ADVANCING THE U.S. DEPARTMENT OF ENERGY'S TECHNOLOGIES THROUGH THE UNDERGROUND STORAGE TANK – INTEGRATED DEMONSTRATION PROGRAM

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ABSTRACT

The integrated demonstration process is a critical component in the evolution of technology development and the demonstration of the applicability of technologies to the environmental restoration and waste management mission. To efficiently bring the best technologies to bear on the needs of the U.S. Department of Energy waste complex and to successfully commercialize or otherwise implement the results of these proven technologies, integration demonstration programs have been created to meet the common needs of multiple U.S. Department of Energy sites. One such need is resolution of the actions required for final closure and disposal of liquid (including sludge and salt cake), radioactive, and chemical wastes that have been transferred to underground storage tanks. Hence, the principal objective of the Underground Storage Tank – Integrated Demonstration Program is the demonstration and continued development of technologies suitable for the remediation of waste stored in underground storage tanks. The Underground Storage Tank – Integrated Demonstration Program is the most complex of the integrated demonstration programs established under the management of the Office of Technology Development. The Program has the following five participating sites: Oak Ridge, Idaho, Fernald, Savannah River, and Hanford. Activities included within the Underground Storage Tank – Integrated Demonstration are 1) characterizating radioactive and hazardous waste constituents, 2) determining the need and methodology for improving the stability of the waste form, 3) determining the performance requirements, 4) demonstrating barrier performance by instrumented field tests, natural analog studies, and modeling, 5) determining the need and method for destroying and stabilizing hazardous waste constituents, 6) developing and evaluating methods for retrieving, processing (pretreatment and treatment), and storing the waste on an interim basis, and 7) defining and evaluating waste packages, transportation options, and ultimate closure techniques including site restoration. The eventual objective is the transfer of new technologies as a system to full-scale remediation at the U.S. Department of Energy complexes and sites in the private sector.

INTRODUCTION

Production of nuclear materials has been a major mission of the U.S. Department of Energy (DOE) for the last 50 years. These activities have contributed to a substantial accumulation of hazardous, radioactive, and mixed wastes. In 1989, the DOE established the Office of Environmental Restoration and Waste Management. This Office coordinates and manages the DOE's remediation, waste minimization, and environmental compliance activities. It also has responsibility for managing waste generated by current operations. Within this Office is the Office of Technology Development, which is responsible for providing technology improvements. The integrated demonstration process is a critical component in the evolution of technology improvements. Integrated demonstrations have been established to efficiently bring the best technologies to bear on the common needs of multiple DOE sites. One such need is resolution of the actions required for final closure and disposal of liquid (including sludge and salt cake), radioactive, and chemical wastes that have been transferred to underground storage tanks.

Technologies must be developed to remediate underground storage tanks containing high-level, low-level, transuranic, and mixed wastes at five DOE sites: Fernald, Idaho, Oak Ridge, Savannah River, and Hanford (the host site). The contents of the tanks, the tanks, ancillary equipment, piping, and contaminated soil around the tanks must be remediated. The cost of cleanup of these tanks is prohibitive using some of the current baseline technologies. Furthermore, major gaps exist in the technology needed for the following: 1) characterization, 2) retrieval, 3) transportation, 4) pretreatment, 5) disposal, and 6) remediation of the waste, tanks, and surrounding soil.

The Underground Storage Tank – Integrated Demonstration effort is led by the DOE, Richland Field Office and the Westinghouse Hanford Company. The program is focusing on the needs of several of the participating sites simultaneously, thus ensuring that technologies under development are applicable to more than one site, which will minimize the cost of development.

PROGRAM OVERVIEW

Created in February 1991, the principal objective of the Underground Storage Tank – Integrated Demonstration Program is to develop and demonstrate technologies that will provide improvements or alternatives to the remediation baseline plan. This demonstration is necessary to enable a final decision on the disposal of underground tank wastes, soils, and ancillary equipment.

Activities included within the Underground Storage Tank – Integrated Demonstration are 1) characterizing radioactive and hazardous waste constituents, 2) determining the need and methodology for improving the stability of the waste form, 3) determining the performance requirements, 4) demonstrating barrier performance by instrumented field tests, natural analog studies, and modeling, 5) determining the need and method for destroying and stabilizing hazardous waste constituents, 6) developing and evaluating methods for retrieving, processing (pretreatment and treatment), and storing the waste on an interim basis, and 7) defining and evaluating waste packages, transportation options, and ultimate closure techniques including site restoration. These investigations include all regulatory interfaces necessary for actual field testing of the potential technologies and the regulatory acceptance of the technologies used.

The Underground Storage Tank – Integrated Demonstration management structure, Fig. 1, has been developed to manage the programmatic activities in an effective and responsible manner for DOE. The integrated demonstration coordinator uses the direction provided by DOE-Headquarters and the Hanford Site technical program officer to develop a comprehensive program. Through the Hanford Site technical program officer, the coordinator serves as the lead interface with the DOE, Office of Technology Development. The integrated demonstration coordinator arranges the delivery of the technologies into the program from a variety of sources. This includes working with the Program Planning Group, the Technical Support Groups, and the integrated demonstration coordinators from across the DOE complex to define each supporting task necessary to meet the program objectives, and with the Office of Technology Development to plan for task funding and initiation.

The Program Planning Group advises the coordinator on the planning, technical direction, and coordination of the Underground Storage Tank – Integrated Demonstration Program. The Program Planning Group is composed of representatives from the participating sites. They function as the program oversight committee and advise the integrated demonstration coordinator on the overall program direction. The Program Planning Group makes recommendations for inclusion of new technologies into the program, defines and implements the technology filtering process, and develops the technology success criteria.

Technical Support Groups have been formed in the technology activity areas to assist the integrated demonstration coordinator. These groups are composed of experts in the respective technology areas. Each Technical Support Group has a designated chairperson who assists in the integration of the technologies being demonstrated. The groups are responsible for developing technical problem statements for solicitation of fiscal year technical task plans. The groups develop a performance evaluation criteria of the technologies being proposed or demonstrated that include comparisons at one site based on 1) cost effectiveness, 2) risk reduction, 3) technology effectiveness, and 4) applicability, including regulatory and public acceptability.

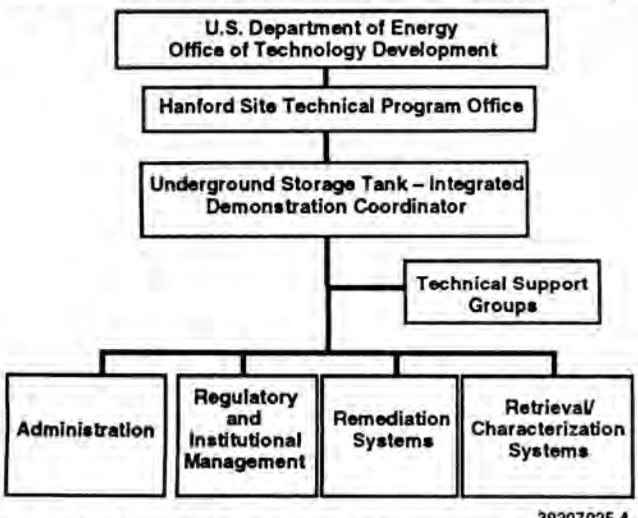

Fig. 1. Underground storage tank - integrated demonstration management structure.

The Technical Support Groups also review and evaluate new technologies and, as appropriate, identify any technologies they determine warrant further research and development to support the Underground Storage Tank – Integrated Demonstration Program.

OBJECTIVES

The principal objective of the Underground Storage Tank – Integrated Demonstration Program is the demonstration and continued development of technologies suitable for remediation of underground storage tanks. This is accomplished by selecting the most promising new technologies for demonstration, testing, and evaluation. The eventual objective is to transfer new technologies as a system to full-scale remediation at the DOE complexes and sites in the private sector.

The DOE is committed to cleaning up the underground storage tanks. In many cases, existing technologies are not adequate to cost effectively and safely clean up the tank waste. The Underground Storage Tank – Integrated Demonstration Program is chartered to identify, develop, test, evaluate, and transfer technologies that will 1) characterize, remove, stabilize, separate, treat, transport, store, and dispose of high-level, low-level, transuranic, and mixed wastes contained in underground storage tanks, 2) decontaminate, stabilize, and dispose of tanks, piping, and ancillary equipment, and 3) remediate contaminated soils resulting from releases from underground storage tanks.

The foundation of the program is the technology base available from within the DOE and from external industrial and institutional programs that can be applied to the underground storage tank remediation efforts. The Underground Storage Tank – Integrated Demonstration secures the active involvement of private industry, universities, and other government agencies, where appropriate, through the following: 1) developing collaborative partnerships, 2) licensing of technologies, 3) fostering technical personnel exchanges, 4) effecting consulting agreements, and 5) promoting shared use of scientific facilities.

TANK WASTE PERSPECTIVE

The Underground Storage Tank – Integrated Demonstration Program is the most complex of the integrated demonstration programs. The Program's scope includes 332 underground storage tanks with compositions that include stainless steel, concrete, and concrete with carbon steel liners. The tanks have an overburden layer of soil ranging from a few feet to tens of feet. The tank's capacity varies from 19 to 3,785 m^3 (5,000 to 1,000,000 gal). At present 371,000 m^3 (98 Mgal) of high-level and low-level radioactive liquid waste are contained within the tanks (Fig. 2). Of the participant site inventories, the tanks at the Hanford and Savannah River Sites contain most of the waste – 62% and 32%, respectively.

The waste contains a wide variety of hazardous and nonhazardous chemical components, including those from sodium salts, acids, metals oxides, and other heavy metals.

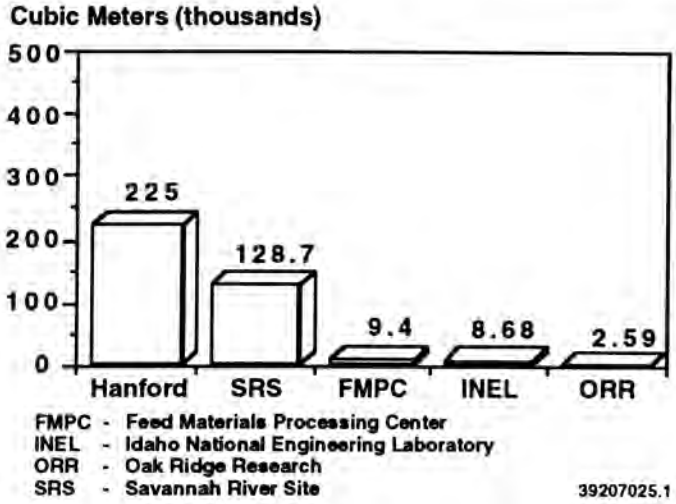

Fig. 2. Total waste volumes at underground storage tank - integrated demonstration sites.

Approximately half of the waste is composed of sodium nitrate and nitrites. Large amounts of metal oxides, especially iron and aluminum oxide, are present also. The 640 MCi of radionuclides are distributed primarily among the transuranic elements and some fission products (^{137}Cs and ^{90}Sr) (Table I). In-tank atmospheric conditions vary in severity from near ambient to temperatures over 93°C (200°F). Some tanks occasionally contain potentially explosive gas mixtures. Tank void-space radiation fields can be as high as 10,000 rad/h.

EMERGING TECHNOLOGIES

The initial Underground Storage Tank – Integrated Demonstration Program focus is on those technologies that can provide near-term benefits towards remediation of underground storage tanks. The Program is currently concentrating on six areas: 1) characterization, 2) high-level and low-level waste treatment and disposal, 3) retrieval, transfer, and storage, 4) waste separation, 5) in situ treatment and disposal, and 6) site closure. The technical work is directed toward three fundamental problem areas that are shared by most of the participant sites. These areas are waste characterization, waste retrieval, and waste separations. Smaller investments are dedicated to the long-term requirements for low-level waste forms, in situ processing, and site closure.

Characterization Needs

Chemical, physical, and radiological properties of the tank waste must be identified and quantified. Characterization traditionally has been limited by high analytical costs and the inability to obtain data from many points in the tanks. Chemical properties are crucial because they provide critical information about the location, concentration, and extent of pollutants, as well as their migration or potential migration. Physical measurements are required to determine how difficult the waste is to break up, how pumpable the waste is, and also to assist with the design of retrieval equipment. A broad spectrum of nonperturbing, in situ characterization is required for real- and near-real-time identification and quantification of the chemical, physical, and radiological properties.

In situ sensing has the advantage of helping to ensure that characterization can be performed safely. In some cases, core sampling or direct measurement capabilities cannot be used, and bulk measurement properties (via tomography, for example) could assist in placing upper and lower bounds on key properties. Sensor technologies have been selected for development that will decrease laboratory analytical time. Consideration also has been given to deploying these sensors inside the tank. For example, laser Raman spectroscopic sensors being developed will be used first in the analytical laboratory and, when proven, will be configured for in-tank use. The characterization technologies under development include 1) Fourier transform infrared spectroscopy, 2) ultrasonic nondestructive evaluation, and 3) laser Raman spectroscopy for ferrocyanide detection.

Retrieval and Transport Needs

Devices and systems are required to convey materials from end effectors to the interarea transport line. Materials must be capable of performing in a radiation environment of 5,000 rad/h and an accumulated dose of 10^7 rad. Removal devices must remove hard salt cake, sludge of varying consistencies, tank hardware, and foreign objects (Fig. 3). Conveyance systems must be capable of handling dislodged or

TABLE I

Underground Storage Tanks Radionuclides Content

Radionuclides	Activity	Mass	
	(Ci)	(kg)	(lb)
^{238}U	644.9	1,917,420.000	4,218,600.000
^{235}U	27.7	12,793.600	28,149.000
^{239}Pu	29,446.0	352.290	1,042.840
^{137}Cs	152,686,679.0	1,765.900	3,885.800
^{90}Sr	173,190,911.0	1,299.000	2,858.000
^{90}Y	126,800,648.0	0.233	0.513
^{144}Ce	2,785,000.0	0.875	1.930
^{147}Pm	25,420,000.0	26.100	57.480
Others	159,330,000.0	28,116.000	261,851.200
Total	640,210,000.0	1,962,120.000	4,317,350.000

mobilized wastes and tank hardware. The waste slurry must be carried over long distances (1.1 to 14.5 km [0.7 to 9 mi]) with negligible solid separation or in-line clogging.

For in situ deployment, a special emphasis has been placed on the development of a light-duty utility arm (articulated and remotely operated). The arm will deliver characterization tools such as optical sensors and physical measurement devices. The arm also will serve to test some features of proposed waste retrieval techniques on actual tank waste. Other investigations are demonstrating dislodging and conveyance technology systems for the full range of waste types, including liquids, sludge, salt cakes, and in-tank equipment. Studies are also underway to confirm correlations developed to retrieve and transport waste slurry over long distance without clogging the transport line.

Separations and Pretreatment Needs

The tank waste remediation strategy includes a permanent disposal option involving the concentration of the radioactivity into forms acceptable for feed to a final low-level waste form. For example, the Hanford Site's current strategy involves concentrating the radioactivity into feed stock for a glass plant and incorporating the residuals in a feed stock for a plant to make a low-level waste form presently designated as grout. Waste separations development areas include the following: 1) removing radioactivity (principally cesium, technetium, and iodine) from the supernate, 2) destructing organics to prevent the build-up of hydrogen, 3) removing/destructing ferrocyanide, and 4) removing strontium from the sludge. Technologies under development include 1) cesium extraction testing, 2) calcination/dissolution process development, 3) biological destruction of tank wastes, 4) compact processing unit demonstration, and 5) tank waste processing analysis.

Fig. 3. Typical Hanford site waste.

SUMMARY

Across the DOE complex, 332 underground storage tanks have been used to capture, process, and store radioactive and chemical mixed waste generated from weapons materials production. To date, little of this waste has been treated and disposed of, and a large inventory exists. The tanks vary in age, size, and design. These tanks contain highly radioactive sludge, salt cake, and supernate. The major chemical constituents are nitrate and nitrite salts, hydrated metal oxides, phosphate precipitates, transuranics, and isotopes of strontium, iodine, and cesium. The initial Underground Storage Tank – Integrated Demonstration Program's focus is on those technologies that can provide near-term benefits toward remediation of underground storage tanks. The current technical work is directed toward three fundamental problem areas that are shared by most of the participant sites: waste characterization, waste retrieval, and waste separations. Smaller investments are dedicated to the long-term requirements for low-level waste forms, in situ processing, and site closure.

For the Underground Storage Tank – Integrated Demonstration Program to be successful there must be a widespread transfer and use of the demonstrated technologies by the DOE complexes and sites in the private sector. This will require that the technologies be better, cheaper, faster, and/or safer than current baseline technologies. These technologies and associated databases must also be defensible to the public, regulators, and the technical community.