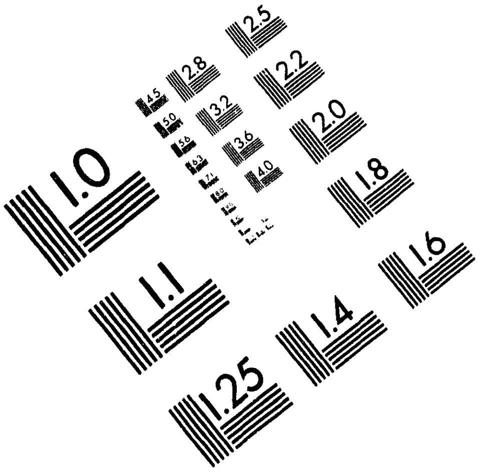

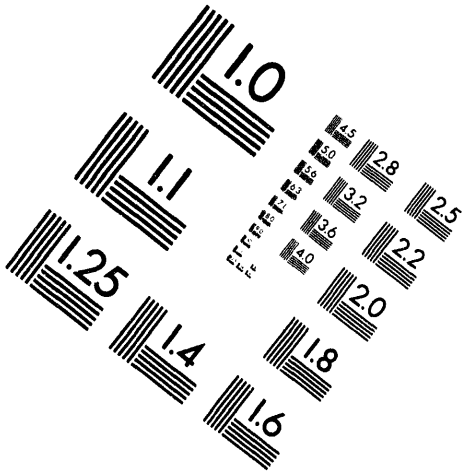

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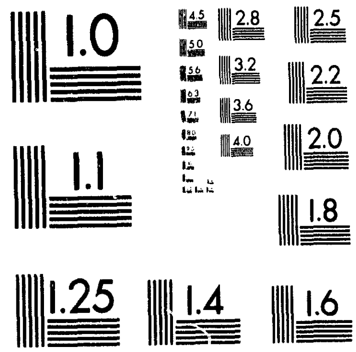

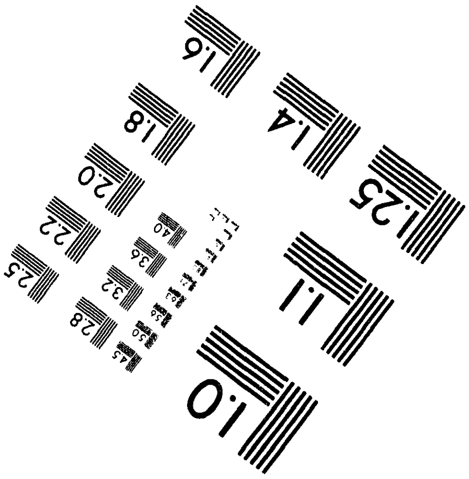

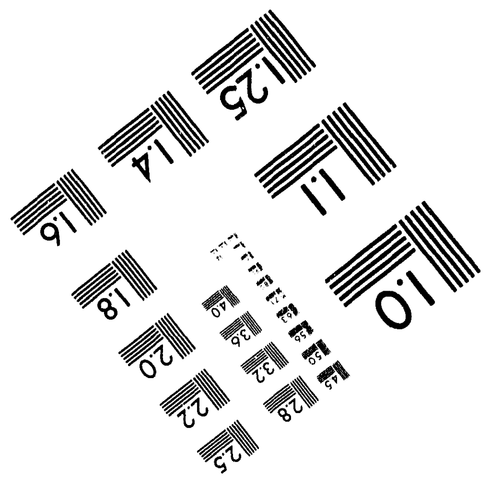

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Office of Environmental Management

Office of Technology Development

Idaho Operations Office

Technology Summary

June 1994

IDAHO OPERATIONS OFFICE TECHNOLOGY SUMMARY

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Foreword

This document has been prepared by the Department of Energy's (DOE) Environmental Management (EM) Office of Technology Development (OTD) in order to highlight research, development, demonstration, testing, and evaluation (RDDT&E) activities funded through the Idaho Operations Office. Technologies and processes described have the potential to enhance DOE's cleanup and waste management efforts, as well as improve U.S. industry's competitiveness in global environmental markets. The information has been assembled from recently produced OTD documents that highlight technology development activities within each of the OTD program elements. These Technology Summaries (as well as other OTD documents) can be obtained through the EM Central Point-of-Contact at 1-800-845-2096 and include:

VOCs in Non-Arid Soils Integrated Demonstration, February 1994 - DOE/EM-0135P
Uranium in Soils Integrated Demonstration - DOE/EM-0148P
Characterization, Monitoring, and Sensor Technology Integrated Program - DOE/EM-0156T
Buried Waste Integrated Demonstration - DOE/EM-0149P
Underground Storage Tanks Integrated Demonstration, February 1994 - DOE/EM-0122P
Efficient Separations and Processing Integrated Program, February 1994 - DOE/EM-0126P
Mixed Waste Integrated Program, February 1994 - DOE/EM-0125P
Supercritical Water Oxidation Program, February 1994 - DOE/EM-0121P
Pollution Prevention Program, February 1994 - DOE/EM-0137P
Innovation Investment Area - DOE/EM-0146P

This document represents one of the documents in a series to be produced for each of DOE's Operations Offices and Energy Technology Centers.

For more information on activities funded through the Idaho Operations Office or being conducted at the Idaho National Engineering Laboratory, please contact:

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INTRODUCTION

DOE's Office of Technology Development

DOE's Environmental Restoration and Waste Management Office of Technology Development manages an aggressive national program for applied research, development, demonstration, testing, and evaluation. This program develops high-payoff technologies to clean up the inventory of DOE nuclear component manufacturing sites and to manage DOE-generated waste faster, safer, and cheaper than current environmental cleanup technologies.

OTD programs are designed to make new, innovative, and more cost-effective technologies available for transfer to DOE environmental restoration and waste management end-users. Projects are demonstrated, tested, and evaluated to produce solutions to current problems. Transition of technologies into more advanced stages of development is based upon technological, regulatory, economic, and institutional criteria. New technologies are made available for use in eliminating radioactive, hazardous, and other wastes in compliance with regulatory mandates. The primary goal is to protect human health and prevent further contamination.

OTD's technology development programs address three major problem areas: (1) groundwater and soils cleanup; (2) waste retrieval and processing; and (3) pollution prevention. These problems are not unique to DOE, but are associated with other Federal agency and industry sites as well. Thus, technical solutions developed within OTD programs will benefit DOE, and should have direct applications in outside markets.

OTD's approach to technology development is an integrated process that seeks to identify technologies and development partners, and facilitates the movement of a technology from applied research to implementation. In an effort to focus resources and address opportunities within the major problem areas, OTD has developed **Integrated Programs (IPs)** and **Integrated Demonstrations (IDs)**. An *Integrated Program* focuses on developing technologies to solve a specific aspect of a waste management or environmental problem either unique to a site or common to many sites. Integrated Programs support applied research activities in key application areas required in each stage of the remediation process (e.g., characterization, treatment, and disposal). An *Integrated Demonstration* is a cost-effective mechanism that assembles a group of related and synergistic technologies to evaluate their performance individually or as a complete system, for solving waste management and environmental problems from cradle to grave. In addition to the IDs and IPs, OTD supports crosscutting research and development through the Innovation Investment Area (IIA) Program and the Robotics Technology Development Program (RTDP).

The role of the IIA 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 principle experimentation, and (2) already proven technologies in other fields that require critical path experimentation to demonstrate feasibility for adaptation to specific EM needs. The underlying strategy is to ensure that private industry, other Federal agencies, universities, and DOE

National Laboratories are major participants in developing and deploying new and emerging technologies. The RTDP is a "needs-driven" program focusing on applied robotics. RTDP activities are funded through most of the DOE Operations Offices and focus on solving site-specific as well as complex-wide environmental problems.

OTD's technology maturation philosophy consists of three components: (1) *technology infusion* - technology transfer from industry, universities, and other Federal agencies; (2) *technology adoption* - shared technology demonstration among DOE laboratories, integrated demonstrations, and programs, and (3) *technology diffusion* - technology transfer from demonstration to industry. To enhance opportunities for technology commercialization, OTD is seeking partnerships with private-sector companies during the technology development and demonstration phases. Industry partners will facilitate implementing these emerging technologies to solve the nation's environmental problems.

Idaho's Contributions

The Idaho National Engineering Laboratory (INEL), operated by DOE's Idaho Operations Office, is a world-renowned research facility and a major force in Idaho's economy. INEL is recognized as a leading center for nuclear safety research, nuclear waste technology, defense programs, and advanced energy concepts. The INEL work force, composed of more than 12,000 people, comprises the largest concentration of technical professionals in the northern Rocky Mountain region.

During its 40-plus year history, INEL has had many accomplishments. In 1951, the then National Reactor Testing Station produced electricity from nuclear energy for the first time. INEL is home to the largest number and most varied types of nuclear reactors in the world. Today the site continues to make scientific and engineering breakthroughs in the areas of waste management and technology development, energy technology and conservation, and nuclear reactor development and safety research. Its unique capabilities in non-nuclear programs provide commercialization potential and enhance the quality of the environment.

Buried Waste

Every industry produces waste, and the nuclear industry is no exception. Waste in the nuclear industry ranges from protective clothing and paper, to sludge and various other processed wastes contaminated with radioactive materials. A number of facilities at INEL process or store radioactive waste. One of these, the Radioactive Waste Management Complex (RWMC), has been collecting solid radioactive waste generated from national defense and research programs. From 1942 - 1970, most of the transuranic (TRU) waste arriving at RWMC was buried, since that was the accepted practice in the nuclear industry at that time. Since 1970, TRU-contaminated waste has been stored above ground in steel drums, fiberglass-covered wooden boxes, and steel bins.

Approximately 40% of all DOE TRU waste is located at INEL, making the site ideal for buried waste demonstrations. OTD sponsors the Buried Waste Integrated Demonstration (BWID) to identify, evaluate, and demonstrate technologies to support cleanup activities of hazardous and radioactive waste buried at INEL and other DOE sites. Treatment of the waste includes processing solid mixed, hazardous, and radioactive waste associated with combustibles, metals, soils, and sludges. Treatment may be conducted using thermal, chemical, biological, physical, or radiological methods. All waste streams generated during the treatment, such as off-gas and ash, must be appropriately handled.

Supercritical Water Oxidation

Supercritical Water Oxidation (SCWO) technology holds promise for treating a portion of DOE's mixed waste. The process involves bringing together organic waste, water, and an oxidant (such as air, oxygen, etc.) to temperatures and pressures above the critical point of water. The resulting products, primarily water and carbon dioxide, are relatively harmless. SCWO can easily be designed as a full containment process with no release of toxic emissions to the atmosphere.

The SCWO Program, managed by INEL, will construct and demonstrate hazardous and mixed waste pilot-scale (30-50 gallons per hour throughput) SCWO units. If successful, program activities may be expanded to other DOE sites, as well as private research and development organizations and other Federal agencies including the Department of Defense (DoD), U.S. Navy, U.S. Air Force (USAF), U.S. Army, the U.S. Environmental Protection Agency (EPA), and the Advanced Research Projects Agency.

DOE/Air Force Memorandum of Understanding

In 1988, a Memorandum of Understanding (MOU) was signed between DOE/EM and the U.S. Air Force Engineering Services Center. The two organizations decided to work together to address common environmental restoration and waste management problems through joint development of mutually beneficial environmental technologies, information exchange, and interlaboratory/industrial partnerships. The program promotes the development of pollution prevention technologies, such as material substitution and advanced manufacturing techniques, to reduce or eliminate the generation of hazardous waste. The MOU covers all phases involved in industrial processes, helping to select and implement the best technologies and show immediate and long-term effectiveness for DOE and USAF sites.

Public Participation

INEL is a pilot site for a Citizen's Advisory Board. In 1993, during a series of briefings and open houses, DOE-Idaho asked stakeholders, including the State of Idaho and the regional EPA office to volunteer to serve on its Design Committee. The Advisory Board is being developed to gather a broad range of stakeholders interested in DOE-Idaho decisions and in working directly with INEL staff. The Idaho Operations Office and INEL emphasize an open environment to create greater opportunities for early public involvement in deciding how programs will be managed.

1.0 GROUNDWATER AND SOILS CLEANUP OVERVIEW

Some of the most pressing environmental restoration needs for the DOE involve clean up or containment of radioactive and hazardous contaminants in soils and groundwater. The DOE soils and groundwater programs were designed to identify, develop, and demonstrate innovative technology systems capable of removing or reducing potential health and environmental risks. These risks are the result of previous storage and disposal practices that left behind a legacy of radioactive and hazardous materials (including heavy metals and toxic organic compounds) in the surrounding soil and groundwater. Sources of this contamination at the DOE sites include: previous disposal of contaminated wastes in ponds, seepage pits, trenches, and shallow land burial sites; spills and leakage from waste transport, temporary storage facilities, and underground storage tanks; and unregulated discharges to the air and surface waters.

DOE is responsible for waste management and clean up of more than 100 contaminated installations in 36 states and territories. This includes 3,700 sites within the DOE Complex; over 26,000 acres with hazardous and radioactive contaminated surface water, groundwater, and soil that are in need of some measure of remediation. Additionally, there are approximately 5,000 peripheral properties (e.g., residences and businesses) that have soil contaminated with uranium tailings. One of the biggest challenges facing DOE is effective characterization of contamination in soil and groundwater. Characterization must take place before a contaminant site can be properly prioritized. To accomplish this, methods are being developed that are capable of mapping vast areas at depths up to 250 ft below ground level. Results are three-dimensional images that are valuable tools for proper selection and placement of remediation technologies. Complicating remediation efforts further is the fact that techniques for accessing and removing contaminants differ in arid and non-arid environments. As a result, technologies must be demonstrated and evaluated at multiple sites.

Volatile Organic Compound (VOC) contamination of soils and groundwater is one of the most common environmental problems in the United States and DOE Complex. When VOCs are released into the soil, they rapidly migrate throughout the environment, forming large contaminant plumes that eventually result in contaminated groundwater. Two of the more prominent examples of this phenomena can be found at the Savannah River site (a non-arid environment) where there is a plume larger then three square miles; and at the Hanford site (an arid site), where a 7 square mile plume resulted from the disposal of an estimated 363-580 cubic meters of carbon tetrachloride. Over 220 sites with similar contamination have been identified in arid environments within the DOE Complex. Add radioactive contamination to the before mentioned hazardous constituents and the result is a DOE problem for which few adequate solutions currently exists.

Also prevalent throughout the DOE Complex is the contamination of surface soils with heavy metals resulting from weapons assembly and testing processes during weapons construction. At the Nevada Test Site, over 5 square miles of soil is contaminated with plutonium. Clean up of this area will require the treatment of approximately 25 million cubic feet of soil. Five other

DOE sites also have contamination similar to that at the Nevada Test Site. Eight other DOE sites have identified similar contamination problems with uranium. At Fernald, uranium has been transported by rain and snow to varying depths below the surface, making remediation difficult. Estimates indicate there are 1.5 million cubic meters of uranium contaminated soil at Fernald. Heavy metal contamination is also a problem in surface and groundwater. The Berkeley Pit at Butte, Montana, contains 17 billion gallons of contaminated water, with an inflow of 5-7 million gallons per day.

The contaminants discussed above exhibit high concentration levels, high mobility, and high toxicity, as well as long-term persistence in the environment, and for these reasons represent some of the high priority problems for which innovative technologies are sought. However, technologies are also under development for treatment of non-volatile organics, dense non-aqueous phase liquids, radionuclides, nitrates and explosive materials. In most cases, non-intrusive or in situ methods (methods that characterize or treat the contaminants in place) for environmental restoration are preferable from technical and regulatory standpoints. From a regulatory standpoint, these technologies are preferable because they minimize (1) harm to the environment, (2) public exposure, and (3) volume of waste. Technically, these methods avoid the risks and costs associated with handling contaminated soils and groundwater. Nevertheless, cases exist for which non-intrusive and in situ methods may not be applicable. Given this circumstance, other innovative technologies must be explored, including extraction, containment, recovery, and processing alternatives that reduce or eliminate environmental and health risks.

Development of innovative technologies for clean up of groundwater and soils is not a need unique to DOE. Other Federal agencies, as well as private industry, are in need of improved methods for these types of clean up. The EPA has identified 1,235 sites with sufficient contamination to place them on their National Priorities List (NPL). In the past two years, the number of sites entering remedial action has grown steadily.[1] Out of 712 NPL sites with Records of Decision (ROD), an estimated 80% require remediation of groundwater, 74% need soil remediation, and 15% require action to clean up sediments. It is estimated that NPL sites without RODs contain similar types of contamination. In an effort to promote the development of new technologies to expedite clean up of the NPL sites, the EPA established the Superfund Innovative Technology Evaluation (SITE) program. The DoD is responsible for clean up of their facilities contaminated as a result of training, industrial, or research activities. As of September 1991, the DoD had identified 7,000 sites that will require remediation. The largest of these DoD remediation sites will result in the treatment of nearly 2.2 million cubic yards of soil. DOE currently works with the EPA SITE, and DoD programs in a joint effort to expedite remediation of groundwater and soils contamination.

[1] U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response Technology Innovation Office

1.1 VOLATILE ORGANIC COMPOUND RECYCLE/RECOVERY

TASK DESCRIPTION

This process consists of activated carbon adsorbers located at each extraction well, plus a truck-mounted Brayton cycle heat pump (BCHP) to regenerate the adsorbers on a periodic basis (see Figure 1.1). The VOC-laden air from the well is passed through the carbon bed, adsorbing the VOCs. When the carbon bed becomes saturated, hot nitrogen from the regenerator is used to desorb the VOCs. The nitrogen is then passed through a chiller, compressed, and then cooled in a recuperator, where 50 to 80 percent of the organics are removed. The partially depleted nitrogen stream is then expanded through a turbine, lowering the temperature down to minus 101°C, to condense the remaining VOCs. The now clean nitrogen passes through the recuperator to cool the incoming VOC-laden nitrogen.

TECHNOLOGY NEEDS

Many DOE sites, as well as private industrial sites, have soil and/or groundwater that are contaminated with organic compounds. These sites will have to undergo remediation in the future. One method of remediation is vapor vacuum extraction, but air quality regulations require that the exhaust be free of organic vapors before they are vented into the atmosphere.

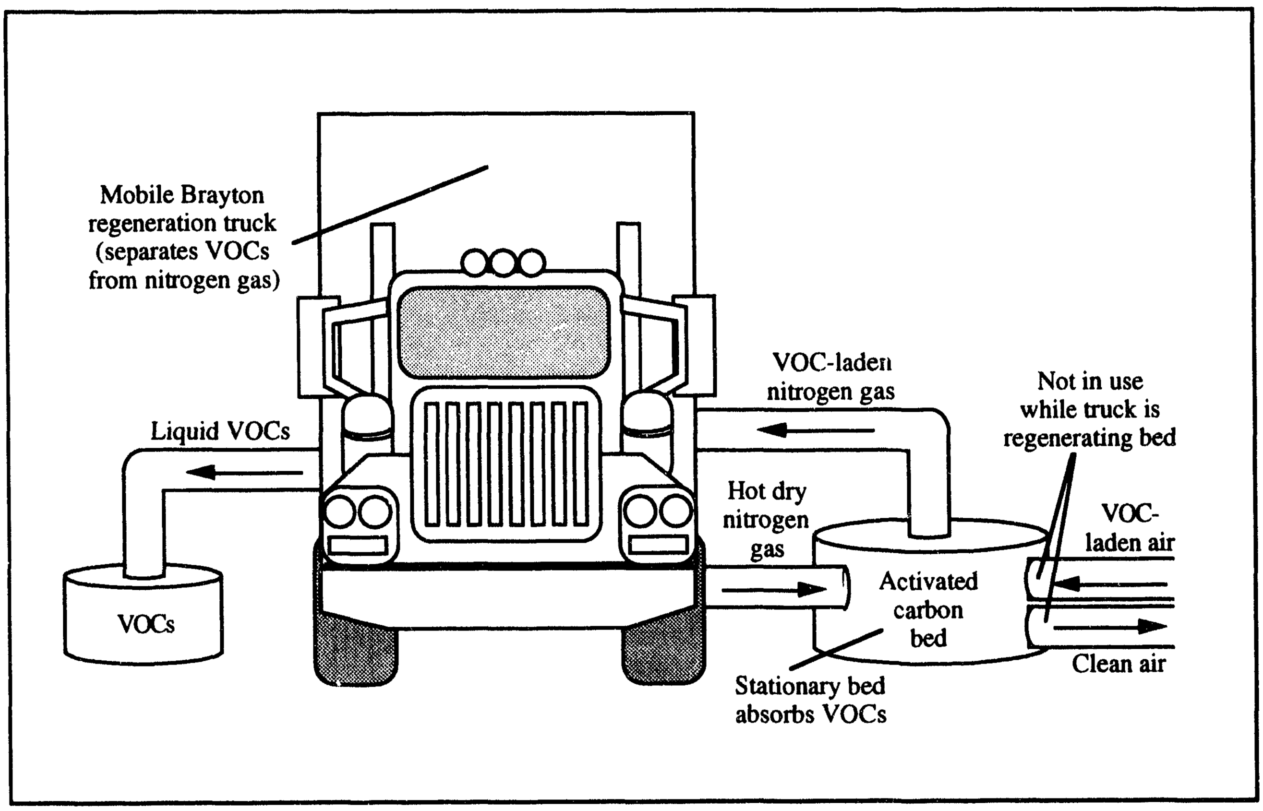

Figure 1.1. Volatile Organic Compound Recovery and Recycle.

Therefore, a method of organic vapor recovery or destruction will be required before vapor vacuum extraction can be used. The BCHP technology provides a lower cost alternative to carbon canisters, which must be shipped to a regenerating facility or disposed of as hazardous waste.

ACCOMPLISHMENTS

This technology was field tested at the Savannah River Site and successfully recovered solvents from the off-gas generated by the vacuum extraction process. Before this process can be used in a long-term application, a use or user for the recovered solvents must be identified. For the test application the solvents will be disposed of after testing.

COLLABORATION/TECHNOLOGY TRANSFER

The BCHP technology is being developed in collaboration with NUCON International, Inc. Numerous other companies have indicated interest in the BCHP technology.

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1.2 BIOPROCESSING TECHNOLOGIES FOR URANIUM-CONTAMINATED SOILS

TASK DESCRIPTION

This task is evaluating biotechnological processes for their potential to decontaminate uranium-contaminated soils. Use of microorganisms (bacteria and fungi) to catalyze the uranium extraction process is being investigated. This method is similar in many respects to those already used by the commercial scale heap and in situ leach processes for uranium and copper extractions. The microorganisms involved in the leaching processes are indigenous and appear in nature wherever favorable living conditions exist: Thiobacillus ferrooxidans are naturally occurring acidophilic iron-oxidizing bacteria that function as an electron pump, oxidize iron, and in turn, oxidize uranium. In nature, Thiobacillus ferrooxidans acidifies its environment to very low pH (sometimes as low as pH 1.5). This ability may be used as part of the cleanup process, or it may be accelerated by addition of sulfuric acid. In this experimental system, the pH is achieved and maintained through titration of the soil with sulfuric acid.

Fungal metabolism is also being considered for uranium extraction; fungi-produced compounds that complex or chelate uranium, and fungal mycelia that accumulate uranium directly. Penicillium simplicissimum and Aspergillis niger are non-pathogenic, naturally occurring fungi that are capable of utilizing low-value carbon sources. Current experiments are utilizing two approaches for uranium extraction. In one set of experiments, the fungi and soil are incubated together, and in the other set, depleted media is extracted from the fungi and applied to the soil. The media and cell mass are then analyzed for uranium content. Preliminary results have been encouraging. It is likely that manipulation of culture conditions will significantly improve extraction. Specific evaluation parameters that are being assessed include:

- the metabolic alteration of contaminant chemistry;
- the microbial generation of acids;
- the use of chelators or specific lixivants in conjunction with microbes for their potential contribution to solubilization and extraction;
- the retrievability of the lechate;
- the residual contaminant concentrations in the soil; and
- the potential for treating the resulting contaminated leachate.

Based on assessment of feasibility studies conducted in FY93, promising methods will be selected for optimization and an emphasis will be placed on methods to treat contaminated leachate.

TECHNOLOGY NEEDS

The uranium content of some contaminated soils at Fernald is very low compared to uranium contents of ores used for yellowcake production. This situation has created a need for evaluation of new technological possibilities for the treatment of large volumes of contaminated soils containing low or trace concentrations of uranium. These new methods must be environmentally acceptable, cost-efficient and applicable to a wide range of situations. One of these possibilities is the biotechnological approach.

ACCOMPLISHMENTS

Evaluation of thiobacillus ferrooxidans for extraction of uranium from Fernald soil indicates that 90+% of the uranium can be extracted; however, the relative contribution of the bacteria to the extraction process in this soil is uncertain.

Results indicate bacteria would likely be effective in improving uranium extraction in soils with a high percentage of tetravalent uranium or low iron content (the opposite of that found at Fernald).

Evaluation of Penicillium simplicissimum and Aspergillis niger for extraction of uranium from Fernald soil has begun and preliminary results are encouraging.

Up to 60% of the uranium has been extracted from the soil at pH 3.8 - 7.0. The extraction does not appear to be pH-dependent and titration of the soil is not required. Maintaining a higher pH in this soil is expected to significantly improve the quality of the leached soil. Extraction has been accomplished by direct contact of the fungi with the soil and application of spent broth from the fungi to the soil. No significant differences in the extraction were seen between the two approaches or the two fungi.

COLLABORATION/TECHNOLOGY TRANSFER

There is a high potential for future development of Cooperative Research and Development Agreements (CRADAs) with the mining and metals industry. This technology will have wide application to the environmental remediation activities for the DOE/DoD Complex.

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1.3 SECONDARY ION MASS SPECTROMETRY ANALYSIS: DEVELOPMENT AND EVALUATION

TASK DESCRIPTION

Fast, inexpensive, and non-polluting instrumentation for the detection of surface contaminants is being developed at INEL using advanced secondary ion mass spectrometry (SIMS) technology. The attributes of this technology make it extremely attractive for waste and environmental characterization:

- no sample preparation is required;
- no waste is generated;
- analysis is rapid and simple;
- it is amenable to almost any sample type;
- it is amenable to non-volatile organics, salts; and
- it is capable of fingerprinting and speciation.

SIMS has a simple principle of operation: surfaces are bombarded with high-energy particles, that sputter the contaminants into the gas-phase, where they can be detected as ions.

The objective of the SIMS Analysis program is to develop instrumentation and chemical applications for the detection of non-volatile or adsorbed contaminants on the surfaces of salts, rocks, minerals, soils, and other difficult to analyze samples. Three subtasks are being pursued to achieve this objective: demonstration of chemical analyses relevant to DOE problems using SIMS; development of SIMS instrumentation which takes advantage of the most recent advances at the INEL and in the mass spectrometer manufacturing industry; and transferring the advanced SIMS technology.

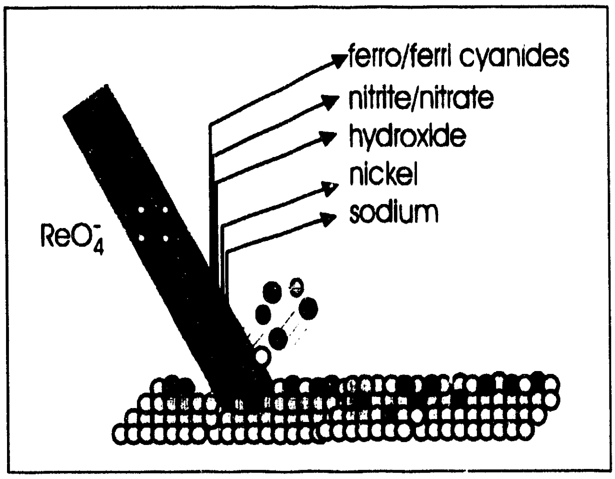

Figure 1.3a. Secondary ion mass spectrometry particle bombardment and sputtering of salt species from tank waste.

TECHNOLOGY NEEDS

DOE has many contamination problems that require the determination of contaminants that adhere tightly to waste, environmental, and industrial surfaces. There is a critical need in DOE and industry for characterization technologies that are fast, inexpensive, and can address surface contamination. An example of this need is characterization of core and particulate samples from high-level waste in underground storage tanks, which currently cost an average of $750,000/core analysis (see Figure 1.3b). Technologies capable of salt fingerprinting, and determining chemical speciation are needed to reduce the number of analyses needed, and to improve the estimation of tank energy content (critical for risk assessment associated with tank characterization and remediation activities).

Needs for technology for non-volatile organics and salts persist in the In Situ Remediation Integrated Program and Decontamination and Decommissioning Integrated Demonstration. There are no easy ways to analyze for non-volatile contaminants on the surfaces of minerals, soils or the surfaces of processing facilities. In both of these need areas, desirable attributes for candidate technology include ease of use, speed, sensitivity, and no waste generation. In all applications, technology that is transportable is needed. The advanced SIMS technology that has been developed at INEL has attributes that are a very close match with the technology development needs of high-level tank waste.

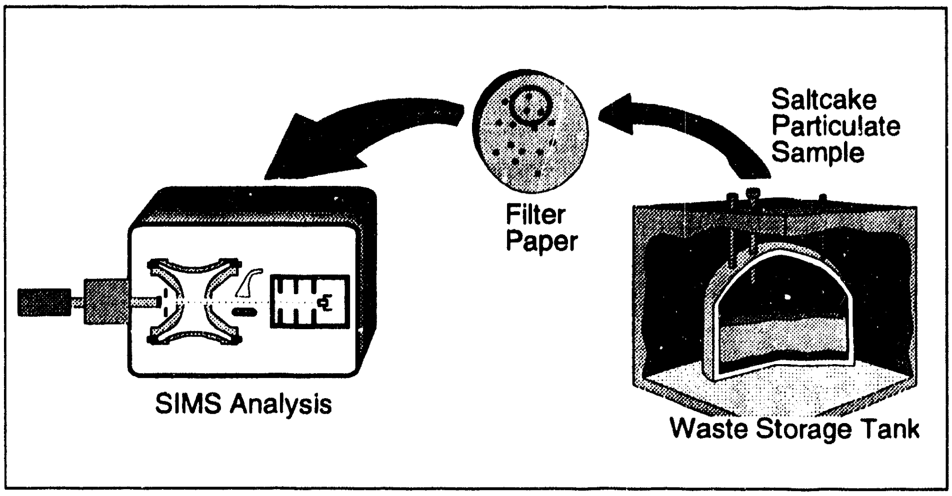

Figure 1.3b. Schematic diagram of transportable SIMS instrument applied to the analysis of salt particulate from underground storage tanks.

ACCOMPLISHMENTS

The rapid analysis of simulated salt cake samples was demonstrated using the laboratory-based SIMS instrument located at INEL. The analyses required no sample preparation, and hence required less than 10 minutes; in addition, no waste was generated. A unique attribute of the pulsed-extraction SIMS instrument is the ability to analyze cations and anions at the same time. This attribute is especially valuable for salt cake analyses because the salt samples contain both anion and cation species: nitrite, nitrate, cyanide, and hydroxide anions, and iron, sodium, potassium and nickel complexes were detected.

SIMS detection of tributyl phosphate (TBP), ethylenediamine tetraacetate (EDTA) and small organic acids has been demonstrated on significant DOE minerals, including basalt (see Figure 1.3c.). These compounds were used in nuclear material processing, and were disposed of with radioactive wastes. The TBP analysis produces information indicative of the mode of TBP-surface binding, in addition to identifying the presence of TBP. As little as 10 ng can be observed on a basalt chip.

Instrument transportability and improved sensitivity and selectivity are desired attributes of the instrumentation that will be constructed in this program. An ion trap mass spectrometer (ITMS) satisfies these requirements, and hence this type of instrument was selected for interfacing with the OTD SIMS technology: ITMS procurement will occur in 1994, and modification in 1995. In addition to the technical offerings of the ITMS, new ITMS instruments will be on the market in early 1994, which opens opportunities for technology transfer.

COLLABORATION/TECHNOLOGY TRANSFER

New ion trap products are being introduced in early 1994, and hence an ion trap/SIMS instrument offers an excellent technology transfer opportunity. Contacts have been made with all ion trap vendors: Teledyne offers the best possibility for technology transfer, and negotiations with Teledyne have been initiated. The Teledyne ITMS product will be introduced at the Pittsburgh Conference in early March. Non-disclosure agreements and the procurement of a Teledyne ITMS are in progress.

[redacted]

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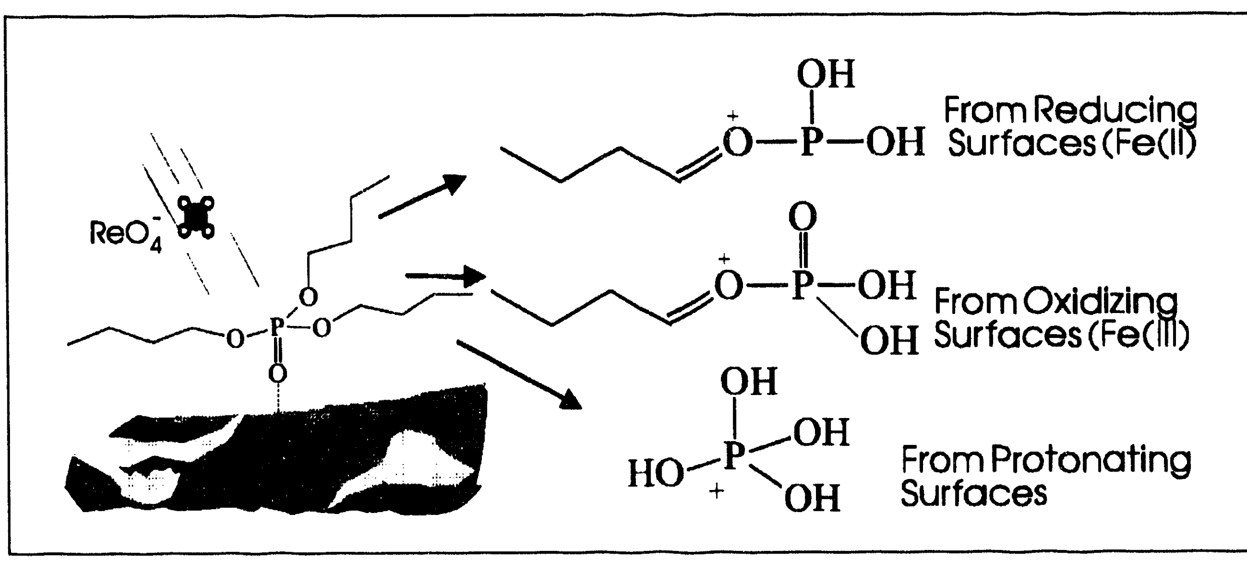

Figure 1.3c. Direct SIMS analysis of basalt chips contaminated with tributyl phosphate.

Waste Retrieval and Processing

2.0 WASTE RETRIEVAL AND PROCESSING OVERVIEW

Waste retrieval and processing constitutes one of the largest DOE problems. To address this need, the DOE Office of Environmental Restoration and Waste Management designed a set of programs focused on identifying, developing and demonstrating innovative technologies for the purpose of treating this waste while reducing the risk to human health and the environment. Within the DOE Complex, large quantities of high-level waste, low-level waste, and transuranic waste have been buried or stored and need retrieval and treatment. Before 1970, most low-level and transuranic wastes were buried in common shallow land burial grounds. A majority of the high-level waste was stored in underground storage tanks.

Effective May 8, 1992, all DOE mixed-waste streams fell under EPA's land disposal restrictions and, as such, can no longer be disposed of without prior treatment to destroy, separate, or immobilize the hazardous component. All mixed low-level and high-level waste must be treated before final disposal. In the case of mixed transuranic wastes destined for deep geologic disposal, the hazardous components must not exceed established waste acceptance criteria. Most of the hazardous components of the mixed wastes have not been characterized; however, from past knowledge, they represent the entire gamut of organic and inorganic hazardous wastes. Available technology is inadequate to solve many of the problems at hand. The result is a mixed waste dilemma that poses serious legal and technical problems that need to be resolved.

DOE has identified more than 1 million 55-gallon drums and boxes of waste in storage, and 3 million cubic meters of buried waste. Over the years, many of the older disposal containers have been breached, resulting in contamination of the adjacent soil. Considering transuranic solid waste, approximately 190,000 cubic meters have been buried, and 60,600 cubic meters have been retrieved and stored. Mixed transuranic waste composes 58,000 cubic meters of this inventory. High-level waste stored at four DOE sites represent another 381,000 cubic meters of volume. Of this, 77 million gallons of high-level waste are contained in 332 underground storage tanks as sludge/liquids and approximately 4,000 cubic meters are stored as granular calcined solids. Most of the high-level waste is mixed with hazardous contaminants and is thus, considered mixed waste. The remainder of the waste in storage, about 3,000,000 cubic meters, is low-level waste and includes 247,000 cubic meters of mixed low-level waste. No effective treatment is known to exist for 107,000 cubic meters of this mixed low-level waste.

Another form of waste, representing potentially large volumes, is associated with decontamination and decommissioning of contaminated buildings and equipment. More than 500 separate facilities have been identified, and it is possible that as many as 7,000 facilities at 39 different sites could be scheduled for decontamination and decommissioning. Although materials will be recycled when possible, this activity will result in new waste generation that is immeasurable at this time. Additionally, as much as 20,000 cubic meters of mixed waste, in 100 separate waste streams, is still being generated on an annual basis from ongoing facility deactivation and transition activities.

Developing cost-effective innovative hazardous and mixed waste characterization and treatment technologies is not only a requirement for DOE, but for other Federal agencies and commercial businesses. EPA estimates project a total national present value program cost of about $18.7 billion, and an annual cost of about $1.8 billion using available technologies. Furthermore, the EPA assumes there exists approximately 773,000 sites with underground storage tanks that are subject to regulation and remediation.[2] Most of these tanks contain petroleum products and require remediation of the tank as well as the surrounding soil as a result of leakage problems. Although occurrences of radioactive contaminated waste is less frequent in the public sector, there are no widely accepted technologies available to treat this waste. Development of efficient, low-risk mixed waste treatment systems and facilities is one of the most pressing issues facing public and private environmental restoration and waste management efforts. DOE is working with other Federal agencies and private sector firms to bring innovative hazardous and mixed-waste treatment technologies on line as swiftly as possible.

[2]U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response Technology Innovation Office, Cleaning Up the Nation's Waste Sites: Markets and Technology Trends.

2.1 RAPID GEOPHYSICAL SURVEYOR

TASK DESCRIPTION

The objective of this project is to design, construct, and demonstrate a device to quickly and inexpensively characterize buried waste sites by collecting high quality, dense sets of magnetic data. The Rapid Geophysical Surveyor (RGS) is a hand-pushed, nonferrous vehicle that carries multiple cesium total-field magnetometers, a data logger, and data storage hardware and software (see Figure 2.1). The unit can be easily adapted to accommodate different magnetic sensors. Magnetic data are collected automatically and stored at user-specified intervals as close as 2 inches apart as the unit is pushed along survey profile lines. The resulting database is very high resolution and can identify individual metallic objects, and object orientation, shape, and depth of burial.

The RGS can perform geophysical magnetic surveys quicker (30 - 300 times faster) and more economically (20 times cheaper per data point) than hand-held instruments. The RGS can be easily and quickly deployed at any DOE or commercial facility where a high resolution magnetic survey is required.

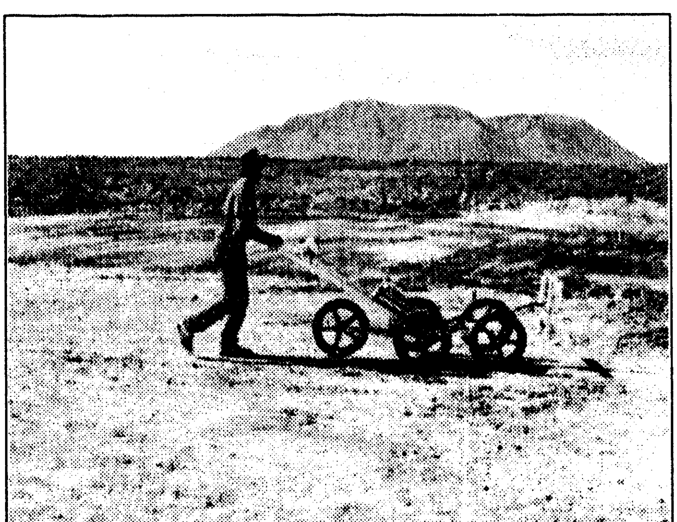

Figure 2.1. Rapid Geophysical Surveyor at the INEL Cold Test Pit.

TECHNOLOGY NEEDS

There is a need to collect more dense magnetic data for better interpretation and characterization of the subsurface at high speed. The collection of dense magnetic data can provide a much clearer image of the subsurface and allow for a more well-defined site characterization. Given the size of the areas to be characterized, current methods would not provide the data density nor the speed necessary to collect enough data in a reasonable time.

ACCOMPLISHMENTS

The RGS was successfully demonstrated at the Cold Test Pit, then used to scan buried waste Pits 7 and 9 at INEL, and to assist with remediation problems at Los Alamos National Laboratory and Camp Pendelton Marine Base.

Straightforward interpretation principles were applied to the magnetic data, which provided reliable detection of all the isolated ferrous objects in the Cold Test Pit Characterization Cell, a general depiction of the Retrieval Cell and an accurate definition of the overall waste pit. The RGS can collect spatially denser data sets than previously possible, thereby providing a much higher resolution picture of the buried waste site. The surveyor was developed for less than $200,000.

COLLABORATION/TECHNOLOGY TRANSFER

The success of this technology has resulted in the spin-off of a small company that will be entering the market place to sell the unit.

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2.2 RAPID TRANSURANIC MONITORING LABORATORY

TASK DESCRIPTION

The focus of this project is to develop a field deployable laboratory that can continuously monitor airborne transuranic (TRU) concentration and rapidly analyze soil, smear, and air filter samples for TRU isotopes and fission and activation products in a cost-effective manner. The Rapid Transuranic Monitoring Laboratory (RTML) is contained in two trailers (8 x 24 feet and 8 x 48 feet). The smaller trailer houses a sample preparation laboratory (see Figures 2.2a and 2.2b) and the larger trailer contains:

- one terminal that controls and displays spectral data from four alpha continuous air monitors;
- two Ordela large-area ionization chamber alpha spectrometers;
- a thin-window gamma-ray spectrometer and automatic sample changer;
- a VAX 4000 Model 100 computer; and
- computer terminals and two printers used to display and generate reports of analysis results.

The unit can process over 100 samples per day of soils, filters, and smears in a field setting. The lower levels of detection vary depending upon analysis system; the large area alpha, ionization spectrometer can process 33 soil samples per day at 20 pCi/g (alpha). The U-L-Shell X-Ray system can process 79 samples per day at 50 pCi/g (alpha) and 1-5 pCi/g (gamma). Simultaneously, the alpha continuous air monitors can analyze air quality continuously at 1-DAC-hr.

The RTML is appropriate for use at any TRU-contaminated waste site being excavated. The RTML provides rapid on-site sample analysis at a lower cost per analysis than conventional methods. The main advantage is that samples can be processed in less than one hour for about $30 per sample using a technician-driven system. This compares to fixed-laboratory results with radiochemists analyzing several samples per day at $200-$300 per sample.

TECHNOLOGY NEEDS

The need for rapid monitoring is expressed in the mandatory operational and safety limits that may not be exceeded, and in the extremely small amounts of plutonium/americium allowed for personal uptake. Techniques are needed to measure both airborne and loose surface contamination in the picocurie per gram-level in a matter of hours, rather than days.

With low levels of detectability, rapid turnaround, and a reduction in the potential for large numbers of samples, the system would reduce costs and improve the ability to meet schedules.

ACCOMPLISHMENTS

The RTML was demonstrated successfully and is presently ready for transfer to the Environmental Restoration Program. The INEL Environmental Restoration Program plans on using the unit for soil sample screening during FY94, and the Fernald Site is exploring the use of the unit to assess soil samples containing uranium and its decay products. The laboratory can be used to analyze any gamma or alpha emitting radionuclides with near radiochemistry LLD.

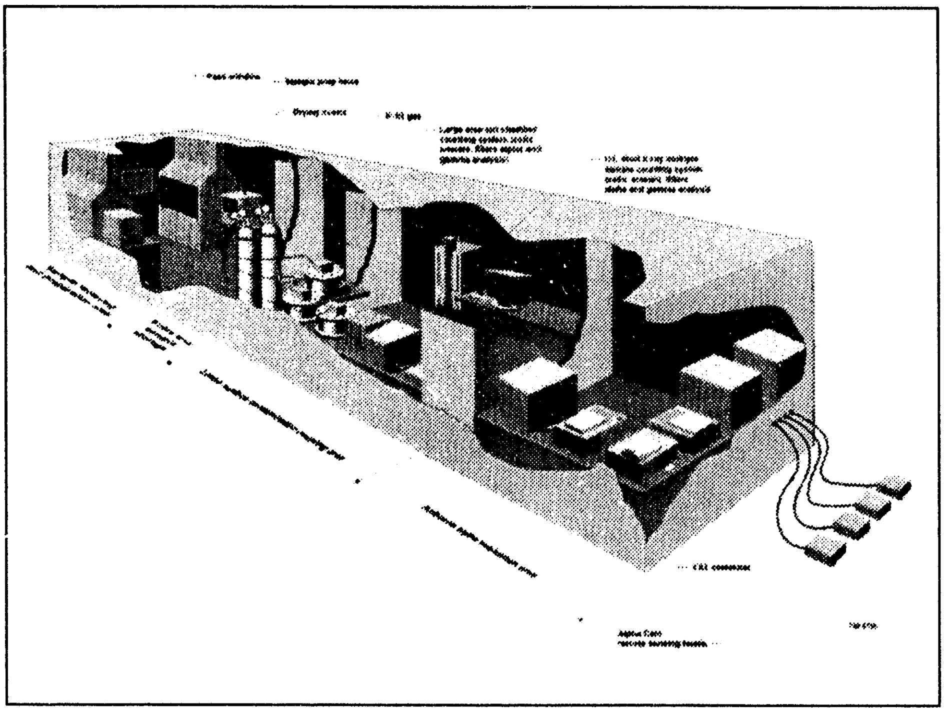

Figure 2.2a. Rapid Transuranic Monitoring Laboratory.

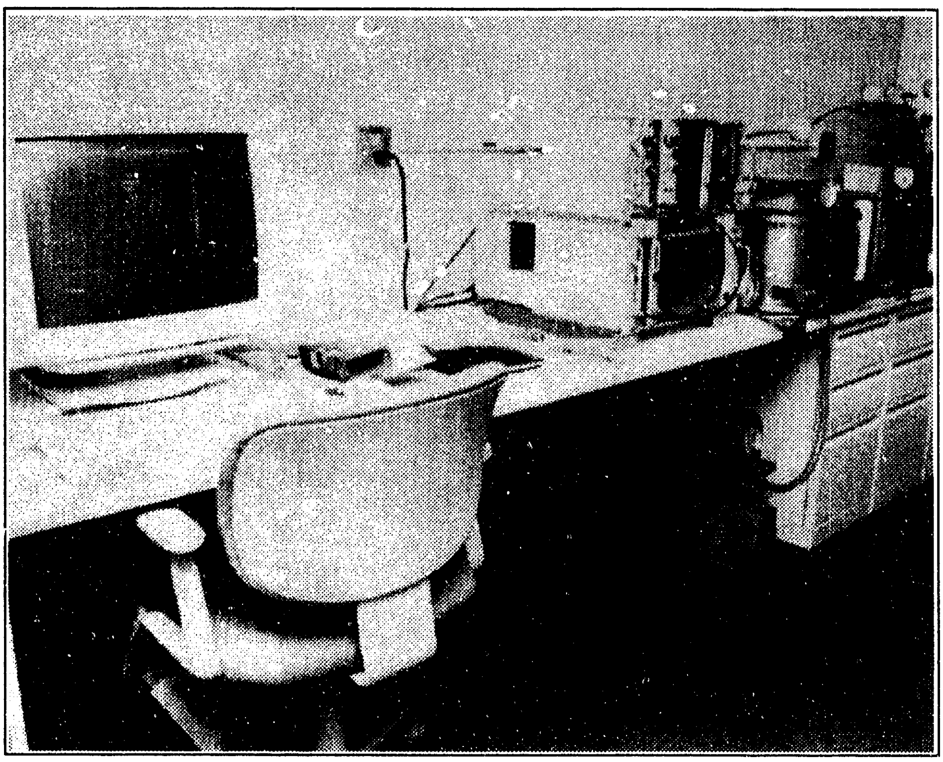

Figure 2.2b. Interior of Rapid Transuranic Monitoring Laboratory: Loose Surface Contamination Counting Area.

COLLABORATION/ TECHNOLOGY TRANSFER

INEL and Fernald Environmental Restoration programs have plans to use the unit in FY94 for soil assessment. In addition, a private company has entered into negotiations with INEL for commercialization of the unit.

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2.3 REMOTE CHARACTERIZATION SYSTEM

TASK DESCRIPTION

This project demonstrates the feasibility of remote, high-precision characterization of buried waste by deploying and operating multiple geophysical sensors over a waste site. The Remote Characterization System (RCS) consists of a vehicle, multiple geophysical radiation and/or chemical sensors, on-board video cameras, data communication equipment, a Global Positioning System, and a control base station (see Figures 2.3a and 2.3b). The vehicle was designed and fabricated specifically for the RCS to minimize the amount of ferrous metal in the vehicle, which would interfere with the operation of the sensors.

Sensors include flux gate, proton precession, and optically-pumped magnetometers; ground penetrating radar; and an EM-31. Other detectors may be added to the array to accommodate different waste stream situations. The control system enables integration of subsurface data with excavation planning, controls the vehicle, and has an ethernet radio frequency link with the sensors and vehicle controls.

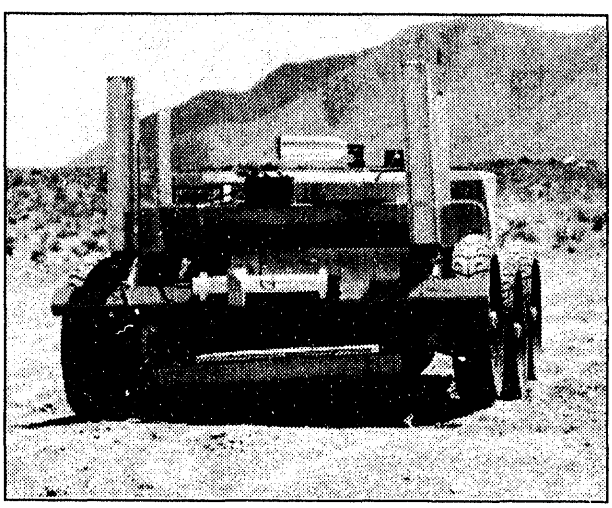

Figure 2.3a. Remote Characterization System at the INEL Cold Test Pit.

The RCS allows simultaneous use of multiple sensors, thereby reducing remediation cost by rapidly characterizing waste sites. The RCS also improves safety by not requiring workers at hazardous waste sites to enter hazardous areas.

The RCS is still in the development stage and not yet ready for field implementation. However, once field-deployable, the RCS can be used at any DOE or industrial facilities that have buried hazardous and/or radioactive waste.

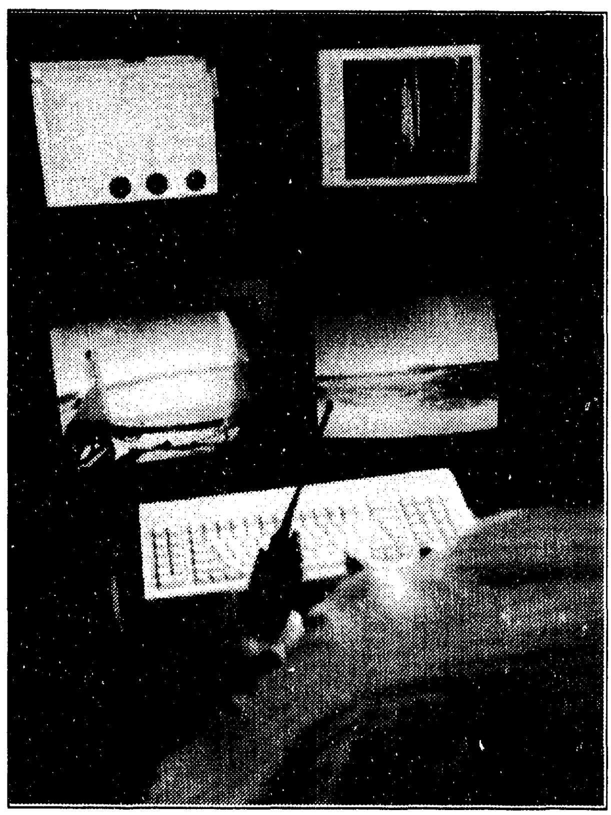

Figure 2.3b. Remote Characterization System Control Station.

TECHNOLOGY NEEDS

Current non-intrusive subsurface mapping techniques are labor intensive and time consuming. Manual methods of data acquisition from geophysical sensors are obtained from one sensor at a time. A system is needed to more quickly and remotely deploy a suite of sensors at the same time to provide information about and identify metallic objects, hot spots, pit and trench boundaries, radiation and levels.

This system will allow improved data quality through automated data acquisition, improved data display for interpretation, and increased safety for personnel, especially when access to the waste site represents risk to personnel.

ACCOMPLISHMENTS

The RCS was demonstrated and tested at the INEL Cold Test Pit in June 1993. The demonstration showed that data from three geophysical sensors can be collected simultaneously and transmitted to the control base station for real-time display. The RCS, while making numerous advances in the technology of remote site characterization, was shown to be still in the development stage. Specifically, further development of the sensors and communication system is needed before reliable operation can be achieved.

COLLABORATION/TECHNOLOGY TRANSFER

The system was developed utilizing five national laboratories (INEL, Oak Ridge, Sandia, Lawrence Livermore, and Pacific Northwest).

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2.4 MAGNETIC AND ELECTROMAGNETIC GEOPHYSICAL SURVEYING

TASK DESCRIPTION

This project is designed to demonstrate how efficiently airborne magnetic and electromagnetic devices can map buried waste sites and

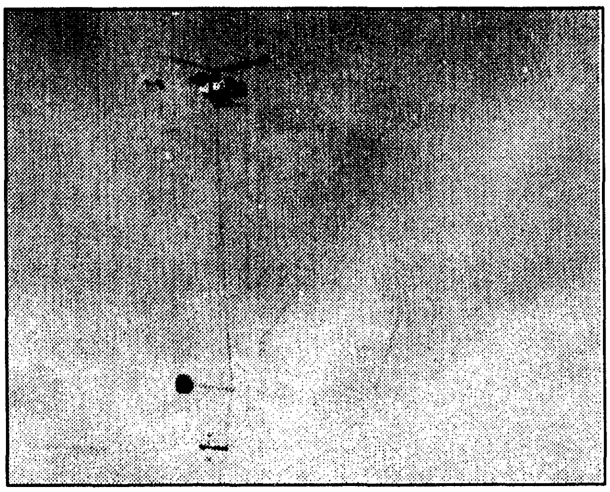

Figure 2.4a. Helicopter-mounted standard mineral exploration sensors, including magnetic and electromagnetic sensor packages.

characterize subsurface waste objects. The airborne geophysical surveying system is a helicopter-mounted set of standard mineral exploration sensors including magnetic and electromagnetic sensor packages and ancillary electronic interrogation packages (see Figures 2.4a and 2.4b). The total magnetic field of the test areas is measured passively with a dual magnetic gradiometer system, which consists of two split-beam, optically-pumped, cesium magnetometers and two optically-pumped helium magnetometers. This allows the vertical and horizontal gradient of the total magnetic field to be computed. The electromagnetic active method uses three horizontal coplanar coil pairs and two vertical coaxial pairs. The accuracy of the sensor platform positioning system is plus or minus 2 meters when mapped against the actual location of an anomaly. Complete interpretation of the position-tagged data will provide detailed information for characterizing buried materials and geologic information that can be used for hydrogeological modelling of the waste area. Data interpretation for each site is based on locating magnetic and electromagnetic anomalies, determining the amplitude of each anomaly above the total magnetic background reading, and correlating these anomalies with their most probable source.

Initial demonstration of these surveying techniques indicate that they can be used to provide the initial field screening of large DOE and industrial waste sites. Questionable areas

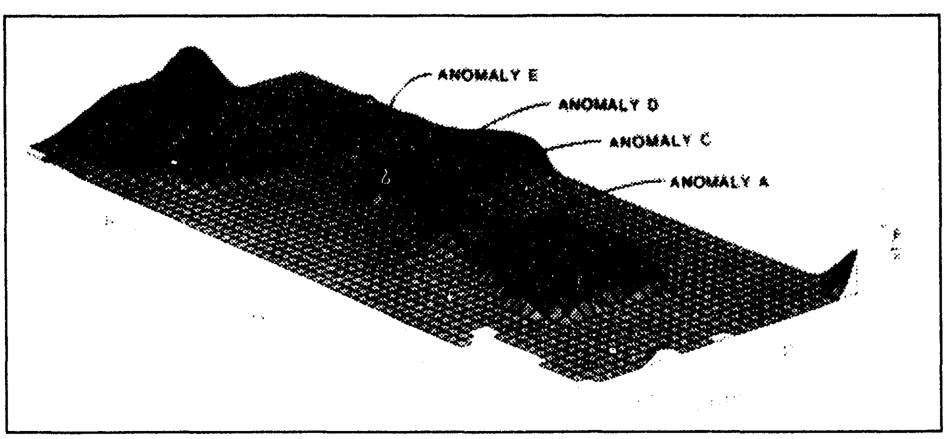

Figure 2.4b. Isometric display of INEL Cold Test Pit.

can be quickly screened for possible burial sites. However, thorough characterization of a site will require combining land-based sensor technologies that obtain high resolution data.

TECHNOLOGY NEEDS

There are many sites where the documentation of the buried waste is incomplete. There are questions about the accuracy of the data that does exist. The sites are very large, and there is a need to establish a method that more quickly screens these areas and identifies potential buried waste sites.

ACCOMPLISHMENTS

Airborne geophysical surveys were flown over the INEL's Naval Ordnance Disposal Area, the Cold Test Pit, Subsurface Disposal Area, and the SL-1 area with EBASCO Environmental's sensors. Approximately 130 line miles of geophysical surveys were obtained during the INEL demonstration. The electromagnetic data produced broad anomalies, and buried waste areas could be defined and anomalies caused by buried objects could be differentiated from anomalies caused by geologic features. The ability to delineate and identify the individual sources was limited. The magnetic data were used successfully to delineate burial trenches and pits and have the potential for detecting ordnance. Magnetic data were also used successfully in locating specific source areas within large burial areas. With additional data analysis and processing, magnetic data can be used to characterize ferrous objects. This technology is available for waste characterization activities involving large surveys over broad areas where, initially, fine detail is not required.

COLLABORATION/TECHNOLOGY TRANSFER

EBASCO performed the fly-over work and the U. S. Geological Survey performed the data manipulation.

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2.5 THERMAL INFRARED IMAGING SYSTEM

TASK DESCRIPTION

The objective of this project is to demonstrate an airborne infrared (IR) sensor method to detect and map ordnance and buried waste, and determine the feasibility of using automatic image processing algorithms to detect objects of interest (see Figure 2.5). Martin Marietta's helicopter-mounted imaging system, demonstrated in 1992, consisted of a gyro-stabilized IR detector of the mercury-cadmium-telluride type consisting of four elements with a spectral range of 8 to 12 m and with closed cycle cooling, control electronics, a time-code generator for time tagging of sensor images, and a video system. A ground station included an advanced thermographic image processor with the ability to process images in real-time. Image processing algorithms used morphological filters, edge-based detection approaches, multiple feature computations, linear classifiers, and other algorithms for object rejection, classification, and reporting. The data collected consisted of time-tagged IR "photographs" with position information contained in "landmark" features. These "photographs" were enhanced using the advanced IR image processing alogrithms.

TECHNOLOGY NEEDS

There are many DOE sites where ordnance have been buried in a shallow landfill or were unexplored during testing. The sites, in general, are very large in surface area as they were once firing and test ranges. This technology would be a quick screening method for buried ordnance.

Figure 2.5. Helicopter-mounted infrared sensor imaging system.

ACCOMPLISHMENTS

Surveys were flown over the INEL Cold Test Pit, Subsurface Disposal Area, Naval Ordnance Disposal Area, and the SL-1 burial pit and trench. Results from this demonstration indicated the system has the potential to detect 6 inch ordnance or shrapnel at depths of 1 to 2 feet below the surface. Ground surveys are necessary to validate identified anomalies.

COLLABORATION/TECHNOLOGY TRANSFER

This work was done in collaboration with Martin Marietta.

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2.6 BROAD BAND ELECTROMAGNETICS

TASK DESCRIPTION

The objective of the Broad Band Electromagnetics (BBEM) Demonstration was to adapt present broad band electromagnetic interpretation technologies used in mineral exploration to locate, in three dimensions, objects buried at shallow depths (see Figure 2.6). The BBEM Demonstration device is an asymmetric two-coil induction system using a large 5-meter diameter transmitting loop to generate the equivalent of a three-decade frequency spectrum. When current flow is interrupted, a transient magnetic field may be briefly observed. This transient decay is analyzed to determine the magnitude of the induced field at systematic intervals. This information provides conductivity information at various delay intervals that may be equated to different penetration depths. The system may be used in either a traverse/profile configuration or as a vertical electric expander, or "sounding" device. For this reason, it is easily adapted to use in describing three-dimensional bodies.

Figure 2.6. Broad Band Electromagnetic Demonstration at INEL.

Conventional equipment and interpretation software provide demonstrated capability to characterize buried waste sites by obtaining a frequency spectrum (approximately 64 values) at a spatial location. Investigation is in progress of enhanced interpretation.

The BBEM Demonstration will be useful in characterizing any waste environment containing conductive material. These sites include buried waste sites, ordnance fields, and hazardous waste sites.

TECHNOLOGY NEEDS

There is a need to have quantifiable data about buried waste pits and trenches. In addition, some further understanding of the buried material would provide an advantage in preparing the remedial design.

ACCOMPLISHMENTS

A time domain BBEM Demonstration system was demonstrated at the INEL Cold Test Pit and the RWMC with encouraging results when compared to historical information collected at the INEL Cold Test Pit and Pit 9. Further development of this technology is necessary.

COLLABORATION/TECHNOLOGY TRANSFER

This activity is being performed in collaboration with the U.S. Geological Survey and Rust Geotech, Inc.

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2.7 TENSOR MAGNETIC GRADIOMETER

TASK DESCRIPTION

The purpose of this joint-development project between DOE and the U.S. Geological Survey is to develop an improved system for nonintrusive site characterization by measuring and interpreting the magnetic gradient tensor.

The Tensor Magnetic Gradiometer (TMG) employs an array of four triaxial vector magnetometers to measure the three magnetic field vectors and five components of its spatial gradient (see Figure 2.7). Using all of the spatial gradients of the earth's magnetic field significantly improves the applicability and efficacy of magnetic methods for subsurface detection and mapping. The technique offers an improved method for simple object location called "dipole mapping", in which small isolated magnetic targets can be accurately located and characterized by only a few measurements. In fact, this omnidirectional, gradient information is sufficient to permit a simple quantitative interpretation from a single station.

The prototype TMG measures the five independent components of the gradient of the vector magnetic field, and has a sensitivity better than 1 nanoTesla/meter. Refinement in temperature and attitude corrections are anticipated to improve sensitivity to 0.1 nT/m. The system is being adapted for mobile deployment using a non-ferrous, manually operated platform. It is anticipated that the overall survey cost will be substantially reduced through the advantage of real-time interpretation and reductions in map compilation and modelling.

TECHNOLOGY NEEDS

There is a need to quickly collect magnetic data for better interpretation and characterization of the subsurface (ideally, real-time). The non-intrusive collection of magnetic data will also increase worker safety.

Figure 2.7. Tensor Magnetic Gradiometer.

ACCOMPLISHMENTS

The U.S. Geological Survey has completed fabrication of a TMG consisting of four triaxle, ringcore fluxgate magnetometers. The software to operate the system is currently being completed. The system will be field-tested during FY94 at the U.S. Geological Survey test area. The integrated hardware/software system, when demonstrated, is expected to provide real-time magnetic imagery of ferrous targets within buried waste sites.

COLLABORATION/TECHNOLOGY TRANSFER

This activity is being done in collaboration with the U.S. Geological Survey and Rust Geotech, Inc.

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2.8 DIG-FACE CHARACTERIZATION

TASK DESCRIPTION

The dig-face characterization project is an integrated demonstration to develop and test multiple sensors that can be used as part of a retrieval effort. The dig-face characterization technology will allow continuous and continually improving monitoring and characterization of the site being remediated. The dig-face characterization technique is integrated into the remediation process itself, and sensor data interpretation skills are improved by comparing interpreted data images with the retrieved targets.

Geophysical, chemical, and radiological sensors are being deployed by a robotic system. The sensors scan over the surface being remediated. As waste retrieval proceeds, the sensors are continuously deployed to characterize the remaining waste. The remediation process proceeds in a stepwise manner in which the characterization data is interpreted on-line to support the retrieval process (see Figures 2.8a and 2.8b).

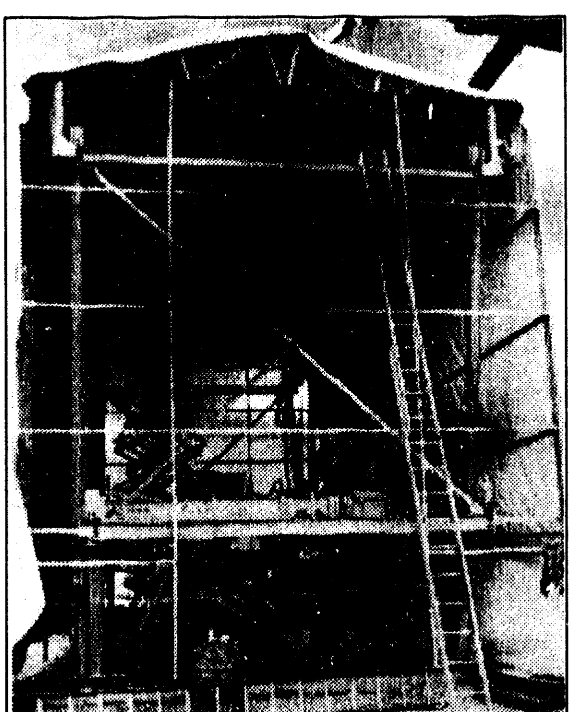

Figure 2.8a. Robotic gantry crane system for deploying the dig-face sensors.

The feasibility of the concept of characterization by deployment of multiple sensors during progressive soil removal has been demonstrated. Candidate sensors (geophysical, radioactive, chemical) have been identified. Development of automatic deployment capability is in progress. Development of refined data interpretation techniques to support rapid target identifications is in progress.

The dig-face technology reduces environmental, health, and safety risks during cleanup of buried waste sites, and is applicable to any waste site undergoing retrieval. Real-time data interpretation during the retrieval process allows for the incorporation of appropriate remediation equipment to maintain safety and environmental standards.

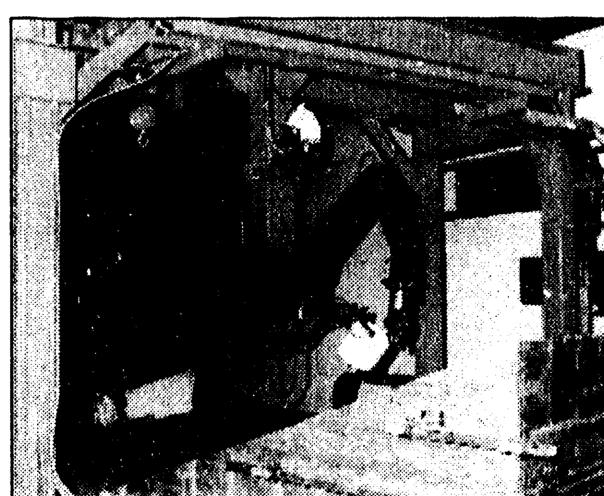

Figure 2.8b. Pilot-scale deployment of dig-face sensors using a soilbox to simulate the dig face.

TECHNOLOGY NEEDS

Real-time data interpretations during the retrieval process allows for the incorporation of appropriate remediation equipment to reduce safety and health risks.

ACCOMPLISHMENTS

Three prototype sensors are being developed for dig-face application: gamma spectrometer, dielectric permittivity sensor, and electromagnetic induction sensor. Initial laboratory data have been obtained for the dielectric permittivity and gamma spectrometer sensors. Data indicate that both are feasible candidates for dig-face application.

Initiated testing for automated deployment of dig-face sensors using a robotic gantry crane system. This testing is being conducted at pilot-scale using a soilbox to simulate the dig face and identify control system issues and needs.

Field testing has started at a test trench at the INEL Cold Test Pit using multiple sensors deployed with a manual nonmetallic gantry designed and constructed to support obtaining dense data sets in a noninterfering environment. Data has been obtained for several commercial sensors (magnetometer, electromagnetic sensor, chemical sensor) deployed over simulated targets in multiple passes as soil layers are progressively removed. The data has been used to evaluate resolution capabilities of sensors deployed in this fashion and provide data for empirical evaluation of the concept feasibility.

COLLABORATION/TECHNOLOGY TRANSFER

Geonics Ltd., Ecology International, Colorado School of Mines, the U.S. Geological Survey, Sandia National Laboratory, and the Grand Junction Project Office are all involved in the development of this technology. It is anticipated that Dig-face Characterization will have several potential commercial applications in manufacturing, mining, and waste cleanup operations.

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2.9 CRYOGENIC RETRIEVAL

TASK DESCRIPTION

A full-scale cryogenic retrieval demonstration was completed at the INEL Cold Test Pit in FY92. A series of carbon and stainless steel, 2-inch schedule, 40 freeze pipes, approximately 10 feet to 12 feet in length, were driven into 3 areas of soil and simulated buried waste. For the field demonstration, about 65 pipes were driven into each of 3 areas that measured 9 feet x 9 feet x 10 feet (810 ft^3). Liquid nitrogen (LN_2) was circulated through the pipes, and small quantities of water were injected to promote cohesion of the soil and simulated waste particles (see Figure 2.9a). Besides freezing the test pit, the perimeter of an adjacent access pit was also frozen. Once the area to be removed was frozen, the center of the access pit was excavated (the access pit was in clean soil). The access pit served to create a dig area from which excavation of the waste could proceed. A gantry with a remotely operated jackhammer, a hydraulic jack, shears, and a grapple was moved over the frozen area to be retrieved.

With the gantry and tools in place, the tools were remotely-operated and the frozen soil and simulated waste were excavated and loaded into transport boxes (see Figure 29b). The jackhammer was used to break up the soil and debris. The shears cut and sized the material, and the grapple picked up the debris and loaded it into the transport boxes.

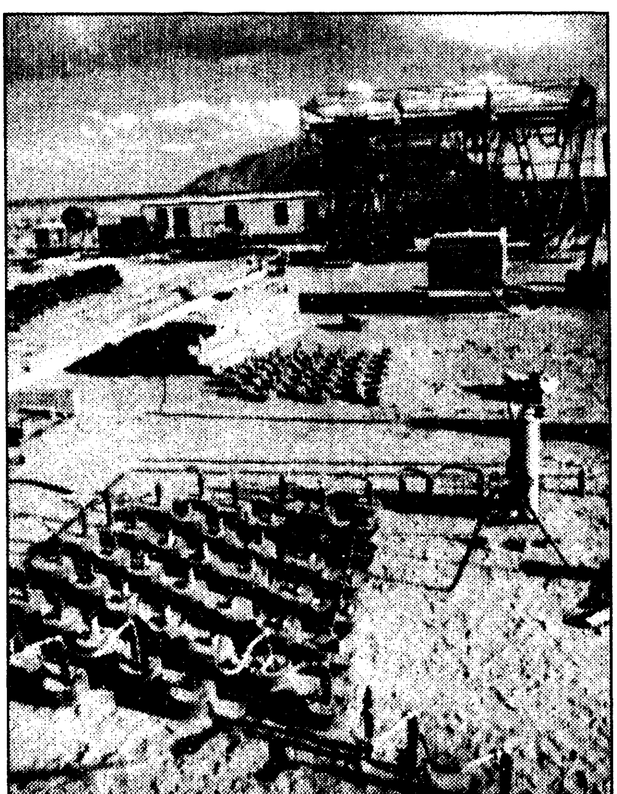

Figure 2.9a. Liquid nitrogen injection pipes inserted into the INEL Cold Test Pit.

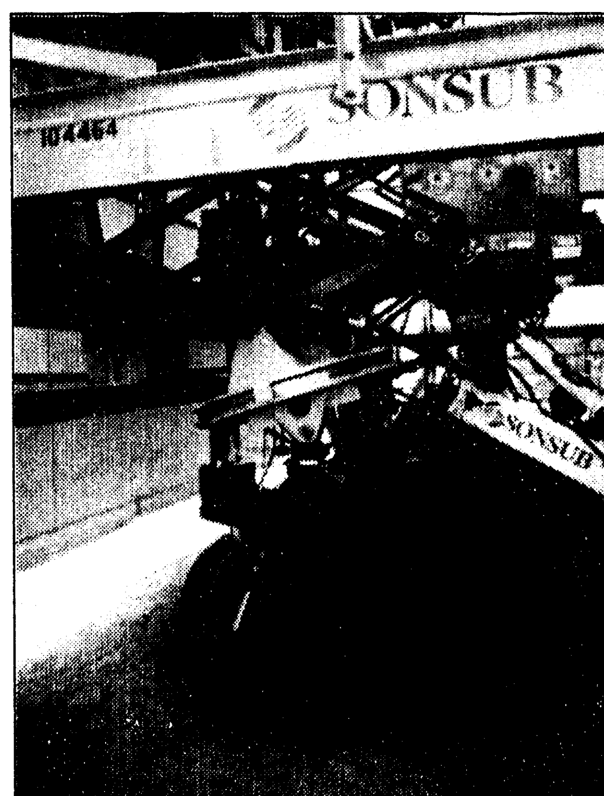

Figure 2.9b. Remotely-operated retrieval equipment.

The prototype system is scalable to support 80 cubic yards of buried waste retrieval per 8-hour day. The retrieval can be accomplished with minimal contamination spread as evidenced by a lack of surrogate tracers on air sampling systems during the proof-of-principle tests.

Cryogenic retrieval can be used at waste disposal sites throughout the DOE Complex and industry. The technology has application to any hazardous site requiring retrieval where the spread of contamination is a high risk.

The benefits of cryogenic freezing followed by retrieval are reduced risk to personnel and minimal spread of contaminated dust and soil moisture during waste excavation and retrieval. By agglomerating contaminated soil particles, the risk of generating, spreading, and inhaling aerosolized dust is greatly reduced.

TECHNOLOGY NEEDS

During retrieval operations, there is a need to reduce the risk to personnel and to minimize the spread of contaminated dust. This is particularly true for sites where the risk of contamination is high and the work must be performed remotely.

ACCOMPLISHMENTS

This technology was successfully demonstrated at the INEL Cold Test Pit in the summer of 1992. The cryogenic retrieval full-scale demonstration showed a positive proof-of-principle for remote retrieval of simulated buried TRU waste, while containing contaminant spread. During the test, approximately 200,000 gallons of LN_2 were used to freeze 4500 ft^3 of soil and debris. The spread of respirable particles was minimized by the freezing process. This technology was successfully demonstrated as mature enough to be considered for actual waste site applications to reduce contamination spread during retrieval operations.

COLLABORATION/TECHNOLOGY TRANSFER

This technology was developed in collaboration with Sonsub™. Sonsub™ currently owns the patent rights and is in the process of marketing the technology.

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2.10 CRYOFRACTURE™

TASK DESCRIPTION

The purpose of this project is to demonstrate Cryofracture™ technology as a pretreatment for processing retrieved and/or stored containerized waste (see Figure 2.10).

General Atomics, San Diego, California, developed this cryofracture™ technology to deactivate chemical and biological weapons. The process uses liquid nitrogen to freeze materials to -320°F, which are then crushed by a large hydraulic press. The freezing process immobilizes the active components, which are then crushed to fragment the material into treatable pieces. The method has been adapted and demonstrated as a pretreatment size-reduction step in processing TRU-contaminated waste stored in drums and boxes.

The system can reduce 55-gallon drums or 4x4x4-foot boxes of waste materials with no probability of fire or explosion. The resultant debris, less than 6" mean size, is much more compatible with most treatment processes.

Potential applications include waste disposal and treatment facilities. The process can replace conventional shredder operations that are challenged by heavy structural materials, cables, cloth, and aerosol containers.

Cryofracture™ enhances the chances for success for post-retrieval treatment of buried and stored waste and results in a more homogenous waste for passive and active assay systems. The hazards and risks associated with the conventional shredding of pyrophorics and other explosives are eliminated with the Cryofracture™ process.

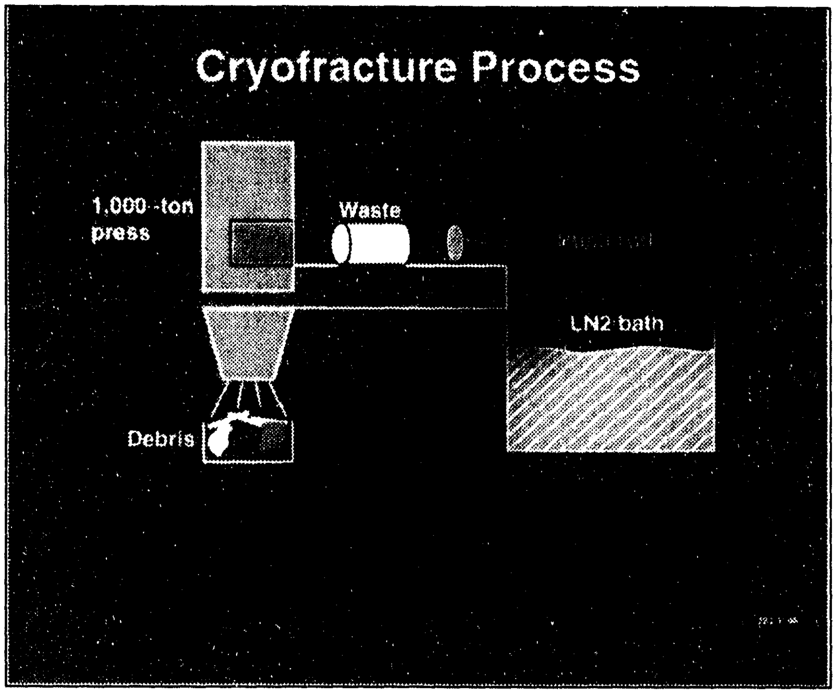

Figure 2.10. Cryofracture Process Description.

TECHNOLOGY NEEDS

This technology provides a method for post-retrieval treatment of buried and stored waste, which results in a more homogenous waste for passive and active assay systems. In addition, it reduces the risks associated with the conventional shredding of pyrophorics and other explosives.

ACCOMPLISHMENTS

The Cryofracture™ facility was developed by General Atomics. The demonstration showed that cryofracture was an effective size reduction process, reducing containerized waste volumes by up to 47%. On the average, 90% of the material (containerized waste in 55-gallon drums or 4x4x4-foot boxes) was fractured to less than 6 inches in size, making this processed waste more compatible with most waste treatment options.

COLLABORATION/TECHNOLOGY TRANSFER

This technology was developed in collaboration with General Atomics. General Atomics owns the patent for this technology and is currently marketing the technology.

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2.11 RETRIEVAL DEMONSTRATION

TASK DESCRIPTION

The objective of the Retrieval Demonstration is to determine the effectiveness of full-scale, commercially-available excavation equipment and end-effectors for the retrieval of simulated buried waste forms typical of DOE sites. Manually-operated commercially-available equipment was evaluated for its suitability for buried waste retrieval. This equipment and its operation were also evaluated in terms of its remotization capability (see Figures 2.11a and 2.11b). The equipment and end-effectors evaluated in this study included a 325L excavator with Balderson thumb end-effector, 935C track loader with multipurpose bucket, EL200B excavator with front shovel, an IT28B integrated tool carrier with a grip and grab end-effector, and 235B excavator outfitted with a pair of Allied-Gator shears. The average production (retrieval) rate of this equipment was determined to be 400 yd^3/day (8-hour day). This rate far exceeded the target goal of 80 yd^3/day. The 325L excavator with Balderson thumb proved to be the most versatile machine evaluated, operating effectively (similar production rates) both above and below grade. It was capable of handing 1 yd^3 load of heterogeneous waste with no spillage. It could selectively grab small 1 inch diameter cables, as well as handle large objects, such as a 6 foot metal cube.

This equipment can be applied today to any retrieval operation requiring capabilities of handling heterogeneous waste forms. This equipment has been evaluated for remotization, which is being considered for radioactive retrieval operations.

Figure 2.11a and 2.11b. Full-scale retrieval demonstrations at Caterpillar Cold Test Pit site, Illinois.

TECHNOLOGY NEEDS

This demonstration addresses the need for identification of retrieval equipment that could best handle the requirements for the retrieval of the buried waste in the DOE Complex. Once identified, these pieces of equipment could be remotized and optimized for retrieval activities.

ACCOMPLISHMENTS

A full-scale retrieval demonstration was conducted in June 1993 at the Caterpillar, Inc. Edwards Training Center near Peoria, Illinois. The demonstration was performed at a simulated waste pit constructed on this site. The simulated waste pit (overall size 70 x 32 x 13 feet) was comprised of three separate cells; a stacked drums and boxes cell (35 x 32 x 13 feet), an earth separation berm (10 x 32 x 13 feet), and a random-dumped drums and boxes cell (25 x 32 x 13 feet). Excavation of the pit occurred in four passes, each 8 feet wide, moving lengthwise along the pit. The first two passes were excavated from the belowgrade position and the last two from abovegrade. Various equipment was tested during the demonstration. The demonstration provided information on retrieval rates at a buried waste site. The average production (retrieval) rate of this equipment was determined to by 400 yd^3/day (8-hour day). This rate far exceeded the target goal of 80 yd^3/day. The 325L excavator with Balderson thumb proved to be the most versatile, operating effectively both abovegrade and belowgrade. It was capable of handling 1 yd^3 loads of heterogeneous waste with no spillage and could selectively grab small 1-inch-diameter cables, as well as handle large objects, such as a six-foot metal cube.

COLLABORATION/TECHNOLOGY TRANSFER

Commercial equipment is readily available to support retrieval operations. This equipment has been used by industry and has been proven reliable. The use of this equipment can improve throughput rates. However, additional development, such as remotization, is required to improve worker safety by removing the workers from the hazards.

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2.12 REMOTE EXCAVATION SYSTEM

TASK DESCRIPTION

The objective of this project is to demonstrate and evaluate a system to remotely excavate radioactive waste, unexploded ordnance and other hazardous wastes. A standard military vehicle, the Small Emplacement Excavator (SEE), was modified by the Oak Ridge National Laboratory for remote operation and computer-assisted control (see Figure 2.12a.). The excavator boasts automated dig and dump functions, multiple video cameras, joint encoders and other sensor feedback. Video and control data is transmitted to the control station via radio frequency links or fiber-optics. A novel joystick controller and a graphical computer interface were developed to provide a remote control station that is easy to use and does not require line-of-sight operation (see Figure 2.12b.).

The Remote Excavation System (RES) is designed for relatively small excavations. Remote operation of the system demonstrated a retrieval rate of approximately 2.4 ft^3/min. Manual operation under test conditions was able to achieve rates 50% higher. However, actual manned operation at a waste site would likely be unable to achieve these rates because of protective equipment and monitoring requirements.

The RES can be used for remote excavation of radioactive and hazardous sites and for retrieval of unexploded ordnance. The controls technology developed for this project was implemented in a modular fashion that permits rapid transfer of the technology to other excavator platforms. With the RES, materials can be excavated and retrieved in a hazardous environment without endangering operator personnel.

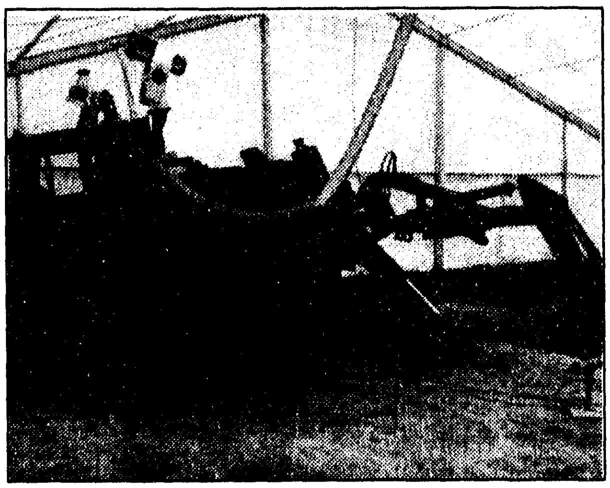

Figure 2.12a. Remote excavation operations at the INEL Cold Test Pit.

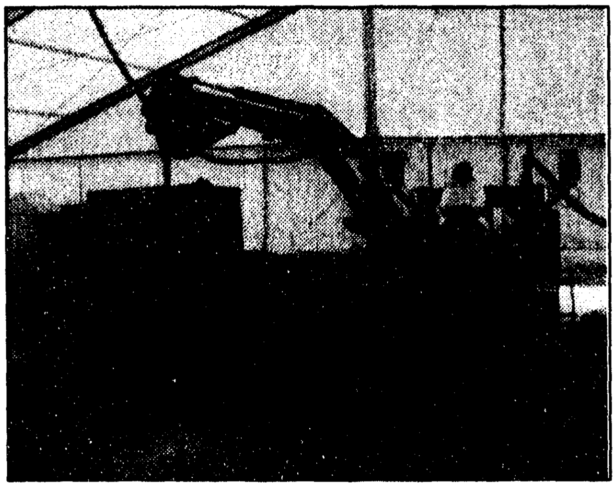

Figure 2.12b. Manual operation of the Remote Excavation System equipment.

TECHNOLOGY NEEDS

Several DOE sites have significant amounts of buried waste and contaminated soil. The mixtures vary from site to site, but the waste and contaminated soil consists of low-level, TRU, and high-level radionuclides, pyrophoric and possibly explosive materials in many forms. The methods of remediation will vary, but given the hazards of the waste, robotic and remote handling techniques will be necessary to reduce the risk to the worker.

ACCOMPLISHMENTS

The RES was demonstrated at the INEL Cold Test Pit and at the U.S. Army Redstone Arsenal to evaluate the feasibility of excavating buried waste and unexploded ordinances with a remotely-operated vehicle. At each of these demonstrations, the relative performance benefits of teleoperation and telerobotic excavation were evaluated and documented. It was demonstrated that the system can be operated remotely to effectively excavate buried waste. The advanced control technology and computer-assisted operations made excavation relatively easy for inexperienced and experienced operators alike.

COLLABORATION/TECHNOLOGY TRANSFER

The system was developed utilizing five national laboratories (INEL, Oak Ridge, Sandia, Lawrence Livermore, and Pacific Northwest). The Department of the Army also provided the platform, which was remotized for use by both DOE and the Army.

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2.13 CONTAMINATION CONTROL UNIT

TASK DESCRIPTION

This project designs, constructs, and tests an easily deployed, mobile unit to efficiently and inexpensively suppress contaminated dust during excavation of buried waste. The Contamination Control Unit (CCU) is a 9 by 26-foot trailer outfitted with a powerful waste vacuuming system and three dust suppression systems (see Figure 2.13). The vacuum, a nuclear-grade system, with a High-Efficiency Particulate Air (HEPA) filter and a critically-safe 55-gallon waste container, can pull one inch debris through 100 feet of hose. The dust suppressing system applies a water mist, a soil fixant and a dust suppressant. The water misting system, Dryfog^{SM} (manufactured by Sonics, Inc.), uses compressed air to force demineralized water through four nozzles. The nozzles discharge a mist curtain that captures and removes aerosolized soil. The concentrated soil fixant, Foamer^{SM} (manufactured by 3M Inc.), is combined with a stabilizer and water pumped from a trailer-mounted 325-gallon tank. The stabilizer and concentrate are stored in 5-gallon cans near the nozzle and are delivered by suction to the nozzle. The dust suppressant, Flambinder^{SM} (calcium lignosulfate manufactured by Flambeau Corporation), is commonly used on forest service roads to suppress dust. This product is mixed with water, stored in a 325-gallon tank and pumped to a nozzle via a hose and reel system. Flambinder^{SM} cures in a few hours, and can withstand traffic of hundreds of vehicles without reapplication.

In a field-deployable setting, the unit is capable of fixing 500 ft^2/minute with a total encapsulated (3M-Foamer), or apply 1000 ft^2/15 minutes of dust suppressant (flambinder) while simultaneously providing 2 gpm mist from 4 misting nozzles. The vacuum system can be operated continuously during the spray operation. In an emergency response situation, the system is capable of spraying dust suppressant at a rate of 1000 ft^2/3 minutes.

The CCU provides a reliable, easy to use, easily deployable system to control dust and windblown contamination at DOE and industrial buried waste sites during excavation and retrieval operations. Use of the CCU improves personnel safety and reduces the risk of contamination spread by airborne dust. Furthermore, all the dust control products are nonhazardous, and can be disposed of in sanitary landfills.

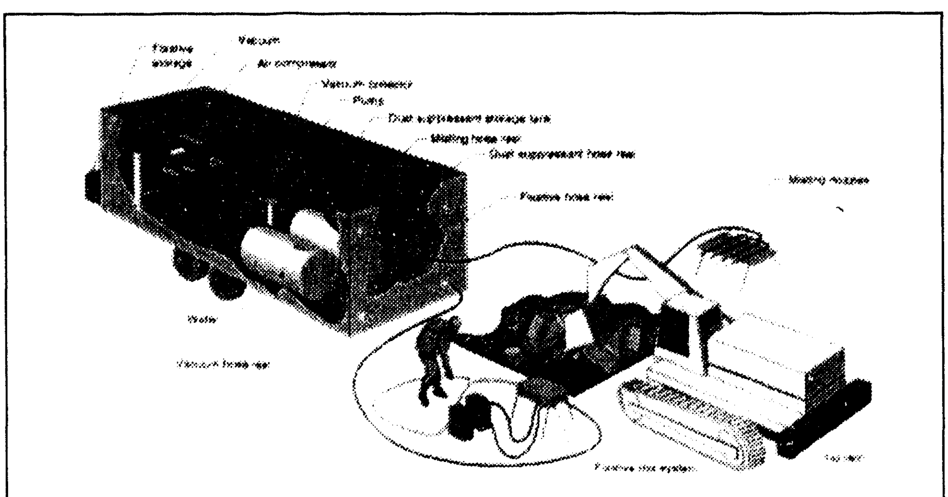

Figure 2.13. Contamination Control Unit.

TECHNOLOGY NEEDS

Handling of TRU-contaminated waste during retrieval operations requires contamination control techniques due to the highly mobile nature of the contaminants. There are mandatory operational and safety limits, which may not be exceeded, and extremely small amounts of plutonium/americium are allowed for personnel uptake.

ACCOMPLISHMENTS

The CCU was designed in FY92, and assembled and its performance tested in FY93. The unit is completely developed and ready for Environmental Restoration use throughout the DOE Complex. Currently it is being used by the Environmental Restoration Program at The Hanford Site for a retrieval treatability study. The unit was also used by the INEL Environmental Restoration Program during a capping action at EBR-1 in which Wendon dust suppressant was sprayed on a slightly contaminated soil site of about 1.5 acres. Fernald is evaluating the use of the unit in the FY94/95 time frame to supply contamination control during actual retrieval actions.

COLLABORATION/TECHNOLOGY TRANSFER

The unit has been used by environmental restoration in INEL and Hanford to assist in a capping action and treatability study respectively.

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TASK DESCRIPTION

The objective of the Overburden Removal project was to demonstrate that discrete thicknesses of overburden soil can be removed with precision and accuracy and that fugitive dust can be controlled during excavation. The overburden removal system is a Caterpillar EL300B excavator fitted with an innovative end-effector (see Figures 2.14a and 2.14b. The end-effector is specially designed to remove incremental layers of soil from the area of excavation. Two vacuum ports were installed on the end-effector's front edge and two on the rear to remove much of the dust generated while cutting. The vacuumed dust is routed through hoses into a knock-down box. The vacuum system reduces potential contamination risks to the operators by reducing the generation of dust. A laser referencing system provides a constant grade reference by transmitting radio signals to a display in the operator's compartment to indicate if the end-effector is above, below, or on-grade.

By using this system, one can accurately skim layers of "clean" overburden soil or surficial contamination from a waste site to minimize the amount of waste soil that needs to be treated. The system can remove clean or contaminated soil in controllable layers using 3", 4", or 6" cuts with an accuracy of + 1". The system can remove 6 feet of soil over 1 acre in ten 8-hour days. This system can be used at any site requiring the removal of incremental layers of soil without dust generation or contamination spread.

The system can also be used to precisely excavate surficial contamination to minimize the amount of waste soil that needs to be treated.

Figure 2.14a. Overburden removal demonstration at the INEL Cold Test Pit.

TECHNOLOGY NEEDS

There is a need to reduce the total amount of soil that requires treatment by removing precise incremental layers of either contaminated or clean soil.

ACCOMPLISHMENTS

A demonstration was completed at the INEL Cold Test Pit. The equipment removed the layers of soil with a cut precision of + 0.57

inches, and an average cut accuracy of only + 0.08 inches. The target cut precision and average cut accuracy was set at + 1 inch. The dust collection system functioned efficiently; the air monitor analysis results proved that the soil could be excavated without spreading contamination. An experienced, proficient operator is essential.

COLLABORATION/TECHNOLOGY TRANSFER

This technology was developed in collaboration with Sonsub, Inc. Sonsub holds the patent on the technology and is currently marketing it for commercial and government application.

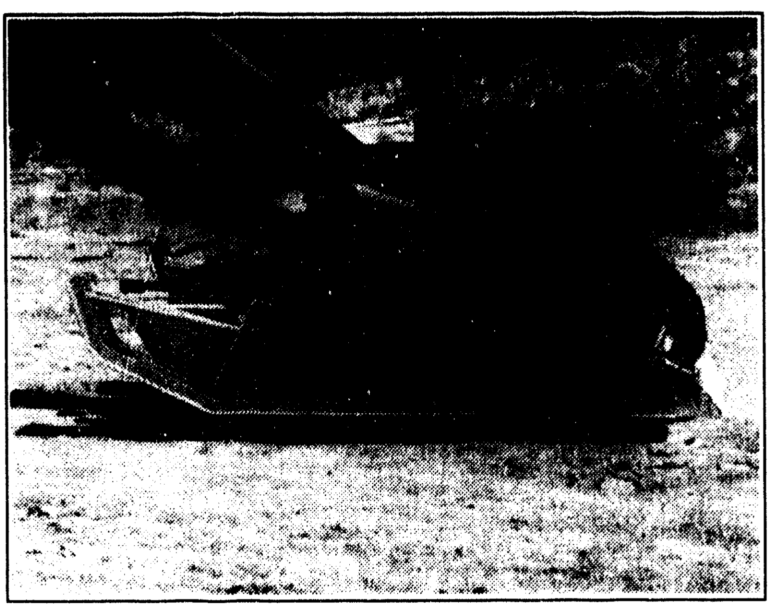

Figure 2.14b. Sonsub-developed end-effector for overburden removal.

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ELECTROSTATIC CURTAIN

TASK DESCRIPTION

The Electrostatic Curtain addresses the problem of containing airborne dust contaminated with plutonium-239 (239Pu) and americium-241 (241Am).

The Electrostatic Curtain uses grounded conducting plates to form the walls of an inner containment structure to capture charged contaminated dust particles (see Figure 2.15). The grounded conducting plates are also used in a ventilation system upstream from a HEPA filter to neutralize charged dust particles entrained in an air stream drawn from within an enclosure. A double enclosure with a ventilation system was used for the experiments.

Electrostatic curtains can provide in-depth contamination control during TRU waste handling operations. Removal efficiencies as high as 99% have been obtained in ventilation systems.

The electrostatic curtain technology minimizes dispersal of contaminated dust during excavation and retrieval. This technology maintains a safer work environment in contaminated environments, and can be used at other DOE and industrial waste disposal sites.

TECHNOLOGY NEEDS

The electrostatic curtain addresses the need for contamination control during transuranic waste retrieval and handling operations. The curtain could be part of an overall electrostatic enclosure that is used as an in-depth contamination control strategy for a TRU waste retrieval/treatment operation.

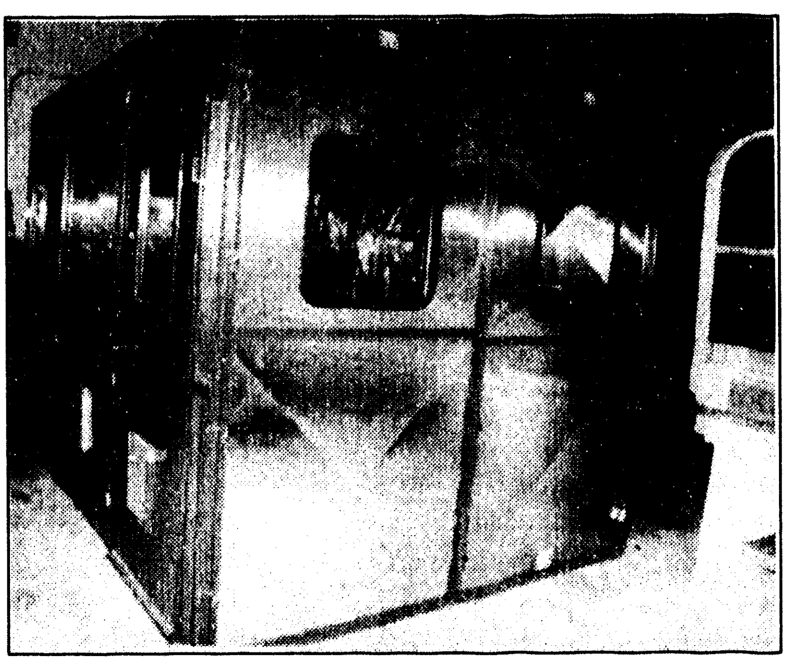

Figure 2.15. Engineering-scale electrostatic curtain enclosure walls with ventilation system.

ACCOMPLISHMENTS

The Electrostatic Curtain project has progressed from proof-of-concept experiments in a glove box to engineering-scale demonstrations in FY93. Three different devices were investigated in the experiments: a 3M Electret Filter, an electric field test fixture, and parallel arrangements of metal plates. Based on the proof-of-concept experiments, the performance goal of 98% removal efficiency of PuO_2 was selected. The Electret Filter was found to be 99%

effective. The other devices were found to be significantly less effective.

COLLABORATION/TECHNOLOGY TRANSFER

Full-scale demonstration of this technology has not been completed. An opportunity exists for private industry that would be interested in further development and commercialization. In addition, this opportunity may involve the demonstration of a full-scale unit in concert with the full-scale FY95 Buried Waste Integrated Demonstration (BWID).

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2.16 ICE ELECTRODES

TASK DESCRIPTION

The objective of this project is to develop and test an ice electrode to remove heavy metals from waste streams and recover valuable metals and minerals. An ice electrode is a conventional electroplating electrode coated with a thin sheath of ice produced by liquid nitrogen-cooled nitrogen gas flowing through an electrode (see Figure 2.16). Bench-scale tests indicate that metals that can be electrodeposited on a conventional electrode can also be electrodeposited on an ice electrode. Preliminary work with metals that cannot be recovered by conventional electrodeposition, including oxides of uranium and tungsten, suggests that they can be retrieved and easily recovered as an ice electrode. In addition, the ice electrode minimizes waste generation because the electrode is not destroyed due to the presence of the ice sheath.

Electrolytic removal of heavy metals from waste solutions using an ice electrode has been demonstrated on a bench-scale test apparatus. Electrodeposition of copper, silver, zinc, cobalt, cadmium, lead, and chromium was accomplished.

The ice electrode technology will have application in any process that produces metal-bearing waste solutions, including private-sector mining waste streams.

TECHNOLOGY NEEDS

There are many buried waste sites that contain a significant amount of heavy metals. The treatment of the waste may potentially result in those heavy metals being suspended in solution. This technology can provide a means to recover those metals.

ACCOMPLISHMENTS

A bench-scale test determined that all plateable metals are candidates for removal from solution as an ice electrode. A pilot-scale reactor has been designed and a demonstration is planned for FY94. BWID is not sponsoring this follow-on effort.

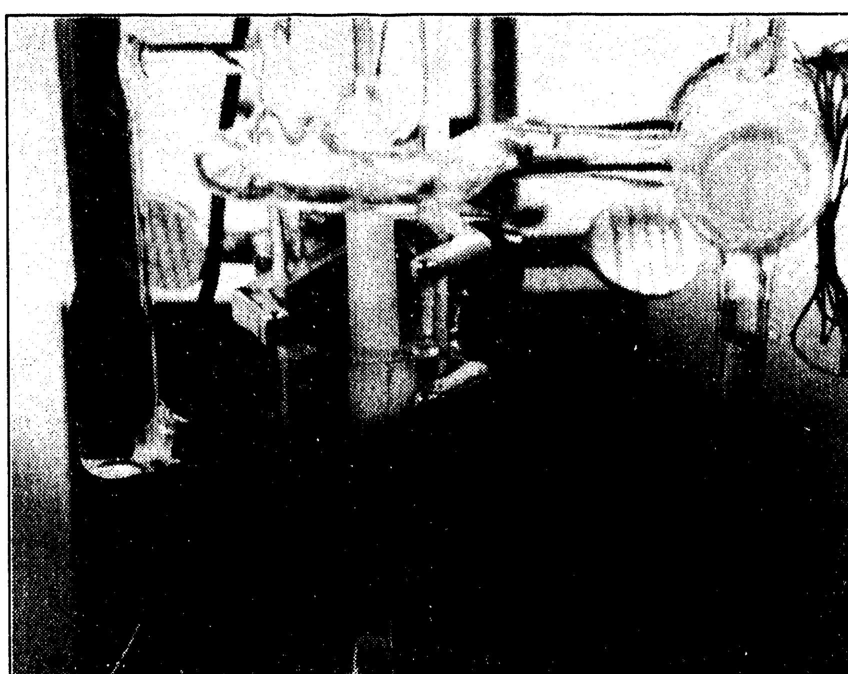

Figure 2.16. Bench-scale demonstration of ice electrode technology at the INEL Research Center.

COLLABORATION/TECHNOLOGY TRANSFER

It is anticipated that the market for the ice electrode technology will be useful for waste treatment and processes that deal with metal-bearing waste solutions, plating companies, mining waste streams, metal cleaning operations, etc.

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TASK DESCRIPTION

The Arc Melter Vitrification project is an extension of an in-progress U. S. Bureau of Mines (USBOM) and American Society of Mechanical Engineers (ASME) demonstration concerned with fly ash vitrification (see Figure 2.17a). This project will evaluate the applicability of a small commercial-scale arc melter to treat mixed TRU-contaminated wastes and buried or stored soils.

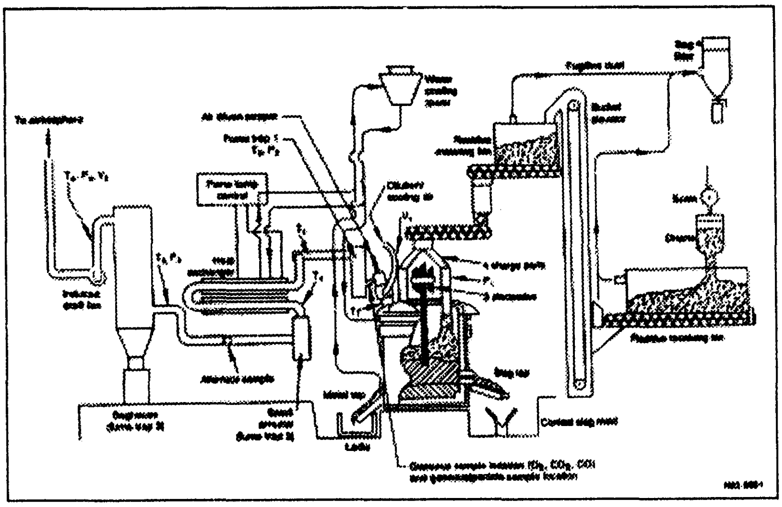

Figure 2.17a. U.S. Bureau of Mines three-phase arc melter furnace at the Albany Research Center, Oak Ridge, TN.

ASME/USBOM test system is a 1.5 MVA, 1.5 ton/hr (nominal) electric arc furnace with three carbon electrodes, cooled sidewalls for skull operation, a continuous feed system, off-gas treatment system, and slag and metals tapping capability (see Figure 2.17b). The existing off-gas system components will be modified if required to be more suitable for TRU surrogates and heavy metals. Experiments will include analysis of slag and metal phases, off-gas, and off-gas system residues. Surrogate wastes, including soils, metals combustibles, and sludges, will be prepared and separately incinerated, as appropriate, in preparation for melter processing.

The near field-scale unit can process a nominal 1.5 ton/hr of buried waste type feeds and soil. However, this technology has been used in the steel industry at scales in excess of 105 tons per day. Feed capabilities in the ASME/USBOM melter are currently limited to a screw feed system, but are being upgraded to handle larger diameter objects (up to 6 inches). A full-scale system would be capable of feeding objects larger than a 55-gallon drum. The current system can handle

Figure 2.17b. Continuous tapping of slag to the slag mold.

limited quantities of hazardous (non-radioactive) materials. Approximately 20 to 30 metric tons of simulated waste will be processed in each melt campaign, or about 4 to 6 metric tons per day.

The technology has application to the treatment and vitrification of hazardous, radioactive (both low- level and TRU), mixed wastes, and contaminated soils. This includes buried waste types of debris. These types of buried and stored waste are found at all DOE sites.

TECHNOLOGY NEEDS

A treatment technology is needed that can handle a wide variety of waste mixtures (radioactive and non-radioactive), significantly reduce the waste volume, and provide a stable, long-lasting, final waste form.

ACCOMPLISHMENTS

Experiments are being coordinated with other on-going and proposed melter development and final waste form evaluation projects in the DOE system, such as laboratory work at INEL, the DC arc work under way for BWID at Pacific Northwest Laboratory/Electro Pyrolysis Inc./Massachusetts Institute of Technology, plasma torch melts at Retech/Science Applications International Corporation (Ukiah, CA), Mountain States Energy (Components Development and Integration Facility at Butte, MT), the high temperature Joule Heated Melter (PNL), and others.

Test wastes were used in the first melt campaign, test data were reduced and reported, and FY94 test plans are being prepared.

COLLABORATION/TECHNOLOGY TRANSFER

University, industry, and other laboratory participants are being solicited. Since many private-sector companies are members of the present ASME test consortium, cooperative development agreements with industrial partners will be sought to expand the scope and speed completion of the demonstration project and accelerate technology transfer to the private sector.

This technology has also been developed in collaboration with the USBOM.

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2.18 LIGHT DUTY UTILITY ARM SYSTEM

TASK DESCRIPTION

The Light Duty Utility Arm (LDUA) is a remotely operated, mobile system to deploy end-effectors for waste characterization and tank inspection (see Figure 2.18). This device brings together technologies developed within multiple DOE laboratories and industry into an integrated system for providing a spectrum of storage tank characterization capabilities. The technology will enhance existing capabilities that are limited to single axis deployment of instruments into tanks. The arm will provide seven degrees of freedom with a 4.5 m (13.5 foot) reach for positioning end-effectors in multiple tank locations.

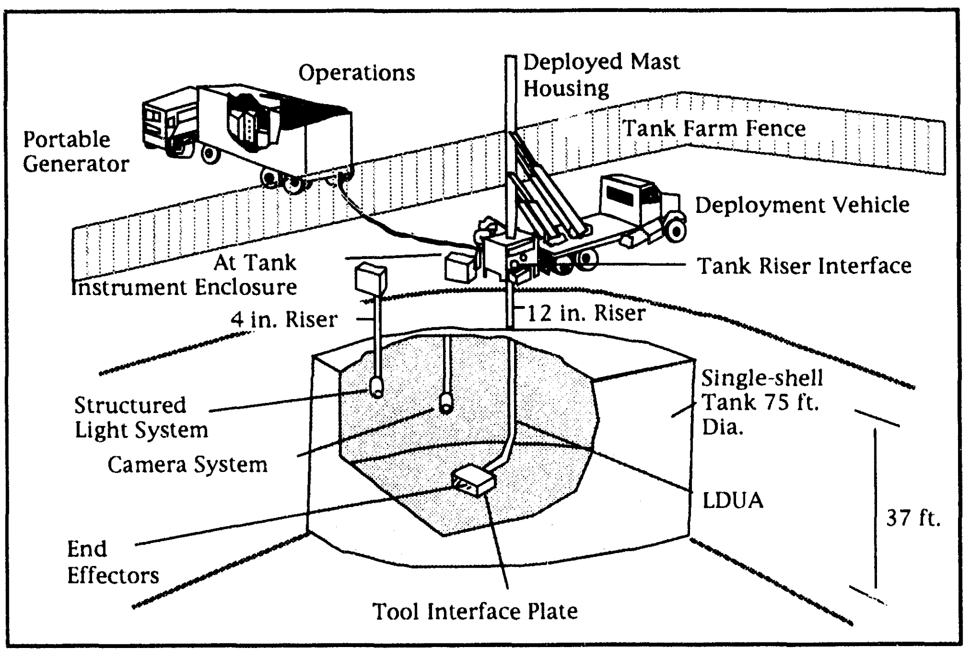

Figure 2.18. Light Duty Utility Arm System.

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

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

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

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

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

TECHNOLOGY NEEDS

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

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

ACCOMPLISHMENTS

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

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

COLLABORATION/TECHNOLOGY TRANSFER

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

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2.19 BIODENITRIFICATION

TASK DESCRIPTION

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

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

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

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

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

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

COLLABORATION/TECHNOLOGY TRANSFER

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

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2.20 PYROCHEMICAL TREATMENT AND IMMOBILIZATION OF IDAHO CHEMICAL PROCESSING PLANT HIGH-LEVEL WASTE CALCINE

TASK DESCRIPTION

This work seeks to establish the feasibility of a pyrochemical treatment for Idaho Chemical Processing Plant (ICPP) High-Level Waste Calcine. The pyrochemical treatment consists of high-temperature processing for the removal of inert materials and the electrolytic separation of the actinides and fission products in a molten metal/molten salt environment (see Figure 2.20.). The work is divided into two phases. In the first phase, the research and development needs associated with demonstrating the feasibility of the pyrochemical treatment will be established, and research and engineering programs to address these needs will be outlined. In the second phase, the technical feasibility of the process will be demonstrated, and scientific and engineering data will be provided for an integrated, small-scale demonstration. Subsequently, an integrated process demonstration will be proposed and a Demonstration, Testing and Evaluation Test Plan will be developed.

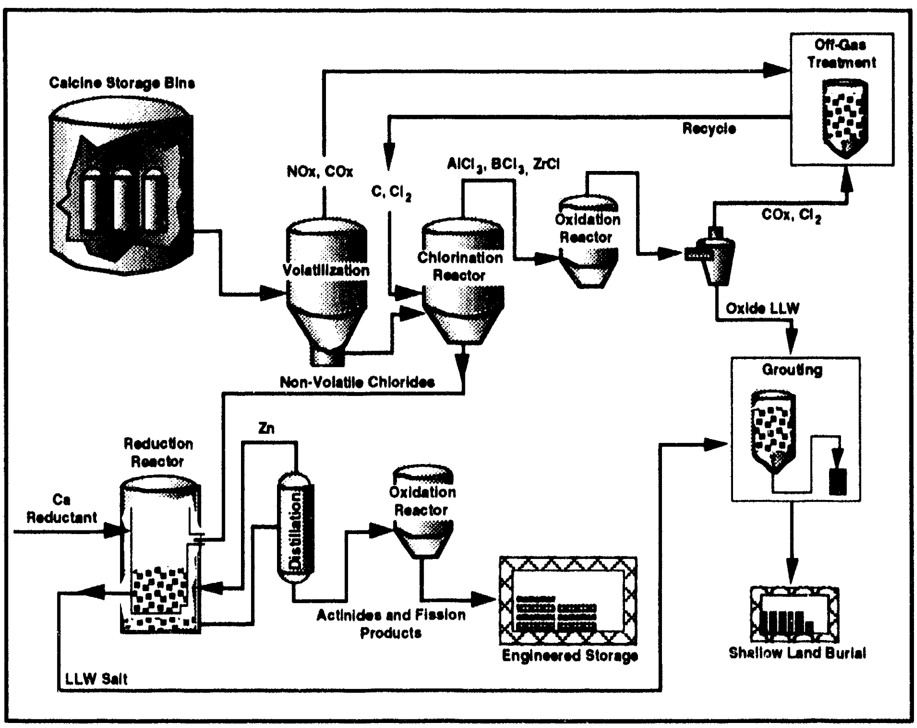

Figure 2.20. Pyrochemical Treatment of Calcine.

TECHNOLOGY NEEDS

About 3,500 cubic meters of radioactive high-level waste (HLW) calcine is currently stored at the ICPP. DOE Order 5820.2A directs that all new and readily retrievable HLW be processed and disposed of in a geologic repository according to the requirements of the Nuclear Waste Policy Act, as amended. ICPP HLW is a mixed waste and the disposal technology must be developed to support near-term relief on the Land Disposal Restriction (LDR) deadline, as well as meeting long-term LDR compliance for storage (refer to 40 CFR Part 268 and the N-Migrations Variance Petition being presently negotiated with the EPA). The State of Idaho Non-Consent Order of April, 1912 requires operation of a calciner. Storage of the resulting calcine will fall directly under Part 268, which requires further treatment using technologies to be developed.

ACCOMPLISHMENTS

The conceptual flowsheet has been revised based on slagging test results. Extensive thermodynamic calculations on calcine volatiles and chloride volatility processes have been conducted, and preliminary calcine volatiles testing on non-radioactive calcine has been completed.

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2.21. FIXED HEARTH PLASMA ARC TREATMENT PROCESS IMPROVED DESIGN TO TREAT LOW-LEVEL MIXED WASTES WITH MINIMAL WASTE STREAM CHARACTERIZATION FOR ACCEPTANCE

TASK DESCRIPTION

A fixed hearth plasma arc thermal treatment unit utilizes a DC-arc generated in a gas flowing between two electrodes. For solid materials, one electrode is the torch, while the other is the material being treated. Energy is resistively dissipated in the arc in the form of heat and light as the electric current flows through the gas between the electrodes. Joule (resistance) heating generates plasma temperatures in the gas (on the order of thousands of degrees Centigrade), which directly heats the wastes in the fixed hearth thermal treatment unit. Organics are destroyed, while metals and inorganics are melted. A vitrified (glassy) waste form is the final product of the process (see Figure 2.21).

Plasma arc thermal treatment technology is characterized by high-efficiency destruction of organics, encapsulation of heavy metals and radionuclides in the vitrified final waste matrix, maximum reduction of waste volume, low off-gas rates, and the capability of processing many waste types in a single-step process.

Under plasma arc technology development and application projects, representative surrogate waste streams will be treated in a plasma

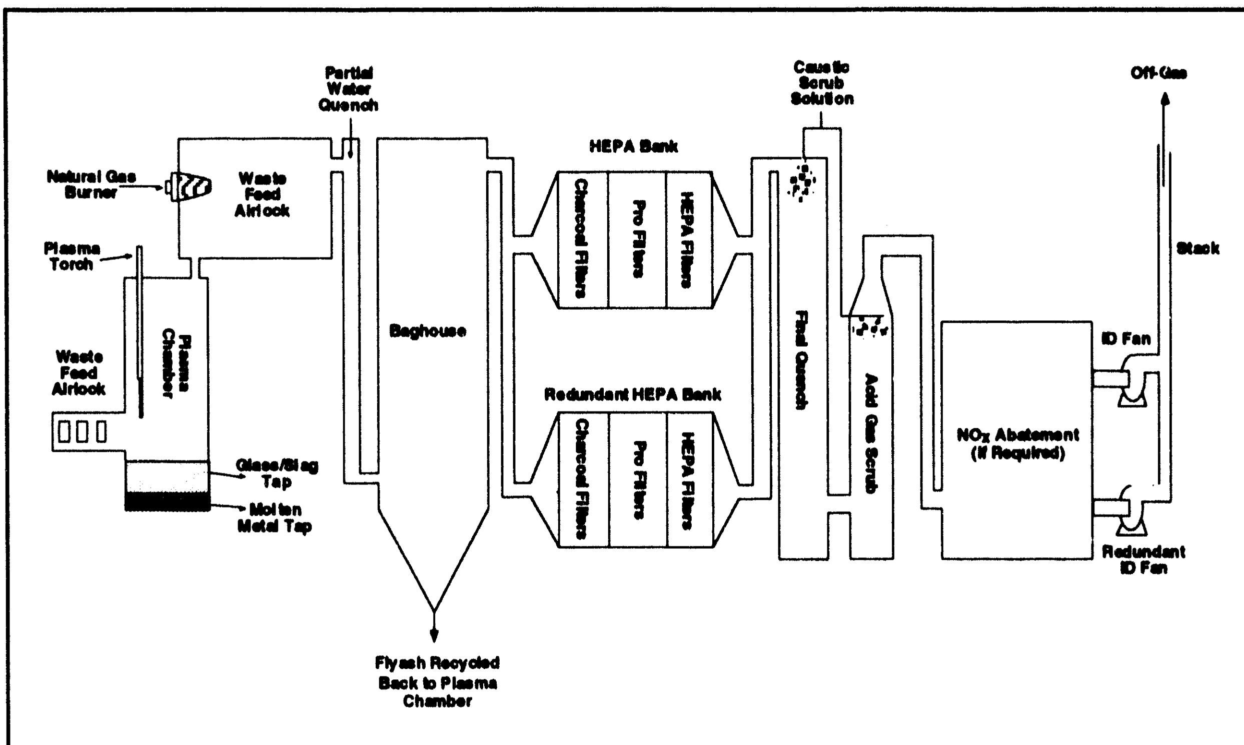

Figure 2.21. Plasma Hearth Process Prototype Design.

arc furnace to determine the applicability of the technology and any unique processing requirements. Surrogates will initially not contain radioactive components. Partitioning of radionuclide surrogates will be determined, and a design for a second generation plasma arc furnace that will safely treat mixed low-level (radioactive) wastes will be developed and tested. Waste stream characteristics which are required for processing will be determined, and the project staff will work with regulatory entities to determine the minimal characterization parameters required to meet regulatory requirements while ensuring process safety and effectiveness. Representative final (vitrified) waste forms produced by the process will be evaluated for their performance with respect to leachability, mechanical strength, integrity, and other parameters determined under the project.

TECHNOLOGY NEEDS

Waste streams under the responsibility of DOE are heterogeneous and, as a result of the conditions under which the waste streams were historically generated, are poorly characterized. Detailed characterization of these wastes would incur significant costs. Technologies are needed, therefore, that can treat wastes, meet permit requirements, and satisfy process monitoring needs, with minimal waste stream (feedstock) characterization and segregation requirements. Further, treatment technologies are needed that dramatically reduce waste volumes and that produce final waste forms that are disposable, that is, that will be accepted by a final waste disposal site.

The fixed hearth plasma arc process provides a relatively near-term solution to these technology needs. Plasma arc technology has been in industrial use for many years for metal ore smelting, metal and refractory production and recycling, and metal cutting and welding. Plasma arc thermal treatment units are commercially available for treating non-radioactive industrial and municipal wastes. The Fixed Hearth Plasma Arc mixed low-level waste treatment development project represents a relatively low-risk modification and application of a proven technology to DOE's unique low-level radiological and hazardous waste stream processing requirements.

ACCOMPLISHMENTS

Proof-of-concept test burns have been performed for materials in drums characteristic of DOE's waste streams but without the radioactive components. Wastes were effectively destroyed in the process and produced a vitrified, high-integrity final waste form.

COLLABORATION/TECHNOLOGY TRANSFER

The plasma arc process can accept a wide variety of waste types including paper, cloth, plastics, metals, glass, soil, and sludges. The ongoing projects are directed to demonstrate the application of the plasma arc process to representative surrogate waste streams. This project is a collaboration between INEL, Oak Ridge National Laboratory, Mountain States Energy, Inc. (MSE), Science Applications International Corporation and RETECH. The principal investigators on these plasma arc projects will work with the Mixed Waste Integrated Program's Program Manager (HQ/USDOE) to ensure that a high level of awareness of the capabilities of this technology is maintained in the waste treatment community, both within and external to DOE.

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Pollution Prevention

3.0 POLLUTION PREVENTION OVERVIEW

Manufacturing processes are the source of much of the generated hazardous waste within DOE, other Federal agencies, and U.S. industry. The EPA estimates that the national cost of pollution control, treatment and disposal in 1990 was almost $115 billion, with industry's share at about $73 billion.[3] The Office of Technology Assessment estimates that 99% of these costs are for end-of-pipe pollution control.[4] Recognizing that pollution prevention is the preferred alternative to end-of-pipe pollution control, DOE has established a national research program for pollution prevention and waste minimization at its production plants. During FY89/90, EM through OTD, established a comprehensive pollution prevention technical support program to demonstrate new, environmentally-conscious technologies for production processes.

DOE/EM is responsible for the dismantlement of approximately 2,000 weapons per year; requiring the treatment of approximately 230 cubic meters of components yearly. DOE estimates that a 10-fold reduction in waste volume is possible through advanced processes and technologies resulting in an annual storage cost savings of about 95 percent, from $2.8 million to $112,000. In addition, EM estimates indicate that innovative resource recovery processes could provide approximately $10 million per year through the resale of precious metals, such as silver, gold, and platinum.

EM together with other agencies and industry, is developing technological solutions to address common waste stream problems, such as chlorinated solvents, toxic metals from finishing operations, VOCs from cleaning operations, and waste acid recycle. For example, EM works closely with the electronics and electromanufacture process industry to develop processes, and their associated technologies, that reduce or eliminate the use of chlorinated fluorocarbons and chlorinated hydrocarbons. DOE estimates that it uses in excess of 180,000 liters of chlorinated hydrocarbons in the cleaning of electronic components annually. EPA estimates indicate that contaminated soil, sediment, and sludges at sites listed on the National Priorities List (those without RODs) from electronic/electrical equipment alone approach 1.5 million cubic yards.[5]

3 U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, Environmental Investment: The Cost of a Clean Environment, EPA-230-11-90-083, November 1990.

4 U.S. Congress, Office of Technology Assessment, Serious Reduction of Hazardous Waste: For Pollution Prevention and Industrial Efficiency, OTA-ITE-317, September 1986.

5 U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response Technology Innovation, Cleaning Up the Nation's Waste Sites: Markets and Technology Trends.

The Pollution Prevention program supports an integrated approach to pollution prevention and waste minimization through the development and demonstration of technologies that focus on process modifications, material substitutions, recycling and reuse, and energy efficiency in support of applicable Federal, State and local environmental regulations. Advances in this area have the potential to provide significant cost savings through efficient use of raw materials and lower costs associated with waste storage, treatment, and disposal. In addition, they have the potential to stimulate U.S. competitiveness and economic growth through the growth of a "clean" technology industry.

The Waste Acid Detoxification and Reclamation Project described in this section is one of eight projects currently funded through the Memorandum of Understanding (MOU) signed between DOE/EM and the Laboratory Commander of the Air Force Engineering Services Center in 1988. The MOU stated that the two organizations would work together to address common environmental restoration and waste management problems through joint development of mutually beneficial environmental technologies, information exchange, and interlaboratory/industrial partnerships. The program promotes the development of pollution prevention technologies, such as material substitution and advanced manufacturing techniques, to reduce or eliminate the generation of hazardous waste. Joint agency development permits leveraging of Federal funds.

The MOU covers all phases involved in industrial processes, helping to expedite future selection and implementation of the best technologies and show immediate and long-term effectiveness for DOE and USAF sites. It conducts performance comparisons of available technologies under field conditions based on effectiveness of the technology itself, risk reduction, and general acceptability.

3.1 CHLORINATED SOLVENT SUBSTITUTION PROGRAM

TASK DESCRIPTION

The objective of this program is to assist in the effective replacement of the toxic halogenated solvents currently used in DOE Defense Program facilities. Solvents and cleaners are used for removing several types of contaminants before repairing or electroplating parts. Halogenated solvents are used primarily for metal cleaning and paint stripping and pose a variety of safety and environmental problems. In addition to threatening human health, these solvents generate hazardous wastes and toxic air emissions. This program developed standardized methods to identify alternative products that are safe to both the workers and the environment, and are at least as efficient as current solvents. The program developed a mechanism to make the resulting data available to all users. Therefore, solvents are being evaluated according to various criteria, such as cleaning/stripping efficiency, corrosion, toxicity, air emissions, compatibility with nonmetals, and recyclability; and the resulting data were incorporated into an easily accessible "living" database for end users. In addition to the database, this data is maintained in a handbook that provides an efficient, easily accessible, electronic utilization database containing standardized test results for chlorinated solvent substitutes.

TECHNOLOGY NEEDS

Substitutes for chlorinated solvents are needed by DOE and the industrial community, both nationally and internationally. The need is driven by tightening environmental regulations including RCRA, CWA, and CAA. These regulations preclude the use of some chemicals and restrict the use of various halogenated hydrocarbons because of their atmospheric-ozone depleting effects, as well as their cancer-related risks. DOE and industry are facing serious pollution problems in soil, water, and air caused by the use of toxic solvents. This technology will prevent pollution from occurring and reduce the need for future environmental restoration.

ACCOMPLISHMENTS

- Tested over 300 substitute solvents and established a database to house all test data for cleaning performance and corrosion properties.
- Held the 3rd Annual International Workshop on Solvent Substitution.
- Demonstrated and evaluated prototype solvent substitution handbook with 50 test users.
- Transferred technology to Safe Solvents Testing Laboratory.

COLLABORATION/TECHNOLOGY TRANSFER

Industry participation has been obtained through three Solvent Substitution Workshops, resulting in the following industry partnerships:

- Contract agreements have been placed with DOW Chemical, National Center for Manufacturing Sciences, Hercules, EG&G, and Eastern Idaho Technical College for Student Training.

- Boeing at INEL and Pacific Northwest Laboratory are involved in collaborative research agreements.

- The technology has been transferred to Safe Solvents Testing Laboratory, a minority-owned business in Idaho Falls, Idaho. The testing lab is a business based on the software/database developed at INEL.

- The National Center for Manufacturing Sciences is interested in operating and maintaining the handbook, and combining it with other databases for use by the manufacturing industry.

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3.2 SPRAY CASTING PROJECT

TASK DESCRIPTION

This task is developing a new manufacturing and repair process to replace electroplating by applying coatings directly onto substrates, and spraying the molten coating material through a specially designed nozzle. The process utilizes a controlled aspiration process to spray liquid metal into a mold for near-net shape forming applications or on a substrate as a protective coating (see Figure 3.2). This technology has a dual application for both DOE and the USAF.

DOE's Office of Technology Development is supporting waste minimization efforts in the fabrication of special nuclear materials. This portion of the project involves spray forming various DOE components to near-net shapes. Spray forming greatly reduces the amount of waste generated during the fabrication of these components compared to existing techniques. Despite a dramatic decrease in production requirements at DOE Defense Program facilities, manufacturing needs still exist. Work is continuing to complete installation and testing of the robotics arm, fabrication and evaluation of near-net shape components, and spraying and evaluation of coatings for corrosion protection.

The USAF effort is directed at replacement of chromium electroplating as a repair/refurbishment technique on aviation parts. Chromium plating processes are being replaced by a thermally sprayed coating of equal or superior mechanical and physical properties. The coating portion of this project is being demonstrated at Robbins Air Force Base (AFB) in Warner-Robbins, Georgia. The USAF portion of the project is sponsored by the USAF Civil Engineering Support Agency at Tyndall AFB. Design and fabrication continues of pilot equipment for installation at Robbins AFB, as does verification testing of selected Air Force parts.

TECHNOLOGY NEEDS

The Spray Casting technology will avoid or eliminate waste as a result of material or process changes from existing methods, and

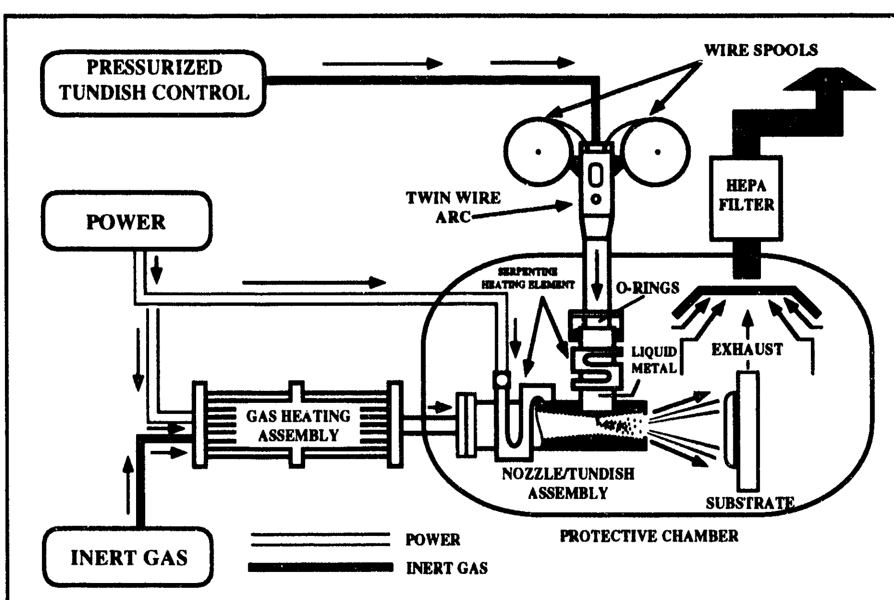

Figure 3.2. Controlled Aspiration Process.

will reduce the generation of waste material at the source. Downsizing, decontamination, and decommissioning are now becoming the focus at DOE facilities such as the Oak Ridge National Laboratory (ORNL) Y-12 Plant. Therefore, spray casting, either as a coating or for producing near-net shape parts, would be of significant value to the DOE Complex. The USAF has a basic need to replace chromium electroplating as a means of repair/refurbishment of aviation parts because hexavalent chromium, a by-product of the plating operation, is a well known carcinogen, and its safe disposal is difficult and expensive. Spray casting of thin, well-adhering, hard metallic coatings onto parts can provide a replacement process for the chromium electroplating. This requirement is directed by RCRA relative to disposal requirements for listed waste streams. Five Air Force Logistics and Service Centers generate approximately 1,000 gallons of hazardous chromium plating waste per week. Disposal costs are $2-3 million per year.

ACCOMPLISHMENTS

- Completed Wright Laboratory testing and qualification to USAF standards.
- Identified Warner-Robbins Air Logistic Center as location for technology demonstration.
- Initiated design and fabrication of pilot equipment for installation at Warner-Robbins, and initiated verification testing of selected USAF parts.
- Completed engineering evaluation of the sprayed deposit characteristics of reactive materials, specification and procurement of the robotics arm for the fabrication of near-net shape components, and initiated spraying of coatings for corrosion protection.
- Completed hardware development.
- Completed process qualification testing.
- Conducted reactivity tests using aluminum to determine how oxygen contamination in the atmosphere surrounding the spray plume might affect the as-spray product.
- Conducted surrogate alloy spraying experiments using the same spray system and monitoring system component configurations as the reactivity tests using converging/diverging nozzles to spray the surrogate alloy.

COLLABORATION/TECHNOLOGY TRANSFER

The spray casting process will be transferred to DOE Defense Program manufacturing facilities once the technology is demonstrated. The project is being developed in collaboration with MSE, Inc., DoD, and ORNL. Boeing and Wright-Patterson AFB have been involved in a test series conducted to provide an engineering evaluation of the spray process for the USAF portion of the project. Tests including chemistry, metallurgy, internal stress measurement, hardness, corrosion resistance, abrasion resistance, and adhesion strength of the sprayed coating have been performed.

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3.3 WASTE ACID DETOXIFICATION AND RECLAMATION

TASK DESCRIPTION

This project is designing, fabricating, assembling, testing, and installing a prototype acid recovery system (see Figure 3.3). It will deal with the large quantities of metal-bearing spent acids produced by electroplating, surface finishing, and chemical milling/dissolution operations common to DOE and USAF manufacturing and chemical processes. The task includes technical analysis of spent acids and chemicals, and laboratory testing of DOE, industrial, and USAF process acids. It is developing engineering design data, generating a conceptual design of a prototype system, and conducting initial testing of the prototype system at Pacific Northwest Laboratory with DOE spent acids. It is conducting demonstration testing of the prototype system at Boeing Aerospace, installation and final acceptance testing at a USAF or DOE facility, and engineering and technical support for operation of the system.

Figure 3.3. Modular Waste Acid Recovery System.

TECHNOLOGY NEEDS

Large quantities of metal-bearing spent acids are produced by electroplating, surface finishing, and chemical milling/dissolution operations common to DOE and USAF manufacturing and chemical processes. In addition, spent acids are widespread throughout U.S. private industry with over 15,000 companies generating over 8 billion pounds of metal-bearing spent acids each year. At the Los Alamos National Laboratory (LANL), ongoing milling operations of uranium metal generate 1000-2000 gallons of spent nitric, hydrofluoric, and sulfuric acids each month. Further, treating the 60 million gallons of tank waste at the Hanford site is expected to require millions of gallons of nitric and other acids that must be effectively recycled and reused.

ACCOMPLISHMENTS

- Conferred with Warner-Robbins and Oklahoma City Air Force Logistics Center, Boeing Defense and Space Group, and LANL.

- Completed collecting preliminary process information.

- Completed technology information profile.

- Conceptual design of 5-gallon per hour system in progress.

- Conceptual design for the industrial prototype has been completed and the task is on track to complete demonstration testing in FY94 with surrogate DOE acids at the Hanford site, spent acids from active plating solutions at Boeing Aerospace and final installation at Tinker Air Force Base.

- Process licensed to Viatec Recovery Systems.

- Received 1993 Federal Laboratory Consortium Award for Excellence in Technology Transfer.

- Received special recognition from *Chemical Processing* magazine's Vaaler Award program significant developments contributing to efficient, cost-effective operations in the chemical process industry.

COLLABORATION/TECHNOLOGY TRANSFER

This project is being jointly developed with DOE laboratories and private industry. Technology has been licensed in partnership with Viatec Recovery Systems to design and manufacture a acid recovery system. This project was included in a top proposal to National Technology Transfer Center in West Virginia linking Federal laboratories with private companies. Cost savings to private industry based on 100,000 gallons per year is estimated at $150,000 - $300,000 per year.

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Innovation Investment Area

4.0 INNOVATION INVESTMENT AREA OVERVIEW

The mission of OTD's Innovation Investment Area (IIA) 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-principle experimentation, and (2) already proven technologies in other fields that require critical path experimentation to demonstrate feasibility for adaptation to specific EM needs.

The underlying strategy is to ensure that private industry, other Federal agencies, universities, and DOE National Laboratories are major participants in developing and deploying new and emerging technologies. This is accomplished through substantial funding set-aside for building public and private-sector partnerships. Tools employed to achieve this include Program Research and Development Announcements, Research Opportunity Announcements, Cooperative Research and Development Agreements, Financial Assistance Awards, Interagency Agreements, and DOE National Laboratory Technical Task Plans. Activities procured through these contracting devices can be promptly moved to other RDDT&E programs that have identified the need for research and development, or to the private sector for commercialization.

This section highlights IIA activities funded through DOE's Idaho Operations Office. The Idaho PRDA solicited innovative characterization, remediation, and treatment technologies and awarded seven private-sector and university technology developers with contracts. Sections 4.5 through 4.11 provide a brief description of all seven PRDA innovative technologies.

4.1 HIGH-ENERGY DECOMPOSITION OF HALOGENATED HYDROCARBONS

TASK DESCRIPTION

The purpose of this task is to develop a technology for the treatment of polychlorinated biphenyl (PCB) containing wastes, and mixed wastes, by the application of ionizing radiation.

High-energy electron irradiation of water solutions and sludges produces a large number of very reactive chemical species, including hydrogen peroxide (see Figure 4.1). The reactive species that are formed are the aqueous electron (e^-_{aq}), the hydrogen radical ($H^\bullet$), and the hydroxyl radical ($OH^\bullet$). These short-lived intermediates react with organic contaminants, transforming them to nontoxic byproducts. The principal reaction that e^-_{aq} undergoes is electron transfer to halogen-containing compounds, which breaks the halogen-carbon bond and liberates the halogen anion. The hydroxyl radical can undergo addition or hydrogen abstraction reactions, producing organic free radicals that decompose in the presence of other hydroxyl radicals and water.

In this study, the experimental focus will be on the use of spent fuel as a gamma-ray source for PCB-waste treatment. Samples will be irradiated to gain an understanding of the mechanism and kinetics, and to provide a mass balance for thc PCB radiolysis reaction. Spent fuel will be evaluated to demonstrate the product as a cost-effective energy resource rather than a liability. Irradiation will be performed at the canal at the Test Reactor Area at INEL. Cross-check irradiation will be performed at Lawrence Livermore National Laboratory using a 9 MeV Linatron accelerator.

TECHNOLOGY NEEDS

Contamination at many DOE sites resulted from a variety of operations. PCBs are generally associated with electrical, hydraulic, and heat transfer equipment and containers. At this time, the only EPA-approved treatment method for PCBs is incineration. However, incineration results in oxidation products

$$(CH_3)_2CHOH + \gamma \rightarrow [(CH_3)_2CHOH]^\bullet$$

$$[(CH_3)_2CHOH]^\bullet \rightarrow e^-_{sol} + [(CH_3)_2CHOH]^+$$

$$[(CH_3)_2CHOH]+ \rightarrow (CH_3)_2\dot{C}OH + H^+$$

$$e^- + C_{12}H_2Cl_8 \rightarrow \dot{C}_{12}H_2Cl_7 + Cl^-$$

$$\dot{C}_{12}H_2C_{17} + (CH_3)_2CHOH \rightarrow C_{12}H_3Cl_7 + (CH_3)_2\dot{C}OH$$

$$(CH_3)_2\dot{C}OH + C_{12}H_2Cl_8 \rightarrow \dot{C}_{12}H_2Cl_7 + (CH_3)_2CO + HCl$$

Figure 4.1. Mechanism for the radiolytic decomposition of PCBs in neural isopropyl (A), and dechlorination of octachlorobiphenyl (PCB 200) as a product of isopropanol radiolysis (B).

more toxic than PCBs. Only a handful of incinerators is licensed in the United States; none are licensed to incinerate mixed wastes. The potential to remediate PCBs in situ may allow remediation of PCBs without destroying transformers or burning their oils. It is also believed that further research will demonstrate that many other organic compounds are susceptible to treatment since PCBs are very stable and yet are, themselves, susceptible.

ACCOMPLISHMENTS

- All PCB-congeners that were irradiated show the same reaction kinetics.
- Scavenger experiment supports the theory that the thermal electron is the principal active agent of PCB decomposition in irradiated, aerated solvents of widely varying dielectric constant (Table 4.1).
- Reaction occurred in transformer oil, although with lower efficiency.
- About 75% of the radiolytic degradation products could be identified.

Dose Constant	Condition
0.024 ± 0.002	Unadulterated
0.024 ± 0.006	Deoxygenated
0.023 ± 0.005	160 mg L^{-1} Benzene
0.013 ± 0.004	160 mg L^{-1} Nitrobenzene
0.005 ± 0.001	Sulfur hexaflouride sparge
0.011 ± 0.005	Nitrous oxide sparge

Table 4.1. Dose constant (kG^{-1}) for PCB 200 in isopropanol under various conditions of irradiation using ATR spent fuel.

COLLABORATION/TECHNOLOGY TRANSFER

This project was funded by DOE as part of a contract to EG&G Idaho. The project was recently completed and a final report on the outcome of the experiment was published. A second phase for technology development, focusing on a treatment process amenable to all halogenated hydrocarbon mixed wastes was recently submitted. A demonstration is proposed to be conducted at the Advanced Test Reactor spent fuel pool.

Several commercial utilities with an interest in high-energy decomposition of PCB disposal-based processes were identified and contacted to facilitate technology transfer opportunities. General Electric and McClaren Hart Environmental Engineering Corporation are currently investigating the possibility of a three-way collaboration researching the use of radioalysis to treat PCB-contaminated Hudson River sludges.

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4.2 VIDEO BAR-CODE READER

TASK DESCRIPTION

The purpose of this task is to demonstrate the feasibility of a system that reads standard bar-code labels in extremely adverse environments while meeting DOE standards.

Experimentally, the project focused on the development of a system that uses a standard video camera in combination with an IBM-compatible personal computer and a commercial video frame-grabber card. The video camera, designed for use in radiation environments, will be the only bar-code-reading system hardware in the hot cell. A commercial video frame-grabber card freezes the frames supplied by the video camera and display them on the computer screen. Special software then reads the bar code off the still picture on the monitor.

Qualification tests have indicated that the error rate for the bar code reader is less than one in 10 billion. In other words, if the device were to read a bar code every minute of every day, there would be, on average, one error every 690 years. As an added safeguard, operators will be able to watch the bar-coded information, printed in readable characters, on a closed circuit television screen.

TECHNOLOGY NEEDS

Bar coding is a desirable tool for controlling and tracking radioactive waste shipments. The technique is essential for automated scanning and computer inventorying and vastly reduces the potential for human tracking and data entry errors. Bar codes and readers represent a mature, widely-used technology, but most commercial bar code scanners and wands cannot survive in adverse environments. The system under development can sustain high doses of radioactivity and still meet DOE quality-assurance standards. It provides an economical alternative to conventional waste tracking technologies that are labor intensive, error prone, time-consuming, and could expose technicians to hazardous and radioactive health hazards.

ACCOMPLISHMENTS

- Completed development of a two-dimensional bar-code waste tracking system.
- Formed a bar code steering committee to coordinate and determine the automatic identification technology standards for DOE.
- Transferred the technology to more than 35 Federal facilities and industrial sites.

COLLABORATION/TECHNOLOGY TRANSFER

The video bar-code reader technology was developed by Ecology and Environment under a subcontract to DOE's Idaho Operations Office. Multiple requests were received from various DOE programs for integration in both environmental restoration and waste management operation activities.

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4.3 DEGRADATION OF HYDRO/HALOCARBON VAPORS BY BIOFILTRATION

TASK DESCRIPTION

The purpose of this task is to investigate the use of biofilters for the removal and degradation of hydrocarbon and halocarbon vapors.

Biofiltration is an emerging technology for the treatment of off-gases that has been used successfully for a number of applications. In a biofilter, the microorganisms grow as a thin biofilm on inert supports in the gas phase of the bioreactor. By establishing a biofilm in the gas phase, transport of gases and vapors to the microorganisms is enhanced. Upon contact with a gas or vapor stream, the microbes in the biofilm physiologically transform the contaminants (e.g., gasoline vapors, trichloroethylene vapors, etc.) in the gas or vapor stream to byproducts, such as carbon dioxide, water, and additional biomass.

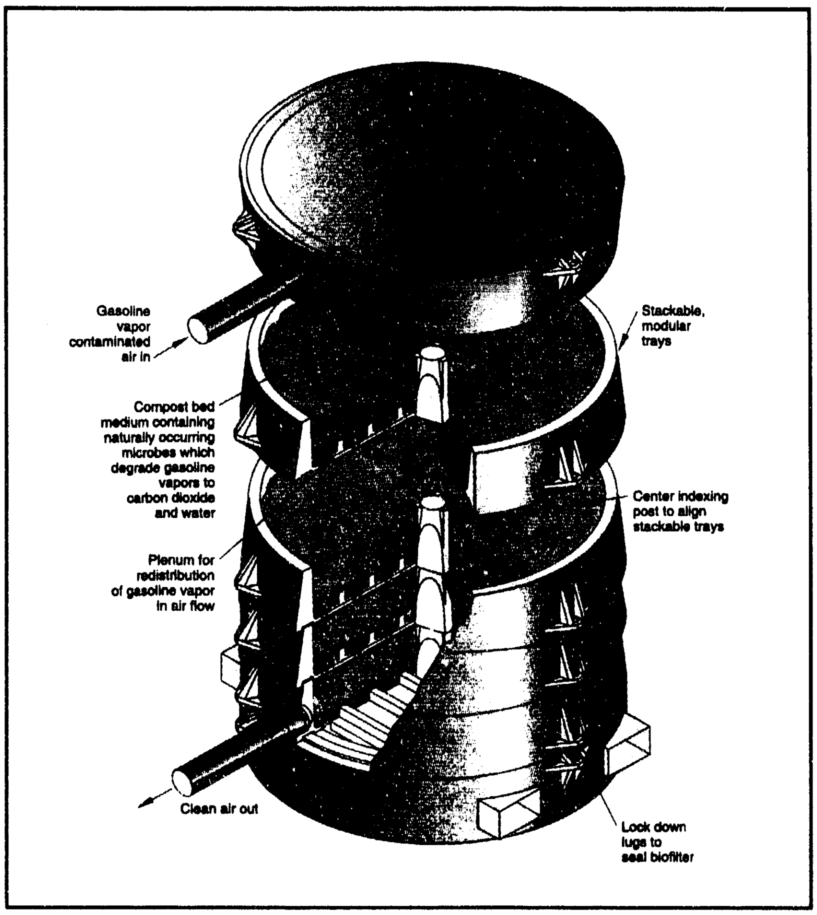

Fig. 4.3. Biofilter Module.

In this task the biofilter consists of a skid mounted, cylindrical steel vessel (see Fig. 4.3). Five stackable modular trays support 2.8 m^3 of compost-based medium containing a mixture of naturally occurring microbes capable of performing the desired bioconversion. Vapor-contaminated air enters the top of the stack and is drawn in a downflow direction through the Quadpack by means of a pressure differential generated by a regenerative blower system attached to the bottom plenum. Prior to injection into the filter, the gas stream is humidified by passage through a flow conditioner to enhance the growth of the microbes which form a thin biofilm on the surface of the bed medium, while allowing maximum gas transport to the bed. Inside the biofilter, conditions are optimized for microbial activity. There is an entry manifold in the bottom of each tray designed for even distribution of the gas stream through the filter. Sufficient water is added to the bed medium to create a soil suction of 10 centibars.

TECHNOLOGY NEEDS

DOE has a recognized need for treatment technologies targeting remediation of hydrocarbon and halocarbon-contaminated subsurface soils. Vapor vacuum extraction (VVE) technologies are becoming a preferred method for remediation of this type of contamination. Current off-gas treatment technologies consist of either sorption of the volatile vapors onto activated carbon or incineration. Both of these methods are economically unfavorable and constitute a significant portion of the operating expenses associated with a VVE system.

ACCOMPLISHMENTS

- Completed field demonstration of the Biocube aerobic biofilter for the removal of gasoline vapors in the Fall of 1992.
- Began commercial production of the Biocube® aerobic biofilter in December 1992 for degradation of hydrocarbon vapors.
- Implemented the technology at more than 100 sites throughout the U. S. for destruction of hydrocarbon vapors.

COLLABORATION/TECHNOLOGY TRANSFER

The Biocube® Aerobic Biofilter was jointly developed by INEL and EG&G Rotron as a technology for the treatment of toxic vapors contained in vacuum vapor extraction off-gases. The mechanism for this joint development was a CRADA funded by the DOE Office of Technology Development and EG&G Rotron. The Biocube, which has been commercialized by EG&G Rotron, is the recipient of a 1993 R&D 100 Award, recognizing it as one of the most technologically significant new products of the year.

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4.4 MAGNETICALLY-CONTROLLED DEPOSITION OF METAL UTILIZING GAS PLASMA

TASK DESCRIPTION

The objective of this task is to develop a process that allows controlled spraying of metal on a substrate using magneto-hydrodynamics to control the plasma/metal stream.

Magneto-hydrodynamics is a patent idea filed by the University of Idaho. It is based on the principle of using commercially-available plasma 'guns' to generate a plasma/metal stream. This plasma stream is columnated and directed using magnetic forces to the extent that items requiring precise control of the metal deposition, such as circuit boards, may be generated without waste.

Experimentally, the project will focus on the development of a model to couple fluid dynamics and magneto-hydrodynamics. To accomplish this, a set of equations will be generated that describe a stream of ionized gas and molten metal that is influenced by magnetic fields. Solution of these equations will provide the information concerning the theoretical feasibility of the process and the requirements needed to design a laboratory demonstration unit.

The demonstration unit will be built and tested to prove (or disprove) the process and validate the numerical model. A clear decision point, the completion of the analytical models, will be used to determine the theoretical feasibility of building and testing a laboratory demonstration unit.

TECHNOLOGY NEEDS

Current plasma spray techniques use a relatively uncontrolled stream of metal that is impinged on a substrate. This normally results in the deposition of copper and other heavy metals on laminated circuit boards. Future environmental problems can be prevented by minimizing the use of hazardous materials and decreasing the amount of waste that is generated. Reducing waste at the source eliminates the need for treatment, storage, and disposal. Technologies are needed to minimize hazardous waste generation and reduce energy consumption while improving operations efficiency, product performance, and safety.

ACCOMPLISHMENTS

This is a new project. No scientific accomplishments to date have been achieved.

COLLABORATION/TECHNOLOGY TRANSFER

This project is funded by DOE under a grant awarded to the University of Idaho. Graduate students under the direction of Professors Lemmon and Lancey at the University of Idaho and laboratory facilities at INEL, will be used to carry out the project. The project may require computer facilities located at

LANL to produce a numerical solution to the analytical model.

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4.5 A METHANOTROPHIC BIOFILTER FOR THE TREATMENT OF AIRSTREAMS CONTAMINATED WITH CHLORINATED HYDROCARBONS

TASK DESCRIPTION

The purpose of this task is to develop a biofiltration process for the removal of chlorinated organics from contaminated airstreams.

Biofiltration utilizes a bed packed with a moist, porous material that the microorganisms can attach to. In a biologically-active system, contaminants diffusing inward from the gas-liquid interface are simultaneously removed from the liquid layer by biodegradation.

In this study, the experimental approach will focus on the degradation of chlorinated aliphatic compounds, such as trichloroethylene (TCE), by a special group of aerobic organisms, the methane-utilizing bacteria (see Figure 4.5). Methanotrophs obtain carbon and energy from methane, converting it to methanol by the action of the enzyme methane monooxygenase. The substrate specificity of this enzyme is relatively low, allowing it to catalyze a number of co-metabolic oxidations.

The project will consist of laboratory experiments designed to develop a biofilter for the removal of TCE from wastestreams. The process will involve the incorporation of methanotrophic bacteria into the solid phase or bed of the reactor. Controlled amounts of methane and TCE will be delivered to the bacteria by means of an airstream passing through the solid phase. Bench-scale biofilter reactors will serve as a starting point for the development of the methanotroph biofilter.

Key steps in the development of the biofiltration process are the absorption of the organics into the liquid phase of the packing material and the efficient degradation of these compounds by the bacteria attached to the material. The composition of the packing material will significantly influence the absorption and degradation and must be optimized to create an efficient filter. Other parameters that must be optimized include pH, moisture content, nutrient levels, and temperature.

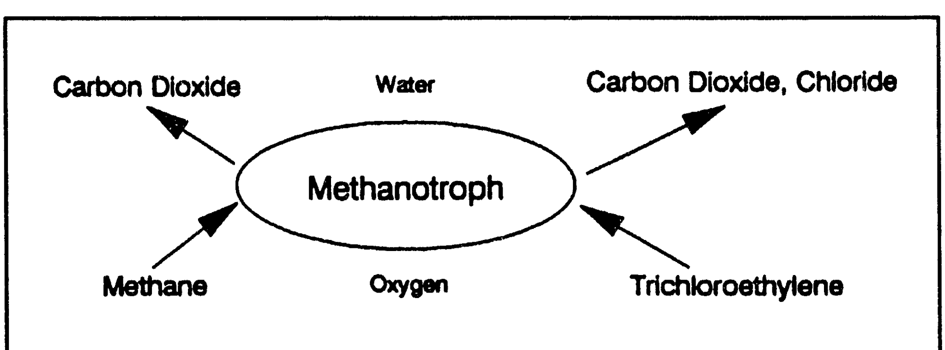

Figure 4.5. Cometabolism of trichloroethylene.

TECHNOLOGY NEEDS

The goal of a biofiltration process is to develop a cost-effective technology for remediation of airstreams contaminated with chlorinated hydrocarbons. Treatment of contaminated wastestreams is presently limited to two techniques, activated carbon adsorption and catalytic oxidation. These technologies have several limitations. Unlike the biofiltration, carbon adsorption is a nondestructive and expensive process requiring either the disposal or regeneration of the adsorbent material. Catalytic oxidation also has high operating costs, particularly when treating chlorinated compounds. A successful biofiltration process would overcome these problems by providing low-cost remediation of hazardous wastes and resulting in the production of nonhazardous end-products.

ACCOMPLISHMENTS

- Proof-of-principle experimentation was recently completed.
- Laboratory studies indicate that the biodegradation of the chlorinated ethenes by methanotrophic cultures is an oxidation by the monooxygenase.
- The degradation process does not result in the accumulation of any volatile chlorinated compounds, such as vinyl chloride, or in the accumulation of chlorinated acids or aldehydes.

COLLABORATION/TECHNOLOGY TRANSFER

This project was performed under a subcontract to ABB Environmental Services, Inc., as part of a PRDA procurement process administered out of DOE's Idaho Operations Office to solicit the collaboration of university and private sector researchers to address specific DOE applied research and development needs.

Proposals were solicited for five major areas, including site characterization, remediation, decontamination and decommissioning, waste treatment and disposal, and waste minimization. The objective was for the contractor to test the proposed technology/technique in the laboratory under conditions which closely simulate the actual environment. Upon completion of proof-of-principle experimentation, technology transfer to one or more of EM's Integrated Programs or Integrated Demonstrations will be evaluated.

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4.6 APPLICATION OF NEURAL NETWORKS TO SITE CHARACTERIZATION

TASK DESCRIPTION

The objective of this task is to develop an analytic/computational technique for characterizing nuclear waste sites.

The technique is based on the principal of artificial neural networks. In simple terms, a neural network is an interconnected collection of "units" that behave similar to neurons in the brain. Each unit receives multiple normalized input signals (activations) and generates a single output signal. The output from each unit is typically connected as inputs to other units in the network. The connections are weighted so that the output of a unit is the weighted sum of the activation signals passed through a nonlinear threshold function.

The overall goal of the project is to develop an inexpensive analytical tool that can interpolate waste concentrations and flow contours between widely spaced boreholes. To accomplish this, two different network designs will be tested: gradient descent back propagation and fully recurrent back propagation (see Figure 4.6).

The experimental approach will focus on the design of an appropriate neural network to perform simulations of the flow of hazardous waste within a site. The network will be trained with the results of numerical solutions to the convective dispersion equations that govern the transport of moisture and hazardous wastes for a model of a waste site. Such a network will then be able to perform these simulations much more quickly and at much less expense than the large numerical codes. Being faster and cheaper, it will be able to use finer grids to interpolate more accurately and extensively between fewer

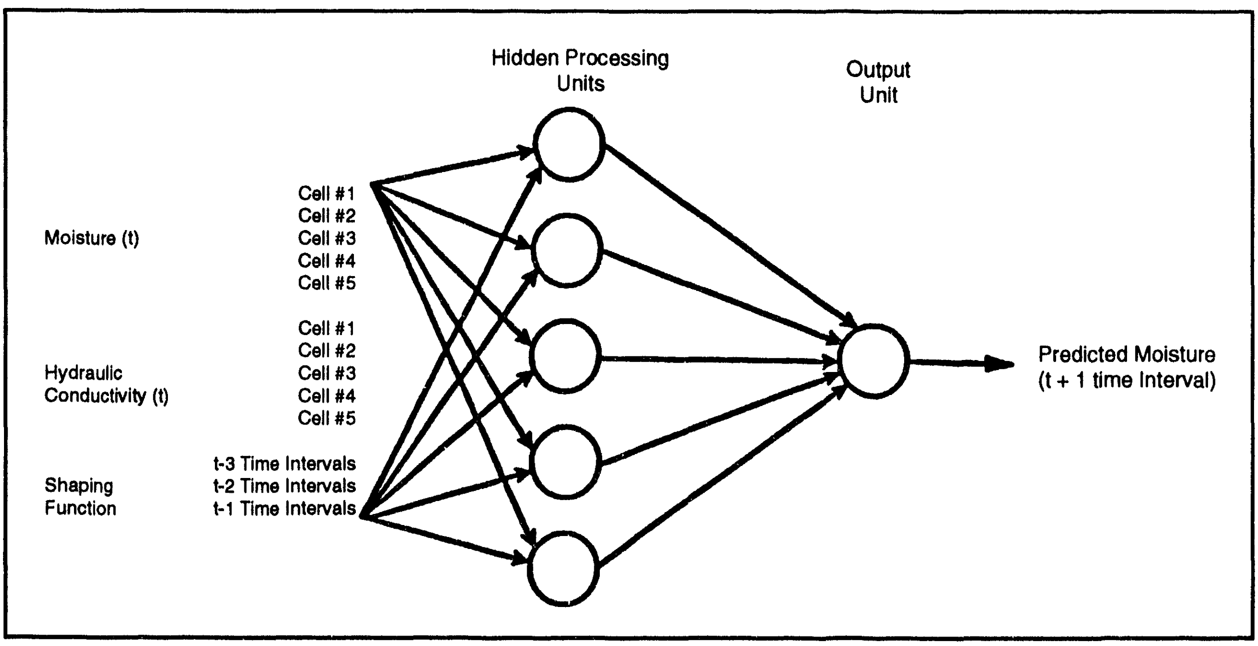

Figure 4.6. Back propagation network architecture.

boreholes, thus reducing the number of required drillings.

TECHNOLOGY NEEDS

Existing State and Federal hazardous waste regulations require all DOE sites to conduct detailed site characterizations. To ensure that these assessments are optimally conducted, improved characterization strategies are needed. Current techniques for predicting the concentrations between boreholes use finite-difference of finite-element methods to solve the convective dispersion equations that govern water and hazardous waste transport. Inaccuracies in these methods are countered by increasing data collection (more boreholes) in order to calibrate the analysis tools. Neural networks avoid these inaccuracies by "learning" from past measurements how to interpolate waste concentration and flow contours between widely spaced boreholes.

ACCOMPLISHMENTS

- The application of neural network to waste site screening was tested using data from a site located in the 200 East area of the Richland/Purex waste disposal reservation.

- Results indicate that the network trained with the fully recurrent technique show satisfactory generalization capability.

- Predicted results are close to results obtained from mathematical flow prediction models, making it possible to develop a new tool to predict the waste plume, thereby substantially reducing the number of boresites and samples.

COLLABORATION/TECHNOLOGY TRANSFER

This project was performed under a subcontract to SAIC, as part of a PRDA procurement process, administered out of DOE's Idaho Operations Office, to solicit the collaboration of the private sector and universities to address specific DOE applied research and development needs. Negotiations are currently under way between the developer of this technique (SAIC) and DOE's Characterization Monitoring and Sensor Technology Integrated Program to have the technology transferred to the Expedited Site Characterization subprogram.

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4.7 IMPROVED MEMBRANES FOR WATER REMEDIATION PROJECTS

TASK DESCRIPTION

The purpose of this task is to develop advanced membranes and membrane modules for the recovery of VOCs from contaminated groundwater by pervaporation.

In pervaporation, a dilute aqueous feed containing dissolved organic solvents is introduced into an array of membrane modules (see Figure 4.7). Organic solvents and water pass through the membrane as a vapor and, after condensation, are removed as a concentrated permeate. The purified water is removed as the residue.

Transport through the membrane is induced by maintaining the vapor pressure on the permeate side of the membrane lower than the vapor pressure of the feed liquid. This vapor pressure difference is achieved by cooling the permeate vapor to below the temperature of the feed water, causing it to condense. A small vacuum pump removes any noncondensable gases that may be present in the feed liquid.

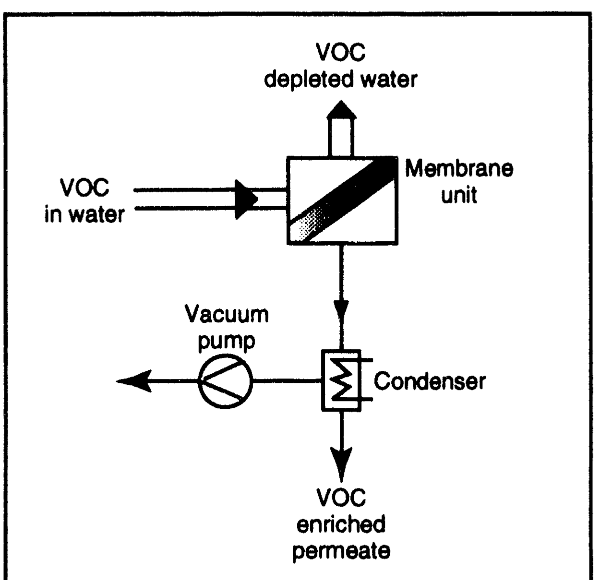

Figure 4.7. Schematic diagram of the pervaporation process.

The project will be accomplished in three phases: In Phase I, bench-scaled membrane modules for groundwater remediation will be developed and demonstrated. In Phase II, a pilot-scale demonstration pervaporation system will be constructed and operated in the laboratory. While in Phase III, the pilot-scale system will be demonstrated at a series of groundwater remediation projects.

TECHNOLOGY NEEDS

Groundwater contamination is a problem at many DOE sites. The most common organic contaminants are TCE, carbon tetrachloride (CTET) and PCE. Air stripping is the least expensive method of removing VOCs, such as these from polluted groundwater. However, increasingly stringent environmental regulations require that VOCs in the air stripper vent steam be captured or destroyed before this stream can be discharged into the atmosphere. Carbon adsorption is the method widely used to capture the VOCs. Pervaporation, a membrane-based separation technology, could replace both the air stripper and the carbon adsorption steps. Since pervaporation membranes do not contain pores, and the modules operate in crossflow modes, pervaporation units are less susceptible to fouling than other membrane processes.

ACCOMPLISHMENTS

- A novel high-flux microporous support membrane made from polyvinylidene-fluoride was developed to provide increased chemical stability and one-tenth of the resistance to flow of conventional support membranes.
- A novel composite membrane, consisting of an ethene-propene co-polymer selective layer coated onto a polyvinylidene-fluoride support membrane, was also developed.
- In pervaporation with TCE/water and toluene/water mixtures, the membrane demonstrated organic enrichments that are two-fold to five-fold better than those obtained with current commercially-available membranes.
- The newly developed membrane is especially suited for water remediation applications involving removal of chlorinated hydrocarbons and aromatic hydrocarbons with low solubility.
- Membrane separation factors of 50,000 or more were obtained with model low-concentration solutions of these solvents.

COLLABORATION/TECHNOLOGY TRANSFER

This project was awarded to Membrane Technology and Research, Inc., as part of a PRDA procurement process, administered out of DOE's Idaho Operations Office, to solicit the collaboration of the private sector and universities to address specific DOE applied research and development needs. Proposals were submitted from five major areas, including site characterization, remediation, decontamination and decommissioning, waste treatment and disposal, and waste minimization. The objective was for the contractor to test the proposed technology/technique in the laboratory under conditions which closely simulate the actual environment. Upon proof-of principle experimentation, technology transfer to one or more of EM's Integrated Programs or Integrated Demonstrations will be evaluated.

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4.8 NOVEL TECHNIQUES FOR INVASIVE SUBSURFACE BARRIERS

TASK DESCRIPTION

The purpose of this task is to evaluate the effectiveness of invasive barriers in controlling the migration of contaminants.

The technology involves injecting a latex emulsion and a reactant/coagulant solution through a series of wells into an aquifer. The latex emulsion, with polymeric particles ranging from 200 to 0.2mm in diameter and having viscosities less than 40 cp reacts with the coagulant solution to form a solid groundwater barrier around or under a contaminated site (see Figure 4.8). This barrier greatly lowers the permeability of selected regions of the aquifer.

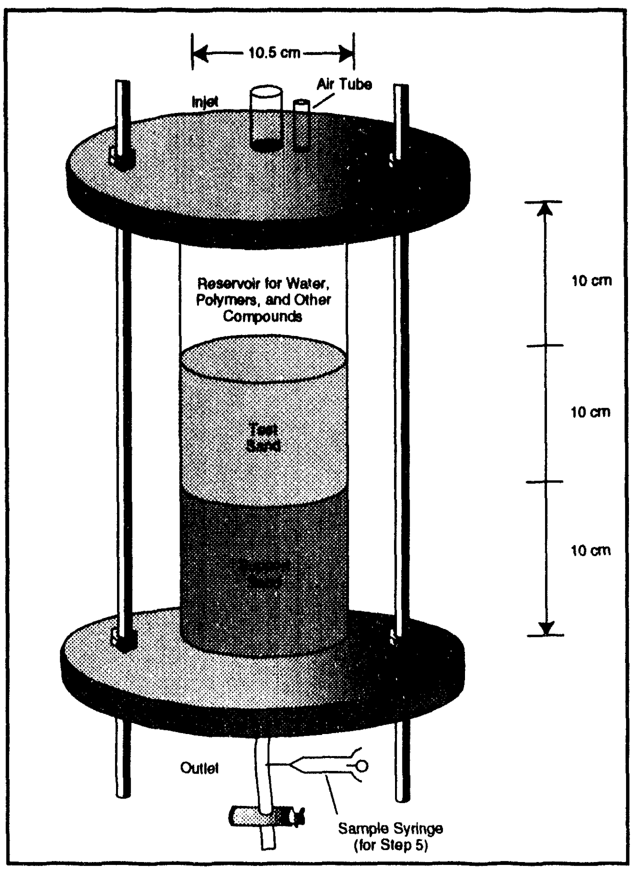

Figure 4.8. Experimental setup for qualitative and quantitative laboratory invasive barriers column experiments.

The reactant/coagulant solution is composed of polyvalent cations dissolved in water. It is anticipated that these solutions could be injected into subsurface formations using upgradient wells or boreholes. Injected polymer solutions will tend to migrate along preferential flow and highest permeability zones within the subsurface formations prior to coagulation. Groundwater will facilitate mixing of the emulsion and reactant solutions and the solid coagulant formed from the reaction will effectively block the highly transmissive pathways.

The invasive barrier technique is novel because it uses newly formulated barrier material composed of natural rubber and commonly occurring multivalent cations (e.g., Ca^{++}, Mg^{++}) in conjunction with the existing soil structure to form a barrier to groundwater flow. It can potentially form a wide barrier with potentially fewer wells than conventional slurry grouting techniques, and it can potentially place a barrier under a contaminated site without disrupting the site or generating hazardous air emissions.

TECHNOLOGY NEEDS

Large volumes of soil have been contaminated by organics, heavy metals, and radionuclides at many DOE sites. The potential for migration of these contaminants requires technologies to isolate or treat the contaminated volume. Either temporary or long-term control of contaminant mobility can significantly mitigate the potential impact of a groundwater contamination problem. Subsurface installations that control movement are difficult to emplace without excavation and construction of the barrier. A technology that does not require excavation and disposal of possibly contaminated material could provide a significant cost savings. The injection of materials from the surface which reacted in situ to form a continuous, unreactive, impermeable barrier would add substantially to the ability to control groundwater contamination problems.

ACCOMPLISHMENTS

- Proof-of-principle experimentation phase was recently completed.
- Column experiments indicate that latex polymer formulations coagulate and set-up in situ, thereby reducing aquifer permeability.
- Formulation No. 1 (Tylac 68323/Fe Cl_3) provided consistent results in terms of reductions in hydraulic conductivity of two orders of magnitude due to its very cohesive characteristics.
- Polymer gels appear to be non-toxic in both as-applied and degraded states.

COLLABORATION/TECHNOLOGY TRANSFER

This project was performed under a subcontract to the Research Triangle Institute as part of a PRDA procurement process administered out of DOE's Idaho Operations Office, to solicit the collaboration of university and private sector researchers to address specific DOE applied research and development needs. It was recently completed and a final report on the outcome of the proof-of-principle experimentation was published.

Proposals were solicited for five major areas, including site characterization, remediation, decontamination and decommissioning, waste treatment and disposal, and waste minimization. The objective was for the contractor to test the proposed technology/technique in the laboratory under conditions which closely simulate the actual environment. The contractor has recently identified a series of stops to demonstrate the technical feasibility of the latex concept. A demonstration project at a selected DOE facility (e.g., Savannah River) was listed as a potential option.

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Centimeter

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2 of 2

4.9 REMOTE FIBER-OPTIC THERMOLUMINESCENCE DOSIMETRY MONITORING SYSTEM

TASK DESCRIPTION

The objective of this task is to demonstrate the feasibility and development of a remote, fiber-optic-based radiation dosimetry system for use in radioactive waste monitoring.

The system is based on the concept of a fiber-optic monitoring system to relay underground analytical data (see Figure 4.9). This monitoring device can record doses of radiation absorbed by remote fiber-optic thermoluminescence dosimetry (TLD) probes. The probes are permanently placed in and outside of contaminated radioactive sites, aboveground or at various depths, to monitor for the presence and migration of radioactive material.

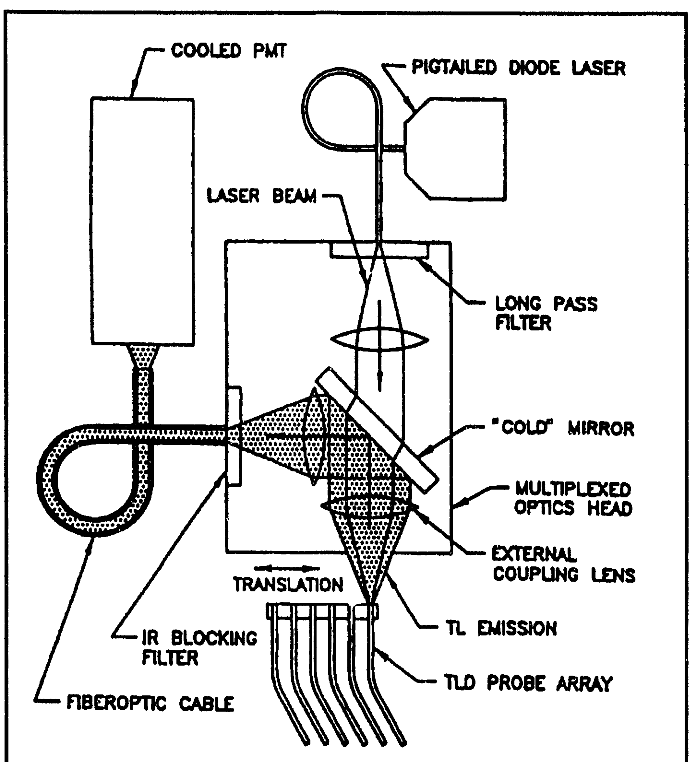

Figure 4.9. Schematic of the prototype fiber-optic probe system.

The doses absorbed over a given selected time can be measured by attaching a laser-equipped TLD-reader unit to these probes using a conventional optical fiber connector.

Experimentally, a laser heating pulse of about 1 watt of power is launched sequentially along each fiber to the remote TLD probe tip. This heats the TLD material to about 300°C resulting in thermoluminescence light emission signals that travel in the opposite direction back to the reader unit. From there the internal optical system delivers the signal to a photomultiplier tube for detection.

Generated data are read by the laser-heated TLD reader than can be mounted in a vehicle and driven to each survey point. A data management software package allows the calculation of dose rates and activity distributions for tracking of radioactive contaminant distribution and transport.

TECHNOLOGY NEEDS

The detection and long-term monitoring of groundwater for radioactive substances using current technologies requires expensive monitoring wells and the collection of samples for analysis. In addition to the labor and health and safety problems of sampling, the transport of samples to a laboratory involves greater risks and expense. The length of time between sampling and availability of results often means that the data does not represent the current situation. Technologies that would avoid physical sampling and provide immediate results on an as-needed basis would substantially improve the detection and monitoring information from groundwater contamination.

ACCOMPLISHMENTS

- A prototype dosimeter probe reader was assembled and fiber-optic TLD probes were designed for adverse environmental conditions.

- Full testing of the system was recently completed. A final report on the proof-of-principle experimentation will be published shortly.

COLLABORATION/TECHNOLOGY TRANSFER

This project was performed under a subcontract to International Sensor Technology, Inc., as part of a PRDA administered out of DOE's Idaho Operations Office process to solicit the collaboration of the private sector and universities to address specific DOE applied research and development needs.

Proposals were solicited for five major areas, including site characterization, remediation, decontamination and decommissioning, waste treatment and disposal, and waste minimization. The objective was for the contractor to test the proposed technology/technique in the laboratory under conditions which closely simulate the actual environment. Upon completion of proof-of-principle experimentation, technology transfer to one or more of EM's Integrated Programs or Integrated Demonstrations will be evaluated.

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4.10 SELECTIVE CHELATION AND EXTRACTION OF LANTHANIDES AND ACTINIDES WITH LARIAT CROWN ETHERS IN SUPERCRITICAL FLUIDS

TASK DESCRIPTION

The purpose of this task is to develop a method for the remediation of metal ions, such as lanthanides and actinides, that are a major concern in the treatment of nuclear wastes at DOE facilities.

The method is based on the combination of two advanced technologies; selective chelation and supercritical fluids extraction (see Figure 4.10). Carbon dioxide will be used in supercritical fluid extraction because of its moderate critical constants (T_c = 32°C and P_c = 73 atm), non-toxic nature, and ease to obtain in pure form. Supercritical carbon dioxide is known to be a good solvent for the extraction of organic compounds. However, direct extraction of metal ions by supercritical carbon dioxide is highly inefficient because of the charge neutralization requirement and the weak solute-solvent interactions. If metal ions are bound to organic ligands, their solubility in supercritical carbon dioxide may be significantly increased. The process involves the formation of organometallic chelates from lanthanides and actinides metals. These organic chelated complexes can then be removed from waste materials by solubilization in supercritical fluids.

Macrocyclic polyethers (crown ethers) are a new generation of chelating agents that can be used for selective separation of metal ions based on the ionic radius-cavity size compatibility concept. By modifying the crown structure with negatively charged functional groups to a macrocycle hose, the selectivity and efficiency for metal ion complexation is improved. This attached functional group can be used to differentiate cations of similar sizes with different chemical properties.

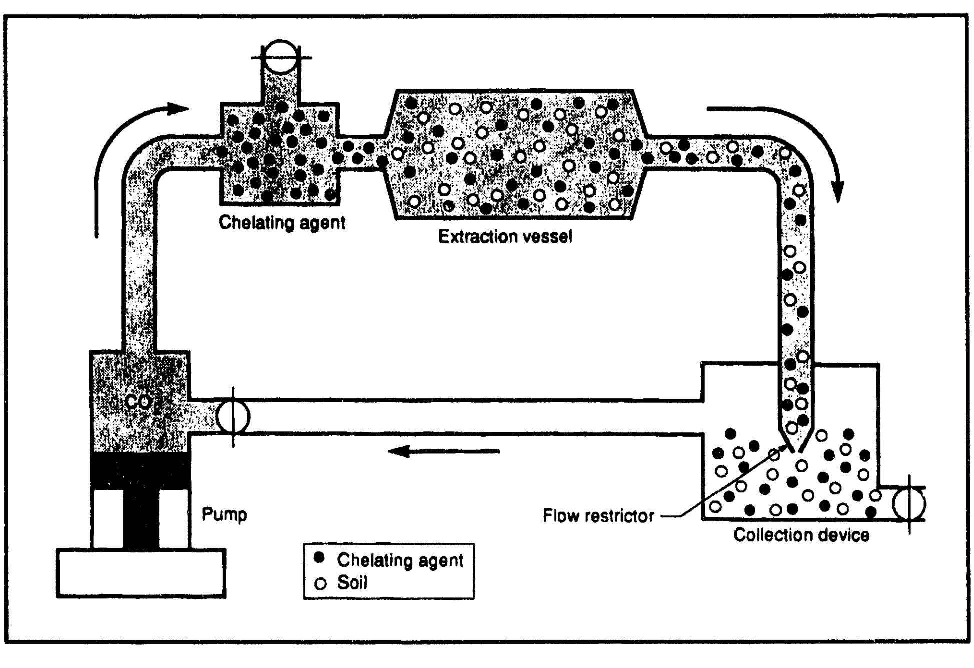

Figure 4.10. In situ supercritical fluid extraction of metal ions.

The overall goal of the research is to understand the factors controlling the complexation of f-block elements with lariat crown ethers in supercritical fluid media. This knowledge will enable design of efficient lariat crown ethers and evaluation of the application of this new extraction system forselective extraction and separation of f-block elements using supercritical fluids.

TECHNOLOGY NEEDS

Materials contaminated with hazardous components and/or radioactive isotopes constitute a major problem at many DOE sites. Separating and concentrating these constituents will allow use of existing treatment and disposal options. New techniques are needed for separation and processing of wastes containing actinides and other radioisotopes to produce stable waste forms or recyclable products and reduce waste volumes. The selective chelation and extraction of lanthanides and actinides with lariat crown ethers in supercritical fluids technology might fill that need.

ACCOMPLISHMENTS

- Proof-of-principle experimentation was recently completed and a final report on the outcome of tests was published.
- Two types of chelating agents for complexation with different metal ions in supercritical carbon dioxide were tested.
- Proton ionizable crown ethers were shown to be highly selective for complexation with lanthanides and actinides.
- Solubilities in supercritical carbon dioxide appeared to be small, in the order of 10^{-6} M.
- Fluorinated beta-diketone chelates results indicate that solubilities of the fluorinated metal chelates in supercritical carbodioxide increased by 2 to 3 orders of magnitude.

COLLABORATION/TECHNOLOGY TRANSFER

The project was performed under a subcontract to the University of Idaho as part of a procurement process, administered out of DOE's Idaho Operations Office, to solicit the input of university and private sector researchers to address specific DOE applied research and development needs. The first phase of the project was recently completed and negotiations have been initiated to transfer the technology to DOE's Efficient Separations and Processing Integrated Program.

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4.11 SONOCHEMICAL WASTE TREATMENT

TASK DESCRIPTION

The purpose of this task is to develop a new technology for the efficient and cost-effective destruction of aqueous wastes containing organic pollutants.

The experimental approach focuses on the in situ application of high-intensity ultrasonic irradiation. The project evaluates the effects of this ultrasonic energy on accelerating and improving the photodegradative process that uses photoreactive semiconductors (see Figure 4.11).

Ultrasonic irradiation provides a form of energy that can modify the chemical reactivity of some chemical processes. Power ultrasound produces its effects via cavitation bubbles. Transient cavities, produced using ultrasonic irradiation, exist briefly expanding to at least double their initial size before violently collapsing into smaller bubbles. The collapse of these bubbles can yield local pressures of hundreds of atmospheres and temperatures of thousands of degrees. Dramatic enhancements in reactivity and rates of chemical processes can arise from the process of cavitational collapse.

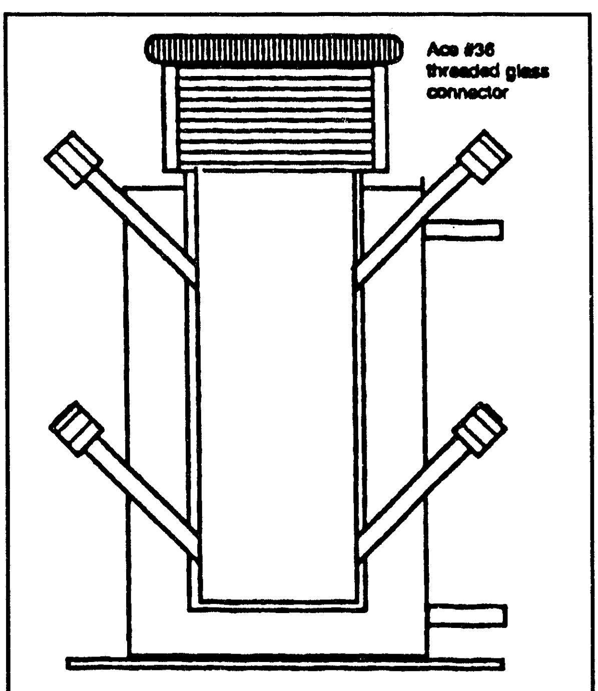

Figure 4.11. Sono-photochemical reaction cell.

Photocatalytic process involves the illumination of the semiconductor with light energy sufficient to generate conduction band electrons (e-CB) and valence band holes (h+VB). The hydroxyl and hydrogen radicals, created by the reaction of absorbed water with the electrons and holes, are generally considered to be the primary cause for the oxidative degradation of organics.

The primary objective of this research is to demonstrate the feasibility of the proposed treatment process. This will require a systematic evaluation of the effects of variables, such as ultraviolet intensity, ultrasound intensity, and catalyst loading, on the enhancement in degradation rates for model substrates. Upon successful demonstration of technical and potential economic feasibility on a laboratory scale, further efforts focusing on technology demonstration on a pilot-plant level will be required.

TECHNOLOGY NEEDS

Contamination of groundwater with organics is a problem at many DOE sites. Technologies currently exist to treat groundwater contaminated with organics. The state-of-the art is to pump-and-treat the groundwater, using either absorption on activated carbon or air stripping to treat the organic. However, treatment with activated carbon and air stripping produces residual streams that require additional treatment to destroy the organic materials. Sonochemical waste treatment might provide an efficient and cost-effective alternative.

ACCOMPLISHMENTS

- Experiments were designed and conducted to evaluate the scope of this technology.
- Degradation rates of selected pollutants were compared for ultraviolet heterogeneous photocatalysis with and without concurrent ultrasonic irradiation.
- Results appeared inconclusive with regard to comparing the rate and efficiency of organic destruction.

COLLABORATION/TECHNOLOGY TRANSFER

This project was performed under a subcontract to SRI International as part of a PRDA process, administered out of DOE's Idaho Operations Office, to solicit the collaboration of the private sector and universities to address specific DOE applied research and development needs.

Proposals were solicited for five major areas, including site characterization, remediation, decontamination and decommissioning, waste treatment and disposal, and waste minimization. The objective was for the contractor to test the proposed technology/technique in the laboratory under conditions which closely simulate the actual environment. Upon completion of proof-of-principle experimentation, technology transfer to one or more of EM's Integrated Programs or Integrated Demonstrations will be evaluated.

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5.0 ROBOTICS TECHNOLOGY DEVELOPMENT PROGRAM OVERVIEW

The Robotics Technology Development Program (RTDP) is a "needs-driven" effort. A lengthy series of presentations and discussions at DOE sites considered critical to the Department's Environmental Restoration and Waste Management (ER&WM) emphasis resulted in a clear understanding of needed robotics applications toward resolving definitive problems at the sites. A detailed analysis of the resulting robotics needs assessment revealed several common threads running through the sites: Tank Waste Retrieval, Contaminant Analysis Automation, Mixed Waste Operations, and Decontamination & Dismantlement. The RTDP Group realized that much of the technology development was common (CrossCutting) to each of these robotics application areas, for example, computer control and sensor interface protocols. Further, the OTD approach to the RDDT&E process urged an additional organizational break-out between short-term (1-3 years) and long-term (3-5 years) efforts (Advanced Technology). Therefore, RDTP is organized around these application areas with the first four developing short-term applied robotics. An RTDP Five-Year Plan was developed for organizing the Program to meet the needs in these application areas.

Each application area is coordinated by a DOE contractor at a site/laboratory chosen for its unique expertise or its situation as paradigmatic of an ER&WM problem. The coordinator leads a team of experts chosen from throughout the DOE Complex, private industry and universities: an integrated, multi-member, team approach.

The DOE Headquarters Robotics Program Manager, a DOE employee, is responsible for higher level management of the entire Program through consultations throughout ER&WM and frequent interactions with coordinators. Overall program direction, as reflected in fiscal emphasis, is a primary responsibility. Another is program integration between the several RTDP application areas, between the various OTD activities supported by the RTDP and between non-OTD offices in ER&WM. Program integration is critical for resource maximization in meeting needs. The Robotics Program Manager's function can summarily be stated as directly managing the RTDP so as to develop and demonstrate efficacious robotics systems, defined as needed by the supported programs, through a complex-wide integrated approach.

The technology development and program management approach followed by the RTDP can be expressed as:

1) TEAMS - pull together the best from DOE National Laboratories, industries and universities.

2) BROAD APPLICABILITY - focused projects to solve complex-wide problems.

3) NEEDS-DRIVEN - direct contact with sites and supported programs to build required systems.

4) EXTERNAL INTEGRATION - each part of the RTDP is directly mapped onto DOE Head quarters organization.

5) INTERNAL INTEGRATION- emphasis on solutions to common problems within the RTDP for application to supported programs.

6) NATIONAL PERSPECTIVE - address complex-wide solutions through direct manage ment by DOE Headquarters.

A brief description of each Technical Application Area appears below. For a more detailed description of the activities occurring in each of the Technical Application Areas, see the *Robotics Technology Development Program Technology Summary*, February 1994, DOE/EM-0127P.

Tank Waste Retrieval

The Tank Waste Retrieval (TWR) Team provides a cost-effective robotics technology base for retrieval of waste from underground storage tanks. Led by PNL, with contributions from ORNL and SNL, this three-laboratory Team works closely with industry and universities to meet program objectives.

The TWR Team provides enhanced research and development tools centered around a robotics test bed and a comprehensive computer-based simulation network shared among the three contributing laboratories. Retrieval-focused robotics technologies are developed by the Team and integrated as part of the test bed demonstration. The Team directly responds to technology needs identified by waste tank remediators and provides robotics technology inputs for tank remediation planning and procurements.

Contaminant Analysis Automation

LANL is the lead laboratory in the CAA coordination area. The other laboratories involved in the CAA effort include PNL, INEL, SNL, and ORNL. The CAA thrust is to address the development of technologies necessary for the automation of DOE and DOE-contract environmental laboratories. The CAA Team develops fully automated modules which perform a generic task common to analytical chemistry. The modules are chosen for their repeated use in DOE analysis methods and represent a significant fraction of sample load. The underlying theme is "plug-and-play", interface standardization, transportability, architectural openness and modularity. This effort is in response to the tremendous need for chemical characterization of soil samples, contents of storage tanks, and water samples that must take place before remediation can be initiated.

Mixed Waste Operations

The Mixed Waste Operations (MWO) Team is composed of six DOE laboratories and sites working with industry and universities to develop state-of-the-art technology to store and treat low-level and transuranic mixed wastes. The Team, led by the Savannah River Technology Center (SRTC), works closely with the Mixed Waste Integrated Program in identifying and prioritizing needs and opportunities to cleanup over 24,000 cubic meters of low-level mixed waste at DOE sites. In addition to SRTC, participants of the MWO Team include Fernald Environmental Management Site, INEL, LLNL, ORNL, and SNL. The Team develops systems for front-end handling and pre-processing of mixed waste containers and contents, plus handling of the final waste forms after processing. Automated inspection of stored waste containers is also a major aspect of the MWO group. Graphical modelling and automation of operations with graphics viewing is a key approach to facilitating operations programming.

Decontamination and Dismantlement

There are a large number of contaminated facilities including hot cells, canyons, glove boxes, and reactor facilities, at DOE sites that must eventually undergo some form of decontamination and dismantlement (D&D). As facilities transition from operational use, facility deactivation, followed by a period of surveillance and maintenance (S&M) pose many of the problems that will need to be addressed in ultimate D&D activities. Deactivation and S&M activities place emphasis on characterization, data capture, and selective D&D in order to define and minimize the risk and cost associated with possible long-term S&M activities required prior to final D&D. The overall emphasis of the D&D application area is the automation of the D&D process, from surveillance to facility characterization to surface decontamination to hot cell dismantlement to maximize efficiency while minimizing human exposure. The work centers around vehicular and crane deployed dual-arm systems using advanced sensors, control and operator interface technologies.

Cross Cutting & Advanced Technology

Several program elements within RTDP have some degree of common technology needs. These common needs, plus the increasing need for technologies that can be directly applied to faster, safer, and more cost-effective robotics systems, are the main focus of the Cross Cutting & Advanced Technology (CC&AT) Team. The CC&AT Team, coordinated by SNL, with participation by PNL, LANL, and ORNL, develops technologies used throughout the RTDP. Projects are directed toward a generic, graphics robot controller based on an integrated multisensory system plus systems analysis and modelling/simulation. Coupling of sensor-based modeling with automated programming of robot operations is a key approach to developing faster, safer, and less expensive waste clean-up systems.

[1]U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response Technology Innovation Office, Cleaning Up the Nation's Waste Sites: Markets and Technology Trends.

[2]U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response Technology Innovation Office, Cleaning Up the Nation's Waste Sites: Markets and Technology Trends.

[3] U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, Environmental Investment: The Cost of a Clean Environment, EPA-230-11-90-083, November 1990.

[4] U.S Congress, Office of Technology Assessment, Serious Reduction of Hazardous Waste: For Pollution Prevention and Industrial Efficiency, OTA-ITE-317, September 1986.

[5] U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response Technology Innovation, Cleaning Up the Nation's Waste Sites: Markets and Technology Trends.

FY94 Activities Funded through the Idaho Operations Office

OFFICE OF TECHNOLOGY DEVELOPMENT EM-50
FY94 ACTIVITIES FUNDED THROUGH THE
IDAHO OPERATIONS OFFICE
(By Program Element)

TTP NUMBER	TITLE	SITE
VOCs in NON-ARID SOILS ID		
ID121102	SOIL BIOREACTOR STUDIES	EG&GID
VOCs in ARID SOILS ID		
ID141001	ARID PASSIVE VENTING	EG&GID
MIXED WASTE LANDFILL ID		
ID141002	BOREHOLE PERMEAMETER FOR MONITORING	EG&GID
URANIUM IN SOILS ID		
ID121103	BIOPROCESSING TECHNOLOGIES FOR URANIUM-CONTAMINATED SOILS	EG&GID
CHARACTERIZATION, MONITORING & SENSOR TECHNOLOGY IP		
ID121110	IN SITU SIMS ANALYSIS	EG&GID
PROGRAM DIRECTION		
ID026001	PROGRAM DIRECTION - SALARIES AND OTHER EXPENSES	ID
PROGRAM SUPPORT		
ID025001	TPM-DETAILEE	ID
ID125001	TPM SUPPORT	EG&GID
ID145001	TECHNICAL SUPPORT - DENNIS MILLER	EG&GID
ID425001	TPM SUPPORT	WINCO
RDDT&E SUPPORT AND NEW INITIATIVES		
ID02132	STATE RESEARCH AND DEVELOPMENT GRANT	ID
ID11171	PROCUREMENT, IT	EG&GID
ID121701	REMOVAL & DEGRADATION OF HYDRO/HALOCARBON VAPORS BY BIOFILTRATION	EG&GID
FEDERAL ADVISORY COMMITTEE (DOIT)		
ID033501	WESTERN GOVERNORS ASSOCIATION	ID
ROBOTICS		
ID413203	ROBOTICS CONTAMINANT ANALYSIS AUTOMATION (WINCO)	WINCO
ID413204	ROBOTICS WASTE FACILITY OPERATIONS (WINCO)	WINCO
ID423201	ROBOTICS DECONTAMINATION & DECOMMISSIONING (INEL)	WINCO
TECHNOLOGY INTEGRATION		
ID144101	TECHNOLOGY TRANSFER NETWORK SUPPORT	EG&GID

OFFICE OF TECHNOLOGY DEVELOPMENT EM-50
FY94 ACTIVITIES FUNDED THROUGH THE
IDAHO OPERATIONS OFFICE
(By Program Element)

TTP NUMBER	TITLE	SITE
DOE/AIR FORCE MOA		
ID121301	DOE/USAF MOA SUPPORT	EG&GID
BURIED WASTE ID		
ID042001	EPA/WGA TECHNOLOGY ACCEPTANCE	ID
ID042002	USGS VETEM	ID
ID121112	INEL NON-INTRUSIVE CHARACTERIZATION STUDIES	EG&GID
ID121210	BWID CONTAMINATION CONTROL	EG&GID
ID121212	RADIOLOGICAL AND HAZARDOUS MATERIALS MEASUREMENT SYSTEM TSR	EG&GID
ID121213	BWID FIELD DEMONSTRATIONS OF CHARACTERIZATION TECHNOLOGIES	EG&GID
ID132003	BWID DIG-FACE CHARACTERIZATION	EG&GID
ID132008	BWID REGULATORY COORDINATION	EG&GID
ID132011	BWID ARC MELTER VITRIFICATION	EG&GID
ID132019	BWID GEOPHYSICS WORKSHOP	EG&GID
ID142002	REAL-TIME MONITORING OF TRU DUST	EG&GID
ID142003	IMAGING INFRARED INTERFERMOTER	EG&GID
ID142004	VERY EARLY TIME ELECTROMAGNETICS (VETEM)	EG&GID
ID142005	VIRTUAL ENVIRONMENT GENERATION OF BW REALITY	EG&GID
ID142006	WASTE CONVEYANCE FOR BURIED WASTE	EG&GID
ID142007	RETRIEVAL TECHNOLOGY - END-EFFECTOR	EG&GID
ID142008	FULL-SCALE TELEROBOTIC RETRIEVAL	EG&GID
ID142009	COOPERATIVE TELEROBOTIC RETRIEVAL	EG&GID
ID142010	MODELLING OF THERMAL PLASMA ARC TECHNOLOGY	EG&GID
ID142011	GRAVITY FIELD MEASUREMENTS	EG&GID
ID142012	IN SITU ENCAPSULATION	EG&GID
ID142013	TECHNOLOGY DEPLOYMENT	EG&GID
ID142014	INNOVATIVE GROUT DEMONSTRATION	EG&GID
ID142015	ASSAY OF CONTAMINATED SOLIDS IN BW PITS PASSIVE GAMMA	EG&GID
ID142016	DIGITAL RADIOGRAPHY	EG&GID
ID142017	AIRBORNE PLATFORMS	EG&GID
ID142018	GPR CONSORTIUM	EG&GID
ID142019	CRYOGENIC CUTTING SYSTEM	EG&GID
ID142020	MACHINE HEALTH MONITORING	EG&GID
ID142022	BWID EPA TECHNOLOGY ACCEPTANCE PROTOCOL	EG&GID
UNDERGROUND STORAGE TANKS ID		
ID121204	BIOLOGICAL DESTRUCTION OF PU NITRATE WASTES	EG&GID
ID442001	DECONTAMINATION SYSTEM & END-EFFECTORS TESTING	WINCO

OFFICE OF TECHNOLOGY DEVELOPMENT EM-50
FY94 ACTIVITIES FUNDED THROUGH THE
IDAHO OPERATIONS OFFICE
(By Program Element)

TTP NUMBER	TITLE	SITE
EFFICIENT SEPARATIONS AND PROCESSING IP		
ID421201	PYROCHEMICAL TREATMENT OF ICPP HLW CALCINE	WINCO
HAZARDOUS & MIXED WASTE DESTRUCTION IP		
ID032001	PLASMA HEARTH PROCESS RADIOACTIVE WASTE TEST	ID
ID133503	INTEG. OF INCINERATION, WASTE DISPOSAL/STA BILIZATION & AIR PC	EG&GID
ID142001	FIXED HEARTH PLASMA TREATMENT PROCESS	EG&GID
ID142021	TLD SUPPORT FOR MIXED WASTE	EG&GID
OTHER TECHNOLOGIES - WASTE RETRIEVAL		
ID132009	TECHNOLOGY LOGIC DIAGRAMS	EG&GID
ID133506	RECYCLE OF DEPLETED URANIUM STUDIES	EG&GID
SUPERCRITICAL WATER OXIDATION		
ID021102	SUPERCRITICAL WATER OXIDATION (MODEC)	ID
ID121217	SUPERCRITICAL WATER OXIDATION (SCWO) DEMONSTRATION PROGRAM	EG&GID

How to Get Involved

7.0 HOW TO GET INVOLVED WORKING WITH THE DOE OFFICE OF ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

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

Cooperative Research and Collaborative Agreements (CRADAs)

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

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

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

Procurement Mechanisms

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

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

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

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

EM awards grants and cooperative agreements if 51 percent or more of the overall value of the effort is related to a public interest goal. Such goals include possible non-DOE or other Federal agency participation and use, advancement of present and future U.S. capabilities in domestic and international environmental cleanup markets, technology transfer, advancement of scientific knowledge, and education and training of individuals and business entities to advance U.S. remediation capabilities.

Licensing of Technology

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

Technical Personnel Exchange Assignments

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

Consulting Arrangements

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

Reimbursable Work for Industry

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

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

EM Small Business Technology Integration Program

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

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

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EM Central Point of Contact

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

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

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

Office of Research and Technology Applications (ORTAs)

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

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

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8.0 ACRONYMS

AFB	Air Force Base
ASME	American Society of Mechanical Engineers
BBEM	Broad Band Electromagnetics (Demonstration)
BCHP	Brayton Cycle Heat Pump
BWID	Buried Waste Integrated Demonstration
CCU	Contaminated Control Unit
CRADA	Cooperative Research and Development Agreements
CTET	carbon tetrachloride
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
EDTA	ethylenediamine tetraacetate
EM	Environmental Management
EPA	U.S. Environmental Protection Agency
HEPA	High-Efficiency Particulate Air (Filter)
HLW	High-Level Waste
IAG	Interagency Agreements
ICPP	Idaho Chemical Processing Plant
ID	Integrated Demonstration
INEL	Idaho National Engineering Laboratory
IP	Integrated program
IR	infrared
ITMS	Ion Trap Mass Spectrometer
LANL	Los Alamos National Laboratory
LDR	Land Disposal Restriction
LDUA	Light Duty Utility Arm
LLW	Low-Level Waste
M&O	Management and Operating (contractor)
MOU	Memorandum of Understanding
MSE	Mountain States Energy, Inc.
NPL	National Priorities List
ORNL	Oak Ridge National Laboratory
ORTA	Office of Research and Technology Applications
OTD	Office of Technology Development
PCB	polychlorinated biphenyl
PNL	Pacific Northwest Laboratory
PRDA	Program Research and Development Announcements
RCS	Remote Characterization System
RDDT&E	Research, Development, Demonstration, Testing, and Evaluation
RES	Remote Excavation System
RGS	Rapid Geophysical Survey

ROA	Research Opportunity Announcement
ROD	Record of Decision
RTDP	Robotics Technology Development Program
RTML	Rapid Transuranic Monitoring Laboratory
RWMC	Radioactive Waste Management Complex
SBIR	Small Business Innovation Research
SB-TIP	Small Business Technology Integration Program
SCWO	Supercritical Water Oxidation (Program)
SEE	Small Emplacement Excavator
SIMS	Secondary Ion Mass Spectrometry
SITE	Superfund Innovative Technology Evaluation
TBP	tributyl phosphate
TCE	tricholorothylene
TLD	thermoluminescence dosimetry
TMG	Tensor Magnetic Gradiometer
TRU	transuranic (waste)
TTP	Technical Task Plan
USAF	U.S. Air Force
USBOM	U.S. Bureau of Mines
VOCs	Volatile Organic Compounds

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