The U.S. Department of Energy – Office of Environmental Management Cooperation Program with the Russian Federal Atomic Energy Agency (ROSATOM)

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ABSTRACT

The U.S. Department of Energy’s (DOE) Office of Environmental Management (EM) has collaborated with the Russian Federal Atomic Energy Agency – Rosatom (formerly Minatom) for 14 years on waste management challenges of mutual concern. Currently, EM is cooperating with Rosatom to explore issues related to high-level waste and investigate Russian experience and technologies that could support EM site cleanup needs. EM and Rosatom are currently implementing six collaborative projects on high-level waste issues: 1) Advanced Melter Technology Application to the U.S. DOE Defense Waste Processing Facility (DWPF) – Cold Crucible Induction Heated Melter (CCIM); 2) - Design Improvements to the Cold Crucible Induction Heated Melter; 3) Long-term Performance of Hanford Low-Activity Glasses in Burial Environments; 4) Low-Activity-Waste (LAW) Glass Sulfur Tolerance; 5) Improved Retention of Key Contaminants of Concern in Low Temperature Immobilized Waste Forms; and, 6) Documentation of Mixing and Retrieval Experience at Zheleznogorsk. Preliminary results and the path forward for these projects will be discussed. An overview of two new projects 7) Entombment technology performance and methodology for the Future 8) Radiation Migration Studies at Key Russian Nuclear Disposal Sites is also provided.

The purpose of this paper is to provide an overview of EM’s objectives for participating in cooperative activities with the Russian Federal Atomic Energy Agency, present programmatic and technical information on these activities, and outline specific technical collaborations currently underway and planned to support DOE’s cleanup and closure mission.

INTRODUCTION

The Office of Environmental Cleanup and Acceleration and the Office of Environmental Management (EM), U.S. Department of Energy is responsible for implementing EM’s international cooperative programs. The Office of Environmental Cleanup and Acceleration’s international efforts are aimed at supporting EM’s mission of accelerated risk reduction and cleanup of the environmental legacy of the nation's nuclear weapons program and governmentsponsored nuclear energy research. To do this, EM pursues collaborations with government organizations, educational institutions, and private industry to identify technologies that can address the site cleanup needs of the U.S. Department of Energy. The Office of Environmental Cleanup and Acceleration currently works with the Russian Federation, Ukraine and Argentina through cooperative bilateral arrangements to support EM's accelerated cleanup and closure mission. The Office of Environmental Cleanup and Acceleration is also currently evaluating the potential benefits to the U.S. by renewing a bilateral agreement with the Japan Atomic Energy Research Institute (JAERI).

Through international arrangements, EM engages in the cooperative exchange of information, technology, and data on technology development. EM works closely with foreign governments, industry and universities to acquire innovative environmental technologies, scientific and engineering expertise, and operational experience that support DOE's objectives.

FRAMEWORK FOR DOE-EM COOPERATION WITH ROSATOM

Background

During the period 1991-2003, the U.S. Department of Energy's (DOE) Office of Environmental Management (EM) coordinated its efforts with the Ministry of the Russian Federation for Atomic Energy (Minatom) to develop technologies to meet EM site cleanup needs under the auspices of the Joint Coordinating Committee for Environmental Restoration and Waste Management (JCCEM) [1]. The following Russian technologies, developed under the auspices of DOE-Minatom Cooperation, have been deployed at DOE sites in the clean-up effort: the Cobalt Dicarbollide Universal Solvent Extraction (UNEX) technology; the Porous Crystalline Matrix for Stabilizing Actinide Solutions (GUBKA) technology; Russian contaminant transport modeling studies; and, the Pulsating Mixer Pump and Monitor technology, which was the first Russian technology to be deployed at a DOE site. The JCCEM Memorandum of Cooperation (MOC) expired in 2001 and all collaborative projects signed prior to the expiration of the MOC were completed in September 2003. Recognizing the significant contributions of DOE-Minatom cooperation to the success of the EM mission, EM management decided to take measures to ensure the continuation of this fruitful program of cooperation beyond September 30, 2003.

EM management made the decision to utilize a DOE Cooperative Agreement with Florida State University (FSU) to implement activities previously conducted under the JCCEM program. FSU has historically supported the JCCEM program by assisting DOE-EM in the identification of applicable Russian technologies, facilitating intergovernmental communication and coordination, and conducting daily management of JCCEM program activities.

The new framework for cooperation between DOE and the Federal Atomic Energy Agency (Rosatom) of the Russian Federation (formerly Minatom) involves a coordinated effort between DOE-EM, Rosatom, Russian institutes, DOE national laboratories, Florida State University and the private sector.

Summary of Activities to Initiate New Cooperative Framework

Representatives from DOE-EM, DOE national laboratories, Florida State University, Rosatom and Russian institutes conducted meetings in March and April 2004 to reinitiate the EM-Rosatom cooperation. Through preliminary discussions between DOE and Rosatom, one of the most prevalent environmental challenges, High-Level Waste (HLW), was agreed upon as the focus of the initial projects. A Record of Meeting signed in April 2004, approved the DOE EM-Rosatom path forward and the 6 initial projects, which are listed below:

- Advanced Melter Technology Application to the Defense Waste Processing Facility (DWPF) –Cold Crucible Induction Heated Melter (CCIM)
- Design Improvements to the Cold Crucible Induction Heated Melter
- Long-term Performance of Hanford Low Activity Glasses in Burial Environments
- Improved Retention of Key Contaminants of Concern in Low Temperature Immobilized Waste Forms
- Documentation of Mixing and Retrieval Experience at Zheleznogorsk
- Low-Activity-Waste (LAW) Glass Sulfur Tolerance

Subcontracts between Florida State University and the Russian institutes were drafted following the April 2004 meeting with Rosatom. All 6 contracts were approved by DOE and Rosatom and work is ongoing or has been completed. Work to document mixing and retrieval experience at Zheleznogorsk has been completed.

EM/ROSATOM COOPERATION SUPPORTS DOE/EM HIGH-LEVEL WASTE GOALS

One of the key risk reduction goals of the U.S. Department of Energy's Office of Environmental Management is to reduce the need to process tank waste in order to accelerate risk reduction. In *EM Closure Planning Guidance, June 1, 2004,* it states "HLW processing is the single largest cost element in the EM program today. At least two proven, cost-effective solutions to each HLW stream in the complex will be developed. For example, (1) HLW waste loadings in glass logs will be increased, (2) more cost-effective technologies will be used for low-activity wastes, and (3) disposal criteria will be developed for non-glass HLW." As outlined in the following section, the EM International Program is working with Rosatom to support this goal by evaluating advanced melter technologies and seeking design improvements to Cold Crucible Induction Heated Melters (CCIM) to increase waste throughput and maximize melter operation efficiency.

Another key risk reduction goal outlined in the EM Closure Planning Guidance, and also aimed at accelerating risk reduction, is to "identify alternative processes, such as steam reforming, calcinations, saltstone, or other grouting techniques, as well as bulk vitrification, to be considered for stabilizing low-activity and transuranic tank wastes." EM is currently working with Rosatom on projects that focus on increasing the loading of high-sulfur low-activity wastes (LAW) in borosilicate glass and studying Russian experience to evaluate LAW waste form performance in shallow land burial configurations. EM is also evaluating potential new projects with Rosatom related to grouting techniques that would support this goal.

The following section provides an overview and discusses results from the current bilateral collaboration projects being implemented by EM and Rosatom in support of the EM accelerated cleanup and closure mission.

FY04-05 DOE-EM/ROSATOM TECHNICAL PROJECTS

Task 1 - Advanced Melter Technology Application to the U.S. DOE Defense Waste Processing Facility (DWPF) – Cold Crucible Induction Heated Melter (CCIM)

Background & Application

The U.S. technical lead for this task is Dr. James Marra of Savannah River National Laboratory (SRNL). DOE’s partner on this project is the Radon Institute with Dr. Sergei Stefanovsky the technical lead on the Russian side. The advanced melter evaluations requested for testing during the contract period are focused on taking the results of prior testing in Russia (at both the SIA Radon and Khlopin Radium Institute facilities) and then applying what we have learned to the processing of difficult Savannah River waste compositions. Once the improvements in melt rate and waste loading have been demonstrated in Russia, then a retrofit of the technology into the U.S. DOE Defense Waste Processing Facility (DWPF) can be evaluated. The accelerated mission objectives continue to emphasize maximizing waste throughput (i.e., to increase waste loading to minimize the number of canisters produced and the melt rate to accelerate project completion). The stirred CCIM appears to be a very robust technology and some of the existing designs appear compatible with the DWPF. Therefore, a thorough evaluation of the existing design and technology should be performed.

Scope of Work and Results

The Radon Institute prepared chemical defense waste simulants from Savannah River Site waste compositions provided by SRNL and formulated glasses using SRS Frit 320 for the CCIM testing. Melter testing consisted of three (3) 216 mm melter tests and two (2) longer duration tests in the 418 mm CCIM (See Fig. 1). SRNL and Radon Institute conducted the testing jointly at the institute’s laboratory. The results are presented in detail in reference [2].

Fig. 1. View of the 418 mm Inner Diameter CCIM as manufactured (left), coated with a protection layer (middle), and pouring unit (right)

Significant FY04-05 Accomplishments:

- Vitrification tests on a SRS defense waste surrogate using the 418 mm inner diameter CCIM have demonstrated the high efficiency of the CCIM technology (glass pour rate and specific glass productivity reached 16.2 kg/h and ~118.2 kg/(m^2h), respectively) and high quality and waste loading(50 wt. %, 31% increase over the baseline of 38 wt. % in the final product).

- Normalized releases of B, Li, Na, and Si from vitrified products with 50 wt.% waste loading were determined using the ASTM PCT-A procedure and were found to be 15 to 30 times lower than those from the EA glass used for waste form repository acceptance. The improved waste loading could be achieved without any throughput penalty.
- The improved waste loading could be achieved without any throughput plenty.

Path Forward

The FY06 project will utilize the existing Radon set up and demonstrated capability to show the importance of the new technology for future DWPF Sludge Batches and to determine the maximum waste loading that can be achieved with the SRS waste (expected to be ~60 wt % versus the current 38 wt. %). Once the improvement is verified in this testing, a life cycle cost savings in excess of $500M should provide the incentive to rapidly pursue implementation of the technology.

Task 2 - Design Improvements to the Cold Crucible Induction Heated Melter

Background & Application

The U.S. technical lead for this task is Dr. John Richardson of the Idaho National Laboratory (INL). DOE’s partner in this effort is the Electrotechnical University and the Russian technical lead is Dr. Dmitry Lopukh. The INL and Electrotechnical University (ETU LETI), St. Petersburg, Russia, have collaboratively developed two sophisticated mathematical models of CCIM operation using both finite-element and bulk-properties approaches. The models will help to design more efficient melters, and to develop a more complete understanding of CCIM theory.

This work was only partially validated in 2003 using the INL CCIM, and further validation was done jointly with LETI faculty, as a natural extension of the work. Further, the INL has been working on a novel control technology that could greatly enhance CCIM operation in both countries.

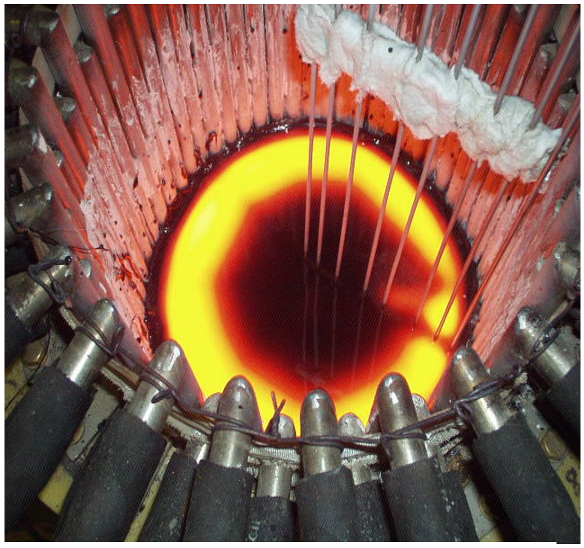

Fig. 2. Temperature profile measurement using 8-point Thermocouple Array inside glass melt

Scope of Work and Results

During FY05 the Idaho National Laboratory (INL) collaborated with the St. Petersburg Electrotechnical University (ETU) to develop methods to characterize and control the operation of a cold crucible induction melter (CCIM) using feedback signals from various operating parameters within the power supply system. Several accomplishments were achieved, including 1) development and testing of unique sensors to measure power factor in a high frequency generator, which is a key parameter in the control scheme (Fig. 3), 2) collecting actual temperature distribution data in the melt volume during processing (Fig. 2), and 3) proof of concept that operational parameters in the generator can be correlated to temperature profiles within the melter.

The Khlopin Radium Institute (KRI) designed, procured, and installed instrumentation in a CCIM system to measure parameters (volt potential, current density and magnetic flux) necessary for INL to validate the CCIM electro-thermal models and measurement scheme. KRI also conducted mathematical modeling of the CCIM operation and testing in a CCIM to gather data to support evaluation of the INL process control strategy at LETI. INL developed the bulk properties model and provided technical oversight during key data gathering tests. INL also provided technical consultation during test data analysis and assisted with report writing for the project.

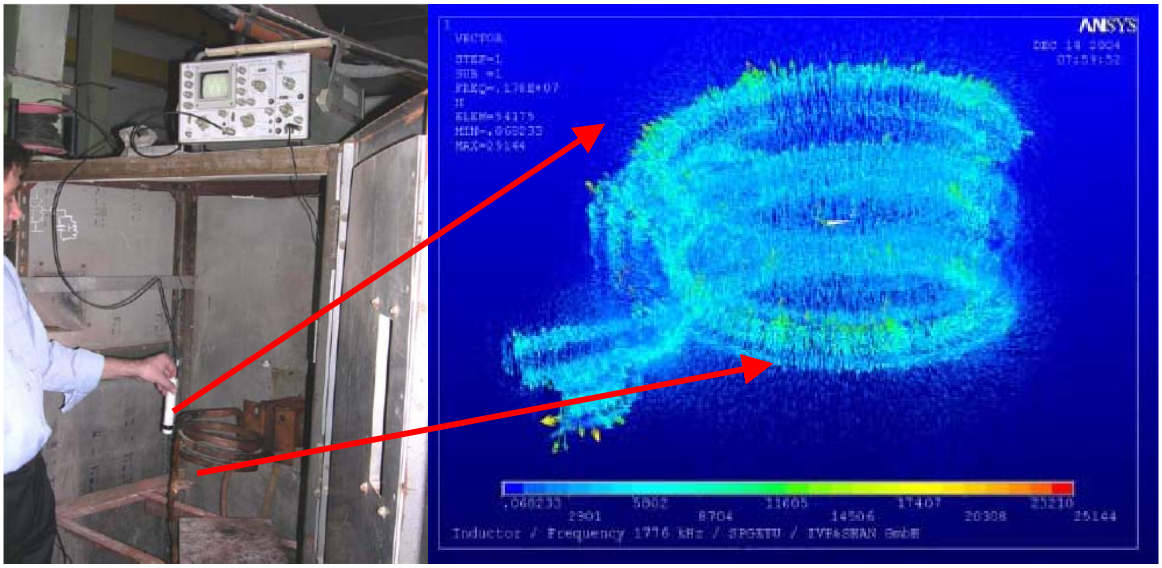

Fig. 3. Measurement of the magnetic flux on the CCIM at Khlopin Radium Institute

Significant FY04-05 Accomplishments

- Demonstrated proof of principle to use operational signals as a feed back control system.
- The electrical signals (phase angle, grid, anode current and voltages) were correlated to a temperature profile in the melter and can be used as a positive feed back control system.
- Developed two unique measurement devices to measure phase angle that can be correlated to a specific operating regime in the melter (temperature profile, electrical resistivity, and the convection currents).

Path Forward

This task will continue to utilize the investment in unique testing equipment with minor modifications to allow testing at higher temperatures. The key data to be measured includes extending the temperature profile to higher temperatures and further characterization of the power factor. Improvements in the design and reliability of the phase, current and voltage sensors will be pursued and a sensor to automatically measure melt level in the CCIM will be developed.

Task 3 - Long-term Performance of Hanford Low-Activity Glasses in Burial Environments

Background & Application

Dr. Peter McGrail, of the Pacific Northwest National Laboratory (PNNL), is the U.S. technical lead and Dr. Galina Varlakova of the Radon Institute is the Russian technical lead. The Radon Institute has carried out long term burial testing since 1987, comparing waste form performance in shallow land burial configurations. One of the glasses tested is a high sodium glass similar to those of the Hanford LAW glasses. Leaching results from that test have been provided to Pacific Northwest National Laboratory to support validation of models used in the LAW performance assessment. Simulants of the actual Russian glass buried at the Radon Institute, Moscow, Russia have been tested by PNNL and SRNL over the past several years. The evaluations to date indicate that an analysis of the actual glass buried at the Radon site would greatly benefit tying the data and analysis together. The project objectives are to obtain a sample of the K-26 glass that was buried by the Radon Institute in the long-term burial studies and perform a thorough chemical analysis of the sample and conduct Single Pass Flow Through (SPFT) testing on the sample.

Scope of Work and Results

The Radon Institute performed a full chemical analysis of a portion of a K-26 glass sample (See Fig. 4) and will also perform the SPFT tests on multiple samples of the glass and analyze the leachate for Na, B, Si, and Al [Ca if possible]. PNNL specified the technical data requirements for the K-26 glass sample that has been buried for over 12 years. Glasses of similar compositions were developed for vitrification of nitrate-containing liquid radioactive waste from nuclear power plants. The major radioactive component of these glasses is Cs-137, and its radioactivity in the final product was $C_0 = 3.7 \cdot 10^6$ Bq/kg. The Na_2O content in the K-26 glass makes it similar to the glasses intended for radioactive waste immobilization at Hanford. Therefore, data on chemical durability can be useful for calculations of the operational characteristics and performance assessment of the vitrified radioactive waste storage facilities. PNNL also provided the specialized equipment for performing the SPFT and provided the expert training and instruction in SPFT equipment operation and analysis and assisted in performance of the test.

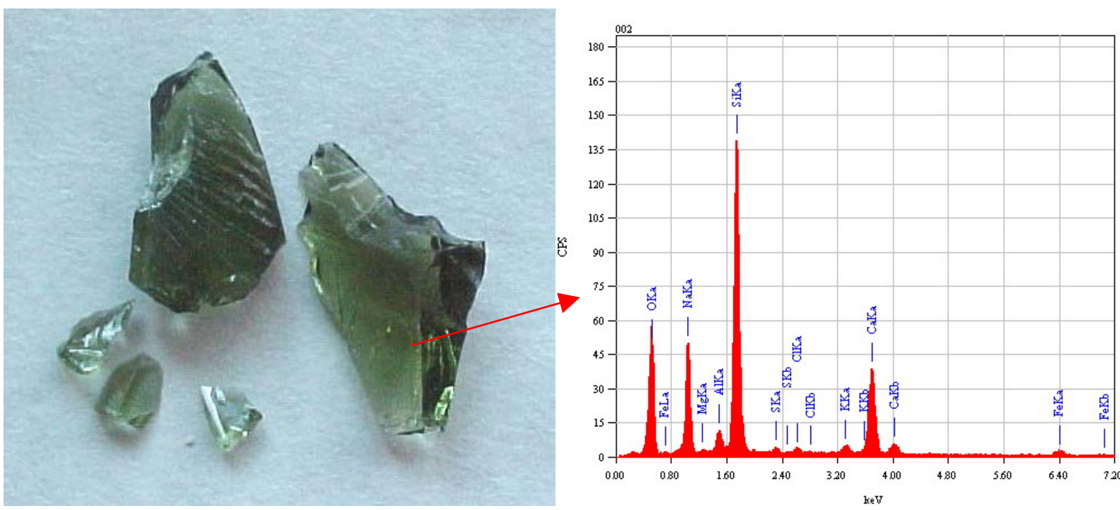

Fig. 4. K-26 radioactive glass sample & chemical analysis spectrum

Path Forward

SPFT testing on multiple samples will be completed in early calendar year 2006. The results will be documented in a future report.

Task 4 - Improved Retention of Key Contaminants of Concern in Low Temperature Immobilized Waste Forms

Background & Application

The technical leads are Dr. Albert Aloy of the Khlopin Radium Institute, and Dr. Christine Langton and Dr. John Harbour of the SRNL. Russian researchers have significant experience in thermodynamic and kinetic calculations that can be applied to grout or other non-thermal waste forms and also possess the capabilities for radioactive and hazardous (RCRA) testing. In addition, they have the knowledge base to identify existing reagents and technical capabilities to develop new technologies for immobilization of contaminants of concern (COC). Innovative approaches to immobilizing COC is crucial to the expanded use of grout and/or other non-thermal waste forms to treat radioactive/hazardous wastes and to dispose of the resulting waste forms in shallow landfills in the DOE complex. This in turn provides additional options to meet accelerated closure goals. The project objectives are to develop and test improved ambient temperature waste forms and waste form/engineered landfill systems to achieve long-term immobilization (> 10,000 yr. stabilization) for at least Tc-99, Np-237, and Se-79, with the objective of improving stabilization of mobile/volatile long-lived radionuclides for final disposal.

Scope of Work and Results

KRI selected suitable waste form matrices for thermodynamic and kinetic evaluation in the shallow land fill configuration; identified potential suitable/stable phases that can be produced by pretreatment and incorporated into waste form matrices; selected or developed a test to predict leaching performance of the designated COC's in land fills; and calculated long term performance under the provided conditions. SRNL reviewed all waste form material constituents to ensure that materials comply with stringent US disposal sites standards and requirements, and prepared the initial test plan objectives and requirements for review with KRI. Additionally, SRNL provided expert consultation to KRI in the selection of systems and techniques, provide technical oversight of the initial testing, and review all data and results and assist in interpreting the data. PORFLOW computer program modeling of the waste matrices was also completed to assess the release of Tc-99 and other radionuclides from the grout.

A series of agreed-upon (SRNL and KRI) grout samples were prepared 28 days prior to KRI. Curing time for the grout is 28 days before the leaching tests can begin. Some of the samples contained the Fe(III) precipitate formed from Fe(II) reduction while others contained ground granulated blast furnace slag as an hydraulic additive to the grout mix. Slag is also known to contain reductant sites that can reduce pertechnetate in solution to the insoluble Tc (IV) state. Finally samples without pretreatment and without slag were also prepared. These samples were ground to a fine powder with a specially designed grinder that prevented the release of this radioactive material to the environment in the laboratory. The material was sieved such that only that fraction between 1 and 2 mm was collected. Leaching experiments using distilled water were conducted according to a modified ASTM D-5233 Procedure.

In these initial experiments, the pretreatment of pertechnetate in solution was accomplished with an Fe(II) reductant that also formed a precipitate of Fe(III) containing the reduced Tc(IV). Leaching results demonstrated that this pretreatment apparently enhanced the retention of Tc-99 in the grout samples but only marginally. The best results for retention of Tc-99 were obtained by Fe(II) pretreatment followed by incorporation into grout that contained ground granulated blast furnace slag.

Significant FY04-05 Accomplishments

- Independent validation of the use of blast furnace slag for the retention of Tc-99 in cement type waste forms (e.g. SRS Saltstone, HLW tank closure grout).
- Provided additional radioactive data on Tc-99 leaching in DOE grout systems to support regulatory reviews.
- Demonstrated that removal of Tc-99 from low level wastes is the most prudent path versus attempting to perform long term stabilization of Tc-99 in a final grout waste form.

Path Forward

Currently slag is assumed to stabilize Np-237 and Se-79 in low level grout waste forms. The first activity in this task is to perform the radioactive demonstrations of stabilization of these isotopes. The second activity will develop grout formulations that will generate less heat during curing. The current temperatures limit the amount of organic wastes that can be processed. The third activity will utilize state of the art models to predict long term stability of radionuclides in grout waste forms.

Task 5 - Documentation of Mixing and Retrieval Experience at Zheleznogorsk

Background & Application

The Russian technical lead is Dr. Konstantin Kudinov of the Mining and Chemical Combine (Zhelezhogorsk, Russia) and the U.S. technical lead is Mr. Michael Rinker of the Pacific Northwest National Laboratory. Removing consolidated, hardened radioactive waste from high level waste (HLW) tanks has been as much a problem for Hanford as it has been for the Mining and Chemical Combine (MCC) in Zheleznogorsk, Russia. U.S.-Russian cooperation has led to four generations of retrieval technologies. Advancements in Russian mixing and retrieval technologies, such as the pulsating mixer/sluicer, may be applicable to retrieving radioactive waste from HLW tanks in Hanford. MCC stores its waste in a 3,200 m^3 tank that has very similar conditions to the Hanford tanks. The MCC retrieval process has been in progress for several years and has a number of the difficult to retrieve characteristics expected as both Hanford and Savannah River continue to retrieve High Level Waste sludge. The U.S. is currently considering the use of the Russian Dual Nozzle PMP in potentially leaking tanks at the Hanford Site. The project objectives are to provide documentation of the MCC retrieval experience to date and to leverage lessons learned by MCC in HLW tank waste retrieval.

Scope of Work and Results

MCC documented the operational characteristics of the retrieval equipment and control systems, documented the quantitative and qualitative characteristics of the retrieved sludge, and documented the analysis of the gases and vapor space in the tank and temperature values of the waste during retrieval operations. Additionally, MCC documented the radioactive contamination in the tank, shielded box and the room where the tank is installed and the dose exposures for the personnel directly involved in sludge retrieval. PNNL provided expert review and analysis of the Russian MCC retrieval equipment, observations and evaluations with respect to limitations to site operations, and provided technical guidance to MCC to ensure the MCC reports will be useful to Hanford Office of River Protection. Some of the lesson learned are discussed below and are available in detail in reference [3]

The following equipment was used to retrieve waste from MCC Sludge Tank AG-8301/3, which was the first tank where MCC performed retrieval operations:

- sluicers (hydromonitors) for mobilization of sludge and generation of slurries
- jet pumps (hydroelevators) for retrieval of generated slurries.

The sluicers consisted of a pipe and two horizontal 10-mm-diameter jet nozzles. They were deployed in a tank riser on a flange connection. Every time the sluicers had to be rotated, the flange connection had to be disassembled. Supernate from the neighboring tank was used as a working fluid for the sluicers. The jet pumps also used supernate from the neighboring tank as a working fluid. Because of an insufficient operating range of the submerged jets, MCC had to install as many as 10 jet pumps in one tank. Since there was no system for remote orientation of jet pumps in the tank, operation of the jet pumps became fairly labor intensive. The jet pumps were frequently clogged with dense slurry since their diameter was small and their design was not optimized. The pilot operation of the sluicers and jet pumps made it clear that the equipment was not effective enough.

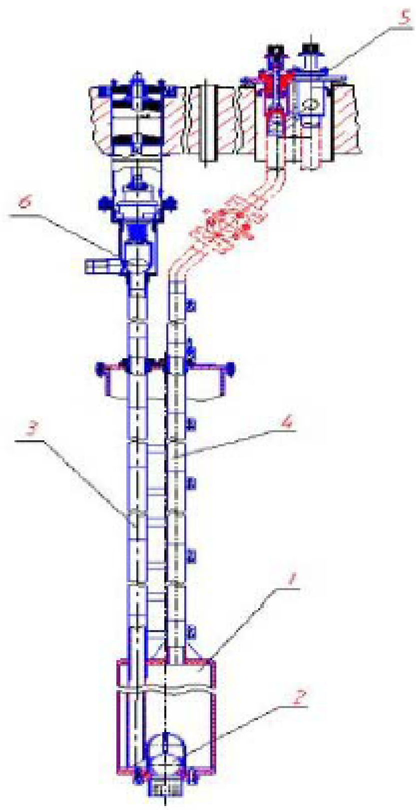

Fig. 5. Pulsating mixer pump

To improve efficiency and minimize the number of equipment items to be placed into the tank, new jet pump designs were needed, with non-submerged jets that have a much greater scouring force than submerged jets. Moreover, the liquid from the tank being retrieved would be more preferable to use as a working fluid than supernate from the neighboring tank. MCC selected the pulsating equipment (See Fig. 5) against the sluicers and jet pumps due to the following advantages:

- repeated use of the in-tank working fluid until the slurry of the required concentration is produced
- mechanical simplicity and high performance of the part of the pulsating equipment that is placed inside the tank
- this equipment can also be used for tank decontamination
- reduced manufacturing and operating costs.

From 1996 to 2001, the design of the pulsating equipment was upgraded and the following tests were performed:

- at MCC: testing of the first pulsating pump in Tank AG-8301/3
- at PNNL (under a DOE Tanks Focus Area (TFA)-sponsored project): cold testing of the quarter-scale pulsating pump
- at ORNL (under a DOE TFA-National Energy & Technology Laboratory-sponsored project): production-scale pulsating mixer pump in Tank TH-4.

This project was successfully completed in FY05.

Task 6 - Low-Activity-Waste (LAW) Glass Sulfur Tolerance

Background & Application

The Russian technical lead is Dr. Albert Aloy of the Khlopin Radium Institute and the U.S. technical leads are Dr. John Vienna and Dr. Michael Elliott of the Pacific Northwest National Laboratory. Roughly 50 Million gallons of high-level radioactive waste is stored in 177 underground tanks at the Hanford Site. The DOE has contracted for the design, construction, and demonstration of Hanford Waste Treatment Plant. The Hanford WTP will separate tank waste into LAW and HLW fractions and vitrify them separately into borosilicate glasses. The LAW fraction is composed primarily of sodium salts. A large fraction of the LAW streams have sufficient concentrations of sulfur to negatively impact their loading in glass. Efforts on this project will focus on increasing the loading of high-sulfur LAWs in borosilicate glass by better understanding the relationships between salt formation and the controllable chemical and physical parameters of waste glass melting. Under this task, researchers from the Pacific Northwest National Laboratory and Khlopin Radium Institute are collaborating to conduct experiments that will evaluate the impacts of chemical and physical parameters on the incorporation of sulfate into Hanford glasses.

Scope of Work and Results

KRI 1) developed glass formulations with systematic variation in key chemical parameters such as concentrations of alkaline-, alkaline-earth-, and other oxides; 2) performed furnace melter testing of the formulations to determine the allowable sulfur loading for each of the formulations both with and without bubbling; and 3) modified KRI melter to include the ability to bubble the melt pool. KRI also performed five melter runs to evaluate the compositions selected and performed analyses of the feed composition and glass composition. PNNL developed the initial test plan for defining the glass formulations that have the highest probability of improving sulfate solubility; reviewed results of small scale crucible tests and provided recommendations for additives, etc. to ensure compatibility with the Waste Treatment Plant Process at Hanford; and provided oversight and evaluation to guide the large crucible testing. Additionally, PNNL provided oversight and consultation during melter tests (See Fig. 6) in Russia to ensure data quality and relevance to the DOE HLW missions. PNNL also provided technical consultation during test data analysis and assisted with report writing.

Significant FY04-05 Accomplishments:

- Evaluated additives to enhance sulfate retention in Hanford LAW Glass.
- Determined that tin and manganese improved sulfate retention while meeting the performance requirements of Hanford LAW Glass.
- Current testing has shown up to 1.5% sulfate retention versus the baseline of 0.8%.

Path Forward

During FY04-05, Khlopin Radium Institute performed testing that identified additives that substantially improved the solubility of sulfate in the Hanford Low Activity Glass production (both Waste Treatment Plant and Bulk Vitrification). For Savannah River sulfate will have a similar impact on future batches of HLW. This task will extend the Hanford LAW sulfate work to include SRS expected future waste compositions. Aluminum is the current bottleneck component for both Hanford and SRS HLW which results in reduced waste loading in glass and more canisters to Yucca Mt. Since aluminum is an issue for both sites, it will be worked jointly between Khlopin Radium Institute, SRNL and PNNL. This project will be retitled as "Improved Solubility and Retention of Troublesome Components in SRS and Hanford HLW Glasses" to reflect the FY06 work scope.

Fig 6. Testing in EP-5 melter at K.R.I.

Task 7 – Entombment Technology Performance and Methodology for the Future

Background & Application

The performance objective of entombment is to provide in-place isolation of the contaminants in a decommissioned piece of equipment or facility permanently (ENTOMB) or until the radioactive contaminants have decayed to acceptable levels (SAFESTOR). Factors considered in an isolation assessment include:

- Characteristics of the site itself (physical and chemical properties of the environmental media, geological setting, current and future land use, etc.)

- Performance of engineered barriers, existing or to be constructed.
- Inventory of radionuclides. (Basis for isolation requirements)
- Contaminant source terms (Flux of each radionuclide leaving the entombment)
    - Leachability of the radioactive species present in the entombment. (Leachability is influenced by the chemical and physical properties of radionuclides in/on the entombed material and in leachate contacting this material.)
    - Transport mechanisms and pathways of the dissolved radioactive species out of the entombment structure.
- Dispersal pathways of contaminants into the environment outside beyond the entombed structure via ground water pathways, plant uptakes, inadvertent intrusion or other scenarios.

To date regulations have not been promulgated for entombment of facilities. However, a strong parallel exists between the technical data required for entombment and that required for shallow-land disposal facilities. The Russians have performed reactor entombments (Chernobyl) and have been able to track the performance of these isolation efforts. They have also applied the permanent entombment technology to radioactively contaminated vessels/ships used to fuel nuclear ships and submarines. This effort is joint project between All-Russia Design and Scientific Research Institute for Complex Power Technology (VNIPIET) and SRNL.

Scope of Work

Past Russian efforts to isolate and entomb nuclear facilities, ships, vessels/tanks, and equipment will be documented. This project shall include requirements, objectives, technical bases for materials selection and engineering implementation (including placement) and subsequent performance evaluation and monitoring results. Site specific conditions and construction issues should also be identified.

Enhanced entombment strategies/concepts will be developed to improve the performance of the overall entombment process. An experimental test plan will be prepared that includes the enhanced entombment strategies/concepts and details the testing and evaluation of entombment materials with respect to the following issues: 1) the effects of entombment matrix porosity, aggregate size and aggregate porosity on liquid and gas permeability. 2) The relationship between strength of an entombment material and permeability, porosity, shrinkage, cracking and leaching. 3) Crack elimination/mitigation for large placement of concrete entombment materials. 4) Evaluation of alternative materials other than Portland cement based concrete/grout. 5) Improved retention of radionuclides and other contaminants by incorporating getters in the entombment material, or in coatings, or in external barrier materials. 6) Compatible materials for providing enhanced shielding.

The DOE EM is still in the planning stages of this project and hopes to initiate this project in FY06. The Russian Design Institute (VNIPIET) and SRNL will participate in this project.

Task 8 – Radionuclide Migration Studies at Key Russian Nuclear Disposal Sites

Background, Application & Preliminary Scope

The Federal Atomic Energy Agency of the Russian Federation (formerly Minatom) submitted five proposals to the U.S. Department of Energy (DOE). All the proposals plan to utilize the results of long-term (over a period of several decades) field monitoring, including the data on the radionuclide migration in surface and ground waters and the solute-sediments (or rocks) interaction. Actual field data from the Tomsk Site, the Techa Cascade Reservoirs, and Lake Karchay projects can be used to further advance our understanding of the radionuclide behavior in the environment and their contribution to worker and public risk. This project provides the documentation of the data in technical journals making it accessible to anyone performing contaminant migration and performance assessment studies. The Russian Institutes will collect and document data from the sites listed above for publication in technical journal.

The DOE EM is still in the planning stages of this project and hopes to initiate this project in FY06. The Russian Institutes and Lawrence Berkley Laboratory will participate in this project.

CONCLUSION

DOE-EM has shown that its current program of cooperation with Rosatom will allow EM to leverage international expertise in support of an accelerated risk reduction and cleanup of DOE sites through the identification of innovative technologies focused on user needs. It is EM’s goal to achieve a program with Rosatom that is solution- and cost savings-oriented. EM has shown that the 6 projects discussed in this paper have extensive application to current DOE high-level waste challenges and will contribute greatly to this goal. EM also looks forward to the possibility of enhancing the scope of the EM-Rosatom cooperation program to investigate other areas of mutual concern.

REFERENCES

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