1 of 2

OFFICE OF TECHNOLOGY DEVELOPMENT

FY 1993

PROGRAM MID-YEAR SUMMARIES

**RESEARCH, DEVELOPMENT, DEMONSTRATION,
TESTING AND EVALUATION**

October 1993

MASTER

**THE OFFICE OF TECHNOLOGY DEVELOPMENT
FY 1993
PROGRAM MID-YEAR SUMMARIES
RESEARCH AND DEVELOPMENT/DEMONSTRATION,
TESTING AND EVALUATION**

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1. RDDT&E Mid-Year Program Review March 22-25, 1993.
2. U.S. Department of Energy *Environmental Cleanup Technology Development Program Business and Research Opportunities Guide*, Environmental Restoration and Waste Management 1993.
3. U.S. Department of Energy Office of Environmental Restoration and Waste Management, Office of Technology Development Annual Report to Congress FY 1992.
4. "Technology Development is a Strategic Investment," presented to Congressional Budget Office February 5, 1993.

The Department of Energy Office of Environmental Restoration and Waste Management Organization

The Department of Energy (DOE) Environmental Restoration and Waste Management (EM) has established seven organizational elements to oversee its environmental cleanup activities. DOE EM's organizational structure is provided as Figure 1*. The EM Office of Policy and Program Information (EM-4) is the focal point for EM public participation and program information activities. The EM Office of Planning and Resource Management (EM-10) provides EM administrative oversight and resource planning. The EM Office of Oversight and Self-Assessment (EM-20) provides an independent oversight function to ensure compliance with relevant environmental and safety laws. The EM Office of Waste Management (EM-30) is responsible for DOE waste management activities to control and reduce the waste generated by DOE sites. The EM Office of Environmental Restoration (EM-40) is responsible for cleaning up and restoring DOE's sites. The EM Office of Technology Development (EM-50) conducts environmental restoration and waste management research, development, demonstration, testing, and evaluation (RDDT&E) for EM-30 and EM-40 when current technologies are inadequate to meet DOE's environmental cleanup needs and provides transportation and emergency management support to EM programs. The EM Office of Facility Transition and Management (EM-60) plans, implements and manages DOE facility decontamination and decommissioning activities.

The Environmental Restoration and Waste Management Office of Technology Development (EM-50)

The EM Office of Technology Development (OTD) is responsible for managing an aggressive national program for applied RDDT&E for environmental cleanup, waste management and related technologies. This program is designed to resolve major technical issues and rapidly advance beyond current technologies for environmental restoration and waste management operations to expedite compliance with applicable environmental laws and regulations. It does this by developing high payoff environmental restoration and waste management technologies that can clean up the 1989 inventory of DOE nuclear component manufacturing sites and manage DOE-generated waste faster, safer, and cheaper than current environmental cleanup technologies. The EM Office of Technology Development (OTD) also manages non-RDDT&E programs that support or further EM environmental objectives (see Figure 2).

*This document reflects the EM organization of March 1993.

Figure 1. The Department of Energy Environmental Restoration and Waste Management Organization.

Figure 2. The Environmental Restoration and Waste Management Office of Technology Development.

OTD has developed strategies to ensure that its RDDT&E activities reach beyond current state-of-the-art. These strategies highlight the importance of developing a focused program, minimizing duplication of effort, and leveraging available technology knowledge and resources to stretch limited research dollars. The strategies also emphasize the importance of maximizing technology transfer, complying with environmental regulatory requirements, and developing the infrastructure to ensure that a qualified workforce is available to support DOE environmental cleanup activities.

The EM Office of Technology Development has taken an active approach to ensuring regulatory acceptance of its products and processes. OTD has established effective dialogue with Federal, State, and local regulatory agencies and has sought active participation by these organizations in technology development activities. OTD has also supported public involvement activities designed to heighten public awareness of the technology development program. These activities include public participation seminars, training programs, and the establishment of open forums with public organizations and interest groups.

Leveraging RDDT&E Dollars

OTD leverages its resources through the use of interagency agreements, domestic and international public/private partnerships, simplified procurements, and small business research opportunities to co-sponsor RDDT&E activities. Specific activities to accomplish technology transfer objectives include small business programs, industrial integration programs, and the International Technology Exchange Program.

FY 1992/1993 FINANCIAL HIGHLIGHTS

Total funding appropriated to the EM Office of Technology Development Program in FY 1993 was \$385 million. This amount represented about 6 percent of the total EM appropriation for FY 1993. The appropriation for RDDT&E activities, as allocated in FY 1993 for the EM Office of Technology Development budget, is shown by major program in Figure 3 and by major function in Figure 4.

(\$ in Millions)	FY 1992 Appns.	FY 1993 Appns.
Research, Development, Demonstration, Testing and Evaluation		
- Groundwater & Soils Cleanup (Technology Activity Data Sheet (TADS))	59.6	60.6
- Waste Retrieval & Processing (TADS)	57.1	59.3
- Pollution Prevention (TADS)	7.4	2.2
- RDDT&E Innovation & Support (TADS)	49.6	44.0
- Congressional Add-On	0.0	40.0
TOTALS	\$173.7	\$206.3
Supporting Technologies and Infrastructure Programs (TADS)		
- Liaison and Communications	0.0	0.0
- Analytical Laboratory Management	10.0	14.5
- Robotics	17.4	24.6
- Decision Support	1.8	1.5
- Emergency Management	0.0	0.0
TOTALS	\$ 29.2	\$ 42.8
Transportation Management (TADS)	\$ 18.9	\$ 19.8
Technology Integration and Education Development (TADS)		
- Educational Development	14.0	21.8
- Technology Integration	9.5	11.0
- International Technology Exchange	5.5	3.0
TOTALS	\$ 29.0	\$ 35.8
Program Support (TADS)	\$ 39.3	\$ 36.4
Program Direction (TADS)	\$ 15.1	\$ 15.6
Environmental & Molecular Sciences Laboratory (TADS)	\$ 17.1	\$ 28.5
TOTAL	\$322.3	\$385.2

Figure 3. Appropriation by Program.

Figure 4. Appropriation by Function.

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PROGRAM MID-YEAR SUMMARIES

RESEARCH AND DEVELOPMENT

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In Situ Remediation

The In Situ Remediation Integrated Program (ISR IP) develops in place containment technologies for hazardous, radioactive and mixed wastes in soils, groundwater and storage tanks. Emphasis is placed on development of both treatment and containment technologies to minimize human exposure to contaminants, isolate physical, chemical or biological treatment, and minimize waste volume generation during restoration. Some technologies under consideration for inclusion in the program are: in situ bioremediation, chemical oxidation, electrokinetics, novel containment or barrier technologies, and in situ solidification.

INTEGRATED PROGRAM FOR DEVELOPMENT OF IN SITU REMEDIATION TECHNOLOGIES

Mary E. Peterson
Pacific Northwest Laboratory

The In Situ Remediation Technologies Integrated Program, under the U.S. Department of Energy (DOE), Office of Technology Development (EM-50), focuses research and development on treating contaminated environmental media, such as soil and groundwater, in place, and containing contaminants to prevent their spread through the environment. ISR technologies do not require the contaminated media to be excavated or removed. These technologies address environmental and waste management problems such as buried waste, contaminated soils, contaminated groundwater, containerized hazardous and radioactive wastes, and underground detonation sites.

A distinct advantage of these technologies is that they minimize adverse health effects on workers and the public by reducing contact exposure. They also reduce cleanup costs by orders of magnitude by eliminating the need for waste excavation, transport, and disposal, and enable the remediation of relatively inaccessible areas, such as the deep subsurface and areas beneath structures.

The ISR IP has three primary DOE customers for its technologies: the EM-50 Integrated Demonstrations, the Office of Environmental Restoration (EM-40), and the Office of Waste Management (EM-30). The ISR IP is intended to link with fundamental and applied research and development organizations to minimize duplication of effort and identify technology gaps. The ISR IP has multiple objectives related to hastening the development of ISR technologies; its ultimate goal is to move the technologies toward full-scale use in the field.

Program Technical Areas

The three major ISR program areas include treatment, containment, and subsurface manipulation; the objectives of the treatment and containment research and development work are described below.

Treatment technologies will be evaluated for in situ destruction, enhanced in situ removal and extraction, and in situ immobilization. Supplementary process monitoring and control technologies will also be developed. In situ destruction research and development will lead to demonstration of biological, chemical, and thermal technologies that destroy contaminants without harming the environment. Technologies may include in situ bioremediation, in situ chemical oxidation, and in situ electrochemical oxidation. In situ removal and extraction can be enhanced by thermal, chemical, or biological subsurface treatments to extract contaminants for destruction or immobilization above ground.

Containment technologies will be evaluated to isolate or contain contaminants within defined zones prior to and during treatment. The goal is to develop physical systems to prevent contaminant

dispersal into the air, surface water, or groundwater. Process monitoring and control techniques will also be developed.

Research and Development Technology Areas for Fiscal Year 1993

The FY 1993 research and development activities are described below for treatment, bioremediation; a subset of the treatment program area, and containment.

Treatment:

- **Electrokinetic Remediation of Heavy Metal Contaminated Unsaturated Soil**

Objective: This task will rapidly develop an in situ electrokinetic process for removing chromate contamination from unsaturated soil in support of the field demonstration efforts at the Mixed Waste Landfill Integrated Demonstration (MWLID).

Scope of Work: Measure electrokinetic movement of ions in unsaturated soils; conduct laboratory studies of soil properties and the relevant water chemistry; measure rate processes, including ion transport, moisture transport, chemical reactions in the electrolyte solution, and electrode reactions at the anode and cathode; determine the effects of soil heterogeneity on the rate process; and analyze and quantitatively interpret the data needed for scale up, including analysis of the optimal layout of electrodes.

- **Electrokinetic Removal of Heavy Metal and Mixed Waste from Partially and Fully Saturated Soils**

Objective: Objectives will be to develop a fundamental understanding of the process for removing metals and mixed wastes from soils using the electrokinetic process and develop a comprehensive, three-dimensional mathematic model of the electrokinetic contaminant process in non-arid regions.

Scope of Work: Conduct a theoretical and experimental investigation to support refinement of a numerical model of the electrokinetic remediation process.

- **Field Demonstration of Electrokinetic Migration Technology at the Old TNX Basin**

Objective: This project will focus on developing technology to remove heavy metal contaminants from unsaturated soil using electrokinetics coupled with Isotron's Isolock™ polymer.

Scope of Work: Based on FY92 laboratory studies, conduct a field-scale demonstration of the technology at the Westinghouse Savannah River Site. Test the potential of the polymer, coupled with the influence of an electric field, to remove mercury from soils.

- **In Situ Redox Manipulation**

Objective: Objective is to develop, test, and evaluate in situ methods for immobilizing organics (metals, inorganic ions and radionuclides) and destroying organic (primarily chlorinated hydrocarbons) contaminants by altering the chemistry of the subsurface system where these contaminants reside. Most of the chemically reactive mass in subsurface systems resides in the solid phases; thus, the solids must be involved in remediation in order to substantially influence the chemistry of the system and thus the remediation of the groundwater.

Scope of Work: Move from laboratory-scale to pilot-scale tests.

- **Optimal Remediation Design: Methodology and User-Friendly Software for Contaminated Aquifers**

Objective: This work will focus on developing a methodology for management and decision-making concerning optimization of groundwater contamination remediation.

Scope of Work: Develop a decision support tool for incorporating information on contamination risk, remedial requirements, optimal remedial design alternatives, and associated engineering costs.

- **In Situ Chemical Treatment: Evaluation of the In Situ Chemical Treatment Approach for Remediation of Soils and Groundwater**

Objective: The objective is to develop, through laboratory testing activities, an in situ chemical treatment approach for remediation of metal- and radionuclide-contaminated soils and groundwater by injecting reactive gases.

Scope of Work: Using artificially contaminated soils from several DOE sites, assess the cost, methods of controlling the reactive gases, homogeneous treatment of large masses of contaminated geomedia, and the regulatory acceptability of this technique and various reactive gases.

- **In Situ Corona for In Situ Treatment of Non-volatile Organic Contaminants**

Objective: This project will develop a practical in situ technique for decomposing non-volatile and bound organic contaminants using gas-phase oxidants produced in situ. The gas-phase oxidants will be produced by electrical corona made to occur on soil particles. The expected result is clean soil.

Scope of Work: Pursue a sufficient understanding of the physics and chemistry of in situ corona to make projections on the effectiveness and practicality of the technique for field application.

- **In Situ Magnetic Separation**

Objective: This project will develop and demonstrate Bradtec's MAG*SEPTM technology (patent pending) for in situ groundwater treatment. This technology uses specially designed particles to selectively adsorb contaminants from effluent water or groundwater.

Scope of Work: Use barriers to force groundwater through a treatment wall; magnetic particles are injected and mixed with the groundwater in the treatment wall. The particles are recovered before the groundwater leaves the treatment wall.

Bioremediation

- **Demonstration of Cometabolic Techniques**

Objective: This task will demonstrate the effectiveness of cometabolic processes in remediating groundwater contaminated by trichloroethylene and other mixed organic contaminants.

Scope of Work: Demonstrate two bioreactor systems, one using methanotrophic microorganisms and the other using pseudomonad toluene degrading organisms, using a groundwater seep at the K-25 Site at Oak Ridge, Tennessee.

- **Modeling Strategies for Optimizing In Situ Bioremediation**

Objective: This task will develop, calibrate, and apply mathematical models of subsurface flow, transport, and fate of halogenated aliphatic compounds to develop conceptual designs for enhancing in situ bioremediation.

Scope of Work: Recommend effective designs of recirculation units and strategies for improving the conditions for bioremediation; evaluate the effect of small-scale variability such as variability on diffusional limits in mixing.

- **In Situ Microbial Filters**

Objective: This task will develop and evaluate an in situ microbial filter technology to decontaminate contaminant plumes at their expanding boundaries using a methanotrophic bacteria.

Scope of work: Inject bacteria along the downstream boundary of a spreading plume to establish a vertical curtain of enhanced microbial activity. Purpose is to cause biotransformation of Trichloroethylene (TCE) at a rate equivalent to the rate at which TCE is delivered to the filter by natural transport processes. The microbe curtain serves as a contaminant-specific fixed filter, capable of remediating substantial amounts of TCE in flowing groundwater.

- **Macrophyte Remediation System for Contaminated Soils**

Objective: This project will demonstrate the macrophyte remediation system which will determine the feasibility of using macrophyte (macroscopic plant life) bioremediation to treat soils, sediments, and surface water contaminated with heavy metals and radionuclides.

Scope of work: Harvest plants grown on contaminated soils and subject the plants to a fractionation process whereby the protein is extracted for use as a food source and the contaminants are recovered and concentrated.

Containment

- **Evaluation of Two New Flowable Grout Techniques for In Situ Barrier Construction**

Objective: Two new grout barrier materials will be evaluated under a range of soil conditions found at DOE sites. The grouts are composed of a bentonite clay/natural paraffin mixture developed by German companies and an inorganic grout developed by a French company.

Scope of Work: Conduct tests to resolve questions concerning the compatibility of the barrier materials and anticipated waste forms, the ability to construct a barrier that is laterally extensive, and the physical and hydraulic integrity of the barrier.

- **Hydraulic and Diffusion Barriers in the Vadose Zone Surrounding Buried Waste**

Objective: This task will investigate and identify the regulatory issues, drivers, and key assumptions associated with aspects of barrier installation.

Scope of Work: Develop and test specific barrier materials for durability, permeability to water, ionic diffusivity, wet/dry cycling, freeze/thaw cycling, and chemical resistivity to acid, base, and solvent conditions under typical waste site conditions.

- **Chemically Enhanced Barriers to Minimize Contaminant Migration of Sediments**

Objective: This activity will develop and determine the effectiveness of a) hydraulic and diffusion barriers and b) permeable barriers to be used in vadose or aquifer sediments to minimize contaminant migration.

Scope of Work: Mix chemical reagents directly within the barrier materials or place a layer of reagents next to the barriers.

- **Containment of Contaminants Through Physical Barriers Formed From Viscous Liquids Emplaced Under Controlled Temperature and Street Conditions**

Objective: This task will identify and evaluate liquids with temperature-dependent viscosity or sets of two fluids which, when mixed and heated to a desired temperature, produce nearly-inert impermeable materials which solidify at average aquifer temperatures.

Scope of Work: Investigate the ability of these substances to provide an effective containment of the contaminated zone by entrapping and immobilizing both the contaminant source (if any) and the plume. Evaluate success by means of numerical simulation, large-scale laboratory experimentation, and field/testing demonstration.

- **Chemical Barriers Feasibility and Field Demonstration**

Objective: Objectives are to determine the feasibility of injecting a ferric oxyhydroxide colloidal suspension into an aquifer; to design and test a low cost field demonstration of an in situ permeable treatment system; and to demonstrate the performance of a ferric oxyhydroxide-based system to control radionuclides and metal contamination in a groundwater plume.

Scope of Work: Inject an in situ permeable treatment system containing ferric oxyhydroxide into a contaminate aquifer at a depth of 50 feet.

Successful completion of these research and development activities will result in the advancement of physical and chemical in situ treatment, in situ bioremediation, and in situ containment technologies to field demonstration in appropriate integrated demonstration test beds.

Characterization, Monitoring and Sensor Technology

This Integrated Program focuses on supporting the research and development of Characterization, Monitoring, and Sensor Technology (CMST) for application to environmental restoration and waste management at DOE sites. The program emphasis is on remote and minimally intrusive characterization, in situ measurements, and field deployable instrumentation. Research and development funding for specific technologies is based upon the priority of the need addressed, the projected advancement over baseline technology, a defined link to Records of Decision, and, an overall cost saving to DOE, evidenced by a low cost/benefit ratio. Short-term goals of the program are to match and adapt available technologies to immediate Environmental Restoration and Waste Management needs at DOE sites. In the long-term, this program aims to stimulate, coordinate, and sponsor relevant research and development within DOE; and to promote, publicize, and transfer established and emerging CMST throughout the Federal Government, universities, and private sector.

The Department of Energy's Integrated Program on Characterization, Monitoring and Sensor Technology

David Roelant¹, Caroline Purdy², and Bryan Albers¹

¹BDM Federal, ²Department of Energy

DOE is the governing agency for the Nuclear Weapons Complex, an industrial network of national laboratories and production facilities created to research, develop, test, and produce nuclear weapons. Throughout 45 years of production, the Complex assembled tens of thousands of warheads and generated millions of cubic meters of hazardous and radioactive waste. Hazardous contaminants have been dumped, leaked or injected into the ground and exist in groundwater at several sites at concentrations well above drinking water standards. Of primary concern are such organic solvents as trichloroethylene, perchloroethylene, and carbon tetrachloride used in metal cleaning and other manufacturing processes.

The Characterization, Monitoring and Sensor Technology Integrated Program (CMST-IP) within DOE/EM supports the development of technologies to characterize contaminated sites, assay stored waste, and monitor waste streams with new on-line, real-time chemical sensors. Program technical areas include:

- (1) technologies for site characterization (i.e., for contaminant identification, location, and measurement in soils and for geophysical, subsurface mapping);
- (2) characterization data analysis, integration and visualization;
- (3) nondestructive assay of container contents; and,
- (4) monitoring of waste streams and airborne contaminants.

Described below are a few high priority projects within the CMST-IP supporting site characterization for environmental restoration purposes and supporting new sensors for monitoring waste streams and waste treatment processes. For environmental restoration, the four-tier system for characterization data collection includes: historical data analysis, remote sensing from satellites and airborne platforms (cost-effective, large area coverage), noninvasive ground-based sensor technologies and finally, higher cost intrusive, but necessary, sample collection and analyses.

Remote Sensing and Other Spatial Data Technologies

Remote sensing is defined as the collection of data on an object (target) from a detached distance. Within the CMST program, remote sensing is confined to sensors mounted on airborne and satellite platforms to prevent confusion with other noninvasive, ground-based technologies. Both passive and active sensors are of interest and include electromagnetic (thermal, multi- and hyper-spectral), magnetostatic, gravimetric, Radar, Lidar, and laser-induced fluorescence.

Since considerable remote sensing research and development has been done by other governmental agencies, DOE is particularly interested in the transfer of advanced technologies to help solve EM problems. Important government agencies include NASA, EPA, DoD, NOAA, and the intelligence community. Current "tech-transfer" avenues include the use of Inter-Agency Agreements (IAGs), inter-agency contractors, and classified community experts. Primary assets offered include classified and commercial satellite data, access to advanced hardware and software, and expertise in technology applications.

To date, no single, remote sensing technology exists to solve the cleanup problems faced by DOE. Research and development must therefore focus on an approach which integrates spatial technologies synergistically. Other key spatial technologies include Geographic Information Systems, data fusion and modelling, and the Global Positioning System. Developing methodologies for the effective integration of these technologies is a top priority of this program.

Noninvasive and Minimally Intrusive Characterization Technologies

Present characterization of contaminated sites usually involves intrusive techniques such as drilling, well installation and extensive off-site laboratory sample analyses. There are two major problems with this method. First, it is ineffective due to cost and time considerations. The large total area (tens of thousands of acres) of contaminated sites and the necessary well spacing would require many billions of dollars in the traditional manner. Second, well drilling may generate new pathways for contaminant migration into uncontaminated areas and has an associated long-term monitoring cost. There is a need for advanced technologies for locating subsurface contaminant plumes and for accurately assessing the site geology and hydrology. Water flow, soil diffusivities, chemical adsorption characteristics and other site-specific information is necessary in general for the simulation of contaminant migration and health risk assessments. For buried waste there is a need for locating trenches and pits filled with boxes, drums and debris that have been covered over and the associated paperwork for the exact location has been lost.

An important need for treating and disposing of stored waste is the noninvasive characterization of drums, casks and tanks of the waste prior to treatment or shipment for disposal. The ability to distinguish transuranic waste from low-level waste, and mixed waste from either hazardous or radioactive waste would result in tremendous savings in waste disposal costs.

Technologies for noninvasive characterization include: magnetostatics, electrostatics, neutronics, gravimetrics, ultrasonics, seismics and electromagnetics. Electromagnetics sensors encompass most of the spectrum including: radiowaves, infrared, visible, ultraviolet, x-rays and gamma rays. An advanced neutron assay technology for drums of waste and an advanced ground penetrating radar system are currently being developed in this program. Finally, a workshop, jointly sponsored between Los Alamos National Labs, Ames Labs and the CMST-IP was held on the topic of, "Geophysics for Noninvasive Waste Site Characterization". Results have been published in a GeoTech document and stress the development of both Data Fusion techniques and ground-penetrating radar.

Chemical and Radionuclide Sensors

Research and development of sensors for hazardous waste include: sensors with lower capital costs; rechargeable or reversible sensors that can be permanently inserted into monitoring wells, greatly reducing maintenance costs; detectors with increased sensitivity for volatile organic compounds (VOC), and for dense nonaqueous phase liquid (DNAPL) contaminants; imaging systems for radioactive isotopes found in the topsoil (e.g., Pu, U, and Am); and for air monitors for both VOCs and airborne radionuclides. Preliminary efforts for sensors to detect carbon tetrachloride, trichloroethylene, nitrous oxides, hydrogen cyanide and phosphates have been initiated throughout the United States. On-site remote monitoring capabilities continue to advance through new sensor development such as fiber optics employing Raman spectroscopy and other techniques. Continuous air monitors for VOCs and other hazardous gases need significant development. They are required by regulatory requirements, are critical from a health safety viewpoint, and are a high priority of this program.

Real-time Techniques for Characterization

Real-time techniques are required for on-line waste processing and for effective, universal monitoring of worker exposure. Some of these techniques allow new remediation options. Advanced sensors are also essential for efficient monitoring of environmental restoration operations and for post-closure monitoring of sites. Finally, these technologies have the potential to greatly decrease costs of handling, processing, storing and disposing of all waste types.

Field-deployable Instrumentation

The development of field-deployable instrumentation for the analysis of organics, RCRA metals, and radioactive contaminants will decrease analysis time, improve worker safety, and reduce both analysis and operating costs. Some recent CMST-IP funded developmental work includes: improving the sensitivity and field-worthiness of the Inductively Coupled Plasma - Mass Spectrometers at Ames Lab for monitoring isotopic composition of elements of any sample; analyzers for on-site samples using infrared spectroscopy; Secondary Ion Mass Spectrometry at Idaho National Engineering Lab for rapid (5-10 minute) laboratory and field-based analysis of semi-volatile and nonvolatile organics on surfaces (e.g. smears, filters); and finally, Ion Trap Mass Spectrometry.

Expedited Site Characterization

The CMST-IP is currently developing a methodology for thorough and cost-effective expedited site characterization. The initial steps in the methodology are to review all site geology and historical records, perform extensive planning prior to arriving at the site, and engage the public through town hall meetings. This is followed up by a site visit to identify possible obstacles (e.g., accessibility, power lines, etc). A multi-disciplinary team (geologists, hydrologist, EPA, computer specialist,

Cone Penetrometer technicians, analytical chemist) all participate in pre-visit planning and in daily strategy meetings. The characterization data is validated and input daily into a computer visualization program (e.g., Geographic Information System) which allows the scientists to corroborate on multiple data sets, modeling assumptions and plan for the next day sample collection. This often results in fused, high quality data and has convinced the EPA in the past of ones understanding of the extent of contamination with less drilling and fewer lab sample analyses.

The expedited site characterization stresses extensive use of field-deployable instrumentation, and non-well sample collection methods (e.g., Cone Penetrometer, Hydropunch, or hollowstem auger). This helps reduce the major costs associated with well drilling and installation and lab sample analyses costs. The field-deployable instrumentation (minutes for results) and on-site mobile laboratory (1-5 day turnaround times for some analytical laboratories (7-30 days). During a field demonstration of an expedited site characterization, personnel from Argonne National Laboratories characterized a U.S. Department of Agriculture (USDA) site in 10 days and with a cost reduction of 90 percent compared to a similar USDA site characterization. By involving the public early and the EPA daily, using state-of-the-practice, field-screening instruments and methods, and performing daily concurrent characterization activities and next day activity planning, the expedited site characterization methodology yields high quality characterization data faster, cheaper and better with both the public and the EPA being satisfied.

Although most chemical sensor development work can be employed either down-well (EM-40) or for monitoring of waste streams (EM-30), much effort in FY93 is geared toward defining EM-30 characterization needs. A major thrust for FY94 will be to finalize requirements for sensors for monitoring the treatment of mixed waste and developing those sensors not available.

In summary, the CMST-IP continues to work with universities, industry and national laboratories to fund and promote the research, development, demonstration, testing and evaluation of advanced sensors, instrumentation data analysis and site assessment.

Minimum Additive Waste Stabilization Program

The Minimum Additive Waste Stabilization (MAWS) Program involves the development and on-site demonstration of an integrated, multiple-technology system for the treatment of blends of several waste streams with the objective of achieving significant reductions in overall treatment and disposal costs.

The MAWS system integrates three primary technologies - vitrification, soil washing, and water treatment - in order to address a variety of waste streams.

The MAWS concept is innovative in that the available waste streams are viewed as resources for the processes that are to be fully exploited in order to minimize the need for purchased additives, and a portfolio approach is adopted to maximize the economic benefits of blending the optimum proportions of multiple waste streams and alternative technologies.

MINIMUM ADDITIVE WASTE STABILIZATION PROGRAM

Ian L. Peggs, GTS Duratek Co., Columbia, MD, and The Catholic University of America, Washington, DC.

Background

The Minimum Additive Waste Stabilization Program involves the development and on-site demonstration of an integrated, multiple-technology system for the treatment of blends of several waste streams with the objective of achieving significant reductions in overall treatment and disposal costs. The field demonstration will be conducted at the Fernald Environmental Management Project (FEMP) site where preparations have been underway for several months for equipment installation to commence early in 1993. The program is supported jointly by the DOE Office of Technology Development and Office of Environmental Restoration through a prime contract to GTS Duratek Corporation, with Lockheed Environmental Services Corporation and The Vitreous State Laboratory of The Catholic University of America as subcontractors. Argonne National Laboratory will provide supplementary glass waste form testing with respect to leach resistance and performance assessment. While FEMP is the focus of the MAWS program, it is anticipated that the benefits will extend to many other remediation sites.

The MAWS system integrates three primary technologies - vitrification, soil washing, and water treatment - in order to address a variety of waste streams. The system is centered around GTS Duratek's DURAMELTER vitrification system with the objective of directing all contaminant streams to a final stabilized glass waste form. Vitrification was selected as the stabilization technology due to the superior leach resistance of the waste form and the very large volume reduction compared to many alternative technologies (e.g. a ten-fold reduction compared to cementing) which significantly reduces life-cycle remediation costs.

From a vitrification perspective, waste streams can be broadly classified on a spectrum of silica-rich to flux-rich; these extremes having opposite effects on melt temperature and viscosity. Due to the very large volume of uranium-contaminated soils at FEMP, the total waste mix will be dominated by the silica-rich components; this is a common situation at many remediation sites. Treatment of the soils alone would typically require addition of fluxing agents which are both an additional expense and diminish the volume reduction. In the MAWS blended-waste stream approach, the FEMP pit sludges play the role of the required fluxing agents. Furthermore, the uranium-contaminated soils undergo a volume reduction step by treatment in a Lockheed TRUclean soil washing system; the contaminant-enriched minor fraction is then used as feed for the vitrification process. The soil washing system is supported by a GTS Duratek ion exchange system with a regeneration cycle designed to direct collected uranium to the vitrification system. Development and support activities include ongoing laboratory treatability studies and stepwise system scale up performed at the Vitreous State Laboratory at The Catholic University of America and Lockheed's soil laboratory.

The MAWS concept is innovative in that the available waste streams are viewed as resources for the processes that are to be fully exploited in order to minimize the need for purchased additives, and a portfolio approach is adopted to maximize the economic benefits of blending the optimum proportions of multiple waste streams and alternative technologies.

Major Accomplishments

Laboratory soil washing studies have demonstrated decontamination levels of 35 pCi/g with volume reductions in excess of 80% in lab-scale tests. These tests were supported by an integrated ion exchange water treatment system.

Fernald pit wastes contain large amounts of calcium, magnesium, and fluorides (in addition to the hazardous and radioactive contaminants) which poses a significant challenge for glass formulation design. A major success has been the development of high-waste loading glasses that are both processable and highly leach resistant. Feed waste loading of above 93% have been demonstrated with resulting volume reduction factors of up to five-fold. These formulations have been developed for Pit 5 wastes and soil-washing concentrates.

The high fluoride concentrations also pose significant problems for off-gas system design. However, the Duramelter system has been successfully demonstrated at the 10kg/day Duramelter system performance and no dies stream waste generation. A 100 kg/day laboratory Duramelter system is now operational with surrogate wastes for testing prior to radioactive operations with Fernald wastes.

MAWS system components at Fernald will include a 300 kg/day Duramelter system, a 0.25 yd³ hr TRUclean soil washing system, and a 100 gallon/min Duratek water treatment system. Installation of these components is planned for March-April 1993 with vitrification testing commencing in May.

Phase II of the MAWS program is planned to begin in June 1993 with on-site proof-of-concept demonstrations with the integrated system using actual Fernald waste blends. Subsequent studies will be directed towards process control development, definition of operational envelopes, determination of system performance, and high-quality assurance runs to provide data to support a delisting application for vitrified Pit 5 wastes. Other waste streams will then be introduced into the test runs, including transite, asbestos, Pit 3 wastes, Pit 4 wastes, and possible silo wastes.

Demonstration of the viability of this approach to site remediation is of great potential economic significance since present estimates for the Fernald site indicate a 56% cost saving (about \$720 M) over cement stabilization, in addition to the benefits of a waste form of superior leach resistance.

Innovative Technology Program

DOE EM is sponsoring an RDDT&E program initiative with emphasis on innovative technology. This program initiative introduces high-risk, high-payoff tasks to the DOE EM RDDT&E program. New technology or innovative technology applications are reviewed, analyzed, and evaluated for their potential in solving user problems. Tasks center on high-risk, high-payoff activities, those having completed proof-of-concept and critical-path experimentation to demonstrate that the technologies are feasible and applicable to DOE needs.

INNOVATIVE TECHNOLOGIES PROGRAM

S. Weber

Objectives

The Innovative Technologies (IT) Program is a component program in OTD. The mission of the IT Program is to identify and provide development support for two types of technologies: (1) technologies that show promise to address specific EM needs, but require proof-of-concept experimentation, and (2) already proven technologies in other fields that show promise of being adapted to specific EM needs. The IT Program provides seed money to DOE field sites, other government agencies, industry, and universities to accelerate research of promising technologies in these two categories, and promptly moves successful projects to the Integrated Program (IP) or Integrated Demonstration (ID) that demonstrated the need or to private sector for commercialization. The approach of targeted and accelerated research will result in timely advances in the state-of-the-art in environmental restoration and waste management technologies so that developed technologies can be used to accomplish the overall EM mission with greater expediency and success.

Program Mandates

The IT program is based on the premise that conventional methods for many environmental restoration and waste management problems are marginal in effectiveness, time consuming, costly, and may not reduce the possibility of future problems. Through a combination of external and internal mandates, IT is charged with finding technologies that are presently beyond the frontiers of science and engineering or that are developed for other purpose but show promise for adaptation to DOE needs. Following is a brief list of the internal and external drivers that influence the program.

- EPA is promoting the development and implementation of innovative, cost-effective solutions to environmental restoration and waste management problems.
- EPA, DoD, and DOE signed a Memorandum of Understanding with the Western Governors' Association to establish a cooperative approach for development of necessary environmental technology.
- EPA, States, and DOE have entered into Federal Facilities Compliance Agreements (FFCAs) relative to DOE's waste management program.
- Research and development communities external to DOE are developing technologies relevant to the EM mission, and are interested in and willing to participate in EM technology development efforts, particularly those that could result in marketable technologies.

- EM's Implementation Plan for environmental restoration and waste management acknowledges that innovative technologies have the potential of significantly reducing waste volumes to be transported, reducing cost of current treatment activities, and reducing risk to workers and to the public.
- EM's Five-Year Plan places emphasis on the development of an aggressive applied research and development program, including research and development on innovative technologies, to develop and implement innovative, cost-effective technologies to yield permanent disposal solutions, facilitate compliance with applicable laws, regulations, and agreements, and minimize the generation of waste.
- EM's Strategic Plan calls for DOE to produce innovative technical solutions to generic DOE problems, and customize and refine systems to address unique needs of individual sites. Also, the Strategic Plan describes the need to provide EM scientists, engineers, and managers with up-to-date scientific and technical information on emerging and innovative technologies from non-DOE sources.

Planning Relationships

TD established its innovative technology program to accelerate fundamental research and provide needs-driven novel technologies in support of environmental restoration and waste management problems.

Within the innovative technologies program, projects can move either directly into integrated demonstrations or indirectly by first moving into integrated programs. The usual path is for innovative technologies to respond to the needs of, and be transitioned to, the integrated programs, except in some circumstances where continuity of operations requires an accelerated approach, in which case technologies proven at some stage of maturity will go directly to an integrated demonstration. In that case, ITs include research up through proof-of-principle and/or technology improvement under the circumstances specified by the integrated demonstration coordinator. Where there is an industrial partner, the technology might go directly to commercialization (e.g., EG&G Rotron's Biofilter).

Program Planning Assumptions

Following is a brief description of the Innovative Technologies Program planning assumptions.

- There is enough time for technologies in the early stages of the research and development cycle to actually be deployed at DOE waste sites, given the regulatory constraints. Additionally, research and development is needed for EM to achieve its mission. That is, existing, off-the-shelf technologies are inadequate.

- The IT Program will continue to receive funding.
- The program will be judged based on its results, i.e., how many projects are transitioned to IPs and IDs, or directly to commercialization, and by how cost-effectively these results are achieved.
- The program will be faced with selecting among competing technologies that seem promising, rather than not being able to find enough candidate technologies.

Planned Activities: Technology Development

The following representative projects are currently funded by the Innovative Technologies Program. The program accomplishes its mission through Program Research and Development Announcements, Research Opportunity Announcements, Interagency Agreements, Cooperative Research and Development Agreements, and Technical Task Plans.

Soils and Groundwater Clean-Up Technology Area

Removal and Degradation of Hydrocarbon and Halocarbon Vapors by Biofiltration (ID121701)

Methanotropic Biofilter for the Treatment of Airstreams Contaminated with Chlorinated Hydrocarbons (ID111701)

Novel Technique for Invasive Subsurface Barriers (ID111701)

Sonochemical Waste Treatment (ID111701)

Improved Membranes for Water Remediation Projects (ID111701)

Application of Neural Networks to Site Characterization (ID111701)

Remote Fiber-Optic TLD Monitoring System (ID111701)

NDA of Mixed Waste Containers Using a Double Compton Telescope (IAG w/NRL [HQ033503])

METC PRDA Selection of 21 Projects (ME001101)

Waste Processing and Retrieval Technology Area

Soil Sorbents for Selective Separation of Radioactive Nuclides (RL321701)

Selective Chelation and Extraction of Lanthanides and Actinides with Lariat Crown Ethers in Supercritical Fluids (ID111701)

Waste Minimization

Magnetically Controlled Deposition of Metals Utilizing a Gas Plasma (ID133051)

Cleanable Steel HEPA Filters (SF201202)

Mixed Waste Treatment

High Energy Decomposition of Halogenated Hydrocarbons (ID101301)

Decontamination and Decommissioning

**Morgantown Energy Technology Center Program Research and Development Announcement
Selection of 19 Projects (ME021103)**

The following are examples of accomplishments of the program:

- **Ground Penetrating Radar Imaging System**
- **Bioprocessing of Mixed Waste**
- **Hexone Tank Waste Treatment (in excess of 34,000 gallons destroyed)**
- **Penetrating Bremstrahlung for Destruction of Organics**
- **Methanotrophic Biofilter**
- **Cleanable Steel HEPA Filter Test**
- **Pneumatic Fracturing**
- **Science and Engineering Associates Instrumentation and Sampling Technique (SEAMIST)
from Argonne Industrial Procurement**
- **Cone Penetrometer from Argonne Industrial Procurement**

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Mixed Waste Integrated Program

The Mixed Waste Program develops technologies to characterize, handle, treat, and dispose of DOE-generated mixed wastes. The program examines technologies for front-end mixed waste handling and feed preparation, characterization, monitoring and assay, chemical and physical treatment, thermal destruction, off-gas treatment and final waste forms. The mixed waste research and development effort is an integral part of EM's National Compliance Plan for Mixed Waste.

MIXED WASTE INTEGRATED PROGRAM

Introduction

The Mixed Waste Integrated Program (MWIP) was established to provide a national focus to DOE's research and development on low-level mixed waste (LLMW). LLMW is the most prevalent waste in the DOE inventory; the current volume is estimated at 107,000 m³. An additional large volume of mixed waste is expected to be generated through restoration and decontamination and decommissioning activities. The technology for processing mixed wastes is currently quite limited and little treatment capacity for LLMW now exists. Hence, an integrated program was developed to conduct RDDT&E aimed at filling key gaps in current technology and developing alternatives to the EM-30 baseline approach. MWIP also serves to coordinate amongst the research and development efforts related to mixed waste which are ongoing throughout DOE.

The need to establish processes for mixed waste treatment has been driven by RCRA Land Disposal Restriction requirements. The enactment of the Federal Facilities Compliance Act (FFCA) in 1992 is likely to result in a state-by-state and site-by-site approach to waste management. The FFCA provides a three year waiver for most mixed wastes, after which "sovereign immunity" is waived, and requires plans for the development of treatment technologies and capacities. These provisions will lead to an increased involvement of regional, state and local agencies in the technology development process.

The initial MWIP program was organized in the following technical program areas: Front-End Handling, Chemical/Physical Treatment, Waste Destruction and Stabilization, Secondary and Off-gas Treatment, and Final Waste Forms. Technical Area Status Reports are being completed to survey the technologies and systems available to treat LLMW and associated technology research and development needs. In addition, MWIP has supported research in several key programs with the goal of developing candidate systems for treating specific waste streams. The following sections review the progress in these programs.

Waste Destruction and Stabilization

The primary waste destruction technology identified in the EM-30 baseline is incineration. MWIP is developing alternate technologies which may lead to an improved waste treatment systems. One aspect of this approach is in the development of versatile thermal treatment technologies. These systems seek to minimize the need for characterization and handling prior to thermal treatment, in part by enlarging the range of waste compositions which can be treated while producing an acceptable final waste form. Work on alternatives to incineration is being coordinated with the Rocky Flats Compliance Program. In addition, MWIP is addressing the needs for improved sampling, characterization, and control of emissions from thermal treatment processes, primarily via the activities in the off-gas technical area.

The focus of MWIP work in this area is on development and testing of Plasma Arc Systems. In this process, a gas plasma would generate high temperatures capable of melting both the inerts and metals as well as destroying any organic material which is present. Ideally, radionuclides and heavy metals, will be captured in an high-integrity final waste form (glass) with low leachability. This approach is designed to be a one-step process which will process complete waste drums without the need for extensive analysis or a separate break-open step. The use of the plasma arc for melting metals is a well-developed technology practiced in the specialty metals industry. The program supported by MWIP is aimed at applying this technology to mixed hazardous and radioactive wastes. The design and construction of a demonstration test system has been completed. In proof-of-concept trials, good processability has been demonstrated for two simulated "super-compacted" wastes, containing combustible and non-combustible wastes. The destruction of the organic material was achieved with residual carbon <2.5% in both the slag and flyash and <100 ppm of CO in the off-gas. The vitrified residual phase passed standard leaching tests without the use of additives. Similar promising results have been obtained in tests of buried waste forms carried out for the Buried Waste Integrated Demonstration.

Successful demonstration of this technology will require resolution of several issues. The high processing temperatures achieved with the plasma arc may require special materials of construction. The degree of volatilization of heavy metals and radionuclides, especially plutonium, is a critical concern under these conditions. The high temperatures may also promote the formation of NO_x which will need to be removed in the off-gas system. The next stage of the program will address these and other environmental performance issues as well as maintenance and operability. This three-year phase will include development of the processing system and be conducted at the pilot-scale. A wider range of waste forms will be tested to develop operations and scale-up data. These results are expected to set the stage for field-scale tests which will utilize an integrated system including handling and off-gas systems.

Final Waste Forms

MWIP programs are studying vitrification as a route to stable waste forms which will meet Land Disposal Restrictions requirements. Vitrification is a well-established thermal process which has been demonstrated to produce a glass phase with low leachability. Work to establish the compositional limits of acceptable glass formulations is underway. In addition to processes which will carry out the vitrification, MWIP is focussing on defining the characterization and test requirements necessary to establish the long-term stability of the final waste forms. The involvement of the states through the FFCA will also be important in seeking agreement on the acceptability of the waste forms for disposal.

MWIP has also supported technology development for the use of microwave processing. Microwave units offer the potential advantage of readily processing sludges and slurries, since the microwave may be able to act as both drier and calciner. In this concept, the wastes are heated using microwave energy to first remove the water and volatile organics. Additional treatment would drive off/destroy the less volatile organic components while sintering the inorganic phases. The sintering of ceramics

using microwaves is known to occur at lower temperatures than those required for conventional heating. Through bench-scale studies at the Oak Ridge National Laboratory (ORNL), the key processing parameters for the drying operations have been established utilizing surrogate wastes. Both the frequency and mode of the electric field have been shown to play important roles. ORNL also patented an acoustic emission feedback control system for controlling boiling.

The next stage of work in this area will include scale-up studies and the initiation of hot testing using actual wastes. Key issues during this phase involve process control at the larger scale, efficiency, sintering and the acceptability of the final waste form, and off-gas composition, especially the potential for volatilization or release of radionuclides. As part of another program, the design and fabrication of a microwave system capable of processing 55 gallon drums is also being carried out under the sponsorships of another program.

Chemical/Physical Treatment

MWIP efforts in this area are primarily concerned with the removal of components which may interfere with downstream processing and the preparation of materials for subsequent treatment steps. These include organics, nitrates, radionuclides, and mercury. Technology development activities have been limited pending a fuller definition of system requirements which would result from the various Technical Area Status Reports. Those research and development activities being conducted are outlined below.

Work at Los Alamos National Laboratory has examined the use of polymers for the removal of plutonium and americium ions. With proper design, systems for the capture of RCRA metals such as Hg, Cd, Cr, and Pb, can also be conceived. Following adsorption, separation of the polymers would allow discharge of a "clean" solution. In this program, work has focussed on the development and demonstration of chelates which will selectively bind the ions of interest. High specificity is necessary to remove the desired constituent from a waste stream with high content of a variety of other species. In addition to the evaluation of commercially available resins, new chelating agents have been synthesized and tested for this program. This approach may be an alternative to the standard flocculation treatment of waste water streams as well as a treatment for current wastes. In addition to the benefit of removing problematic constituents from the waste, the treatment may result in a reduction in secondary waste volume. During this program, a new technique for the analysis of low levels of radionuclides has also been developed. This approach combines sequestering of the ions with separation using an ultrafiltration membrane and may also be applicable to waste stream purification. Future work will also examine scale-up of both the separation processes and the preparation of the chelating resins.

Conclusions

The Mixed Waste Integrated Program has developed a structured systems approach to advance technologies which will fill gaps, enhance, and provide alternatives to the EM-30 baseline. In

addition to providing an overview of available technologies through the preparation of Technical Area Status Reports, research and development activities have focussed on several key technologies for mixed waste processing. Several of these operations have been demonstrated in the laboratory and are being scaled-up to pilot tests. MWIP's goal is to integrate these activities to develop candidate mixed waste treatment systems. These systems will demonstrate a comprehensive approach from waste handling through preparation of final waste forms acceptable for disposal. In the upcoming years, MWIP will focus on this systems approach while incorporating up-front interactions with both its DOE customers and state and Federal regulatory agencies.

Efficient Separations and Processing Integrated Program

The objective of the Efficient Separations and Processing Integrated Program (ESPIP) is to identify, develop and perfect separations technologies and processes to treat highly radioactive wastes. These technologies and processes are designed to separate radioactive and hazardous components from hazardous waste. Emphasis is placed on improving the quality and robustness of waste stream separations technologies, to minimize the volume of waste sent to repositories.

EFFICIENT SEPARATIONS INTEGRATED PROGRAM

Dr. Teresa Fryberger (PM) & Dr. John Morrey (IPC)
February 17, 1993

Orientation

The origin of ESPIP owes its beginning to the realization that advanced separations processes on High Level Defense Waste (HLW) could save billions of dollars while at the same time substantially improving the environmental quality of the resulting Low Level Waste (LLW). Consequently, as will be obvious, the program's early focus has been on the pretreatment of HLW. However, as further environmental separations needs are identified for Buried Wastes, Contaminated Soils, and Groundwaters, the program will expand to meet these needs. During FY94 and subsequent years, ESPIP will broaden the development of needs-driven technologies that apply to remediation problems throughout the DOE complex. It relates principally to the EM Office of Waste Operations (EM-30), but it also has important applications for the EM Office of Environmental Restoration (EM-40), particularly in developing separations technologies to clean up buried wastes and contaminated soils and groundwater, and to facilitate decontamination and decommissioning via secondary waste cleanup.

Cost of Minimal Waste Processing

The cost of cleaning up DOE radioactive and hazardous wastes has been estimated to be in the hundreds of billions of dollars. Remediating high-level defense waste in tanks alone could exceed \$50 billion if a course of minimal processing is pursued. The cost of caring for the LLW and Transuranium Wastes are additional. Unmet regulatory requirements or lack of societal confidence will also translate into further costs from delayed schedules or fines. For example, noncompliance at Rocky Flats Plant could cause Colorado to levy some very large fines (millions of dollars per day) against DOE.

Challenges and Opportunities in Efficient Separations

If the radionuclide constituents could be separated from the largely inert constituents in HLW, the number of canisters requiring geologic storage could be dramatically reduced to a few hundred, saving tens of billions of dollars.

Separations Technologies and Processes (STPs) will be required to process a variety of nuclear wastes under widely varying conditions:

HLW	Liquid or solid wastes that have been generated by reprocessing nuclear fuels (10 CFR Part 60).
TRU	Radioactive wastes that exceed 100 Nci/g of alpha activity from radioactive transuranium elements and have not been generated directly through nuclear reprocessing.
LLW	Wastes that contain only small quantities of specific radionuclides but not necessarily small quantities of radiation. The U.S. Nuclear Regulatory Commission defines 3 levels of low-level waste; A, B, and C.
Mixed Wastes	Wastes that contain both unnatural radionuclides and materials listed as RCRA hazardous wastes.
Hazardous Wastes	Wastes that contain hazardous chemicals but no unnatural radionuclides.

ESPIP Mission

The ultimate mission of ESPIP is

- 1) to provide STPs to process and immobilize a wide spectrum of radioactive and hazardous defense wastes,
- 2) to coordinate STP research and development efforts within DOE,
- 3) to explore the potential uses of separated radionuclides, and
- 4) to transfer demonstrated separations and processing technologies developed by DOE to the U.S. industrial sector to facilitate competitiveness of U.S. technology and industry in the world market.

ESPIP intends to accomplish this mission by developing new and adapting emerging technologies for use in total-waste-treatment and by integrating STP efforts within DOE. Chemical separations and processing technologies developed by the program will provide alternatives to minimize the overall risk of failing to complete the ER/EM mission. This effort will heavily involve U.S. universities and industry. As STPs are developed, they will become available for use by U.S. industry.

In its integrating role, ESPIP will coordinate separations research, development, demonstration, testing, and evaluation activities within the EM Office of Technology Development. ESPIP

interfaces closely with other OTD Integrated Demonstrations and Integrated Programs. It also is attempting to anticipate the separations needs that will be required in Waste Operations and Environmental Restoration as well as other DOE offices, e.g., Nuclear Energy, and the Division of Production.

When the ESPIP mission is successfully completed, transuranic waste and most of the high level waste associated with storage tanks and calcine bins will be processed to create a minimum total volume of HLW and TRU, destined for geologic repository or the Waste Isolation Pilot Plant, and other wastes will be processed to minimize their environmental effects. The technologies developed for waste processing are also expected to help remediate groundwater and soil-contamination by extracting low-level radionuclides and hazardous chemicals. These technologies should provide the best possible environmental separations and processing options for nuclear waste cleanup.

Elements of Program

The program elements listed below are the central thrust of ESPIP:

- **Systems Integration and Analysis.** A systems-oriented effort has been developed that consists of two levels of analysis: 1) a global decision tool, and 2) unit-process tools. The unit-process tools will guide Research and Development in separation technology development and will integrate the data for use by the global decision tool. This tool in turn will develop pretreatment process options that include retrieving (technology not developed by ESPIP), separating, and packaging individual tank wastes into acceptable low-level and high-level fractions. The effort will integrate tasks in robotics (not developed by ESPIP), chemical and physical separations, in situ and in-line instrumentation (not developed by ESPIP), and final waste-form generation (to be developed by a separate Waste Form Integrated Program) and will also identify voids or weaknesses in separations technologies that make up the process. Key data from all Research and Development efforts will be fed into the database used by the systems model.
- **Pretreatment Sludge Science and Technology.** Aqueous defense HLW across the DOE complex contains chemically complex sludges with small quantities of radionuclides. Separating the radionuclides from the non-radioactive components is essential because of the high cost of handling HLW. STPs for this sludge may include water washing, acid leaching, caustic leaching, and acid dissolution. ESPIP is addressing the treatment of HLW solids by coupling thermodynamic modeling with experimental measurements in the laboratory. Successful implementation will result in optimum treatment of the solids to ensure proper feedstock for the HLW processors.
- **Aqueous Pretreatment Processes.** ESPIP is measuring and evaluating the performance of promising new chemical agents for separating cesium, strontium, and TRUs from HLW waste. Included in this part of the program are the sequestering-agent design and synthesis and RDDT&E activities required to successfully extract small quantities of these elements from HLW. Efforts will be strengthened in FY94 and succeeding years to the development of STPs for separation of technetium, RCRA metals, noble metals, iodine, ^{14}C , and ^3H for designated

waste streams. Some of these technologies are expected to apply to low-level and mixed waste, groundwater, contaminated-soil and decommissioning cleanup as well as to HLW and LLW. Technologies from industry and universities are being jointly developed to meet some of the aqueous needs.

- **Pyrochemical Separations Processes.** Some HLW, e.g., Idaho calcine and Hanford HLW, and unprocessed defense fuel elements, may be more amenable to pyrochemical processes, where separations are accomplished at high temperatures, rather than to aqueous processes. The Idaho calcine waste contains large quantities of zirconium which, if volatilized, would decrease the volume of HLW from this source that requires geologic disposal by a factor of 20-30.

Needs Driven Focus

For FY93, ESPIP has focused on treatment of HLW at Hanford, Idaho, Oak Ridge, and Savannah River. Efforts for Hanford correspond with the anticipated start-up date for the Hanford Waste Vitrification Plant (HWVP) in 1999 and its operation thereafter. The plant is expected to run until 2003 with waste sources that produce a moderate number of HLW glass canisters. However, continued operation without implementation of advanced STPs would generate canisters with much larger quantities of non-radioactive waste. Unless advanced STPs are identified, refined, tested and put into operation, the number of canisters could exceed the current defense-allocated capacity of the first geologic repository and two additional HWVPs would be required if the Hanford waste is to be processed within 30 years.

ESPIP is also addressing the need to transform and permanently store calcine and high-sodium acid waste at Idaho. One project is exploring the feasibility of transforming the HLW calcine waste into more compact quantities via pyrochemistry, and contracts with the Lebedev Institute in Saint Petersburg, Russia will be exploring the applicability of Russian separations processes to the high-sodium acid waste as well as Hanford singleshell tank waste. Negotiations are also underway with the Japanese to test transuranium extraction on simulated Idaho high-sodium acid waste.

Since highly radioactive sludges are common to a number of HLW in the DOE defense complex, ESPIP is supporting efforts to better understand the chemistry of sludges and developing technologies for treating them. An example is the project to demonstrate the washing and leaching of the Melton Valley HLW at Oak Ridge. This project allows us to start working with real HLW on a pilot plant scale within a year or so. Emphasis will be given to transferring the knowledge and technologies developed in this project to the processing of Hanford sludges as well.

Finally, ESPIP is extending its activities to address recently identified problems at Savannah River where the operation of its HLW vitrification plant threatens to be delayed until a new method is found to replace the tetraphenyl borate precipitation of cesium from supernate. ESPIP is funding efforts to develop this need.

In its broader scope, ESPIP will focus on the development of separations technologies and processes required to treat transuranium waste and mixed waste. Emphasis for new projects in FY94 will be

on the acquisition of technologies to treat a multitude of DOE wastes containing hazardous metals (RCRA metals). In this regard, process and groundwater problems will be targeted.

Program Goals

Major short-term goals of ESPIP are to: 1) respond to EM-30 separations and processing needs by identifying required research and development to meet those needs; 2) demonstrate the utility of new, simple-to-operate, solid-based separations technologies in efficiently separating radionuclides and other hazardous materials from wastes while generating minimal secondary wastes; 3) develop and implement a systems tool to evaluate the cost, required research and development, potential savings, and secondary waste generated by radionuclide processing options; 4) establish a separations/processing network to coordinate DOE separations efforts and ensure against redundant pursuits.

Intermediate and long-term goals include developing STPs to save \$30-40 billion in remediating HLW defense wastes, and to help Rocky Flats meet its separations-related commitments to the State of Colorado in time to minimize burdensome State-imposed penalties. Other goals will be added as they are defined to address needs of other DOE sites.

The following table summarizes the activities being supported by ESPIP in FY93.

Table 1. FY93 Support

PRINCIPAL INVESTIGATOR	PROJECT	MAN YEARS FY92	START DATE
Jim Helt, ANL	Evaluate status of sludge technology & recommend balanced program	0.25	12/01/92
Phil McGinnis, ORNL	Develop sludge technology using MVST (Oak Ridge) sludge	3	02/01/93
John Geeting, PNL	Evaluate Bradtec ACT*DE*CON as a leachant of Hanford sludges	0.75	01/01/93
David Hobbs, SRL	Develop/evaluate electrochemical dest'n of organics/nitrates with Tex. A&M	2	01/01/93
Dick Cowan, WHC	Develop leaching technology for calcined Hanford sludge	1	10/01/92
Terry Todd, WINCO	Evaluate pyrochemical method of reducing volume of INEL calcine waste	3	10/01/92
Dennis Wester, PNL	Develop and test solid sequestering agents on Hanford HLW	3.6	10/01/92
Dennis Kried, PNL	Industrial contracts to develop sequestering agents	5	06/01/92
Gordon Jarvinen, LANL	Develop sequestering agents for TRUs	1.5	11/01/92
Louis Nunez, ANL	Develop sequestering agent coated magnetic beads for TRUs	1.5	02/01/93
Phil Horwitz, ANL	Develop advanced solvent extraction for "Clean Option"	1.2	02/01/93
Norman Brown, SNL	Develop and test silicotitanate exchangers for cesium	1.5	12/01/92
David Chaiko, ANL	Develop/evaluate biphasic systems for radionuclide extraction	1.5	01/01/93
Darleane Hoffman, LLNL	Develop & test naturally occurring sequestering agents for TRUs	1.5	02/01/93
Harry Dewey, LANL&OKNL	Develop separations process for Accelerated Transmutation of Waste	20^	03/01/93
Charles King, SRL	Develop Cs separations process to replace tetraphenyl borate process at SRL	3	03/01/93
Bill Kuhn, PNL	Test and define unit processes for separations processes	1.2	01/01/93
Steve Seeman, WHC	Define, test, & evaluate separations processes (waste volumes, cost, health)	1	01/01/93

A number of Technical Task Plans are being developed for support at Oak Ridge National Laboratory and Los Alamos National Laboratory. Most of the effort will be directed at "head-end" processing. This effort will support DOE/EM needs independently of whether the Accelerated Transmutation of Waste concept is implemented.

Technology Logic Diagram

The Technology Logic Diagram (TLD) is a planning document, in diagrammatic form, which integrates information about a DOE site's environmental and waste management problems with analysis of technologies which can potentially be applied to ameliorate the problems. A major objective of the TLD process is to clearly link the EM-50 technology development and demonstration activities to the specific EM-30, -40, and -60 field problems.

TECHNOLOGY LOGIC DIAGRAM DEVELOPMENT A JOINT PROJECT OF DOE-HQ, -OR, -ID

Stan Wolf, Director
Waste Management R&D Division, EM-542

Background

DOE's environmental problems span the sites across the DOE complex. These problems result from a broad range of contaminants and wastes which must be addressed by DOE's waste management, remedial action, and decontamination and decommissioning (D&D) activities. TLDs have been developed as a technology planning tool to address DOE's environmental problems.

Accomplishments To Date

To date, TLD development, which has been limited to studies in Oak Ridge National Laboratory (ORNL) and Idaho National Engineering Laboratory (INEL), has notable success. At Oak Ridge's K-25 plant, the TLD effort has helped identify a **fluorine-trichloride gas phase cleaning** technology for cleaning the interior of gas cylinders. Their studies of D&D requirements at K-25 has also led to the identification of **cutting technology** for dismantling the Tokamak Test Reactor Facility Torus at the Princeton Plasma Physics Laboratory. At INEL, the TLD effort has identified previously developed technology for **remote excavation and geophysical surveying** to provide characterization at INEL's WAG 1.

Methodology

TLDs are developed to logically link technology solutions to specific problems in the DOE complex. Linkage is made through site specific environmental restoration and waste management needs related to an analysis of a spectrum of appropriate technologies. TLDs are developed as a **twelve step process**. These steps follow the high-level EM goals and related problems, through site-specific problems, down to specific technology needs and requirements.

TLD efforts, to date, are completed at OR's K-25 plant and in progress at ORNL and INEL. The first TLDs have been developed to flush out the TLD development methodology and also begin to identify core technologies applicable to problems across the DOE complex. K-25 was chosen as the first site due to both the challenging problems at K-25 and the broad scope of its D&D needs. The K-25 TLD results will be applicable to other gaseous diffusion plants across the complex. Other TLDs at ORNL and INEL were chosen to develop the TLD methodology for a broad remedial action program. Both sites have major on-going remediation activities which are considered representative of problems across the DOE complex. Future TLDs at other sites across the DOE complex are being considered.

Program Direction

The major goal of the TLDs is to bring the technology to the DOE technology user. To meet this goal, TLD development is also taking the following steps:

- provide for wider distribution of TLDs as they become available,
- develop a TLD database to allow rapid access to the detailed TLD information and analysis which has been performed,
- identify and develop linkages between the TLDs and the roadmap process and other EM needs assessments,
- maintain the TLDs as living documentation which will be expanded and updated as necessary, and,
- develop a team at DOE-HQ to provide assistance to DOE managers and technology users to assist in utilizing the TLDs.

FY 1993

PROGRAM MID-YEAR SUMMARIES

DEMONSTRATION, TESTING AND EVALUATION

EM-55

Robotics Technology Development

This program develops robotics technology to retrieve buried waste, characterize it for immediate processing, and disposal at approved storage sites. This technology is being developed with applications for laboratory automation to remotely handle and analyze radioactive and hazardous materials. Robotics technology is also being developed for underground storage tanks.

ROBOTICS TECHNOLOGY DEVELOPMENT PROGRAM

Introduction

The Robotics Technology Development Program (RTDP) is a "needs driven" effort providing the development of applied robotics organized around several complex-wide Technical Application Areas (TAA): Storage Tanks, Buried Waste, Contaminant Analysis Automation, Waste Facilities Operations, and Waste Processing Operations. The Decontamination and Decommissioning area is in the advanced planning stage and will be strongly emphasized in RTDP in upcoming fiscal years. An additional application area; Cross-Cutting and Advanced Technology focuses on long-term Research and Development and on areas common to the entire program. The objective of this national program, RTDP, is to develop technologies for Environmental Restoration and Waste Management (EM) that have complex-wide impact. This is aimed at: (1) reducing worker exposure and increasing worker safety through remote operation and control of equipment; (2) increasing productivity through enhanced capabilities and automation; and (3) reducing cost through developing faster EM technology, thus reducing life-cycle costs.

RTDP has seven general activity areas where the national laboratories are providing and developing technologies for use by EM-30/40. An individual contractor (TAA Coordinator) from a DOE national laboratory or site coordinates the RTDP multi-laboratory team. Each team member has well-defined responsibilities which interlock with other TAA/Technical Task Plans. Areas of technical expertise are the basis for assigning responsibilities. The current organization of the RTDP is illustrated on the next page.

The key element in convincing customers and regulators that advanced robotics systems are faster, safer, and cheaper than existing alternatives is the full-scale, full-complexity of system prototypes operating in an environment closely simulating real-world problems. RTDP applies this concept by developing computer controlled, sensor-based robotics systems for technology demonstration.

FY 1993

PROGRAM MID-YEAR SUMMARIES

DEMONSTRATION, TESTING AND EVALUATION

EM-551

Mixed Waste Landfill Integrated Demonstration

Characterization, stabilization, and cleanup technologies are being examined for remediating soils contaminated with toxic chemicals and mixed waste. The initial focus is on in situ techniques to characterize and remediate heavy metals in landfills containing organic, inorganic and radioactive wastes. The Mixed Waste Landfill Integrated Demonstration is also developing site-specific and transferable methods to remove or immobilize contaminants in soils, including nitrates, cyanides, and sulfates.

MIXED WASTE LANDFILL INTEGRATED DEMONSTRATION

Assessing, demonstrating, and transferring technologies and systems that lead to faster, better, cheaper, and safer in situ characterization, remediation and containment of landfills in arid environments that contain heavy metals in complex mixtures with organic, inorganic, and radioactive wastes is the mission of the Mixed Waste Landfill Integrated Demonstration (MWLID) Program located at Sandia National Laboratories. Few technologies are currently available that address these issues. This technology gap affords opportunities to make significant contributions to the environmental restoration effort within the DOE complex.

Characterization

An integrated Landfill Characterization System (LCS) has been designed to characterize metal and mixed waste contaminants and their migration beneath landfills in arid environments. The LCS emphasizes minimally intrusive technologies and downhole geochemical/geological sensors that are cheaper and faster than conventional methods. Major goals include cost savings; promoting and nurturing industrial/university partnerships; and field demonstrating innovative technologies.

Within the last year, 12 out of 13 technologies were successfully demonstrated in the field and involved industry and/or university partnerships. Many of the technologies that comprise the LCS are readily deployable and some are beginning to be commercially available. Potential cost savings of the LCS are considerable because its application should result in fewer boreholes drilled, fewer samples analyzed, and decreased labor requirements. A cost analysis for three scenarios involving a hypothetical release beneath several trenches indicated a projected savings of 50-95%, due mainly to cheaper on-site analyses and fewer holes drilled.

The LCS consists of four separate subsystems: (1) **Pre-screening Technologies**, (2) **Drilling Technologies**, (3) **On-Site Field Laboratory**, and (4) **Borehole Technologies**. A representative technology from each of these categories is described below.

(1) Pre-Screening Technologies

A "Smart Sampling Methodology" with applications before, during and after drilling has been developed through a collaborative effort between Argonne National Laboratory and Consolve, Inc. Commercial software (SITEPLANNER™) will combine data visualization and management with geostatistical routines (PLUME) to optimize the number and location of boreholes and samples needed to not only characterize a site, but also in the near future, to perform risk assessments at locations of concern. One of the goals of this approach is to provide rapid data reduction in near real time. Such a capability would enable decisions to be made during drilling regarding additional sampling requirements and the necessity for costly off-site analyses. Version 1.2 of SITEPLANNER™ is due for commercial release in March 1993. Documentation for PLUME is currently being written

and commercialization of this product is expected in late 1993 or early 1994. Potential cost savings of using this software are expected to be 30-70%. For example, a conventional approach to characterizing a portion of the Chemical Waste Landfill at Sandia required drilling 5 holes and analyzing 24 samples off-site at a cost of \$100K. The Smart Sampling Methodology would have required only 2 holes and the analysis of 8 samples at a cost of \$32K, a 68% savings.

(2) Drilling Technologies

Directional boring techniques adapted from the underground utilities industry are being refined and field tested through a partnership involving Sandia and Charles Machine Works/Ditch Witch™. This type of drilling provides horizontal access beneath contaminated sites with minimal intrusion and minimal waste generation. Cost is a major advantage: \$20 to \$50/ft vs. \$300+/ft (potentially >80% savings above baseline). A successful field demonstration of this technology took place in 1992 at an uncontaminated area located adjacent to the Kirtland Air Force Base RB-11 mixed-waste landfill. Drilling is scheduled to be completed beneath the Kirtland Air Force Base RB-11 landfill in May 1993.

(3) Field Laboratory

One of the field screening analytical methods being carried out in an on site mobile laboratory is Absorptive Stripping Voltammetry (ASV). ASV is a mature analytical technique that has been modified to provide rapid analyses of metals in soils at the part per billion (ppb) range. A collaborative effort between New Mexico State University and Pacific Northwest Laboratories has culminated in the development of a lab procedure for chromium analysis in as little as 8 minutes, as well as analysis of four additional metals within several hours. As a result, real time decisions regarding drilling and sampling strategies may now be possible by linking these and other data with the Smart Sampling Methodology described previously. Commercialization of this technology would require minor customization for field screening activities. Potential cost savings are in the realm of 30% in laboratory analytical costs and 10-20% in drilling costs.

(4) Borehole Technologies

An integral part of our Borehole Subsystem is the SEAMIST™ liner, an impermeable membrane designed for in-situ characterization, monitoring, sensor emplacement, and vapor/liquid sampling. Developed by Science Engineering Associates and presently commercially available, SEAMIST™ has been successfully demonstrated on numerous occasions. Last year, this versatile technology was used to transport logging tools and cameras in horizontal boreholes; performed multilevel gas sampling in vertical boreholes; and served as a support or casing for numerous downhole sensors. Cost savings for SEAMIST™ are difficult to quantify but an obvious benefit is reduced drilling costs because of the multiple use of boreholes.

Remediation

Waste disposed of in landfills can be segregated based on their mobility. High mobility wastes are typically Volatile Organic Compounds and large volume aqueous or liquid streams. Moderately mobile wastes can include leachable anion/cations. By far the largest volumes of waste disposed of in landfills fall into the realm of low mobility waste. These wastes are either bound, adsorbed, or low-water solubility contaminants.

The approach the MWLID has taken in remediation is based on two assumptions:

1. Existing landfills can remain in place. This infers that there is no mandate to perform wholesale excavation.
2. Environmental problems are caused by migration of contaminants out of the waste disposal zone.

Using these assumptions, three remediation subsystems have been developed: 1) Extraction, 2) Transformation, and 3) Containment. Extraction is applied to those wastes that are the most mobile in the system. These contaminants are typically those of most concern to the regulatory community. Their removal is facilitated by in-situ type systems, not excavation mechanisms. Transformation is based on the alteration of the form of the waste in the soil to reduce its mobility. Containment is then selected to enhance the soil isolation of the remaining constituents that are the least mobile.

Those projects in the Extraction area that are currently funded include the *Thermal Enhanced Vapor Extraction system (TEVES)* and *Electrokinetic Removal of Unsaturated Zone Ionic Contaminants*. TEVES is an in-situ process that combines vacuum vapor extraction, AC resistance heating, and RF dielectric heating. The objective of the demonstration is to evaluate the impact of buried objects on energy delivery systems and the combined effects of AC and RF heating. Currently the engineering design is complete and awaiting the approval of the RD&D permit from the New Mexico Environment Department. The reduction in conventional vacuum vapor extraction should result in a sizeable cost savings.

Electrokinetics is the other technology sponsored under the Extraction subsystem. This process utilizes an electric current to induce the movement of chromium. Lab scale tests have been successful in unsaturated soils. Currently field scale electrode design is in progress.

The Transformation area includes *Geochemical Controls on Chromium Mobility*. This technology evaluates the chromium speciation and mobility in soils. Investigation into the "permanence" of chromium incorporation into the soil matrix is a major thrust. The techniques to change the oxidation state of chromium currently exist but without the information as to the modification of the stability/mobility of the reduced ion, such changes were not justifiable to regulatory agencies. This technology has also proven a systematic weakness in the EPA analytical methods.

The Containment area includes *Effects of Site Capping on Contaminant Transport*, *Dry Barrier Applications for Landfills*, *Prototype Decision Support System to Select Cover Systems*, *Migration Barrier Emplacement Development*.

The *Effects of Site Capping on Contaminant Transport* effort is involved with the evaluation of subsurface water movement resulting from placement of a surface landfill cover analog. It has identified water vapor phase movement by thermal induced gradients. The implication of this is that landfill covers may actually enhance the movement of subsurface waters unless the thermal gradients are taken into account during the design.

The *Dry Barrier Applications for Landfills* is evaluating a dry barrier precipitation removal technology for inclusion in cover systems designs. This involves the development of a high permeability layer that, either through active or passive mechanisms, can be dried to act as a barrier to the further movement of water in the soil profile.

The *Prototype Decision Support System to Select Cover Systems* is an alternative design evaluation tool to maximize decision elements on important design parameters. It incorporates the use of parameter estimation/simulation tools and scoring functions to identify sensitive decision variables. Also incorporated into the model is the USDA/ARS groundwater quality model. This will allow capping designers to concentrate on those parameters that have the most sensitivity.

The *Migration Barrier Covers for Mixed Waste Landfills* is an activity that includes four landfill caps at Hill AFB. Included are two vegetative caps, one RCRA cap, and one soil cap. The water balance for each has been evaluated to determine their strength and weaknesses. RCRA clay caps have failed within 2-3 years while the vegetative covers have proved to provide an excellent adaptable water removal system.

The *In-Situ Containment/Stabilization of Buried Wastes and Subsurface Barrier Emplacement Development* efforts are involved in the development of grouting mixtures as well as the emplacement of those mixtures in a subsurface environment.

Technology Integration

The Technology Integration effort at the MWLID is divided into three areas: 1) the encouragement of the transfer of technologies to the private sector, 2) the involvement of the public in the MWLID, and 3) the assistance in securing regulatory acceptance for technologies developed by the MWLID. All of the principal investigators in the MWLID are being assisted in publicizing their technologies through the DOE Technology Catalogue. This, combined with the Protech software system developed at Battelle, will result in a much wider audience than any single PI can currently command. More mature technologies, such as SEAMIST™ and the Hybrid Directional Boring (Ditch Witch™), are being assisted by the MWLID in the commercialization of their technologies and the identification of markets within Environmental Restoration (EM-40).

The public involvement is being addressed through working groups being set up by the MWLID, DOE-AL and DOE-KOA to facilitate an information exchange between interested parties. Local community leaders are also being involved through MWLID outreach activities.

In order to help facilitate the regulatory acceptance of technologies developed under the MWLID, the EPA is being contacted to investigate the possibility of their activity in the Technology Support Groups for the MWLID. Briefings and ongoing communication are also continuing with the New Mexico Environment Department.

For more information, please contact Skip Chamberlain, DOE Program Manager, at (301) 903-7248, or Jennifer Nelson, Integrated Demonstration Coordinator, at (505) 845-8348.

Volatile Organic Compounds In Arid Soils

The Volatile Organic Compounds (VOCs) In Arid Soils Program develops and compares technologies that are used to characterize, remove, or monitor volatile organic compounds in arid soils and groundwater. Work has been focused on developing and testing characterization, sonic drilling, and interim containment technologies.

The Volatile Organic Compounds Arid Integrated Demonstration

Integrated Demonstrations (ID) are part of an innovative program by DOE to speed up the development and demonstration of new technologies for cleaning up hazardous and radioactive wastes. DOE has found that existing technologies are not sufficient to do the job. In some cases, the necessary technologies don't yet exist, and in other cases the existing technologies are too costly, slow, or ineffective. New technologies are being evaluated based on technical, economic, regulatory, and public acceptability criteria. The goal is that these new technologies will provide DOE with a better way to accomplish its cleanup mission.

The Volatile Organic Compounds-Arid Integrated Demonstration focuses on technologies to clean up volatile organic compounds and associated contaminants in soil and groundwater at arid sites. The initial host site is the 200 West Area at DOE's Hanford site in southeastern Washington state. The primary VOC contaminant is carbon tetrachloride, in association with heavy metals and radionuclides. An estimated 580-920 metric tons of carbon tetrachloride were disposed of between 1955 and 1973, resulting in extensive soil and groundwater contamination.

The VOC-Arid Integrated Demonstration schedule has been divided into three phases of implementation. The phased approach provides for 1) rapid transfer of technologies to EM-40 programs once demonstrated, 2) logical progression in the complexity of demonstration based on improved understanding of the VOC problem, and 3) leveraging of the host site EM-40 activities to reduce the overall cost of the demonstrations. During FY 1992 and 1993, the primary technology demonstrations within the ID were and continue to be leveraged with an ongoing expedited response action which is directed at vapor extraction of VOCs from the vadose (unsaturated) zone. Demonstration efforts are underway in the areas of subsurface characterization including drilling and access improvements, off-gas and borehole monitoring of vadose zone VOC concentrations to aid in soil vapor extraction performance evaluation, and treatment of VOC-contaminated off-gas. These current demonstration efforts constitute **Phase I** of the ID and, because of the ongoing vadose zone can result in immediate transfer of successful technologies to EM-40.

In **Phase II**, demonstration of techniques to enhance and control (e.g., contain or direct) the transport of VOC vadose zone contaminants is a primary goal because a significant percentage of the VOC contamination resident at the Hanford host site and other DOE sites is still held up in unsaturated soils. Emphasis will be placed on: demonstrating enhanced techniques for VOC removal and control in vadose zone soils; and improved methods for accessing the subsurface to reduce the cost of characterization and improve the likelihood for success of the in situ treatment technologies. The baseline technology, SUE, will have been operating at the host site for a sufficient period of time before Phase II to allow for adequate analysis of cost and technical performance. Monitoring technologies for VOCs will be developed and demonstrated throughout Phase I to ensure availability for Phase II remediation technology demonstrations. With baseline technology performance, and availability of monitoring tools, demonstration of innovative remediation technologies can then be effectively conducted.

Phase II will also expand the focus of the demonstrations to groundwater contamination which is consistent with the general strategy of the Environmental Restoration program. EM-40 is moving forward with a proposed expedited response action for groundwater treatment in FY 1993 and 1994; therefore, there will again be a direct transfer route for demonstrated technologies to environmental restoration. In anticipation of this, the Integrated Demonstration has supported research and development activities that focused on groundwater remediation. With the initiation of a new expedited response action and opportunities for leveraged work activities, the Arid Integrated Demonstration is moving more aggressively to support technologies in FY 1993 and 1994 for the enhanced removal and treatment of groundwater contaminants. Pump and treat is an unacceptable, baseline approach for extracting groundwater VOCs, unfortunately, it is currently the only available method. Unlike vadose zone remediation using Soil Vapor Extraction, groundwater remediation is an extremely expensive option with the current baseline. Investments in groundwater remediation will have significant cost benefits. Technologies for in situ treatment of groundwater, and to a lesser extent, more cost-effective treatment of extracted groundwater will be developed and demonstrated. Characterization and monitoring technologies will continue to be developed to ensure that the necessary tools are available as the focus shifts from bulk contaminant (VOC) removal from soil to enhanced techniques for VOC residuals removal, and groundwater treatment.

Phase III of the VOC-Arid Integrated Demonstration will begin to address issues related to co-contaminants within the VOC plume. Specifically, emphasis will be placed on developing and demonstrating technologies for containing, mobilizing for recovery, and/or immobilizing metals and radionuclides in both soil and groundwater. Phase III will build on the base characterization and VOC treatment programs conducted during the first two phases of the program to focus efforts on high priority areas. Efforts will primarily focus on in situ treatment or enhanced recovery techniques for americium and plutonium in soils, and uranium and chromium in groundwater. These contaminants represent common VOC co-contaminants at DOE sites, and are significant problems at the host site. The focus on metal and radionuclide contamination in Phase III is consistent with EM-40 program needs, and the general schedule for restoration activities associated with these plumes in the 200-West Area of the Hanford Site. These efforts will build on applicable technology development and demonstration, activities associated with the Mixed-Waste Landfill Integrated Demonstration, and Integrated Programs focusing on in situ treatment, in situ monitoring, and metals treatment technologies.

The VOC-Arid ID will develop and demonstrate technologies in all phases of the program. Technologies ready for demonstration at or near the onset of the Integrated Demonstration program will be demonstrated in FY 1993 if they are technically and/or logistically consistent with the goals of Phase I. Longer term development efforts have, and will be, initiated in FY 1992 and 1993 to ensure that the technologies are ready for demonstration in Phases II and III. Other developing technologies will be transitioned from Integrated Programs to the Integrated Demonstration for demonstration in Phases II and III. Technologies supporting the objectives of Phase I or II will continue to be demonstrated over the duration of the Integrated Demonstration as they become available.

The VOC-Arid Integrated Demonstration is demonstrating technologies for all phases of remediation. These include:

- drilling
- site characterization and monitoring
- retrieval of contaminants
- above-ground treatment of contaminants
- in-ground treatment of contaminants

Drilling: Techniques are needed that can gain access to underground contamination to obtain samples, place monitoring sensors, retrieve contaminants, or treat contaminants in place. Cable tool drilling is the current baseline technology being used at many arid sites. Techniques are being pursued that are faster, easier to use, and safer. Two that have successfully met these criteria through demonstration are the cone penetrometer and sonic drilling. Since neither technology uses drilling fluids, no secondary waste is generated. A cone penetrometer has been deployed at Hanford and will be transferred to other arid sites. Sonic drilling has been adopted by the Hanford Environmental Restoration Program and transferred to other sites. A third innovative technology enables access to areas that vertical drilling cannot reach (e.g., under a building).

Site Characterization and Monitoring: To design an effective method for site cleanup, an engineer must know the types, location and concentration of contaminants, and the hydrogeology and microbiology of the site. Typically, site characterization and monitoring are time intensive (e.g., samples are sent offsite for analysis) and expensive. Several technologies have been successfully demonstrated at the VOC-Arid Integrated Demonstration that can accelerate characterization and monitoring. For example, the Unsaturated Flow Apparatus™ is a centrifuge system that measures the movement of contaminants in arid soils. It is much faster than standard techniques available (e.g., days rather than months to years to generate a single data point) and has been validated by the Environmental Protection Agency. An industrial partner has been found to produce the system and it has been transferred to Hanford, Los Alamos National Laboratory, and industry.

Retrieval of Contaminants: Techniques are needed to more effectively remove VOCs and other associated contaminants from soils and groundwater. Two technologies, soil heating and in situ vapor stripping wells, are being readied for demonstrations in FY 1993 and 1994. Heating enhances volatilization of VOCs from unsaturated soils and improves the performance of soil vapor extraction. This technology is being demonstrated in late FY 1993 through the VOC-Non Arid Integrated Demonstration, and will be tested for Arid soil applications in FY 1994 at Hanford. In situ Vapor stripping wells remove dissolved VOCs from groundwater without the added cost and difficulty of extracting large volumes of water.

Above-ground Treatment of Contaminants: Once retrieved from soils and groundwater, effective and economical methods for treating contaminants are required. For VOCs, granular

activated carbon canisters are currently used to trap the contaminants for subsequent off-site destruction. Steam reforming and membrane separation are two technologies being demonstrated in FY 1993 to reduce the cost of off-site granular activated carbon regeneration. Other destruction and separations technologies, such as an on-line tunable plasma (low energy E-beam) system, are being readied for demonstration in FY 1994.

In-ground Treatment of Contaminants: A longer term goal of the Integrated Demonstration is to develop and demonstrate in-ground treatment technologies that destroy organics, and immobilize or contain other contaminants. In-ground treatment offers significant economic and performance benefits over retrieval and treatment. Bioremediation is one example of an in-ground process for destruction of VOCs and nitrates in groundwater that is being developed for demonstration in FY 1994 at the host site.

A technology will be judged ready to be deployed in a cleanup if it is technically sound and acceptable to the regulators and the public. Success of an integrated demonstration will be realized if such technologies are transferred, ready for immediate use, to DOE environmental restoration personnel and private industry. In addition, such transfer will help address environmental concerns at other sites and make U.S. industry more competitive in the global marketplace.

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Volatile Organic Compounds in Non-Arid Soils

The Volatile Organic Compounds in Non-Arid Soils program develops, demonstrates and compares technologies for in situ remediation actions to remove volatile organic compounds from soils and groundwater. It also provides a test bed for field demonstration of air-stripping techniques combining horizontal wells, vapor extraction, and bioremediation. New technologies for monitoring, including geophysical tomography and sensor for tracing in situ groundwater flow, have been demonstrated.

VOLATILE ORGANIC COMPOUNDS IN NON-ARID SOILS INTEGRATED DEMONSTRATION

Project Background

The Savannah River Site (SRS) was especially well suited as the test bed for this integrated demonstration project due to the presence of a pre-existing line source that contributed contamination to both soil and groundwater, on-going environmental remediation efforts at the site, and full cooperation from the concerned environmental regulatory agencies.

Conventional means for removal of volatile contaminants from soils and groundwater include pumping the groundwater to the surface followed by air stripping with aboveground equipment, vacuum extraction of volatile subsurface contamination, or site excavation for physical removal of the contaminated materials. Pump-and-treat groundwater technology has been demonstrated at the SRS as an effective method for hydraulic plume control and for removal of significant contaminant mass.

However, cleanup of groundwater to drinking water standards is problematical using the conventional technology. The EPA presently recommends installation of pump and treat systems as a first step in remediation of groundwater, but also recognizes the need to develop innovative solutions that can be used to enhance the conventional systems. In-situ remediation technologies can destroy contaminants in place or contaminants can be extracted as a vapor, reducing the excessive energy requirements for pumping groundwater to the surface to treatment. The remediation system enhancements should be directed at source zone treatments such as vapor extraction of the vadose zone.

A promising technology for enhancement of remediation system performance is horizontal drilling, developed by the petroleum and utility installation industries and demonstrated at the SRS. Horizontal wells can significantly improve access to the subsurface. Just as horizontal wells have improved the performance of oil recovery systems in old petroleum fields, they have been shown to improve environmental remediation system recovery at SRS. In conjunction with other supporting technologies, horizontal well systems represent a promising new approach for environmental remediation.

Four different directional drilling technologies have been modified from the petroleum, river crossing, and utility industries for demonstration for environmental applications at the SRS.

Remediation System Demonstration

The technology emphasis for this integrated demonstration is in situ remediation because it has tremendous advantage over above-ground treatment. In situ remediation technology has the potential to be more effective, in less time, at a reduced cost and also has the benefit of minimizing

worker exposure. Three in situ remediation systems have been or will soon be demonstrated: (1) in situ air stripping or air sparging, (2) in situ bioremediation, and (3) in situ heating. Innovative characterization and monitoring technologies directly support the system performance analysis and thus are discussed in conjunction with the remediation systems.

In Situ Air Stripping

The first remediation technology demonstrated as part of this integrated demonstration was the DOE patented in-situ air stripping horizontal well system designed to remove solvents from soils and groundwater. This remediation system combines vapor extraction of the vadose zone with air injection into the groundwater. The air injection is based upon the same principle utilized by the above-ground pump and treat conventional technology. Two horizontal wells were installed along an abandoned process sewer line that was known to have leaked trichloroethylene and tetrachloroethylene to the subsurface. One well, installed below the water table and within the contaminated zone, was used for injection of air. The second well, installed above the water table, was used as a vapor extraction well. Both wells were designed to be operated concurrently to remove the volatile organics stripped from both the groundwater and soils.

Horizontal well in-situ air stripping was demonstrated for a period of twenty weeks. A total of 16,000 pounds of chlorinated solvents were removed from the test site during that period. This solvent removal rate was equivalent to that of 11 groundwater pump and treat wells pumping 500 gallons per minute.

Analysis of groundwater samples from monitoring wells, measurements of injection and extraction well gas pressure and contaminant chemistry, and helium tracer tests were conducted to document the performance of the system. Groundwater monitoring has shown that trichloroethylene and tetrachloroethylene concentrations in groundwater monitoring dropped significantly in many of the monitoring wells. Helium tracer testing was used to determine if the injected and purged gases were quantitatively recovered. Helium was added to the injected air and the distribution of helium moving through the groundwater soils in the unsaturated zone was measured and profiled. The data obtained confirmed the fact that the subsurface at the SRS test site contained high permeability and low permeability heterogeneities. The results of this tracer testing enhance the understanding of flow paths, residence times, and distribution of the gases between the air injection and extraction wells.

Depth discrete sampling of the sediments provide 3-dimensional characterization data both before and after the demonstration. This information is used to support evaluation of the performance of the remediation system. Biological monitoring of groundwater and sediment samples has shown that contaminant degrading organisms have flourished at the site during air injection. Crosshole geophysical tomography (both seismic and resistivity) successfully mapped moisture changes (fluid saturation distribution) in the subsurface as air stripping test conditions were modified. These technologies successfully demonstrated a method to detect the area of influence of the air injection by generating and recording the progress of various waves as they move through the ground. In addition, single-point in situ fluid flow sensors, based on thermal perturbation principles, monitored

groundwater flow paths (direction and rate) in three dimensions during the air injection. This information is critical to evaluating the effectiveness of the remediation system and design of full-scale systems.

Comparison of the costs of an in-situ air stripping system with horizontal wells versus a standard pump-and-treat system predicts a saving of approximately 40% using the innovative technology.

In Situ Bioremediation

Enhancement of the in-situ air stripping/horizontal well system to encourage in-situ bioremediation is presently being demonstrated at the same site where the in-situ air stripping was demonstrated. Injection of 1 to 4% methane in the air provides a food source to stimulate the indigenous microorganisms known to be capable of degrading tetrachloroethylene (TCE). Addition of nitrogen and phosphorous as nutrients is planned for the final stage of operation. In-situ bioremediation is an attractive technology because the contaminants are destroyed rather than moved from one medium to another. In situ biologically assisted destruction reduces costs and time of remediation, while increasing remediation efficiency and public and regulatory acceptability.

To support evaluation of the performance of the bioremediation system, groundwater and sediment samples have been chemically and microbially assayed, while vapor samples have been collected from the extraction well and from vadose zone piezometers to be analyzed for chlorinated compounds, carbon dioxide, and methane. These samples were collected before, during, and after the demonstration to evaluate system performance.

Evidence of biostimulation includes (1) complete consumption of all injected methane at the 1% level, (2) increasing densities of methanotrophic microorganisms by as much as five orders of magnitude in groundwater from monitoring wells sampled during the methane injection, (3) decreases in groundwater VOC concentrations in the same monitoring wells where the methanotrophic populations increased significantly, (4) increased biomass, mineralization, and enzyme activities in groundwater from monitoring wells, (5) increases in carbon dioxide concentrations in the extraction well and in vadose zone piezometers, and (6) decreases in TCE and PCE concentrations in sediments collected after the initial methane injection campaign.

In Situ Heating

Characterization of the contaminant plume has demonstrated that a significant proportion of the contamination is present within the more clay-rich layers of the vadose zone at the Integrated Demonstration Site. Removal of this material by simple vacuum extraction is problematical because of mass transfer limitations in low permeability sediments. Treatment of these zones with heat to enhance the volatility of the contaminants will facilitate removal by vapor extraction. Two innovative thermal treatment systems, radiofrequency and ohmic heating enhanced vapor extraction, will be compared to one another and to conventional vapor extraction using a horizontal well installed

within a shallow clay layer. The radiofrequency heating will utilize a dipole wand placed down the horizontal wellbore to heat a 25-foot long zone within the screened area of the well. The ohmic heating demonstration will be conducted at a later time, heating an adjacent zone within the same horizontal well. The ohmic heating is a six-phase system that will utilize a ring of six electrodes that surround the horizontal extraction well. Technical performance of these systems will be evaluated using two different types of temperature sensing devices, chemical monitoring of the vapor stream extracted from the horizontal well, chemical monitoring of vadose zone piezometers, and pre- and post-test chemical characterization of the sediments. Evaluation of the effects of heating on the indigenous microbial population and their ability to degrade contaminants will also be conducted.

Off-gas Treatment System Demonstration

Characterization of the Integrated Demonstration Site has demonstrated that at least 50% of the contaminants in the upper 200 feet are present within the vadose zone. Vacuum (vapor) extraction, a well accepted and previously demonstrated technology for treatment of the vadose zone, generates a waste stream containing VOC's. In fact, all in situ remediation systems being demonstrated include a vapor extraction component. The Clean Air Act will require treatment of all vapor streams by 1995. Baseline technology for such treatment is carbon absorption, which generates a secondary waste that must be treated or stored, and incineration, which does not have public acceptance. Thus, innovative offgas treatment technologies that destroy the VOC's, producing carbon dioxide and water, will be demonstrated side by side to be compared for technical performance and cost efficiency. Classes of technologies to be demonstrated include but are not limited to catalytic oxidation, free radical generation, biotreatment, and carbon regeneration.

Other Characterization and Monitoring Technologies

Innovative sensors, samplers and real-time analytical measurements have been developed, demonstrated, and evaluated to monitor the effectiveness of the in-situ remediation activities at the demonstration site. These technologies have broad applications for innumerable environmental restoration problems. Technologies in this category include both vadose-zone and groundwater multilevel samplers (SEAMIST, arrayed sampler, membrane sampler, etc.), fiber optic sensors, groundwater flow sensors (thermal and microphotographic), real-time field analytical equipment (ITMS, PAWS), and seismic and resistivity crosshole geophysical tomography.

The mobile cone penetrometer, capable of rapidly penetrating the ground for collection of real-time geological, geophysical, and geochemical data, has been demonstrated as a cost-effective subsurface characterization tool. The cone penetrometer can deploy many different state-of-the-art line sampling and instrument devices, such as a basic screening detector for soil resistivity and a fiber-optic fluorometric sensor that detects petroleum hydrocarbons (SCAPS). New sensors, such as TCE sensors, have been incorporated into the cone penetrometer for demonstration. This characterization technique, can improve design of monitoring well networks, while cutting costs by reducing the number of monitoring wells required.

Technology Implementation/Transfer

Implementation of innovative remediation systems that have been demonstrated as part of this Integrated Demonstration will potentially save DOE and other Federal agencies several hundred million dollars. Following successful demonstration of a new technology or system, the performance and cost effectiveness of the technology or system is evaluated against that of existing baseline technologies. Application to industrial sector problems will add significantly to overall cost savings. For example, the cost analysis report that evaluates the cost and performance of the in-situ air stripping system relative to conventional cleanup technologies such as soil vapor extraction and pump and treat for the removal of VOCs, has estimated that cleanup costs at applicable sites could be reduced by 50 - 60%. This represents a potential cost savings of over \$140 million (assuming that this technology is suitable at 10% of the DOE sites). A cost analysis report has also been prepared for the Site Characterization and Analysis Penetrometer System, with projected federal agency cost savings of \$300 million.

To achieve these projected savings, a critical step in the integrated demonstration program is implementation of the successfully demonstrated technologies and systems by DOE's Environmental Restoration organizations and transfer of technologies to other government agencies and the public sector.

A number of innovative characterization technologies have been successfully transferred to SRS Environmental Restoration and have been utilized at other SRS waste sites. Licensing of the in-situ air stripping horizontal well patent to commercial vendors is another example of technology transfer. At least thirteen licenses for this technology have been granted or filed. Licenses for Sandia National Laboratory's fluid flow sensors and Lawrence Livermore National Laboratory's TCE sensor have also been granted. The cone penetrometer fluorescence sensor has also recently been patented. The use of horizontal wells for environmental applications has flourished over the last year. DOE's involvement in promoting this innovative technology has been instrumental in its implementation.

Uranium Soils Integrated Demonstration

An optimized system is being developed to clean up uranium and other radionuclides from surface soils. Research and testing is being conducted to characterize and remediate radionuclides present in conglomerates of organic, inorganic and radioactive wastes which require chemical extraction. Research is also being conducted to improve radioactive detection system accuracy in site characterization activities and enhance chemical decontamination methods which permit cleaned soil to be used for vegetation.

URANIUM SOILS INTEGRATED DEMONSTRATION

The objective of this Integrated Demonstration is to develop and demonstrate remediation methods which address the cradle to grave elements involved in the remediation of soils contaminated with radionuclides, principally uranium. The remediation of radionuclide contaminated soils is difficult and expensive using traditional excavation, transportation, and radiological waste disposal methods because of the large volume of media to be remediated. The approach of the Integrated Demonstration is to establish the optimal techniques (e.g., real-time field characterization and monitoring, physical size separation, chemical treatment, ...), as well as system performance, on the basis of efficiency, cost, risk, applicability range, and community/regulatory acceptance for remediation of large surface areas contaminated with uranium. Initial focus is on ex situ technologies with initiation of real time analysis techniques, treatability studies, precise excavation techniques and secondary waste testing. The technologies can be transferred potentially to Oak Ridge, Paducah, Portsmouth, Savannah River, Idaho, Los Alamos, and Richland for cleanup of radionuclide contaminated soils at these locations.

The Uranium Soils Integrated Demonstration was initially funded in FY91 and Fernald was selected as the host site. The following six Technical Support Groups were formed to focus on Integrated Demonstration objectives: Characterization, Excavation, Decontamination, Waste Treatment/Disposal, Regulatory, and Performance Assessment.

Upon initiation of the Integrated Demonstration, extensive data was available from the ongoing Remedial Investigation/Feasibility Study process at Fernald on the quantities and locations of uranium contamination on the host site. However, insufficient data was available on the physical/chemical forms of the uranium waste in the soil. This data is extremely important in designing an efficient remediation system and in assessing its applicability to other DOE sites. Therefore, significant resources were devoted in this area.

In June of 1991, two soil samples were obtained from each of five locations representing the following three models of release to the environment: aqueous uranium waste (liquid spills), solid uranium product particulate (solid spills), and airborne uranium waste particulate (dust and aerosols). Based on laboratory screening results, six soil samples were selected for detailed characterization. To establish a baseline, two samples of "clean" representative soil were collected off-site and subsequently characterized.

Analysis of Fernald Soil samples is aimed at characterizing the chemical and physical properties of both the soils and uranium wastes. Physical characterization of the soils and uranium wastes is being conducted at Oak Ridge National Laboratory (ORNL). These tests are defining the basic chemistry and mineralogy of the soils, size fractionation of the soils, uranium/soil fractionation characteristics, and physical characterization of the particulate and occluded uranium waste. Chemical characterization of the uranium waste is being performed at Los Alamos National Laboratory (LANL). These tests are addressing questions concerning the speciation (oxidation state, chemical structure, mode of binding) of uranium and uranium/organic mixtures in the Fernald soils. In addition to these tests, Argonne National Laboratory (ANL) is conducting studies to determine if the chemical and physical

forms of uranium in the soil matrix can be characterized by analytical transmission electron microscopy (i.e. transmission electron microscopy with X-ray diffraction and electron energy-loss spectroscopy capabilities).

Based on the mineralogical analysis and the scanning electron microscopy, it has been determined that the uranium exists predominately in the particulate form. The uranium is associated primarily with the sand and silt fractions of the soil, but some samples also have a significant amount of uranium associated with the clay fraction. In most cases, the uranium is found to be associated with the more dense fractions of the soil components. However, significant variations were noted in the density fractions of the samples with which the uranium is associated.

Based on x-ray absorption analysis, the uranium in all samples analyzed thus far exists principally (80-90%) in the hexavalent oxidation state. In general, hexavalent uranium has greater solubility than uranium in other oxidation states, thus strong oxidizing agents may not be necessary as part of a chemical remediation scheme. Note, however, that this result implies that the uranium is less stable in the soils than would be a tetravalent uranium species.

Both microscopic (SEM and TEM) and spectroscopic (luminescence) techniques indicate that much of the particulate uranium exist in discrete, crystalline mineralogical phases, and these techniques are in agreement with respect to the classes of minerals that are present. In contrast to the dominance of a single oxidation state, there is a wide variability in the speciation of the hexavalent uranium from site to site and in some cases with the depth at a given site. TEM results further demonstrate that there is mineralogical heterogeneity even at the microscopic scale. Finally, the limestone gravel overburden appears to have played a significant role in defining the uranium speciation in the shallow subsurface as a result of increased pH and elevated carbonate concentration.

In FY93 the focus of characterization shifted from characterization of uranium waste forms in the original soil to characterization of the remaining uranium waste forms in treated soils (after lab scale extraction/leaching treatability test). This data will be utilized by the Decontamination Task Group to optimize the soil decontamination processes as well as determine the most effective linkage of technologies.

Based on initial physical and chemical data provided by the Characterization Technical Support Groups, the Decontamination Technical Support Groups selected two locations from which to collect samples to be used for treatability tests. Soil was collected and blended at each location to provide fifteen drums of homogenous soil from each of the two areas. Samples of this material were then shipped in 1992 to multiple laboratories for initiation of lab scale treatability tests.

Removal of uranium from heavy textured soils by conventional soil washing processes is ineffective because of the sorption of uranium on the high silt and clay content of these soils. True restoration of these soils is highly dependent on the application of a chemical extraction technique that will selectively extract uranium from the soils without doing serious physicochemical damage to them. The degree of selectivity is extremely important in terms of achieving waste volume reduction.

Some of the most promising chemical extraction techniques are centered around the use of chemical reagents that form strong binding constants with uranium. These include natural as well synthetic organic chelators (e.g., microbial chelators, citrate, DPTA) and inorganic complexes of uranium (namely, carbonate for the uranyl species). Treatability tests are being conducted on the following processes: carbonate and citrate leaching (at ORNL), aqueous biphasic separation (at ANL), extraction utilizing chelators (at LANL), the SEG soil washing process, the Bradtec ACT*DE*CON process, bioextraction at Idaho National Engineering Laboratory (INEL), and column leach test to allow comparisons between batch extraction and heap leaching (at LANL). The technologies and the testing are at various stages of maturity. Based on preliminary test results > 90% extraction has been achieved with some of the technologies.

The focus of decontamination in FY93 is on improving extraction performance through modification of conditions, increasing the degree of selectivity, and decreasing the extraction time. A Field scale test will be initiated on carbonate and citrate leaching in June 1993. Revegetation studies are being conducted on the treated soil from the carbonate and citric acid leaching to determine if the quality of the soil will permit its use for landscaping with grass, shrubs, and trees around buildings, etc. Initial cost data is being collected on the various technologies for utilization in future cost/benefit analysis. In FY93 a task was initiated to address the feasibility of treating the effluent from carbonate and citric acid leaching of uranium from contaminated soil. Bench top tests will be run to determine those unit processes which might apply to steps such as: (a) filtration, (b) clarification, (c) washing, (d) uranium concentration or precipitation, and (e) recovery and reuse of chemicals; and to study discharge volumes and composition of solution.

In August/September of 1992, the following field screening characterization technologies were demonstrated at Fernald: surface and subsurface gamma spectroscopy, mobile laser ablation inductively coupled plasma-atomic emission spectroscopy, beta scintillation detector, and long range alpha detector. Two locations, the Decontamination and Decommissioning and the Incinerator areas, were characterized utilizing the above techniques as well as the standard grab sample and laboratory analysis. The result of the technologies were generally consistent, particularly at higher contamination. However, there was considerable scatter in the data. The demonstration clearly pointed out the importance of interpreting the data in relation to regulatory cleanup limits. Improvements for field screening, as well as modification for conveyor belt application, are being made to the techniques as a result of the demonstration findings. A cost/benefit analysis is being conducted on application of these techniques.

Additional activities of the Integrated Demonstration include: an integrated effort initiated between ORNL, LLNL and the University of Cincinnati to develop and implement a scientifically sound methodology to determine risk based cleanup limits for residual uranium in soils treated by decontamination technologies; demonstration at the Buried Waste Integrated Demonstration test site of the Remote Excavation System for application to precise surface soil removal; and development of a Quality Assurance/Quality Control plan for field scale decontamination treatability test.

Resource Recovery Project

The purpose of this project is to evaluate, test and demonstrate technologies, at pilot scale, for recovery of both surface and groundwater from dilute heavy metal aqueous solutions. The project will emphasize recovery of valuable mineral resources, including heavy and/or precious metals, as well as industrial minerals. The project will focus on resource conservation and end-use applications of the recovered resources by maximizing resource utilization and minimizing non-useable byproducts. Resource utilization will address industrial, commercial, municipal/governmental, agricultural and recreational uses of the water, metals and other resources.

RESOURCE RECOVERY PROJECT ABSTRACT AND OVERVIEW

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Introduction and Objectives

The Resource Recovery Project (RRP) was funded in August 1992, by the DOE, Office of Technology Development. The purpose of the project is to evaluate, test and demonstrate technologies, at pilot scale, for recovery of both surface and groundwater from dilute heavy metal aqueous solutions. The project will emphasize recovery of valuable mineral resources, including heavy and/or precious metals, as well as industrial minerals. Economic analyses of each technology and the resources recovered will be used to project resource recovery and/or remediation costs of similar DOE and industrial sites using similar technologies. The project will focus on resource conservation and end-use applications of the recovered resources by maximizing resource utilization and minimizing non-useable byproducts. Resource utilization will address industrial, commercial, municipal/governmental, agricultural and recreational uses of the water, metals and other resources.

Economic and technical feasibility analyses of each technology demonstrated will be conducted. The analyses will include potential revenues from sale of water and mineral resources. Cost/benefit analyses will be an integral part of the project. The data gathered from these demonstrations will be applicable throughout the nation-wide DOE complex of facilities, where the removal of heavy metals from aqueous solutions has been demonstrated at pilot scale, which technologies are the most effective at recovering resources and remediating contaminated waters, and which are the most cost efficient, including the costs realized from resource utilization.

The primary goal of the RRP is to develop data through demonstrations that will allow DOE and other project managers, engineers, and scientists to screen and select "off-the-shelf" technologies for the recovery of ground and surface waters containing dilute heavy metals. The data generated will address the effectiveness, implementability, limitations, and costs of the technologies demonstrated. The information developed will allow for the timely, confident, and cost-effective selection of appropriate reclamation technologies at various sites throughout the DOE complex. Through technology transfer, the information generated can also be applied to non-DOE sites.

The Resource Recovery Project will attempt to minimize non-useable byproducts of water treatment, e.g., waste sludges, by identifying potential end use applications of all treatment byproducts. Resource utilization will identify potential opportunities for "value-adding" of recovered minerals to further enhance the utilization potential of the treatment byproducts.

Milestones and Accomplishments

Through the first six months of the project, several crucial tasks have been completed. The Resource Characterization Report and Interim Technology Evaluation Report have been completed, and technology screening criteria have been established. With this background work completed, the technology selection process is well underway.

Another major accomplishment is the completion of a regulatory compliance strategy. This strategy considers NEPA, CERCLA, and other environmental and legal requirements, and will serve as guidance for compliance with all applicable laws and regulations as the project proceeds.

A tentative facility site has been selected at the southeast rim of the Berkeley Pit in Butte, Montana. Based on this site, preliminary facility design has been completed. The facility will allow for on-site demonstrations to be conducted, thus minimizing the costs and liabilities associated with transportation of Berkeley Pit water and disposal of process products and byproducts.

The Technical Support Group for technology screening and selection has been formed and had its first meeting. This group brings a wealth of expertise on the test bed and resource recovery issues to the RRP. A charter outlining the purpose and goals of the Technical Support Group has been prepared.

There are many crucial future milestones for the RRP. Foremost among those is the initial selection and testing of technologies. Initial technology selection should be completed by April 1993. It is the goal of the RRP to begin technology demonstrations in FY93.

Technologies

Technologies for the recovery of water, metals, and other resources will be considered. Both conventional and innovative technologies will be considered for demonstration. A technology's need and readiness for demonstration will be considered during the technology screening and selection process.

A "Technology Characterization Interim Report" was published in February 1993. This report identified technologies potentially applicable to the reclamation of dilute heavy metal solutions.

The following general types of technologies were recognized:

Adsorption	Anaerobic trickling filters
Bio-adsorption	Biological reduction
Chelation chromatography	Chemical precipitation
Coagulation	Sedimentation
Flocculation	Dilution
Distillation	Electrochemical and electrokinetic methods
Evaporation	Filtration
Froth Flotation	Freeze crystallization
Gas hydrate formation	Ion exchange
Neutralization	Oxidation
Reverse Osmosis	Solvent Extraction
Ultracentrifuge	Ultrafiltration

Individual technologies and processes from each of these technology types were identified and evaluated. In all, over 55 separate technologies were evaluated in the first interim report.

Test Bed

The Berkeley Pit, an inactive open pit copper mine, has been selected as the RRP test bed. The Berkeley Pit and surrounding groundwater systems were de-watered by active mining operations for over 100 years. In April 1982, the de-watering pumps located approximately 3,900 feet below surface were shut off. Groundwaters and surface waters are now recharging. The Berkeley Pit is acting as a collection point, or "sink", for the recharging waters. Currently, the Berkeley Pit alone is estimated to contain over 20 Billion gallons of acidic, highly mineralized water. The Pit is filling at a rate of approximately 5 million gallons per day. The EPA has estimated that the Pit will contain as much as 56 Billion gallons of contaminated water at its maximum water level. Average contaminant concentrations in the Berkeley Pit are shown in Table 1.

Table 2. Average Berkeley Pit Water Quality.

CONTAMINANT	AVERAGE CONCENTRATION
Iron	1000 mg/L
Zinc	540 mg/L
Aluminum	270 mg/L
Copper	185 mg/L
Manganese	180 mg/L
Cadmium	1.60 mg/L
Arsenic	0.70 mg/L
Lead	0.05 mg/L
Sulfate (SO ₄ ²⁻)	7900 mg/L
pH	2.63 s.u.

Project Description

To satisfy DOE needs, the RRP has been broken into seven tasks. Each is described briefly below.

Task 1: Resource Characterization

In this task, the waters of the Berkeley Pit and its associated groundwater systems are described and characterized in great detail.

Task 2: Issue Identification and Analysis

This task identifies, characterizes, and analyzes issues relevant to resource recovery efforts. Four subtasks will be completed as part of this task. (1) **DOE Needs** for resource recovery will be continuously identified and analyzed for application throughout the DOE complex. (2) **Regulatory-Compliance Issues** associated with RRP are identified and plans are made to assure compliance. Issues include state and Federal permitting requirements, NEPA requirements; water end-use criteria (drinking water, municipal, industrial, commercial, and agricultural); water discharge standards; and waste management issues. (3) **Legal Issues** pertaining to resource recovery projects are also addressed. These issues include CERCLA liability issues; water and mineral rights; the use and demonstration of proprietary technologies; intellectual property and confidentiality issues; and patenting and licensing issues. (4) **Economic Issues** pertaining to resource recovery projects will be identified and analyzed. Economic issues include reclamation costs; water utilization costs; costs for bringing other resources to market; waste disposal costs; and cost benefits for "value-adding". Many of these issues are technology-specific.

Task 3: Technology Evaluation Screening and Selection

In this task, technologies potentially applicable to the recovery of resources from dilute heavy metal solutions are identified, evaluated, screened, and ultimately selected for demonstration under the RRP.

Task 4: Technology Demonstration and Development

In this task, those technologies selected will be demonstrated. Demonstrations may take place at the Berkeley Pit facility or at some remote location provided by a technology vendor. The scale of demonstration may vary depending on the technology.

Task 5: Facility Development and Construction

A facility for obtaining water from the Berkeley Pit and conducting demonstrations will be developed and constructed in this task. The facility development will begin with facility siting, proceed to facility design, and ultimately be constructed.

Task 6: Technology Transfer

Information gathered during the RRP will be compiled and transferred throughout the DOE complex and throughout the nation. Emphasis will be placed on water recovery and utilization of all recoverable resources.

Task 7: Formation of Technical Support Groups

Due to the many entities with existing interests in the Berkeley Pit, and the wealth of knowledge that has been developed by these entities, a Technical Support Group (TSG) has been formed to advise the RRP managers on the issues of technology screening and selection. The purpose of the TSG is to advise the RRP managers of recommended project directions, with the ultimate goal of keeping the project focused and targeted on maximizing and utilizing the knowledge gained.

FY 1993
PROGRAM MID-YEAR SUMMARIES
DEMONSTRATION, TESTING AND EVALUATION
EM-552

Buried Waste

Buried Waste activities include demonstrating and evaluating a suite of advanced technologies for the effective remediation of mixed and/or transuranic buried waste. Research, development, demonstration, testing and evaluation is being conducted at a DOE site. Methods for mapping and characterization, retrieval, pretreatment and treatment, and disposal of buried waste are being developed.

BURIED WASTE INTEGRATED DEMONSTRATION

Introduction

The Buried Waste Integrated Demonstration (BWID) supports Research, Development, Demonstration, Testing, and Evaluation (RDDT&E) of emerging technologies that offer promising solutions to the problems with the environmental restoration of DOE buried waste. Engineers and scientists from throughout the DOE complex, universities, private sector, and international communities are involved to accomplish the BWID mission.

Mission

The mission of BWID is to support the development and demonstration of a suite of technologies that, when integrated with commercially-available baseline technologies, form a comprehensive system for the effective and efficient remediation of buried waste. BWID will evaluate and validate technologies and transfer this information and equipment to support remediation planning and implementation.

The goal of BWID is to determine the capability of emerging technology. Technologies will be identified, screened for applicability to the identified needs and requirements, selected for demonstration, and evaluated based on prescribed performance objectives. This effort will determine implementability, effectiveness, potential schedule reduction, and cost savings associated with emerging technology to shape remediation plans and implementation of the environmental restoration of buried waste.

BWID is achieving its objectives by *forming alliances* with industry, DOE laboratories, universities, and Federal agencies to improve communication and transfer information on sponsored and demonstrated technologies; *leveraging related activities* with other integrated programs and demonstrations, DOE Environmental Restoration and Waste Management, other government agencies, and private industry; and *integrating field demonstrations*.

Background

The amount of buried waste located throughout the DOE complex as of 1990 is estimated at approximately 2.1 million cubic meters with an additional 5 to 10 times this volume estimated to be contaminated soils. This waste is predominantly located at Hanford, Savannah River Site, Idaho National Engineering Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, and Rocky Flats Plant. The wastes at these various DOE sites have been buried or stored in trenches, pits, building, storage pads, or other specific structures.

Approximately half of all DOE buried waste was disposed of before 1970. Disposal regulations at that time permitted the commingling of various types of waste (i.e., transuranic (TRU), low-level radioactive, and hazardous). As a result, much of the buried waste throughout the DOE complex is presently believed to be contaminated with hazardous and radioactive materials. Significant remediation challenges are presented for buried waste, particularly the pre-1970 buried TRU-contaminated waste.

Systems Approach

A systems approach to problem characterization, need identification, and technology development has been established to advance the understanding of potential technologies for remediation. This approach towards technology development has defined four high-level systems for the remediation. These systems include the characterize/retrieve/ex situ treat including total and limited "surgical" retrieval of specific wastes identified as driving the risk assessments, characterize/in situ treat/retrieve, characterize/in-situ treat/monitor, and characterize/contain/stabilize/monitor systems. BWID has jointly developed with Idaho National Engineering Laboratory EM-40 the configuration option for characterize/retrieve/ex situ treat and characterize/contain/stabilize/monitor. The remaining configuration options will be jointly developed this fiscal year.

Technology process options within each system offer opportunities for technology development. These process options form the basis for the BWID Needs Statements. BWID supports technology development for those process options in which no baseline technology presently exists. Technological gaps for the characterize/retrieve/ex situ treat option have been identified. Identifying technology gaps associated with the remaining three options will be accomplished through collaborative efforts with Environmental Restoration and Waste Management (ERWM). Development and demonstration of viable technologies to fill these gaps will be accomplished through collaboration with EM-30, EM-40, and other integrated demonstrations and programs.

Characterize, Retrieve and Ex Situ Treat Technology Process Option

The major field demonstration thrust for the BWID fiscal year FY93 program focuses on the characterize/retrieve/ex situ treat technology process option. The specific system requirements for this option are described in the *INEL Operable Unit 7-13 Configuration Option Report* (EGG-WTD-10204, Rev. 0, July 1992). Technologies were selected for participation in the FY93 program based on these specific requirements.

A key aspect of FY93 is the integrated field deployment of technologies satisfying the first half of the characterize/retrieve/ex situ treat technology process option. Multiple technologies are being integrated for field demonstration and testing at the INEL Cold Test Pit during the summer of 1993. Key technologies involved with the BWID FY93 system demonstration include the Remote Characterization System (RCS), Remote Excavation System (RES), Contamination Control Unit, Rapid Monitoring Unit, and Polysaccharide Soils Fixation System, and the Rapid Geophysical

Surveyor. Additional technologies such as the Graphite DC Arc Plasma Furnace will undergo laboratory testing.

The Remote Characterization System, developed by the Buried Waste Robotics Program, is a mobile remote-controlled low-signature vehicle. The vehicle uses a global positioning system to precisely position a suite of geophysical sensors. The geophysical measurements are derived by the use of magnetometers, ground penetrating radar, and electromagnetic sensors. Various chemical and radiological sensors are also deployable with the Remote Characterization System. A real time data acquisition and display system for sensor data will be evaluated. The high speed/high volume video and sensor data radio frequency transmission will be evaluated for precision, accuracy, and reliability.

The Remote Excavation System, developed by the Buried Waste Robotics Program, involves a mobile remote-controlled Small Emplacement Excavator. The key development features of this system include an advanced operator control station, the electronics and communication package for remote control, and end-effector teleoperations. The advanced control station technology is being shared between the Remote Excavation System and the Remote Characterization System. The feasibility of the remote excavation will be compared to manual operations. Force feedback control, vehicle maneuverability, and waste handling operations and throughput will be evaluated. The global positioning system, camera monitoring system, and data communication system will be evaluated.

The Contamination Control Unit, developed at the Idaho National Engineering Laboratory, is a system designed to dispense fixants, dust suppressants, and misting agents as well as provide vacuuming capabilities for loose debris. This equipment is being assembled in a self-contained mobile trailer for manual operations at a retrieval site. The fixants will be used to provide a moisture barrier to maintain the naturally occurring moisture in the soil/waste matrix. The dust suppressants are designed to eliminate dust generated from vehicle traffic areas. The misting agent is designed to remove dust that has become aerosolized. The vacuuming system is designed to remove soil debris that has accumulated around the excavation and dumping equipment. All systems are operable up to 100 feet away from the trailer by a system of retractable hose reels.

The Rapid Monitoring Unit, developed at the Idaho National Engineering Laboratory, consists of a collection of monitoring devices that measure loose surface and airborne contamination at a retrieval site. This system, contained in a mobile trailer, includes a large area alpha spectrometer and U-L-shell X-ray spectrometer, a large area ionization chamber, and alpha continuous air monitors. The system is designed to control contaminants at the source of operation by early detection of airborne and loose surface contamination thereby reducing potential escape of the contaminants and exposure to the public. The unique feature of this unit is that it provides lower levels of detection in a shorter time as compared with conventional techniques. This technology has shortened the processing time for detection of loose surface contaminations from twenty-four hours for 1 ci/g to approximately ten minutes for detection limits of 10 to 40 pci/g. Airborne detection limits have been lowered from approximately eight derived air concentrations (DAC) per hour to less than one DAC per hour.

The Polysaccharide Soils Fixation Technique, developed at Westinghouse Hanford, involves the demonstration of a method to control the wind transport of contaminated soil from excavation and clean-up sites. The technique uses natural polysaccharides as soil fixation agents. These natural polysaccharide solutions have the potential to fix surface soil contaminants in a soluble matrix that will minimize contaminant release while on the soil surface but can be easily resolubilized or broken down during subsequent soil treatment steps. The polysaccharides can be dispensed through a portable misting system.

The Rapid Geophysical Surveyor, developed at the Idaho National Engineering Laboratory, is a prototype system designed to rapidly and economically collect closely-spaced geophysical data for characterization of buried waste sites. The system consists of vector magnetic sensors, a positioning wheel, a data logger, and the manually pushed cart. Extremely high resolution vertical magnetic gradient data has been obtained by this system in support of remediation efforts. Measurements at a nominal density of 2.5 inches along survey lines spaced 1 foot apart were obtained to resolve features and anomalies identified from conventional surveys. The Rapid Geophysical Surveyor operated in the order of thirty times faster for data collection as compared to conventional ground survey techniques thus reducing the cost per data point collection and processing by 95%.

The Graphite Electrode DC Arc Plasma Furnace, developed by the Pacific Northwest Laboratory, Massachusetts Institute of Technology and Electro-Pyrolysis Inc., is a pilot-scale furnace including prototype provisions for alpha-containment and the capability of continuous processing at power levels of over 1 MVA with a waste processing rate of 500-700 pounds per hour. The electrode includes a unique coaxial feature which possesses the capability of operating in both the transferred or nontransferred arc mode. This effort also includes the development and application of furnace diagnostics. The diagnostics includes the development of analytical equipment for spatially resolved measurements of furnace and glass temperatures and online measurements of exhaust emissions both in the furnace chamber and off-gas line.

The *Buried Waste Integrated Demonstration FY-93 Deployment Plan* (EGG-WTD-10539, February 1993) provides a detailed description, schedules, and other logistical information on each of the technologies involved in the FY93 system demonstration.

Technology Commercialization

Following demonstration, many technological, institutional, and regulatory factors can still inhibit the use of innovative technologies for environmental remediation efforts. Overcoming these obstacles, improving the mechanisms for innovative technology use, and supporting the commercialization of technologies will expedite remediation efforts and provide cost savings to DOE.

BWID is committed to overcoming transfer barriers and fostering the use of innovative technologies for application to buried waste remediation. Several approaches have been initiated by BWID in FY92 and FY93 to accomplish the objective of technology transfer. A technology integration

workshop for private industry and universities was conducted to enhance their involvement. Twelve community outreach presentations were conducted to foster an understanding of the BWID. BWID is also initiating a technology exchange cooperative with the U.S. Environmental Protection Agency. BWID is also preparing a Technology Exhibition which will showcase the technologies demonstrated during FY93. These initiatives will continue to be coordinated with the OTD Technology Integration Branch and its procedures. Specific mechanisms used by BWID for technology transfer are described in the *Buried Waste Integrated Demonstration Technology Integration Process Report*, (EGG-WTD-9928, April 1992).

Underground Storage Tanks

Research is being conducted to develop requirements and technologies to address radioactive and mixed waste underground storage tanks. Initial efforts on single shell tanks establishes baseline characterization requirements and identify candidate processes for dislodging and conveyance. Other activities include identifying and designing retrieval systems, high-level waste separation and pretreatment methods, and integrating technologies.

UNDERGROUND STORAGE TANK INTEGRATED DEMONSTRATION

APPLYING TOMORROW'S TECHNOLOGY TODAY

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Abstract

The Underground Storage Tank-Integrated Demonstration (UST-ID) was created in February 1991 to develop state-of-the-art technologies that can be applied to remediate radioactive and hazardous waste stored in underground storage tanks at 5 DOE sites: Fernald, Hanford, Idaho Falls, Oak Ridge, and Savannah River. The key feature of this demonstration is a diversity of technologies being developed at multiple sites as part of integrated systems, for application to multiple sites.

The purpose of any integrated demonstration is to effectively integrate emerging technologies into a coherent system that provides a better, safer, faster, or cheaper solution than the current baseline. The UST-ID has addressed this task by employing a system engineering oriented approach to technology development. To achieve success within the UST-ID, a systems approach is crucial. It requires extensive coordination among principal investigators and UST-ID technical coordinators.

Demonstration Host Site

Hanford was selected to be the Host site for the demonstration based upon their schedule for remediation and the complexity of the tank waste issues. The demonstration was originated to develop, demonstrate, test and evaluate remediation technologies for underground storage tanks that contained radioactive waste or a mixture of radioactive and hazardous (chemical) waste (petrochemical tanks are excluded).

The Hanford site is located in the southeastern section of Washington State near the cities of Richland, Kennewick, and Pasco. It has operated since 1943 with a primary mission of producing plutonium isotopes. Plutonium was produced by irradiation of enriched uranium in eight nuclear reactors located along the Columbia River. The plutonium was then separated from the remaining uranium and fission products by chemical processes. It was then sent offsite for further purification. The waste generated from the different chemical separation processes has been stored in 177 USTs for future retrieval and treatment for final disposal. There are eight UST design types, ranging in age from 6 to 49 yr. Of the 177 USTs, 149 are of a single carbon steel shell with a reinforced concrete shell. The remaining 28 USTs have dual carbon steel liners. The USTs range in operating capacities

from 208 to 3,785 m³ (55,000 to 1 million gal). Approximately 225,000 m³ (59.4 million gal) of high-level waste is stored in the USTs. The waste has four general physical forms; sludge, supernatant (liquid), salt cake, and slurry. All of the waste is alkaline with a large percentage of sodium nitrate and nitrite salts and metal oxides. The principle radionuclides include ²³⁵U, ²³⁸U, ²³⁹Pu, and the uranium fission products ⁹⁰Sr and ¹³⁷Cs, as well as their decay products.

Technical Areas Of The Demonstration

The demonstration was originally separated into five technical areas: Characterization, Retrieval, Waste Separation (pretreatment), Low Level Waste, and Barriers. During FY92, the UST-ID evaluated technology needs in these areas and identified a set of promising technologies that would fit into these 5 systems. Evaluation criterion included statements of EM-30's needs at different sites, as well as various feasibility measures. The highest ranked technology development areas were described in a Needs Statement for FY93, which was issued to all DOE contractors.

Concurrent with the national review process, Hanford's EM-30 office developed the Tank Waste Remediation System Program. The UST-ID and its principal investigators actively participated in developing the technology plan for tank remediation. From the EM-30 preliminary planning information, the UST-ID agreed to pursue four technical areas using a system approach during FY93. These involve retrieval, characterization, pretreatment and limited low level form alternatives. During FY92, the UST-ID evolved from a program of diverse technologies to adopt a focused approach. The demonstration is divided into two groups with two complementary technical disciplines in each. The first group blends characterization and retrieval using an arm based manipulator system. The retrieval portion is made up from the UST-ID and the Robotics Technology Development Program. The second group combines tank waste pretreatment (separation) and Low Level Waste form development.

Technical direction of the UST-ID in characterization is focused during FY93 on spectrographic demonstrations in a hot cell using actual waste core samples. The primary technologies currently under development and review are the Laser Raman Scattering Spectroscopy and the Aceto-Optic Tunable Filter Spectroscopy. The spectroscopy systems will be demonstrated in a hot cell to screen tank waste core samples. The preliminary success of the Raman system has secured co-funding with EM-30, who has also begun project plans to implement the spectroscopy system in the hot cell as soon as the demonstration is complete. The UST-ID will then take the system into one of the Hanford tanks and demonstrate it on the Light Duty Utility Arm for in-situ characterization.

Further Characterization coordination is required to support the retrieval and robotic aspects of the UST-ID; specifically, the end effector development (including sensors) and interface with the control systems will be accomplished. Close coordination with Characterization Integrated Program and the Robotics Technology Development Program mini-laboratory will be essential as will coordination with the Early Deployment System staff.

The retrieval portion of the demonstration will focus on four major systems: Early Deployment (EDS), Light Duty Utility Arm (LDUA), Long Reach Arm (LRA), and End Effectors. Each system will be driven toward the rapid industrialization of the technology based upon a firm understanding of the parameters required for hot deployment. A joint working relationship will be maintained with the EM-30 for cold testing and technology transfer to hot demonstration.

The EDS is designed to provide early access to a tank for testing systems and equipment that will be used on the LDUA. It will provide training to the team that will deploy the LDUA and address most of the regulatory and NEPA issues that the LDUA will have to comply with. The LDUA is a surveillance, characterization and limited sampling (e.g., 5 gallon samples) articulated robotic arm. It is designed to access a tank through a 12 inch riser, deploy vertically 40 feet, extend horizontally a minimum of 9 feet, be intrinsically safe, and carry with it a large variety of end effectors for characterization, surveillance and limited sampling. (Procurement of this system will be initiated in FY93.)

The LRA is a large retrieval articulated robotic arm that is designed to aid in retrieving waste from USTs. It will be designed to access a small riser (approximately 40 inches), be controlled by an operator or computer (includes full range of sensor control systems), deploy vertically 40 feet, extend horizontally a minimum of 45 feet, be intrinsically safe, deploy a variety of retrieval end effectors (currently under development), be capable of retrieving all three waste forms, and be capable of retrieving in-tank hardware. End Effectors are being developed to accomplish retrieval, characterization, surveillance and sampling.

The separation portion of the demonstration will involve a three phased development approach corresponding to types of UST waste to be treated: supernate, saltcake and sludge. The first phase will focus on removing key constituents for supernate using ion exchange (for Cs and Sr removal), calcination and other methods (for destroying organics and nitrates), and methods yet to be identified for removing selected radionuclides (e.g., Tc). The second phase will focus on treating saltcake by dissolution and will develop methods for separating solids and liquids (scheduled for initiation in FY95). Lastly, sludge treatment will be developed in conjunction with the Efficient Separations and Processing Integrated Program.

To support the separation technologies, "Compact Processing Units (CPU)" will be developed using a modular or distributed processing concept. These CPUs are currently being considered by EM-30 as one means of demonstrating their Initial Processing Module technologies. Plans are underway to produce an interface module for the CPUs to connect with. During FY93, the ion exchange technologies developed by the Savannah River National Laboratory will be evaluated for incorporation into the first fieldable CPU. The organic and nitrate destruction technologies will be initiated late in FY93. The CPUs will be designed and a system specification will be developed for competitive bid by industry.

Selected sludge technology development by the Oak Ridge National Laboratory will be accomplished and validated using the TRUEX model. Sludge from the Melton Valley waste tanks will be washed, the supernate passed through ion exchange columns containing the SRS resin, the sludge will be

treated with a TRUEX process and the results will be compared to the predictive model for TUREX, supported by the Argonne National Laboratory.

The Low Level Waste form development will focus on testing the two best options compared to grout: Nitrate to Ammonia and Ceramic (NAC) and Polyethylene. The NAC process destroys nitrates and produces a ceramic LLW form in one process. The resulting ceramic can be sintered, which would destroy all organics by the high heat added during the final phase. The Polyethylene process takes a dry waste stream and encapsulates it into a solid polyethylene matrix that can be extruded into the desired form.

Rocky Flats Compliance Program

The primary objective of the Rocky Flats Compliance Program is to develop mixed waste treatment technologies that will be used to bring the Rocky Flats Plant into compliance with Federal and state regulations and agreements. In addition to developing treatment technologies, the Rocky Flats Program is demonstrating, testing, and evaluating systems to reduce the amount of mixed waste requiring disposal.

Rocky Flats Compliance Program

Introduction

The primary objective of the Rocky Flats Compliance Program is to develop mixed waste treatment technologies that will be used to bring the Rocky Flats Plant (RFP) into compliance with Federal and state regulations and agreements. Approximately 11,000 cubic yards and 29,000 gallons of low level mixed waste are stored at the Rocky Flats Plant. In addition, newly generated waste from cleanup and decontamination and decommissioning activities will require treatment and disposal. Currently, no method for this treatment is approved and no approved final disposal facility exists. In addition to developing treatment technologies, the Rocky Flats program is demonstrating, testing, and evaluating systems to reduce the amount of mixed waste requiring disposal. The program is also designed to maximize the alignment of its activities with the Mixed Waste Integrated Program (MWIP) to ensure consistency with the national approach to developing mixed waste treatment technologies.

The cleanup of the Rocky Flats site is driven by agreements between DOE, the EPA, and the Colorado Department of Health (CDH). Under these agreements, a Comprehensive Treatment and Management Plan (CTMP) was drafted to outline the mechanisms by which RFP will achieve compliance with the regulations and agreements. This document describes DOE's strategy to treat low level mixed waste to meet Land Disposal Restrictions. The CTMP further listed a wide variety of technology options which may be considered. The projects supported under the Rocky Flats Compliance Program are focussed on developing new treatment facilities as outlined in the CTMP.

The technology development activities supported by the RF Compliance Program are organized into a set of systems, each designed to treat a specific waste stream or group of wastes. In FY 93, work has been initiated on four waste stream groups (Solvent Contaminated Wastes, Solidified Bypass Sludge, Building 374/774 Waste Forms, and Surface Organics on Bulk Lead/Other Bulk Items). This comprises the majority of the low-level mixed wastes at Rocky Flats. The efforts in these areas range from laboratory feasibility trials on individual technologies to pilot-scale demonstrations of integrated waste treatment systems. In one case, Solvent Contaminated Wastes, two different approaches (thermal, non-thermal) are being developed. The accomplishments and status of the programs in each of these five systems is outlined in the following sections.

Thermal Treatment - Solvent Contaminated Wastes

The central operation in this system is incineration. Rocky Flats has previously utilized a Fluid Bed Incinerator (FBU) for the destruction of organics. The potential for the emission of toxic and/or radioactive compounds has been raised as an issue in permitting of this unit. The Rocky Flats Compliance Program has completed a state-of-the-art assessment of off-gas systems to control emissions from the FBU. A report evaluating the options for capturing the off-gasses to allow complete characterization prior to release was also completed. Since characterization of the off-gas

is crucial in assuring safety during operation, the program has also been supporting work on the design and testing of equipment for monitoring alpha radiation; initial tests have established detection efficiencies of over 90%. A related effort to predict and measure the volatility will be very low at FBU temperatures. The potential for increased volatility in the presence of other contaminants is also being examined.

Non-Thermal Treatment - Solvent Contaminated Wastes

Work on alternatives to incineration involves several potential technologies which have been shown to destroy organic compounds in hazardous wastes. A series of lab-scale tests using surrogates have shown four technologies which may treat the Fluidized Bed Incinerator Oils: Chemical Catalytic Oxidation, Mediated Electrolytic Oxidation, Silent Discharge Plasma, and Biodegradation. These approaches provide treatment options for liquid and/or solid combustible waste streams in the event that incineration is not performed at the RFP. Work is underway to initiate the design for cold pilot-scale tests of one or more of these technologies. The selection of a candidate system for the demonstration of a complete incineration alternative system is planned for FY95 with the demonstration to begin the following year.

Microwave Solidification - Solidified Bypass Sludge

Microwave solidification utilizes microwave energy to glassify waste solids to a stable final waste form. In contrast to the use of cementation to process this waste the microwave approach would avoid a large increase in the volume of waste for disposal. RF's work on microwave solidification has proceeded through a pilot-scale demonstration using surrogate waste. Work using actual wastes was also successful in bench-scale experiments. The program has prepared a preliminary definition of an off-gas system. The emphasis in ongoing work is toward developing a complete system for use with the microwave and on evaluating the acceptability of the final waste form. A full-scale integrated demonstration is planned beginning in FY94.

Polymer Solidification - Building 374/774 Waste Forms

Solidification of the waste in a polymer offers another alternative to the current cement process. Since high loadings of waste may be incorporated into the polymer, a substantial reduction in volume may be possible relative to cementation. This program has succeeded in extruding nitrate containing slats at the lab- and pilot-scales. The radioactive and thermal stability of the final waste form has been demonstrated. Preliminary tests have also suggested that the polymer product will provide sufficient compressive strength, resistance to biodegradation and thermal cycling, and low leaching rates. Additional leaching tests are planned and long-term durability trials are underway. Other FY93 work includes treatability studies on actual waste and the design/development of a complete processing system. Completion of a pilot scale test is expected in FY95.

Surface Organic Removal - Bulk Lead/Other Bulk Items

Some of the wastes at the RFP consist of bulk items with contaminated surfaces. Technologies to clean these surfaces would allow the separation of the hazardous and radioactive components for treatment and disposal as hazardous and low-level waste. The RF Compliance Program is evaluating commercial technologies for the removal of the organic components. A report examining volatilization technologies has been drafted. Initiation of a demonstration of one or more of these approaches will be dependent on review of the data in this report. Another potential technology for surface organic removal involves the use of supercritical carbon dioxide. A laboratory-scale test unit has been installed at the University of Colorado. Surrogate waste streams have been identified and a test plan is being completed. A pilot test may be conducted by the end of FY94 if results are successful at the lab-scale.

Rocky Flats Technology Issues

The development activities described above are consistent with those technologies outlined in the draft CTMP. The CTMP has been reviewed by the Environmental Protection Agency, along with the CDH and a Citizens Review Group which RF coordinated as a mechanism for public participation. A draft of the comments from those reviews has recently been submitted to DOE. A revision of the CTMP is currently being initiated to respond to those comments. This process will allow update of the CTMP to incorporate progress in technology development activities which have been carried out. In addition, other waste management issues which may impact technology needs, including residue elimination, will be examined in discussions with the Environmental Protection Agency and CDH.

Many of the technologies included in the RF Compliance Program have been successfully demonstrated at a laboratory or pilot-scale. As the development of these approaches reaches an advanced stage, the issues which need to be addressed are increasing specific to the Rocky Flats facility. Work on site specific issues and application engineering and design is expected to transition to EM-30, while programs with a broader orientation will continue to be coordinated with EM-50 Mixed Waste Integrated Program.

Supercritical Water Oxidation

Technologies are being tested at pilot-scale to examine supercritical water oxidation as a viable treatment for hazardous and mixed wastes. Major activities involved in this program include construction and demonstration on a non-radioactive pilot plant unit, followed by a radioactive pilot plant unit for treating hazardous and mixed wastes.

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Supercritical Water Oxidation Program¹

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The DOE Office of Technology Development (EM-50) established a national program with the overall objective of developing Supercritical Water Oxidation (SCWO) as a viable treatment technology for mixed waste. To achieve this objective, EM-50 designated the Idaho National Engineering Laboratory (INEL) as the point of coordination for all SCWO related activities being conducted by DOE, other Federal agencies, industry, and academia to bring a sharp focus to the overall development and implementation of SCWO for DOE hazardous and mixed waste.

Supercritical Water Oxidation

SCWO technology brings organic waste, water, and oxygen together at a temperature and pressure above the critical point of water (374°C, 22.1 MPa). Above this point, water becomes a single phase fluid with a density near that of a liquid and the transport properties of a gas. Here, water serves as an effective solvent for organic compounds. Organics are quickly oxidized to carbon dioxide and water with destruction efficiencies of over 99.99%.

SCWO technology has several technical issues that must be overcome before DOE mixed waste objectives can be achieved. These issues include problems with materials of construction, control and removal of precipitating and sticky solids, and radionuclide chemistry in supercritical water. The program is looking to the DOE complex, Department of Defense (DoD), and private industry to find solutions to these issues.

SCWO Program

The SCWO Program is divided into two main elements to evaluate the technology for mixed waste applications. These include; (1) SCWO Research and Development (SCWO R&D) and (2) SCWO Demonstration (SCWOD). SCWO R&D focuses on finding solutions for the technical issues, such as corrosion and sticky solids. In addition, this element provides for collaboration with other agencies such as the DoD, National Aeronautics and Space Administration, Environmental Protection Agency, industry, enhance acceptance and progress, and leverage resources.

¹Work supported by the U.S. Department of Energy, Office of Environmental Restoration and Waste Management, under DOE Field Office, Contract DE-AC07-76ID01570.

The second element, SCWOD, includes the design, construction, and operation of a SCWO mixed waste pilot plant capable of 300-500 gallons per day of water throughput. This plant will be used for demonstrating the SCWO technology's ability to safely and effectively treat applicable DOE mixed radioactive waste.

The technology, as it presently exists, is not considered sufficiently mature to proceed directly to the treatment of radioactive waste. The direct scale-up from bench scale to a radioactive waste pilot plant is considered to be high risk and costly. Much of the technology development required for demonstration can be performed on a considerably less expensive nonradioactive pilot plant. Therefore, the demonstration of a SCWO mixed waste pilot plant will be undertaken in two phases.

Phase I, Hazardous Waste SCWOD, will demonstrate (1) the technical efficiency and cost effectiveness of SCWO technology for destroying DOE industrial and hazardous wastes; (2) provide valuable engineering design data, including safety considerations, for scale-up of the technology; (3) answer key questions regarding issues such as throughput, materials, and corrosion related to various waste streams; (4) generate data that will be useful to DOE regarding mixed waste treatment options; and (5) evaluate the technology for DoD industrial waste streams if an interested joint participant is identified. The hazardous waste SCWO unit is scheduled to start testing in the summer of 1994.

Phase II, Mixed Waste SCWOD, will design, construct, and test a pilot scale SCWO unit for processing mixed waste. This phase will include the design and fabrication of a facility for housing the pilot plant. Some activities included in these two phases will be conducted in parallel to accelerate demonstration of a mixed waste unit. The Mixed Waste SCWO unit is scheduled to start testing in Fiscal Year 2001.

Surrogate Waste Tests

Surrogate waste tests were conducted in October 1992 using Modell Development Corporation's (MODEC) bench scale SCWO unit. These tests had the objective of evaluating SCWO and MODEC's Technology in particular, for its ability to process highly chlorinated mixed waste. Specific objectives included; 1) assessing corrosion effects of highly chlorinated waste, 2) tracking deposition of simulated radionuclides through the system, and 3) evaluating the resultant products. Tests were run using TRIM-SOL and radionuclide surrogates (cerium) and metals (zinc, lead, and iron). In addition, one set of tests was run with Inconel 625 witness tube placed in the reactor to evaluate corrosion effects.

Off-gas samples showed carbon dioxide (22%), oxygen (75%), carbon monoxide at 80 ppm and minor levels of other gasses. NO_x was not measured. Liquid and solid effluent showed significant levels of chromium, nickel, molybdenum, and iron, resulting from high temperature rates inside the reactor. The mass balances of surrogates through the system showed significant scaling. Destruction efficiencies, measured as one minus the ratio of effluent total organic content (TOC) divided by influent TOC, was 99.9635.

The tests support the concern that corrosion and scaling of sticky solids are the major technical constraints that must be overcome for implementation of SCWO for mixed waste application. Ongoing efforts are being identified to resolve these issues.

Pilot Plant Design

The program has been evaluating whether existing cooperative agreements are an appropriate mechanism for designing, fabricating, and testing the hazardous waste pilot plant. Specific requirements were identified which had to be met for an agreement to be utilized. These included; 1) DOE would retain ownership of the pilot plant, 2) the pilot plant would be designed, fabricated and tested under a DOE developed performance specification, 3) the agreement must support the project schedule, 4) all applicable regulatory requirements would have to be adhered to, 5) the pilot plant would be located at a Federal site, 6) all appropriate technical, operational, and administrative requirements, as permitted by law, must be included in the modification to the cooperative agreement, 7) all activities shall be conducted under a DOE-approved, quality assurance plan, and 8) design, analytical codes, procedures, and documents will all be controlled under the SCWO Demonstration Configuration Management Plan.

These points are to serve as the outline for utilizing a cooperative agreement. A detailed performance specification for the design, fabrication, and testing has been developed and forwarded to one potential cooperative agreement participant in January 1993. Their proposal was received in February 1993. The program is presently reviewing the proposal.

National SCWO Program Steering Committee

The program supported the establishment of the National SCWO program steering committee with the purpose of focusing the research, development, demonstration, testing and evaluation of SCWO activities being supported by the Federal government. The fledgling organization, which consists of members from DOE, DoD, EPA, NIST, and NASA, has met twice initiating communication between the agencies. In addition the organization prepared a Strategic Environmental Research and Development Program (SERDP) proposal for the joint development of SCWO. The proposal has been highly rated.

Conclusions

The surrogate waste tests support the concern that corrosion and sticky solids are a significant concern in the development of SCWO for mixed waste applications. The program is actively evaluating ongoing work, Federally-funded and in industry, to resolve these concerns. In addition, we are looking at directly supporting research activities in FY94.

All program planning documents for the design, fabrication, and testing of both the hazardous waste SCWO pilot plant and the mixed waste pilot plant have been identified and are in place or are scheduled. Work is ongoing with the DoD to identify a site for testing the hazardous waste pilot plant. The design of the hazardous waste pilot plant is anticipated to begin this summer.

Decontamination, Decommissioning and Recycle

The Decontamination, Decommissioning (D&D) and Recycle Program develops characterization, decontamination, dismantlement, material disposition, and secondary waste treatment methods, designed to reduce worker exposure, cost and generation of secondary waste. The methods for the decontamination and decommissioning of contaminated facilities are developed or improved by both industry and government laboratories, resulting in improved performance over current baseline methods. Other support is provided in the areas of robotics/automation, regulatory compliance and transportation.

Deactivation, Decommissioning and Recycle

Problem

The aging of DOE Complex facilities, along with the changing DOE Complex missions, are resulting in a need to deactivate and decommission a large number of surplus facilities.

These facilities currently contain radionuclide, hazardous, mixed and special contaminants. For the radionuclide contaminants, these facilities are similar to the commercial nuclear plants being deactivated and decommissioned (Fort St Vrain, Shoreham, Yankee Rowe). For the hazardous (lead, mercury) and special contaminants (asbestos, transite), these facilities are similar to the shipyards and bases being deactivated and decommissioned by the Department of Defense.

Limited deactivation and decommissioning activities are underway at Fernald, Hanford, Idaho, Mound, Oak Ridge, Princeton, Rocky Flats, Savannah River and Weldon Springs.

Although the exact quantities of all building and scrap material at the DOE Complex sites have not been identified, some site estimates result in about 600,000 tons of scrap steel, stainless steel, nickel, aluminum and copper being available for reuse and recycle.

Major Drivers

The major drivers for the project are:

- Little reuse and recycle of valuable building and scrap material.
- Declining worker safety.
- High deactivation costs.
- High surveillance and maintenance costs.
- High decommissioning costs.
- High burial costs.

Mission

This project has the mission to:

Develop processes to reduce the costs of facility deactivation and decommissioning by the reuse and recycle of building and scrap material, and develop processes for the bulk/volumetric decontamination of metal and concrete; the surface decontamination of concrete and equipment; the deactivation of facilities; and the dismantlement of facilities that exceed the performance of today's baseline methods in terms of worker exposure, cost, schedule and effectiveness.

Objectives

This project has two objectives:

To develop and compare processes for material reuse and recycle, and for facility deactivation, characterization, decontamination and dismantlement.

To develop a comprehensive system of characterization, decontamination, dismantlement, recycle and disposition processes that are available for the deactivation and decommissioning of facilities.

Obstacles

There are five major obstacles to the success of this project:

1. Lack of release standards for bulk/volumetric contaminated material.
2. Reluctance to use release standards for surface contaminated material.
3. Public understanding of the risks associated with the reuse and recycle of contaminated material (hazardous, radiological, mixed, special).
4. Public understanding of the risks associated with facility, deactivation, surveillance and maintenance, and decommissioning.
5. Lack of confidence in the DOE's ability to adequately assess risk, protect worker health and safety, and protect public health and safety.

Technology Assumption

For FY93, it is assumed that the following processes have no known technology barriers, worker safety, or public health limitations:

- Surface decontamination of concrete using a microwave process.
- Surface decontamination of metal using a laser process.

In addition, for FY94, it is assumed that the following processes have no known technology barriers, worker safety or public health limitations:

- Bulk/volumetric decontamination of concrete using a electroosmosis process.
- Bulk/volumetric decontamination of stainless steel using a refining process.

In addition, for FY95, it is assumed that the following processes have no known technology barriers, worker safety or public health limitations:

- Bulk/volumetric decontamination of mild steel using a refining process.
- Surface decontamination (internal) of equipment using a gas phase process.
- Bulk/volumetric decontamination of transite/asbestos using a melting process.

Issues

De minimis criteria for the unrestricted/restricted release of bulk/volumetric contaminated material have not been established. Since the release of surface decontaminated material required 100 percent access for surveys, little building and scrap material is currently being reused or recycled.

FY92 Accomplishments

Martin Marietta Energy Systems/Oak Ridge National Laboratory demonstrated the surface decontamination of concrete using a bench scale microwave process in the laboratory.

Ames Laboratory/Iowa State University demonstrated the surface decontamination of metal coupons using a bench scale laser process in the laboratory.

FY93 Accomplishments

Martin Marietta Energy Systems published the Decontamination and Decommissioning Technology Assessment based on industry/government workshops and public comments.

Strategy

The strategies to be used in accomplishing future objectives include:

- Use expertise in the private sector.
- Develop industrial capacity for the reuse and recycle of contaminated material.
- Identify market incentives (both domestic and international) for the reuse and recycle of contaminated material.
- Gain stakeholder acceptance.
- Integrate Technology Development activities with the programs in other governmental agencies and the private sector.

FY93 Objectives

Martin Marietta Energy Systems will demonstrate the surface decontamination of concrete using a microwave process mounted on a tethered vehicle in the laboratory.

Ames Laboratory/Iowa State University will demonstrate the surface decontamination of metal plates using a bench scale laser process in the laboratory.

FY94 Objectives

Westinghouse Savannah River Company will demonstrate the bulk/volumetric decontamination of stainless steel using a bench scale refining process in the field.

Martin Marietta Energy Systems will demonstrate the surface decontamination of concrete using a microwave process mounted on a self-propelled, remotely operated vehicle in the laboratory.

Martin Marietta Energy Systems will demonstrate the bulk/volumetric decontamination of concrete using a bench scale electro-osmosis process on sections of the Hanford concrete lined 183-H solar pond.

Environmentally Conscious Manufacturing Integrated Demonstration

The Environmentally Conscious Manufacturing Integrated Demonstration is a program funded by the Office of Technology Development in the area of waste minimization/pollution prevention. This program has led in technology development at Sandia National Laboratories and Allied Signal Kansas City Division of the manufacturing of electronic and electromechanical components.

Environmentally Conscious Manufacturing Integrated Demonstration¹

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The Environmentally Conscious Manufacturing (ECM) Integrated Demonstration (ECMID) is a program funded by the Office of Technology Development in the area of waste minimization/pollution prevention. This program has led in technology development at Sandia National Laboratories and Allied Signal Kansas City Division in the manufacturing of electronic and electromechanical components. The integrated demonstration has been broken into eight technology areas where significant reduction in waste and human health hazards are both regulated and make good business sense. These eight areas are: Life cycle and system methodologies, Sensor technologies, Cleaning technologies, Soldering technologies, Organic materials, Coating technologies, Qualification technologies, and Demonstration components.

The first demonstration component select was a B61 programmer manufactured at Allied Signal Kansas City Division. This component is representative of electronics manufactured in DOE and U.S. industry. Several ECM technologies were implemented in the manufacturing of this demo component. These included aqueous and d-limonene cleaning to replace chlorinated hydrocarbons and chlorofluorocarbons (CHCs and CFCs respectively), use of no-clean fluxes in soldering, use of laser soldering, monitoring using the Portable Acoustic Wave Sensor Module (PAWS), elimination of methylene dianiline and toluene diisocyanate in printed wiring boards, foam encapsulants, and polyurethane elastomers and elimination of inks, dyes and marking materials which contain volatile organic compounds.

The units fabricated using ECM technologies are currently being tested under the same rigorous requirements that the traditionally manufactured units were tested, using the same testing equipment and testing parameters. To date, each of the functional units has functioned with no indication that there is any difference in the units. In addition, the waste generated from the ECM demo units was significantly reduced from those manufactured using traditional processes.

To effectively tie each of these technology areas together, lifecycle methodologies for ECM are being developed and applied to the demonstration components. By effectively modeling the lifecycle of the component, and evaluating the environmental impact from each of the new technologies introduced, the overall waste minimization of the product can be maximized, and technologies can be selected which do not adversely affect other processes in the manufacturing.

Several new areas are under development to address new or anticipated regulations. These include recycling and reuse of cleaning materials, the use of supercritical CO² for cleaning electronics, lead-free solder, and laser and laser-ablative soldering. Each of these development areas will be demonstrated on a second component in FY93.

¹This work was performed at Sandia National Laboratories and supports the DOE under contract #DE-AC04-76DP00789.

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