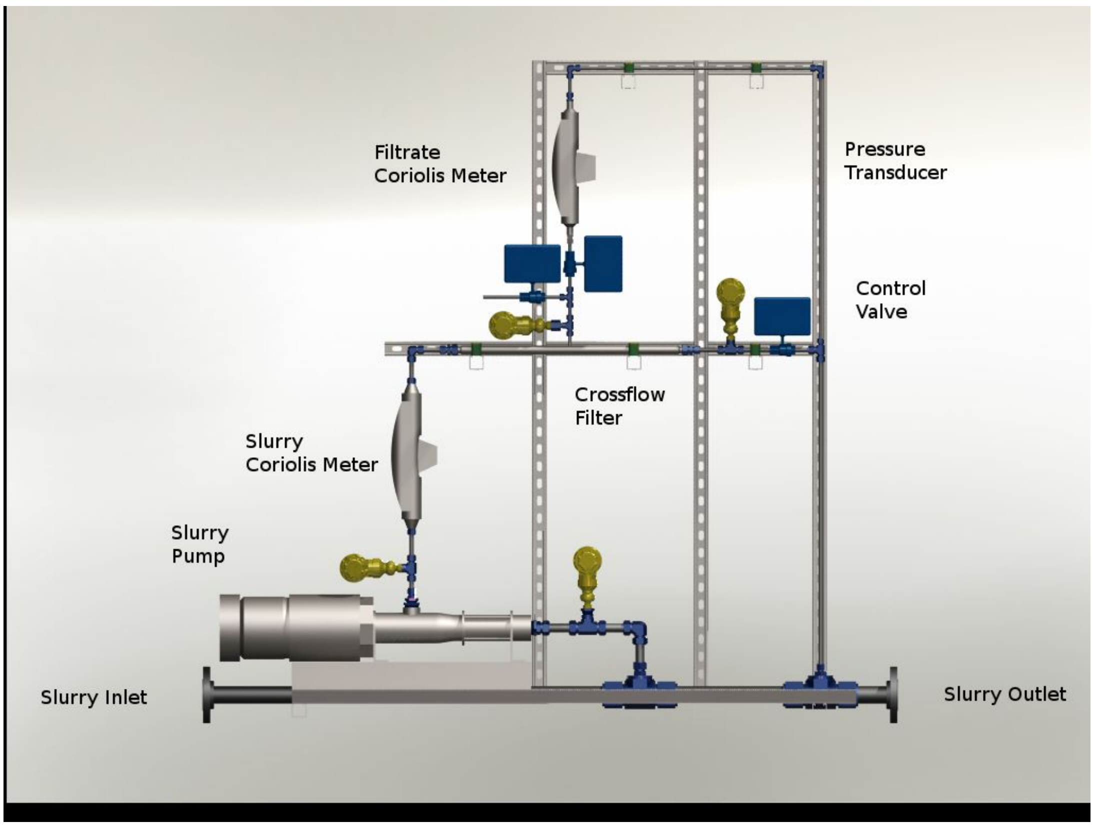
The percent solids monitors will assist site engineers by providing more detailed characterization of the slurry prior to the transport of the tank waste than previously available. This additional information will reduce the risk of plugging in pumps and pipelines, reducing cost associated with repair and reducing the risk of hazardous exposure to site personnel and the environment. In addition, integrating the solids being transported will allow the site a more accurate and independent measurement of solids being transferred among tanks, across tank farms, and eventually to the WTP.

Research Objective

Florida International University with its expertise in tank waste composition and transport has developed a proprietary technology that allows for the direct measurement of percent solids entrained in two-phase fluids. In addition to preventing plugging, this technology can help monitor and calculate the total solids being transferred to the Waste Treatment Plant (WTP) for final treatment. The focus of the 2008 work in support of this project was to develop an In-line Solids Monitor (ILSM) design that integrates the proprietary technology into a system that can be installed within the tank-waste transfer lines. In 2009 the Hanford Site and the Savannah River Site have both shown more interest in an in-tank solids monitor.

Research Progress

During 2008, transfer line properties were identified, including flow parameters, slurry properties and pipeline dimension and connections. After performing system flow calculations, the ILSM design was developed and the system components were identified. The ILSM consists of a progressive cavity pump, two Endress Hauser Coriolis meters capable of simultaneous measurement of flow (mass and volume flow), density, and temperature with an accuracy of ± 0.15%, a 0.5-micrometer Mott® cross-flow filter, four pressure transducers and three electronically controlled ball valves. All components are designed to withstand the harsh properties of the waste stream including; highly caustic (pH~14), high Gamma radiation, and an abrasive solids content.



In-line solids monitor

Planned Activities

Due to the site's recent interest in a system that can be deployed into the HLW tanks to determine the percent solids profile of the sludge within the tank, FIU will focus on taking the basic percent solids monitoring system developed at FIU and apply it to an in-tank monitor in

2009. Current site requirements call for the In-tank Solids Monitor (ITSM) to be capable of deployment through an 8-inch diameter tank riser.

In addition, FIU will perform verification testing of the system at FIU, develop manuals and have technology ready for deployment when the opportunity arises.

Reference

Roelant, D., McDaniel, D., Awwad, A. Srivastava, R., Varona, J., Tachiev, G., "Chemical Process Alternatives for Radioactive Waste", Environmental Management Mid-Year Presentation, July 2008.

3.4 Large Scale Demonstration Testing of an Alternative Approach for the Retrieval of K-Basin Container Sludge Simulant

Principal Investigator: Erich Keszler, keszler@nuvisioneng.com, 704-799-2707; Laurie Judd, and Paul Fallows of NuVision Engineering (NVE)

Collaborators: CH2M Hill Plateau Remediation Company (CHPRC)

Project Duration: 2008-2009

Waste Processing Challenge

As part of the continuing Hanford Site restoration, K-Basin sludges have been containerized prior to treatment and ultimate disposal. Each container consists of a number of chambers which slope to the base and an outlet connection. The baseline approach for sludge retrieval and transfer from these containers is to pump the sludge from a manifold arrangement which connects all of these outlets. Concerns regarding the technology maturity of this approach led to investigations into alternative methods for removing the sludge from these containers.

Research Objectives

The baseline approach to retrieval of sludge from the K Basin containers has been identified as being 'technically immature'. The proposed approach has been demonstrated to have the potential to provide DOE with a 'top retrieval' approach which is both more flexible and applicable to the requirements.

An alternative 'top retrieval' option was proposed by NVE in 2007 and resulted in proof of principle trials at facilities in the Richland area in 2008. These trials successfully demonstrated that the proposed approach was capable of mobilizing and transferring container sludge simulant. Success of the first phase of these demonstrations has led to the proposal of an extension of the trials into a second phase of activities to be conducted in Richland, WA, close to the Hanford site. The stated objective of this second phase of testing is to 'Characterize the retrieval of a representative Container simulant at 25 volume percent solids & 75 volume percent water and show that it can be transferred at a minimum of 5 volume percent, to a staging tank.

Research Progress

All testing has been completed. The unit under test (Figures 1 and 2) met or exceeded all stated test objectives, successfully transferring both Basin and Settler simulants from the test tank to the receiving tank.

Figure 1. Test Unit in Hopper Bottom Tank Prior to Testing

Figure 2. Test Personnel Inspecting Test Tank Contents after Retrieval

Planned Activities

The next phase of work will be to design a system in a prototypical configuration that could be tested prior to field deployment. This system must contain the operational features to enhance entry to the containers and operations in the basin. This prototypical unit will also be matched to the transfer system in terms of flows and pressures so that the entire system can be tested together.

3.5 Evaluation of HEPA Filter Performance under Upset Conditions

Principal Investigator: Charles A. Waggoner, Institute for Clean Energy Technology (ICET), waggoner@icet.msstate.edu, 662-325-7601

Collaborators: Steven L. Alderman and R. Arunkumar of ICET; Duane Adamson, Savannah River National Laboratory (SRNL), Leader of AG-1 Section FI Working Group (High Efficiency Metal Media Filters); Jim Slawski, Editor of the Nuclear Air Cleaning Handbook; Jim Honeyman (CH2MHill Hanford); David Eaton, Idaho National Engineering Laboratory (INEL); Pat Suggs, DOE Savannah River Operations Office (DOE-SR); Billie Mauss, DOE Office of River Protection (DOE-ORP)

Project Duration: 2008-2011

Waste Processing Challenge

Numerous applications exist within the waste treatment operations at DOE sites where temperature or moisture conditions exceed acceptable ranges for conventional fibrous glass HEPA filters. Sintered metal fiber media has emerged in the market place as a highly desirable substitute for fibrous glass media in these more aggressive environments. There is currently no standard covering use of such media in nuclear applications; however, Section FI Metal Media Filters of the AG-1 standard is under development.

Research Objective

Evaluate effects of media velocity on filter performance and loading capacity. These evaluations provide needed information for improved designs of new systems and operating strategies, updating AG-1 codes, and improving filter loading models.

Research Progress

Media velocity testing results were submitted for publication and appeared in the November, 2008 issue of Journal of Occupational and Environmental Health. Additional findings were reported at the 2008 Nuclear Air Cleaning Conference in Seattle, WA. These findings were based on studies involving 12”x12”x11.5” AG-1 HEPA filters challenged with two different particle size distributions of potassium chloride at media velocities ranging from four to eight feet per minute. Findings included determination of the variability of the most penetrating particle size over the test range for both of the particle size distributions tested. All filters tested had passed manufacturer conventional dioctyl phthalate (DOP) testing and had filtering efficiencies in excess of 99.97%. While numerous filters were tested at elevated media velocities without demonstrating leaks, ICET testing demonstrated excellent sensitivity in the detection of pinhole leaks not otherwise seen by conventional DOP testing. This testing demonstrates the sensitivity of polydisperse aerosol challenges to identify the presence of pinholes as opposed to elevated media velocities increasing leak rates through pinholes. Testing also demonstrated no effective change in the most penetrating particle size as a function of media velocity up to the maximum 8 feet per minute

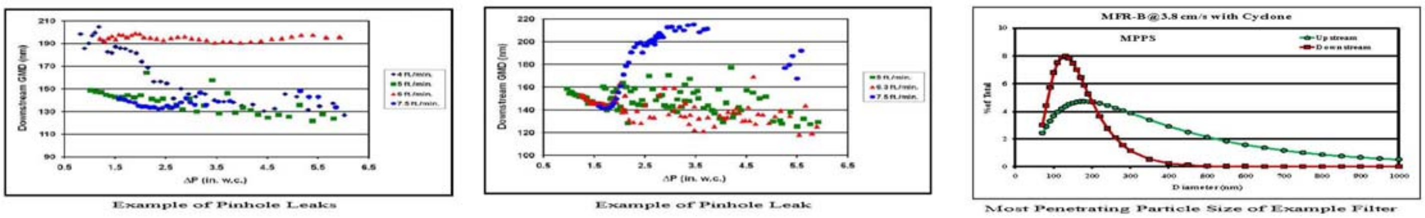
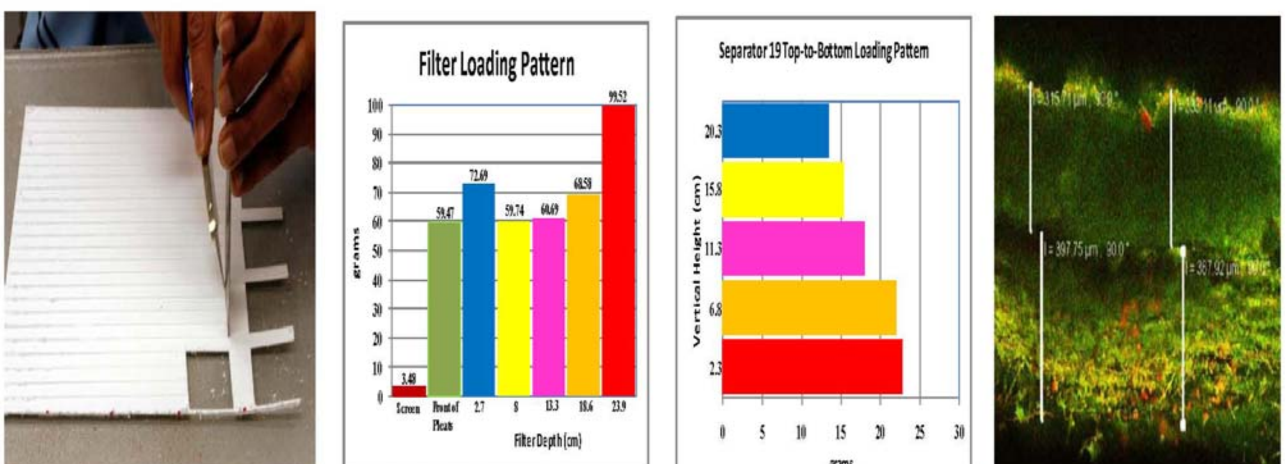


Figure 1 Media velocity text results

Autopsies were performed on all of the filters that were involved in media velocity testing conducted at ICET. Small coupons were excised from pleats representative of the filter media pack. These coupons were then utilized to determine the loading patterns of the individual pleats as well as the filter loading patterns from front-to-back and top-to-bottom for each media velocity tested. Selected samples were examined by electron microscopy to determine media depth loading.



Excising sample coupons

Front-to-Back Loading Pattern of Filter

Top-to-Bottom Loading Pattern of Filter

Electron Micrograph Depicting Depth Loading

Figure 2. Filter autopsy results

Planned Activities

Collaborators: Elaine Diaz, DOE-ORP; Sharon Steele, National Nuclear Security Agency (NNSA)

ICET is developing a larger-scale HEPA filter test stand to evaluate the performance of one to four 1000 CFM (AG-1, Section FC) filters or up to two 2000 CFM (AG-1, Section FK) filters at rate flow velocities and to differential pressure levels of 30 in w.g.

Activities to be conducted during 2009 include design and fabrication of new test stand, characterization of its performance and challenging AG-1 Section FK radial flow filters with carbon black. The test stand and auxiliary equipment will include the capability of challenging filters with smoke, soot, high moisture levels, and high temperatures. Test plans are currently under development through collaborations with representatives from Hanford ORP and from NNSA responsible for reviewing DOE-STD-1066-99 "Fire Protection Design Criteria".

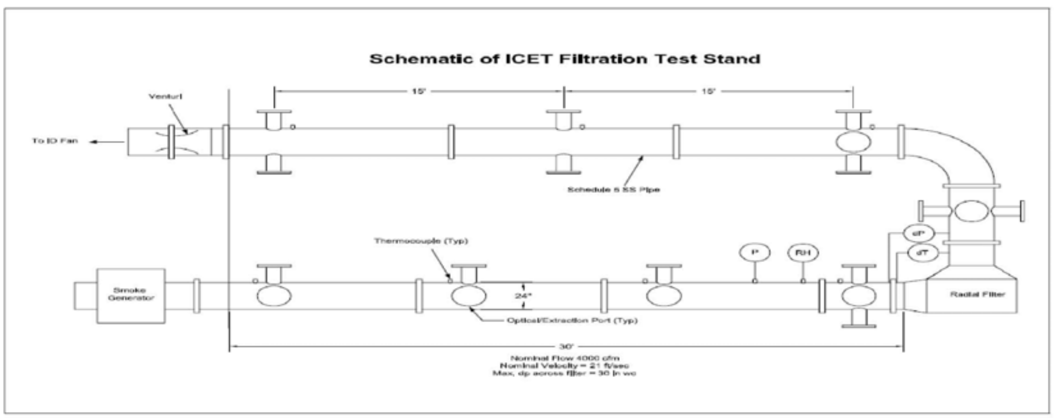


Figure 3. Schematic of New ICET Large-Scale HEPA Test Stand

References

1. Alderman, Steven L., Parsons, Michael S., Hogancamp, Kristina U. and Waggoner, Charles A. (2008) "Evaluation of the Effect of Media Velocity on Filter Efficiency and Most Penetrating Particle Size of Nuclear Grade High-Efficiency Particulate Air Filters"; Journal of Occupational and Environmental Hygiene, 5:11,713-720
2. S.L. Alderman et al, "The Effects of Media Velocity and Particle Size Distribution on Most Penetrating Particle Size and Filter Loading Capacity of 12"x12"x11.5" AG-1 HEPA Filters", Nuclear Air Cleaning Conference, Seattle, WA (2008).
3. Alderman, Steven L., Parsons, Michael S., Waggoner, Charles A., "Filter Autopsy for Evaluating Effects of Particle Size Distribution and Media Velocity on Loading Patterns", Nuclear Air Cleaning Conference, Seattle, WA (2008).

3.6 Partnership for the Development of Next-Generation Simulation Tools to Evaluate Cementitious Barriers and Materials Used in Nuclear Applications (Cementitious Barriers Partnership Project)

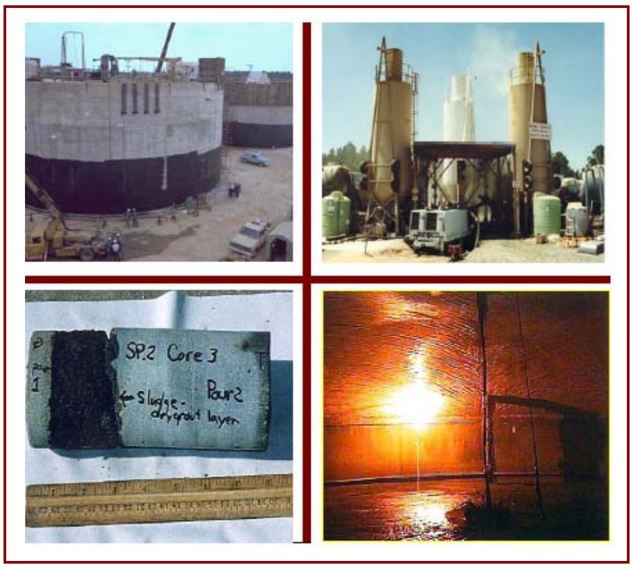
Principal Investigator: C. Langton, Savannah River National Laboratory (SRNL), christine.langton@srnl.doe.gov, 803-725-5806

Collaborators: A. Baione, U.S. Department of Energy, Office of Environmental Management (DOE-EM); D. Esh, M. Fuhrmann, J. Philip, U.S. Nuclear Regulatory Commission (NRC); D. Kosson, S. Mahadevan, A. Garrabrants, Consortium for Risk Evaluation with Stakeholder Participation (CRESP)/Vanderbilt University; H. van der Sloot, R. Comans, J. C. L. Meeussen, P. F. A. B. Seignette, Energy Research Centre of The Netherlands (ECN); E. Garboczi, K. Snyder, National Institute of Standards and Technology (NIST); E. Samson, J. Marchand, SIMCO, Inc.; R. Dimenna, SRNL

Project Duration: 2008-2013

Waste Processing Challenge

The US DOE has been and plans to continue using engineered cementitious barriers to enhance the performance of low-level radioactive waste (LLW) disposal sites located in the near-surface environment.



Research Objective

The US DOE intends to support this practice by funding a project that is expected to result in improving performance of engineered cementitious barriers and also in predicting the performance of the barriers over long periods of time.

There are several key impacts:
- Reduced uncertainty and improved consistency for performance assessments
- Updated guidance documents (assessment tools, test methods, data)
- Industry-wide technical basis for evaluation amongst stakeholders

- Improved technology foundation and integration of existing and new scope.

Research Progress

During 2008, the Cementitious Barriers Partnership (CBP) was formed with partners from government (DOE, NRC, and NIST), academia (CRESP/Vanderbilt), and international entities (ECN, SIMCO). The objective of the partnership is to develop a reasonable and credible set of tools to predict the structural, hydraulic, and chemical performance of cement barriers used in nuclear applications over extended time frames (up to 10,000 years) in the DOE complex and in commercial nuclear industry. A Memorandum of Understanding (MOU) and a Cooperative Research and Development Agreement (CRADA) were developed, and an Expert Advisory Panel was chartered.

The 5-year CBP Project Plan was issued. The plan is organized into Phases, each containing multiple tasks:

- Phase I is documentation of the current status for predicting service life of cementitious barriers for performance assessments;
- Phase IIA is model development;
- Phase IIB is experimental model support;
- Phase III is advanced processes, demonstration and validation.

Technical work has started; current state-of-the-art information is being documented, and model development has been initiated.

Planned Activities

During 2009, the partnership is scheduled to begin issuing documentation addressing tasks in both Phase I and Phase II as well as to address CBP topics in national and international symposia:

MISCELLANEOUS TASKS
- Establish and Implement CBP QA Plan

PHASE 1
Task 1: Current Performance Assessment Modeling Approaches
- Report: Summary of DOE and NRC PA Approaches
- Report: DOE PA Uncertainty Needs and Methods Roadmap
- Present paper at WM09: Summary of DOE and NRC PA Approaches and DOE PA Uncertainty Needs and Methods.

Task 2: Review State-of-the-Art Mechanistic and Process Understanding and Approaches
- Report: Current Understanding of the Parameters that Influence Hydraulic and Leaching Properties and Uncertainty Analysis of Cementitious Barriers (multiple chapters)
- Report: Description of the Candidate Software and Integrating Platform for the CBP Project (multiple chapters)

PHASE 2
- Task 6: Prototype Reference Cases
- Task 7: Demonstrate Software on Prototype Case(s)

EVENTS
- DOE Waste Management Symposium, February 2009, Phoenix AZ
- Team Meeting at Vanderbilt University, February 2009, Nashville TN

- International Workshop on Long-term Performance of Cementitious Barriers and Reinforced Concrete in Nuclear Power Plants and Waste Management, March 2009, Cadarache, France
- 33rd International Symposium: "Scientific Basis for Nuclear Waste Management", May 2009, St. Petersburg, Russia
- The 12th International Conference on Environmental Remediation and Radioactive Waste Management, October 2009, Liverpool, UK

Reference

Project Plan for the Partnership for the Development of Next Generation Simulation Tools to Evaluate Cementitious Barriers and Materials Used in Nuclear Applications (Cement Barriers Partnership) WSRC-SRNL-PR-008-001-01.

3.7 Design and Delivery of a Fluidic Sampler for Tank 50 at the Savannah River Site

Principal Investigators: Erich Keszler, keszler@nuvisioneng.com, 704-799-2707, Laurie Judd, and Paul Fallows of NuVision Engineering (NVE)

Collaborators: Savannah River Site (SRS) and Savannah River National Laboratory (SRNL)

Project Duration: 2007-ongoing

Waste Processing Challenge

At Savannah River and Hanford waste material is batched into large storage tanks prior to transfer to a treatment facility. The waste is collected, mixed, and sampled to ensure that it is within the acceptable predetermined envelope for the particular treatment plant. Once the sampling results have been confirmed by the site contractor, a small volume of the waste is transferred from the million gallon tank to the smaller treatment facility storage tanks where the waste is again mixed and sampled to ensure conformance with the process requirements. If the waste is found to be outside the acceptable envelope then it must be transferred back to the million gallon tank for conditioning, potentially causing the treatment facility to stop processing waste temporarily.

Sampling of waste tanks at DOE sites has traditionally been conducted by mixing the tanks for a long period, switching off the mixer pump nearest the sampling location, opening a tank riser, and manually collecting a sample from one location. This technique has the inherent problem that once the mixer pump is switched off the material in the tank will start to settle or stratify and the sample from the one location may not be truly representative of all the tank contents.

Research Objective

NVE has successfully developed and deployed Fluidic Single Point Samplers to collect samples of waste from waste tanks in nuclear process plants in the United Kingdom (UK). The sampler design (Figure 1) has a number of distinct advantages over the baseline sampling method. The sampler is installed into the tank through available risers and becomes a permanent tank feature with no moving parts in the tank, consequently requiring no maintenance of the in-tank assembly. The dose to operators is negligible during sampling of the tank, and the mixer pumps can be left running during the sampling operation. Both Savannah River and Hanford have expressed an interest in the fluidic sampler to reduce the technical uncertainties and risk associated with tank-waste sampling. This project will start a phased approach to the design and fabrication of a unit for tank 50 at Savannah River.

Research Progress

Definitive design of the sampling system is nearing completion. The design work (3-D model) was created in Solidworks and drawings were generated directly from that model (see Figure 2). The design incorporates valuable input from SRS and will soon be ready for Design Review and HAZOP by SRS.

Planned Activities

NVE will complete the detailed design and submit it for Design Review and final HAZOP. Once all comments have been received, resolved, incorporated and closed, the final design package will be sent to SRS for approval. When the design is approved it will be released for bid by fabricators. Following selection of the fabricator, then fabrication and construction of the first unit for field deployment will begin.

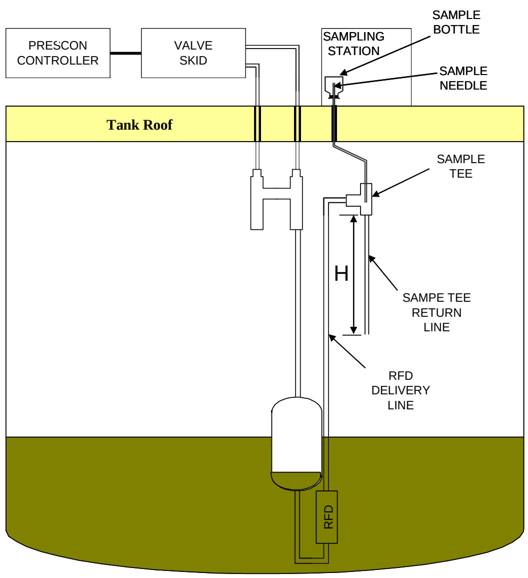


Figure 1. Schematic of Sampler System

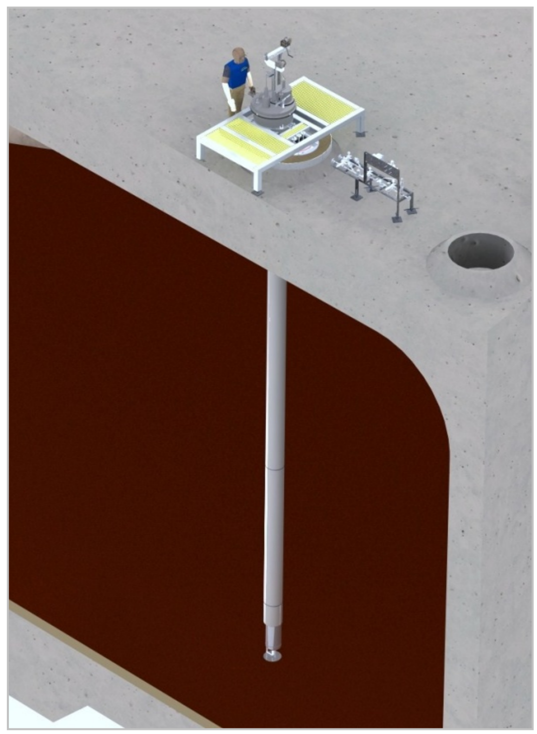


Figure 2. Rendering of 3-D model used to generate drawings

3.8 Remediation Of Cooling Coils In Large Tanks

Principal Investigators: Erich Keszler, keszler@nuvisioneng.com, 704-799-2707, and Laurie Judd of NuVision Engineering (NVE)

Collaborators: Savannah River Site (SRS) and Savannah River National Laboratory (SRNL)

Project Duration: 2008-2009

Waste Processing Challenge

At DOE sites such as Savannah River and Hanford, large tanks (~1M gallons) have been used for storage of radioactive salts, sludge, and supernatant liquid. The Type I, II, and III tanks at SRS were built with internal carbon steel cooling coils used to remove the heat of radioactive decay from the stored waste. Each tank contains multiple cooling circuits up to 600 feet long (Figure 1).

Figure 1. Type 1 Tank Cooling Coils (before waste additions to tank)

As this waste is being retrieved and the tanks are prepared for permanent closure, the cooling coils present a significant challenge to satisfying the closure requirements. The coils obstruct access to areas of the tank, thereby restricting waste removal. It is expected that the waste determination process prescribed by Section 3116 of the Ronald W. Reagan National Defense Authorization Act of Fiscal Year 2005 (NDAA) will require the elimination, or at least the reduction, of fast flow paths for infiltration water to travel through the closed, grouted tanks. If left intact, the cooling coils could allow water infiltration to migrate through the tank. Many possibilities exist for the final endstate of large high level Type I tanks with interior obstructions. However, nearly every possibility will require some level of cooling coil management or closure to reach an acceptable tank end-state.

Research Objective

The objective is to develop a cost effective approach for removing all the cooling coils from the Type I tanks, utilizing a rugged and reliable manipulator technology. The required capabilities consist of tight manipulations and complex kinematics required to position a cutting tool in order to cut and then remove the cooling coil segments.

Research Progress

Each of the technologies considered was analyzed to determine if the equipment could fit through the 23 inch diameter Type I tank risers through which the equipment will be deployed to access the inside of the tank.

Other evaluated capabilities were the technology's ability to perform the cutting operations and also to remove the cut segments of cooling coils from the tanks. The technologies satisfying those criteria were further evaluated to determine the most cost effective technology system.

Also, the project focused on developing a baseline cost estimate. The estimate for this feasibility study will include the hardware design/ fabrication costs, coil flushing and grouting, field operation/installation, riser

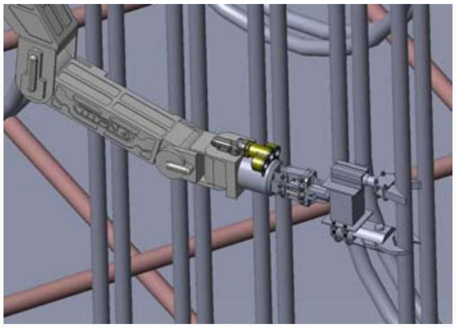


Figure 2. Dual function end effector

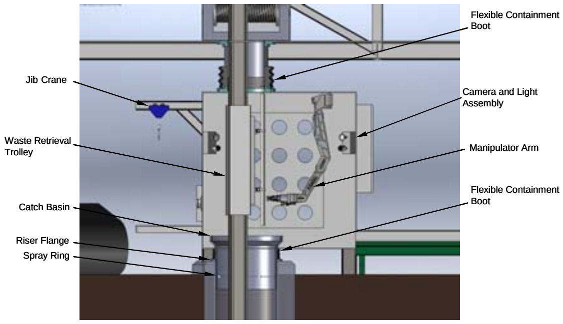


Figure 3. Material Removal Trolley

Figure 4. Dual Trolley System

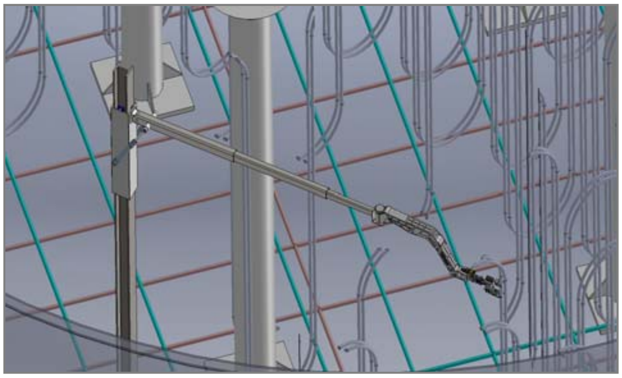


Figure 5. 20-ft coverage radius of Tool Delivery System

jump estimates, additional riser additions, equipment demobilization and disposal, and removed coil handling and indefinite storage costs.

NVE conducted a survey of prior, similar, successful manipulator deployments across the DOE network. In order to minimize the equipment cost, and reduce the possibility of tank farm operational delays, while still providing an effective technology system, it was concluded that a system similar to the West Valley Mast Tool Delivery System (MTDS) offers the greatest operational flexibility and requires the least amount of tank top superstructure to execute the in-tank cutting and material removal operations.

The West Valley MTDS can provide the required reach and kinematics needed to maneuver in the heavily congested environment of the Type I Tanks. Additionally, this system utilizes a floor supported mast which will minimize the tank top work structure needed to support the in-tank equipment. It will minimize the challenges of fitting a tank top supporting structure in the congested foot print of the Type I tanks. The West Valley technology provides acceptable capabilities for both the cooling coil cutting and removal of the cut coils from the tank's interior. The proposed NVE design is illustrated in Figures 2-5.

Planned Activities

The next steps are fabrication and demonstration of the proposed design.

3.9 In-Tank Characterization for Closure of Hanford Waste Tanks

Principal Investigator: David L. Monts, Institute for Clean Energy Technology (ICET), monts@icet.msstate.edu, 662-325-7389

Collaborators: Ping-Rey Jang, Yi Su, and Zhiling Long of ICET; Dennis Hamilton and Rick Raymond of CH2MHILL Hanford; Billie Mauss of DOE Office of River Protection (ORP)

Project Duration: 2007-2010

Waste Processing Challenge

Currently two techniques are used for assessing the amount of waste remaining within a tank following retrieval activities. The first technique is to photograph the waste tank from different locations and use objects of known size within the tanks to estimate the waste volume, and the second is to photograph the waste tank as a function of water volume displacement. The first approach often has large uncertainties associated with the waste volume estimates. The second approach is expected to increase risks associated with tank structures that have exceeded the design life. The ability to precisely determine residual waste volumes using non-intrusive diagnostic instrumentation will also allow for a more accurate measure and pinpoint specific locations within a waste tank where tailored grouts can be applied.

Research Objective

The goal of this project is to develop an in situ quantitative imaging tool based on Fourier transform profilometry (FTP) for residual waste volume characterization.

Fourier transform profilometry (FTP) is a non-contact, 3-D shape measurement technique. By projecting a fringe pattern onto a target surface and by using a camera to observe the fringe pattern's deformation due to surface irregularities, FTP is capable of determining the height (depth) distribution of the target surface, thus reproducing the profile of the target accurately. The steps of FTP image acquisition and analysis are under computer control.

Research Progress

During 2008, the prototype FTP system demonstrated the ability to reliably determine volumes under the most challenging conditions that are expected to occur within a Hanford waste tank. Assuming access to a Hanford waste tank through a 4" ID riser, the furthest part of the tank will be about 53' away when the FTP instrument arm is 25' above the floor. Under these conditions, the system was able to determine the volume of small non-descript targets with an average volume error of about 5-10%.

Figure 1 shows an FTP image of a non-descript target under simulated most challenging tank conditions and the resulting 3-D reconstruction of the object. Figure 2 shows a similar image and reconstruction at a distance of 25 feet. Here the average volume error for a number of different targets was 5-10%.

A technical feasibility study to characterize and document factors (both inherent and instrumental) that affect the accuracy, precision, and operational performance of the FTP system was initiated. Increasing the camera-to-projector distance was found to reduce the measurement uncertainty. The effects of projected light field uniformity and intensity were examined. The ranges of the optimum camera parameters (such as zoom, f-number, shutter speed, etc.) were determined. The effects of and uncertainty introduced by warm-up by the FTP system were identified and characterized. The capabilities and limitations of the present imager are being compared with alternatives.

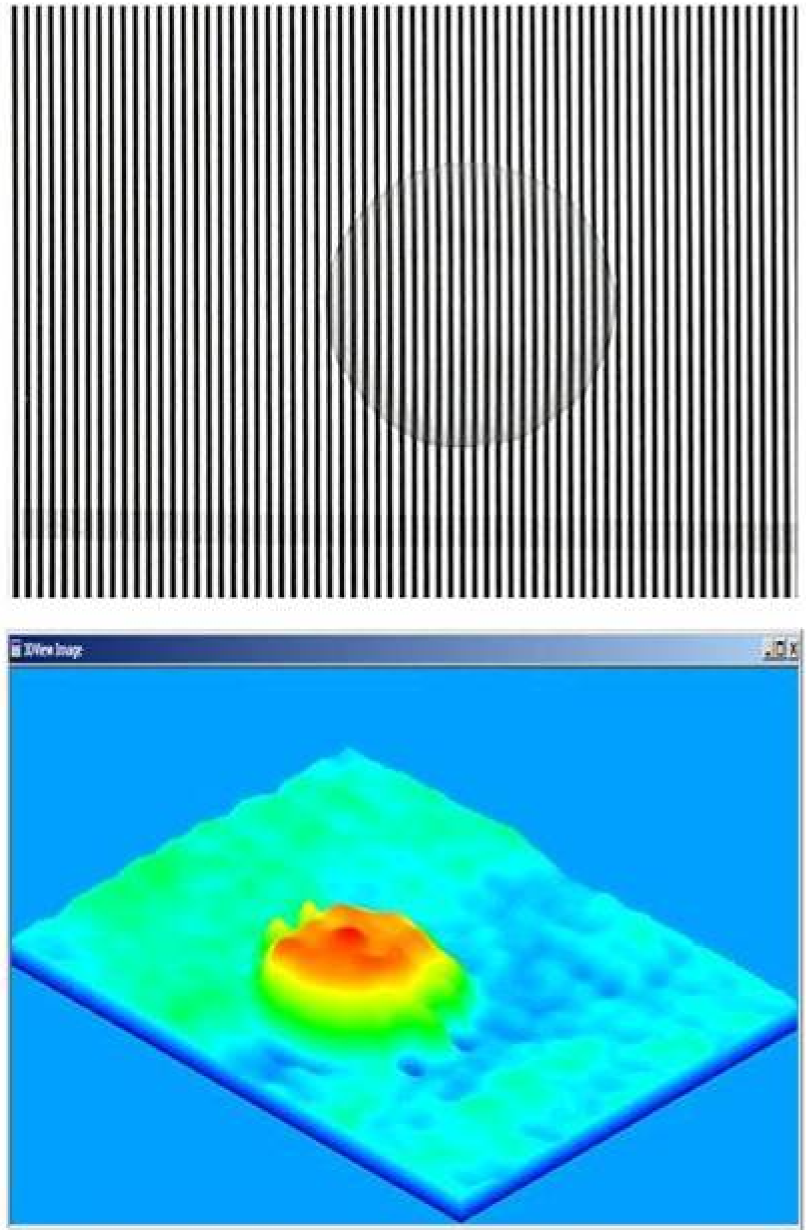


Figure 1. FTP image collected at a distance of 53 feet and 3-D reconstruction of non-descript object using the FTP system.

Planned Activities

The technical feasibility study will be completed during 2009. Items that remain to be completed are a comparison of the present imager with alternatives; optimization of the FTP optics; characterization of the uncertainty introduced by the process of combining single-image volumes to obtain the total tank waste volume; and characterization of the uncertainty introduced by non-flat (curved) tank floors.

During 2010, a prototype FTP system will be demonstrated initially at ICET and then field tested. The FTP technology will be transferred to a commercial partner.

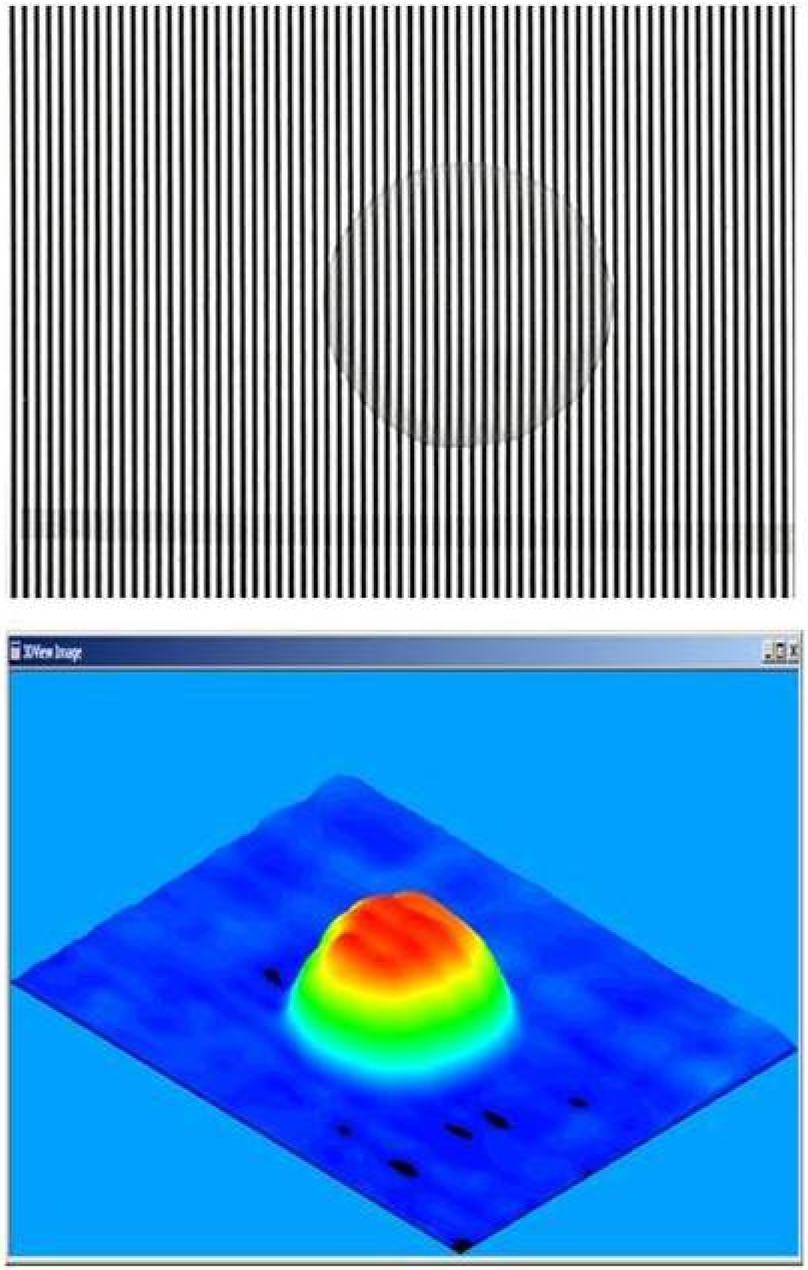


Figure 2. FTP image collected at a distance of 25 feet and 3-D reconstruction of non-descript object using the FTP system.

References

1. John A. Etheridge, Ping-Rey Jang, Teresa Leone, Zhiling Long, O. Perry Norton, Walter P. Okhuysen, David L. Monts, and Terry L. Coggins, "Evaluation of Fourier Transform Profilometry for Quantitative Waste Volume Determination under Simulated Hanford Waste Tank Conditions," Proceedings of 34th Waste Management Symposium (WM08), Phoenix, AZ, February 24-28, 2008, Paper No. 8106.
2. David L. Monts, Ping-Rey Jang, Zhiling Long, O. Perry Norton, Walter P. Okhuysen, Yi Su, and Charles A. Waggoner, "Technical Performance Capability of Fourier Transform Profilometry for Quantitative Waste Volume Determination under Hanford Waste Tank Conditions," Proceedings of 35th Waste Management Symposium (WM'09), March 1-5, 2009, Phoenix, AZ, Paper No. 9333.

3.10 Aluminum Solubility

Principal Investigator: L. T. Smith, Institute for Clean Energy Technology (ICET), lsmith@icet.msstate.edu, 662-325-0499

Collaborators: R. K. Toghiani and J. L. Lindner of ICET; Dan Herting, Heinz Huber, and Blaine Barton of Washington River Protection Solutions; Billie Mauss, DOE Office of River Protection (ORP)

Project Duration: 2008-20109

Waste Processing Challenge

Aluminum is a major component in Hanford tank wastes accounting for 1.3 % by weight of the total mass. Current plans call for the addition of large amounts of sodium hydroxide to dissolve solid phase aluminum and to maintain aluminum in the aqueous phase during downstream processing. An increase in the sodium content has implications on the generation and processing of additional low activity waste and on unit operations associated with the Waste Treatment Plant (WTP). High sodium concentrations interfere with the separation of ^{137}Cs in the ion exchange process. Dilution of the wastes prior to ion exchange will alter the thermodynamics of aluminum and could result in unwanted solids re-precipitation.

Research Objective

Knowledge of the solubility of aluminum under typical process conditions is needed to determine the need for additional processing capacity and for developing waste composition envelopes for ion exchange.

Research Progress

Initial efforts centered on thermodynamic modeling of aluminum using the Environmental Simulation Program (ESP, OLI Systems Inc.). Figure 1 provides comparisons of current model predictions with experimental solubility data of Szita and Berecz taken from Apps et al (1988) for aluminum in sodium hydroxide. At the lowest temperature (25 °C), ESP predictions are in excellent agreement with the experimental data over the sodium molality range. However, at 50°C, the predictions are slightly lower than the experimental data, with a greater difference observed for the lower end of the sodium molality range.

Predictions were also performed to examine the impact of sodium nitrate on the gibbsite solubility. Shown in Figures 2 and 3 are the predictions at 25 °C. In Figure 2, the horizontal axis is sodium in solution (m), while in Figure 3, the horizontal axis is free hydroxide in

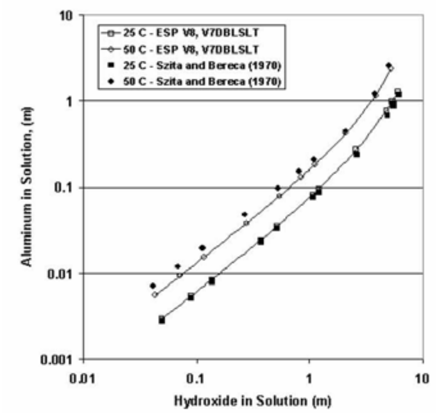


Figure 1. Comparison of ESP (V8 and V7DBLSLT database) predictions to literature data.

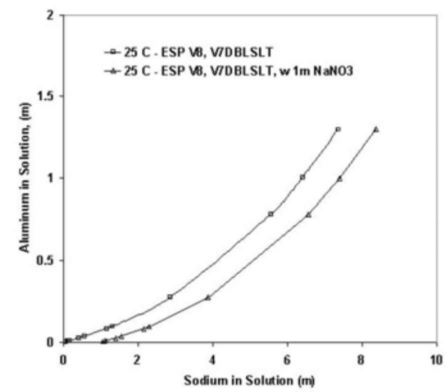


Figure 2. Comparison of ESP Predictions of aluminum solubility in presence of sodium nitrate (horizontal axis is sodium molality in solution).

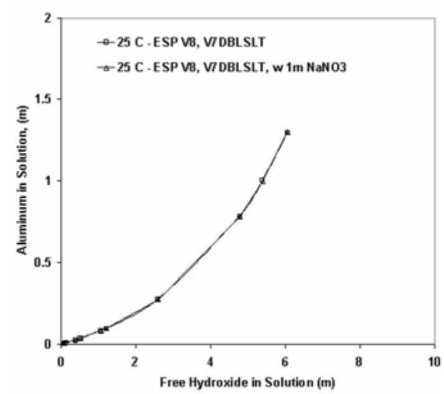


Figure 3. Comparison of ESP Predictions of aluminum solubility in the presence or absence of sodium nitrate (horizontal axis is free hydroxide molality in solution).

solution. The presence of sodium nitrate in solution at 1m concentration essentially shifts the curve along the sodium axis, but when the data are plotted using free hydroxide along the horizontal axis, the predictions fundamentally fall on the same curve. There appears to be no significant difference in the predicted gibbsite solubility in the presence of 1m sodium nitrate in solution versus no sodium nitrate.

Values for sodium salts anticipated in Hanford waste streams for WTP processing were obtained and development of a test plan was begun. Experiments have been designed to obtain an understanding of the effects of sodium and hydroxide as well as major anions such as nitrate, nitrite and carbonate, on aluminum solubility at the processing temperature ranges of interest. Statistical methods (Taguchi) will be used to populate the test matrix.

Planned Activities

Completion and approval by site personnel of the aluminum test plan and all necessary equipment will be obtained. Previous work with aluminum systems has shown extended equilibrium times up to 6 months, however, some options exist for decreasing the equilibration time and these will be investigated. Solubility data, along with existing data in the literature will be subjected to analysis such that revisions and omissions in currently available thermodynamic databases will be corrected. The results of this study will then be available for workers in the future.

References

1. Barney, G. S. “Vapor-Liquid-Solid Phase Equilibria of Radioactive Sodium Salt Wastes at Hanford,” ARH-St-133, Dist. Cat. UC-4, Atlantic Richfield Hanford Company, Richland, WA, 1976.
2. Felmy, A. R.; Rustad, J. R.; Mason, M. J.; and de la Bretonne, R. “A Chemical Model For the Electrolyte Components of the Hanford Waste Tanks: The Binary Electrolytes In the System: Na-NO_3-NO_2-SO_4-CO_3-F-PO_4-OH-$Al(OH)_4$-H_2O,” PNL-SA-23952, Pacific Northwest Laboratory, Richland, WA, 1994.
3. Reynolds, D.A. “Practical Modeling of the Aluminum Species in High-pH Waste,” WHC-EP-0872, Westinghouse Hanford Company, Richland, WA, 1995.
4. Smith, L. T.; Ruff, T. J.; Phillips, V.; Jung, M.; Toghiani, R. K., and Lindner, J. S. “Aluminum Solubility,” presentation, Aluminum Chromium Leaching Workshop, Hosted by Savannah River Site, Atlanta, GA, January, 2007.
5. Ruff, T. J.; Toghiani, R. K.; Smith, L. T.; and Lindner, J. S. “Studies on the Gibbsite to Bohemite Transition,” Sep. Sci. and Technol. 43(9-10), 2008, 2887-2899.
6. Apps, J. A., Neil, J. M., Jun, C. H., "Thermochemical Properties of Gibbsite, Bayerite, Boehmite, Diaspore, and the Aluminate Ion between 0 and 350 °C", Technical Report, LBL-21482, August 1998.

3.11 Advanced Mixing Models

Principal Investigator: Richard A. Dimenna, Savannah River National Laboratory (SRNL), Richard.dimenna@srnl.doe.gov, 803-725-8203

Collaborators: David A. Tamburello, SRNL; Si Young Lee and David R. Rector of Pacific Northwest National Laboratory (PNNL)

Project Duration: 2008-ongoing

Waste Processing Challenge

Pump mixing times in the large waste tanks at the Savannah River Site (SRS) are based largely upon custom established over the years. Operational cautiousness may have made those values overly conservative. Operational considerations include potential down-stream impacts of inadequate mixing and possibly unrepresentative tank waste samples resulting from tank configurations that limit access to most of the tank.

More reliably quantifying the mixing time required to suspend sludge particles in waste tanks could reduce operating time and maintenance (including replacement) costs of the mixer pumps because of significantly reduced mixing time requirements. Safety improvements related to reduced operating and maintenance times also could be achieved through reduced exposure to operating and maintenance personnel.

Research Objective

The objective of this research is to quantify the mixing time required to suspend sludge particles with the mixer pumps in an SRS waste tank by establishing a reliable, computational mixing criterion.

Implementing objectives include determining the state of mixing technology and developing an interim report on current methodologies and developing a computational indicator for mixing performance in large tanks.

Research Progress

Accomplishments to date include:

- Identified a widely accepted and appropriate mixing correlation in the mixing literature, the Grenville-Tilton correlation [1, 2].
- Identified candidate computational parameters, turbulent kinetic energy, turbulent kinetic energy dissipation rate, and turbulent eddy viscosity to use as measures of mixing.
- Completed initial calculations showing qualitatively good agreement between these computational parameters and the Grenville-Tilton correlation. Figure 1 shows induced velocity profiles from a jet mixer in a tank, and Figure 2 shows contours of constant turbulent kinetic energy dissipation rate showing lowest

values near the bottom of the tank. This indicates that this is the slowest region to mix.

- o Initiated additional calculations with an outside contractor (Clemson University) to evaluate computational results, sensitivities, boundary conditions, etc.
- o Proposed and tested an additional mixing criterion, the Taylor Reynolds number, and found qualitatively acceptable comparisons with Grenville-Tilton results.

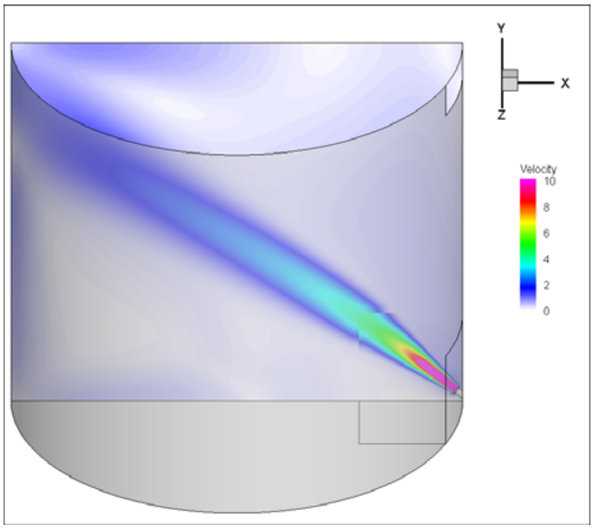


Figure 1. Induced velocity profiles from a jet mixer in a tank.

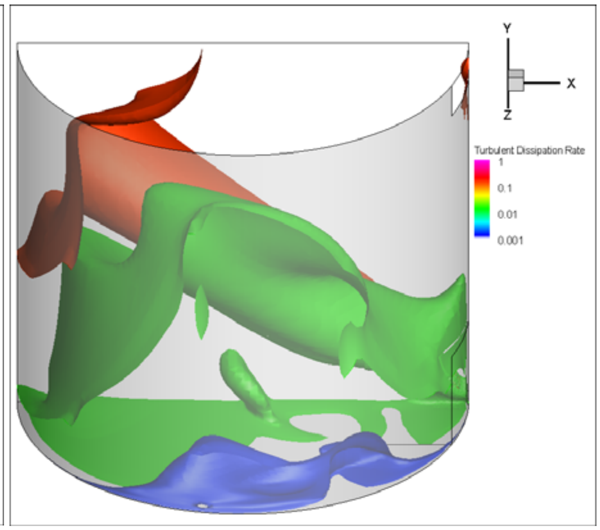


Figure 2. Contours of constant turbulent kinetic energy dissipation rate showing lowest values near the bottom of the tank.

Planned Activities

Several activities are ongoing or planned to evaluate the usefulness of the Taylor Reynolds number as a threshold indicator of a mixed condition. These include:

- o Grid and time-step sensitivity calculations to evaluate computational convergence.
- o Grid sensitivity to evaluate the kinetic energy and energy dissipation rates from a coarse-grid model to similar values calculated with a fine-grid model.
- o Boundary condition sensitivity calculations to ensure the jet mixer is being properly calculated.
- o Determination and comparison of a threshold value of the Taylor Reynolds number for comparison with the Grenville-Tilton correlation.
- o Comparison of the Reynolds-averaged Navier Stokes (RANS) approach to a large-eddy simulation (LES) for a representative geometry.
- o Application of the RANS approach to a Savannah River waste tank for a single-phase mixing condition.

References:

1. Grenville, R. K. and Tilton, J. N., 1996. "A New Theory Improves the Correlation of Blend Time Data from

Turbulent Jet Mixed Vessels," *Chem. Eng. Res. Des.*, *74*, pp. 390-396.

2. Grenville, R. K. and Tilton, J. N., 1997. "Turbulence of Flow as a Predictor of Blend Time in Turbulent Jet Mixed Vessels," *Proceedings of the Ninth European Conference on Mixing*, pp. 67-74.
3. Dimenna, R. A et al., 2008. "Advanced Mixing Models," SRNL-STI-2008-00417.
4. Dimenna, R. A., Lee, S. Y., and Rector, D. R., 2009. "Advanced Mixing Models," DOE/NNSA Nuclear Safety
5. Research and Development Forum, McLean, VA, February 18-19.
6. Dimenna, R. A., Lee, S. Y., Tamburello, D. A., and Rector, D. R., 2009. "Advanced Mixing Models," EM-21 Technical Exchange, Denver, CO., May 19-21

3.12 Demonstrate HIP Process for INL Calcine Waste and DOE Legacy Waste

Principal Investigator: Ken Bateman, Idaho National Laboratory (INL), ken.bateman@inl.gov, 208-533-7061

Collaborators: Bruce Begg, Sam Moricca, ANSTO Inc.

Project Duration: 2008-Ongoing

Waste Processing Challenge

Idaho calcine is derived from calcining first cycle-raffinate from reprocessed spent fuel. It is classified as mixed high-level waste and consists of 4400m3 of heterogenous granular material in six bin-sets. The calcine contains varying quantities of heavy metals regulated under the Resource Conservation Recovery Act (RCRA).

Research Objective

The objective of this research is to demonstrate the benefits that tailored waste forms and flexible hot-isostatic pressing (HIP) technology can provide to either the treatment or super-compaction of Idaho calcines.

The process of HIPing radioactive wastes involves a can being filled with the calcined feed (with or without treatment additives). The can is evacuated and sealed, then placed into the HIP furnace and the vessel closed, heated and pressurized. Pressure is applied isostatically via argon gas. The combined effect of heat and pressure consolidates and immobilizes the waste into a dense monolithic block sealed within the can. The chemical durability of the resulting waste form is driven by the nature of the additives included in the process. There are no off-gas emissions during the high-temperature processing. The process can be applied to a wide range of legacy waste streams.

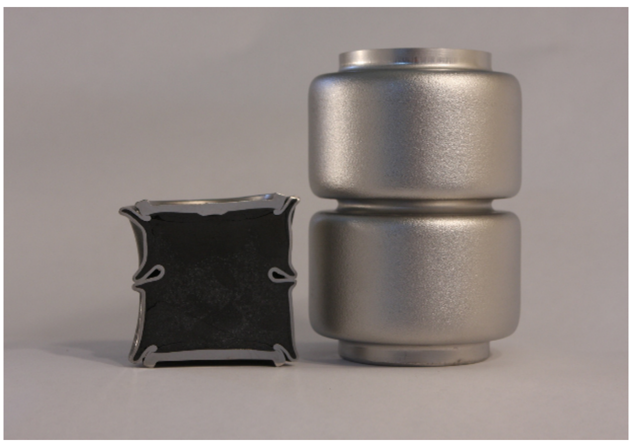
Research Progress

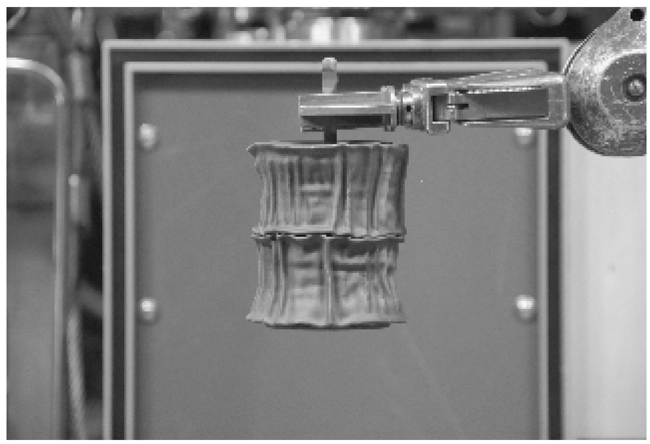
Simulated alumina and zirconia calcine, containing full RCRA heavy metal components, was produced in a pilot-scale fluidized bed calciner. Calcine liquid feed compositions were based on historical process model data, provided by CWI (Idaho cleanup contractor), and reflect actual calcination runs. To account for significant differences noted in the key RCRA components, specifically mercury in the alumina calcine and cadmium in the zirconia calcine, three separate RCRA variants of each calcine composition were prepared. The concentrations of mercury and cadmium were varied from a baseline average, through a transition to a maximum concentration for the alumina and zirconia calcine respectively. All other RCRA components were kept constant and at maximum concentrations.

Chemical analysis of the resulting solid calcine simulant was found to be in good agreement with data available on actual calcine, representing baseline chemical durability for direct disposal of calcine. Toxic characteristic leaching procedure (TCLP) tests on those calcine simulants indicated that all failed to meet the universal treatment standard (UTS) for multiple elements.

However, direct HIPing of the alumina and zirconia calcine, without treatment additives, confirmed the significant economic, environmental, and regulatory advantages that HIPing offers compared to direct disposal.

Vast volume reductions of between 50% and 70% compared to as stored calcine, for zirconia and alumina calcines respectively, have been demonstrated. Volume reduction calculations have been conservatively calculated based on the maximum cylindrical envelope volume of the final HIPed can. This equates to a multibillion-dollar repository cost saving compared to direct disposal (based on a geologic repository disposal cost of $620,000 per canister). In addition, the conversion of the loose granular calcine into a dense monolithic solid without treatment additives, also significantly enhances the chemical durability of the disposal product. This was most pronounced for the alumina calcine, where the direct HIPed maximum RCRA sample completely met the UTS requirement.





Direct HIPed alumina calcine showing a 69% volume reduction (left), and post-HIPed treated zirconia calcine inside the INL's Materials and Fuel Complex (MFC) hot-cell HIP facility (right).

Four independent treatment trials of the baseline RCRA zirconia calcine have been performed. These samples each had an 80wt% waste loading, and exhibited on average a 39% volume reduction compared to the as-stored calcine. Volume reductions compared to alternative treatment technologies would be very much larger. In addition to this very significant volume reduction, the chemical durability of this treated sample exceeded the regulatory UTS and environmental assessment (EA) requirements. The feasibility of HIPing calcine samples in a hot-cell has also been confirmed. Two trials conducted to date within the Idaho National Laboratory Hot Fuel Examination Facility HIP hot-cell, have verified the results obtained by ANSTO.

Industrial scale maturity of HIP technology has also been confirmed. Over thirty HIP units are in production operation in the US that have capacity up to twice that proposed for calcine disposition. These units remotely process work pieces between 10,000 lbs and 18,000 lbs at temperatures and pressures exceeding those proposed for calcine treatment. Many of these industrial HIP units have been in operation for over 30 years in a production environment.

An engineering conceptual outline for a HIP production facility for calcine disposition has been developed and costed. The facility is designed to be co-located to the Idaho Integrated Waste Treatment Unit (IWTU) and consists of a dual interchangeable process line. The dry mechanical process, in which calcine is processed inside sealed HIP cans offers significant advantages and minimizes process risks. In particular the enhanced contamination control measures and the absence of off-gas emissions during hot consolidation significantly simplify process design and implementation. In addition, as waste never comes into contact with the HIP process vessel, final decontamination costs are minimized.

The engineering feasibility together with the technical demonstration trials are confirming that flexible HIP technology can mitigate the current regulatory uncertainty regarding final calcine disposition pathway and deliver multi-billion dollar repository cost savings irrespective of whether direct disposal or treatment is required.

Planned Activities

Further demonstration trials are ongoing to examine performance for transition and maximum RCRA containing calcine. Calcine mixtures and treatment of surrogate calcine spiked with radioactive components are also planned, as is a 100-fold scale demonstration. Proof-of-concept demonstrations highlighting the benefits HIP tailored waste forms can provide to a wide range of other problematic legacy wastes are to be conducted in 2009.

3.13 Direct Analysis of Slurry Receipt and Adjustment Tank Contents

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Collaborators: Fang Yu Yueh, ICET; Kristine Zeigler and James Marra of Savannah River National Laboratory (SRNL)

Project Duration: 2006-2008

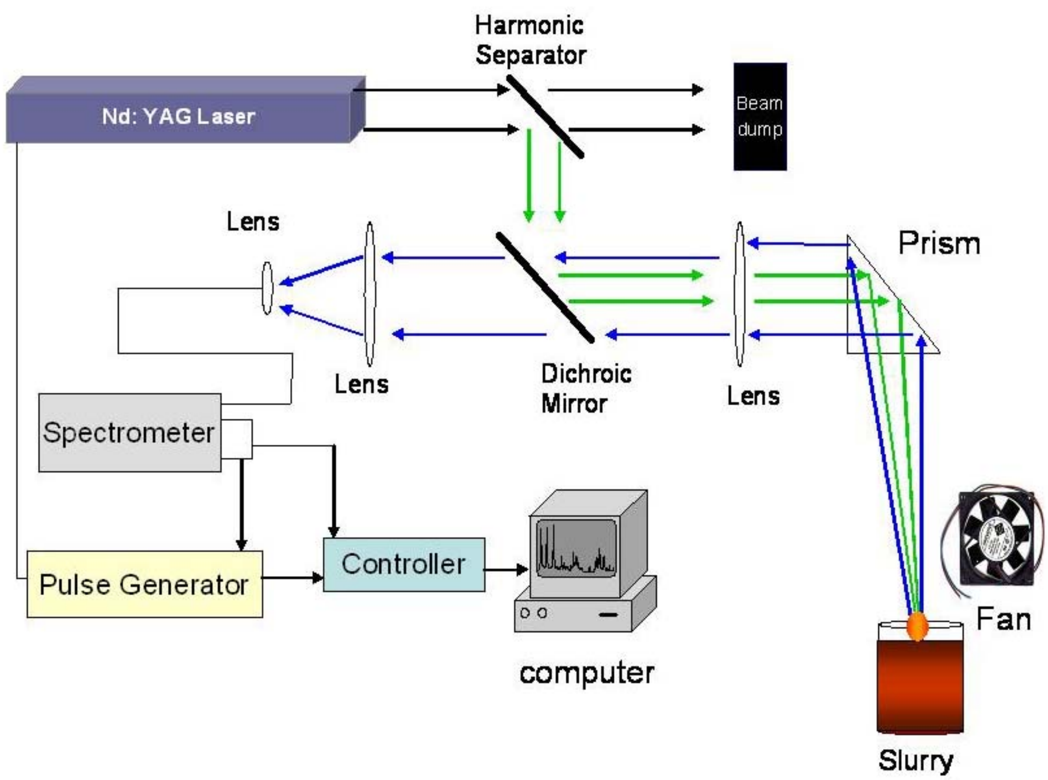

Figure 1. Experimental setup for slurry measurement

Waste Processing Challenge

The goal of this project is to assist the Defense Waste Processing Facility (DWPF) at the Savannah River Site (SRS) in accelerating melter operations.

Research Objective

The first task of this project was to provide a system for direct slurry analysis in the DWPF's shielded cells. Availability of this capability could significantly increase analytical throughput, reduce waste generation in radiological analytical facilities, and provide data suitable for waste acceptance and production records.

Laser Induced Breakdown Spectroscopy (LIBS) was selected as the system for direct analysis of DWPF Sludge Receipt and Adjustment Tank (SRAT) sludge slurry product. The analytical results will be used to support the determination of the appropriate amount of frit to be combined with the sludge in the melter. LIBS will also be used to provide the analytical data to support Slurry Mix Evaporator (SME) (slurry containing both the sludge + frit) acceptability decisions within the Process Composition Control System (PCCS). The SME product is also referred to as the melter feed material.

Research Progress

Previous work had demonstrated that LIBS measurement in some solid samples has an accuracy of 3-6% for elements with a concentration greater than 1 wt% and an accuracy of 5-10% or better for minor elements depending on their concentration (based on statistical confidence). The accuracy has been poorer in the case of slurry analysis due to the short lifetime of the laser-induced plasma and sedimentation and turbulence on the slurry surface owing to the laser induced shock wave. The major research efforts are in improving the performance of LIBS measurement with slurry sample. LIBS experiments of DWPF slurry continued by direct sampling the slurry in a small beaker (see Fig.1). Experiments were performed with different laser frequencies and it was found that a laser frequency of 1Hz gives a more stable emission spectrum with reduced splashing. However, splashing is still a problem for maintaining clean optics for long-term system operation. Different experimental configurations to minimize this problem were evaluated. To minimize the slurry sedimentation problem for long-term operation, experiments were performed with two methods. First, the slurry sample in a beaker was placed on a rotation stage to maintain constant motion. Second, magnetic stirrer was placed inside the slurry container to stir the sample during the measurement. The measurement results show that the data using a magnetic stirrer has better reproducibility for an over 30-minute test (see Figure 2).

Planned Activities

In the first quarter of 2009, efforts will continue to investigate the feasibility of using LIBS for quantification of key constituents in slurries. The effect of water loading on emission spectra and the use of different substrates, upon which a sample of slurry can be placed and interrogated, will be evaluated. Working in conjunction with ICET chemists a series of four sludges will be tested to establish secondary calibration. The calibration will be evaluated using unknowns and the results of the work will be disseminated.

References

1. Hongbo Zheng, Fang Yu Yueh, Tracy Miller, Jagdish P. Singh, Kristine E. Zeigler, James C. Marra,, Analysis of plutonium oxide surrogate residue using laser-induced breakdown spectroscopy, Spectrochimica Acta Part B 63 (2008) 968–974.

2. Seong Yong Oh, Fang Yu Yueh, Jagdish P. Singh, Preliminary Evaluation of Laser Induced Breakdown Spectroscopy for Slurry Samples, Spectrochimica Acta Part B 64, 113-118, 2008.
3. Jagdish P. Singh, Kristine Zeigler and Fang Yu Yueh, Laser-Induced Breakdown Spectroscopy: Application to Nuclear Waste Management, 5th International Conference On Laser-Induced Breakdown Spectroscopy 22-26, September 2008, Berlin, Adlershof, Germany.

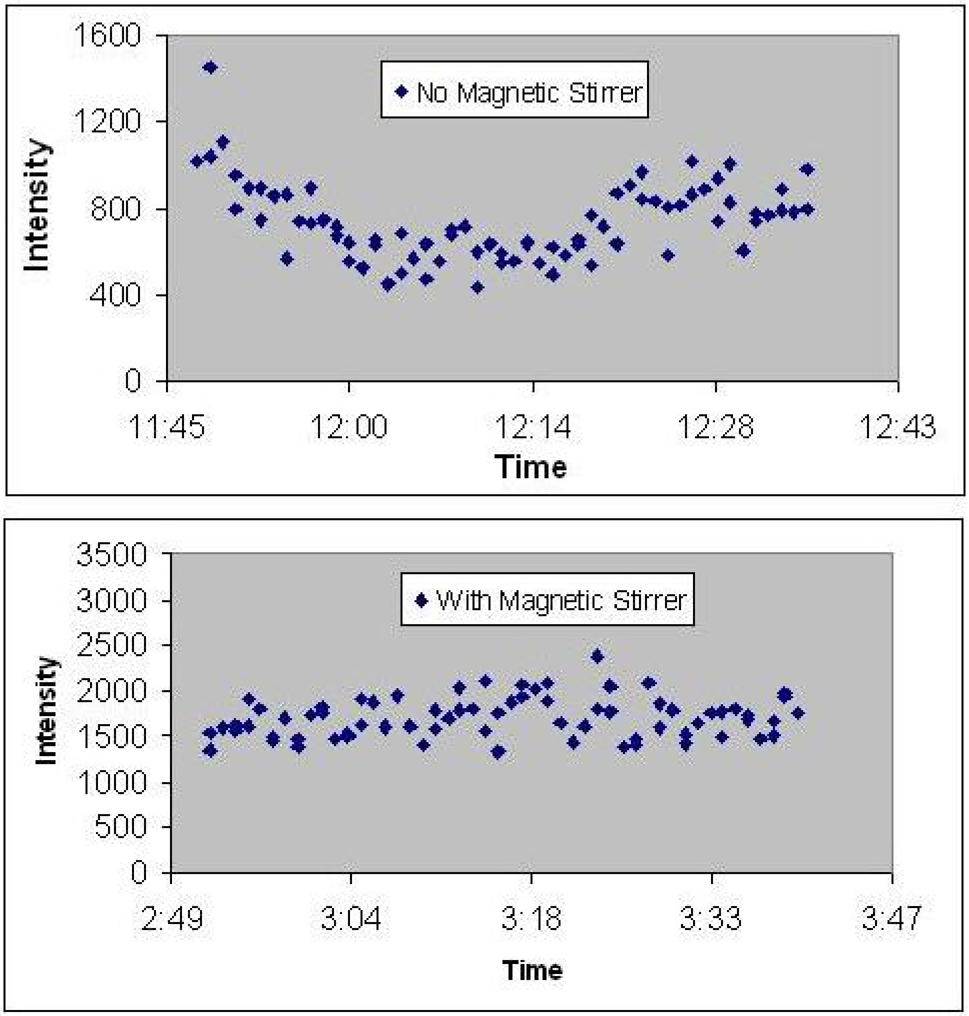

Figure 2. Slurry LIBS data taken with no magnetic stirrer and with magnetic stirrer