Tanks Focus Area

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1998

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TANKS

FOCUS AREA

U.S. Department of Energy

Office of Environmental Management

Office of Science & Technology

Tanks Focus Area

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In 1994, the Department of Energy (DOE) Office of Environmental Management (EM) established the Tanks Focus Area to address technical needs associated with management of radioactive wastes in over 250 major underground storage tanks. The Tanks Focus Area is a valuable tool in reducing the risks in remediating high-level waste (HLW) and certain transuranic (TRU) waste streams across the DOE complex. The Tanks Focus Area has worked with the problem owners to address their technological risks. Tanks Focus Area products include technologies implemented in the retrieval, pretreatment, characterization, immobilization of HLW and TRU waste, and in tank closure; as well as key data and technical assistance necessary for programmatic decisions.

The Tanks Focus Area completed a number of important technical activities in Fiscal Year 1998. These accomplishments include fourteen technology demonstrations and 8 technology deployments. Specific accomplishments include deployment of new waste mobilization and retrieval technologies (e.g., fluidic pulse jet mixers); demonstration of tank corrosion probe; and development of a disposable crawler for in-tank cleaning.

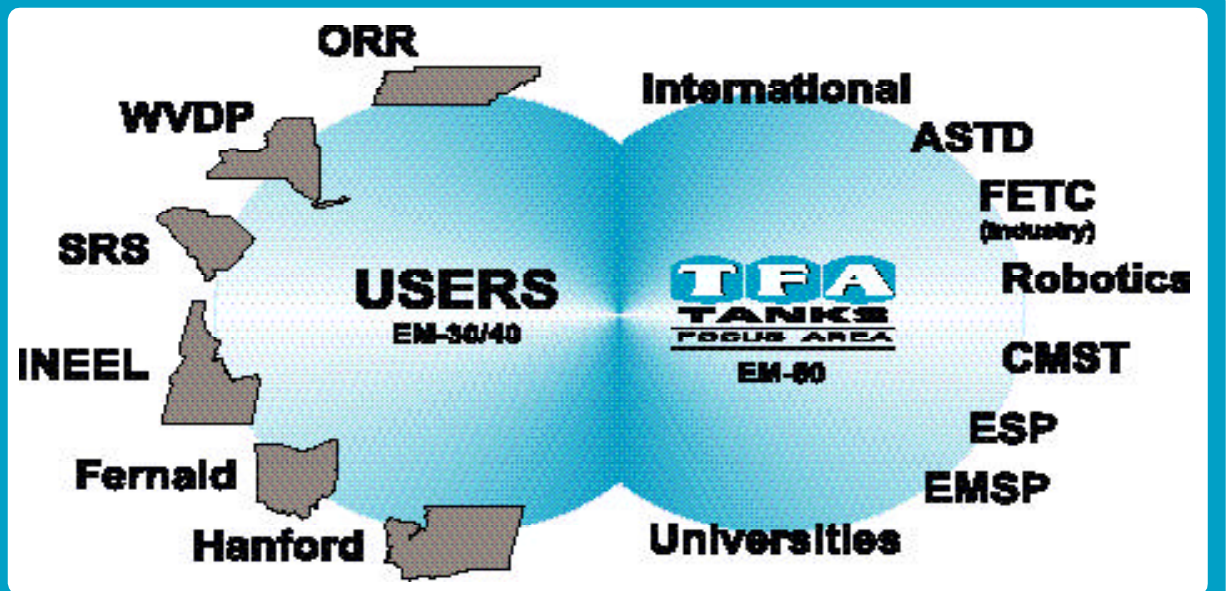
In 1996, DOE managers of HLW programs in the field and at headquarters established a HLW Steering Committee (HLWSC) to develop policies, planning, and the integration necessary to formulate and implement an effective and efficient complex-wide HLW program. One of the functions of the HLWSC is to serve as the EM user steering organization for the Tanks Focus Area to ensure it meets program needs. The HLWSC endorsed the FY1998 Tanks Focus Area program through their concurrence on the FY1998-2002 Multi Year Program Plan, and has endorsed the FY1999-2003 plan. As the Coordinator of the HLWSC, it has been my privilege to work with this dedicated organization over the past year.

Kenneth G. Picha, Jr., Coordinator, High-Level Waste Steering Committee

THE TANKS FOCUS AREA STRATEGY

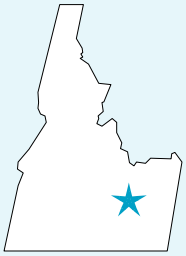
The U.S. Department of Energy (DOE) Office of Environmental Management (EM) established the Tanks Focus Area through the Office of Science and Technology (OST) to develop and deliver technical solutions that will enable safe and effective tank waste remediation and closure. The Tanks Focus Area is one of five focus areas within OST: subsurface contaminants, mixed waste, deactivation and decommissioning, plutonium stabilization, and waste tank remediation. These focus areas form the foundation of the department's response to the daunting task of cleaning up waste generated during nuclear weapons production.

The Tanks Focus Area targets the disposition of more than 90 million gallons of radioactive and chemically hazardous waste stored in 271 underground storage tanks and seven calcine vaults at four DOE sites. The tanks are approaching, and in many cases have exceeded, their design service life, making tank waste



"Focus Area Centered" describes the use of the Tanks Focus Area as the hub of DOE's OST program elements - bringing them together for the users. User sites include the Oak Ridge Reservation (ORR), Savannah River Site (SRS), Idaho National Engineering and Environmental Laboratory (INEEL), Fernald Site, and the West Valley Demonstration Project (WVDP). OST program elements include the Characterization, Monitoring, and Sensor Technology (CMST), Efficient Separations and Processing (ESP), and Robotics Crosscutting Programs; Industry, International, and University Programs; the Accelerated Site Technology Deployment (ASTD) Program; and the Environmental Management Science Program (EMSP).

Oak Ridge Reservation
34 Tanks
0.6M Gallons
0.2M Curies



Idaho National Environmental and Engineering Laboratory
11 Tanks
7 Calcine Storage Facilities
3M Gallons
52M Curies

Hanford Site
177 Tanks
54M Gallons
198M Curies

Savannah River Site
51 Tanks (2 closed)
33M Gallons
534M Curies

271 Tanks
7 Calcine Storage Facilities
90.6M Gallons
784.2M Curies

remediation an issue of urgency and public concern. Sixty-eight tanks are known or assumed to have leaked since they were built in the 1950s. Sixty-four tanks have been interim stabilized to prevent leakage. Leaked waste migrates into the soil surrounding a tank and eventually reaches ground water. In some cases, tank contents react to form flammable gases, introducing another safety problem. These tanks must be maintained in a safe condition to control the risks of waste migration and exposure to workers, the public, and the environment.

Mission Not Impossible

Until recently, many of the steps necessary to safely store, characterize, retrieve, pretreat, immobilize, and ultimately close tanks were not possible. Today, they are being achieved with the new technical solutions provided by the Tanks Focus Area and its partner programs. In fiscal year (FY) 1998, a second high-level waste tank was declared closed at SRS, and waste was removed from eight tanks at the ORR. Significant progress was also made towards developing other technical solutions to achieve waste retrieval, pretreatment, immobilization, and tank closure.

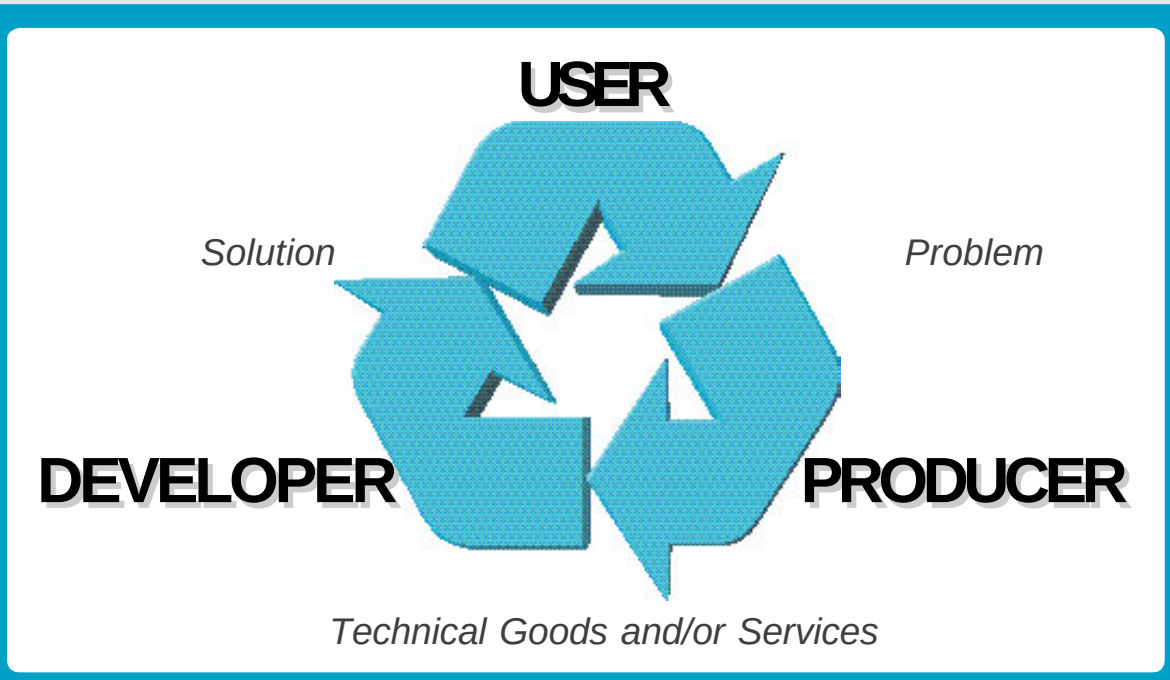
Accomplishments like these do not come easily. New technical challenges are encountered at every step. To meet these challenges, the Tanks Focus Area responds to the highest-priority needs with the technical solutions that enable baseline remediation, improve operations, and answer the questions necessary to address both current and future operational issues.

Users Drive the Program

The Tanks Focus Area builds its technical program based on needs submitted by user organizations. Individual site needs are analyzed and technical responses developed to address the needs. Users review the responses for applicability and adequacy to the submitted need. Accepted technical responses are then subjected to ranking criteria and prioritized by user participants to develop the program. User organizations validate the final program priorities. This practice ensures consensus and user acceptance.

The Tanks Focus Area program uses a User-Producer-Developer model. Users, the sites who will benefit from the technical solution, define the problem. Producers include industry, universities, and national laboratories that provide technical goods and services. Developers modify the technical goods and services into a solution and deliver it to the user. Users implement the solution. This model emphasizes the user's participation to ensure the solution meets their need.

To accomplish its mission, the Tanks Focus Area goals include increasing sites' use of OST-funded solutions, reducing programmatic and technical risk, and dedicating a portion of the program to contingency or alternative technology approaches. Several strategies are required to support the Tanks Focus Area mission and goals: meeting user needs, building and nurturing user-producer-developer teams, developing and executing a leveraged program, and providing a balanced portfolio of near- and long-term investments.



The Tanks Focus Area's program uses a User-Producer-Developer model. Users, the sites who will benefit from the technical solution, define the problem. Producers include industry, universities, and national laboratories who provide technical goods and services. Developers modify the technical goods and services into a solution and deliver it to the user. Users implement the solution. This model emphasizes the user's partcipation to ensure the solution meets their need.

Tank waste remediation is accomplished through an integrated flowsheet that includes the following activities:

- **Safe Waste Storage**
- **Waste Mobilization and Retrieval**
- **Conditioning, Transfer, and Retrieval-Pretreatment Integration**
- **Waste Pretreatment**
- **Waste Immobilization**
- **Tank Closure**

These six areas represent major groupings of tank remediation process steps, critical needs, and the Tanks Focus Area technical solutions.

Mark Frei is excited about the role of new technology in the closure of gunite tanks at the ORR. These tanks, which store transuranic waste from activities at the Oak Ridge National Laboratory during the 1950s and '60s, are being successfully closed because of a suite of new technologies including the Light-Duty Utility Arm; its associated Confined Sluicing End Effector, a high pressure water sludge and scale remover; and the Houdini robot. This last device has cleaned out the sludge from the Melton Valley tanks and performed decontamination of tank walls, which was "not possible a year ago."

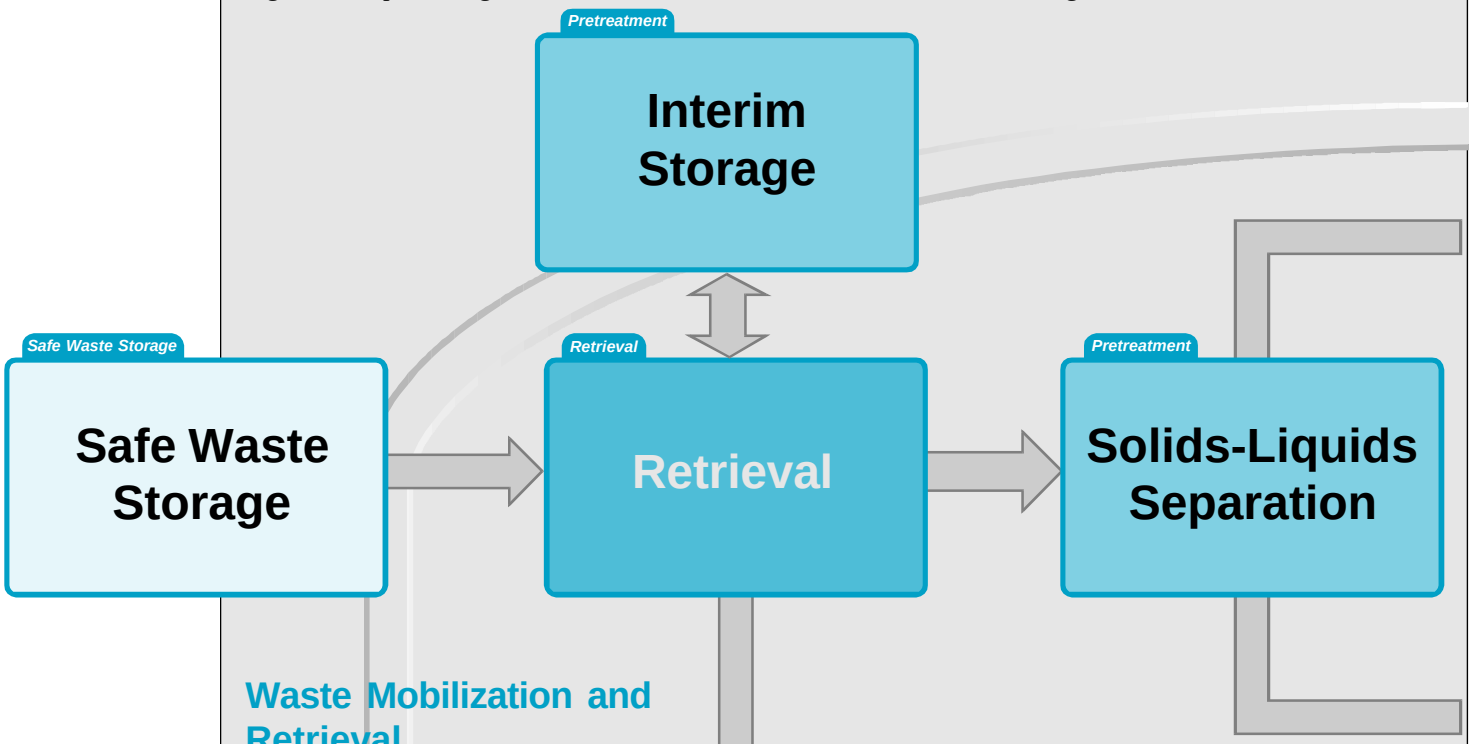
All in all, Frei sees "good things on the horizon." He views the Tanks Focus Area as "a model of connecting the science, the technology, and the users."

"You hear it from field office people. The ultimate customer is out there, and OST is paying attention. I'm excited," he says, "by the change in focus of the science and technology program over the last one-and-a-half years towards user needs. That's huge. That's not just words."

Safe Waste Storage

Each site requires improvements in monitoring tank integrity, preventing tank corrosion, ventilating tanks, and characterizing the waste within the tanks. Additionally, waste reduction technologies are needed to minimize the amount of waste entering the tank farms.

The Tanks Focus Area is investing in the development of monitors and sensors to better control the addition of chemicals added to the tanks to prevent corrosion. Real-time tank wall inspection and corrosion-monitoring technologies will permit a more proactive approach to monitoring the condition of the tanks. Other Tanks Focus Area investments include passive ventilation systems and high-efficiency particulate air filters that can be regenerated, promising reduced cost and risk associated with safe waste storage.



Waste Mobilization and Retrieval

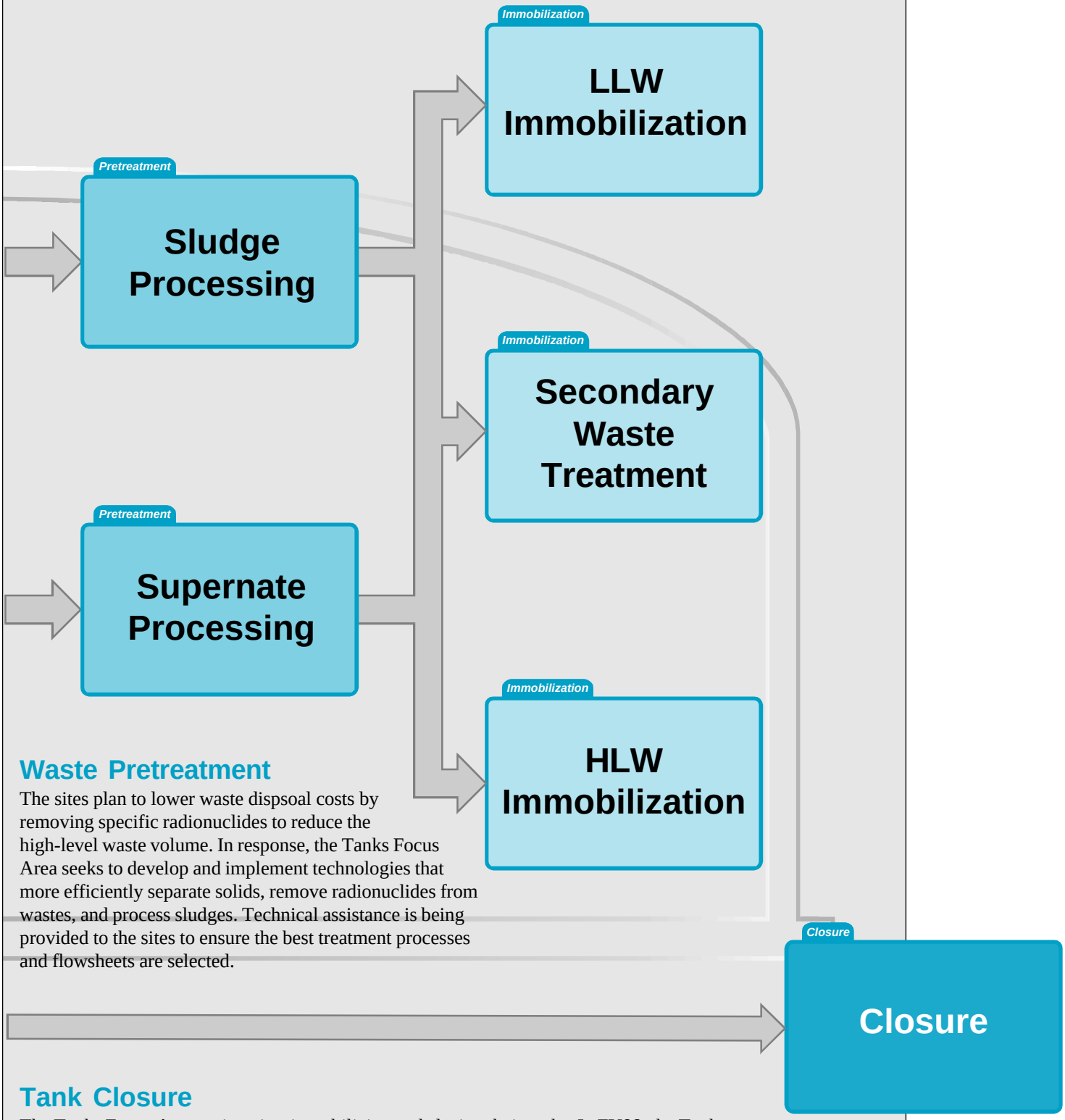
Improved or new methods to safely mobilize wastes constitute the Tanks Focus Area's major areas of emphasis in waste mobilization and retrieval. The Tanks Focus Area will continue its investigation of improved mixing and pumping technologies, including potential developments available from the United Kingdom and Russia. The sites' concerns with waste leakage during retrieval operations are being addressed through a wide range of Tanks Focus Area activities that include improved control of water addition during retrieval, technologies for detecting leaks, and operational strategies in the event a leak is detected.

Conditioning, Transfer, and Retrieval-Pretreatment Integration

The Tanks Focus Area supports site efforts to resolve technical issues associated with storing retrieved wastes and transferring the wastes for treatment and immobilization. The Tanks Focus Area is investigating waste reprecipitation, solids formation, and waste transfer line plugging. This work includes monitors that report the condition of the waste and adapting and testing systems that unplug pipe blockages. Thermodynamic laboratory studies increase the knowledge of waste chemistry to plan for waste storage and transfer. These studies will produce results that impact both retrieval and pretreatment operations.

Waste Immobilization

The Tanks Focus Area continues to support sites' requirements for immobilization operations and privatization of waste treatment. This wide-ranging work includes studies and tests on glass formulations, waste product performance, feed preparation, improved melter designs, and more efficient and productive melter operations. The Tanks Focus Area's work provides DOE needed product acceptance criteria that can be used to evaluate the immobilized waste form delivered from privatization contractors.



Waste Pretreatment

The sites plan to lower waste dispsoal costs by removing specific radionuclides to reduce the high-level waste volume. In response, the Tanks Focus Area seeks to develop and implement technologies that more efficiently separate solids, remove radionuclides from wastes, and process sludges. Technical assistance is being provided to the sites to ensure the best treatment processes and flowsheets are selected.

Tank Closure

The Tanks Focus Area assists sites in stabilizing and closing their tanks. In FY98, the Tanks Focus Area invested in improving grout formulation to stabilize tanks and providing technical bases for tank closure. Based on site needs, the Tanks Focus Area is investigating vadose zone contamination. The Tanks Focus Area integrates a wide range of activities from other OST programs directed at solving these problems. These activities include characterization, retrieval, ex situ tank processing, and in situ grouting systems.

A YEAR OF ACCOMPLISHMENT

Delivering innovative solutions is the critical measure of the Tanks Focus Area's success. These solutions come in three forms:

- **Deployment** of technical solutions, including actual installation and operation of technologies in tanks or waste treatment facilities
- **Demonstration** of technologies to support selection of technology alternatives or to demonstrate progress towards ultimate deployment of selected technologies
- **Data delivery** to fill gaps and support key decisions defining paths to closure

Supplementing these products is technical assistance to the user community. The Tanks Focus Area Technical Team and its Technical Advisory Group include scientists and engineers with extensive background and experience in addressing waste remediation issues unique to DOE. As part of their responsibilities within the Tanks Focus Area, these technical experts are often called upon to provide technical assistance directly to end users to support implementation of alternative cleanup approaches and technologies, help solve immediate operational issues, and improve efficiencies. Technical assistance is provided through technical exchanges, technical reviews, and direct consultation on specific technical issues.

Joel Case, DOE-ID HLW Program Director and HLW Steering Committee Member, approves the Tanks Focus Area's Multi Year Program Plan for FY99-03

Accelerated Site Technology Deployment Program

In FY98, the Tanks Focus Area became an active participant in the Accelerated Site Technology Deployment (ASTD) program. The purpose of the ASTD program is to accelerate the use of new technologies and innovative approaches to achieve the cleanup goals identified by DOE-EM. Waste tank sites submitted proposals to apply several technologies developed by the Tanks Focus Area and its partner programs–the Crosscutting, Industry, International, University, and Science Programs–in their field operations.

Oak Ridge

Two Tanks Focus Area technologies, the Cesium Removal Demonstration System (TMS ID 21) and the Out-of-Tank Evaporator (TMS ID 20), were joined under an ASTD project to efficiently reduce the radioactivity and volume to tank waste, freeing up valuable space for newly generated waste. The Out of Tank Evaporator was deployed in FY98

Another ASTD project improved waste mobilization and retrieval operations by delivering a new Waste Dislodging and Conveyance System (TMS ID 2116) to support coordination of retrieval operations with other OST technologies, including the Modified Light Duty Utility Arm (TMS IDs 85, 810, 835, and 890) and the Houdini remotely operated vehicle (TMS ID 98). Together these technologies helped ORR remove the liquid, sludge, and debris from three radioactive waste storage tanks.

Savannah River

In FY98, the Fluidic Sampler (TMS ID 2007) was deployed at SRS in a waste processing tank to better characterize the solutions prior to transfer to the Defense Waste Processing Facility. In FY99, a Fluidic Sampler deployment will occur in a sludge processing tank at SRS under the ASTD Program.

Hanford

Hanford will deploy Slurry Monitoring (TMS ID 1547) as part of the Hanford Tank Initiative to determine suspended solids concentration to prevent transfer line plugging.

DEPLOYMENTS

Safe Waste Storage

Second-Generation Corrosion Probe (TMS ID 1985)

Corrosion probe during insertion at Hanford in September 1998. The sensors are located right below the worker's hands. Data gathered by these samples will be used to protect the tank from corrosion and minimize waste volumes.

Costs related to waste tank corrosion at DOE sites can be as high as $27 million per year. Tanks at Hanford and SRS are protected from corrosion by the addition of corrosion inhibitors. The Corrosion Probe provides real-time monitoring of the electrochemical noise produced by corrosion processes. This noise can be correlated to corrosion activity occurring in the tank. The Corrosion Probe's monitoring capability enables the sites to add corrosion inhibitor when it is needed most and to add only the amount needed. Reducing the amount of inhibitor significantly reduces downstream processing and immobilization costs associated with additional volume.

The second-generation electrochemical noise Corrosion Probe was deployed to monitor tank corrosion at Hanford. In addition to the Corrosion Probe, CMST Crosscutting Program is supporting development of a corrosion species monitor. A hybrid probe combining the electrochemical noise technology with corrosion species detection capabilities is planned for deployment at SRS in FY00.

Pretreatment

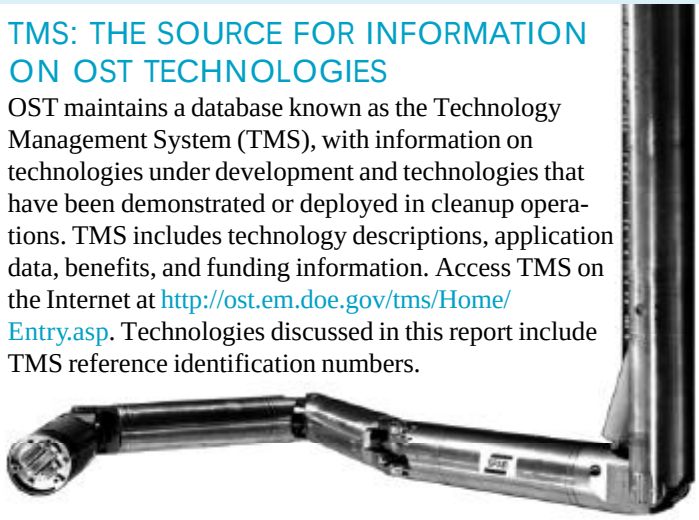
Fluidic Sampler (TMS ID 2007)

Tank sampling is a critical part of waste tank operations from monitoring the tank contents to ensuring the privatization contractor is receiving waste that meets contractual requirements. In FY98, the Fluidic Sampler was deployed at SRS to gether tank waste samples. Additional samplers are being deployed for sludge processing tasks at SRS in FY99. An additional sampler will be deployed in a sludge processing tank at SRS in FY99 through the ASTD program.

Compared to current sampling methods, the Fluidic Sampler is safer, requires less maintenance, and delivers more representative samples. The sampler is completely shielded and can be left in the tank to minimize worker radiation exposure.

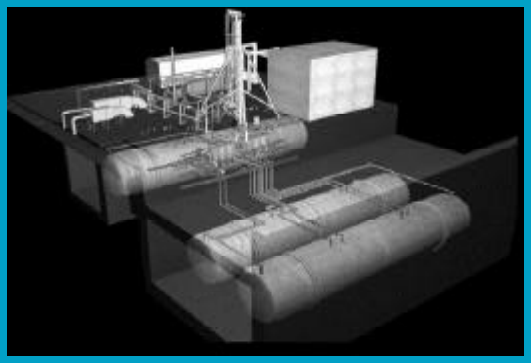
TMS: THE SOURCE FOR INFORMATION ON OST TECHNOLOGIES

OST maintains a database known as the Technology Management System (TMS), with information on technologies under development and technologies that have been demonstrated or deployed in cleanup operations. TMS includes technology descriptions, application data, benefits, and funding information. Access TMS on the Internet at http://ost.em.doe.gov/tms/Home/Entry.asp. Technologies discussed in this report include TMS reference identification numbers.



Retrieval

Fluidic Pulse Jet Mixer (TMS ID 1511)



Computer graphic of the Fluidic Pulse Jet Mixer installation at ORR. This technology uses existing piping and has no in-tank moving parts, simplifying deployment and maintenance.

The Fluidic Pulse Jet Mixer was deployed at ORR to mobilize tank waste in horizontal tanks with limited access so it could be pumped to a holding facility to await immobilization. The Fluidic Pulse Jet Mixer uses a set of pulse tubes submersed in the waste. Supernatant is suctioned into a holding vessel and then expelled, mixing the tank contents (usually liquids and sludge). The mixing action is repeated until the tank contents are suitable for pumping. This technology can use available in-tank piping, has no in-tank moving parts, and minimizes the need to add liquid. In its first deployment, the Fluidic Pulse Jet Mixer retrieved an estimated 80-90% of the tank's waste. Additional deployments of the Fluidic Pulse Jet Mixer are planned at Oak Ridge through the ASTD program.

Retrieval

Borehole Miner (TMS ID 1499)

The Borehole Miner in use at ORR. Compared to baseline methods, the adjustable and extendible nozzle is able to mobilize more effectively, allowing more waste to be removed.

The Borehole Miner was deployed in four tanks during July 1998 at ORR to mobilize tank sludge and saltcake waste and to clean tank interior surfaces. In only two months, retrieval of all four tanks was completed, and approximately 60,000 gallons of waste were mobilized and transferred to a holding facility.

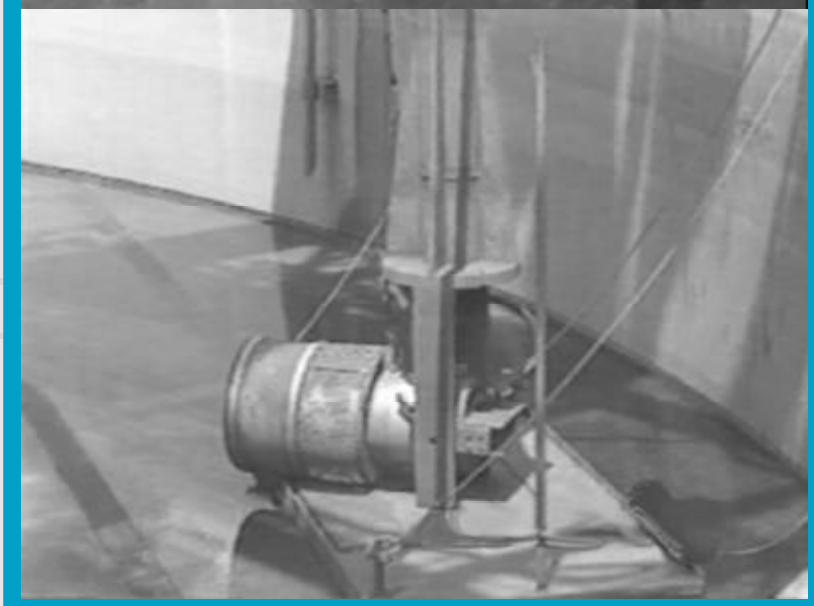
The Borehole Miner uses a water jet located on an extendible and adjustable nozzle. The system recirculates fluid through the water jet. The Borehole Miner is more precise and efficient than sluicing, is able to thoroughly clean tank surfaces, can clean complex tank structures, and minimizes the addition of water. An innovative user interface provides a real-time graphic display of the system in the tank.

Retrieval

Flygt Mixer (TMS ID 2232)

The Flygt Mixer is a submersible mixer for large quantities of tank waste. Mixing is necessary to prepare the waste for transfer for final treatment and immobilization. The equipment was installed and is being tested at ORR. The Flygt Mixer offers a low-cost alternative to the baseline mixing technology currently identified for Hanford and SRS.

The Flygt Mixer uses an open propeller to move waste within the tank. This configuration creates long-range currents capable of mixing over 20,000 gal/min of tank waste. A test program developed recommendations on a number of mixers, mixer sizing and configuration data, and recommended operating practices in full-scale waste tanks. Flygt Mixers are smaller and less costly to deploy than standard mixer pumps.



Above: A single submersible Flygt mixer during testing in the full-scale mockup tank.
Below: SRS developed a mixer deployment mast to enhance the mixer's capabilities.

Retrieval

Salt Sampler (TMS ID 2359)

Above: The salt sampler during a demonstration
Below: The salt sampler uses two different sample cylinders to accommodate different salt waste surfaces.

Salt samples are an important part of waste characterization to support tank waste retrieval and closure. Proven in testing on dry materials, the Salt Sampler was deployed at SRS in FY98 to gather salt samples from a tank annulus. The Salt Sampler, an Industry Program technology, successfully retrieved dry samples, but had difficulty with unforeseen wet salt samples.

The Salt Sampler uses a lightweight, segmented mast equipped with sample cylinders. The mast design allows the sampler to be assembled, then lowered to the proper depth inside the tank. The sample cylinders are designed to either cut core samples or scrape and vacuum samples from the salt surface.

Closure

Shallow-Fluted Auger (TMS ID 2230)

The Hanford Tanks Initiative project obtained four hard heel samples from the floor of a tank using a new auger-sampling tool with shallow-pitched flutes. Samples were taken from a waste mound that had the highest radiation reading (430 Rad per hour) during a waste depth and radiation survey conducted last year. The successful sampling campaign demonstrated for the first time that waste can be recovered from the deepest tanks at Hanford with simple auger tools and that, using a special riser adapter, two auger samples at different locations on the tank floor can be retrieved from a six-inch riser.

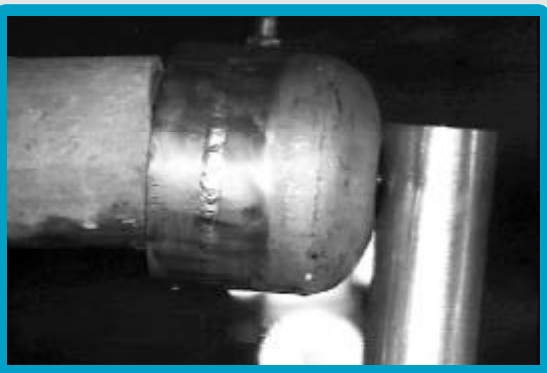
After retrieval from the tank, the auger samples were transferred to an on-site laboratory for analysis. Analyses of the retrieved hard heel waste samples will be used to validate or revise best-basis inventory estimates of the key risk-based radionuclides and hazardous chemicals left in the tank. Results support the ongoing Retrieval Performance Evaluation at Hanford.

Previously, auger-sampling tools of various designs have been used with limited success in Hanford tanks containing sludge, saltcake, and dry waste. Adaptation of the new bit with shallow-pitched flutes by the Hanford Tanks Initiative project team enabled this technology to succeed. This successful deployment resulted in auger sampling using the shallow-fluted bit being reintroduced as the Hanford baseline sampling technology.

The shallow-fluted auger obtained four samples from the floor of a Hanford tank. Based on its success, this tool became a new baseline sampling technology.

Closure

Pipe-Plugging End Effector (TMS ID 2093)



The Pipe-Plugging end effector is used to isolate tanks by plugging inlet piping. Plugging these pipes prevents water intrusion into the tank.

Tanks at ORR contain several openings for pipes once used to deliver waste to the tanks. Rainwater can enter a tank through these pipes. To prevent water from leaking into the tanks after retrieval and closure activities are finished the pipelines must be plugged. A suite of tools is being developed to accomplish tank isolation once waste retrieval is complete. These tools will be deployed remotely using the Modified Light-Duty Utility Arm (MLDUA) and the Houdini remotely operated vehicle (TMS ID 85 and 98 respectively).

Historically, efforts to externally plug the openings where pipes enter the tank have been unsuccessful. In FY98, a prototype sealant cup was used to plug a pipeline in a tank at ORR. The plug, installed remotely from inside the tank, successfully stopped the influx of water and significantly improved the vacuum control on the tank. Pipe-plugging tools will be further tested in other tanks at Oak Ridge after waste retrieval.

DEMONSTRATIONS

Closure

Pipe-Cutting/Cleaning System (TMS ID 2093)

Designed for use with the MLDUA and Houdini systems, the pipe-cutting and pipe-cleaning end effectors prepare tank piping for the pipe plugging end effector.

To effectively seal pipes in tanks at ORR as described above; the pipes must be properly cut and cleaned. To meet these needs, two additional tools are under development. These are a pipe-cutting end effector and a pipe-cleaning end effector. The pipe-cutting end effector is a portable band saw modified for operation and handling by the MLDUA and Houdini syatems. The pipe-cleaning end effector is a drill motor equipped with an abrasive wheel for cleaning the outside surface of a pipe, also altered for remote handling. The pipe-cutting and -cleaning end effectors were fabricated and demonstrated in FY98. In FY99, the pipe-cutting, -cleaning, and -plugging end effectors will be deployed together at Oak Ridge.

Closure

Multipoint Grout Injection (TMS ID 2093)

Residual contamination remaining after waste retrieval and the high cost of retrieval are two factors that restrict tank closure. A technology is needed to stabilize waste heels in situ and to fill tank void space to meet closure criteria. The Tanks Focus Area is investigating multipoint grout injection technology using a tailored grout formulation. Oak Ridge will use multipoint grout injection to grout a tank for closure in FY00. In FY98, grout specifications and process requirements for in situ stabilization were developed and published in a report titled *Grout and Glass Performance in Support of Stabilization/Solidification of ORNL Tank Sludges (September 30, 1998)*. SRS is also evaluating multipoint grout injection for use in closing their solvent extraction tanks

Rather than injecting grout into the tank with a single low-pressure or gravity flow system, a multipoint grout injection system uses multiple high-pressure injectors to grout the tank. Application of multipoint grout injection results in the production of a uniformly mixed monolith of grout and waste with superior leach-resistance properties. Multipoint grout injection was successfully tested in a large-scale cold demonstration. Additional cold grout-sensitivity tests and hot tests with actual tank sludge were performed to demonstrate the compatibility of the grout and the sludge.

In addition to the grout injection demonstration, the Tanks Focus Area provided technical assistance to SRS. The overall closure plan for the solvent extraction tanks was reviewed to help identify potential problems and integrate lessons learned from other closure activities.

Retrieval

Fixed-Depth Nested Sampler (TMS ID 2119)

The Fixed-Depth Nested Sampler is being developed collaboratively with Hanford Tank Farm Operations, Industry Programs, CMST, and Robotics, to provide a method for collecting representative waste samples from the Hanford tanks. In August 1998, cold tests were conducted using waste tank simulants to demonstrate feasibility of the technology.

The Fixed-Depth Nested Sampler is used to safely sample radioactive waste from large underground tanks. The sampler gathers discrete data at different tank depths, resulting in a more representative sample. The Fixed-Depth Nested Sampler solves a number of the problems associated with current tank sampling methods through safer operation, reduced sampler maintenance, safer and easier ultimate disposal, and improved sample representation. A Fixed-Depth Nested Sampler will be used to determine the waste composition in Hanford feed staging tanks to ensure compliance with contractual agreements between DOE and privatization contractors.

Closure

Hanford Tanks Initiative Vadose Zone Characterization System (TMS ID 2118)

The Vadose Zone Characterization System consists of three components: the Cone Penetrometer, a Multisensor package, and the Multipoint Soil Sampler.

To obtain data from the vadose zone surrounding the Hanford Tanks Initiative project tank, the Tanks Focus Area demonstrated the Cone Penetrometer. The data gained from this demonstration will verify or be used to revise current estimates of contamination leaked from the tank. This information is vital to the performance assessment in support of tank waste retrieval and tank closure decisions.

Shown here ready to "push," the Cone Penetrometer can deploy a sensor package to gather data about the vadose zone. Vadose zone is a term that refers to the unsaturated soil above the water table. This data is critical to understanding the magnitude and movement of waste in the soil surrounding tanks.

Cone Penetrometer
The Cone Penetrometer platform is a skid-mounted version of a commercially available, truck-mounted unit designed by Applied Research Associates, Inc. A skid-mounted system allows greater flexibility for placement in a tank farm. The Cone Penetrometer is a deployment tool whose application is determined by the sensor package. A grouting tip is used to close the Cone Penetrometer borehole during withdrawal of the drill string. As part of the Vadose Zone Characterization System, the Cone Penetrometer will be used to place sensors around a tank to provide vadose zone characterization data. In April 1998, push performance testing of the Cone Penetrometer Platform and selected probes at Hanford achieved a depth of 160 feet, exceeding the performance goal by 10 feet. This push performance test demonstrated that the Cone Penetrometer could meet and exceed the performance criteria. Cone Penetrometer probe developmental testing is planned for completion in early FY99 with full deployment following later in FY99.

Multipoint Soil Sampler
The soil sample chamber of the Multipoint Soil Sampler is designed to take samples at several discrete depths during a single Cone Penetrometer push, reducing the number of pushes necessary to characterize an area of subsurface contamination.

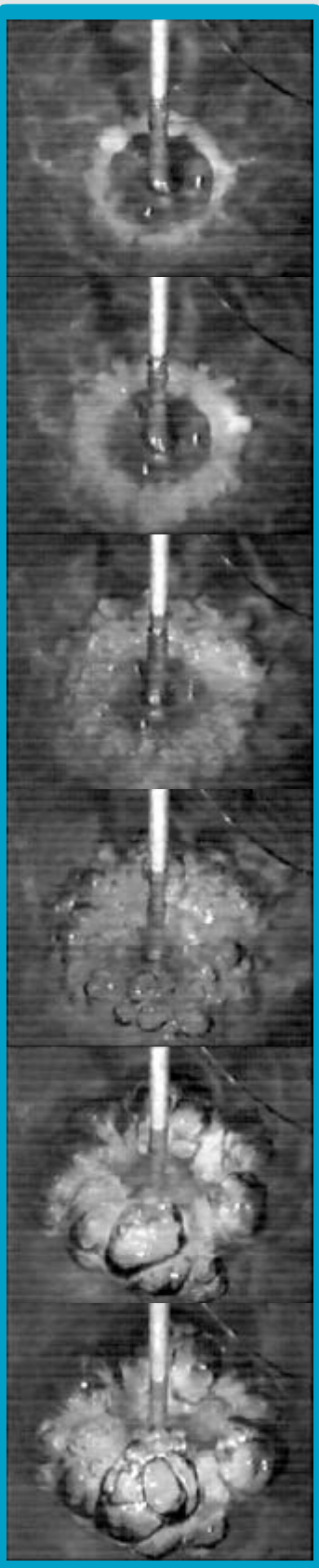
Multisensor Probe
The Multisensor Probe combines X-ray fluorescence and a gamma detector, enabling the user to analyze for a larger number of analytical parameters than a typical single-sensor probe.

Retrieval

Pulsed-Air Mixing (TMS ID 1510)

Pulsed-Air Mixing was demonstrated at ORR in FY98. Pulses of air are introduced using large horizontal, circular plates positioned just above the tank floor. The pulses of air can be delivered between the plates or from the underside of the lower plate. Pulsed-Air Mixing differs from conventional air sparging in that single, large bubbles are introduced into the tank fluid periodically instead of small bubbles being injected continuously. This results in vigorous mixing that effectively suspends solids from the tank floor and maintains those solids in a uniform suspension.

The Pulsed-Air Mixing system is more economical than large mixer pumps for suspending sludge and has few moving parts. Thorough and uniform mixing is important to prevent pipeline plugging when waste is transferred. Pipeline plugging results in months of project downtime to construct a new pipeline or to repair the existing pipeline.

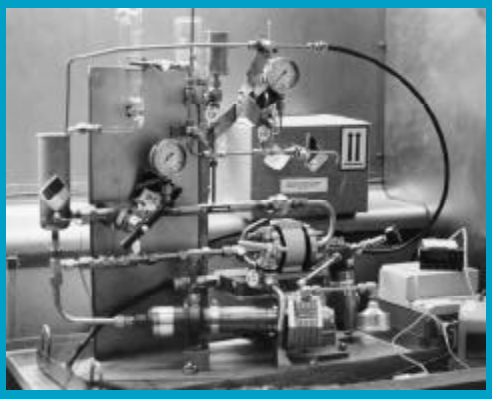


Pulsed-Air mixing introduces large bubbles that grow and collapse, creating a vigorous mixing action.

Pretreatment

Crossflow Filtration-Cells Unit Filter (TMS ID 350)

Testing and evaluation of a Cells Unit Filter (CUF) has been demonstrated at INEEL Remote Analytical Laboratory. The testing was conducted to determine the efficiency of the CUF in removing solids from INEEL calcined waste, and the ability to regenerate the filter by backflushing or chemical treatment. Results of the test and associated analysis are documented in an INEEL technical report titled *Evaluation and Testing of the Cells Unit Crossflow Filter on INEEL Dissolved Calcine Slurries (August 1998)*.



The removal of undissolved solids is necessary to prepare the waste for radionuclide separation. At INEEL, the Cells Unit Filter demonstration removed these solids from dissolved calcine waste.

Current planning baselines require that Idaho's inventory of calcined waste be separated into high- and low-activity waste fractions before vitrification. Removal of the solids is required so that the majority of the separated waste stream can meet the U.S. Nuclear Regulatory Commission's regulations for low-level waste disposal, while also reducing the amount of high-activity waste requiring vitrification. Successful implementation of a solids-separation system and the ability for in situ filter regeneration (the ability to re-use a filter without removing it) would mean a significant overall cost reduction for disposal of INEEL wastes. Results of this work will be incorporated into an integrated demonstration of technologies for actinide and fission product removal in FY99.

Pretreatment

Saltcake Dissolution (TMS ID 1989)

Saltcake is dissolved prior to waste being retrieved. There is potential for dissolved wastes to form solids through reprecipitation. Hanford Tank Farm Operations must have a clear understanding of the chemical and physical properties of the waste feed. No significant data is available to evaluate in-tank dissolution parameters for the various saltcake wastes that exist in Hanford's single-shell tanks. In conjunction with University Programs, the Tanks Focus Area is performing the first major studies to evaluate saltcake dissolution and reprecipitation.

Initial laboratory tests were performed in FY98 to determine how much saltcake could be dissolved at various dissolution levels. Actual saltcake samples representing three different types of single-shell tank waste were tested. The FY98 results provided thermodynamic data to Tank Farm Operations that will aid modeling efforts. Continuing studies will expand on these tests. Plans call for an additional saltcake type to be tested, samples analyzed for additional components, and tests in addition to saltcake dissolution to be performed.

As a result of advancements in the understanding of saltcake dissolution chemistry, the Tanks Focus Area was able to provide technical assistance to Hanford Tank Farm Operations for a related technical problem. The crust in a Hanford tank has been growing and the growth raises safety questions. Tanks Focus Area researchers used dilution and pumping models to determine the consequences of adding 1%, 5%, and 10% inhibited water to the tank's crust. The extensive thermodynamic calculations done as part of the modeling showed that adding 5% inhibited water would reduce the solids volume by 30%. These modeling calculations will be used further to evaluate waste transfers and water additions as a solution to this pressing safety issue.

DATA DELIVERIES

Pretreatment

Leachate Chemistry

In addition to solids formation in saltcakes, processing of sludge leachates can result in formation of particulate, gels, or colloids. Acidic and caustic pretreatment procedures were run on samples of sludge from Hanford waste tanks. All leachates and wash solutions from the tests were examined for the formation of solids. Conditions where gelation and precipitation in leachates or wash solutions were found and strategies for avoiding them were proposed. Data from side-by-side comparison of acidic and caustic treatment strategies was summarized and published in a deliverable report *Status of Solids Control in Leachates (July 1998)*.

Pretreatment

Sludge Washing (TMS ID 233)

Sludges retrieved from tank waste require processing to remove entrained radionuclides for downstream processing and to remove salts and minerals that may impact vitrification. Sludge processing consists of washing and separations operations.

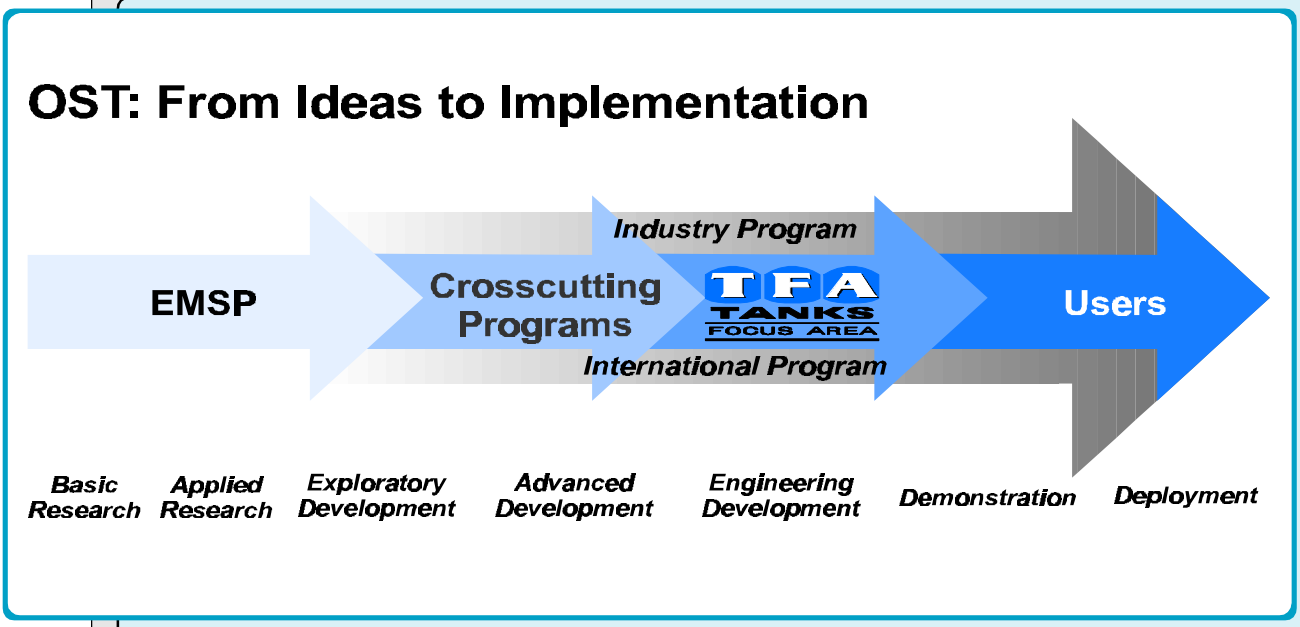
Water washing followed by dilute caustic soda washing is the baseline process for Hanford tank sludges. Testing the baseline process with actual sludge samples is necessary to either confirm or recommend changes to assumptions made in developing the process flowsheet. In FY98, sludge washing, parametric caustic leaching, and chromium removal tests were completed on radioactive sludge samples from Hanford tanks.

Pretreatment

Washing and Caustic Leaching of Hot Sludge Samples

The results of the sludge washing and caustic leaching tests, which establish the basis for process parameters, were published in a report entitled *Washing and Caustic Leaching of Hanford Tank Sludge: Results of FY 1998 Studies (December 1998).*

Spectroscopy, radiochemical analyses, and microscopy studies coupled with X-ray diffraction techniques were performed on samples of untreated and treated sludge to determine chemical species present. The process variables investigated included time, temperature, and hydroxide concentration. A number of factors influencing process effectiveness were identified.



The Tanks Focus Area maintains partnerships to develop, produce, and deploy technical solutions. One of these partners is the Environmental Management Science Program (EMSP). This program focuses science on the high-impact needs of the user by teaming scientists and engineers in the research, technology development, and deployment process. A few examples of ongoing EMSP projects are highlighted below.

- *Mechanism of Pitting Corrosion Prevention by Nitrite in Carbon Steel Exposed to Dilute Salt Solutions* will develop a fundamental understanding of the role of nitrite in preventing the breakdown of protective oxide coating on steel and the onset of pitting. An understanding is expected to lead to superior and more cost-effective corrosion prevention.

- *Removal of Technetium, Carbon Tetrachloride, and Metals from DOE Properties* defines a new class of powerful reducing agents that are particularly effective at reducing technetium to forms not likely to volatilize during vitrification.

- *Fundamental Chemistry, Characterization, and Separation of Technetium Complexes in Hanford Waste*, and *Research Program to Investigate the Fundamental Chemistry of Technetium* are determining the fundamental and complexation chemistry of technetium. These data assist DOE to better evaluate and understand privatization proposals to remove technetium during HLW processing.

- Two of the four alternatives to In-Tank Precipitation at SRS, *Ion Exchange Using Crystalline Silicotitanate (CST)*, and *Alkaline Solvent Extraction*, are new technologies that resulted from EMSP research.

- *New Silicotitanate Waste Forms: Development and Characterization* presents a new strategy for disposing of CST ion exchangers by in situ heat treatment to produce an alternate waste form with improved durability over borosilicate glass.

- *Design and Synthesis of the Next Generation of Crown Ethers for Waste Separations* compliments an ESP Crosscutting Program effort on cesium removal. This EMSP technology competed as one of the top four candidates for SRS salt disposition, illustrating the importance of combining directed research with technology development.

- Current methods for measuring and predicting long-term glass performance, especially for less-studied low-activity waste glasses, are not complete. Under the project, *Ion-Exchange Processes and Mechanisms in Glasses*, EMSP is developing an understanding of the processes and mechanisms controlling alkali ion exchange and correlating the kinetics of the ion-exchange reaction with structural glass properties.

Pretreatment

Chromium Removal

Chromium limits the amount of waste that can be added to a glass waste form. Removing chromium from the waste decreases the amount of glass to be disposed as HLW, significantly reducing disposal costs. In FY98, a series of small-scale laboratory tests evaluated chromium oxidation for removing chromium from actual samples of Hanford tank sludge. Testing showed that the removal of the water-insoluble chromium fraction by caustic leaching was inadequate. Thus, investigation turned to developing an alternative technology for removing chromium from Hanford sludges. The most promising method to date involves treating the sludge with permanganate. Data documented in the report *Oxidative Alkaline Dissolution of Chromium from Hanford Tank Sludges: Results of FY 1998 Studies (August 1998)* will help guide flowsheet development. A bench-scale demonstration of chromium leaching is planned in FY00.

Closure

Hanford Tanks Initiative - Interface Control

The residual hard heel waste in the Hanford Tanks Initiative's Tank C-106 will be removed using commercially available technologies. Documentation for site upgrades and vendor interface control was completed for testing an industrial retrieval system.

The tank will be sluiced to remove most of the waste. Waste remaining after sluicing may exceed the levels required by agreement between the DOE and Washington State. Technology alternatives to conventional sluicing are being investigated to remove this residual hard heel waste. Commercially available technologies are planned to be tested, selected, and installed by FY00.

Pretreatment

Cesium Removal from Dissolved Calcine

Cesium removal tests are conducted in "hot cells" to prevent radiation exposure to workers. Hot cells are heavily shielded compartments with thick lead glass windows and remote manipulators.

Several ion-exchange sorbents for removing cesium from INEEL dissolved calcine waste were tested and evaluated in FY98. CST, an inorganic ion-exchange sorbent, was recommended for future demonstration.

Plans for treating INEEL waste call for separating the site's liquid and calcined waste, into high- and low-activity portions. The low-activity portion must meet the U.S. Nuclear Regulatory Commission's definition of low-level waste. For INEEL waste to meet the commission's requirements, the bulk of the waste's cesium must be removed. Three ion-exchange sorbents were tested on simulated and actual waste. CST was selected for future demonstration because of its high capacity and ability to strongly hold cesium for storage. Results of the laboratory testing and data analysis will be published in FY99.

Pretreatment

Technical Assistance for SRS Salt Disposition

Highly radioactive cesium was previously removed from SRS tank supernatant using In-Tank Precipitation. However, In-Tank Precipitation was suspended in February 1998 because of technical and safety issues related to unwanted benzene generation during processing. A selection committee evaluated 130 alternative approaches to separating cesium from the supernatant. Those approaches were narrowed down to four: small-tank In-Tank Precipitation, ion-exchange using CST, solvent extraction, and direct grouting.

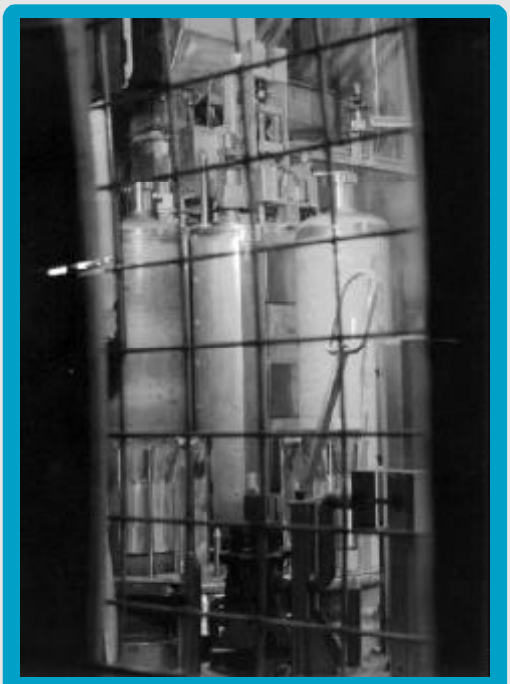
The Tanks Focus Area and ESP Crosscutting Program assisted SRS in identifying alternatives to the previously identified baseline of In-Tank Precipitation. Technical assistance involved collecting information on technologies developed through the Tanks Focus Area including CST, cesium removal technology, and alkaline solvent extraction developed by ESP. Alternatives were evaluated that led to selection and recommendation. A science and technology roadmap is being prepared for addressing questions and issues that must be answered to complete the design, construction, and operation of the recommended alternatives.

Immobilization

Defense Waste Processing Facility Liquidus Temperature (TMS ID 2009)

Liquidus temperature is the temperature at which crystals start to form in molten glass, producing problems with long-term glass performance and durability. The existing model for liquidus temperature is limited by available data, which has led to conservative waste loading. Better data on liquidus temperature will reduce the uncertainty in the process control model so the amount of waste loading in the glass can be increased resulting in major life cycle cost savings.

Vitrified glass samples were prepared in the laboratory and measurements taken to document the effect of glass composition on liquidus temperature. A liquidus temperature database was developed to support process control models. The data was presented in a technical report entitled *Liquidus Temperature Data for DWPF Glass (September 1998)*.



Melters combine waste and glass making materials together at high temperatures. This crystal formation in the glass results in a waste form with poor durability.

Immobilization

INEEL Thermal Denitration Process (TMS ID 82)

High nitrate in INEEL waste is detrimental to grout performance. Data was collected for recommending the best approach to remove nitrate from INEEL low-activity waste. Activities included laboratory and bench-scale testing of thermochemical denitration and an extensive survey to identify technologies used by the chemical process industries. The report titled *Denitration of High Nitrate Salts Using Reductants (September 1998)* recommended a thermochemical process. Low-activity waste will be immobilized in grout.

Immobilization

Grout versus Glass Life-Cycle Cost Analysis (TMS ID 82)

Grout and Glass (shown here) waste forms each have strengths and weaknesses. Tanks Focus Area life-cycle cost analysis helps the users to evaluate their low-activity waste form options.

Life-cycle cost analyses were conducted for treating tank sludges at ORR. Results supported evaluation of vendor proposals to treat TRU wastes in a privatized facility.

Selecting a final waste form for radioactive tank sludges was a critical decision. Grout and vitrification are two widely accepted technologies being used by the DOE to immobilize radioactive waste. Results of life-cycle cost analysis show that final disposal costs for immobilized remotely handled TRU from ORR would be $26.6 million for grout and $6.9 million for glass. Although vitrification has higher facility processing and decommissioning costs, disposal costs result in vitrification being more cost-effective. If permanent facilities are required, life-cycle costs tend to favor grout. However, if temporary facilities are adequate, life-cycle costs favor vitrification based on disposal costs and lower volume of immobilized product.

Immobilization

Melter Materials for High-Activity Sodium-Bearing Waste (TMS ID 2092)

A report published in FY98, *INEEL HLW Corrosion and Preliminary Glass Formulation for INEEL Zirconia HAW-Final Report (September 1998)* describes melter feed formulations and testing to support INEEL high-activity waste vitrification. High-activity waste compositions, analysis, appropriate glass formulations, development, and glass performance testing must be accomplished to support scaling up the INEEL high-activity waste vitrification process. Testing will be performed in these areas in FY99 to support process selection decisions.

Presently, vitrification is being studied to immobilize INEEL high-activity wastes. Production-scale vitrification technologies exist, but they have not been tested for INEEL waste chemistries. Consequently, the reaction of INEEL waste and melter feed formulation with the construction materials for the melter refractory, melter electrodes, and off-gas system components needs to be determined.

Report References for Data Delivery

Beahm, E. C., et al. Status of Solids Control in Leachates. ORNL/TM-13660. Oak Ridge, Tenn.: Oak Ridge National Laboratory, July 1998

Hrma, P., et al. Liquidus Temperature Data for DWPF Glass. PNNL-11790. Richland, Wash.: Pacific Northwest National Laboratory, September 1998.

Lumetta, G. J., et al. Washing and Caustic Leaching of Hanford Tank Sludge: Results of FY 1998 Studies. PNNL-12026. Richland, Wash.: Pacific Northwest National Laboratory, December 1998.

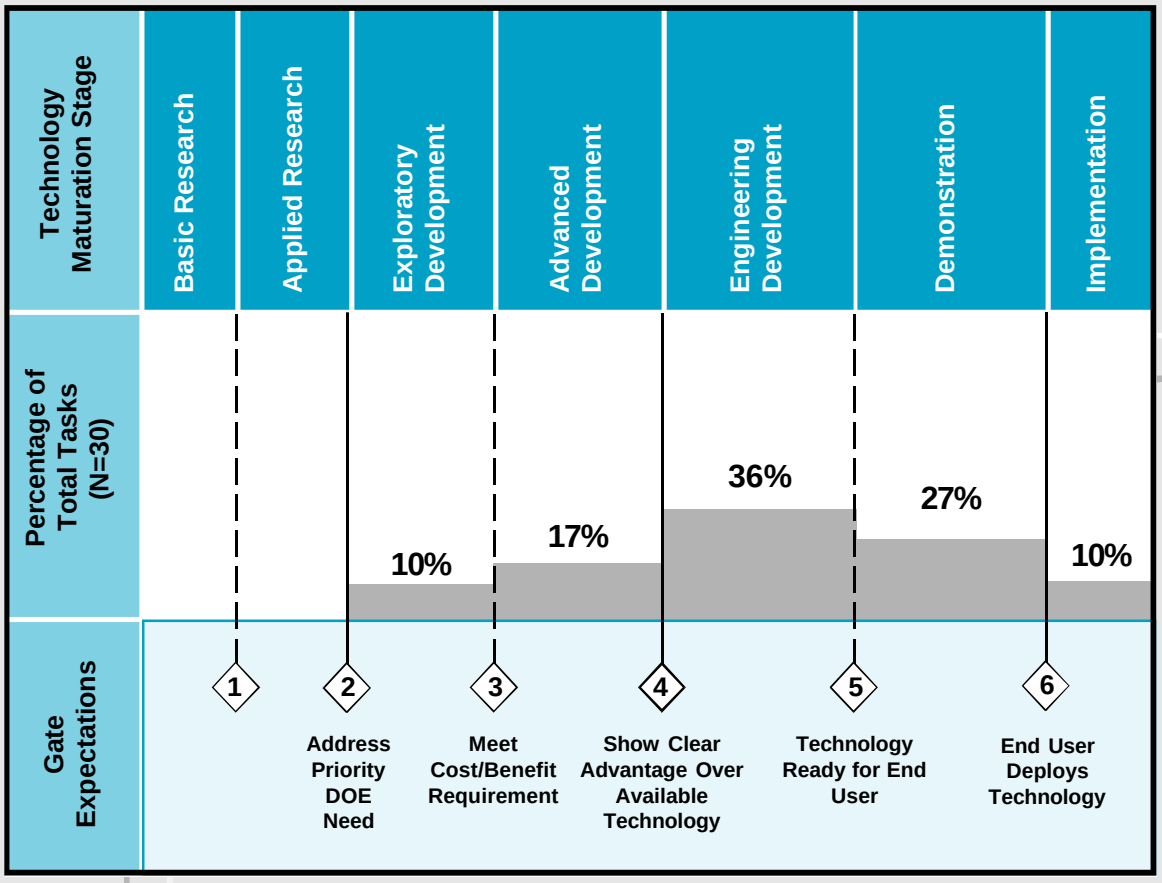
Mann, N. R., and T. A. Todd, Evaluation and Testing of the Cells Unit Crossflow Filter on INEEL Dissolved Calcine Slurries, INEL/EXT-98-00749, Idaho Falls, Id.: Idaho National Engineering and Environmental Laboratory, August 1998.

Rapko, B. M. Oxidative Alkaline Dissolution of Chromium from Hanford Tank Sludges: Results of FY 1998 Studies. PNNL-11908. Richland, Wash.: Pacific Northwest National Laboratory, August 1998.

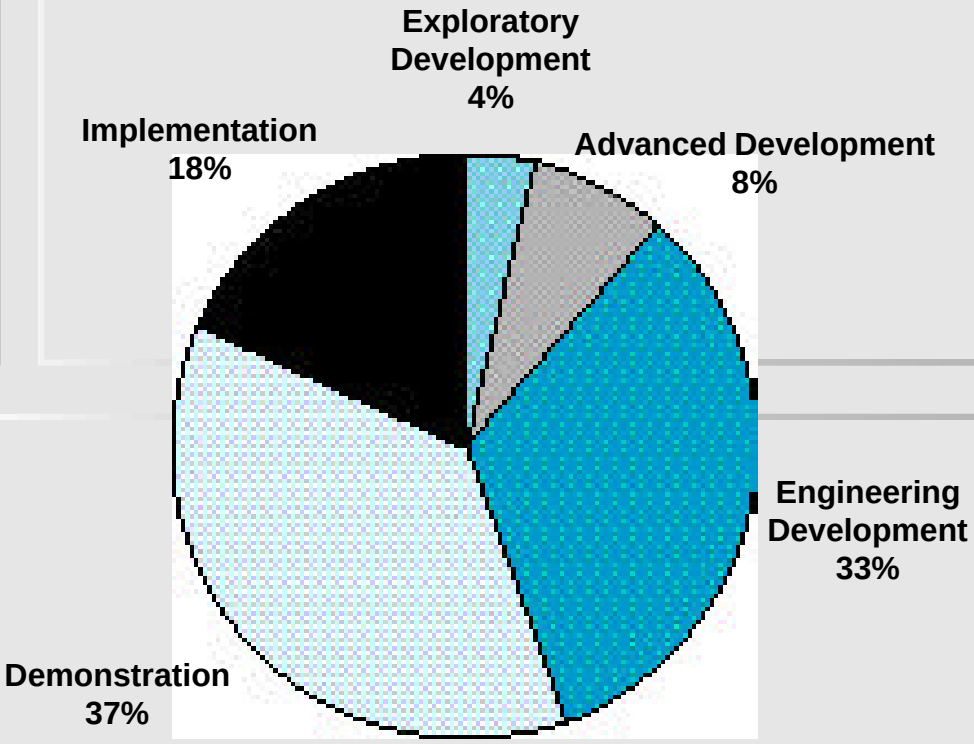
Smith, H. D., et al. Denitration of High Nitrate Salts Using Reductants. Richland, Wash.: Pacific Northwest National Laboratory, September 1998.

Sundaram, S. K., et al. INEEL HLW Corrosion and Preliminary Glass Formulation for INEEL Zirconia HAW-Final Report. PNNL-SA-12012. Richland, Wash.: Pacific Northwest National Laboratory, August 1998.

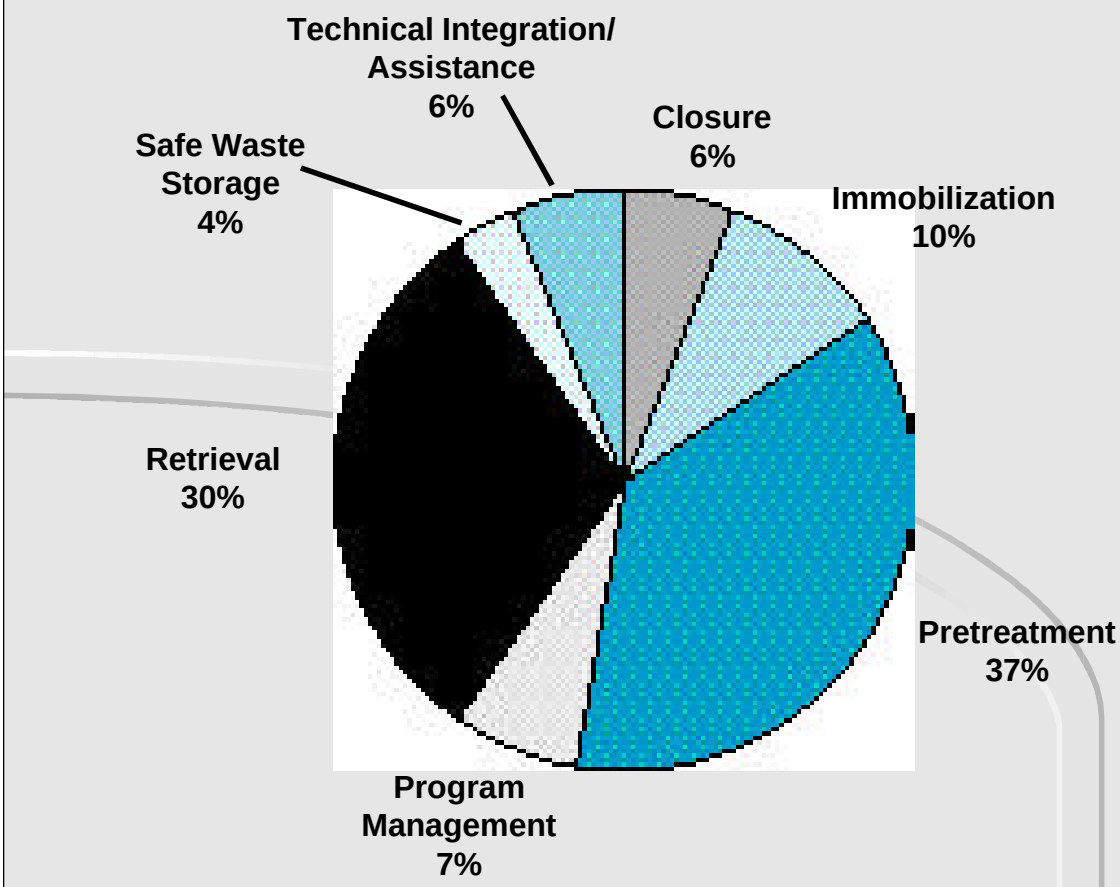
Task Distribution by Maturation Stage



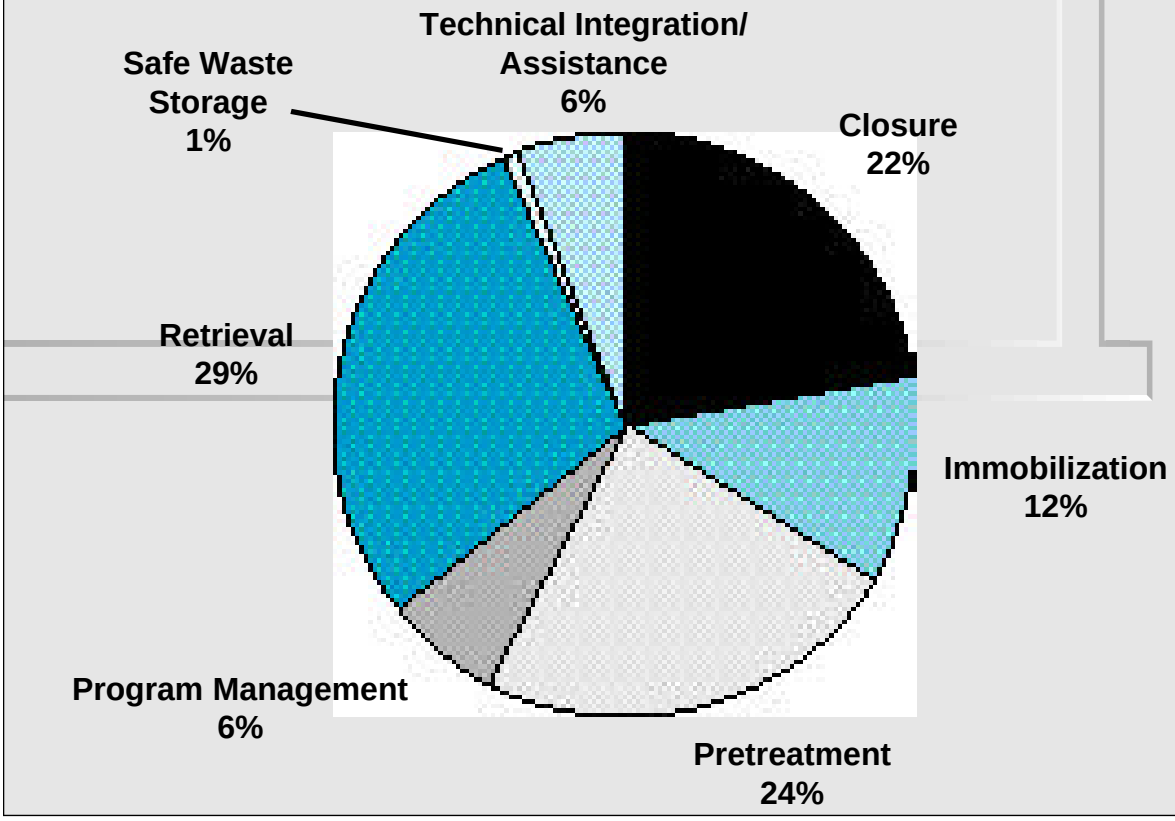
Task Funding by Maturation Stage



Task Distribution by Area



Task Funding by Area



Priority	TMS ID	TFA Task Title	Site	Site Need	PBS	Funding	Stage	Area
1	2009	Waste Loading Improvement for HAW Glass	SRS	SR-2906	SR-HL05	400	5	Immobilization
2	2216, 2359	Salt Removal Systems	SRS	SR-2902	SR-HL03	630	6	Retrieval
3	1490	Slurry Monitors (CMST)	ORR	TK-04	OR-43203			Retrieval
4	2093	GAAT Tank Closure	ORR	TK-09	OR-43203	800	5	Closure
5	347	TRUEX/SREX for Idaho Pretreatment	INEEL	ID-2.1.06	ID-HLW-103	550	5	Pretreatment
6	2010, 2011, 2012, 2118, 2230	Hanford Tanks Initiative	Hanford	RL-WT013	RL-TW04	7060	6	Closure
7	1985, 2119	Corrosion Probe and Corrosion Inhibitor Monitoring	Hanford	RL-WT04	RL-TW03	345	6	Safe Waste Storage
8	2094	Waste Form Product Acceptance Testing	Hanford	RL-WT010	RL-TW06	500	5	Immobilization
9	350	SLS for Melton Valley Storage Tanks	ORR	TK-05	OR-43203	500	6	Pretreatment
10	350	CUF SLS for Idaho	INEEL	ID-2.1.04	ID-HLW-103	200	6	Pretreatment
11	82	LAW Waste Form for Idaho (Grout)	INEEL	ID-2.1.07	ID-HLW-102	800	5	Immobilization
12	881, 1989	Studies of Saltcake Dissolution and Concentrate Reprecipitation	Hanford	RL-WT023	RL-TW04	250	5	Pretreatment
13	233	Control of Leachate Solids Formation	Hanford	RL-WT023	RL-TW04	525	4	Pretreatment
14	2117	Enhanced Sluicing Systems	Hanford	RL-WT014	RL-TW04	300	5	Retrieval
15	82	Grout & Glass Waste Forms for ORR	ORR	TK-06	OR-38113	1242	5	Immobilization
16	20	OTE Deployment for SRS	SRS	SR-2921	SR-HW01	130	5	Pretreatment
17	1499, 1511	Borehole Miner and Fluidic Jets for OHF and BVEST	ORR	TK-03	OR-43201	400	6	Retrieval
18	2097	Heel Retrieval for SRS	SRS	SR-2911	SR-HL03	1100	6	Retrieval
19	2009	Process for Idaho HAW Immobilization	INEEL	ID-2.1.08	ID-HLW-102	700	5	Immobilization
20	2091	Metal Filters for Waste Tank Ventilation	SRS	SR-2901	SR-HL01	50	4	Safe Waste Storage
21	2007	Variable Depth Fluidic Sampling and Analysis	Hanford	RL-WT09	RL-TW04	300	5	Retrieval
22	1510	Waste Conditioning CPU	ORR	TK-02	OR-43203	481	6	Pretreatment
23	1510	Pulse Air	ORR	TK-02	OR-43203	192	6	Retrieval
24	82	ILAW Form Release Test	Hanford	RL-WT015	RL-TW09	200	4	Immobilization

Priority	TMS ID	TFA Task Title	Site	Site Need	PBS	Funding	Stage	Area
25	2090	DWPF Level and Density Monitors (CMST)	SRS	SR-2920	SR-HL05	50		Pretreatment
26	21	Cesium Removal Demonstration	ORR	TK-11	OR-38113	210	7	Pretreatment
27	85, 810, 835, 860, 890	LDUA Deployment at Idaho	INEEL	ID-2.1.10	ID-HLW-103	2500	6	Closure
28	350	Parametric Studies of Hanford Sludge Washing	Hanford	RL-WT024	RL-TW05	1550	4	Pretreatment
29	2093	GAAT Tank Isolation	ORR	TK-10	OR-43203	470	5	Closure
30	1510	Jet Pump	ORR	TK-02	OR-43203	388	7	Retrieval
31	2092	DWPF Process and Pour Spout Enhancements (FIU)	SRS	SR-2910	SR-HL05	490	5	Immobilization
32	881	Advanced Calcination for Idaho	INEEL	ID-2.1.02	ID-HLW-101	350	5	Pretreatment
--	2115	Retrieval Technology Guide	N/A	N/A	N/A	149	-	Retrieval
--	2096	Pretreatment Analysis Tool	N/A	N/A	N/A	300	-	Pretreatment
--	2113	Safety Technical Integration Manager (TIM)	Technical Assistance/Integration			280	-	
--	2111	Closure TIM	Technical Assistance/Integration			250	-	
--	2111	Retrieval TIM	Technical Assistance/Integration			250	-	
--	2109	Characterization TIM	Technical Assistance/Integration			300	-	
--	2110	Pretreatment TIM	Technical Assistance/Integration			480	-	
--	2112	Immobilization TIM	Technical Assistance/Integration			490	-	
--	2108	Technical Implementation Team	Technical Assistance/Integration			1580	-	
--	2108	Technical Implementation Team	Program Management			711	-	
--		Technical Support Services	Program Management			1600		
TOTALS:			**42 Tasks**			**$30,053**	**($ in thousands)**	

For clarity, only one PBS and Site Need was reported for each technology in this table. In many cases, the reported technology will address multiple PBS and Site Needs.

TMS ID	TFA Task Title	Site	Site Need	PBS	Funding	Stage	Area
Industry Programs							
277	Liquid Membrane System for Removal and Concentration of Transuranic Elements	Hanford	RL-WT024	RL-TW05	251	5	Pretreatment
278	Robotic End Effector for Inspection and Sampling of Storage Tanks	Hanford	RL-WT05	RL-TW04	153	6	Retrieval
280	Advanced, Open-Path Atmospheric Pollution Monitor for Large Areas	SRS	SR-2910	SR-HL01	48	4	Retrieval
2173	Dual-Point Impedance Control for Telerobotics	ORR	TK03	OR-43201	428	4	Retrieval
2198	TARZAN Mobile Manipulator	WVDP	N/A	OH-WV-01	2500	5	Retrieval
N/A	WVU: Technology Deployment	Various	N/A	N/A	425	N/A	Pretreatment
N/A	AEA Ltd: Technology Deployment	Various	N/A	N/A	1000	N/A	All
N/A	UNDEERC: Technology Assessment		N/A	N/A	250	N/A	Pretreatment
TOTALS:			**8**	**Tasks**	**5055**	**($ in thousands)**	
University Programs							
N/A	University Robotics Program	ORR	N/A	N/A	1500	4	Closure
N/A	Florida International University	SRS	N/A	SR-HL05	2500	5	Retrieval & Immobilization
N/A	Mississippi State University (DIAL)	Hanford	N/A	RL-TW04	1700	5	Retrieval & Immobilization
TOTALS:			**3**	**Tasks**	**5700**	**($ in thousands)**	
Efficient Seperations & Processing Program							
1441	Oxidation, Characterization, and Separation of Non-pertechnetate Species in Hanford Waste	Hanford	RL-WT01	RL-TW05	300	3	Pretreatment
204	Advanced Integrated Solvent Extraction Systems	INEEL	ID-2.1.06	ID-HLW-103	100	3	Pretreatment
206	Bench Scale Testing of Separation Technologies for INEEL Waste	INEEL	ID-2.1.06	ID-HLW-103	325	4	Pretreatment
2213	ESP Program Coordination and Support -ORNL	N/A	N/A	N/A	242	N/A	Project Management
2212	Cost Savings Analysis/Technology Summaries	N/A	N/A	N/A	237	N/A	Project Management
226	Fission Product Solvent Extraction	SRS	SR-2034	SR-HL04	378	3	Pretreatment
38	Development and Testing of Inorganic Sorbents for Radionuclide and Heavy Metal Separations	All Sites	SR-2009	SR-HL04	235	3	Pretreatment
2215	Ligand Modeling and Design	All Sites	N/A	RL-TW05	80	N/A	Pretreatment
248	Salt Splitting Using Ceramic Membranes	Hanford	RL-WT012	RL-TW05	323	3	Pretreatment
2214	Liaison with Institute of Physical Chemistry	Hanford	RL-WT012	RL-TW05	100	N/A	Pretreatment
245	Advanced Chemical Separations at SRS	SRS	SR-2033	SR-HL04	388	3	Pretreatment
TOTALS:			**11**	**Tasks**	**2708**	**($ in thousands)**	

TMS ID	TFA Task Title	Site	Site Need	PBS	Funding	Stage	Area
Accelerated Site Technology Deployment Program							
85, 98, 810, 835, 890, 2116, 2232	Improved Systems for Tank Sludge Retrieval	ORR	TK-02	OR-43203	2550	7	Retrieval
20,21	Electrochemical Ion Exchange for Contamination Removal	ORR	TK-11	OR-43203	3175	7	Pretreatment
1547	Slurry Monitoring	Hanford	RL-WT013	RL-TW04	220	7	Retrieval
2007	AEA Fluidic Sampler	SRS	SR-2916	SR-HL01	1250	7	Pretreatment
20,21	Modular Evaporator & Ion Exchange System for Waste Reduction	ORR	TK-11	OR-43203	225	7	Pretreatment
N/A	ASTD Mangement	N/A	N/A	N/A	417	N/A	Program Management
TOTALS:			**5**	**Tasks**	**7837**	**($ in thousands)**	
Characterization, Monitoring, and Sensor Technology Program							
214	Ultrasonic Sensors for In-Situ Monitoring of Physical Properties of Tank Waste	Hanford	RL-WT022	RL-TW03	237	5	Retrieval
2015	Integrated Raman Sensor for In-Tank Corrosion Monitoring	Hanford	RL-WT04	RL-TW03	179	4	Safe Waste Storage
1513	Development of Magnetic Resonance Monitor for Tc-99 Column Breakthrough	Hanford	RL-WT01	RL-TW05	300	5	Pretreatment
1547	Comparative Testing of Pipeline Slurry Monitors	ORR	TK04	OR-43203	350	6	Retrieval
1515	Development of Process Monitors for Cs-137 Column Breakthrough	ORR	TK05	OR-43203	250	6	Pretreatment
279	Automated Tank Waste Level Monitor	SRS	SR-2044	SR-HL01	193	5	Pretreatment
N/A	CMST Program Technical Oversight, Documentation and Project Management	N/A	N/A	N/A	326	N/A	Program Management
TOTALS:			**7**	**Tasks**	**1835**	**($ in thousands)**	
Robotics Program							
2085	Houdini-II Remotely Operated Vehicle System	ORR	TK09	OR-43203	970	6	Retrieval
2086	Remotely Operated Vehicle (ROV) System for Horizontal Tanks	ORR	TK09	OR-43203	600	6	Retrieval
2087	Remote Maintenance Design for Tank Waste Compact Processing Units	ORR	TK11	OR-43202	150	4	Retrieval
2088	Automated Analysis Tool for Waste Feed Tanks	Hanford	RL-WT09	RL-TW04	100	4	Retrieval
2089	Modeling and Analysis Applied to the West Valley Demonstration Project Remote Tool Delivery (RTD) System	ORR	N/A	N/A	173	5	Retrieval
TOTALS:			**5**	**Tasks**	**1993**	**($ in thousands)**	

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