U.S. DEPARTMENT OF ENERGY OFFICE OF ENVIRONMENTAL MANAGEMENT

SUMMARY REPORT OF 2007 WASTE PROCESSING TECHNICAL EXCHANGES AND WORKSHOPS

September 2008

Environmental Management

safety ❖ performance ❖ cleanup ❖ closure

www.em.doe.gov

EXECUTIVE SUMMARY

WASTE PROCESSING CHALLENGES

Department of Energy (DOE) Office of Environmental Management (EM) is responsible for the cleanup of the environmental legacy of the Nation's nuclear weapons program. The waste processing part of this mission includes 1) treatment and disposition of high-level waste (HLW), and 2) transportation and disposal of low-level waste (LLW), transuranic waste (TRU), spent nuclear fuel (SNF), and other nuclear materials. A large majority of these wastes and facilities are unique to DOE, such that waste treatment is often "first-of-a-kind" and unprecedented in scope and complexity. As a result, the technologies required to disposition these wastes must be developed from scratch or may require significant re-engineering to adapt to EM's needs.

Waste processing challenges have been classified into seven categories as follows: Safe Storage, Waste Retrieval, Waste Pretreatment, Waste Treatment and Stabilization, Tank Closure, Spent Nuclear Fuel, and Challenging Nuclear Materials.

OFFICE OF WASTE PROCESSING

To address the above challenges, DOE - EM Office of Waste Processing (EM-21) reduces the technical risk and uncertainty of EM waste-processing programs and projects through timely development of solutions to technical issues. The risks and the actions taken to mitigate those risks are determined through technical assessments, quarterly program reviews, external technical reviews, technical assistance, and targeted technology development and deployment. The Office works with program, project, and field organizations to proactively evaluate technical needs, identify multi-site solutions, and improve related project and contract management approaches.

ROADMAP: RISKS AND STRATEGIC INITIATIVES

In 2007, EM's Office of Engineering and Technology (EM-20) prepared a Roadmap to define its strategy to reduce the technical risk and uncertainty in its cleanup programs. The roadmapping effort resulted in identification of risks and strategic initiatives to address these risks. The Office of Waste Processing supports the goals and objectives of the Roadmap by providing the strategic direction for technology enhancement, development, and demonstrations that will lead to a reduction of technical vulnerabilities in EM waste-processing activities.

The research and development portfolio resulting from this process is based upon a

balanced approach to addressing both near-term project needs and longer-term strategic needs in waste processing. An effort was made to leverage prior EM development work, as well as commercial and international experience. The strategic initiatives, which map to the classes of waste-processing challenges, are described below.

- The Improved Waste Storage strategic initiative targets cost-effective, real-time monitoring of tank integrity and waste volumes and improved understanding of changing waste chemistry to support safety analyses.
- The Reliable and Efficient Waste Retrieval strategic initiative targets development of optimization strategies and technologies that lead to successful tank closure.
- The Enhanced Tank Closure Processes strategic initiative targets improved methods for characterization and stabilization of residual materials and complicated ancillary systems, as well as integrated cleaning, closure, and capping technologies.
- The Next-Generation Pretreatment Solutions strategic initiative targets development of in- or at-tank separations solutions, as well as those integrated into treatment operations, all focused on minimizing the amount of waste processed as HLW.
- The Enhanced Stabilization Technologies strategic initiative targets development of improved operations, advanced glass formulations that maximize loading and throughput, and supplemental treatment technologies.

A COLLABORATIVE APPROACH

Because waste-processing challenges exist at multiple DOE sites, Office of Waste Processing strives to promote communication from site to site. Office of Waste Processing activities are coordinated with the field offices/projects, by building a collaborative relationship that begins during project planning and follows through execution and transfer of results and products for implementation. This collaborative approach enables staff from multiple DOE sites to discuss common problems, leverage each other's work, and share lessons learned. This site-to-site communication is supported at every level, from one-on-one telephone calls to conference calls to collaborative workshops and technical exchanges held at various times of the year. At these workshops and technical exchanges, solid relationships are built, and support is provided to ensure continuation of these relationships throughout the life of the project.

SUMMARY OF 2007 WORKSHOPS

This report summarizes four workshops/technical exchanges sponsored by the Office of Waste Processing during Calendar Year 2007: Cementitious Barriers; Savannah River, Hanford, and Idaho Technical Exchange; Aluminum and Chromium Leaching; and the Test Facility Lessons Learned Technical Exchange.

CEMENTITIOUS BARRIERS

Cementitious materials have been used for low-activity radioactive waste disposal as waste forms; waste, soil, and groundwater containments; and entombments since the early 1970s. There are many examples of successfully engineered cementitious barriers for both waste management and environmental restoration throughout the DOE complex.

These barriers are used to limit the flux of water that contacts the waste, minimizing subsequent release or leaching of radionuclides from the disposal unit; modify the chemistry of the disposal environment to reduce radionuclide mobility; and provide physical stability to prevent subsidence and deter intrusion and physical disruption.

Design, construction, and performance assessment of engineered cementitious barriers are critical path items for many DOE EM projects, including Hanford secondary waste treatment and Savannah River Site (SRS) tank waste treatment (saltstone). In December 2006, a workshop entitled *"Use of Cementitious Barriers for Low-Activity Radioactive Waste Treatment, Containments, Environmental Restoration, and D&D,"* sponsored by Office of Waste Processing, was held in Aiken, South Carolina, to define:

- DOE needs for cementitious barriers;
- the state of the art;
- the state of practice in DOE-EM.

The Cementitious Barriers Workshop identified a number of issues associated with enhancing performance of DOE near-surface radioactive waste disposal sites through the use of engineered barriers. These issues fall into two categories:

- providing a technical basis for improving designs;
- reducing risk in predicting long-term performance.

The workshop participants also developed recommendations, which are described below, in concert with the identified issues/needs. The Cementitious Barriers Workshop was extremely valuable in that it brought together scientists and engineers

from a variety of disciplines, experience, and venues in an attempt to improve the understanding of engineering cementitious barriers, the design bases, and the risk analysis that is a critical part of the DOE decision-making process. Potential impacts of this increased understanding ultimately include more effective and efficient barrier systems that will likely provide for better protection of human health and the environment.

The December 2006 workshop resulted in the formation of the Cementitious Barriers Partnership in early 2007 with the goal to identify and develop tools necessary to predict the structural, hydraulic, and chemical performance of cementitious materials in the near-surface low-level radioactive waste disposal environment.

SAVANNAH RIVER, HANFORD, AND IDAHO TECHNICAL EXCHANGE

The DOE SRS, Hanford, and Idaho Sites each have significant waste processing challenges related to safe storage, waste retrieval, waste pretreatment, waste treatment/stabilization, and tank closure activities for HLW and transportation and disposal activities for low-activity waste (LAW). Each of these sites participates in the Office of Waste Processing Programs.

In October 2007, the Office of Waste Processing sponsored the Savannah River, Hanford, Idaho Technical Exchange in Atlanta, Georgia. The purpose of the Technical Exchange was to facilitate communication among technical and management staff from each of the sites, and from the Defense Nuclear Facilities Safety Board (DNFSB), DOE laboratories, academia, and private industry.

The technology and project needs/technical risks, recent accomplishments, and lessons learned at each of the three sites were discussed in detail at the technical exchange. This technical exchange is anticipated to continue each year to promote communication and improve project decision-making at DOE sites, while maximizing benefits from R&D performed across the DOE Complex.

The 2007 Hanford, Savannah River, and Idaho Technical Exchange was extremely valuable, because it brought together scientists, engineers, and managers from a variety of disciplines, experience, and sites to discuss both individual and common issues and lessons learned related to progress in project and technology development and completion. The increased understanding of lessons learned and the enhanced communication will enable these sites to make better decisions for cleanup projects. The technical exchanges promote collaboration and

communication among the DOE sites that face common challenges.

ALUMINUM AND CHROMIUM LEACHING

Non-radioactive aluminum and chromium exist in the alkaline sludge wastes stored at SRS (~1440 Metric Tons [MT] aluminum) and Hanford (~8660 MT aluminum). Some aluminum in the waste feed to the vitrification plants is good (3%-5%), because it improves glass durability. But if aluminum concentrations are as high as 10%, problems related to glass quality can occur. In addition, if aluminum can be removed from the Immobilization Plant (WTP) or Defense Waste Processing Facility (DWPF) feed, the burden of vitrifying large volumes of aluminum-rich material in the HLW melter systems can be reduced. This would also reduce the number of HLW canisters produced (e.g., reducing the number by 15,000 – 30,000 at Hanford and by 1,000 at SRS) and disposal costs, and would shorten the life-cycle completion schedule (e.g., reducing operations by seven years at SRS and 20 years at Hanford).

Because SRS and Hanford both have problems with aluminum in HLW, the Office of Waste Processing convened a technical workshop on aluminum/chromium leaching to enable

- identification of common needs;
- review of historical programmatic approaches and results;
- comparison of DOE approaches to industrial practices;
- review of fundamental physiochemical data and kinetic models on leaching of aluminum and chromium in sludge waste;
- consideration of impacts of leaching on other aspects of sludge chemistry;
- evaluation of alternative treatment technologies;
- sharing of lessons learned.

Specific objectives were to examine the needs and requirements of the HLW flowsheet for each site, discuss the status of knowledge of leaching processes, communicate research plans, and identify opportunities for synergy to address knowledge gaps.

The workshop brought scientists and engineers together, thus promoting collaboration and dialogue. They are continuing communications through bi-weekly conference calls, an integrated task list, and other workshop venues, such as the ongoing SRS – Hanford – Idaho Technical Exchange. Potential impacts of the collaborations developed through the Aluminum-Chromium Leaching Workshop and the integrated research and development projects include a variety of

improvements in process chemistry and process engineering related to removal of aluminum and chromium in the HLW feed prior to vitrification. In addition, improvements in the interface from pretreatment to vitrification will likely be developed.

TEST FACILITY LESSONS LEARNED TECHNICAL EXCHANGE

Because the DOE Office of River Protection (ORP) at the Hanford Site is overseeing the design of the WTP that will process approximately 53 million gallons of HLW currently stored in underground single-shell and double-shell tanks, a quarter-scale test platform of the WTP pretreatment facility is under construction. The test facility, called the Pretreatment Engineering Platform (PEP), is scheduled to begin test operations in the fourth quarter of 2008.

Because design, construction, and testing of pilot-scale facilities are critical path items for many DOE EM projects, shared lessons learned can provide important information necessary for successful testing and evaluation. As such, in 2007, DOE identified the need for assembling lessons learned from pilot projects across the DOE Complex. On December 4 and 5, 2007, a technical exchange entitled "Test Facility Lessons Learned Technical Exchange" was held at Richland, Washington, sponsored by the Office of Waste Processing. The purpose of the meeting was to share experiences and lessons learned in test facility and test platform operations, so that all sites could benefit and improve the efficiency and effectiveness of their testing.

As a result of the technical exchange, 32 lessons learned from the operation of test facilities at DOE sites were discussed and compiled. The identification of these lessons learned has provided the PEP facility with key information that will be used in constructing, installing, and operating the pretreatment test facility. Because the PEP is the largest and most complex test platform to be installed and tested by DOE, the technical exchange affirmed the need for careful and thorough planning during all phases of test facility development and operation. One particular subject, the use of simulants, was thoroughly discussed at the exchange. As a result, WTP has designated a Simulant Coordinator to track simulant use from individual testing to final plant operation and to develop a stimulant checklist for WTP.

Many of the lessons learned identified at the December 2007 Technical Exchange are being incorporated into the PEP plans and testing at Hanford and will be considered by other sites as they develop other HLW test facilities.

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ACRONYMS

C&I	Control and Instrument
CRADA	Cooperative Research and Development Agreement
D&D	decontamination and decommissioning
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
DWPF	Defense Waste Processing Facility
EM	Office of Environmental Management
EPA	Environmental Protection Agency
HTWOS	Hanford Tank Waste Operations Simulator
HLW	high-level waste
ICP	Idaho Cleanup Project
LAW	low-activity waste
LLW	low-level waste
MT	Metric Ton
MYPP	Multi-Year Program Plan
NRC	Nuclear Regulatory Commission
ORP	Office of River Protection
PA	Performance Assessment
PEP	Pretreatment Engineering Platform
PNNL	Pacific Northwest National Laboratory
R&D	Research & Development
SSAB	Site Specific Advisory Board
SNF	spent nuclear fuel
SRS	Savannah River Site
TRA	Technology Readiness Assessment
TRU	transuranic waste
U.S.	United States
WTP	Waste Treatment Plant

SUMMARY REPORT OF 2007 WASTE PROCESSING WORKSHOPS

1.0 BACKGROUND

1.1 WASTE PROCESSING CHALLENGES

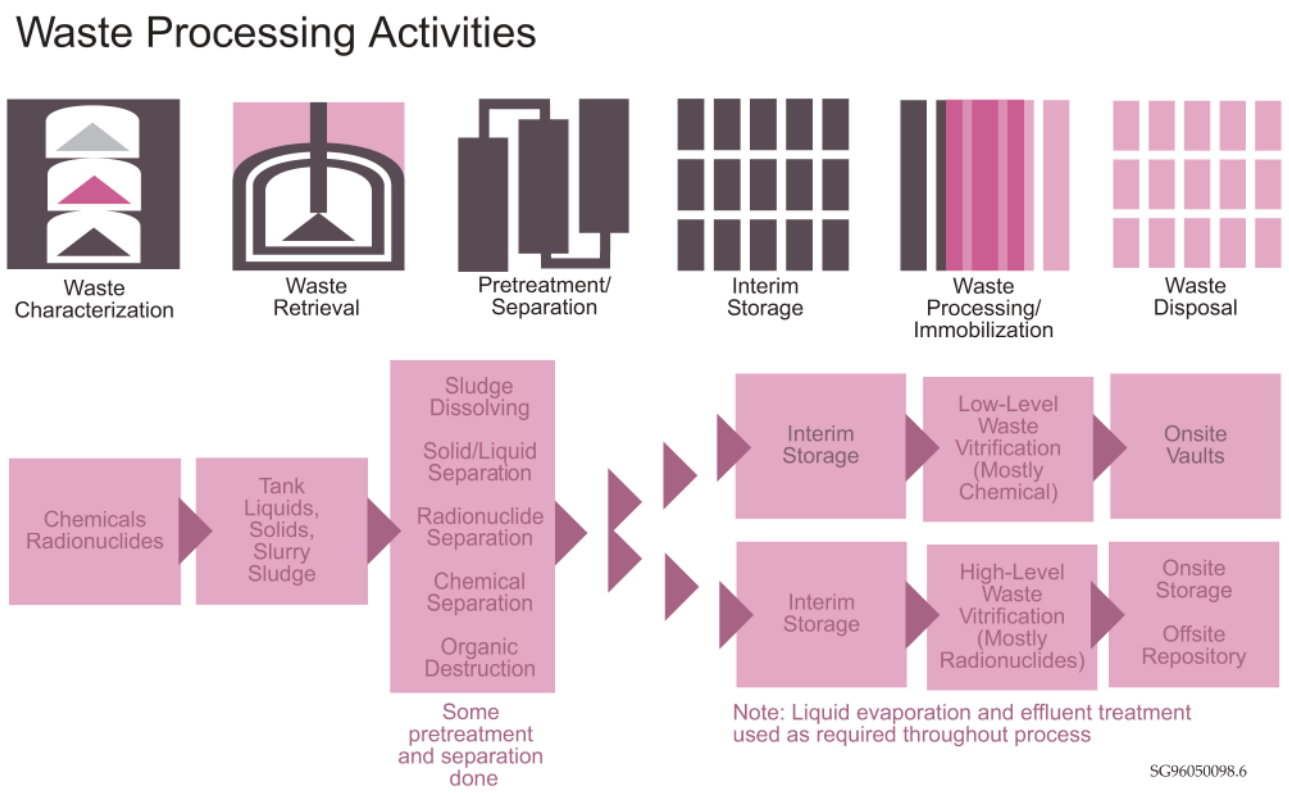
Department of Energy (DOE) Office of Environmental Management (EM) is responsible for the cleanup of the environmental legacy of the Nation's nuclear weapons program. The waste processing part of this mission includes 1) treatment and disposition of high-level liquid waste (HLW), and 2) transportation and disposal of low-level waste (LLW), transuranic waste (TRU), spent nuclear fuel (SNF), and other nuclear materials. A large majority of these wastes is unique to DOE, with the result that many of the programs to treat these wastes are "first-of-a-kind" and unprecedented in scope and complexity. As a result, the technologies required to disposition these wastes must be developed from scratch or may require significant re-engineering to adapt to EM's needs.

Waste processing challenges are classified as:

- Safe Storage
- Waste Retrieval
- Waste Pretreatment
- Waste Treatment/Stabilization
- Tank Closure
- Spent Nuclear Fuel
- Challenging nuclear materials.

- Safe storage – At Hanford, Idaho, and Savannah River, millions of gallons of HLW are located in underground tanks, which have been in storage longer than their original design life and will be in service for a long time. Storage space is at a premium; tanks must be maintained.
- Waste retrieval – Safe, effective methods must be developed for retrieval and transport of HLW from the storage tanks to a treatment facility. It is particularly challenging because waste composition in various tanks varies substantially.
- Waste pretreatment – HLW can be separated into low-activity waste (LAW) and HLW components, which can be processed and disposed in different facilities. This pretreatment step reduces volume of HLW, which is more expensive to process and dispose, and results in a more efficient waste processing operation. Every pretreatment process must be tailored to waste composition and the waste treatment process that follows.
- Waste treatment/stabilization – LAW and HLW waste fractions must be treated to render them into forms suitable for long-term disposal. In some cases, new treatment or stabilization processes must be developed for a particular waste stream; in other cases, an existing process can be modified to accept a new stream.
- Tank closure – Following removal of the HLW from a tank, it must be cleaned to an appropriate level and closed. The tank closure process usually involves assessment of residual contamination remaining after the retrieval is completed, followed by addition of a material that can fix any contamination in place, so the tank can be declared safe and stable.

A diagram showing these waste processing challenges in the full scope of waste processing activities follows.



1.2 INTRODUCTION TO THE OFFICE OF WASTE PROCESSING

To address the above challenges, DOE established the Office of Waste Processing, which has the mission of reducing the technical risk and uncertainty of EM waste-processing programs and projects through the timely development of solutions to technical issues. Office of Waste Processing

- provides technical guidance and assistance to EM sites conducting waste-processing operations for especially difficult technical problems;
- is responsible for development of technology to address these types of problems;
- sponsors cross-site integration efforts, where appropriate;
- provides engineering and scientific expertise for external technical reviews to address difficult technical problems or project management issues.

The Office of Waste Processing vision is to identify and reduce engineering and technical risks associated with key waste-processing project decisions. The risks, and actions taken to mitigate those risks, are determined through technical assessments, technical program reviews, identification of technical needs, external technical reviews, technical assistance, and targeted technology development and deployment. The Office works with program, project, and field organizations to proactively evaluate technical needs, identify multi-site

solutions, and improve related project and contract management approaches.

1.3 ROADMAP: RISKS AND STRATEGIC INITIATIVES

In early 2007, the Office of Environmental Management Engineering and Technology prepared a Roadmap to define its intent to reduce the technical risk and uncertainty in its cleanup programs. More specifically, the Office of Waste Processing supports the goals and objectives of the Roadmap by providing the strategic direction for technology enhancement, development, and demonstrations that will lead to a reduction of technical vulnerabilities in EM waste-processing activities.

The following risks and strategic initiatives were identified to meet the above waste-processing challenges. They were developed by a team of experts from national laboratories, industry, and academia with input from the appropriate EM sites, projects, and programs. In addition to their corporate knowledge base, additional information was provided from external technical reviews, technology readiness assessments, National Academy of Sciences review reports, and stakeholder comments on the draft Roadmap. Specific activities to be conducted within each of the strategic initiatives were developed by Initiative Development Teams composed of scientists and engineers from national laboratories, industry, and academia, after they had completed a gap analysis. The recommended investments for each of the strategic initiative activities were reviewed with DOE senior management from the sites and headquarters.

The research and development portfolio resulting from this process is based upon a balanced approach to addressing both near-term project needs and longer-term strategic needs in waste processing. An effort was made to leverage prior EM development work, as well as commercial and international experience. The strategic initiatives, which map the classes of waste-processing challenges identified in Section 1.1, are described below.

WASTE PROCESSING STRATEGIC INITIATIVES

- The Improved Waste Storage strategic initiative targets
  - Development of cost-effective, real-time monitoring of tank integrity and waste volumes to ensure safe storage and maximum storage capacity
  - Improving understanding of changing waste chemistry, including flammable gas generation, retention, release, and behavior to eliminate conservative assumptions in safety analyses.
- The Reliable and Efficient Waste Retrieval strategic initiative targets development of
  - Optimization strategies and technologies for waste retrieval that lead to successful processing and tank closure
  - A suite of demonstrated cleaning technologies that can be readily deployed throughout the complex to achieve required levels of removal.
- The Enhanced Tank Closure Processes initiative targets
  - Improving methods for characterization and stabilization of residual materials
  - Developing cost-effective and improved materials (i.e., grouts) and technologies to efficiently close complicated ancillary systems
  - Performing integrated cleaning, closure, and capping demonstrations.
- The Next-Generation Pretreatment Solutions initiative targets
  - Development of in- or at-tank separations solutions for varying tank compositions and configurations
  - Improving methods for separation to minimize the amount of waste processed as HLW.
- The Enhanced Stabilization Technologies initiative targets development of:
  - Next-generation stabilization technologies to facilitate improved operations and costs
  - Advanced glass formulations that simultaneously maximize loading and throughput
  - Supplemental treatment technologies.
- The Spent Nuclear Fuels strategic initiative targets development of improved SNF storage, stabilization, and disposal preparation, including monitoring and process analysis.
- The Challenging Materials strategic initiative targets development of enhanced storage, monitoring, and stabilization systems. This includes improved understanding of material inventory and material behavior.

1.4 IMPLEMENTING COMMUNITIES OF PRACTICE

To implement the Office of Waste Processing Program, a Multi-Year Program Plan (MYPP) was prepared to summarize the strategic initiatives and the scope of the activities within each initiative proposed for the next five years (FY2008–2012). Each Initiative engages a Community of Practice, composed of staff from national laboratories, EM-directed programs, universities, private sector entities, and others. Members of each Community of Practice have specialized experience that will enable the successful results for that strategic initiative.

The Communities of Practice provide technical oversight and review of the Office of Waste Processing Program. They are also be involved in other programmatic reviews, such as External Technical Reviews, National Academy of Sciences, etc.

2.0 COMMUNICATIONS AND COLLABORATIONS

2.1 OVERALL GOAL AND SPECIFIC OBJECTIVES

The overall goal of the Office of Waste Processing-supported communications and collaborations is to establish an effective information network to foster effective communication and encourage collaboration. Specific objectives include:

- ensuring the technology development and demonstration meets the users' needs within the required scope and schedule;
- producing efficiency in the R&D through solution of problems at multiple sites;
- leveraging resources and share lessons learned to ensure a more efficient, cost-effective waste-processing program.

2.2 APPROACH

Because waste-processing challenges exist at multiple DOE sites, the Office of Waste Processing strives to promote communication from site to site. Office of Waste Processing activities are coordinated with the field offices/projects and a collaborative relationship beginning with project planning and following through execution and the transfer of results and products for implementation. In this way, staff from multiple DOE sites can discuss common problems, leverage each other's work, and share lessons learned. This site-to-site communication is supported at every level, from one-on-one telephone calls to conference calls to collaborative technical exchanges and workshops held at various times of the year. At these meetings, relationships are built and support is provided to ensure continuation of these relationships throughout the life of the project.

Nearly seven years ago, the three major EM cleanup sites (Hanford-ORP, Savannah River Site [SRS], and Idaho) recognized the need for better and more frequent communications among the sites' management and technical staff. A program of bi-weekly technical conference calls was established to discuss

technical progress and issues for each site's cleanup projects. They have also held annual technical exchanges (on an as-needed basis) to review progress and issues.

In addition to sharing common problems across DOE sites, Office of Waste Processing also supports collaboration and leveraging both within other offices in DOE (e.g., Office of Science), and outside of DOE (e.g., industrial, academic, and government experts from the U.S. and internationally).

These collaborations consist of a variety of venues from joint projects to technical workshops and international conferences. Leveraging opportunities identified by the Office of Waste Processing include national laboratory work directly for the site customer, interface with the Global Nuclear Energy Partnership, private industry, academia, DOE Office of Science, the EM International Program, and conferences, workshops, and technical exchanges.

Other communication efforts include interactions with regulators, Congress, other government agencies, and stakeholders. These types of communications are also essential to the overall success of the program.

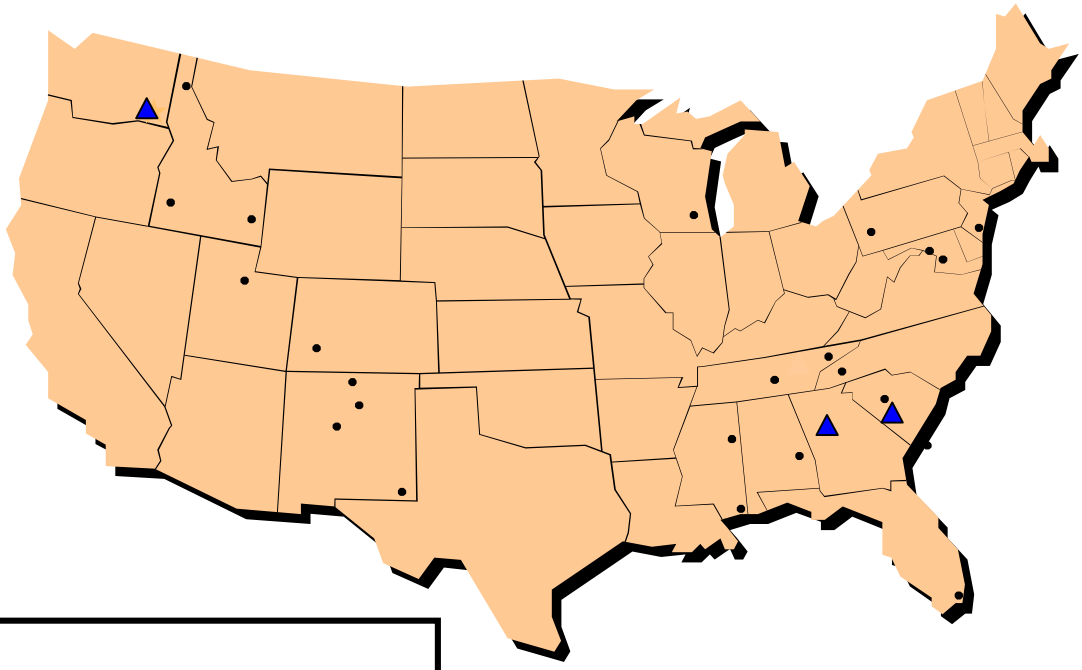
The strength of many of the Office of Waste Processing-supported communications and collaborations lies in the building of multi-disciplinary, broad-based teams of experts from many venues working together on a common problem. Examples of these communications and collaborations are the basis of this report; they are further described in later sections of the report.

3.0 SUMMARY OF 2007 WORKSHOPS

During calendar year 2007, the Office of Waste Processing sponsored four technical exchanges/workshops related to waste processing challenges. The map below identifies the locations of the four workshops and the locations where workshop attendees travelled from to attend the

workshop. From this graphic you can see how involved scientists and engineers from across the U.S. are in the DOE waste-processing program. In addition, participants from abroad attended the Cementitious Barriers Workshop and are involved in a number of DOE research and development projects. *Additional information on these workshops can be found by visiting www.em.doe/gov/Pages/EngTech.*

TECHNICAL EXCHANGE/WORKSHOP AND ATTENDEE LOCATIONS



Attendee International Locations

- France
- Russia
- Belgium
- Canada
- Scotland
- The Netherlands

▲ Workshop and Attendee Location

• Attendee Location

4.0 CEMENTITIOUS BARRIERS

4.1 CHALLENGES

4.1.1 Applications

Cementitious materials have been used for low-activity radioactive waste disposal as waste forms; waste, soil, and groundwater containments; and entombments since the early 1970s. There are many examples of successfully engineered cementitious barriers for both waste management and environmental restoration throughout the DOE complex.

These barriers are used by the DOE and commercial LLW disposal facilities to:

- limit the flux of water that contacts the waste, minimizing subsequent release or leaching of radionuclides from the disposal unit;
- modify the chemistry of the disposal environment to reduce the mobility of the radionuclides from the disposal unit;

- provide physical stability to prevent subsidence and deter intrusion and physical disruption.

Design, construction, and performance assessment of engineered cementitious barriers are critical path items for many DOE EM projects, including: Hanford secondary waste treatment, SRS tank waste treatment (saltstone), fill materials for HLW tanks, concrete vaults for low activity waste (LAW) disposal, decontamination and decommissioning (D&D) entombments, and debris encapsulation.

Radioactive waste remaining in the Silos after retrieval operations at the Fernald Site in Ohio was successfully grouted to reduce dose to workers performing the decontamination and decommissioning of the Silos.

4.1.2 State of Knowledge

The materials science and engineering of cementitious materials have been investigated from the micro-scale to the macro-(structure) scale. The majority of studies have been directed towards conventional concrete, structural engineering, and waste management applications. Peer-reviewed technical publications, standard practice documents, standard test methods, empirical relationships, and building codes provide the technical understanding and basis for the successful use of the multitude of different cementitious materials. National and international professional organizations and committees have been generating, reviewing, and distributing this information in numerous formats, including peer-reviewed publications and professional meetings, for many decades.

Although DOE has numerous successful applications of cementitious barrier technology, the current bases for using these materials rely upon

- material science and engineering data from conventional (non-radiological) applications of cementitious materials, literature, and/or data developed for specific conventional operational needs;
- short-term laboratory testing;
- empirical extrapolation of literature data for related materials; and,
- very limited field testing.

4.1.3 DOE Challenges

A substantial amount of the information from conventional applications has been incorporated into DOE waste disposal projects. However, disposal of DOE radioactive waste presents several challenges that require unique technical approaches and application-specific data to accommodate the nature of the constituents to be managed (e.g., long-lived and/or highly mobile radionuclides).

Disposal of LAW requires:

- disposal sites that provide robust features for controlling migration of radionuclides;
- design, construction, monitoring, and maintenance of engineered barriers with very long service lives (on the order of hundreds to thousands of years).

Current challenges related to the use of cementitious materials by DOE EM include a lack of:

- test methods for long-term evaluations (laboratory and field) that include accelerated aging and analogues;
- guidance on the use of data generated by such long-term evaluations;
- monitoring of full-scale structures and actual materials at DOE waste disposal facilities.

Although numerous standardized laboratory test protocols, including short-term leach testing, physical property testing, and structural, thermodynamic, and transport calculations/modeling, have been used throughout the DOE complex for short-term evaluations of engineered construction materials, many of the test protocols do not account for the current understanding of the mechanisms and processes that control long-term system leaching and structural performance. Independent peer review of test methods and data is challenging, because of the lack of standardized approaches and protocols.

Understanding of the performance of cementitious engineered barriers is used as input to design of disposal systems, DOE Performance Assessments (PA), and Composite Analyses, per DOE Order 435.1. The DOE PA process evaluates waste-disposal activities for facilities to provide a reasonable expectation of compliance with performance objectives, which are intended to provide protection of human health and the environment based on:

- dose from a combination of all exposure pathways, including the air pathway (e.g., radon release);
- water resource protection in compliance with applicable federal, state and local requirements.

Currently, data for engineered cementitious materials used as PA input are often limited by the following constraints.

- Samples of the actual materials are unavailable, because the materials are contaminated with radionuclides and unsuitable for testing in existing facilities with test equipment designated for non-radioactive samples.

- Laboratories for testing radioactive samples are limited in number and typically can handle only very small amounts of material in order to maintain acceptable dose levels.
- Current DOE operations do not include collection and testing of samples from ongoing disposal operations with the intent of improving current and future systems performance.
- DOE programs for pilot-scale field testing of materials or structural components prior to, or in parallel with, operations do not exist.
- Many of the experimental designs for material evaluation and selection are overly specific, and consequently, do not address data collection that would be useful to describe performance under variable conditions or under the range of conditions encountered throughout the DOE complex.
- There are no programs for archiving laboratory or field samples to provide specimens for aging studies and to test assumptions.

Stakeholders, including:

- State regulators
- Citizens' groups (e.g., SRS Site Specific Advisory Board [SSAB])
- Federal regulating organizations (Environmental Protection Agency [EPA] and Nuclear Regulatory Commission [NRC]),

are aware of the general limitations in material characterization and predictive methodology. Consequently, they are sensitive to the need for monitoring of existing disposal sites and using this information to test assumptions and predict performance.

4.2 SOLUTION/APPROACH

In 2006, DOE identified the need for technology development related to durability of engineered barriers for radioactive waste treatment and disposal. In December 2006, a workshop entitled *"Use of Cementitious Barriers for Low-Activity Radioactive Waste Treatment, Containments, Environmental Restoration, and D&D,"* sponsored by Office of Waste Processing, was held in Aiken, South Carolina, to define:

- DOE needs for cementitious barriers
- the state of the art
- the state of practice in DOE-EM.

Attendees at the Cementitious Barriers Workshop in Aiken South Carolina, December 2006.

One hundred and thirty-four people attended the workshop, and another two hundred fifty people participated via Web cast. The

workshop was intended to facilitate technical exchange among experts from within the DOE complex, national and international experts, and representatives from local advisory groups, as well as state and federal agencies that have roles with DOE sites. The overall goal was to identify methods to improve design, use, and long-term PAs of cementitious barriers for enhanced shallow-land disposal and entombments of radioactive waste. The workshop involved technical presentations that were organized into six different sessions.

The workshop also included presentation and discussion of perspectives from representatives of several stakeholder groups, including the SRS SSAB, state regulators from South Carolina and Washington, the NRC, and the EPA. The views presented provided information on issues of concern with a view towards improving credibility and acceptance of engineered cementitious barriers to enhance the performance of DOE radioactive waste near-surface disposal facilities and other waste-management activities.

The workshop incorporated discussion of research efforts from several countries that are focused on both practical and predictive aspects of using engineered cementitious barriers for radioactive waste disposal. Several countries (Canada, France, and the United Kingdom) have invested in long-term (10 – 20 years) test programs to support materials design and aging studies.

4.3 SUMMARY OF TECHNICAL ACCOMPLISHMENTS

The Cementitious Barriers Workshop identified a number of issues associated with enhancing performance of DOE near-surface radioactive waste disposal sites through the use of engineered barriers. These issues fall into two categories:

- providing a technical basis for improving designs;
- reducing risk in predicting long-term performance.

The workshop participants also developed recommendations, which are described below in concert with the identified issues/needs. The recommendations are intended to improve the understanding of engineered cementitious barriers, the design bases, and the risk analysis that should be incorporated into the DOE decision-making process for radioactive waste-disposal facilities.

4.3.1 Standardized Practice, Test Methods, and Guidance

Although test methods are well established for commercial uses of cementitious materials, DOE does not have a set of standard test methods for characterizing waste, waste forms, and engineered barriers or a guidance document on methodology for developing a mechanistic understanding of the waste-engineered barrier-landfill system.

Standardized performance criteria, evaluation methods, and guidance are needed for each of

the primary types of engineered cementitious barriers used in the DOE complex, including waste forms, stabilization materials for HLW tanks, soil and groundwater containment, and entombment and encapsulation of D&D wastes.

In addition, standardized test methods for generating data used in PAs are highly recommended, because they will save time, reduce costs, provide internally consistent data for DOE databases, improve acceptance of the data, and support independent peer reviews.

Existing peer-reviewed test methods should be used to the greatest extent technically appropriate and practical. All new methods and procedures should be subject to independent peer review.

4.3.2 Performance Assessment Modeling

The need for predicting long-term performance of engineered cementitious barriers used in DOE LAW disposal facilities and HLW tank closure programs is driven by the need for disposal of long-lived mobile radionuclides. At the present time, each DOE PA uses *a unique* strategy, set of assumptions, boundary conditions (time frames, starting conditions), material properties from actual materials and various databases, structural analyses, computer codes, and approach to uncertainty analyses. Standardizing the approach for modeling system performance and cementitious barrier performance and associated contaminant release from shallow land disposal facilities is recommended.

4.3.3 Data Quality Objectives and Decision Making Process

A data-quality objectives and decision-making process to determine the need for and cost effectiveness of new data should be developed and implemented. This process would highlight the sensitivity of barrier performance to material properties and design features (e.g., thickness of the barriers) and provide the potential for cost savings and implementation of innovative technologies through more extensive use of performance specifications, rather than materials specifications, for procuring engineered materials (concrete vaults, tank fill materials, entombment materials, and soil and groundwater containment).

4.3.4 Waste Characterization

Radiological, chemical, mineralogical, and physical characterization for each waste type is recommended to optimize the engineered cementitious barriers employed in the waste disposal system. Specifics of data required should be linked to the data quality objectives established for a particular project.

4.3.5 Design

Design methodologies should incorporate the latest state-of-the-practice and be updated every 3 – 5 years. For long-term storage structures (greater than 75-year life expectancy), emphasis should be placed on highly durable construction materials and methods. Therefore, long-term storage structures should not contain conventional steel reinforcement. Methods for

repair and retrofit of existing storage facilities should also be developed.

New materials such as self-consolidating, engineered nano-composite and shrinkage-compensating concrete offer advantages and should be investigated and assessed.

4.3.6 Contaminant Transport and Stabilization Mechanisms

Transport mechanisms for soluble ions through saturated porous media are well established, but there is no integrated model describing either the movement and exchange of gas and water, or the mass transfer of reactants (e.g., carbon dioxide, oxygen) and constituents of concern (e.g., radionuclides) in engineered cementitious barrier systems.

Stabilization mechanisms for many radioactive isotopes and RCRA-hazardous contaminants are well established and consist of chemical stabilization and micro/macro-encapsulation. However, this information has not been readily applied to design of waste forms and other engineered barriers.

4.3.7 Aging/Durability

The effect of time and dynamic conditions, which vary in response to the local environment, on the ability of engineered barriers to control or influence transport of radionuclides is somewhat understood. However, current information alone is insufficient for understanding and improving the longevity of cementitious materials used for engineered barriers in LAW disposal facilities containing long-lived isotopes that are required to perform for hundreds to thousands of years. Characterization of aged samples is needed to monitor changes over time, improve facility designs, and predict systems service life.

4.3.8 Pilot-Scale Field Testing

Pilot-scale testing and evaluation is an important step to understand controlling mechanisms and rates of system evolution (e.g., constituent release, oxidation, physical degradation) and to confirm modeling approaches to be used for assessment purposes. The three major waste management sites (Hanford, Idaho, Savannah River) have sufficiently different environmental conditions to warrant pilot-scale testing at each site. If practical, field tests can be constructed alongside operating facilities to evaluate site-specific exposure conditions beyond those experienced by the actual engineered barriers, and improve/validate assessment models.

4.3.9 Monitoring Engineered Cementitious Barriers

Characterization of as-built engineered cementitious barriers and subsequent monitoring to detect changes in properties as a function of time is necessary to improve designs and operational activities and to develop and refine concepts and cases for PAs. A program for monitoring the component materials and structures of existing disposal facilities (e.g., SRS saltstone and SRS E-Area Vaults), during the operational phase is recommended. The resulting information is

needed to validate the base case(s) in the PA modeling.

4.3.10 Sample Archive Programs

A sample archive program for laboratory samples and as-built or implemented materials throughout the DOE complex is recommended to support current and future durability and aging evaluations.

4.3.11 Databases and Knowledge Retention

A recommendation is made to develop and maintain several key databases, which would include data on waste characterization, laboratory, pilot and field test results, and other key information that should be retained for future retrieval by staff at any DOE site interested in these data.

4.3.12 Stakeholder Involvement

Active stakeholder involvement is an important programmatic component to ensure that stakeholder concerns are appropriately addressed, to provide first-hand knowledge of program design and results to stakeholders, and to facilitate transparency. Active stakeholder involvement is recommended to be included as an integral part of broad program planning and specific program components, such as developing performance specifications, field demonstrations, and PA base cases/conceptual models to ensure that critical questions are identified and addressed, and to improve stakeholder understanding of program outcomes through direct interactions.

4.3.13 Independent Expert Review and Knowledge Exchange

Independent expert review (peer review) is required by stakeholders for acceptance of DOE waste disposal projects. This review is recommended at every stage in a PA. Embedding independent peer review as a program component is essential to ensure application of the available state-of-knowledge, transparency and stakeholder acceptance.

More emphasis on technical exchanges among research scientists, risk assessment modelers, and operations personnel within the DOE complex and with independent experts is also recommended.

4.3.14 Leveraging Resources

Leveraging DOE investments to advance the state-of-knowledge and practice for the use of engineered cementitious materials is strongly recommended. One approach to leveraging technology is to take advantage of parallel or related efforts at other Federal Agencies and International Radioactive Waste Management Agencies.

4.4 POTENTIAL IMPACTS

The Cementitious Barriers Workshop was extremely valuable in that it brought together scientists and engineers from a variety of disciplines, experience, and venues in an attempt to improve the understanding of engineering cementitious barriers, the design bases, and the risk analysis that is a critical part of the DOE decision-making process. Potential

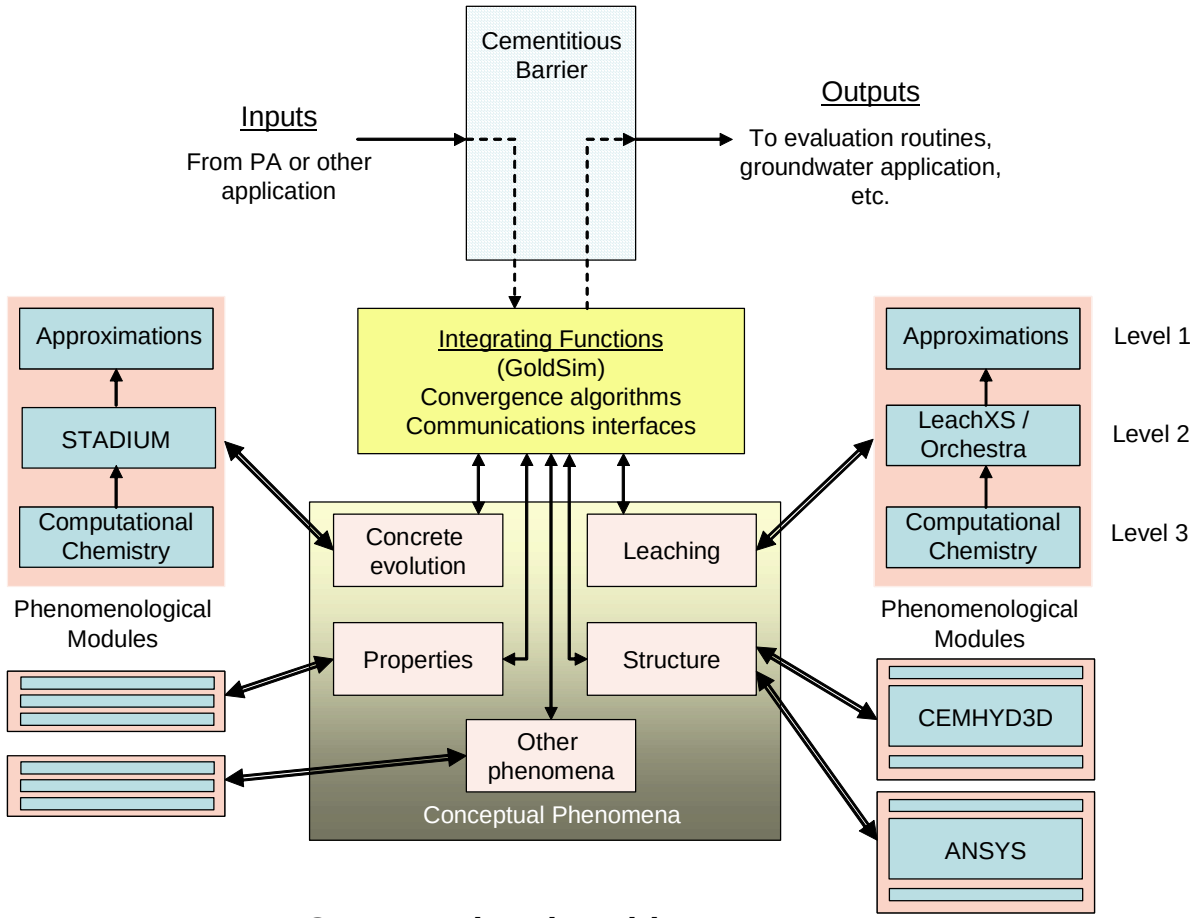
impacts of this increased understanding ultimately include more effective and efficient barrier systems that will likely provide for better protection of human health and the environment. In the interim, the workshop promoted collaboration and communication across DOE sites with common problems and beyond to the academic, international, other governmental agencies, and vendor communities.

4.5 PATH FORWARD

The December 2006 workshop resulted in the formation of the Cementitious Barriers Partnership in early 2007. The Cementitious Barriers Partnership consists of members from government (DOE, NRC, National Institute of Standards and Technology), academics (Vanderbilt University), and international organizations (Energy Research Center of the Netherlands) and SIMCO technologies. The overall goal of the Cementitious Barriers Partnership is to identify and develop tools necessary to predict the structural, hydraulic, and chemical performance of cementitious materials in the near-surface low-level radioactive waste disposal environment.

A project plan to be implemented through a CRADA for a phased effort over five years was finalized in October 2007. In the initial phase (six months) background information will be documented, reference cases will be identified, and existing software will be tested, and input will be developed for test bed objectives and design. The second phase (three years), includes development of simulation tools models, integrating framework, and the user interface; also the second phase will involve studies regarding uncertainty reduction and specific experiments. The third phase (two years) involves additional work related to reduction of uncertainty, refinement of simulation tools, and validation of the tools.

The project structure is shown in the figure below.



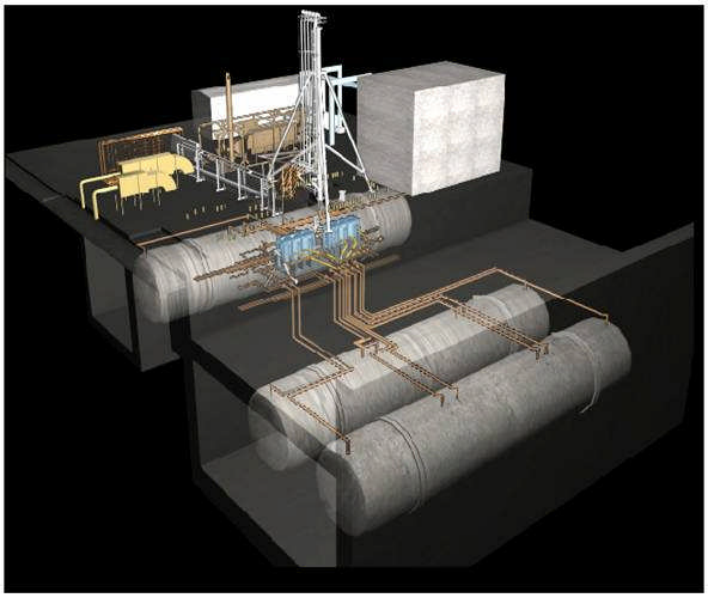
Cementitious Barriers Computational Architecture.

5.0 SAVANNAH RIVER, HANFORD, AND IDAHO TECHNICAL EXCHANGE

5.1 CHALLENGES

5.1.1 DOE Sites

The DOE Savannah River, Hanford, and Idaho Sites each have significant waste processing challenges related to safe storage, waste retrieval, waste pretreatment, waste treatment/stabilization, and tank closure activities for HLW(each of these challenges is described in Section 1.1) and transportation and disposal activities for LAW. Each of these sites participates in the Office of Waste Processing strategic initiatives for improved waste storage, reliable and efficient waste retrieval, enhanced tank closure processes, next-generation pretreatment solutions, and enhanced stabilization technologies.



Fluidic mixing systems have demonstrated their ability to retrieve wastes from tanks.

The Office of Waste Processing has found that Technology Exchange meetings have maximized benefits from outcomes of R&D performed across the DOE complex. Examples of these exchanges have included focused workshops (such as those described in this report), and common issues teleconferences.

5.1.1.1 Savannah River Site (SRS)

The SRS has reported the following technology needs:

- Federal Facility Agreement Regulatory Commitments to close tanks
- Sludge heel removal from Types I, II, and IV tanks (including chemical and mechanical cleaning)
- Waste removal from tank annuli
- Closure of tank cooling coils and transfer lines
- Waste processing: waste vitrification throughput, waste loading in glass, and tank sludge preparation
- Deliquifaction, Dissolution, and Adjustment Process for salt waste (initially from Tank 41)
- Actinide Removal Process (to provide near-term capability) to remove actinides and strontium from salt waste (1.2 million gallons/year)
- Modular Caustic Side Solvent Extraction Unit to remove cesium-137 from about 1.2 million gallons/year of salt waste.

5.1.1.2 Hanford (Office of River Protection)

The Office of River Protection (ORP) has grouped their technology needs into the following categories: waste storage, waste retrieval, pretreatment/separations, treatment, characterization, waste feed delivery, and tank closure. Within each category, ORP has identified high and medium priority needs.

- Waste Storage
  The high-priority needs are: double-shell tank integrity, and approaches for increasing tank storage capacity. The medium priority need is a double-shell tank remote inspection system.
- Waste Retrieval
  The high-priority need is alternative single-shell tank retrieval technologies. The medium priorities are improved technologies for installing risers, and improved operating life for remote cameras.

- Pretreatment/Separations
  The high-priority needs are: caustic management; pretreatment experimental platform data (cross-flow filtration and aluminum dissolution); and supplemental pretreatment (fractional crystallization and tank-side ion exchange). The medium priorities are: solid/liquid separations at the Tank Farms, and alternative reagents for caustic and oxidative leaching.

- Treatment
  The high-priority needs are: validation and enhancement of the Bulk Vitrification Process: improved secondary waste treatment: and increased high level waste glass loading. The medium priority is LAW and HLW waste form development for operations.

- Characterization
  The high-priority needs are residual tank waste measurement and HLW slurry hardness and abrasitivity.

- Waste Feed Delivery
  The high-priority need is double-shell tank mixing and sampling. The medium priority is online monitoring of solids concentrations.

- Tank Closure
  The high-priority needs are: waste slurry transport characterization and pipeline unplugging; immobilization of post retrieval tank waste residuals; pipeline characterization to support closure; and performance monitoring for the 200 West Area Closure Demonstration

.

The Immobilization Plant (WTP) at Hanford is currently under construction.

5.1.1.3 Idaho Cleanup Project (ICP)

The Idaho Cleanup Project (ICP) is focused on five major project areas at the DOE Idaho Site: Test Area North, Reactor Technology Complex, Idaho Nuclear Technology and Engineering Center, Power Burst Facility, and the Radioactive Waste Management Complex. The scope of the cleanup includes: nuclear material disposition, spent nuclear fuel stabilization and storage, sodium-bearing waste treatment and disposition, waste management, and environmental restoration.

At the Idaho Site, the sodium-bearing waste treatment is the major technology focus. The history of the sodium-bearing waste is as follows.

- SNF processing was discontinued at Idaho in 1991 and high level waste was no longer generated.

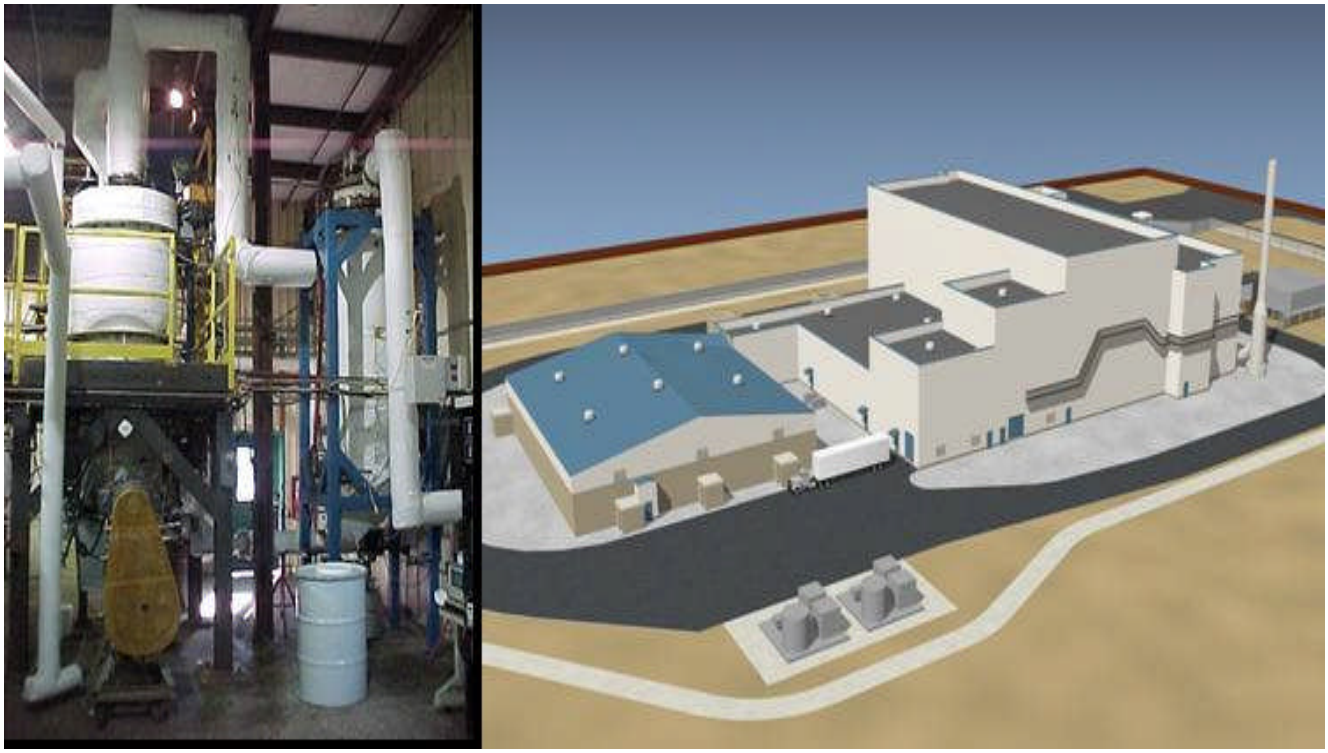
- Liquid sodium-bearing waste has continued to accumulate in the tank farm tanks from operation of the new Waste Calcining Facility, and from decontamination activities.

- The Idaho HLW and Facilities Disposition Environmental Impact Statement evaluated more than 100 treatment systems, and chose five for further consideration.

- Steam Reforming has been selected as the preferred technology to be implemented.

- Pilot-plant testing of steam reforming has been completed.

The ICP has identified remaining technology risks associated with the sodium bearing waste treatment. These include: packaging and handling systems, welding of exotic materials, and scaling inside the reformer.



Steam Reforming has been demonstrated at engineering scale and is now being designed for full-scale application at the Idaho National Laboratory.

5.2 SOLUTION/APPROACH

In October 2007, the Office of Waste Processing sponsored the Savannah River, Hanford, Idaho Technical Exchange in Atlanta, Georgia. Approximately 172 people attended the technical exchange. The purpose of the Technical Exchange was to facilitate communication among technical and management staff from each of the sites, the Defense Nuclear Facilities Safety Board (DNFSB), DOE national laboratories, and private industry. The technical exchange incorporated presentations that were organized into five different technical sessions: introduction, waste retrieval, technology development, retrieval tools, and facility readiness.

Technical Exchange Participants.

5.3 SUMMARY OF TECHNICAL ACCOMPLISHMENTS

The technical accomplishments at each of the three EM sites were discussed at the technical exchange and are summarized in the following paragraphs.

5.3.1 Savannah River Site

SRS reported that the Deliquification, Dissolution, and Adjustment Process of salt waste in Tank 41 is scheduled for completion in the Spring of 2008.

The Actinide Removal Process will provide near term capability to remove actinides and salt waste at 1.2 million gallons/year, using two existing modified site facilities. The effluent from Actinide Removal is sent to the Modular Caustic Side Solvent Extraction Unit where cesium-137 is removed. This combination of treatments is scheduled to be ready for hot operations in the Spring of 2008.

For tank sludge heel removal, SRS completed a proof of concept study and initiated a full scale demonstration in Tanks 18 and 19; SRS also completed mechanical cleaning in Tanks 5 and 6, where oxalic acid cleaning is scheduled for completion in Fall of 2008.

SRS reported that they had completed Technology Readiness Assessments (TRAs) for two technologies for disposition of Tank 48 organics.

SRS also reported progress in: closing cooling coils and tank transfer lines, vitrification throughput, and waste loading in glass.

5.3.2 Hanford (Office of River Protection)

The ORP reported that results for the Bulk Vitrification (BV) Demonstration Program are encouraging as follows.

- BV glass is comparable to the WTP immobilized LAW.
- BV allows treatment flexibility for difficult waste streams.
- Secondary waste is minimized and recycled.
- BV may allow LAW treatment prior to startup of the WTP.

The ORP described several innovative tank waste retrieval technologies including:

- The Sand Mantis and Aardvark for waste breakup and mixing
- The Rotary Viper for waste mixing
- The Squid Pump for in-line waste transfer.

Bulk Vitrification Demonstration Plant under construction.

The ORP reported completion of TRAs [1] to assess the maturity of critical technology elements for:

- the Waste Treatment and Immobilization Plant Analytical Laboratory, Balance of Facilities, and LAW Vitrification Facilities;
- the Waste Treatment and Immobilization Plant and the Waste Treatment and Immobilization Plant Pretreatment Facility.

A number of WTP Systems was found to require further maturation: pulse jet mixing, radioactive cesium removal, laser-ablation-inductively coupled plasma-atomic emission spectrometer, and HLW off-gas melter.

5.3.3 Idaho Cleanup Project

During the Technical Exchange, the ICP reported progress related to:

- disposition of un-irradiated special nuclear materials;
- transfer and storage of EM-owned spent nuclear fuel.
- design of an integrated waste treatment unit for sodium bearing waste;
- progressively closing tanks in the tank Farm using grout;
- treatment and disposal of mixed waste;
- retrieval and processing of 9400 cubic yards of buried waste.

The ICP indicated that a one-tenth scale pilot test:

- demonstrated long-term integrated operation of the sodium bearing waste processing system;
- confirmed process chemistry and material flows;
- produced data to support environmental permitting;
- produced granular product for solids handling and packaging equipment demonstration;
- validated the hazard/safety analysis. The pilot project lessons learned were: testing always required longer than planned, and communications with stakeholders were critical to success.

Remaining technology risks for the sodium bearing waste processing system include: packaging and handling systems, welding of exotic materials, and scaling inside the reformer. The ICP is completing mockup and prototype testing to mitigate these risks.

5.3.4 Summary of Technical Sessions

The Technical Exchange incorporated presentations that were organized into five

[1] Key aspects of the TRA Process include:

- determining readiness of continuing with design and construction;
- identifying immature technologies and components (for tracking maturity);
- identifying technology development needs for immature technologies.

different technical sessions: Introduction, Waste Retrieval, Technology Development, Retrieval Tools, and Facility Readiness.

The Waste Retrieval Session included: a discussion of the Hanford Tank S-102 soil contamination event; the Savannah River Tank 6 mechanical and chemical sludge removal; a presentation of the results of the SRS Sludge Heel Chemical Cleaning Project; the Hanford C Farm retrieval with vacuum and modified sluicing; the SRS Tank 5 cooling coil cutting process; the SRS tank 16 annulus cleaning initial phase demonstration; and a description of a modeling approach for liquid-solid behavior in SRS tanks.

The initial Technology Development Session included: discussion of evaluation of the SpinTek Rotary Microfilter technology to treat radioactive liquid waste at SRS; discussion of a full-scale test of Cross Flow Filtration for salt waste at SRS; evaluation of an in-tank small-column ion exchange system at SRS; solubility studies and database development for Hanford tank waste; studies of glass formulations at Hanford; studies of the Fractional Crystallization technology at Hanford; and evaluation of wet air oxidation for SRS Tank 48H waste treatment.

The Session for Retrieval Tools included: discussion of high pressure technologies for waste retrieval from Hanford tanks; use of the Sand Mantis technology for mechanical cleaning at SRS tanks 18 and 19; and evaluation of residuals in seven Hanford tanks where retrieval has been completed.

The second Technology Development Session included: the results of initial testing of fluidized bed steam reforming for SRS tank 48 waste treatment; use of a steam reforming process to treat sodium-bearing waste at the Idaho Cleanup Project; results of a project to resolve the sludge mass issue for SRS tank waste; discussion of the Hanford Waste Treatment Plant planned leaching process; description of an approach to recycle sodium using the NaSICON ceramic membrane technology; and a description of the ion recognition approach to minimizing waste volumes.

The Facility Readiness Session included: the lessons from the Actinide Removal Process at SRS; the lessons learned from the modular CSSX Project at SRS; and discussion of a process to achieve readiness for a demonstration of a Bulk Vitrification technology at Hanford.

5.4 POTENTIAL IMPACTS

The Hanford, Savannah River, and Idaho Technology Exchange is extremely valuable, because it brings together scientists, engineers, and managers from a variety of disciplines, experience, and sites to discuss both individual and common issues and lessons learned related to progress in project and technology development and completion. The increased understanding of lessons learned and the enhanced communication will continue to assist

these sites with future decisions for technology and cleanup projects. The Technical Exchanges promote collaboration and communication among the DOE sites that face common challenges.

5.5 PATH FORWARD

The continuation of this technical exchange each year will promote communication, and improve project decision-making at these sites, and will maximize benefits from R&D performed across the DOE complex.

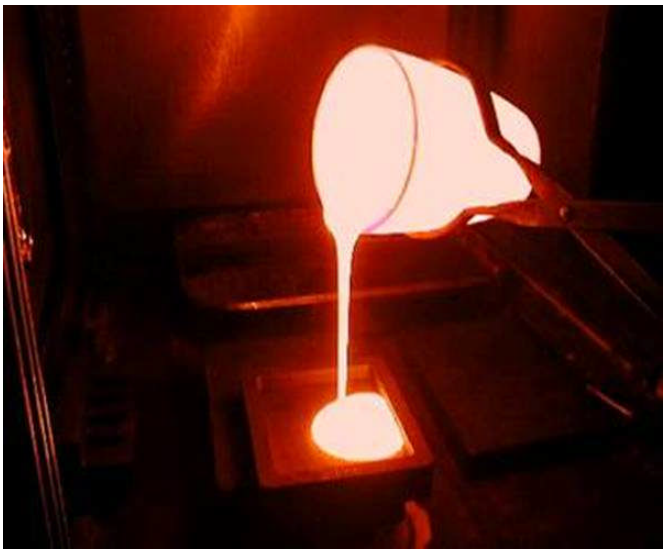
6.0 ALUMINUM CHROMIUM LEACHING

6.1 CHALLENGES

Non-radioactive aluminum and chromium exist in the alkaline sludge wastes stored at SRS (~1440 Metric Tons [MT] aluminum) and Hanford (~8660 MT aluminum). Some aluminum in the waste feed to the vitrification plants is good (3%-5%), because it improves glass durability. If aluminum concentrations are as high as 10%, problems can occur:

- Crystalline phases may form in the melt pool and may not be incorporated into the glass matrix upon cooling; this may lead to leaching of radionuclides during long-term storage.
- High-alumina sludges have experienced elongated processing times at the Defense Waste Processing Facililty (DWPF), likely due to the aluminum's impact on glass viscosity.

In addition, if aluminum can be removed from the WTP or DWPF feed, the burden of vitrifying large volumes of material in the HLW melter systems can be reduced, as well as reducing the number of HLW canisters produced (e.g., reducing the number by 15,000–30,000 at Hanford and by 1,000 at SRS), reducing disposal costs, and shortening the life-cycle completion schedule (e.g., SRS from 2035 to 2028; reducing operations by 20 years at Hanford). However, the mass and composition of the subsequent LAW waste stream will be changed, because sodium hydroxide (caustic) is used to remove the aluminum (e.g., Hanford: ~40,000 MT sodium added).



Molten glass testing to optimize waste loading, as well as aluminum content, is underway.

Both Hanford and SRS have concerns related to aluminum and chromium in their HLW, but each site has different conditions and different plans for final disposition of the aluminum in LAW.

- At Hanford, aluminum is widely distributed among the tanks. Thus, plans for removal call for a treatment process in the Pretreatment portion of the WTP. Current concerns focus on the large volumes of sodium hydroxide (caustic) to be added during this step.

- At SRS, aluminum is primarily contained in ~6 tanks. Plans call for waste to be dissolved in tank or staged in batches sent to the DWPF.

- At SRS, the estimated inventory of sludge has recently increased significantly, causing the aluminum leaching to become vital to meeting site treatment schedules.

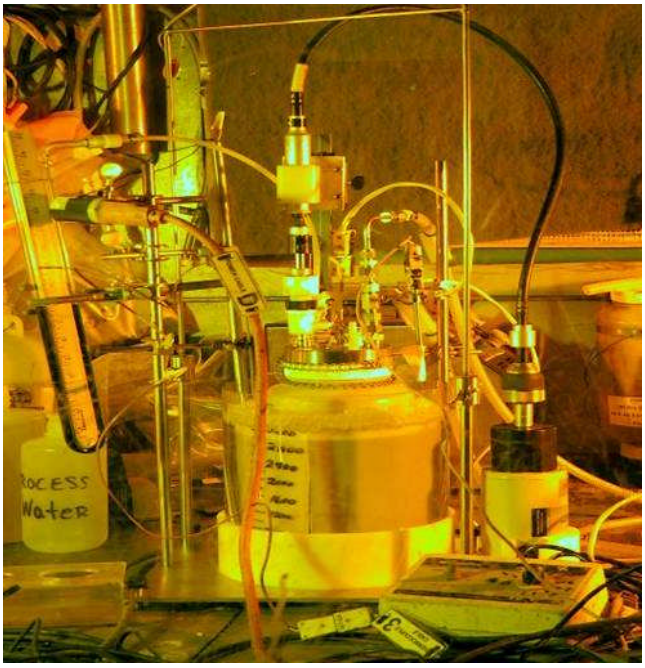
- At Hanford, methods are needed to minimize the amount of caustic used for dissolution and to speed the dissolution.

- At Hanford, the LAW, which will contain both aluminum and chromium, will be vitrified and stored on site.

- At SRS, the LAW will be made into saltstone, which will also be stored on site.

Because of these differences in conditions between the two sites, there are many differences in the approaches and technology needs for each site.

Historically at SRS, a full-scale in-tank demonstration of aluminum dissolution was performed in 1982. The process successfully removed 79% of the aluminum from the sludge, but generated 2.975 million gallons of liquid waste as well as encountering difficulties in the ventilation system and sludge settling times. More recently, low-temperature caustic leaching was demonstrated full-scale in Tank 51 at SRS (see photo below). No large-scale tests have been completed at Hanford. Although the data from small-scale tests give a positive indication that aluminum dissolution will work, many issues remain, predominantly because of variable waste compositions and changes in process conditions, downstream processing, or storage limitations.



Caustic leaching has successfully removed aluminum from tank waste sludges at SRS.

Better approaches are needed to deal with the waste volumes and limitations on disposal methods. A more extensive understanding of the kinetics of dissolution, as well as the factors that affect rates, effectiveness, and secondary species, is needed. Models of dissolution rates that have been developed are useful, but suffer from limitations on applicable compositional ranges, mineral phases, and particle properties that are difficult to measure. The experimental bases for the models contain very few data points.

6.2 SOLUTIONS

DOE convened a technical workshop on the aluminum/chromium leaching problem to enable

- identification of common needs;
- review of historical programmatic approaches and results;
- comparison of DOE approaches to industrial practices;
- review of fundamental physiochemical data and kinetic models on leaching of aluminum and chromium in sludge waste;
- consideration of impacts of leaching on other aspects of sludge chemistry;
- evaluation of alternative treatment technologies; and,
- sharing of lessons learned.

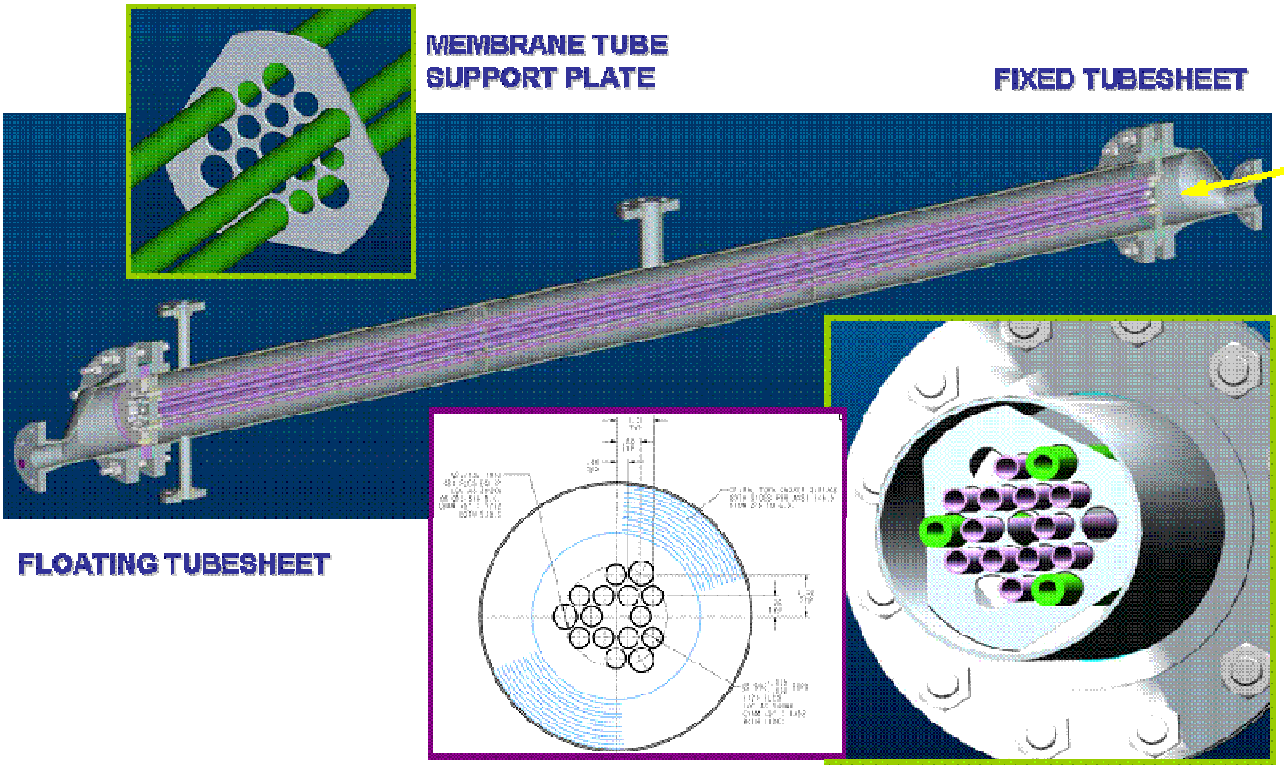
Specific objectives were to examine the needs and requirements of the HLW flowsheet for each site, discuss the status of knowledge of leaching processes, communicate research plans, and identify opportunities for synergy to address knowledge gaps.

The workshop, held in Atlanta Georgia, brought together scientists and engineers with different expertise and experiences, thus promoting collaboration and continuing dialogue. They are continuing communications through bi-weekly conference calls, an integrated task list, and other workshop venues, such as the ongoing SRS – Hanford – Idaho Technical Exchange.

Workshop attendees.

In addition, DOE is addressing the aluminum problem through study of a variety of research and development projects:

- Continuous sludge leaching
- Caustic recycling
- Improved glass formulations to accept higher levels of aluminum and sodium



Ultrafiltration technology must be tested for specific Hanford applications to ensure successful plant operations.

- New approaches to concentrate HLW slurry after pretreatment
- Alternative reagents to optimize oxidative leaching process operations.

In addition, an expert review of the WTP ultrafiltration system design and sludge leaching process was conducted.

6.3 SUMMARY OF TECHNICAL ACCOMPLISHMENTS

A large body of literature was shared among participants at the aluminum/chromium leaching workshop. Because of differences in conditions at both Hanford and SRS, technical approaches to remove aluminum and chromium from HLW sludges are different at each site. However, because both sites have common goals of producing a quality glass product and reducing the number of HLW canisters, the workshop enabled scientists and engineers to share information of common interest, such as predictive models of mineral dissolution.

Many laboratory-scale tests for aluminum and chromium dissolution have been run on Hanford waste, with samples from 46 different tanks for aluminum dissolution and from 10 tanks for oxidative leaching of chromium. These data have been modeled using the Hanford Tank Waste Operations Simulator (HTWOS) to project effectiveness. Three samples from SRS tanks have also been tested. Conditions of each test varied widely, with varying hydroxide concentrations, temperatures, and durations. Some conditions exceeded the hydroxide content and/or temperature limits currently achievable for an in-tank process. Sixty-five to ninety-five percent of the aluminum in the tank-waste samples was dissolved in the SRS small-scale tests. The SRS in-tank demonstration conducted in 1982 successfully removed 79% of the aluminum from the sludge, but generated 2.875 M gallons liquid.

More recently, the low-temperature caustic leaching full-scale demonstration in SRS Tank 51 removed 65% of the aluminum in the sludge, reducing the volume of HLW glass canisters to be produced at SRS by 100.

6.4 POTENTIAL IMPACTS

Dissolution of aluminum and chromium from sludge wastes at SRS and Hanford is key to optimizing throughput of the HLW melters and minimizing the number of canisters. Potential impacts of the collaborations developed through the Aluminum-Chromium Leaching Workshop and the integrated research and development projects include a variety of improvements in process chemistry and process engineering related to removal of aluminum and chromium in the HLW feed prior to vitrification. In addition, improvements in interface from pretreatment to vitrification will likely be developed. All of these improvements will ultimately result in more efficient HLW operations that mean:

- optimized throughput of the HLW melters;
- generation of lower volumes of HLW, minimizing number of canisters and lowering disposal costs; and,
- significant acceleration of HLW treatment schedules.

Technical areas where improvements may most likely make the most significant impacts include the following.

- Rates of dissolution of the aluminum minerals likely present, gibbsite and/or boehmite, are critical factors of significant uncertainty under tank sludge conditions. Variables impacting this uncertainty include temperature and particle size.
- Dissolution of co-contaminants, such as actinides (e.g., plutonium) during leaching of aluminum and chromium needs to be better understood and controlled.
- Optimization of aluminum concentrations in glass and rheology of the sludge could have significant benefits in reducing the number of HLW canisters at both sites.

6.5 PATH FORWARD

DOE will continue support of research and development to promote understanding and engineering of processes to remove aluminum and chromium from the HLW feed and to optimize concentrations of these constituents in the waste glass. Collaborations between the DOE sites will be continued to ensure sharing of lessons learned and technical resources.

At SRS, real-waste testing will be performed to confirm rate predictions and solubility of aluminum as well as actinides. Other testing to be completed includes: mixing simulations, viability of low-cost pump systems, real waste tests for effect on sludge settling rates, corrosion tests to identify temperature limitations, investigation of viable in-tank chemical probes and engineering design evaluations of the tank ventilation, heating, and cooling systems.

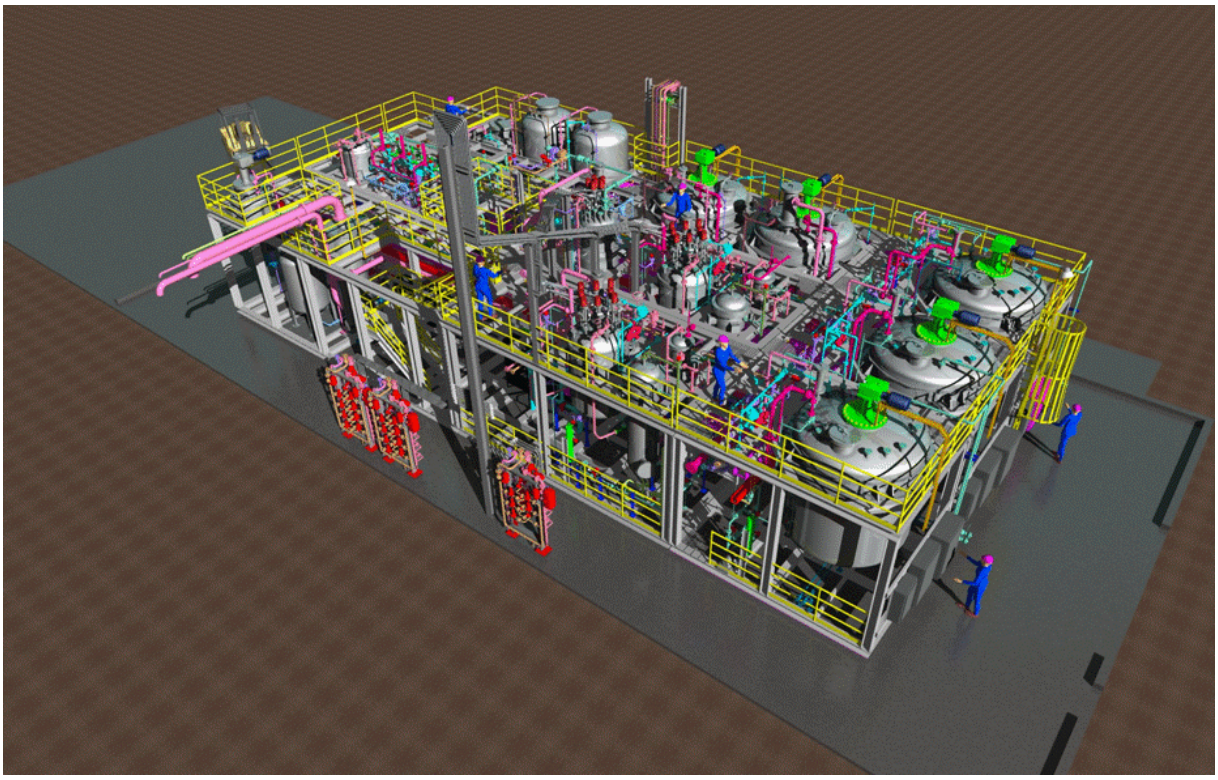
At Hanford, Pacific Northwest National Laboratory (PNNL) is proceeding on eight composite samples to be evaluated for leaching and filtration behavior. Samples from multiple tanks with similar processing history have been identified out of the existing sample archive. Parametric tests over a range of processing conditions will be performed with seven of these composites.

7.0 TEST FACILITY LESSONS LEARNED TECHNICAL EXCHANGE

7.1 CHALLENGES

7.1.1 Office of River Protection (ORP) Waste Treatment Plant (WTP)

Because DOE-ORP is overseeing the design of the WTP that will process approximately 53 million gallons of HLW currently stored in underground single-shell and double-shell tanks, a quarter-scale test platform of the WTP pretreatment facility is currently under construction. The test facility, called the Pretreatment Engineering Platform (PEP), is scheduled to begin test operations in the fourth quarter of 2008.



Pretreatment Engineering Platform Rendering of the.

The PEP testing was recommended by ORP and ORP expert panels who felt that pilot-scale testing is required because:

- the leaching processes and ultrafiltration system have not been demonstrated beyond bench scale, and testing with conditions representing the WTP flow sheet had not been completed;
- the capacity of the ultrafiltration system is uncertain; and,
- operating approaches for the ultrafiltration system were not demonstrated.

Because design, construction, and testing of pilot-scale facilities are critical path items for many DOE EM projects, shared lessons learned can provide important information necessary for successful testing and evaluation.

7.2 SOLUTION/APPROACH

In 2007, DOE identified the need for assembling lessons learned from HLW pilot projects across the DOE Complex. On December 4 and 5, 2007, a Technical Exchange entitled "Test Facility Lessons Learned Technical Exchange" was held at Richland, Washington, sponsored by the DOE Office of Waste Processing (Office of Waste Processing). Approximately sixty-five people attended the exchange; they represented ORP, Hanford, SRS, three national laboratories, and private industry. The purpose of the

meeting was to share experiences and lessons learned in test facility and test platform operations so that all sites can benefit and improve the efficiency and effectiveness of their testing. This technical exchange included eighteen presentations.

LAW Pilot Melter Feed System.

7.3 SUMMARY OF TECHNICAL ACCOMPLISHMENTS

As a result of the technical exchange, 32 lessons learned from the operation of test facilities at DOE sites were compiled. These are important considerations when planning and pursuing pilot plant testing and operations. In the following paragraphs consolidated lessons learned and associated PEP plans that incorporate lessons learned are presented in groups for easier review.

7.3.1 Design

Process Scaling and Assumptions

A scaling factor, together with a technical rationale, that can be applied to the key unit operations and equipment to be tested should be selected early in the conceptual design phase of a project. The assumptions and basis for the scaling must be carefully documented.

For the ORP PEP facility, a 4.5 scale factor was selected and applied to the PEP leaching and filtration unit operations; this scale factor

provides adequate scale up for mixing and maintaining key process cycle times.

Site Selection

The site/facility for testing should be selected to meet project objectives and programmatic needs. The project should consider: both private sites and DOE facilities; long term use and/or or disposition; and proximity to qualified personnel.

The PEP site is located within the PNNL Process Development Laboratory-West, near engineering/operations staff and it provides separate and sheltered operations.

Logistics and Support Facilities

The test facility requires support from other facilities, including: loading dock, parking, offices, cafeteria, and others. Test facility lighting and security are important. Shipping and delivery of oversize or very large equipment can require special transportation and handling; maintaining the safety and cleanliness of equipment during shipment may require special measures.

ORP has developed special lifting and handling plans for the PEP facility. Location of the PEP within the Pacific Northwest Laboratory facility provides good access to support facilities.

7.3.2 Test and Operational Planning

Test Plans

Test Plans must address a wide range of considerations, including:

- implementing a Joint Test Group with defined roles and responsibilities to allow changes in the test program;
- carefully pre-plan testing and operating activities, allowing sufficient time for: equipment acceptance testing, Control and Instrument (C&I) system testing, personnel training; transition from construction to operation, and transition issue resolution process;
- developing a detailed test plan that identifies: emergency communications, the type and quantity of data that are needed, how data will be used, quality standards, the operating range of the test facility (upper limit), and success criteria;
- developing a disciplined process to allow timely change of test procedures and configuration so that documented review and disposition of proposed changes to equipment configuration and test sequencing can be accomplished rapidly and safely;
- developing a defined safety envelope and waste management plan to ensure personnel safety, equipment protection, and waste handling and disposition;
- completing management assessments prior to testing; and,
- communicating with stakeholders and implement a “bus stop” tour.

Current plans for PEP include establishment of two Joint Test Groups for the PEP: one to oversee water and simulant shakedown

activities, and one to oversee PEP testing. The roles, responsibilities, and accountability will be defined using this technical exchange information and lessons learned from other WTP testing. A Test Specification and Test Plan have been developed and have been reviewed by ORP and external reviewers. A documented approach to configuration control for PEP is being developed and implemented. A list of essential design documents and procedures will form the basis for configuration management. The PEP project will establish an emergency action and communications plan based upon WTP and Pacific Northwest Laboratory procedures. The PEP project will use an NQA-1 data acquisition system and will develop plans that will identify how the data are to be used; a dedicated data assessment team is also being planned. A management assessment of the PEP testing will be incorporated into test planning. An integrated program schedule identifying interfaces is being developed for management of the testing. Key aspects of the testing and the schedule will be communicated to stakeholders prior to commencement of testing. A "tour stop" location with pictures, diagrams, status and test information is planned.

7.3.3 Personnel

The installation, acceptance testing, shakedown, and testing activities should include the right number and mix of staff to ensure that test objectives can be safely and effectively met. Including the appropriate management and production engineering staff (who are assigned to the design of the full scale system) and C&I engineering staff was strongly recommended at the technical exchange. Key roles in the testing program (shift manager and testing director) should have knowledgeable backups.

All shift engineers, testing staff, and shift management should be trained prior to initiating shakedown and testing; the training should include procedures for normal and off-normal response and recovery, and testing. A formal mechanism to communicate to test/operating shifts and crews should be implemented.

Based upon the results of the technical exchange, the PEP is re-evaluating the staffing (and back-ups) required to achieve operational and testing objectives. Training of shift and testing personnel is incorporated into PEP test planning. Test Instructions that contain specific directions for shift and testing staff are planned for PEP.

7.3.4 Simulants

The selection, development, and use of stimulants was a significant topic at the technical exchange. The choice of stimulant, the relationship to actual waste, and its performance before and during the test can greatly influence test results. The physical/chemical parameters of the simulant, and the attributes that the simulant is designed to mimic need to be carefully defined and approved by stakeholders prior to initiating the procurement of a simulant. Projects should consider identifying a single point of contact to address all simulant recipe, procurement,

transportation, and batch testing activities. The procurement of simulant should be carefully managed to: understand how the vendor is preparing the simulant (recipe steps and quality of ingredients), how the simulant ages, how much is required to conduct the testing (allowance for spills or additional testing), and pre-testing by the vendor and the project. Simulant transportation and handling require extensive prior planning (special handling, inert environment and other factors).

The technical exchange resulted in a careful review of the PEP plans for: use of simulants, simulant properties, procurement, and storage. A Simulant Coordinator was assigned to the WTP and a checklist of simulant issues and considerations was developed.

7.3.5 Equipment

An appropriately scoped and designed maintenance program should be considered to maximize availability of equipment for testing. Equipment acceptance testing and shakedown of control and instrumentation systems should be planned and realistically scheduled. Equipment and test facilities may have longer term use beyond the initial testing. A long-term plan for the facilities should be considered.

PEP is considering the development of a maintenance plan. PEP plans to staff maintenance activities with available craft from the Pacific Northwest National Laboratory craft pool. PEP is using the results of the technical exchange to incorporate the complexity of the PEP controls and instrumentation system shakedown into the schedule. Currently, the long-term disposition plan for the PEP is to use it for optimization and alternate equipment testing or to donate it to local universities.

Equipment installed at the PEP.

7.3.6 Operations

The technical exchange recommended that a graded conduct of operations approach be used to ensure safe and effective test facility operations. The graded approach includes clearly identified roles, responsibilities, authorities, startup and operating procedures, test procedures and implementing instructions, and a document hierarchy. An event management process should be developed and implemented, including the tools required to identify events and to implement corrective actions. Unexpected outcomes from testing should not be considered failures, but should be

used to better understand the system and should be fully analyzed and incorporated into lessons learned.

Current plans for PEP anticipate using a graded approach to Conduct of Operations. An assessment is being performed to identify potential issues and to identify and implement strategies to mitigate these issues. The PEP communications plan may address off-normal events. At PEP, all data will be analyzed, including those from unexpected outcomes.

7.4 POTENTIAL IMPACTS

The identification of lessons learned from HLW pilot testing across the DOE complex has provided the PEP facility with key information that will be used in constructing, installing, and operating the pretreatment test facility. The PEP is the largest and most complex test platform to be installed and tested by DOE. The technical exchange highlighted the complexity of PEP and affirmed the need for careful and thorough planning during all phases of test facility development and operation. One particular subject, the use of simulants, was thoroughly discussed at the Exchange. As a result, WTP designated a Simulant Coordinator to coordinate simulant use from individual testing to final plant operation and to develop a stimulant checklist for WTP.

7.5 PATH FORWARD

The December 2007 technical exchange provided an extensive set of lessons learned from HLW testing across DOE. Many of these lessons learned are being incorporated into the PEP plans and testing at Hanford and will be considered by other sites as they develop other HLW test facilities.