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Office of Environmental Management

Office of Technology Development

Underground Storage Tank Integrated Demonstration (UST-ID)

Technology Summary

MASTER

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UNDERGROUND STORAGE TANK INTEGRATED DEMONSTRATION

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OFFICE OF TECHNOLOGY DEVELOPMENT OVERVIEW

The Department of Energy (DOE) established the Office of Technology Development (OTD) (EM-50) as an element of Environmental Restoration and Waste Management (EM) in November, 1989 (see Figure 1). The organizational structure of EM-50 is shown in Figure 2.

EM manages remediation of all DOE sites, as well as wastes from current operations. The goal of the EM program is to minimize risks to human health, safety and the environment, and to bring all DOE sites into compliance with Federal, state, and local regulations by 2019. EM-50 is charged with developing new technologies that are safer, faster, more effective and less expensive than current methods.

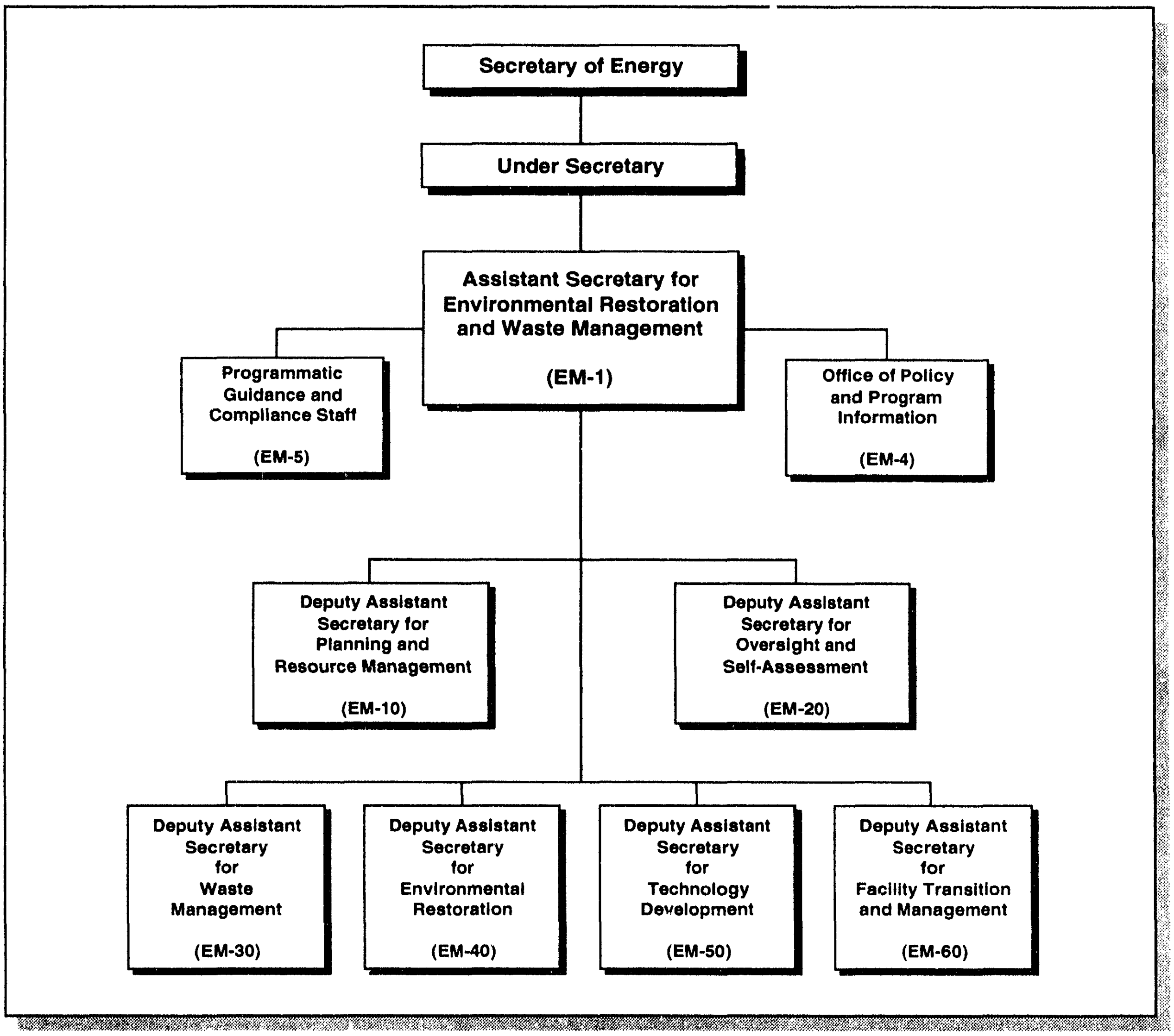

Figure 1. DOE Organizational Structure as of June 1993.

In an effort to focus resources and address opportunities, EM-50 has developed **Integrated Programs (IP)** and **Integrated Demonstrations (ID)**. An *Integrated Program* is the cost-effective mechanism used to solve a specific aspect of a waste management or environmental problem either unique to a site or common to many sites. An Integrated Program supports applied research to develop innovative technologies in key application areas organized around specific activities required in each stage of the remediation process (e.g., characterization, treatment, and disposal).

The *Integrated Demonstration* is the cost-effective mechanism that assembles a group of related and synergistic technologies to evaluate their performance individually or as a complete system in correcting waste management and environmental problems from cradle to grave.

The Underground Storage Tank Integrated Demonstration (the subject of this report) is part of EM-552, the Waste Management Division of EM-55.

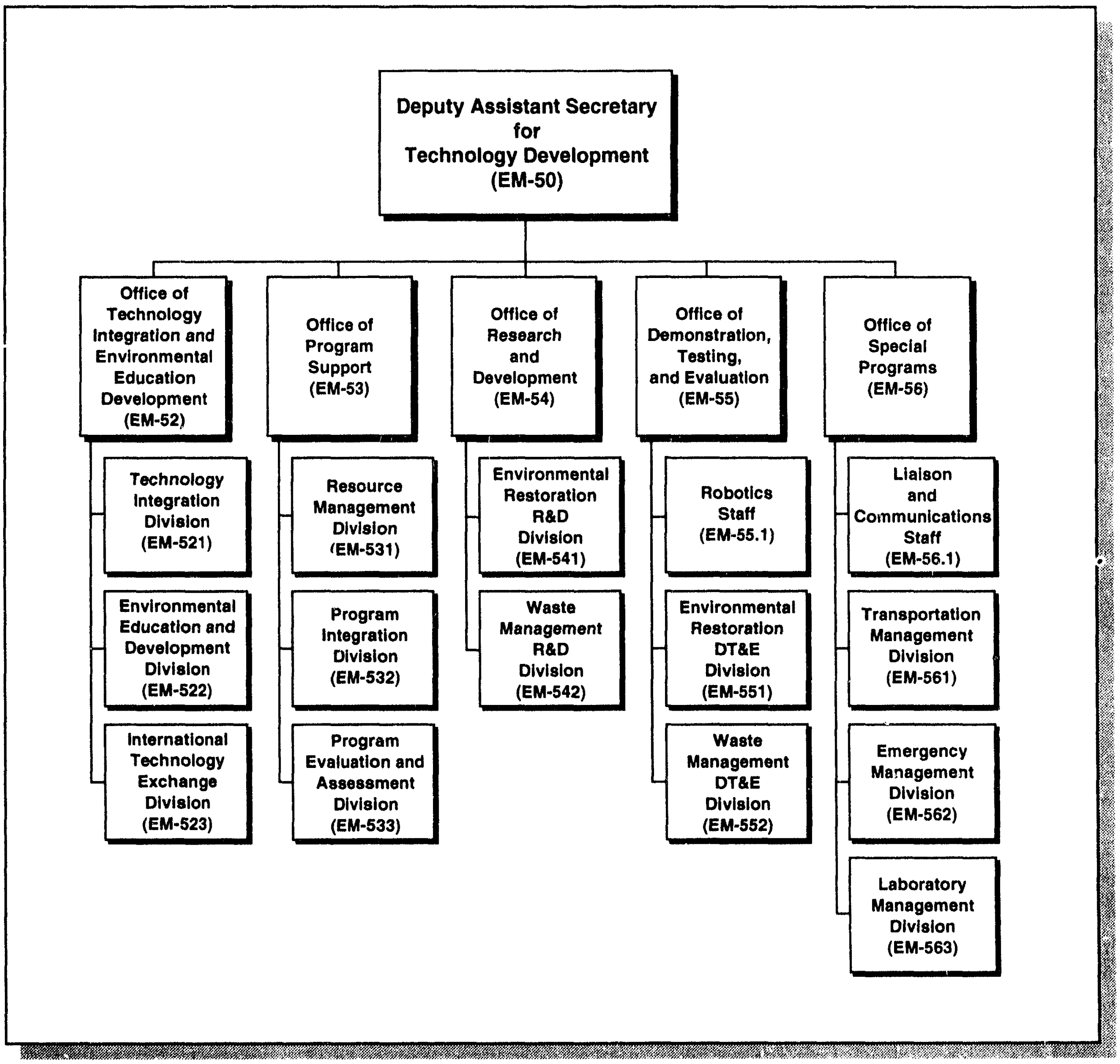

Figure 2. Office of Technology Development Organizational Structure as of June 1993.

UNDERGROUND STORAGE TANK INTEGRATED DEMONSTRATION OVERVIEW

THE CHALLENGE

The DOE complex currently has 332 underground storage tanks (USTs) that have been used to process and store radioactive and chemical mixed waste generated from weapon materials production. Very little of the over 100 million gallons of high-level and low-level radioactive liquid waste has been treated and disposed of in final form.

Two waste storage tank design types are prevalent across the DOE complex: single-shell wall and double-shell wall designs (see Figure 3). They are made of stainless steel, concrete, and concrete with carbon steel liners, and their capacities vary from 5,000 gallons (19 m^3) to 10^6 gallons (3,785 m^3). The tanks have an overburden layer of soil ranging from a few feet to tens of feet.

Tank waste consists of several physical forms: sludge, supernatant, and salt cake. Most of the waste is alkaline, and contains the following chemical constituents: nitrate and nitrite salts (approximately half of the total waste), hydrated metal oxides, phosphate precipitates, and ferrocyanides. The 640 MCi of radionuclides are distributed primarily among the transuranic (TRU) elements and fission products, primarily ^{90}Sr and ^{137}Cs. In-tank atmospheric conditions vary in severity from near ambient to temperatures over 93^{0}C; tank void-space radiation fields can be as high as 10,000 rad/h.

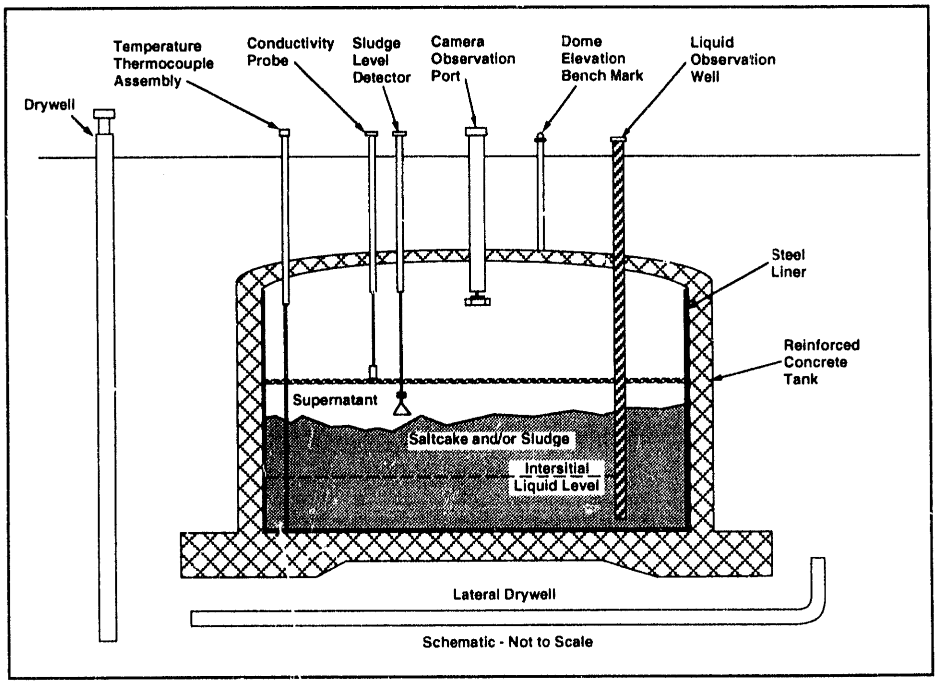

Figure 3. Typical Single-Shell Tank.

Responding to the need for remediation of tank waste, driven by Federal Facility Compliance Agreements (FFCAs) at all participating sites, the Underground Storage Tank Integrated Demonstration (UST-ID) Program was created by the US DOE Office of Technology Development in February 1991. Its mission is to focus the development, testing, and evaluation of remediation technologies within a system architecture to characterize, retrieve, treat to concentrate, and dispose of radioactive waste stored in USTs at DOE facilities. The ultimate goal is to provide safe and cost-effective solutions that are acceptable to the public and the regulators.

TECHNOLOGY NEEDS

The UST-ID has focused on five DOE locations:

- the Hanford Site, which is the host site, in Richland, Washington,
- the Fernald Site in Fernald, Ohio,
- the Idaho National Engineering Laboratory near Idaho Falls, Idaho,
- the Oak Ridge Reservation in Oak Ridge, Tennessee, and
- the Savannah River Site in Savannah River, South Carolina.

Hanford has 177 tanks that hold over 60 percent of the total DOE tank waste. Most of these are single-shell tanks that have exceeded their life capacity, and many are leaking. Due to several changes in the production processes since the early 1940's, some of the tanks contain incompatible waste components, and generate hydrogen and excess heat that risk tank integrity.

The UST-ID has focused its technology development on those fields where currently available technology does not meet the technical and safety requirements for tank waste remediation. The fundamental problem areas that are shared by most of the participant sites, and have been designated as subprogram elements, are (see Figure 4):

- waste characterization;
- waste retrieval and conveyance;
- waste separation and pretreatment;
- low-level waste treatment and disposal; and
- site closure.

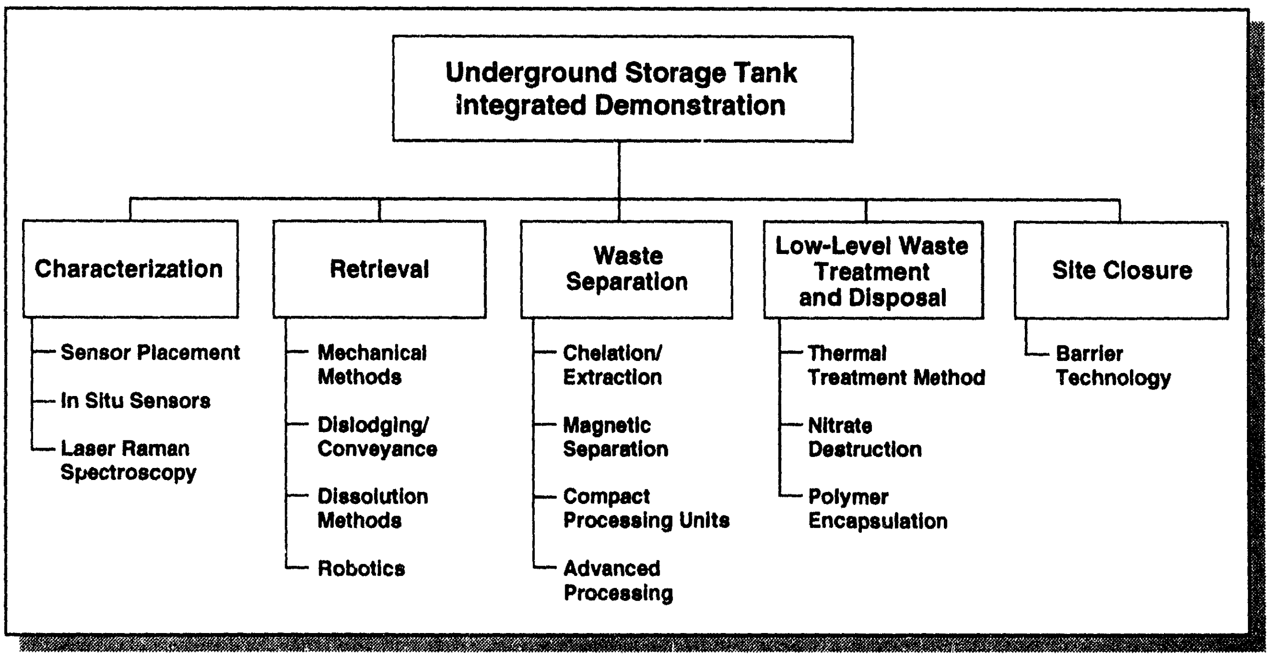

Figure 4. Underground Storage Tank Integrated Demonstration Subprogram Elements.

Characterization of tank wastes has historically been very expensive, and has failed to obtain representative data for many tanks. Under the UST-ID Program, sensors are being developed which will decrease laboratory analytical sample handling, alleviating safety concerns associated with handling. For example, Fiber Optic Laser Raman spectroscopy would be applied towards the in situ identification of radioactive tank wastes. Low-level waste (LLW) treatment will produce waste forms which are chemically and physically durable, and will reduce waste volume. Remotely controlled waste retrieval devices are being developed jointly with the Robotics Program of the OTD, which are capable of dislodging the sludge and saltcake fractions of the wastes and conveying them outside of the tanks. These devices are designed to fit through 12 inch diameter access ports, and work in highly radioactive environments. Waste separation techniques will separate tank wastes into low-level, TRU and high-level fractions, thereby significantly reducing the volumes of high-level wastes requiring costly disposal. Site closure technologies, a variety of containment barriers designed to capture effluents escaping from the tanks due to leakage, are currently being developed by related programs; they will be adopted in the near future by the UST-ID for full-scale testing, once their feasibility has been satisfactorily demonstrated.

ACCOMPLISHMENTS

In the waste characterization development program, the Raman spectrometer and infrared spectroscopy system have been demonstrated on real waste in a hot cell, setting the stage for the development of a multi-sensor system for placement in tanks. Retrieval tool development includes the completion of testing of the Soft Waste Dislodging Tool and air conveyance system on a waste simulant, demonstrated control of intelligent end effectors, and extensive tests of waste dislodging and conveyance end effectors for the first generation Long Reach Arm. Successes in Waste Processing include the initiation of hot cell testing of liter quantity volumes of sludge and supernatant for processing of Oak Ridge Melton Valley Storage Tank (MVST) wastes, and demonstration of calcination/dissolution process for destruction of organics, ferrocyanides, and nitrate/nitrite salts in tank wastes using simulated wastes. Waste forms development includes the completion of leachability tests for both polyethylene and alumina-based ceramic waste forms.

COLLABORATION/ TECHNOLOGY TRANSFER

The UST-ID secures the active involvement of private industry, universities, and other government agencies, where appropriate, through establishing collaborative partnerships (CRADAs), licensing of technologies, fostering technical personnel exchanges, effecting consulting agreements, and prompting shared use of scientific facilities.

A number of the technologies developed under the UST-ID will be transferrable to other applications outside the DOE complex. Newly developed characterization technologies will be used in tanks and pipes containing materials other than waste. The retrieval technologies developed may contribute to automation-assisted manufacturing, non-radioactive waste management, underwater mining and retrieval operations, and nuclear power plant operations. New barrier technologies will be more robust than those currently employed, and will contribute to the ability to isolate non-nuclear contaminants.

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Characterization

Section 1.0

1.0 CHARACTERIZATION SUBPROGRAM

DOE has committed itself to safe and complete remediation of High-Level Waste (HLW) stored in underground tanks throughout the DOE complex. The Office of Technology Development (OTD), or EM-50, of the DOE's EM has undertaken the task of developing new technologies needed for safe, expedient, and cost-effective remediation of HLW in tanks. The UST-ID Program is developing technologies which focus on HLW tank remediation.

The goal of the UST-ID is to develop remediation technologies which are inherently safe. Safe remediation of HLW from tanks is impossible without the knowledge of waste's chemical and radioactive composition, and basic physical parameters. The UST-ID Program's Characterization task is focused on developing technologies which identify the waste's chemical species, rheological properties such as density and viscosity, moisture content, and TRU waste content. In order to assure that the waste characteristics obtained truly reflect the waste as it exists in tanks, all of the characterization methods being developed by the UST-ID program emphasize in situ characterization. In situ characterization technologies of tank waste, once deployed, will significantly decrease the cost of waste analysis, which is currently performed in laboratories on core samples taken from tanks at a very high expense. Most importantly, in situ characterization methods are much safer than any methods which require direct handling and transportation of high-level waste.

In situ chemical speciation analysis methods currently being developed include spectrographic methods, such as Laser Raman, and infrared, both of which utilize fiber optic probes for delivery of light signals to the waste.

Prior to deployment of in situ sensors, and during the retrieval operations, it will be necessary to know the topography of the waste in tanks. Two methods are being developed to address that need. The laser range finder (LRF) will provide quick but coarse mapping of the tank interior. A structured light technique will be used for detailed mapping of the tank interior.

These characterization and surveillance instruments will be deployed and positioned within the tanks using a remotely operated, robotic arm. This Light Duty Utility Arm (LDUA) will operate as a versatile platform in a HLW environment, and therefore need to be hardened against the hostile (radiation, caustics, water vapor, etc.) elements present in the tank surroundings.

1.1 CHARACTERIZATION FIELD SUPPORT SYSTEM FOR IN SITU CHARACTERIZATION OF TANK WASTE

TASK DESCRIPTION

Prior to understanding all the aspects of remediating the underground storage tanks at Hanford and across the entire DOE complex, extensive characterization is required of the waste stored within the tanks as well as of the integrity of the tanks themselves.

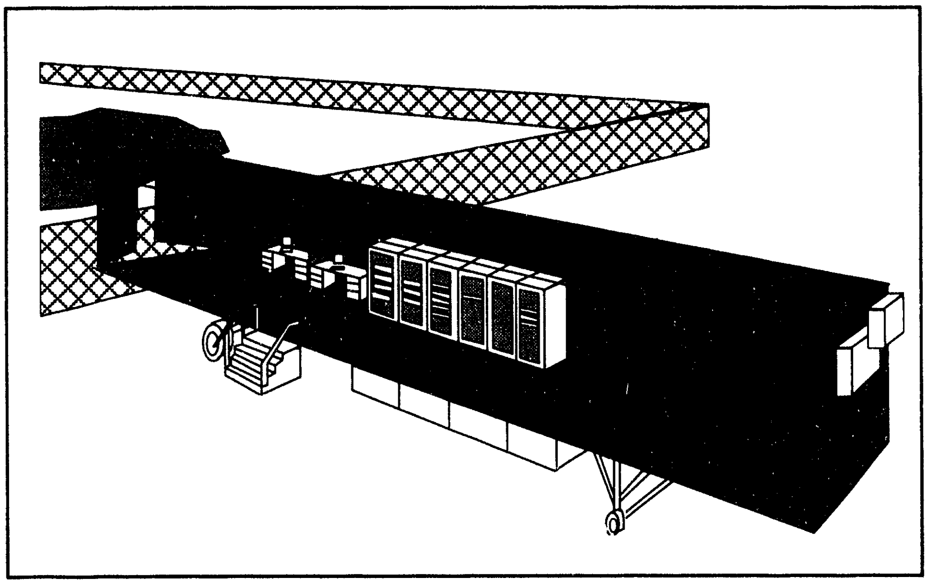

Figure 5. In Situ Characterization Field Support System.

This particular task includes interfacing with the Tank Waste Remediation System program at Hanford to define specific characterization needs, functions and requirements. This task also provides the focal point for coordinating all characterization activities. An important goal is the development of a field support system including a trailer that contains data acquisition and control equipment (see Figure 5).

A deployment device, equipped with characterization and/or sampling end effectors, will be inserted into the tank through an existing riser. Data will be collected, analyzed, recorded and all processes will be controlled from the mobile operations trailer. All functions necessary for in-field, in situ data acquisition, recording, analysis and reporting will be provided in the trailer. Power supplies, heating, ventilation and air conditioning, and communications subsystems will be integrated as needed to support technology deployment.

The trailer and equipment will be located up to nine hundred feet away from the tank in an uncontaminated area. It will support a deployment device, such as a robotic arm, which is placed inside the tank to deploy sensors and cameras. The trailer will provide an operations center for the robot arm, power supplies, video monitors, computers, data acquisition equipment and test equipment. This trailer is expected to be deployed with the Light Duty Utility Arm with the following instruments:

- Raman spectrometer;
- video and film cameras;
- radiation dosimeter;
- structured light mapping system;
- laser range finder system; and
- infrared spectrometer.

Other instruments are under consideration.

This task provides the support infrastructure (operations trailer, power supplies, data and control systems, test equipment) which can interface with a variety of instruments and deployment devices. Techniques for determining the physical, chemical and radiological nature of UST wastes will be developed by others and integrated into a system design. The complete system will provide in situ, multi-sensor characterization and sampling capability for the USTs.

TECHNOLOGY NEEDS

UST-ID must provide a means to characterize the physical, chemical and radiological properties of the tank waste in order to plan for the waste retrieval and processing. Tank waste characterization presently involves removing two core samples from each tank and subsequently evaluating these samples in a hot cell and preparing them for detailed analysis. A single core sample can take up to six months to process and costs more than a million dollars. Expediting the process with in situ characterization is greatly needed. For safety reasons, the characterization equipment must be operated remotely from an uncontaminated area.

Also, many of the single shell tanks are known or suspected leakers. The cause of the leaks is not known in every case. Characterization of the tanks themselves is required to ensure that the methods of waste removal will not jeopardize the tank integrity.

ACCOMPLISHMENTS

The support system design has been completed and a trailer is being procured and outfitted for field use. Most of the control and data acquisition systems have also been procured. The trailer instrumentation will be installed and tested in the near future.

COLLABORATION/ TECHNOLOGY TRANSFER

Commercial computer systems have been employed in the design. The control software development has been led by Sandia National Laboratories, which is in the process of commercializing the product.

The initial development phase has been completed and the instrument and control trailer task will be transferred to the Light Duty Utility Arm system in FY94. Installation activities will continue through to completion and the various systems will be tested both individually and as an integrated system. Once testing is complete, the system will be ready to deploy.

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1.2 FIBER OPTIC NEAR INFRARED SPECTROMETER SYSTEM

TASK DESCRIPTION

Westinghouse Savannah River Company (WSRC) at the Savannah River Technology Center (SRTC) is developing a fiber optic probe to accurately measure the moisture content of underground storage tank waste. The probe will be designed for use in a hot cell and as an end effector on the Light Duty Utility Arm for in situ measurements. This technology will allow a radiation resistant and easy to use sensor to rapidly make moisture measurements.

Near infrared (NIR) spectroscopy is a reasonably well established technology that is being adapted for tank waste remediation. A diffuse reflection fiber optic probe will be inserted into the material. The reflection of a light signal (both the signal and its reflections transmitted through optical fibers) will be analyzed. The frequency and intensity of the reflected light will reveal the quantity of moisture present in the tested material. The technology is compatible with Raman and fluorescence technologies such that a single probe can be used for multiple measurements.

One of the primary activities is to determine the radiation effects on the measurements and the lifetime of the probe. The probe must be calibrated and the effects of different waste material and moisture contents evaluated. The SRTC is developing the chemometrics and spectrometer control for use with commercially available equipment.

TECHNOLOGY NEEDS

Ferrocyanides were used in the processing of fission products. Their existence in the tank raises the possibility of an explosion if the moisture within the tank is insufficient. To fully understand the conditions inside these tanks, an in situ method is needed to measure tank waste moisture content.

The present system requires core samples to be removed from the tank, processed through a hot cell and then undergo extensive analysis. Because each core sample can take up to six months to process, a large backlog exists for characterizing the 332 underground storage tanks across the DOE complex. An easily deployable, in situ method of analyzing safety-related characteristics will help eliminate the backlog.

Knowledge of the moisture content is also required for waste retrieval and process planning.

ACCOMPLISHMENTS

Initial moisture level testing has been quite successful. Tapered fiber probes have been fabricated and moisture calibration procedures completed. Preparations are underway to integrate the NIR and the Raman spectroscopy systems for in situ applications.

COLLABORATION/ TECHNOLOGY TRANSFER

NIR technology is reasonably well established. Commercial equipment has been adapted for fiber optic use. Three companies have applied for a license to produce the fiber optic probe. A CRADA is being negotiated with Ciba-Geigy to test systems in a commercial pesticide plant.

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1.3 FIBER OPTIC LASER RAMAN SPECTROSCOPIES FOR TANK WASTE CHARACTERIZATION

TASK DESCRIPTION

Fiber Optic Laser Raman spectroscopy systems will be developed and tested in this task for characterization of tank wastes. These systems are designed so they can be deployed in either hot cells or in waste tanks, enabling both ex- (see Figure 6) and in-situ characterization.

Two different ways to chemically profile waste surface inside waste tanks will be investigated. One consists of a mechanically-driven fiber optic probe that will be swept over the surface to be interrogated; the Light Duty Utility Arm (see Section 1.4) will be used to precisely position the probe (Remote Fiber Optic Raman Spectroscopy). The other involves a scanner that will directly sweep a laser beam and the field-of-view of a spectrometer across the surface; in this case the simple rotation of a mirror can be used to guide the laser beam and collect the scattered radiation (non-contact Raman spectroscopy). Relatively modest laser powers (100 mW) and small collection optics (22 mm) have been found to be effective to characterize samples up to tens of feet away in non-contact Raman spectroscopy. Performance parameters (e.g., spatial resolution, sample to probe distance) of the two systems will be evaluated and compared.

In-situ characterization of core sections will be achieved with the use of a Raman fiber optic probe fitted inside a cone penetrometer. Such a probe is being developed at WSRC. Elements that define performance objectives of the Raman probe include the expected tank environment, cone penetrometer requirements, and contaminants to be measured.

Complementing these activities in a system approach are two other subtasks. One is the development of a Raman library/database to support qualitative and quantitative applications of the spectroscopic techniques. The library/database will contain archived Raman spectra that have been obtained from pure material, simulated and real tank waste (see Figure 7). The database will initially hold spectroscopic information on ferrocyanide, ferricyanide, nitrate and nitrite, but will be expanded to include other chemical species such as organic compounds. The other subtask is the ra-

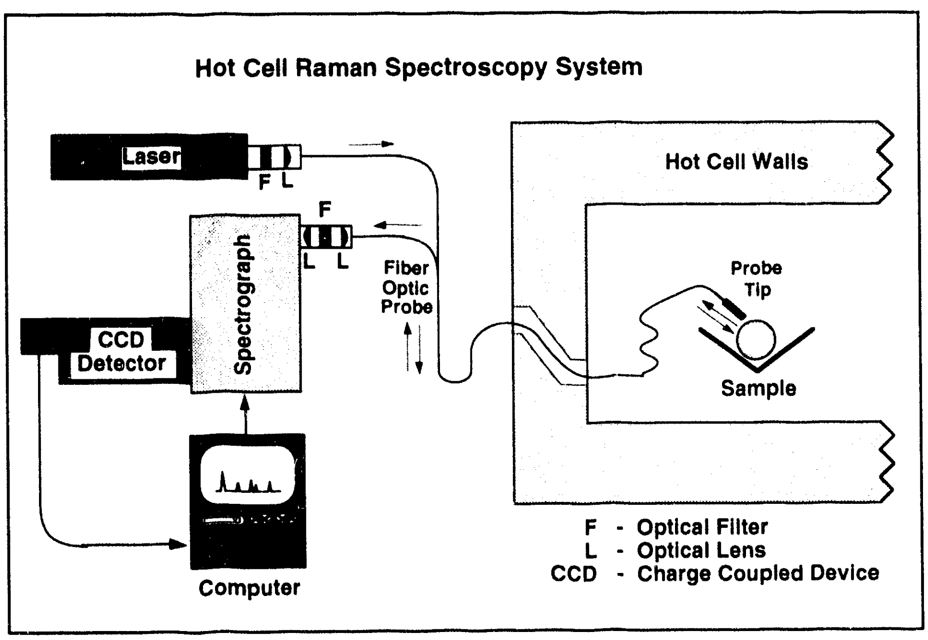

Figure 6. Hot Cell Laser Raman Spectroscopy System.

diation testing of fiber optics. Two aspects will be addressed in this subtask: survival of optical fiber material in radiation environments; and changes in Raman spectral signal induced by the radiation.

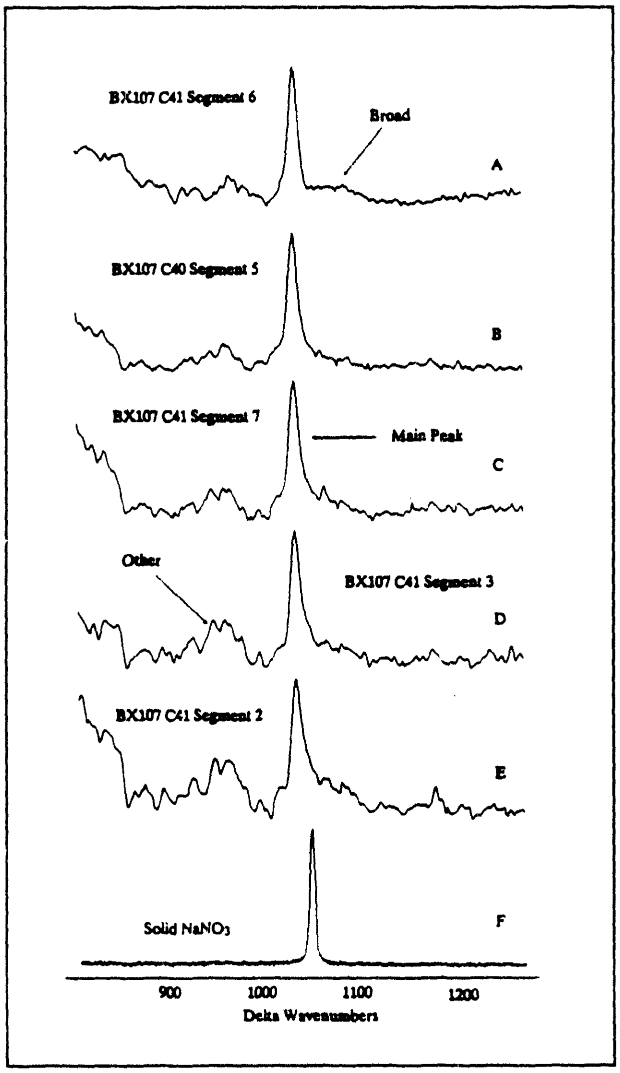

Figure 7. Laser Raman Spectra of Various Nitrate-Containing Materials.

TECHNOLOGY NEEDS

Laboratory analysis of tank waste is both time consuming and expensive. While Raman spectroscopy will not replace established regulatory analysis, its development as a screening technique for both ex- and in-situ characterization offers significant reduction in time, cost, and secondary waste generation; minimizes radiation exposure of personnel; and provides valuable guide to sampling and analysis of core waste material.

An in-situ waste probe will also provide data on the homogeneity, location and mapping of key waste materials (e.g., ferro/ferricyanide) inside the tanks; these are data necessary to direct and monitor waste retrieval.

ACCOMPLISHMENTS

The feasibility of applying laser Raman spectroscopy to tank waste characterization has been demonstrated. Analyses of pure materials and surrogates showed that unique Raman scattering can be used to identify major tank waste components including ferrocyanide, ferricyanide, nitrates and nitrites. In addition, a remote fiber optic probe has been installed in a hot cell at Hanford and used to record Raman spectra of real tank waste material.

COLLABORATION/ TECHNOLOGY TRANSFER

Basic support and coordination for the development, integration and testing of the spectroscopic systems are provided by the Westinghouse Hanford Company. Lawrence Livermore National Laboratory will evaluate the two spectroscopic methods — remote fiber optic and non-contact Raman spectroscopies — and recommend a conceptual design for a Raman probe suitable for incorporation in a cone penetrometer; the Raman probe will be designed and developed by WSRC. Florida State University and the Naval Research Laboratory have been contracted to establish the Raman library/database and perform the radiation testing, respectively.

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1.4 LIGHT DUTY UTILITY ARM SYSTEM

TASK DESCRIPTION

The Light Duty Utility Arm (LDUA) is a remotely operated, mobile system to deploy end effectors for waste characterization and tank inspection (see Figure 8). This device brings together technologies developed within multiple DOE laboratories and industry into an integrated system for providing a spectrum of storage tank characterization capabilities. The technology will enhance existing capabilities which are limited to single axis deployment of instruments into tanks. The arm will provide seven degrees of freedom with a 4.5 m (13.5 foot) reach for positioning end effectors in multiple tank locations.

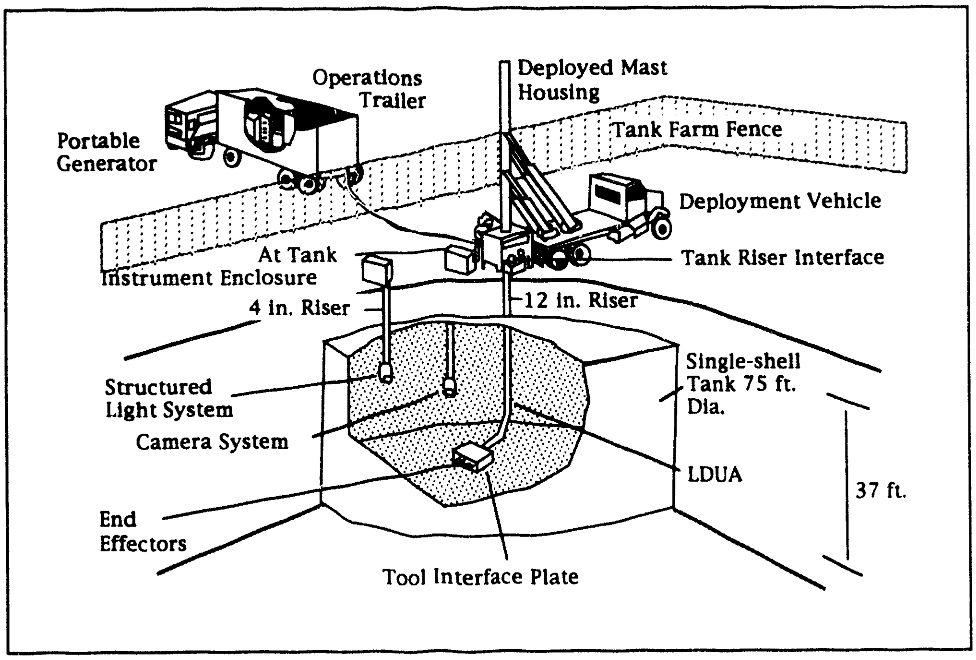

Figure 8. Light Duty Utility Arm System.

This pilot project is slated for field deployment and testing of an initial unit in Hanford single shell tanks. It is comprised of six major subsystems:

- LDUA robotic manipulator, deployment mast, containment housing, and vehicle;
- tank riser interface and confinement;
- maintenance subsystem;
- control and data acquisition;
- operations and control trailer; and
- end effectors.

Combining these into one integrated system is the primary focus of this activity. To ensure compatibility, the interface plate for the end effectors must be carefully specified to ensure the end effectors developed under the characterization activities can be efficiently integrated into the system.

Depending upon the individual tank contents and the characterization needs of each tank, the set of end effectors can be adjusted to meet those needs.

Within this task, significant effort has been put forth on developing and designing the confinement and maintenance subsystems. The LDUA and associated equipment must be decontaminated as it exits from the tank, and an automated end effector exchange station is being designed to maintain and change out the characterization and surveillance equipment. A future need for the LDUA may include some form of waste sampling. Methods to obtain and transfer small samples are being evaluated.

TECHNOLOGY NEEDS

The present process of tank waste characterization requires core samples to be removed from the tank, processed through a hot cell and then undergo extensive analysis. Because each core sample can take up to six months to process, a large backlog exists for characterizing the 332 underground storage tanks across the DOE complex. An easily deployable, in situ method of analyzing safety-related waste characteristics will expedite these characterization activities.

Core samples do not provide information on the integrity of the tanks themselves. Current capabilities for performing tank inspection have the same limitations as characterization techniques. Cameras and sensors are inserted into the tanks through risers on fixed supports. These systems are limited to vertical deployment of sensing devices and can only operate directly below a tank penetration. Tank wall integrity and dispersion of material laterally cannot be properly evaluated. Remote in situ characterization helps to ensure a minimum of risk to personnel performing the characterization operation.

ACCOMPLISHMENTS

The contract for the deployment arm and deployment system has been placed with SPAR Aerospace Company, located in Toronto, Canada. The instrumentation and control trailer conceptual design has been completed and will be procured in FY94. The decontamination process has been defined and the design is being developed with a CRADA partner.

The first tanks to be evaluated have been chosen and the end effector package to address these specific tank issues is being determined. The task of determining just what the needs are is a complex activity, and establishing these criteria is a significant accomplishment, as well.

COLLABORATION/TECHNOLOGY TRANSFER

All subsystems are being developed with varying degrees of industry and/or university involvement. The LDUA itself will initially be deployed at Hanford. The Idaho National Engineering Laboratory is planning to procure a LDUA for use at that site as well.

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1.5 LASER RANGE FINDER AND STRUCTURED LIGHT MAPPING SYSTEMS

TASK DESCRIPTION

Oak Ridge National Laboratory (ORNL) and Pacific Northwest Laboratory (PNL) are each developing laser based systems to characterize the inside of waste storage tanks. The PNL system is a Laser Range Finder (LRF) and it will be designed to take advantage of the LDUA as a platform for the hardware. The ORNL system is a self-deployed, structured light mapping system that may be used with the LDUA.

Structured Light and Laser Range Finder are technologies that are well established due to the relatively simple concepts on which they are based. Essentially, the hardware consists of a laser and a receiver (such as a camera) and data processing equipment. For the structured light system, the position and direction of propagation of the laser beam is known and controlled. The camera shows the two dimensional projected position of the beam on the surface to be mapped. Knowing that this position is the intersection of the laser beam with the object, one can perform simple trigonometric calculations to determine the position of the point in space. The laser range finder uses a laser to measure line of sight distance to an object. Given the distance to this object in a known (controlled) direction, the position of it in space is easily calculated. In each of these cases, from the measurement of multiple points, a three dimensional image of the object and its position can be determined (see Figure 9).

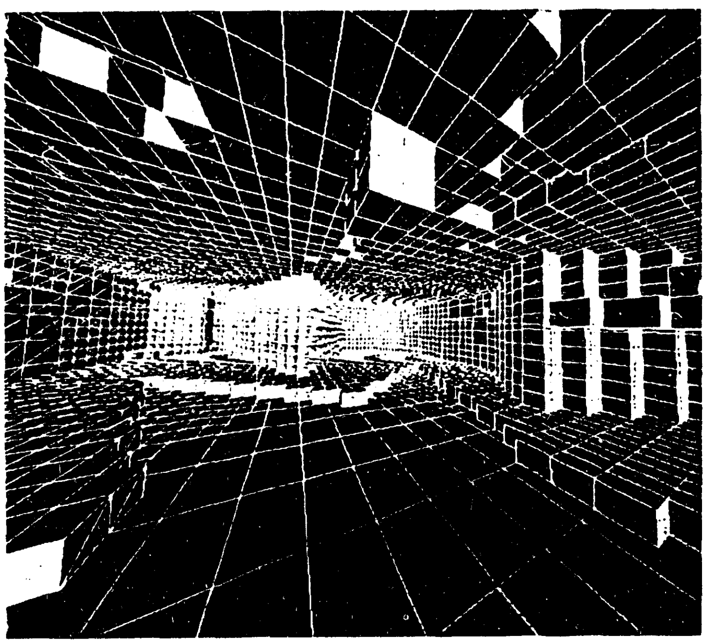

Figure 9. World view after first rough cut by Laser Range Finder.

TECHNOLOGY NEEDS

The benefits of these systems are many. They enable the creation of a three dimensional map (world model) inside the tank, including the waste surface shape, contour, and volumetric data. They will also assist in the planning and execution of waste characterization and retrieval operations.

The PNL Laser Range Finder System is based on the LASAR scanning laser range finder manufactured by Perceptron. As compared to the structured light system, the Laser Range Finder has lower resolution, but is capable of providing near real time images. These capabilities qualify it for use in supervisory control and/or periodic surveillance. The structured light approach is slower, but gives a much finer resolution in all three dimensions. The Structured Light System has demon-

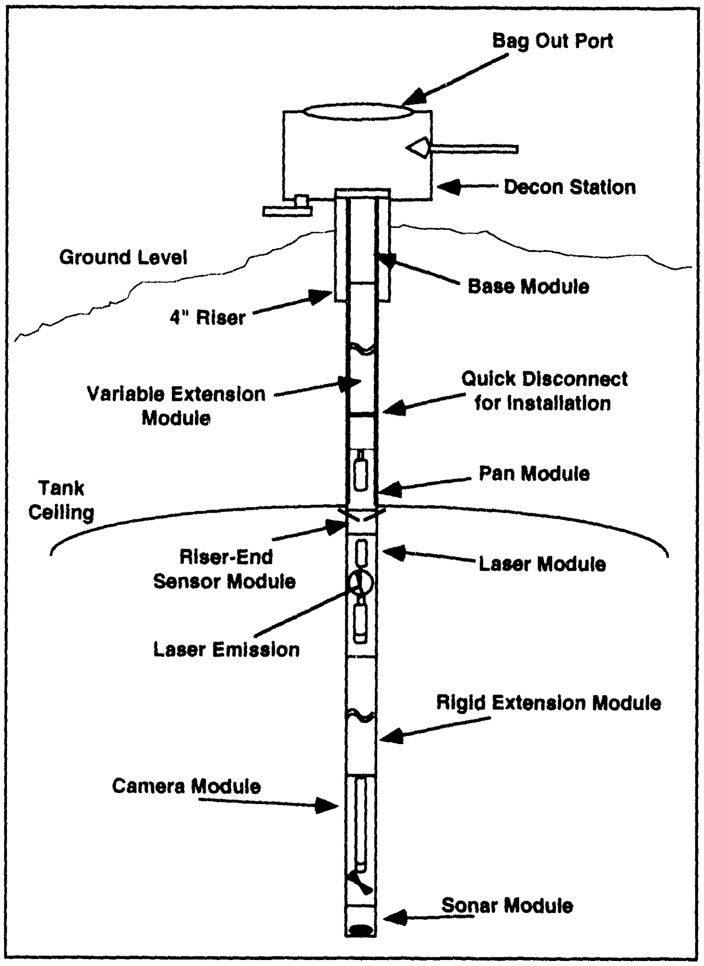

Figure 10. LDUA Structured Light Surface Mapping Conceptual Design for Sensor Probe.

strated field performance of accuracy and repeatability of better than 0.5". It may be used to map the interior of the tank including, among others, the surface contour, the condition of the walls and dome, and the location of in-tank hardware.

The Structured Light Surface Mapping System will be deployed through either single or multiple risers (see Figure 10). In the case of multiple riser deployment, the laser and the camera are inserted in separate risers, giving a very accurate and efficient "pitch and catch" set-up (see Figure 11).

For those cases where it may be necessary to deploy the entire system through a single penetration, the system will be capable of being deployed through a single 4" riser, albeit with some loss of accuracy and detail.

The Laser Range Finder is based on an existing piece of commercial hardware and appears to be well suited for use in tanks. Data fusion capability is being developed to combine data from the Laser Range Finder and Structured Light to provide an integrated world map, which will aid in path planning and collision avoidance. Each of these systems will be radiation-hardened to allow for longer in-tank time and therefore, higher resolution. Along with the hardware, software is being developed to aid in data acquisition and control.

ACCOMPLISHMENTS

In 1992, a surface mapping system based on the structured light approach was deployed at Fernald to map waste surfaces in the K-65 silos. The system contributed significantly to the successful completion of a CERCLA Removal Action Milestone in December 1993. The successful field deployment of structured light technology at Fernald made it highly desirable to both commercialize the technology and transfer it to the Hanford site.

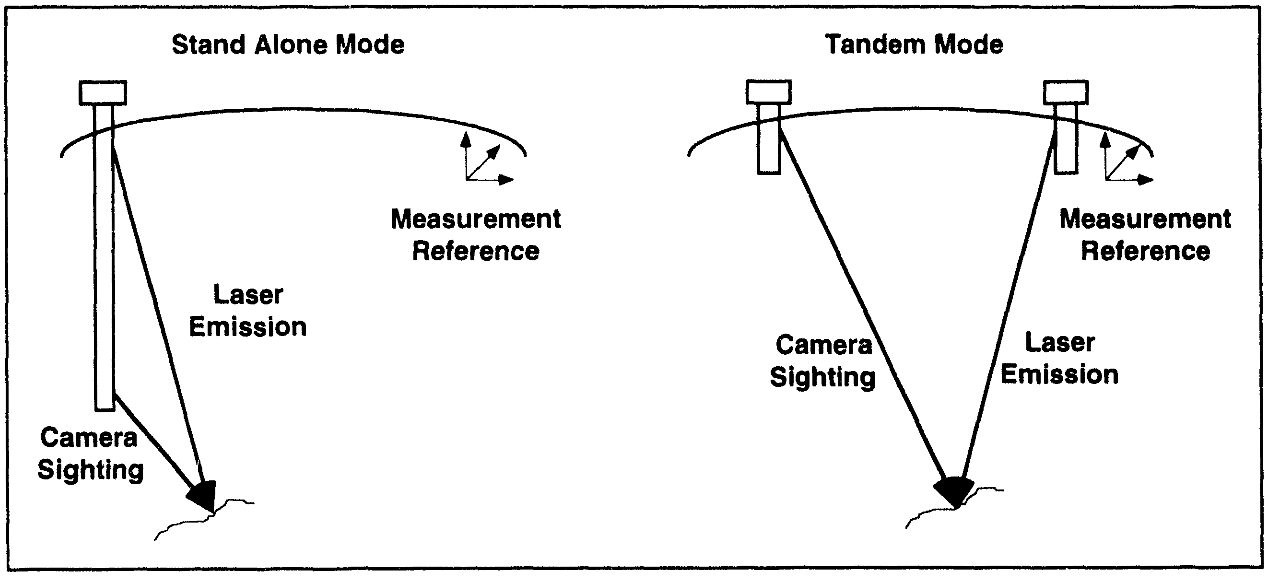

Figure 11. LDUA Structured Light Surface Mapping Sensor Probe Operation.

COLLABORATION / TECHNOLOGY TRANSFER

Mechanical Technology Incorporated (MTI) has entered into two CRADAs with Sandia National Laboratory and ORNL to develop a second generation surface mapping system suitable for deployment in the tanks at Hanford. They bring technological, system integration, and calibration expertise. These CRADAs also allow technology transfer of the Fernald mapping system as well as new technologies developed within the CRADA.

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Waste Dislodging and Conveyance

Section 2.0

2.0 WASTE DISLODGING AND CONVEYANCE SUBPROGRAM

The 332 underground storage tanks throughout the DOE complex have received a diverse accumulation of wastes during the past fifty years of weapons production by the DOE. Recently, as the condition of the tanks has deteriorated and the risk of leakage increased, dewatering processes have removed much of the free liquid. The tanks now contain wastes ranging in consistency from remaining supernate (liquid) and soft sludges to concrete-like salt cake. Tanks also contain miscellaneous foreign objects and in-tank hardware such as piping. Unlimited sluicing, adding large quantities of water to suspend solids, is the baseline DOE method for sludge removal from tanks. This process is not capable of removing all of the material from tanks. Its use has been questioned by the State of Washington, due to the existing and potential leaks of hazardous and radioactive liquids from deteriorated tanks into nearby soils and groundwater.

The Waste Dislodging and Conveyance task of the Underground Storage Tank Integrated Demonstration is developing tools for the removal of materials from these tanks. The working tools and removal devices being developed include suction devices, rubblizing devices, water and air jets, waste conditioning devices, grit blasting devices, transport and conveyance devices, cutting and extraction tools, monitoring devices, and various mechanical devices for recovery or repair of waste dislodging and conveyance tools. For some retrieval operations it may be necessary to add small amounts of water to facilitate waste dislodging and removal. However, systems are being optimized to minimize the amount of water to be added to tanks, and to position the conveyance equipment deployed with the dislodging equipment to remove solid waste and free liquid as promptly as possible.

Dislodging and conveyance tools will ultimately be deployed as end effectors on a remotely operated, articulated arm called the Long Reach Arm being developed by the Office of Technology Development's Robotics Program. They will need to be capable of performing in a radiation environment of up to 10,000 rad/h and withstanding an accumulated dose of 10^7 rad.

2.1 HIGH PRESSURE WATERJET DISLODGING AND CONVEYANCE END EFFECTOR USING CONFINED SLUICING

TASK DESCRIPTION

The underground storage tanks at Hanford contain three basic material types, both individually and in combination: liquid supernatant, sludge, and hard saltcake. Removal of the sludge and saltcake has presented a technological challenge. A high pressure waterjet can be used to cut up and dislodge the tenacious sludge and saltcake. Combined with a conveyance system operating simultaneously, this confined sluicing can be used to effectively remove and convey waste from the tanks (see Figure 12).

The University of Missouri-Rolla, in conjunction with Sandia National Laboratory, has been developing a confined sluicing technique to dislodge and convey difficult wastes from the underground storage tanks. Confined sluicing uses high pressure (70 MPa or 10,000 psi) to cut the material in the tank into small pieces and then sucks the material out using a high pressure (50 Mpa or 7,000 psi) jet pump. All the water and debris is removed without significant water loss to the tank. The device is attached as an end effector to an articulated arm that enters the tank through an existing riser. The result of the process is a steady flow (at around 1.9 liters/second (30 gpm)) of extracted material from the tank as an aqueous slurry. This minimizes handling problems and converts the tank wastes to a form that can be more easily treated.

TECHNOLOGY NEEDS

The baseline technology calls for sluicing techniques used in past practices. This method introduces a large quantity of water into the tank that is not immediately removed, increasing the possibility of uncontrolled leakage, even if only for a short time. Developing other methods or improving the sluicing method for removing these difficult materials from the tanks makes cleaning out the tanks safer and more efficient. Confined sluicing reduces the water needed to clean the tanks, and therefore reduces the quantity of waste that must be processed.

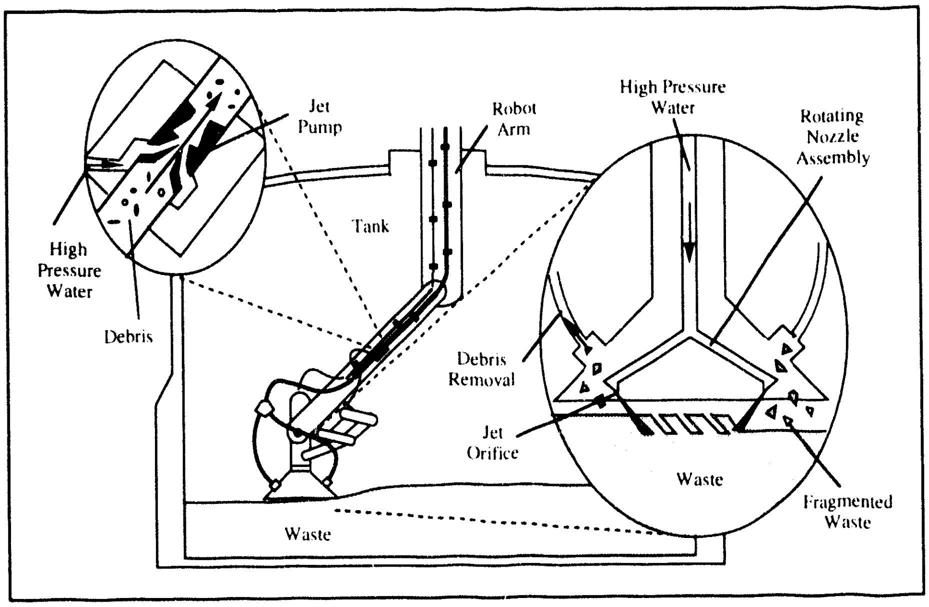

Figure 12. Water Jet Cutting.

ACCOMPLISHMENTS

The operational parameters of the waterjets that control the cutting and removal of waste material have been identified in the feasibility study. A shrouded waterjet has been designed and demonstrated to be effective on the sludge and is within the required pressure and volume flow requirements. Results to date show that the method has the potential to meet or exceed the performance requirements expected of it.

COLLABORATION/ TECHNOLOGY TRANSFER

This technology is an adaptation of existing systems for cleaning materials. Modifications are required to establish the parameters of performance and to design the equipment to work effectively within the restricted conditions encountered in the underground storage tanks at Hanford.

Informal discussions with possible industrial partners have taken place with some interest being expressed. As the system becomes better defined, development of a commercial vendor has become a greater part of the program. An advisory group of interested equipment manufacturers has been assembled and a commercial partner bringing the necessary industrial expertise will be brought on line as the program moves toward the point of field application.

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2.2 HYDRAULIC IMPACT END EFFECTOR

TASK DESCRIPTION

Lawrence Livermore National Laboratory (LLNL) has teamed with Quest Integrated, Inc. to develop an efficient method of breaking up large blocks of hard saltcake that have developed in underground storage tanks within the DOE complex. These remaining wastes often surround tank risers and equipment, making their removal doubly difficult. LLNL and Quest are developing a water cannon rubblizer as a hydraulic tool capable of fracturing the hard saltcake.

The system uses ultra-high pressure (276 MPa, 40,000 psi) to generate a powerful hydraulic shock to fragment the monoliths. The resulting fragmentation is comparable to that achieved by explosive charges without the hazard of "fly" rock or toxic fumes and without the precise positioning required for water jet cutters. The resulting fragment size varies with material. The current tool uses water as the working fluid, with only about 200 ml (one-half pint) per blast. The control console monitors the pressurization of the tool and controls the discharge of the tool through the control valve assembly. The end effector can be fired repeatedly with 5-10 seconds between blasts. The end effector is remotely operated, and the design incorporates several features to provide "fail safe" operation.

Development tasks are varied. The design can be refined to reduce the amount of additional processing required for the fragments. Alternative fluids are being evaluated which either vaporize or gel in the tank after discharge to limit the addition of water to the tank. Reduction of the poppet valve opening time will increase the shock energy rate. Finally, the end effector is being radiation-hardened and will be capable of accommodating remote decontamination.

TECHNOLOGY NEEDS

Many DOE sites have stored high-level radioactive wastes in underground tanks. Interim stabilization activities have removed much of the liquid from the tanks, leaving waste deposits in the form of sludge and hard saltcake. Removal of this saltcake from the tank equipment requires breaking up monolithic or large pieces of the saltcake into smaller fragments that can be easily handled and removed by other end effectors. The rubblizer requires a less complex and forgiving positioning system than waterjet technology, allowing for a simpler control system. The control system allows for either manual or automatic operation of the end effector.

ACCOMPLISHMENTS

Tests involving charge pressure effects, stand off distance, effector angle, dilution level, cycle rate and interface loads have been successfully completed. The results have led to a refinement of the design. Many parameters are being optimized and, with that, failure modes are better understood, such that failure mode recovery methods can be developed.

COLLABORATION/ TECHNOLOGY TRANSFER

LLNL is working with Quest Integrated Inc. to develop this technology. Joint testing is underway at both facilities and Quest is involved in evaluating the alternate fluid studies. Once developed, Quest will be able to commercialize the resulting product for use at other storage tank sites as well as market the product in other areas.

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2.3 SOFT WASTE END EFFECTOR, AIR CONVEYANCE SYSTEM

TASK DESCRIPTION

One of the major remediation activities within the DOE complex is the removal of waste materials from 332 underground storage tanks. These tanks contain liquid, sludge, and hard saltcake. This specific task involves developing the technical knowledge required for dislodging and retrieval of soft sludge waste stored in the tanks. With this understanding, Hanford engineers will be able to write technical specifications that industry will use to produce equipment to retrieve the sludge.

The testing equipment uses a developmental tool which can be tested in a mechanical agitator configuration using blades and nozzles for water or air injection, or a scarifier configuration using only injection nozzles. The blades and injected air or water cut through the waste. The spray helps move the wastes to the air-conveyance system inlet. The air conveyance system includes a water injection spray ring inside the conveyance hose, to facilitate waste transfer. The water that is injected by the conveyance system is immediately removed from the tank along with the waste, thereby causing no increase in risk of liquid leaking from the tank (see Figure 13).

The system can be attached as an end effector to a long reach, remotely controlled manipulator arm. The Long Reach Arm will move the scarifier through the sludge until it is all successfully removed from the tank.

TECHNOLOGY NEEDS

The heavy sludge presents many difficult problems from the standpoint of its varying consistency. A system is needed that can adapt to the changing sludge and still effectively and efficiently remove and convey the material from the tanks. Currently, there is no baseline technology to deal specifically with this waste type.

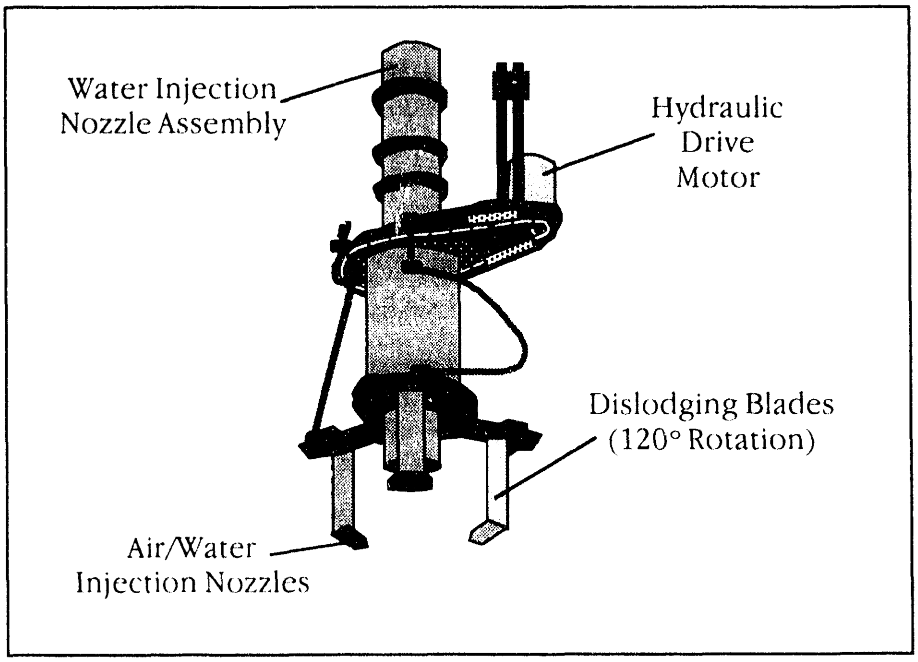

Figure 13. Sludge Dislodging End-Effector Assembly.

ACCOMPLISHMENTS

The team evaluated studies performed over the last 20 to 30 years, building on the knowledge gained over that time. Successful demonstrations have been performed on two types of simulated clay wastes. Short runs have shown that a retrieval rate of 4.9 liters/second (78 gpm) can be attained. This is more than 2.5 times the goal retrieval rate. The demonstrations supported the completion of a Hanford site milestone in an agreement between DOE, the State of Washington, and the Environmental Protection Agency. The tool was found to operate most successfully in the scarifier configuration, with nozzles injecting water instead of air.

This program has resulted in three invention disclosures. Two have been filed for developmental agitator/scarifier equipment, and the other addresses the water spray ring for the air conveyance system. This is a new application of air conveyance. The industry has never before conveyed wet, sticky material with its systems.

COLLABORATION/ TECHNOLOGY TRANSFER

The dislodging agitator/scarifier equipment is currently not commercially available. An equipment specification will be written to procure a viable sludge retrieval system, based on the technological specifications determined in this testing. An interface plate for mating the retrieval system to the Long Reach Arm will also be specified and procured. Industry partners presently include Hi-Vac (the air conveyance system) and EOA who supplied the interface plate.

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Waste Processing and Disposal

Section 3.0

3.0 WASTE PROCESSING AND DISPOSAL SUBPROGRAM

Employing current baseline technologies to clean up and remediate waste stored in USTs at the five DOE sites (Fernald, Idaho, Oak Ridge, Richland, and Savannah River) is both ineffective and expensive. Technology gaps exist, and large volumes of HLW will be generated while there is only limited space in the first planned nuclear waste repository for storing HLW generated from defense activities. Even if adequate space is made available, disposal of HLW will be very expensive, since each canister of vitrified HLW will cost up to one million dollars.

The Waste Processing and Disposal Subprogram seeks to demonstrate treatment and remediation technologies that will address the needs and requirements of all USTs in the DOE complex. In particular, the primary objective is to minimize the volume of HLW being produced, such that disposal costs can be reduced. Performance of new and improved waste forms for disposal of LLW will also be evaluated.

Tank wastes found primarily in Oak Ridge, Hanford, and Savannah River are in the form of salt cake, supernatant and sludge; they are alkaline, rich in sodium and nitrate. They also contain organic material and various radionuclides including cesium, strontium, technetium, iodine, and transuranics, such as plutonium and americium. The presence of organics is a safety concern because of the potential of reaction with nitrate and radiolytic hydrogen generation. Technologies that efficiently remove radionuclides and hazardous materials from LLW, rendering it eligible for near-surface disposal, are critical to the subprogram. Volumes of HLW will also be kept at a minimum by separating non-transuranics and non-HLW constituents from HLW sludges and acidic wastes. Equally important are technologies that maximize releasable/reusable waste fractions and minimize chemical pretreatment.

The reference waste form for LLW is cement-based grout; however, it increases the volume of the waste, does not effectively retain certain contaminants, and has questionable long-term stability. Alternate waste forms must therefore be tested and evaluated. Polyethylene and ceramics are examples of new waste forms being explored that offer diminished waste volume, reduced processing and disposal costs, and enhanced performance and long-term stability.

3.1 CESIUM REMOVAL COMPACT PROCESSING UNITS FOR RADIOACTIVE WASTE TREATMENT

TASK DESCRIPTION

Compact processing is a concept that was developed at PNL for rapidly deploying technologies for the treatment of radioactive underground storage tank waste. A Compact Processing Unit (CPU) is a relatively small and mobile process unit that will be located near waste storage tanks to perform waste treatment at a rate of 2 to 5 gallons per minute (see Figure 14).

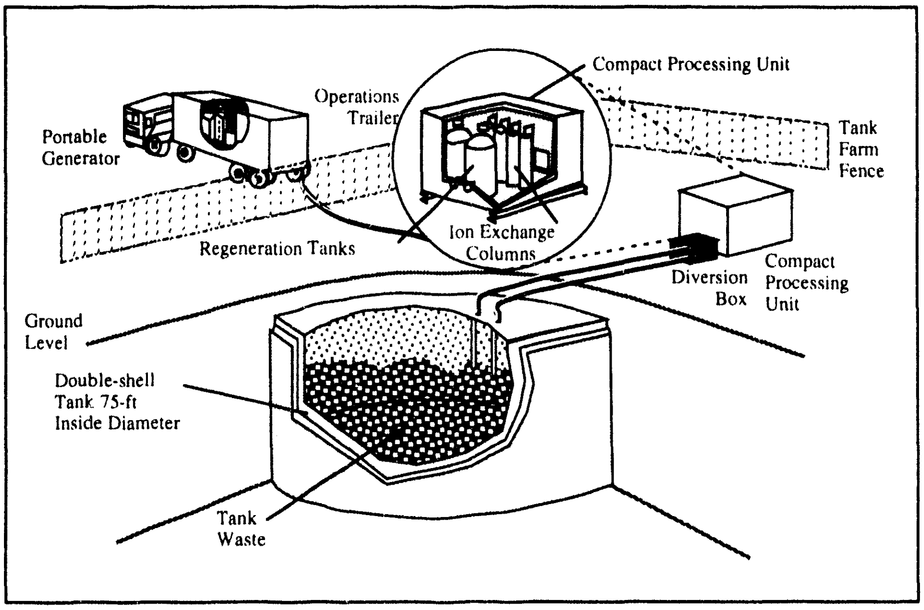

Figure 14. Compact Processing Unit.

The CPU consists of four major sub-systems: the enclosure/containment subsystem, the process subsystem, the process control subsystem, and the interface-with-the-tank-farm subsystem. The modular design concept will allow off-site commercial fabrication of CPU components and reuse of the components for different unit processes or process deployment.

A CPU can be used to deploy various waste treatment technologies and processes; one such process is the removal of radioactive cesium from the tank waste using ion-exchange. The cesium removal CPU will pump waste from a storage tank or receive waste from a waste retrieval system for treatment. Solids will be filtered and transferred to a holding tank for further analysis and processing, while the filtered waste will be processed by ion-exchange columns to remove cesium. Processed tank waste will be returned to a product waste tank in the tank farm. Loaded ion-exchange resin will be regenerated with the cesium sent to be vitrified. Process flow is limited by the size of equipment that can fit into a CPU; multiple unit operations can be combined as desired for different waste types, while support services, such as process control, can be provided in separate modules.

The initial principal design criteria for the cesium removal CPU are:

- capacity to process 1,000,000 gallons of tank waste in one year;
- cesium decontamination factor of 10,000;
- design that permits relocation using a construction crane and transport trailer; and
- compliance with the applicable DOE and RCRA regulations.

TECHNOLOGY NEEDS

The presence of radioactive cesium (e.g., ^{137}Cs) is a major source of radioactivity (beta and gamma activities) in tank wastes. Removal of cesium is required for the subsequent processing and disposal of the tank wastes.

The current processes used for cesium removal in the DOE Complex do not meet the processing or schedule requirements for treatment of the Hanford wastes. Deployment of these processes requires major new facilities, the construction of which makes meeting the schedule commitments in the Tri-Party Agreement difficult. The CPU enables acceleration of the schedule for the start of waste treatment by increasing the use of parallel activity scheduling (e.g., process development and selection, process design, facility design) without increasing project risk — the smaller scale of the CPU allows the final development of the process to proceed in parallel with the CPU design. In addition, the CPU option is more cost-effective compared to centralized facilities. It also reduces the technical and cost uncertainties associated with the deployment of waste treatment processes.

ACCOMPLISHMENTS

Conceptual design of the Heating, Ventilation and Air Conditioning (HVAC) system for the CPU has been completed, while a contract is in place for the conceptual design and analysis of the CPU enclosure module. Development of the CPU has been accepted by the DOE Office of Waste Management for cesium/strontium removal, leading to on-site hot demonstration at Hanford.

COLLABORATION/ TECHNOLOGY TRANSFER

Kaiser Engineering provided the conceptual design of the HVAC system, while the design and analysis for the enclosure/containment system will be performed by Washington State University. Commercial design and fabrication vendors will also be identified for the construction of the CPU.

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3.2 THE NITRATE TO AMMONIA AND CERAMIC PROCESS

TASK DESCRIPTION

The Nitrate To Ammonia and Ceramic (NAC) process involves chemical reduction of the nitrate contained in the mixed (hazardous and radioactive) tank waste to gaseous ammonia utilizing a new technology developed at Oak Ridge National Laboratory (ORNL). The NAC process can achieve concentrations of nitrate below drinking water standards (see Figure 15).

It is expected that radioactive species such as plutonium and strontium will enter the solid ceramic phase during the reduction of the nitrate anion. The alumina-based ceramic host matrix will undergo calcination, pressing and sintering which will generate a solid waste form capable of binding nearly all elements. Sodium will be in a nepheline ceramic phase. In the process, radioactive-contaminated scrap aluminum from various DOE sites could be shredded and used as feed to the NAC reactor. Therefore, the need for decommissioning and decontamination of such metal will be eliminated.

Laboratory experiments have shown that a decontaminated solid nitrate waste stream can be solidified by using a catalytic material to decompose the sodium nitrate to innocuous gas and a liquid secondary waste stream containing only trace amounts of nitrate. Additional advantages of the process are solidification of the radioactive fraction of the waste at rather low temperatures (50-90°C; unlike vitrification) and a final waste volume reduction of 55 to 75 vol% (as compared to a 30% to 40% volume increase by grouting).

TECHNOLOGY NEEDS

The NAC process addresses the primary liquid and sludge leachate component at the Hanford and the Melton Valley Storage Tanks in Oak Ridge. Underground storage tanks at both sites contain large amounts of highly alkaline, nitrate based mixed liquid waste. Current plans are to place the liquid phase in grout and the acid washed solids (TRUEX process) in glass. The NAC project will support these objectives by generating innocuous gaseous and liquid products and a low volume, chemically stable solid waste form.

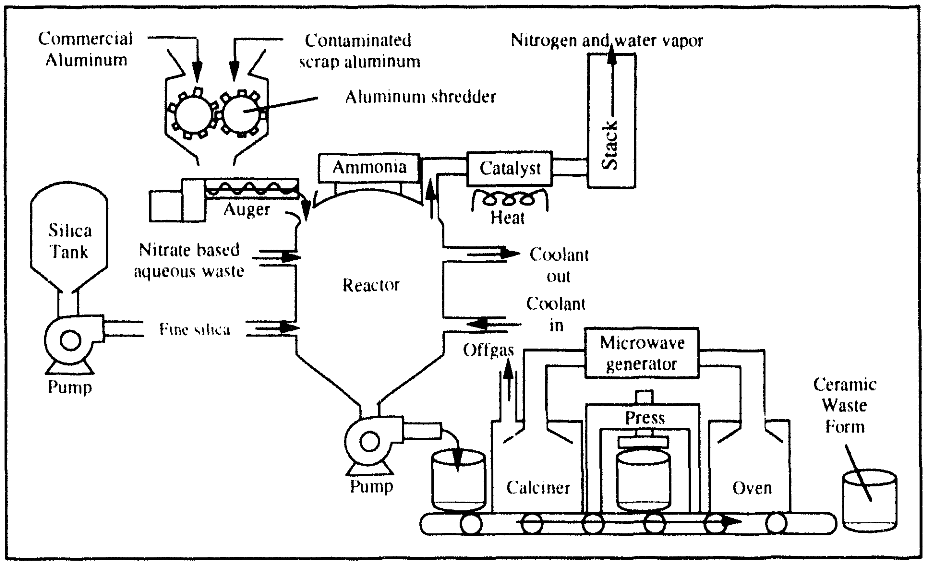

Figure 15. The Nitrate to Ammonia and Ceramic Process.

ACCOMPLISHMENTS

The overall efficiency of the use of aluminum metal reactant has been lately increased from 50% to 91% by operating the NAC reactor in a continuous mode. This operation mode will:

- reduce processing costs by decreasing the amount of aluminum, a costly reactant, down to approximately $2/kg of nitrate converted; and

- operate with waste solution feeds containing nitrate at near saturation.

Sintering temperatures of the final ceramic product have been reduced by 150°C to 1350°C, while sintering time was cut in half.

COLLABORATION/ TECHNOLOGY TRANSFER

A patent is pending and its ownership was awarded to Martin Marietta Energy Systems, Inc. In virtue of its adaptability to alkaline supernates, numerous DOE sites could make use of the NAC process technology, including Savannah River, Oak Ridge, and Richland. Whereas no industrial partners are currently involved in the NAC process technology development, Florida International University is working to aid and support the development effort in FY94.

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3.3 POLYETHYLENE ENCAPSULATION OF LOW-LEVEL WASTE

TASK DESCRIPTION

The initial objective of this project under development at Brookhaven National Laboratory (BNL) is to investigate the effects of high radiation doses and elevated temperatures on polyethylene mechanical and leaching properties. Polyethylene is an inert thermoplastic polymer with a processing temperature of about 150°C. The polyethylene is produced using a screw extrusion process, which simultaneously heats, mixes, and conveys the waste and binder (see Figure 16). A homogeneous, molten mixture is extruded into a container for cooling. Once this mixture is cooled below 120°C, a monolithic waste form is ensured. Upcoming tests include treatability studies using surrogate Hanford waste to examine waste loading potential and waste form performance. Ultimately, full-scale technology feasibility will be demonstrated.

TECHNOLOGY NEEDS

Polyethylene encapsulation is a waste form developed to treat mixed tank waste separated from the sodium-nitrate high-level waste present at many DOE facilities (Hanford, Rocky Flats, Savannah River, Oak Ridge, and West Valley). This demonstration is driven by the Hanford Federal Facility Compliance Agreement (FFCA), which mandates identification of tank waste disposal methods by 1999 and full-scale single-shell tank (SST) closure by 2004. Completion of the cited tasks by the end of 1995 is needed in

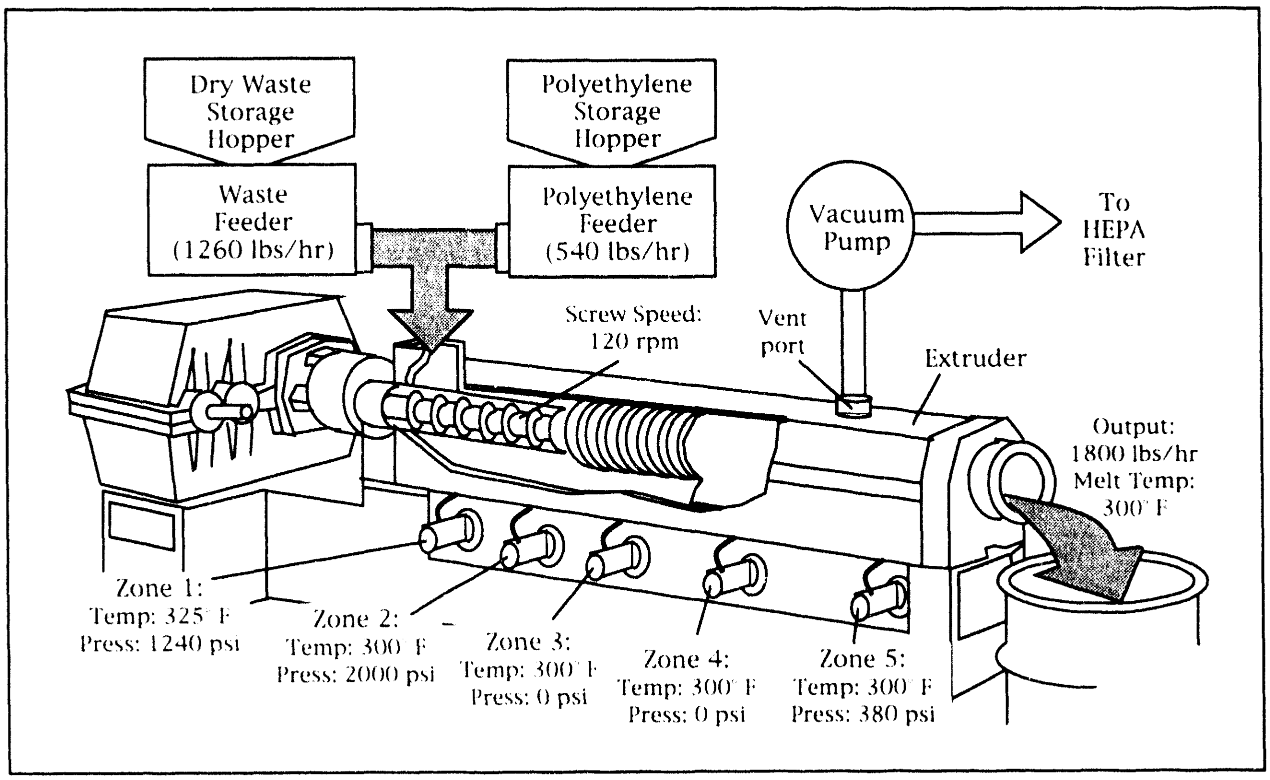

Figure 16. Polyethylene Encapsulation System.

order to evaluate the applicability of polyethylene encapsulation for SST low-level waste treatment/disposal and to provide necessary data for comparison with the base-line technology, grout solidification, on time to meet the FFCA scheduling milestones.

Polyethylene waste forms are superior to grout waste forms. Polyethylene is less dependent on the waste chemistry, accepts a wider range of waste types, and increases waste loading. Finally, polyethylene is easier to process under heterogeneous waste conditions.

ACCOMPLISHMENTS

Extensive waste form performance testing has been completed, including compressive strength, water immersion, thermal cycling, radioactive and hazardous constituent leachability, radiation stability and biodegradation. Scale-up feasibility has been confirmed by processing simulated nitrate wastes at production output rates up to 2,000 lbs/hr.

For nitrate salt wastes, polyethylene encapsulation provides between 3.5 and 5 times greater volume reduction than conventional cement-based grout formulations. Microencapsulation of individual contaminant particles results in leachabilities measured at 100 to 1000 times lower than grout waste forms. Waste forms containing up to several hundred ppms of toxic metal contaminants have passed the Environmental Protection Agency's Toxicity Characteristic Leaching Procedure (TCLP).

COLLABORATION/ TECHNOLOGY TRANSFER

As of February 1993, a waste management vendor was negotiating a Cooperative Research & Development Agreement with BNL for the application of polyethylene encapsulation to utilize this technology for improved waste treatment at DOE and commercial nuclear waste generation sites. A patent application is being prepared for submission.

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3.4 TRUEX MODEL DEVELOPMENT

TASK DESCRIPTION

The TRUEX process is a solvent extraction procedure that can very efficiently separate transuranic (TRU) elements (e.g., Np, Pu, Am and Cm) from aqueous nitrate- or chloride-containing wastes. These wastes are typically generated in reprocessing plant operations or in plutonium production and purification operations. The resulting solutions after extraction may be sufficiently free of TRU elements to warrant their disposal as non-TRU, low-level wastes. Furthermore, plutonium can be recovered and purified by this process. Treatment of stored wastes by the TRUEX process will lower the costs of final disposal significantly; treatment of waste streams as they are generated will allow recycle of streams and avoidance of future waste treatment and disposal costs.

The key extractant in the TRUEX process is octyl-(phenyl)-N, N-diisobutylcarbamoylmethylphosphine oxide (CMPO) (see Figures 17a and 17b). It is combined with tributyl phosphate (TBP) and a diluent to formulate the TRUEX solvent. The diluent is typically a normal paraffinic hydrocarbon (either a C_{12}-C_{14} mixture or n-dodecane) or a non-flammable chlorocarbon such as tetrachloroethylene.

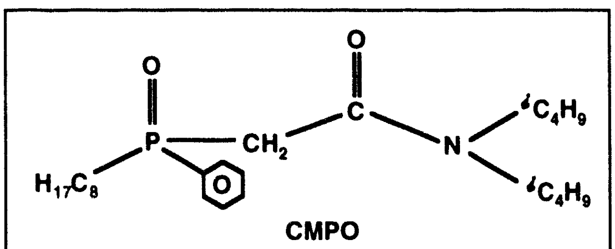

Figure 17a. CMPO-Extractant Chemical Formula.

The Center for TRUEX Technology Development at Argonne National Laboratory (ANL) continually performs research and development (R&D) to broaden the applicability of the TRUEX

$$Am^{3+} + 3NO_3^- + 3CMPO \longrightarrow Am(NO_3)_3(CMPO)_3$$

Aqueous Phase	Organic Phase	Organic Phase

Figure 17b. TRUEX-Process Extraction Equilibrium Example.

process in the treatment of high-level waste and TRU-containing waste streams. A major part of the effort was to develop and upgrade the Generic TRUEX Model (GTM) to assist in designing feed- and site-specific processes and evaluating their economics. The GTM is an user-friendly computer software that models and predicts the TRUEX extraction behavior, calculates TRUEX flowsheets, and estimates space and cost requirements for installation. The GTM runs on a personal computer (IBM-compatible or MacIntosh), and is executed by Microsoft Excel software.

The objective of the current task is to validate and refine the GTM's ability to design flowsheets for specific feeds and process goals and to predict extraction behavior of feed components and potential processing difficulties. This task also aims to discover and identify R&D needs for getting TRUEX ready for broader implementation. The TRUEX processing of actual HLW and TRU wastes at Oak Ridge National Laboratory (ORNL) will validate the GTM. Finally, ANL will cooperate with the Power Reactor and

Nuclear Fuel Development Corporation (PNC) of Japan to model their data on continuous TRUEX processing of high-level waste.

TECHNOLOGY NEEDS

If the TRU content of TRU waste streams can be lowered to below 100 nCi/g of solid, the waste can be classified as non-TRU. Additionally, if the radioactivity of other isotopes, such as ^{137}Cs and ^{90}Sr, is reduced to an acceptable level, the wastes will be eligible for near-surface disposal. Use of the TRUEX process to treat TRU waste will greatly reduce the volume of high-level waste, resulting in high cost savings during disposal.

The GTM is an indispensable tool in designing site- and feed-specific TRUEX flowsheets and estimating the space and cost requirements for a TRUEX process installation. The continuous enhancement of the GTM through improved thermodynamic and computer modelling will require a parallel validation of the model by collecting laboratory and pilot-plant data.

ACCOMPLISHMENTS

Modifications to the GTM have been completed to allow design of a TRUEX processing flowsheet for Mark 42 targets (ORNL). Test runs using the Mark 42 dissolution feed material have also been concluded. Data collection for zirconium and fluoride has been completed, while that for chromium and thorium has begun. Version 2.7 of the GTM has been completed, tested, and released.

COLLABORATION/ TECHNOLOGY TRANSFER

All technical users at ANL, Hanford, Idaho, Los Alamos, ORNL and Rocky Flats share information pertaining to further development and use of the model. University partners at the University of Illinois and Spring Arbor College, MI are collecting extraction data. Collaboration also exists to demonstrate the process and model the data with the PNC of Japan.

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3.5 COMPREHENSIVE SLUDGE/SUPERNATE DEMONSTRATION, TESTING, AND EVALUATION

TASK DESCRIPTION

This task demonstrates, tests, and evaluates technology components that are part of a complete system-level plan for handling and processing wastes in the forms of sludge and supernate. These waste forms are the major constituents in underground storage tanks. Particular emphasis is on understanding and developing sludge dissolution treatments.

One objective of this project is to develop a comprehensive sludge processing flowsheet using actual tank wastes. Individual technologies and processes within the flowsheet will be tested in bench-scale batch tests in a hot cell on wastes from the ORNL Melton Valley Storage Tanks. Comprehensive testing of each of the processing components of the flowsheet is necessary to:

- establish the best combination of processes;
- verify that the selected technologies are compatible;
- provide a realistic assessment of the performance of the individual processes; and
- generate operating results which will be useful for pilot plant design.

The processes and technologies that will be tested and evaluated include:

- acid dissolution of sludge;
- removal of cesium and strontium from supernate using ferrocyanide precipitation, ion exchange, and solid extractant; and
- TRUEX solvent extraction of transuranic elements.

Another objective of this task is validation of the Generic TRUEX Model. A TRUEX flowsheet was developed using the GTM and a solution containing Pu, Am and Cm was processed using the Solvent Extraction Test Facility (SETF) at the Radiochemical Engineering Development Center (REDC). Samples are being analyzed by the ORNL Analytical Chemistry Division. The data will be used, in collaboration with Argonne National Laboratory, to validate the computer model GTM.

Finally, a technical interchange with the Commissariat à l'Energie Atomique (CEA) in France will examine the technical problems associated with underground storage tanks. This exchange will initially focus on the French ACTINEX process which uses diamides as extractants for the actinides; this process will be evaluated against comparable US extraction technologies, such as the TRUEX process.

TECHNOLOGY NEEDS

In retrieving, processing and disposing of these wastes, separation technologies are the primary means to concentrate and chemically partition the wastes such that the volume of waste to be vitrified can be minimized. It is estimated that the volume of waste to be vitrified can be reduced by a factor of 10 to 200 using separation technologies.

Comprehensive bench-scale testing on actual wastes is the best way to ensure that individual process technology will achieve the required degree of performance in an integrated system. Evaluation and testing of comparable technologies will ensure that the appropriate processes will be used. It will also provide the necessary data that are required for further scale-up and transfer of the technologies.

ACCOMPLISHMENTS

Supernate and sludge have been retrieved and transferred from MVST to hot cells at ORNL. Experimental testing has been initiated. The TRUEX process test runs using the SETF mixers/settlers have been completed; and the Analytical Chemistry Division at ORNL is analyzing the samples from the runs to generate data for the validation of the GTM. Agreement has been reached between DOE and the French CEA to assign an ORNL engineer/chemist to a CEA site for a year to work in technical R&D and to develop an understanding of the French waste management programs.

COLLABORATION/ TECHNOLOGY TRANSFER

Technical interchange with the French CEA has been initiated to evaluate French technologies for HLW treatment and to explore possibilities of technical collaborations in mutually beneficial areas.

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3.6 CALCINATION/DISSOLUTION PRETREATMENT

TASK DESCRIPTION

This process combines calcination and dissolution in a new and innovative manner in order to thermally destroy organic and inorganic constituents. A large scale plasma arc heats the tank waste in excess of 800°C to destroy organic compounds, ferrocyanide, nitrate, and nitrite and to separate the strontium and transuranic waste into a small volume via water dissolution (see Figure 18).

Target process flow is about 20-80 gpm for a typical operating unit. Previous attempts at calcining high sodium waste material using conventional calcining concepts such as rotary kiln, spray tower, and fluidized bed have encountered problems due to plugging of the reactors by molten material.

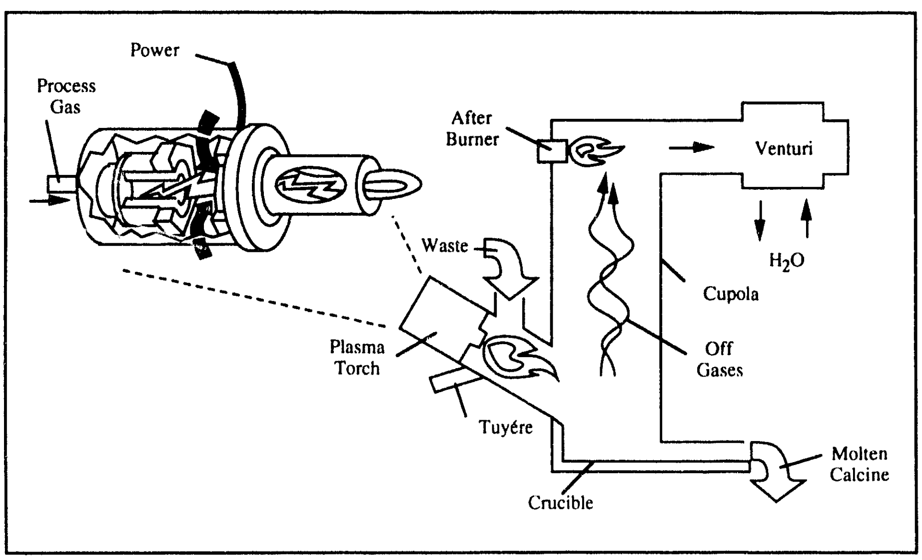

Figure 18. Plasma Arc.

The treated offgas exhaust steam will contain CO_2, N_2, O_2, and H_2O, which will be released into the atmosphere. The calcined product is expected to be further treated by dissolution, which produces high-level and low-level waste streams. The high-level stream will be vitrified, and the low-level stream is slated for near surface disposal.

Large scale pilot plant tests to determine the feasibility for plasma arc calcination will be conducted using Hanford waste simulants. Major test objectives include equipment performance, such as continuous operation without plugging, and process performance, such as organics, ferrocyanide and nitrate destruction efficiency.

TECHNOLOGY NEEDS

The process is especially applicable to the 41 million gallons of radioactive waste stored at Hanford, which contain high concentrations of sodium salts and trace quantities of actinides. Hanford tank waste needs to be processed to resolve tank safety issues regarding organic components, ferrocyanides, and possible nitrates/nitrites for its ultimate disposal in a safe and cost effective manner. The process may also serve to treat wastes at the other DOE sites.

ACCOMPLISHMENTS

A large-scale plasma arc demonstration at the Westinghouse Science and Technology Center successfully calcined 3,000 pounds of simulated Hanford tank waste continuously without plugging. This demonstrates that large scale, high calcination of high sodium wastes is possible. Future plans include a second demonstration of plasma arc calcination of a 101-SY tank simulated waste. This longer test will couple calcination and dissolution operations with enhanced sample analysis.

COLLABORATION/ TECHNOLOGY TRANSFER

A DOE patent application was filed. Industrial partners include Westinghouse Science and Technology Center, which is in charge of performing plasma arc calcination demonstrations, and Washington State University, which is developing transuranic separation techniques for the post-calcination product. A vendor solicitation to identify and potentially demonstrate other candidate calcination technologies is underway.

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3.7 RESORCINOL/FORMALDEHYDE RESIN FOR ELUTABLE ION EXCHANGE IN COMPACT PROCESSING UNITS

TASK DESCRIPTION

The Savannah River Site (SRS) has developed a resorcinol-formaldehyde ion exchange resin for cesium removal. The resin has been demonstrated to give excellent performance in testing. Other cesium removing materials either have much lower capacity or are incompatible with the high *p*H and aluminum concentration that is found in the Hanford and SRS tank wastes. In particular, the resorcinol-formaldehyde resin is found to have 10 times the capacity of Duolite™ CS-100, a phenol-formaldehyde resin.

The objective of this task is to test the resorcinol-formaldehyde resin in column mode with tank waste simulant. The resulting data will be critical in determining the optimum processing conditions (e.g., flow rate, elution volume and eluent). The data will also aid in the design of a Compact Processing Unit (CPU) for removal of cesium from Hanford tank wastes. Engineering-scale tests will be run on the Skid-mounted Ion exchange Demonstration (SKID) unit at the Westinghouse Savannah River Company. This task is also continuing to study the radiolytic properties of the resin to determine radiolytic stability, radiolytic byproducts and dose dependence of the resin's performance.

TECHNOLOGY NEEDS

Ion exchange is one of the proposed technologies to remove cesium and strontium from high-level waste found in underground storage tanks. Due to the somewhat unique chemical characteristics of the tank wastes (i.e., high *p*H and aluminum concentration), most common ion exchangers are not suitable for their processing. The resorcinol-formaldehyde resin has been demonstrated to give excellent performance with tank wastes; its high capacity will also allow a notable reduction in the size of process equipment (CPU). High-level supernatant from a waste tank will be processed in a CPU. Cesium will be sorbed onto the resorcinol-formaldehyde resin and then eluted with dilute acid, resulting in a concentrated Cs stream that can then be sent for vitrification. The treated stream will be processed further (e.g., removal of strontium in a CPU) before it is disposed of as low-level waste. This will produce a significant reduction in the volume of waste to be vitrified.

ACCOMPLISHMENTS

Optimum operating conditions, such as extraction and elution flow rates, have been developed. The first series of radiolysis studies on the resin has also been finished: the resin is stable up to a dosage of 5×10^8 rad, and a higher dosage causes some loss of extraction efficiency in a high *p*H environment, but not in water.

COLLABORATION/ TECHNOLOGY TRANSFER

The resorcinol-formaldehyde resin is manufactured by Boulder Scientific Company. Interest has also been expressed by Georgia Pacific Company and Rohm & Haas. A contract with Clark University is in place to conduct experimental study on the degradation properties of the resin. British Nuclear Fuels (BNFL) Inc. is to provide technical support for and make modifications to the SKID unit for the resin demonstration.

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3.8 BIODENITRIFICATION

TASK DESCRIPTION

This technology uses bacteria to reduce the nitrates in waste to nitrogen gas and separate the metals by a combination of biosorption (adsorption onto bacteria) and precipitation. Some degradation of organics is also anticipated.

The process uses a mixed culture of natural bacteria isolated from the Great Salt Lake and the Death Valley area. These bacteria are able to grow and reduce nitrate in the very high salt concentrations found in the tank wastes. The bacteria are grown in a bioreactor and then recycled to a biosorption tank where they are mixed with the incoming waste. The high radioactivity and metals concentration in this tank may kill the bacteria, but dead bacteria biosorb metals equally well.

The bacteria and any chemical precipitates that may have formed are removed by filtration, generating a biomass sludge waste containing the metals and radioactivity. In most cases this sludge will be a low-level radioactive waste, and will be dried and sent for final disposal by grouting or vitrification. The liquid containing the nitrate, organics and very low levels of metals flows into the bioreactor, where it is mixed with acetic acid as a carbon source for bacterial growth.

In the bioreactor, the nitrate is reduced to innocuous nitrogen gas that is released to the atmosphere after being filtered. Any remaining metals adsorb onto the growing bacteria, but their concentration is now too low to inhibit bacterial metabolism. The effluent from the bioreactor, after filtration, is a concentrated solution of non-radioactive, non-hazardous salts in which nitrate has been replaced mainly by bicarbonate.

TECHNOLOGY NEEDS

Many DOE sites including Hanford, Oak Ridge, and INEL have tanks containing wastes resulting from the processing of nuclear materials. The exact composition varies between tanks, but most contain uranium and transuranic elements, radioactive isotopes (cesium, strontium) resulting from their decay, and nitrates from the nitric acid used in processing. There may also be some organic contaminants and metals such as chromium, zirconium and bismuth. These wastes have separated into chemical sludge containing most of the metals, transuranics, and radionuclides; a salt cake consisting mainly of solid sodium nitrate with lower levels of metals and organics; and concentrated aqueous supernatant, whose composition is in equilibrium with the sludge and salt cake. The retrieval task of the UST-ID is charged with developing technology to pump the supernatant out of the tanks and to remove the salt cake by sluicing with water. The goal of the pre-treatment and separations task is to treat the resulting solutions to remove the nitrate; destroy the organics; and separate and concentrate the metals for safe final disposal in a radioactive waste repository.

ACCOMPLISHMENTS

Tests to determine the minimum waste residence time and maximum feed nitrate concentration are ongoing in bench-scale bioreactors. Issues are whether essential micro-nutrients (Ca, Mg, etc.) will precipitate out and whether supersaturation of the media with HCO_3^- will inhibit metabolism. Adsorption isotherms for single metals/radionuclides using spent biomass have been defined, but the combined effects of biosorption and precipitation of carbonates, aluminates, etc., are to be determined. Inhibition evaluations for fluoride, EDTA, aluminum, nitrite and citrate were completed. These compounds may be present in reactor inflow, and could inhibit bacterial metabolism. Conceptual process design of bioremediation process is updated as new theoretical and experimental information becomes available.

COLLABORATION/ TECHNOLOGY TRANSFER

This technology is currently being developed by EG&G at Idaho National Engineering Lab. It has potential application to treat waste streams from metals reprocessing facilities in addition to those from nuclear fuels processing and reprocessing facilities.

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How To Get Involved

Section 4.0

4.0 HOW TO GET INVOLVED

WORKING WITH THE DOE OFFICE OF ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

DOE provides a range of programs and services to assist universities, industry, and other private-sector organizations and individuals interested in developing or applying environmental technologies. Working with DOE Operations Offices and management and operating contractors, EM uses conventional and innovative mechanisms to identify, integrate, develop, and adapt promising emerging technologies. These mechanisms include contracting and collaborative arrangements, procurement provisions, licensing of technology, consulting arrangements, reimbursable work for industry, and special consideration for small business.

Cooperative Research and Development Agreements (CRADAs)

EM will facilitate the development of subcontracts, R&D contracts, and cooperative agreements to work collaboratively with the private sector.

EM uses CRADAs as an incentive for collaborative R&D. CRADAs are agreements between a DOE R&D laboratory and any non Federal source to conduct cooperative R&D that is consistent with the laboratory's mission. The partner may provide funds, facilities, people, or other resources. DOE provides the CRADA partner access to facilities and expertise; however, no Federal funds are provided to external participants. Rights to inventions and other intellectual property are negotiated between the laboratory and participant, and certain data that are generated may be protected for up to 5 years.

Consortia will also be considered for situations where several companies will be combining their resources to address a common technical problem. Leveraging of funds to implement a consortium can offer a synergism to overall program effectiveness.

Procurement Mechanisms

DOE EM has developed an environmental management technology development acquisition policy and strategy that uses phased procurements to span the RDDT&E continuum from applied R&D concept feasibility through full scale remediation. DOE EM phased procurements make provisions for unsolicited proposals, but formal solicitations are the preferred responses. The principle contractual mechanisms used by EM for industrial and academic response include Research Opportunity Announcements (ROAs) and Program R&D Announcements (PRDAs). In general, EM Technology Development uses ROAs to solicit proposals for R&D projects and PRDAs for proposals for its DT&E projects.

EM uses the ROA to solicit advanced research and technologies for a broad range of cleanup needs. The ROA supports applied research ranging from concept feasibility through full-scale demonstration. In addition, the ROA is open continuously for a full year following the date of issue and includes a partial procurement set aside for small businesses. Typically, ROAs are published annually in the Federal Register and the Commerce Business Daily, and multiple awards are made.

PRDAs are program announcements used to solicit a broad mix of R&D and DT&E proposals. Typically, a PRDA is used to solicit proposals for a wide-range of technical solutions to specific EM problem areas. PRDAs may be used to solicit proposals for contracts, grants, or cooperative agreements. Multiple awards, which may have dissimilar approaches or concepts, are generally made. Numerous PRDAs may be issued each year.

In addition to PRDAs and ROAs, EM uses financial assistance awards when the technology is developed for public purpose. Financial assistance awards are solicited through publication in the Federal Register. These announcements are called Program Rules. A Program Rule can either be a one time solicitation or an open ended, general solicitation with annual or more frequent announcements concerning specific funding availability and desired R&D agreements. The Program Rule can also be used to award both grants and cooperative agreements.

EM awards grants and cooperative agreements if fifty-one percent or more of the overall value of the effort is related to a public interest goal. Such goals include possible non DOE or other Federal agency participation and use, advancement of present and future U.S. capabilities in domestic and international environmental cleanup markets, technology transfer, advancement of scientific knowledge, and education and training of individuals and business entities to advance U.S. remediation capabilities.

Licensing of Technology

DOE contractor-operated laboratories can license DOE/EM-developed technology and software to which they elect to take title. In other situations where DOE owns title to the resultant inventions, DOE's Office of General Counsel will do the licensing. Licensing activities are done within existing DOE intellectual property provisions.

Technical Personnel Exchange Assignments

Personnel exchanges provide opportunities for industrial and laboratory scientists to work together at various sites on environmental restoration and waste management technical problems of mutual interest. Industry is expected to contribute substantial cost sharing for these personnel exchanges. To encourage such collaboration, the rights to any resulting patents go to the private sector company. These exchanges, which can last from 3 to 6 months, are opportunities for the laboratories and industry to better understand the differing operating cultures, and are an ideal mechanism for transferring technical skills and knowledge.

Consulting Arrangements

Laboratory scientists and engineers are available to consult in their areas of technical expertise. Most contractors operating laboratories have consulting provisions. Laboratory employees who wish to consult can sign non-disclosure agreements, and are encouraged to do so.

Reimbursable Work for Industry

DOE laboratories are available to perform work for industry, or other Federal agencies, as long as the work pertains to the mission of a respective laboratory and does not compete with the private sector.

The special technical capabilities and unique facilities at DOE laboratories are an incentive for the private sector to use DOE's facilities and contractors expertise in this reimbursable work for industry mode. An advanced class patent waiver gives ownership of any inventions resulting from the research to the participating private sector company.

EM Small Business Technology Integration Program

The EM Small Business Technology Integration Program (SB-TIP) seeks the participation of small businesses in the EM Research, Development, Demonstration, Testing and Evaluation programs. Through workshops and frequent communication, the EM SB TIP provides information on opportunities for funding and collaborative efforts relative to advancing technologies for DOE environmental restoration and waste management applications.

EM SB TIP has established a special EM procurement set aside for small firms (500 employees or less) to be used for applied research projects, through its ROA. The program also serves as the EM liaison to the DOE Small Business Innovation Research (SBIR) Program Office, and interfaces with other DOE small business offices, as well.

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EM Central Point of Contact

The EM Central Point of Contact is designed to provide ready access to prospective research and business opportunities in waste management, environmental restoration, and decontamination and decommissioning activities, as well as information on EM 50 IPs and IDs. The EM Central Point of Contact can identify links between industry technologies and program needs, and provides potential partners with a connection to an extensive complex-wide network of DOE Headquarters and field program contacts.

The EM Central Point of Contact is the best single source of information for private sector technology developers looking to collaborate with EM scientists and engineers. It provides a real time information referral service to expedite and monitor private sector interaction with EM.

To reach the EM Central Point of Contact, call 1-800-845-2096 during normal business hours (Eastern time).

Office of Research and Technology Applications

Office of Research and Technology Applications (ORTAs) serve as technology transfer agents at the Federal laboratories, and provide an internal coordination in the laboratory for technology transfer and an external point of contact for industry and universities. To fulfill this dual purpose, ORTAs license patents and coordinate technology transfer activities for the laboratory's scientific departments. They also facilitate one on one interactions between the laboratory's scientific personnel and technology recipients, and provide information on laboratory technologies with potential applications in private industry for state and local governments.

For more information about these programs and services, please contact:

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Acronyms

Section 5.0

5.0 ACRONYMS

ANL	Argonne National Laboratory
BNFL	British Nuclear Fuels Inc.
BNL	Brookhaven National Laboratory
CEA	Commissariat à l'Energie Atomique
CMPO	Octyl-(phenyl)-N, N-diisobutylcarbamoyl-methylphosphine oxide
CPU	Compact Processing Unit
CRADA	Cooperative Research & Development Agreement
DOE	U.S. Department of Energy
EM	Environmental Restoration and Waste Management
FFCA	Federal Facility Compliance Agreement
GTM	Generic TRUEX Model
HLW	High-Level Waste
HVAC	Heating, Ventilation and Air Conditioning
ID	Integrated Demonstration
INEL	Idaho National Engineering Laboratory
IP	Integrated Program
LDUA	Light Duty Utility Arm
LLNL	Lawrence Livermore National Laboratory
LLW	Low-Level Waste
LRA	Long Reach Arm

LRF	Laser Range Finder
MVST	Melton Valley Storage Tanks
NAC	Nitrate to Ammonia and Ceramic
NIR	Near Infrared
ORNL	Oak Ridge National Laboratory
ORTA	Office of Research and Technology Applications
OTD	Office of Technology Development
PNC	Power Reactor and Nuclear Fuel Development Corporation
PNL	Pacific Northwest Laboratory
PRDA	Program R&D Announcements
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act of 1976
RDDT&E	Research, Development, Demonstration, Testing and Evaluation
REDC	Radiochemical Engineering Development Center
ROA	Research Opportunity Announcement
SBIR	Small Business Innovation Research
SB-TIP	Small Business Technology Integration Program
SETF	Solvent Extraction Test Facility
SKID	Skid-mounted Ion exchange Demonstration
SRS	Savannah River Site
SST	Single-Shell Tank
TBP	Tributyl Phosphate

TCLP	Toxicity Characteristic Leaching Procedure
TRU	Transuranic
UST	Underground Storage Tank
UST-ID	Underground Storage Tank Integrated Demonstration
WHC	Westinghouse Hanford Company
WSRC	Westinghouse Savannah River Company

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