The Office of Waste Processing Fiscal Year 2011 Program Plan for Research & Development – 11531

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ABSTRACT

The Office of Waste Processing within the DOE EM Office of Technology Innovation and Development manages technology development and maturation to advance the treatment and disposition of high-level and low-level radioactive liquid wastes. Most of these wastes and associated facilities are unique to the DOE, meaning many of the programs to treat these materials 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 basic principles or require significant re-engineering to adapt to EM's specific applications.

In fiscal year 2010 (FY2010), the efforts of the Office of Waste Processing focused on developing and instituting an enhanced tank waste strategy that will dramatically reduce the life-cycle risk, schedule, and cost of the EM clean-up mission. The Waste Processing research and development program was consequently reshaped with the development of the *Tank Waste Research and Development Plan*. Based upon numerous studies specific to EM, the tank waste R&D plan details various technology efforts required to expedite the tank waste strategy to safely retrieve, stabilize, and dispose of radioactive tank waste and to close waste tanks. Those efforts include initiatives to increase tank waste processing rates and/or efficiencies; to remove material from the process flow, and to accelerate tank waste retrieval and closure.

This paper describes Office of Waste Processing's research and development FY2010 accomplishments as well as plans for FY2011 and eventual technology deployment.

INTRODUCTION

Tank waste is the most significant environmental, safety, and health threat in the Department of Energy (DOE) and is the largest cost element for the DOE Office of Environmental Management (EM) [1]. The remaining tank waste challenges, some of which are one-of-a-kind and unique to DOE, require a strong and responsive applied research and development (R&D) program. EM's enhanced tank waste strategy will focus technology development and deployment investments to mature and deploy science and technology to accelerate the tank waste mission.

The Office of Waste Processing is leading the EM tank waste R&D program to develop transformational technologies to expedite the tank waste strategy to safely retrieve, stabilize and dispose of radioactive tank waste and close the waste tanks. Those technologies will optimize tank waste processing by increasing processing rates and/or efficiencies to reduce life-cycle cost and schedule; removing material from the process flow to reduce life-cycle cost and schedule; accelerating tank waste retrieval and closure; and developing and reducing identified project and safety risks. The deployment of the technologies developed through execution of the Waste Processing R&D Program support Goal 2 of the *Roadmap for EM's Journey to Excellence*: "Reduce the life-cycle costs and accelerate the cleanup of the Cold War environmental legacy" [2]. Examples of these efforts include taking a mobile, modular, at-/near-tank approach to tank waste treatment to eliminate the need for costly additional treatment plants; investigating the viability of alternative treatment processes to generate an alternative waste form with higher "single pass" capture of problematic radionuclides (i.e., Tc-99 and I-129); increasing radioactive glass loading and processing throughput to reduce tank waste canister production and processing schedules; and developing next generation melters to improve waste processing.

The June 2010 issuance of the EM *Tank Waste Research and Development Plan* was the culmination of numerous independent studies aimed at transforming the tank waste system, including those documented in these reports and plans:

1. The 2008 EM *Engineering and Technology Roadmap*, which identifies the technical risks and uncertainties in the EM program, most of which are in the tank waste system [3];
2. The 2009 National Academy of Sciences report entitled *Advice on the Department of Energy's Cleanup Technology Roadmap, Gaps and Bridges*, which identifies five technology gaps directly applicable to the tank waste program [4];
3. The January 2010 Integrated Project Team report entitled *Technical Evaluation of Strategies for Transforming the Tank Waste System*, which recommends development of at-tank/near-tank processing, improved vitrification capacity, increased waste loading, advanced separations processes, alternative treatment and disposal processes, and optimized systems for mixing and blending [5];
4. The Hanford and Savannah River system plans for disposition of tank waste, which indicate that the insertion of technologies and data will reduce project risks and potentially provide significant life-cycle cost savings. Updates to the system plans have incorporated evaluations of the life-cycle impacts of development and deployment of new technologies [6, 7].

Successful completion of the Tank Waste R&D Plan will result in a potential reduction to the tank waste system life-cycle schedule of 5 to 7 years, a potential reduction of the tank waste system life-cycle cost of more than $19 billion, the potential elimination of the need for additional major nuclear waste processing facilities, and the reduction in the environmental, safety and health risks through accelerated disposition of tank waste.

TANK WASTE PROCESSING TECHNOLOGIES AND FY2010 ACCOMPLISHMENTS

Pursuit of enhanced tank waste processing strategies during fiscal year 2010 (FY2010) has resulted in significant progress in the development of transformational technologies. The key strategies that were addressed in FY2010 are:

- Develop at-/near-tank processing to increase waste processing rates
  - Small column ion exchange
  - Rotary microfilter
- Increase waste loading to reduce high level waste (HLW) canister production
  - Advanced silicate glasses

- Develop next-generation melters to improve waste processing
  - International collaboration to develop Advanced Joule-Heated Ceramic and Cold Crucible Induction Melters
- Develop alternative treatment processes to generate new waste forms and reduce the volume of waste
  - Fluidized bed steam reforming
- Develop advanced separations processes to accelerate waste retrieval and minimize downstream HLW disposition
  - Next-generation cesium solvent.

Small-Column Ion Exchange

Small column ion exchange (SCIX) is a sorbent column system to remove cesium, strontium, and select actinides from radioactive salt solutions in waste tanks. Ideally, the SCIX module will be deployed in-tank, using existing waste tanks for shielding.

The Savannah River and Oak Ridge National Laboratories are maturing an elutable ion exchange resin, spherical resorcinol formaldehyde (sRF), for in-riser cesium decontamination with elution for use at both the Savannah River and Hanford sites. In addition to completing radiation stability testing on sRF to confirm that it will accommodate high-dose feeds, a major undertaking during FY2010 was development of a non-acid eluant to mitigate tank corrosion during elution. Thirty-six potential non-acid eluant combinations were screened and five selected for additional testing, which will lead to selection of the most effective eluant.

Spintek Rotary Microfilter

The SpinTek™ rotary microfilter (RMF) is a compact filtration system that uses steel membrane filters mounted on rotating disks. The rotary action of the filter produces high shear at the membrane surface, reducing the fouling of the membrane, thus producing higher filtrate flow rates than the current technology of crossflow filtration. Increasing the solid-liquid separation rate increases the process throughput, reducing the time it takes to complete waste treatment. It also reduces the size and cost of the filtration equipment.

The Savannah River National Laboratory in collaboration with SpinTek Systems are testing the second-generation full-scale rotary microfilter. In FY2010, a 1000-hour test at SpinTek using a high-solids Savannah River Site (SRS) simulated sludge feed to demonstrate the endurance of the newly designed RMF for sludge washing was completed, and development of a filter media with improved durability was begun. Development of the first of two Hanford radioactive waste surrogates for RMF testing was initiated.

Fluidized Bed Steam Reforming

The THermal Organic Reduction (THOR) Treatment Technologies (TTT) fluidized bed steam reforming (FBSR) technology converts radioactive liquid wastes to solid aluminosilicate or carbonate particles suitable for disposal.

A coordinated effort of Pacific Northwest National Laboratory, Savannah River National Laboratory (SRNL), Washington River Protection Solutions, and TTT is confirming the effectiveness of FBSR for treating multiple wastes as well as the environmental durability of the mineralized waste forms. During FY2010, the challenge of demonstrating the capability of FBSR technology to process lower-activity waste into a final waste form suitable for disposal in the Hanford Integrated Disposal Facility (IDF) was tackled. Generation of the data and models for a technically defensible evaluation of the FBSR sodium-alumino-silicate monolithic waste form for Hanford low-activity waste (LAW) was begun to be followed by development of a complete waste form source term model required for IDF performance asessment. The first two of three actual Hanford waste samples were decontaminated of cesium at Hanford and shipped to SRNL for FBSR treatment and testing. In addition, SRNL tested an amended SRS Defense Waste Processing Facility (DWPF) radiological waste sample emulating future Hanford secondary waste.

Next-Generation Cesium Solvent

The next-generation caustic-side solvent extraction (NG-CSSX) process provides a transformational tool for the removal of cesium from radioactive salt waste. It features dramatically enhanced ability to decontaminate the waste for on-site disposal and to concentrate the cesium for vitrification, with markedly increased throughput and compacted footprint. The Modular CSSX Unit (MCU) at SRS is a pilot-scale facility designed to treat a small inventory of low-curie waste at limited throughput until the Salt Waste Processing Facility (SWPF), under construction at SRS, comes on line. MCU is designed for a modest decontamination factor (DF) of 12 for the interim treatment of a few million gallons of low-curie feed; MCU has successfully operated since 2008 at 4–6 gpm, decontaminating well over one million gallons of waste with a DF of >200. However, about 34 million gallons of salt waste still to be processed remain in the tank farm inventory.

In FY2010, research efforts by the Oak Ridge and Savannah River National Laboratories have delivered the solvent chemistry of the NG-CSSX process that is expected to transform the performance of MCU so that it will deliver a DF of 40,000 and waste throughput as high as 12 gpm. The next-generation solvent system will employ a new, more soluble calixarene extractant called MaxCalix, and the stripping is accomplished by a vitrification-friendly dilute boric acid solution. Further testing of the solvent chemistry and system is needed.

Next-Generation Melters

The Joule-heated ceramic melter (JHCM) technology in use in the DWPF at SRS has proven effective in vitrifying radioactive wastes. However, next-generation JHCMs and other advanced melter technologies (e.g., cold crucible induction melter, or CCIM) may dramatically reduce operational durations, potentially achieving life-cycle cost savings of billions of dollars. Active melt pool mixing using bubbler arrays provides drastic increases in melt rates for advanced JHCMs. Routine operation at melt temperatures significantly higher than the current JHCM can be maintained in the CCIM, significantly increasing processing rates and allowing for greater throughput and a smaller footprint.

In March 2010, DOE EM sponsored the "Next-Generation Melter Technology" workshop. Experts from nine countries met in Washington, D.C., to discuss the current state of melter technologies, technology needs, and future direction. As a result, DOE EM has embarked on collaborative projects with partners world-wide to develop next-generation melters and associated systems for EM applications. In FY2010, progress included development of glass formulations to significantly increase waste loading, bench-scale testing of advanced melter technologies to demonstrate those improvements, and conceptual design of next-generation melter systems.

Advanced Silicate Glasses

Increasing waste loading—increasing the amount of HLW incorporated into a glass waste form—has the potential to reduce the time and cost of waste processing exponentially. Various initiatives have previously achieved significant waste-loading improvements (e.g., increase from 28% to 38%) in the DWPF at SRS.

Pacific Northwest and Savannah River National Laboratories in collaboration with Catholic University of America are now developing advanced crystal-tolerant glasses and advanced glasses for difficult waste types, such as high alumina, high sulfur, and bismuth phosphate. The work includes developing the necessary predictive models to improve waste loading, and is applicable to both the DWPF at SRS and in the Waste Treatment and Immobilization Plant (WTP) under construction at Hanford. In FY2010, accomplishments included completion of the initial model for crystal-tolerant glass, development of crystal-tolerant glasses for high-iron wastes, extending high alumina glasses to cover the range of Hanford HLW compositions, and initiation of high-sulfate HLW glass development.

In addition, results of a preliminary assessment of the effect on waste loading of raising the permissible liquidus temperature relative to the melter operating temperature suggest that constraints of the current vitrification process may be overcome through changes that may not require hardware changes. A preliminary assessment predicts that decreasing the difference in temperature between the liquidus and the melter of one particular system (sludge batch 10 at SRS) may potentially achieve a waste loading of about 50% compared to an upper waste loading limit of approximately 40% under current constraints. If confirmed and implemented, this could reduce the quantity of glass waste canisters and decrease life-cycle costs for DWPF.

PLANS FOR TANK WASTE PROCESSING R&D IN FY2011 AND EVENTUAL TECHNOLOGY DEPLOYMENT

Waste Processing R&D activities in FY2011 and beyond are contingent upon receiving sufficient annual appropriations, which will be determined by budget decisions as well as continual evaluation of safety and compliance with environmental and legal obligations. Plans or schedules for deployment described herein do not imply that decisions to implement have been finalized by the Department. All technology selection decisions will be evaluated for safety and compliance with environmental and legal obligations prior to deployment.

Small-Column Ion Exchange

SCIX work in FY2011 includes completing batch contact data to refine the models of the ion exchange behavior of spherical RF; generating the first-generation alternative-elution model; downselecting the alternative eluant; and testing the alternative eluant at pilot scale.

Deployment of SCIX at the SRS will expedite salt waste processing in advance of start-up of the SWPF now under construction, reducing the current life-cycle by about six years and $3.6 billion. Deployment of SCIX at Hanford could enable retrieval and treatment of salt waste from single-shell tanks nearly a decade ahead of the pretreatment capabilities of the WTP now under construction.

Rotary Microfilter

RMF work in FY2011 includes preparing simulated sludges of different compositions, conducting 100-hour tests with prepared sludges, and beginning systematic testing of filtration for processing Hanford actual sludge samples and sludge blends.

The RMF is scheduled to be deployed in two applications at SRS. The first SRS application is clarification of the salt waste feed to the sorbent column to expedite SCIX. The second is continuous sludge washing to replace settle decantation to expedite preparation of HLW sludge batches for vitrification. The RMF also is proposed to process double-shell tank waste in conjunction with SCIX at Hanford.

Deployment of SCIX and RMF at SRS is expected to occur late in 2013. R&D for SCIX/RMF at Hanford is expected to be completed in 2014.

Fluidized Bed Steam Reforming

FBSR work in FY2011 includes completing bench-scale FBSR tests on three actual Hanford waste samples (low sulfur / Tc / Iodide Hanford LAW, Hanford complexant LAW, and high sulfur / Tc / Iodide Hanford LAW); completing a preliminary FBSR technical viability determination; and completing FBSR source-term data for performance assessment modeling.

Planned uses for FBSR include treatment of sodium-bearing waste at Idaho to produce a stable waste form suitable for disposal off site and treatment of Tank 48 waste containing organic cesium tetraphenyl borate at SRS to enable downstream processing and vitrification. FBSR to produce a sodium-alumino-silicate (NAS) waste form is a promising technology to supplement treatment of LAW to meet approved closure deadlines at Hanford.

Deployment of FBSR at SRS to treat Tank 48 waste containing organic cesium tetraphenyl borate is expected to occur in 2014. Selection of a supplemental treatment technology for Hanford LAW is expected to occur in 2014.

Next Generation Cesium Solvent

NG-CSSX work in FY2011 includes completing initial MCU actual waste batch tests; initiating 2-cm diameter contactor testing to compare MCU solvent performance to next generation solvent; completing R&D for ARP/MCU next generation solvent at SRS; providing SWPF solvent recommendation; completing MCU actual waste batch testing; completing hydraulic testing in 13-cm diameter and 25-cm diameter contactors with MCU salt simulant; and completing MCU actual waste testing in the continuous flow in 2-cm diameter contactors in a shielded cell.

Implementation in MCU will enable the facility to process a full spectrum of salt wastes, boost throughput, and increase its operational flexibility. The SWPF is designed to use the same process as the MCU but on a much larger scale. The performance of SWPF also can be improved with an adaptation of the next-generation solvent system.

NG-CSSX is expected to be ready for deployment in MCU at SRS late in 2011.

Next-Generation Melters

Next-Generation Melter work in FY2011 includes reporting initial glass formulations for Hanford LAW and HLW; completing the initial bench-scale test sequence for the CCIM and reporting melter DFs and off-gas of the CCIM and AJHM; completing the conceptual study of CCIM installation for Hanford LAW; completing test facility design for the CCIM and selecting the next-generation melter technology test platform for R&D. Proof of principle tests on the initial two methods will be completed.

Next-generation melter technologies are targeted for future deployment to treat HLW and LAW at Hanford.

Expected next-generation-melter insertion points are currently forecast to coincide with the first Hanford HLW melter change out in 2024; and for implementation for LAW vitrification processing in 2024.

Advanced Silicate Glasses

Advanced Silicate Glass work in FY2011 includes completing crystal-tolerant glass validation testing for increased waste loading and issuing the model for nepheline precipitation.

Deployment is planned for WTP start-up in FY2019.

CLOSING

The Office of Waste Processing in leading the EM tank waste R&D program has developed a Tank Waste R&D program that supports the *Roadmap for EM's Journey to Excellence* [2] and the enhanced tank waste strategy to accelerate the tank waste mission. Significant R&D progress was made in FY2010 in key areas of at-/near-tank processing, increased waste loading, next-generation melters, alternative treatment processes to generate new waste forms, and advanced separation processes. Plans for FY2011 are focused in these same areas with the vision of deployments in the near term.

Successful completion of the Tank Waste R&D Plan will result in a potential reduction to the tank waste system life-cycle schedule of 5 to 7 years, a potential reduction of the tank waste system life-cycle cost of more than $19 billion, the potential elimination of the need for additional major nuclear waste processing facilities, and the reduction in the environmental, safety and health risks through accelerated disposition of tank waste.

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