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Office of Environmental Management

Office of Technology Development

Albuquerque Operations Office
Albuquerque, New Mexico

Technology Summary

August 1994

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ALBUQUERQUE 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 Albuquerque 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 the following:

Volatile Organic Compounds in Non-Arid Soils Integrated Demonstration, February 1994 - DOE/EM-0135P
Volatile Organic Compounds in Arid Soils Integrated Demonstration, February 1994 - DOE/EM-0136P
Mixed Waste Landfill Integrated Demonstration, February 1994 - DOE/EM-0128P
Uranium in Soils Integrated Demonstration, February 1994 - DOE/EM-0148P
Characterization, Monitoring, and Sensor Technology Integrated Program, February 1994 - DOE/EM-0156T
In Situ Remediation Integrated Program, February 1994 - DOE/EM-0134P
Buried Waste Integrated Demonstration, February 1994 - DOE/EM-0149P
Underground Storage Tank 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
Rocky Flats Compliance Program, February 1994 - DOE/EM-0123P
Pollution Prevention Program, February 1994 - DOE/EM-0137P
Innovation Investment Area, March 1994 - DOE/EM-0146P
Robotics Technology Development Program, February 1994 - DOE/EM-0127P

For more information on activities funded through the Albuquerque Operations Office or its affiliated laboratories, please contact:

PAMELA A. SAXMAN
Technical Program Manager
Albuquerque Operations Office
(505) 845-6101

INTRODUCTION

DOE's Office of Technology Development

DOE's Environmental 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 effective technologies available for transfer to users through progressive development. 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 technologies address three specific 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, 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 in the area of robotics. The Robotics Technology Development Program (RTDP) is a "needs-driven" effort. RTDP program activities are funded through most of the DOE Operation 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.

Albuquerque's Contributions

The Manhattan Project during World War II brought together scientists, engineers, and technicians at Los Alamos, New Mexico, to produce the world's first atomic bombs. Started in 1943, the Los Alamos effort led to the nationwide laboratory and industrial complex of DOE. The Albuquerque Operations Office (DOE-AL) was formally established in 1956. DOE-AL has been part of three federal agencies: the Atomic Energy Commission until January 1975; the Energy Research and Development Agency from 1975 to 1977; and DOE since October 1977.

Located on Kirtland Air Force Base, in Albuquerque, New Mexico, DOE-AL oversees environmental restoration and waste management activities at eight sites: the Kansas City Plant, near Kansas City, Missouri; Los Alamos National Laboratory, northwest of Santa Fe, New Mexico; the Lovelace Inhalation Toxicology Research Institute, Albuquerque, New Mexico; Sandia National Laboratories, in Albuquerque, New Mexico and Livermore, California; the Grand Junction Project Office, Grand Junction, Colorado; the Pantex Plant, near Amarillo, Texas; and the Pinellas Plant, north of St. Petersburg, Florida.

DOE-AL contributes to the welfare of the nation by providing field-level federal management to assure effective, efficient, safe and secure accomplishment of DOE's national defense, environmental quality, science and technology, technology development, technology transfer and commercialization, and national energy objectives. DOE-AL facilities will continue to have an important role is helping U.S. industry to compete more effectively as a part of the global market in the near-term and also to meet its need for long term research. DOE-AL fosters teamwork among all technology sectors—university, industry, and government—to expedite transfer of new technologies into practical solutions for critical problems.

Mixed Waste Landfill Integrated Demonstration

Sandia National Laboratories' chemical waste landfill received chemical hazardous waste from 1962 to 1985. Its mixed waste landfill received hazardous waste and radioactive wastes from 1959 to 1988 from various Sandia nuclear research programs. Both landfills are now closed. The Kirtland Air Force Hazardous and Solid Waste Amendments (HSWA) site, operated from 1960 to 1973 by the Air Force Weapons Laboratory, received waste from radiobiological experiments.

Originally, these sites were selected for disposal purposes because of Albuquerque's arid climate and thick layer of sediment deposits that overlay the groundwater 480 feet below the landfills. The thick layer of dry soils, gravel, and clay acted as a natural barrier between the landfills and groundwater. Today we know that additional precautions are necessary to ensure safe disposal. For example, the chemical waste landfill did not have a liner system to impede contaminant migration or instrumentation to monitor its migration under the landfill. Now, all landfills must be designed with such advanced technology. The contamination that has been detected below these landfills must be characterized, remediated, and monitored.

Sandia's landfills have been selected as demonstration sites because they are representative of many landfills sited throughout the southwest and other arid climates. The Mixed Waste Landfill Integrated Demonstration is assessing, demonstrating, and transferring technologies and systems that will lead to faster, better, cheaper, and safer in situ or in-place characterization, monitoring, remediation, and containment of these types of landfills.

Robotic Systems for Underground Storage Tank Cleanup

Hazardous waste cleanup requires systems that not only retrieve the waste but monitor its condition, ensure environmental and personnel safety, meet changing regulatory requirements, and are affordable. At Sandia National Laboratories, the Intelligent Systems and Robotics Center (ISRC) is developing key automation technologies which integrate computer-based intelligence with machines to perform operations faster, safer, and more economically than conventional approaches.

The waste in underground storage tanks (USTs), such as those in Hanford, Washington, represent a significant clean up problem for the DOE. The Hanford site alone has 149 USTs with a total inventory of waste estimated to be more than 37 million gallons. The radioactive waste, ranging in consistency from thick sludge to liquids, must be removed since some of the tanks are leaking. To assist UST cleanup, Sandia researchers developed a Genetic Intelligent System Control (GISC) for the DOE Robotics Development Program. This system integrated sensors, mechanisms, and software into robot operating systems. The goal was to deliver waste mobilization and removal technologies safely and quickly to the interiors of the tanks. A laser-based system was also designed to map the surface of the waste and locate large objects.

Sandia staff have integrated GISC information with robot prototypes to construct computer models of the entire robot work space and to automate waste removal operations. The GISC-based control system allowed a multi-laboratory team which include Westinghouse Hanford Company, Idaho National Engineering Lab, Pacific Northwest Lab, Oak Ridge National Lab, Lawrence Livermore National Lab, and Sandia to merge component technologies developed at individual laboratories into a functioning robotic system.

Sandia researchers have developed laser-based mapping to measure the in-tank waste surface contour of large above-ground waste storage silos at the Fernald Environment Management Project (FEMP), near Miamisburg, Ohio. This information assisted DOE in its efforts to apply a clay cap on the storage silos in order to reduce radon gas releases. Accurate measurements met EPA requirements, eliminated the need to add excess materials, and enabled FEMP remediation milestones to be completed on time.

High-Gradient Magnetic Separation

Los Alamos National Laboratory, in conjunction with its industrial partner Lockheed Environmental Systems and Technology Co., is exploring a promising new technique to remove radioactive contaminants from soils. The technique, high-gradient magnetic separation (HGMS), takes advantage of the fact that all actinide compounds are slightly magnetic. Much of the contaminated soil contains plutonium and uranium oxide particles; these slightly magnetic particles are attracted by very strong magnetic fields and thus can be separated from the mostly nonmagnetic soil. The availability of reliable superconducting magnets, which create very strong magnetic fields, make HGMS an attractive method for extracting actinide contaminants.

Preliminary experiments with magnetic surrogates and modeling of the process have yielded encouraging results. Contaminated soil samples from DOE sites are now being tested, and the partners are planning the process for full-scale site remediation.

Electron-Beam Accelerator

Electron-beam accelerator employing electromagnetic radiation to alter molecular structural properties has many potential technological applications. It can be utilized to destroy hazardous and radioactive waste, to process food, to sterilize medical waste or to disinfect drinking water and sewage.

Researchers at Los Alamos National Laboratory have built a pulsed electron-beam accelerator that could deliver more electron-beam energy per unit volume of water. The beam has 1.5 million volts of energy and each pulse lasts about 100 nanoseconds. Studies on the laser probe with the electron-beam accelerator will be conducted to determine chemical reactions during the treatment process for different types of waste.

The pulsed beam will allow separation of treatment process into two phases. In the first phase, free radicals are produced when the electrons react with the water molecules. In the second phase, the free radicals react with organic contaminants to generate nonhazardous substances such as carbon dioxide, water and salt. Researchers at Los Alamos believe it may be possible to use electron-beam technology with nuclear waste treatments to dispose of mixed waste.

Underground Storage Tank Integrated Demonstration

Hanford's 177 underground storage tanks (USTs) were built to store by-products of the nuclear production process that supplied plutonium for the Nation's nuclear weapons program. The steel lined, concrete tanks are up to 75 feet wide and 32 feet high and contain 55,000 to one million gallons of waste. They are buried in the ground and are covered with 5 to 12 feet of earth. The tanks are now 30 - 50 years old. Of 149 older, single-shell tanks, 67 have shown signs of leaking. None of the double-shell tanks are leaking. The project is focusing on a number of high-profile tanks that present safety issues. Several tanks periodically vent flammable or noxious gases.

Hanford serves as the host site for this demonstration. Program elements include waste characterization, waste retrieval and conveyance, waste separation and pretreatment, low-level waste treatment and disposal, and site closure. Scientific research and technology development funded by EM-50 could save taxpayer dollars in cleanup of waste tanks at Hanford and ultimately the tanks throughout the DOE Complex.

Volatile Organic Compounds in Arid Soils Integrated Demonstration

Integrated demonstrations are part of DOE's innovative program to speed up development and testing of new technologies for cleaning up hazardous and radioactive wastes. The VOC in Arid Soils ID focuses on technologies to clean up VOCs and associated contaminants in soil and groundwater at arid sites.

The initial host site is located at Hanford's 200 West area.

The primary VOC contaminant is carbon tetrachloride, in association with heavy metals and radionuclides. An estimated 1,000 tons of carbon tetrachloride were disposed of at Hanford between 1955 and 1973, resulting in extensive soil contamination and a groundwater plume that extends more than seven miles.

The VOC in Arid Soils ID is demonstrating technologies in five major areas: (1) site characterization; (2) retrieval and ex situ treatment of contaminants; (3) in situ destruction or immobilization of contaminants; (4) remediation system design and evaluation; and (5) enhanced drilling. This ID is linked directly to an Expedited Response Action, a cleanup effort that focuses on rapid removal of carbon tetrachloride from the soil. A top priority is transferring new technologies to meet the needs of other arid sites. Success will be the transfer to industry of technologies that are ready for immediate use.

In Situ Remediation Integrated Program

The In Situ Remediation Integrated Program was instituted out of recognition that in situ remediation could fulfill three important criteria:

- Significant cost reduction of cleanup by eliminating or minimizing excavation, transportation, and disposal of wastes.
- Reduced health impacts on workers and the public by minimizing exposure to wastes during excavation and processing.
- Remediation of inaccessible sites, including:
  - deep subsurfaces.
  - in, under, and around buildings.

Buried waste, contaminated soils and groundwater, and containerized wastes are all candidates for in situ remediation. Contaminants include radioactive wastes, volatile and non-volatile organics, heavy metals, nitrates, and explosive materials. The ISR-IP intends to facilitate development of in situ remediation technologies for hazardous, radioactive, and mixed wastes in soils, groundwater, and storage tanks. Near-term focus is on containment of the wastes, with treatment receiving greater effort in future years.

Efficient Separations and Processing Integrated Program

DOE sponsors research and development in advanced radiochemical separations to reduce the volume of high-level waste that must be disposed of in deep geological repositories, and to cut the toxicity and volume of low-level acceptable for near-surface disposal. These research and development activities are sponsored throughout the DOE Office of Technology Development ESPIP. ESPIP also develops separation processes to extract high-value materials and non-radioactive hazardous components form nuclear waste and will transfer separations processing to commercial markets.

ESPIP research and development activities are designed to remove radionuclides and hazardous material and chemicals from radioactive defense waste. Radionuclides and other materials under consideration for separation include transuranic elements, such as neptunium, plutonium, americium, and cerium, highly radioactive elements (Strontium-99 and Cesium-137), and long-lived soluble fission products, including technetium-99 and iodine-129. Separation processes will also be developed to extract the long-lived soluble activation product carbon-14; aluminum, phosphorous, and chromium, and the elements that degrade borosilicate glass waste forms; the strategic metals rhodium, palladium, and ruthenium; and Resource Conservation and Recover Act (RCRA) elements and compounds.

The program oversees efficient separations research and development for DOE sites. Current priorities are the cleanup of high-level waste in USTs at Hanford Production Operation, Hanford, Washington, and the cleanup of high-level waste at Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho. Many of the technologies developed for high-level waste will be applicable to other waste streams throughout the DOE Complex and ESPIP will transfer technologies as appropriate.

Tank Waste Retrieval Robotics Test Bed

Emptying the USTs is a technically challenging task made difficult because of the hazardous nature of the tank contents. This waste material is chemically complex and includes physical forms ranging from thick, sticky sludge to a crystalline saltcake. The sludge has a consistency of soft mud and the saltcake approximates low-grade concrete. Most of the tanks also contain small amounts of liquid.

PNL, Oak Ridge National Laboratory (ORNL), and Sandia National Laboratory (SNL) are working together with the OTD to develop an advanced robotics retrieval system that will use robots - remote manipulators to get into the tanks to break up and remove the sludge and solidified waste. Since the project is technically complex, and because hazardous materials are involved, the development team is creating a full-scale, realistic mockup of the tank structure.

The facility, located at Hanford, will be used to test and fine tune all major subsystems of tank retrieval robotics using harmless simulated waste forms. The facility will use a 75 by 100-foot wide self-supporting platform that sits over the ground surrounding the underground tank. The platform supports the "long reach manipulator," a robotics arm that positions and operates waste-dislodging tools within the waste storage tank. Researchers hope to start using the test bed facility in 1994, with plans for it to become fully operational in 1996.

The project has several important objectives: (1) to explore the capabilities of retrieval manipulator systems and acquire data necessary to develop specific remediation equipment and techniques; (2) to provide performance guidelines for large manipulator-based retrieval systems; (3) to improve the productivity and safety of such systems by first using them in a non-hazardous environment; and (4) to reduce costs for long-term national remediation requirement. Developers expect lessons learned from this testing to have applications to nuclear waste sites throughout the country.

Groundwater and Soils Cleanup Overview

Section 1.0

1.0 GROUNDWATER AND SOILS CLEANUP OVERVIEW

Some of the most pressing environmental restoration needs for DOE involve cleanup or containment of radioactive and hazardous contaminants (including heavy metals and toxic organic compounds) in soils and groundwater. Sources of this contamination 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. EM soils and groundwater programs are designed to identify, develop, and demonstrate innovative technology systems capable of removing or reducing potential health and environmental risks resulting from these previous storage and disposal practices.

Volatile Organic Compound (VOC) contamination of soils and groundwater is one of the most common environmental problems in the United States and the DOE Complex. When VOCs are released into the soil, they rapidly migrate throughout the environment, forming large plumes that eventually result in contaminated groundwater. Two of the more prominent examples of VOC contamination can be found at the Savannah River Site (a non-arid environment) where there is a plume larger than three square miles; and at the Hanford Site (an arid site), where an eleven square kilometer mile plume resulted from the disposal of an estimated 580-920 metric tons of carbon tetrachloride between 1955 and 1973. Over 220 sites with similar contamination have been identified in arid environments within the DOE Complex. Add radioactive contamination to these hazardous constituents and the result is a DOE problem for which few adequate remediation solutions exist. 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.

Also prevalent throughout the DOE Complex is the contamination of surface soils with heavy metals resulting form weapons assembly and testing processes during weapons production. At the Nevada Test Site, over 5-square miles of soil is contaminated with plutonium. Cleanup of this area will require the treatment of approximately 25 million cubic feet of soil. Five other DOE sites have similar plutonium contamination problems and eight other DOE sites have identified problems associated with uranium-contaminated soils. At Fernald near Cincinnati, Ohio, 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 (m^3) 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 of surface water and groundwater.

The contaminants discussed above exhibit high concentration levels, high mobility, and high toxicity, as well as long-term persistence in the environment. For these reasons they represent some of the highest 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.

One of the biggest challenges facing DOE is effective characterization of contamination in soil and groundwater. Characterization must take place before a contaminated site can be properly prioritized for remediation. To accomplish this, non-invasive, field-deployable methods are being developed that are capable of mapping vast areas at depths up to 250 feet below ground level. Results are three-dimensional images that are valuable tools for proper selection and placement of remediation technologies.

The necessity to develop innovative technologies for characterization and treatment of groundwater and soils is not unique to DOE. Other Federal agencies, as well as private industry, are in need of improved methods for these types of cleanup. The EPA has identified 1,235 sites with sufficient contamination to place them on its 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, EPA established the Superfund Innovative Technology Evaluation (SITE) program. DoD is responsible for clean up of its facilities contaminated as a result of training, industrial, or research activities. As of September 1991, DoD 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 works with the EPA SITE, and DoD programs in a joint effort to expedite remediation of groundwater and soils contamination.

1.1 IN SITU PERMEABLE FLOW SENSOR

TASK DESCRIPTION

This in situ flow sensor technology uses a thin cylinder heater buried vertically in the ground at the point where the groundwater flow is to be measured (see Figure 1.1). The temperature distribution over the surface of the cylinder will vary as a function of the magnitude and direction of the groundwater flow past the cylinder. In the absence of any flow past the device, the temperature on the surface of the probe will be independent of azimuth and symmetric about the vertical midpoint of the probe.

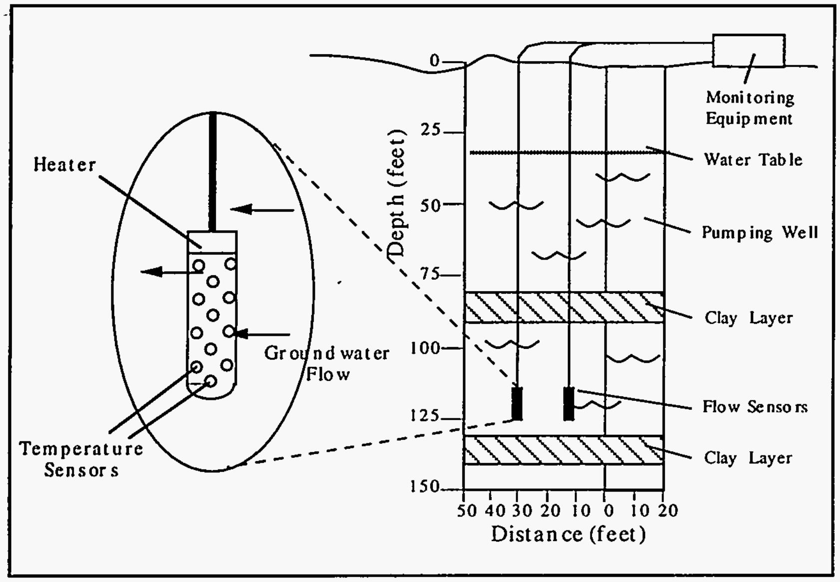

Figure 1.1. In Situ Permeable Flow Sensor.

Groundwater flow past the device perturbs the surface temperature distribution of the sensor, with the pattern and magnitude of the temperature variations reflecting the direction and magnitude of the groundwater flow velocity. In essence, relatively warm temperatures will be observed on the downstream side and relatively cool temperatures on the upstream side of the probe. If the groundwater flow has a vertical component then the temperature will no longer be symmetrical about the vertical midpoint. The magnitude and direction of the three-dimensional flow velocity vector are determined from the magnitude and the pattern of the temperature variations on the surface of the probe. The sensor should be sensitive to groundwater flows as low as a few meters per year.

TECHNOLOGY NEEDS

Because groundwater flow is perhaps the most important mechanism for the dispersal of many types of toxic wastes once they have been released to the subsurface, accurate information about the groundwater flow is critical to the characterization of waste sites, monitoring of the waste remediation activities and monitoring the post-closure performance of remediated waste sites.

The primary, currently accepted method of obtaining flow velocity information is to make water level measurements in screened boreholes to determine the hydraulic gradients in the subsurface. With hydraulic conductivity data the velocity field between the boreholes can be modelled. The shortcomings of this technique are:

- to obtain detailed knowledge of the hydraulic conductivity distribution in the subsurface, a pump test must be performed, and the extracted contaminated water must be disposed of as hazardous waste;

- a relatively large number of boreholes (four or more) are required to make one, three-dimensional flow velocity vector measurement; and

- the velocity determination is an average value characteristic of a broad region.

In contrast, in situ permeable flow sensors require only very crude estimates of the hydraulic conductivity, only a single hole needs to be drilled to measure the full three-dimensional groundwater flow velocity vector, and the flow velocity that is measured is characteristic of a region with scale lengths on the order of one meter.

ACCOMPLISHMENTS

This system has been successfully demonstrated and the technology has been licensed for use at other sites. Currently, temperature differences of about 0.10°C can be measured. At this level, flow velocities as low as a few meters per year can be resolved. The probe design needs to be improved to assure long-term reliability of electronics and sensors in groundwater conditions. Currently, the lifetime of the sensors is on the order of one year.

COLLABORATION/TECHNOLOGY TRANSFER

This technology was developed by SNL. While the technology is not patented, SNL has applied for copyrights for the interpretation software used in the probe. A number of private companies have expressed interest in the probe and SIE, Inc., of Ft. Worth, Texas is engaged in discussions with plans to commercialize the technology.

For further information, please contact:

Sanford Ballard
Sandia National Laboratory
(505) 844-6293

Dennis Berry
Technical Program Manager
Sandia National Laboratory
(505) 844-0234

1.2 CROSSWELL SEISMIC IMAGING

TASK DESCRIPTION

This technology utilizes seismic imaging to gain a better understanding of remediation system performance. Seismic images provide a means to image geologic conditions non intrusively. By placing the seismic source and receivers downhole (in boreholes) on the sides of the area to be imaged, travel distance is reduced; this preserves higher seismic frequencies resulting in better resolution. Seismic travel times are measured among a great number (over 300) of source and receiver locations in the two boreholes (see Figure 1.2). These travel times are then inverted into a two-dimensional velocity through a method known as tomography.

Shear wave and compressional wave sources were used. Both sources are pneumatic devices and operate on a compressed gas line from gas cylinders at the surface. The shear wave source is a controlled vibrator while the compressional wave source is an impulse source. Comparison of the velocity structures for the compressional and shear waves provides information about rock properties and fluid content.

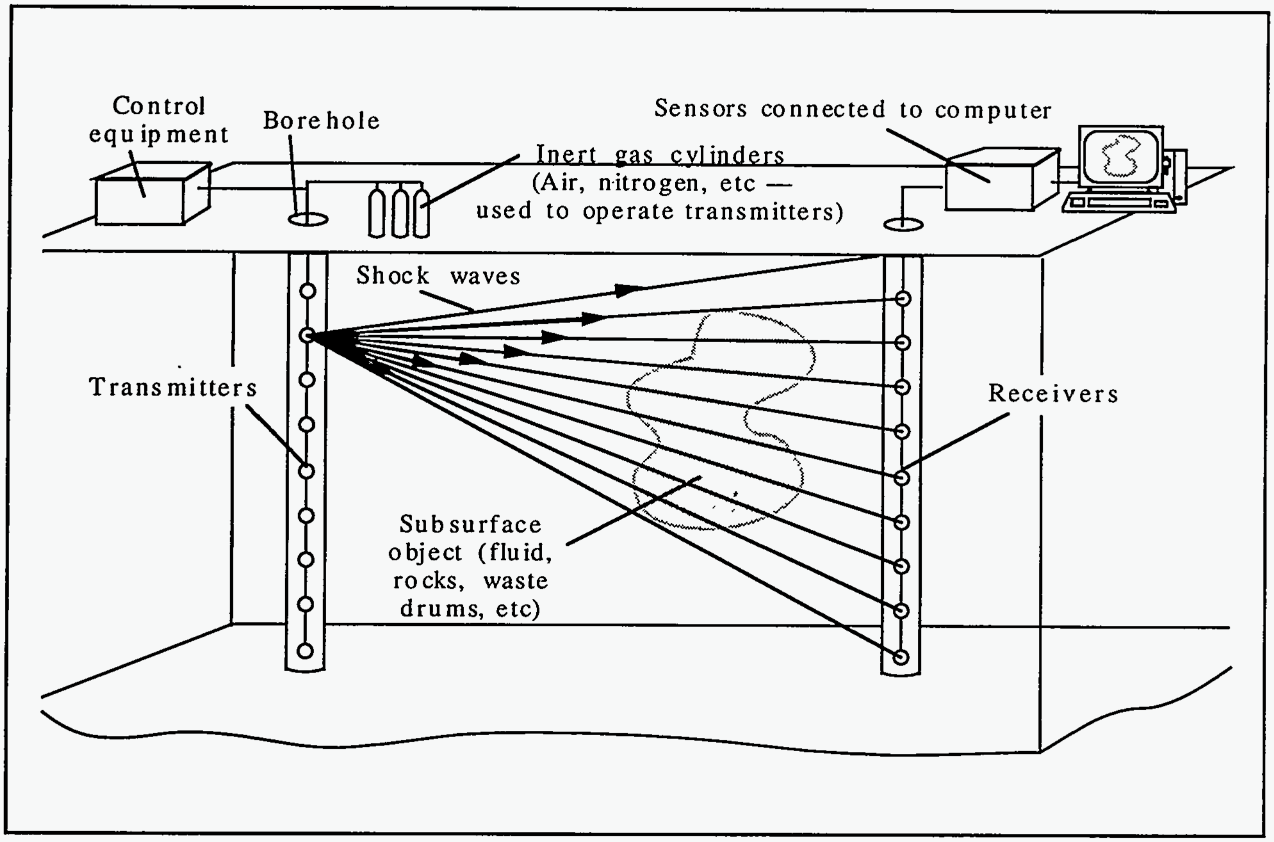

Figure 1.2. Crosswell Seismic Imaging.

TECHNOLOGY NEEDS

For all remediation technologies, a coherent image of the subsurface geology must be obtained to understand contaminant transport and to devise the proper remediation strategy. Much of this geologic input is presently derived from well log data, which may be scarce, especially in contaminated areas where drilling must be kept to a minimum. Seismic imaging provides a means to image the geologic conditions between boreholes non-intrusively. Some of this imaging can be done with surface seismic data. However, placing both the source and receivers downhole results in shorter travel paths, which preserves higher seismic frequencies resulting in better resolution.

For remediation processes where the properties of the subsurface are changed (e.g., air sparging, steam flooding, or in situ vitrification), comparison of seismic velocity images before, during, and after the process can provide needed information on where technology is being effective and to what degree the desired changes are being effected in the subsurface.

ACCOMPLISHMENTS

This technology has been successfully demonstrated at the Savannah River Site (SRS). In addition to providing valuable data in the characterization of the geological conditions that existed prior to remedial activities, the method was also able to identify saturation changes associated with the in situ air stripping tests at the site. These changes in saturation ranged from a few percent up to 22 percent. The spatial resolution of the present system is approximately 1 m in size and saturation changes of about 5% can be seen.

The major technical challenges include: increasing the frequency and power output of the sources to increase resolution, improving the imaging and inversion codes to handle problems such as anisotropy, and decreasing the survey time through development of more rapid fielding sources and multi-station receiver strings. Times for fielding and interpretation should decrease significantly as the method develops further.

COLLABORATION/TECHNOLOGY TRANSFER

This project is being performed by SNL in cooperation with Santerra Corporation. Santerra plans to develop the process for both environmental and oil and gas applications. A patent, "Advanced Downhole Periodic Seismic Generator", is co-owned by DOE, SNL, and Richard Hills.

For further information, please contact:

Greg Elbring
Sandia National Laboratory
(505) 844-4904

Dennis Berry
Technical Program Manager
Sandia National Laboratory
(505) 844-0234

1.3 RESONANTSONIC℠ DRILLING

TASK DESCRIPTION

The objective of this task is to enhance the sonic drilling method to obtain representative geologic samples that meet data quality objectives. Furthermore, secondary waste generated will be minimized and costs for drilling will be reduced through increased productivity. Minimizing operational and contamination exposure hazards to personnel is also a requirement of this task. An additional goal is the deployment of instruments, sensors and other devices to the subsurface for characterization, remediation and monitoring purposes.

While the ResonantSonic℠ drilling method (see Figures 1.3 a&b) has produced improvements to baseline methods, a definite area for improvement is the minimization of downtime which is directly related to equipment failures both in the drill head and drill pipe. Currently sonic drilling is rated as marginal; however, recently tested enhancements in industry applications will increase the reliability to an acceptable level. The goal is to reduce overall down time from equipment failure and drilling related problems to less than 10%. Reduction of downtime rates to levels consistent with other drilling methods will result in significant cost reductions compared to the current baseline.

The major challenge of this project is the development of reliable drill pipe for resonant sonic drilling. A resonance monitoring system will provide valuable input in determining the threshold energy levels for the drill pipe design basis. In addition, an accurate measurement system to determine the thermal effects from the bit to the core sample is necessary to develop bits which will maintain temperatures of the contaminants being characterized at acceptable levels

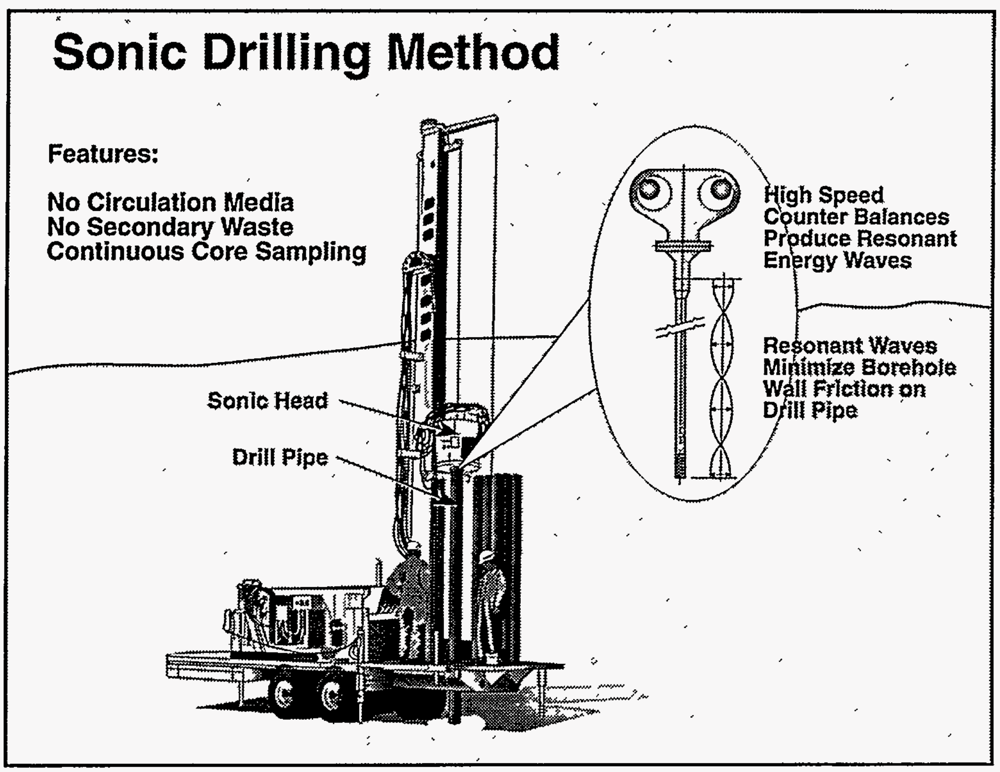

Figure 1.3a. ResonantSonic℠ Drilling.

(e.g. to avoid volatilizing organics), while maintaining acceptable penetration rates. Resonant sonic methods for directional drilling applications are also being pursued, as is driving of casings up to 10 foot diameter.

TECHNOLOGY NEEDS

Advanced and improved drilling technologies are needed to:

- reduce costs;
- minimize waste from drilling; and
- maintain containment of drill cuttings and effluents while drilling.

ResonantSonic℠ drilling is a promising method for several drilling applications including: characterization boring, groundwater monitoring wells, vapor and water extraction wells, and barrier installation holes, vertical to horizontal continuous coring, or any type/size earth penetration with a steel pipe.

BENEFITS

The key advantages of the resonant sonic drilling method are:

- increased rate of drilling;
- containment of drill cuttings;
- minimization of secondary drilling waste;
- sample quality in formations where the baseline method cannot retrieve high quality samples (e.g., caliche, boulders); and
- increased safety due to less hands on exposure to physical hazards and waste contaminants.

Additionally, ResonantSonic℠ drilling minimizes contamination to supplemental drilling components (which occurs with systems which require a circulation media), and maintains excellent contamination control at the collar of the borehole. Drilling at any angle from horizontal to vertical is also possible.

PROCESS DESCRIPTION

ResonantSonic℠ drilling has three major components: a drill rig with the sonic head, drill pipe, and a core retrieval system. The drill head uses offset counter-rotating weights to generate sinusoidal wave force energy, and operates at frequencies close to the natural frequency of the steel drill column (up to 150 cycles per second). This causes the column to vibrate elastically along its entire length. In the resonant condition, drill pipe acceleration rates exceed 500 g's and forces up to 200,000 lbs per cycle are efficiently transmitted to the drill bit face to create a very effective cutting action.

As the pipe moves through the ground during drilling, the walls of the steel pipe expand and contract helping to reduce dampening of the vibrations caused by ground swelling. The drill bit can be designed to either push all the soils into the borehole wall or modified to allow a continuous core to enter into a core barrel. High quality core samples can be continuously retrieved by using either a wireline latch or small inner rod retrieval assembly, or acquisition of data can take place via down hole probes and sensors. No circulation medium is required with the resonant sonic method; therefore, unused core samples are the only secondary by-product from drilling. On a typical well (8 inch hole diameter) this relates to 1 drum of cuttings for every 60 feet drilled. This results from the fact that the resonant energy causes sands, gravels, cobbles and even clays to displace into the adjacent formation just enough to permit the drill pipe to advance into the formation.

ACCOMPLISHMENTS

Preliminary testing of sonic drilling at the Hanford site in 1991 resulted in a cost reduction of approximately 15-20% over 11 holes. Testing in 1993 with a redesigned sonic drill head has reduced downtime to less than 1% and resulted in significant improvements in core quality, core temperature reduction, use of robotic arms, and greatly reduced secondary waste generation. Angle drilling at 45 degrees and well completion were accomplished to 170 feet as per plan.

COLLABORATION/TECHNOLOGY TRANSFER

Development of the resonant sonic drilling method is being accomplished in coordination with Water Development Corporation (WDC). The DOE is currently operating under a Cooperative Research and Development Agreement (CRADA) with WDC. Due to the relatively unknown nature of the resonance impacts to drill pipe, teaming with an industry lead contractor for this system is a positive step toward solving it and other equipment reliability issues. WDC currently has all the patents, documentation files, and previous sonic drilling equipment from the resonant drilling system developed by Albert Bodine, the inventor of sonic drilling.

For further information, please contact:

Don Moak
Westinghouse Hanford Company
P.O. Box 1970 MS N3-05
Richland, WA 99352
(509) 376-5991

Jeffrey Barrow
Water Development Corporation
1202 Kentucky Avenue
Woodland, CA 95776
(916) 662-2829

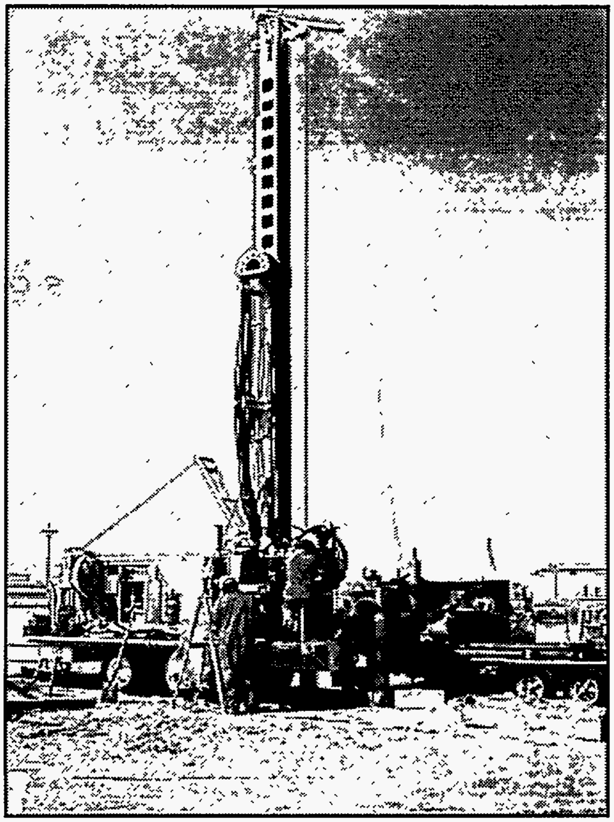

Figure 1.3b. Sonic Drilling Rig.

1.4 PORTABLE ACOUSTIC WAVE SENSOR

TASK DESCRIPTION

The objective of this project is to develop, test, and demonstrate field monitoring systems capable of quantitative detection of volatile organic contaminants found in vadose zone soils and in groundwater.

Current activities are focused in three areas. First, the down hole probe, successfully demonstrated in July 1993 at the Hanford Carbon Tetrachloride Site, will continue to be evaluated. As part of this evaluation, this down hole probe system will be transferred to Hanford Site environmental restoration personnel for their use on site over several months. The other two activates focus on the above ground version of the Portable Acoustic Wave Sensor (PAWS) technology (currently contained in a module about the size of a shoebox) (see Figures 1.4 a&b). One task involves providing a PAWS module to Hanford site personnel for their ongoing use as a real-time, continuous monitor of carbon tetrachloride in the off-gas streams from the soil vapor extraction systems. The final task involves developing an environmental sampling system using preconcentrators and semi-permeable membranes that will enable the PAWS system to be used to monitor the

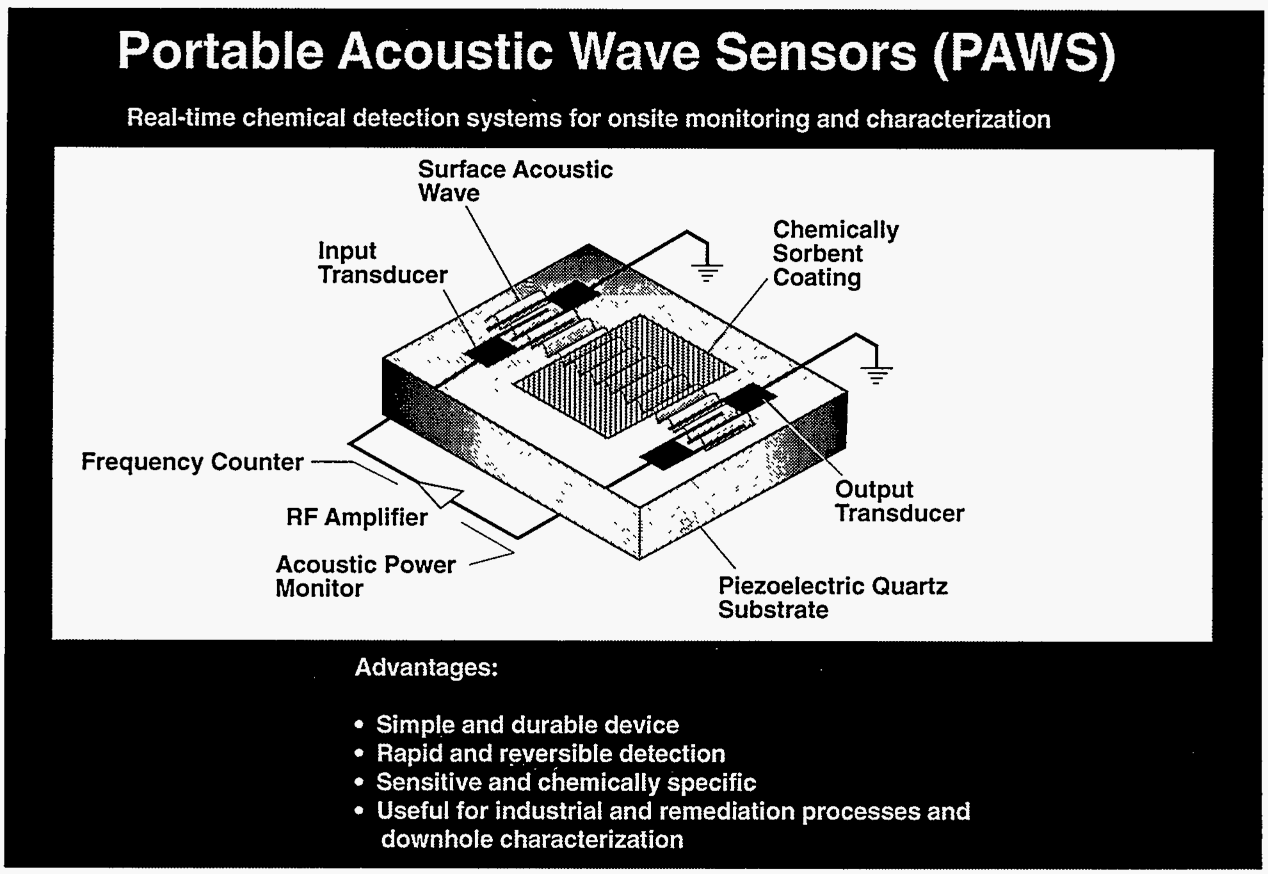

Figure 1.4a. Portable Acoustic Wave Sensor (PAWS).

residual carbon tetrachloride after on-site destruction in off-gas streams. These treated streams have high acid contents making them a special challenge for a monitoring system. Hardware miniaturization is especially important if the PAWS is to be used with the cone penetrometer. Development of coatings and pattern recognition for characterizing multiple chemical species simultaneously is also important. Another challenge is to decrease the detection limits based upon improved coatings and environmental sampling techniques. The development and evaluation of semi-permeable membranes for groundwater analysis, and for monitoring of residual contamination in acidic treated streams is also being examined.

In some situations the current level of accuracy may need to more sensitive. For groundwater measurements, the sensor may need to operate in the ppb range. There appear to be no major technical issues associated with dropping the order of magnitude of the sensors, i.e., making the sensor more sensitive.

TECHNOLOGY NEEDS

Many DOE sites have been contaminated with volatile organic compounds, such as the carbon tetrachloride and trichloroethylene (TCE) that are found at the Hanford site. To characterize this contamination sensors are needed that can be put down into monitoring wells or holes drilled for characterizing a site. One example of these sensors is PAWS. Using a downhole sensor allows for characterization of a site in real time, instead of waiting for a laboratory to analyze every sample.

BENEFITS

PAWS can perform continuous, on-line or in- situ monitoring, with rapid and reversible response. In comparison to offsite grab sample analysis, PAWS will perform real-time monitoring of carbon tetrachloride. This can be beneficial when conducting remediation activities. The sensor can be placed down a hole for in-situ monitoring, and can be automated to provide chemical information to site remediation workers on the distribution and concentration of contaminants. PAWS has capabilities for determining both molecular species and concentration of isolated chemicals. It is faster, cheaper, and as safe as a gas chromatograph or infrared analyzer.

PROCESS DESCRIPTION

PAWS involves monitoring down-hole contaminant levels for volatile organic compounds using acoustic wave sensors. These sensors will be used with on-site monitoring wells or placed in the ground using a technology such as a cone penetrometer (see the fact sheet on the cone penetrometer).

The sensor module contains:

- a coated sensor;
- gas handling equipment; and
- electronics to operate the device.

The PAWS system monitors changes in the speed and power of the wave as it travels across the sensor. These changes occur because a film coating the sensor softens and becomes heavier when it absorbs the contaminant.

Coatings have been developed that respond to volatile organic compounds (VOCs). Using one coating material, polyisobutylene, the PAWS system is able to discriminate carbon tetrachloride from many other contaminants based on a comparison of the two sensor responses. This and other coatings will be tested and used with the probe.

ACCOMPLISHMENTS

Two basic sensor systems have been developed and tested in five field demonstrations at the Hanford Carbon Tetrachloride Site. One is an above ground system for on-line monitoring, while the other is a down hole probe for in-situ characterization of VOC contaminants in the vadose zone. Both systems provide sensitive and accurate (within 2%) analysis, rapid response (few seconds) for real-time monitoring, wide dynamic range (10-50,000 ppm for carbon tetrachloride), an ability to provide molecular discrimination of isolated species based on a patented dual output technique, simple set-up and operation, and low maintenance.

Using the above ground system, on-line monitoring of contaminant concentration for soil vapor extraction systems was demonstrated at both Savannah River and Hanford. Based on the success of these tests, a PAWS system is being provided to Hanford environmental restoration personnel for their on-going use. Demonstrations were also performed showing the potential for real-time analysis of gas samples as a cone penetrometer probe is pushed into the soil at a contaminated site.

The PAWS down hole probe has been demonstrated at the Hanford site as part of the VOC-Arid ID. The probe was placed in six different wells with diameters from four to eight inches. Concentrations from below 10 ppm to over 20,000 ppm were successfully observed during the demonstration, illustrating the wide range of concentrations these systems can monitor.

COLLABORATION/TECHNOLOGY TRANSFER

A key component of this program is the transfer of the PAWS monitoring technology to industry. PAWS systems are currently being evaluated by two U.S. companies for other markets including industrial waste applications. One potential commercialization partner has already completed tests exploring PAWS performance characteristics. Another partnership focuses on developing and demonstrating a more advanced PAWS system to provide on-line chemical information for a VOC recovery and recycling system. In addition to these interactions, a recent commerce business daily announcement has been published seeking additional industrial partners for the use, development, and manufacturing of monitoring systems based on the PAWS technology. Thirty respondents have expressed interest in commercialization of this technology. Information exchanges are in progress.

A patent has been issued to DOE and transferred to Sandia National Labs. The PAWS is covered under patent number 5,076,094.

Similar work is being done by universities and private industry but no sensors have dual output. In addition to its application for environmental restoration, this technology could have applications in industry for real-time, on-line monitoring of exhaust stacks, or work place environments. Sensors could be integrated into on-line process control systems to optimize process operations.

For further information, please contact:

Greg Frye
Sandia National Laboratories
Division 1315, P.O. Box 5800
Albuquerque, NM 87185-5800
(509) 844-0787

Tom Brouns
Pacific Northwest Laboratory
P.O. Box 999 MS P7-35
Richland, WA 99352
(509) 376-7855

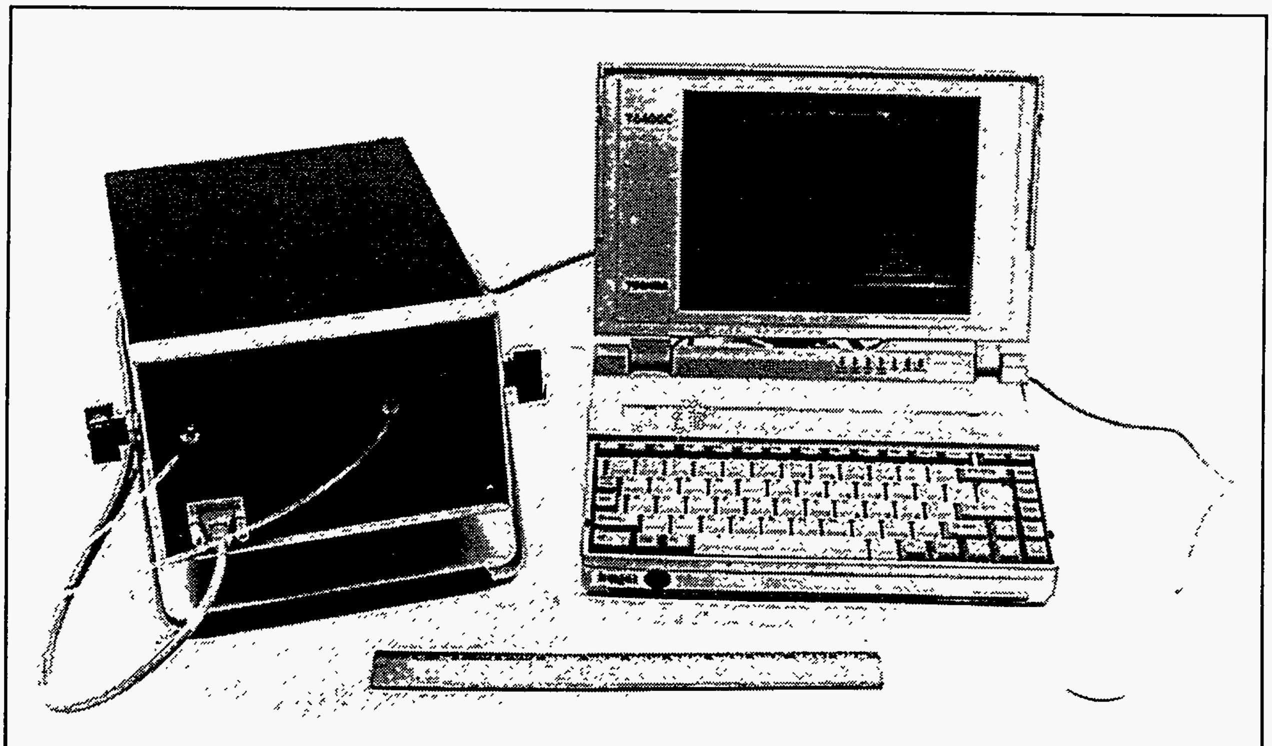

Figure 1.4b. Bench-Top Portable Acoustic Wave Sensor.

1.5 STEAM REFORMING

TASK DESCRIPTION

The objective of this task is to develop a technology to destroy VOCs (carbon tetrachloride (CCl_4), and chloroform ($CHCl_3$) adsorbed on activated carbon. This will be accomplished by reacting the VOCs with superheated steam (steam reforming), after vaporization from the granular activated carbon (GAC), by exposure to steam at moderate temperatures (see Figure 1.5).

At this time there is still a need to complete the development and testing of the moving bed evaporator which uses an alkali base to capture acids generated in the bed by gasification of wastes that contain halogenated solvents.

Sandia National Laboratory is developing a chlorocarbon sensor that uses Surface acoustic wave sensing elements for use with the detoxifier. The chlorocarbon sensor will be used to monitor the vaporization of chlorocarbon solvents in the drum feeder and their gasification in the moving bed evaporator.

The spent slurry and salts generated in the Moving Bed Evaporator would be regulated wastes if toxic or inorganic materials are constituents of these wastes.

However, this is not the case for the off-gas being treated in the VOC-Arid ID. In such cases, further treatment of the spent slurry and salts may be required prior to disposal.

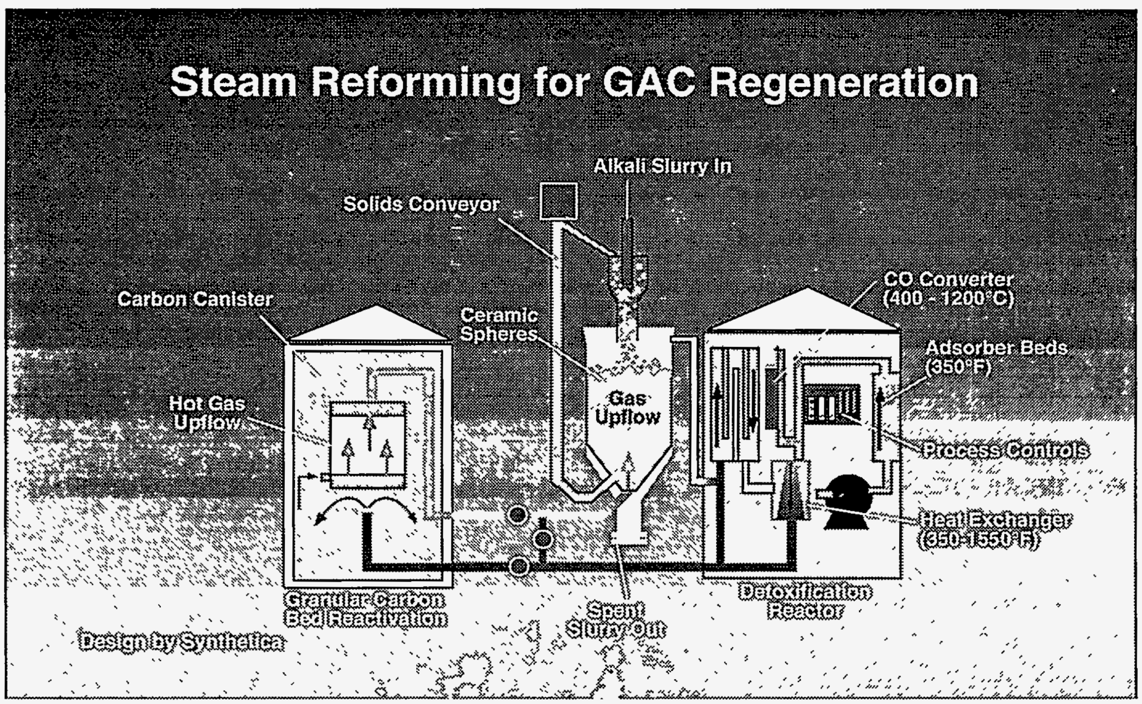

Figure 1.5. Steam Reforming for Granular Activated Carbon Regeneration.

TECHNOLOGY NEEDS

Based on regulator concern over available off-gas treatment technologies, DOE has been required to use expensive GAC beds to remove VOCs from the off-gas stream. GAC currently requires off-site shipment and regeneration at a cost that exceeds that estimated for on-site treatment, if available. Technologies are needed to reduce the cost and potential public exposure associated with GAC treatment and regeneration offsite.

PROCESS DESCRIPTION

Carbon tetrachloride and chloroform stripped from Hanford arid soils will be adsorbed on activated carbon in 55-gallon steel drums. The drums will be placed in a drum feeder and the adsorbed chlorocarbons will be vaporized by exposure to 300° C steam.

The chlorocarbon laden steam effluent from the drum feeder is fed to a moving bed evaporator, that consists of a bed of ceramic spheres coated with alkali base. At the bottom of the evaporator, spheres are removed and transported to the top of the evaporator by a bucket elevator, where they are coated with fresh base and re-injected into the evaporator.

At the 600° C operating temperature of the evaporator, the chlorocarbons will be efficiently decomposed releasing HCl which will be neutralized by the alkali base coating on the spheres. As the spheres settle to the bottom of the evaporator, spent base, and chloride salts formed by the neutralization of HCl, are mechanically scraped off of the spheres and removed from the bottom of the evaporator through a star valve. The star valve allows waste products to exit the bottom of the evaporator, while sending the scraped spheres to a bucket elevator to be re-injected into the top of the evaporator.

The effluent steam stream from the Moving Bed Evaporator is fed to the high-temperature (1200°C) reaction chamber of the steam reforming reactor, where any organic fragments released in the Moving Bed Evaporator are destroyed. Any HCl released in the Detoxifier is removed by adsorption and neutralization by Selexsorb™, a commercial adsorbent. Finally, the effluent from the reactor is passed through a catalytic converter where carbon monoxide and hydrogen are converted to carbon dioxide and water.

BENEFITS

In comparison to SVE using GACs and processing them offsite, Steam Reforming is faster, 75% cheaper, and 99.99% effective in destroying off-gas contaminants. GACs can be processed and re-activated on-site, eliminating the need for shipment and replacement. Because Steam Reforming is not a combustion process, fuel and air are not used and products of incomplete combustion are not generated. The detoxifier can handle a wide variety of waste forms. Liquid and solid wastes in drums are gasified in the drum feeder. Liquid waste streams are flash vaporized in the moving bed evaporator. Solids requiring shredding to enhance gasification are processed using a heated shredder. Contaminated soils are processed using a heated screw feeder.

COLLABORATION/TECHNOLOGY TRANSFER

Steam Reforming is being developed in cooperation with Synthetica Technologies, Inc. The DOE is currently testing the Synthetica Detoxifier for use in DOE Complex cleanup. Synthetical holds the patents for this technology, #4874587, and steam detoxifier systems are available through them.

A CRADA between Synthetica Technologies and Sandia National Laboratories will support studies of alternative heating methods (e.g., microwave heating) for the detoxifier. Use of steam reforming catalysts in the detoxifier, and the conversion of the synthesis gas effluent from the Detoxifier into light hydrocarbons using Fischer-Tropsch catalysts will also be addressed under the CRADA.

For further information, please contact:

Jerry Sprung
Sandia National Laboratory
(505) 844-0134

Tom Brouns
Pacific Northwest Laboratory
P.O. Box 999 MS P7-35
Richland, WA 99352
(509) 376-5368

1.6 LANDFILL CHARACTERIZATION SYSTEM

TASK DESCRIPTION

The Landfill Characterization System (LCS) is a method to characterize metal and mixed waste contaminant sources and their migration beneath landfills (see Figure 1.6). The emphasis of the system is on minimally intrusive technologies and downhole sensors where possible. The system is to utilize the best of available and emerging technologies with minimal development work.

The LCS is envisioned to be a cradle-to-grave system for landfill characterization, with compatible, complementary, and integrated technologies. Cost and time savings will result. The LCS may include commercially-available technologies, as well as those being demonstrated individually as part of the Mixed Waste Landfill Integrated Demonstration (MWLID). The LCS consists of four separate subsystems: pre-screening technologies, drilling technologies, on-site field laboratory analysis, and borehole technologies. In some instances, technologies may be combined to produce hybrid systems, such as directional boring and downhole sensing. The LCS approach will employ nonintrusive characterization, safer directionally drilled access, measurement while drilling, an optimal sampling strategy, a membrane liner, in-situ sensors, and an on-site laboratory. As long-term monitoring activities become increasingly emphasized, the LCS will transition to a Landfill Characterization and Monitoring System (LCMS).

TECHNOLOGY NEEDS

A systems approach for characterization of metal contamination ensures that the technologies are directed toward solving the problem at hand. By considering the entire system, the technologies are more likely to be practical and useful in the field. As technologies and opportunities emerge, they can be incorporated into the system. Similar technologies can be evaluated side-by-side in the system.

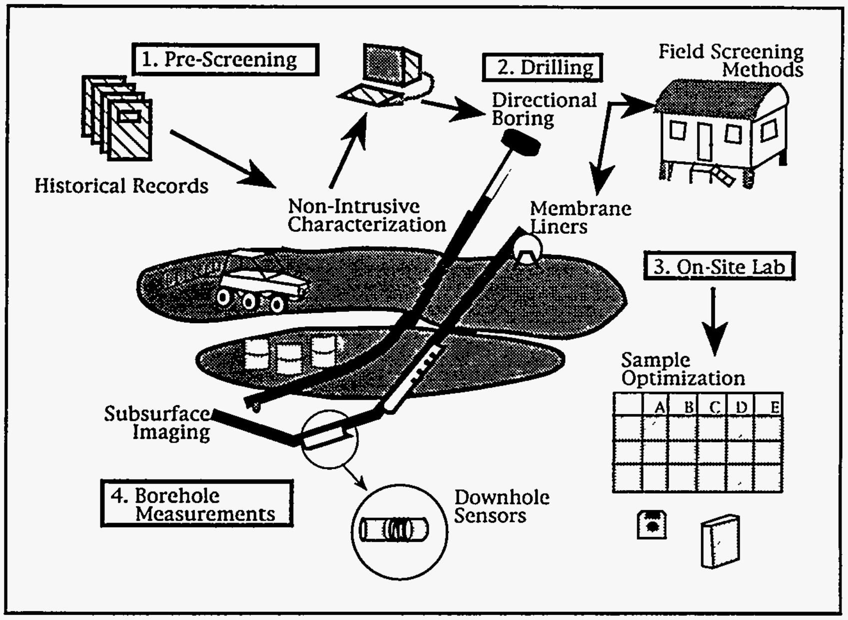

Figure 1.6. Landfill Characterization System.

ACCOMPLISHMENTS

In 1993, the LCS was conceptualized as the following closely integrated subsystems:

- pre-screening methods;
- drilling;
- field screening laboratory; and
- borehole sensors.

These subsystems were field demonstrated during FY93, primarily at Sandia's Chemical Waste Landfill (CWL). Some technologies were also being demonstrated at the Kirtland Air Force Base RB-11 Landfill as the fiscal year drew to a close.

In April 1993, resonant sonic drilling was used to bore two parallel shallow boreholes, 150 feet long and at 15° to the horizontal, beneath the 60's pits at the CWL. This drilling was combined with near-real-time, on-site field screening for metals analysis by X-ray fluorescence and stripping voltammetry. The field screening effort discovered a major source of chromium contamination, previously unknown. After completion of drilling, including casing, the SEAMIST™ membrane instrumentation and sampling system was installed for vapor phase sampling. During the summer, these two holes, as well as three previously drilled holes at the Unlined Chromic Acid Pit (UNCAP) were used to demonstrate and test various downhole sensors (e.g., cross-borehole and surface-to-borehole electromagnetic imaging; cross-borehole seismic imaging; downhole X-ray fluorescence; and microgravity). In September, the magnetometer towed array was successfully field demonstrated at the RB-11 site, and a calibration test was carried out at the CWL. A surface-to-surface cased borehole using directional drilling technology was also successfully completed at RB-11.

A milestone report dealing with technical and economic evaluations of selected LCS technologies was completed at the end of FY93, and was the subject of an oral presentation at the ER '93 Conference in Augusta, Georgia (October, 1993).

COLLABORATION/TECHNOLOGY TRANSFER

This project involved collaboration with the following National Laboratories and commercial industries.

Argonne National Laboratory
9700 South Cass Ave.
EID/Bldg. 900
Argonne, IL 60439
Contact: Robert Johnson
Phone: (708) 252-7004

Pacific Northwest Laboratory
Battelle NW
P.O. Box 999
Richland, WA 99352
Contact: Ronald Brodzinski
Phone: (509) 444-3529

Science & Engineering Associates
1570 Pacheco, Suite D-1
Santa Fe, NM 87501
Contact: William Lowry
Phone: (505) 983-6698

Troxler Corp.
3008 Cornwallis Rd.
Research Triangle Pk., NC 27709
Contact: Rich Orban
Phone: (919) 549-8661

Charles Machine Works, Inc.
P.O. Box 66
Perry, OK 73077
Contact: Roger Layne
Phone: (405) 336-4402

Chem-Nuclear Geotech
P.O. Box 1400
Grand Junction, CO 81505
Contact: David George
Phone: (303) 248-6699

New Mexico State University
Dept of Chemistry
Las Cruces, NM 88003
Contact: Joseph Wang
Phone: (505) 646-21

For further information, please contact:

Robert Floran
Principal Investigator
Sandia National Laboratories
(505) 844-0543

George Allen
Technical Program Manager
Sandia National Laboratories
(505) 845-7015

1.7 FIELD SCREENING LABORATORY

TASK DESCRIPTION

The objective of this task is to develop a mobile field screening laboratory capable of high-quality, same-day metals and organic analysis of toxic, radioactive, or mixed waste environmental samples. The task intends to rapidly develop new methods to enhance and more fully utilize the capabilities of commercially available X-ray fluorescence (XRF) for metals analysis, and gas chromatograph with a mass spectrometer (GCMS) for volatile organic analysis of water and soil.

The XRF tool is a benchtop instrument that uses an X-ray tube to excite the soil. A dry soil sample is taken and sifted through a 10-mesh screen and analyzed. If any chrome is found, it is ground to 200-mesh and another analysis is conducted. Efforts are now being made to use thin films of ground powdered samples, which reduces the mass of the sample without reducing sensitivity. The GCMS is used for volatile organic analysis by taking a bulb of gas extracted from the soil. A small aliquot is sent into the gas chromatograph (GC) for analysis, resulting in a chromatograph. Methods have been developed to achieve better detection limits, to monitor well gas sampling (see Figure 1.7).

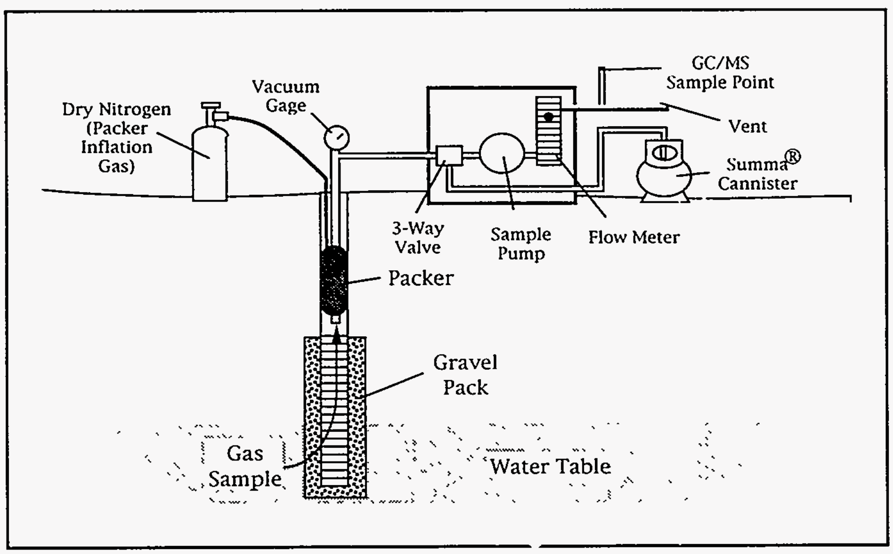

Figure 1.7. Monitor Well Sampling.

TECHNOLOGY NEEDS

There are both cost- and time-saving advantages of operating a field screening lab rather than sending samples off-site for analysis. Cost savings are even greater with radioactive samples. Results obtained in near-real time can be input immediately into the sampling optimization methodology to determine the optimal location and number of additional samples. This can potentially reduce the total number of samples required to adequately delineate the contaminant plume and speed up the characterization effort. The currently accepted alternative is to send samples to an analytical laboratory for analysis. This requires a more lengthy chain of custody to be followed, and typically, weeks pass before results are available. Often, characterization activities have been concluded before the first analytical result is obtained. A characterization effort could be completed, and the analytical results weeks later indicate that the plume was missed and the effort must be repeated. The long delay in obtaining results from the analytical laboratory also has an impact on health and safety. Overly conservative personal protection equipment may be used because the extent and nature of the contamination is unknown. This drives up the cost and slows down the characterization effort.

ACCOMPLISHMENTS

New methods for the GCMS have greatly improved detection limits, for both soil gas and water. For soil gas, the entire content of a gas sample bulb is purged onto a trap, which is then thermally desorbed onto the GC column for analysis. Water samples are also purged onto a similar trap and thermally desorbed in the same manner. The similarity in the soil gas and water analysis allows the same instrument to be used for both analyses with minimal changes in the instruments operation parameters. One round of monitor well gas sampling has been completed and the second round is in progress.

The thin-film XRF methods are now available and a training session on the procedures will begin soon.

COLLABORATION/TECHNOLOGY TRANSFER

This project involves collaboration with the following commercial industries.

Advanced Analytical Inc.

1753 Cape Aston Ct.
San Jose, CA 95133
Contact: Jim Wriggly
Phone: (408) 226-4057

Spectrace Instruments

2401 Research Blvd. # 206
Ft. Collins, CO 80526
Contact: Todd Rhea
Phone: (303) 493-2219

Viking Instruments

12007 Sunrise Valley Dr.
Reston, VA 22091
Contact: Rudy Askew
Phone: (703) 758-9339

For further information, please contact:

Eric Lindgren
Principal Investigator
Sandia National Laboratories
(505) 844-3820

George Allen
Technical Program Manager
Sandia National Laboratories
(505) 845-7015

1.8 INVERTING MEMBRANE BOREHOLE INSTRUMENTATION TECHNIQUES (SEAMIST™)

TASK DESCRIPTION

SEAMIST™ is an instrumentation and fluid sampler emplacement technique designed for in-situ characterization and monitoring. It uses an inverting, pneumatically-deployed tubular membrane (impermeable material) to deploy sensors and/or samplers in boreholes or to tow instruments downhole in a clean, stable borehole environment (see Figure 1.8).

The membrane, made of coated fabric or synthetic film, is forced from a holding canister by air pressure into a drilled or punched well. The membrane descends, everts, and presses against the hole wall, providing wall support and the effect of a continuous packer. After emplacement, the entire hole wall is sealed, thus preventing ventilation of the pore space or circulation of pore water in the well. The membrane can be retrieved from the hole.

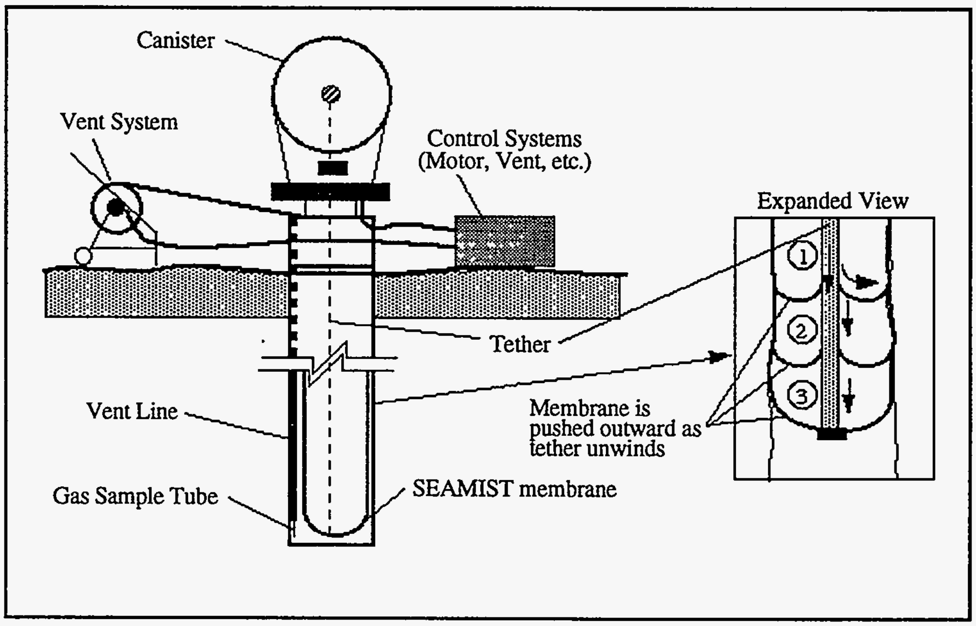

Figure 1.8. SEAMIST™.

Permanent installation of the membrane is possible by filling the membrane with grout after emplacement. Semi-permanent installation can be accomplished by filling the membrane with sand after emplacement, which can be removed by vacuuming where membrane retrieval is desired.

Monitoring instruments and pore fluid sampling devices are placed on the outer surface of the membrane, in contact with the hole wall. The membrane isolates each measurement location. Emplacement has been demonstrated for vertical, horizontal, and crooked or partially obstructed holes. Instruments or samplers are not dragged along the hole wall at any time.

The membrane can be used to perform vadose zone pore and fracture fluid sampling using absorbent pads. Electrical resistance measurements inside the pads indicate moisture uptake. By attaching an array of absorbent pads to the membrane, high spatial resolution of the contaminant distribution is possible.

Extraction of soil gas samples from a downhole can be accomplished via tubes to surface sample collectors. Getters (such as activated charcoal adsorbers) can also be attached to the membrane surface to adsorb contaminants. A hybrid concept is to pull a gas sample through a filter positioned at the sampling point.

Additional classes of sensors and/or sampler instruments can be integrated with the SEAMIST deployment system. These include thermocouple psychrometers, gypsum blocks, pressure transducers, temperature sensors, calorimetric indicators, and hydrocarbon-sensitive adsorbing resistors.

TECHNOLOGY NEEDS

Many of the problems with conventional vadose zone monitoring techniques are eliminated or minimized by the SEAMIST™ design. Because it is customizable, retrievable, reusable, and leaves the borehole clean, SEAMIST saves not only time, but also money in drilling costs, tool rehabilitation (rather than replacement and upgrades), and waste stream disposal. It also minimizes or eliminates problems that conventional systems experience, such as retrieval and repair of buried instrumentation, cross-contamination of samples, single-point sampling with screened wells, and borehole stability. The system is ideal for field work, as the device is easily handled and transported. A small unit can fit into the trunk of a car and installation is fast: emplacement in a 100-foot borehole can take less than five minutes.

ACCOMPLISHMENTS

- Tritium Plume Monitoring. Two systems installed at LLNL in 1991 are tracking the movement/concentrations of a tritiated water plume (vapor and liquid water sampling) to 40-ft depths.

- Carbon Tetrachloride Monitoring. Two emplacement systems with disposable membrane liners are in use at Hanford for carbon tetrachloride plume monitoring.

- Fracture Flow Mapping and Rate Measurement. Membranes coated with liquid-indicating and wicking layers were used to map and measure brine flows underground at the Waste Isolation Pilot Plant (WIPP).

- Tritium and VOC Sampling. The SEAMIST™ system transported vapor sampling tubes and adsorbent collectors 230 feet horizontally beneath an old radwaste landfill at LANL.

- Mixed Waste Landfill Demonstrations. Transported logging tools and cameras in horizontal boreholes of up to 230-ft length and 1.75 to 4.0-in diameters. Performed gas sampling and permeability measurements in two vertical boreholes of 11.5-in diameter and 110-ft depth immediately after auguring in SNL's CWL. Installed three borehole liners of 110-ft length.

- Emplaced, operated and removed a vapor sampling membrane in the CWL 60's pit horizontal borehole that incorporated seven sampling points on 170' length, 4" diameter membrane.

- Emplaced, operated (~2 weeks) and removed SEAMIST membranes incorporating physical process and chemical sensors in 110' deep borehole at CWL.

- Standard SEAMIST vapor sampling systems were integrated with surface-based VOC analysis systems (automated/unattended gas chromatograph and ultraviolet fluorometer).

- Emplaced and currently operating a 400' long 4.5" diameter vapor sampling membrane in the KAFB RB-11 landfill horizontal borehole.

- Vapor Sampling/Permeability Measurements. Three membranes were instrumented and installed at SRS in July 1992 for soil vapor, vapor pressure, and permeability measurements. Maximum depth was 130 ft, with 10 sampling elevations per membrane.

- Neutron Logging Tool Transport. The membrane towed a 3-lb neutron moisture logging tool in horizontal boreholes. Typically, four 4.5-inch diameter holes (200-250 feet) were logged in one day, with data taken every 2 feet.

- Vapor Sampling. A vapor sampling system was installed to 90-foot depths for long-term monitoring.

- Borehole Liners. SEAMIST™ liners were installed to support/seal holes while a long-term monitoring system is designed. Hole diameter was 8.5 inches and depths were 80-100 feet.

- High-Pressure Borehole Liners. Two Kevlar-reinforced membranes were installed to a depth of 155 feet, then filled with water inside cased walls to prevent collapse of PVC casing during remediation experiments.

COLLABORATION/TECHNOLOGY TRANSFER

This project involves collaboration with:

Science & Engineering Associates
1570 Pacheco, Suite D-1
Santa Fe, NM 87501
Contact: William Lowry
Phone: (505) 983-6698.

The geologic patent for SEAMIST™ was sold to Eastman Cherrington Environmental, Inc. for commercial use in 1993.

For further information, please contact:

Cecelia Williams
Principal Investigator
Sandia National Laboratories
(505) 844-5722

George Allen
Technical Program Manager
Sandia National Laboratories
(505) 845-7015

1.9 HYBRID DIRECTIONAL BORING AND HORIZONTAL LOGGING

TASK DESCRIPTION

The objective of this task is to develop the capability to emplace usable cased/screened directional boreholes in desired locations at environmental sites cost-effectively.

Hybrid directional boring machinery capable of exerting hydraulic thrust forces greater than 80,000 pounds are used to push directional boring heads into the earth. Directional control is obtained by proper positioning of the non-symmetric face of the boring head. Slow rotation of the boring head cuts and compacts the geologic material. Pushing a non-rotating boring head causes directional change. Machinery is capable of initiating a borehole at ground or shallow pit level, steering down to the desired depth, continuing horizontally at that depth, and then steering back to the surface. Casing and/or screen material can be installed in the borehole by attaching it to the drill rod being retrieved.

TECHNOLOGY NEEDS

This technology is well suited to provide quality access beneath landfills, buildings, and buried tanks as it uses minimal fluids for drilling, and since cuttings are compacted in the borehole, very little material is returned to the surface. It is estimated to cost between $25-75 per foot compared to over $300 for larger conventional rigs.

ACCOMPLISHMENTS

- Developed a new prototype drilling machine with larger hydraulic thrusting capacity, (minimum of 80,000 pounds) and with the capabilities to rotate while thrusting and do limited drilling in rock.
- Developed an on-board tracking system to give drill bit location during drilling, thereby enabling penetration at depths greater than 15 feet.
- Directionally drilled pilot hole using a redesigned drill bit in difficult sand/cobble formations at Sandia National Laboratories' CWL site.
- Successfully installed a horizontal well using the new prototype machine at Savannah River for the use of radio frequency heating, accelerating remediation of a VOC-contaminated zone (FY92).
- Successfully installed a horizontal well using the testbed prototype under the RB-11 site at Kirtland Air Force Base. The well will initially be used for vapor sampling and gamma spectroscopy studies by SEAMIST and PNL researchers.

COLLABORATION/TECHNOLOGY TRANSFER

This project is being jointly developed with Charles Machinery Works; commercialization of the technology will be completed in 1994.

Charles Machine Works, Inc.
P.O. Box 66
Perry, OK 73077
Contact: Roger Layne
Phone: (405) 336-4402

For further information, please contact:

Robert Wemple
Principal Investigator
Sandia National Laboratories
(505) 844-2230

George Allen
Technical Program Manager
Sandia National Laboratories
(505) 845-7015

1.10 INTEGRATED GEOPHYSICS PROGRAM

TASK DESCRIPTION

The objective of this task is to demonstrate that an integrated program of surface geophysics can effectively address the need for non-intrusive characterization of mixed waste landfill sites (see Figure 1.10). Qualitative descriptions of the test sites and their contents suggest that a number of established geophysical methods may be applicable. Using multiple testing techniques, this approach is designed to make characterization efforts more accurate and more complete by integrating data from multiple techniques, e.g. by integrating the data from the magnetic gradiometer technique with the data from the complex resistivity method.

The use of a particular geophysical technique depends primarily upon the target of interest, the geology of the survey area, and the possible interference from surrounding objects. Because each technique measures different physical parameters and is appropriate for different situations, an integrated approach offers data and interpretation not attainable by using a single technique. A brief description of each geophysical technique to be demonstrated in this program follows.

The magnetic gradiometer technique measures variations in the intensity of the earth's magnetic field. Ferromagnetic objects affect the earth's magnetic field and can produce a magnetic anomaly. With the assumption that many metal waste storage drums and metallic debris exist within the confines of a pit, a minimum boundary can be quickly determined.

Certain chemicals react with clays to produce substances that provide a characteristic response to the complex galvanic resistivity method. In addition to possibly identifying broad classes of wastes in the pits, the complex resistivity response may delineate the chemical interaction boundary and, thus, the waste pit boundaries. Naturally occurring voltage, generally termed a spontaneous potential (SP), frequently builds up at the boundaries of a waste pit, due to the difference in chemical composition and solution pressure of the material on each side of the boundary. A simple map of the voltage measured over disturbed and undisturbed areas can be used to define pit boundaries.

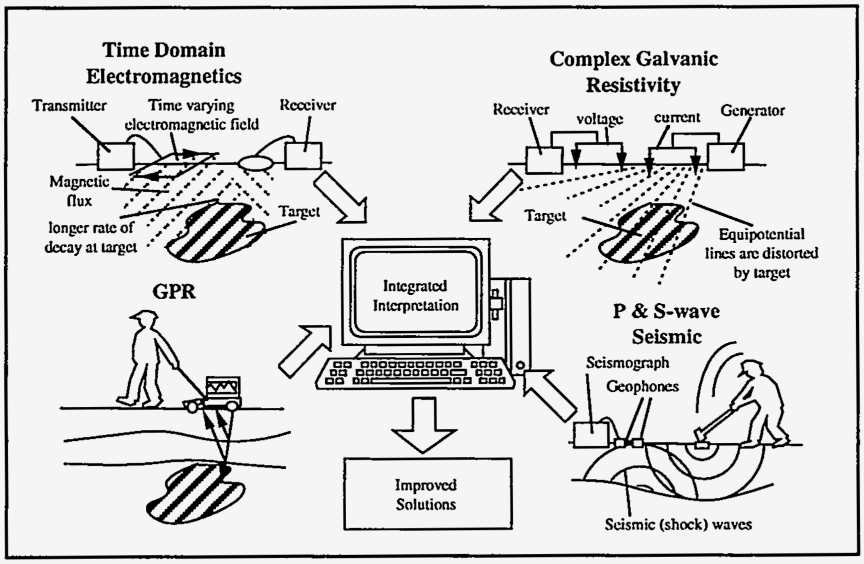

Figure 1.10. Integrated Geophysics.

Under favorable transmissivity circumstances, ground-penetrating radar (GPR) profiles may indicate pit boundaries because of a propagation contrast in the disturbed area compared with undisturbed soil. This may be attributed to a moisture contrast or mechanical factors related to soil disturbance. In this manner, GPR measurements may yield information on the volume of wastes within a pit.

The waste materials within the pits (such as metals, metal salts, and other chemicals) have a profound effect on the conductivity of the pit in contrast to undisturbed ground. Time-domain electromagnetic (TDEM) methods can be used to map conductivity/resistivity contrasts. In addition to delimiting the pit area, the conductivity data can provide insights to the type and quantity of material in the pits. A conductive plume that is migrating beyond the pit boundary toward a borehole can be readily detected with this technique.

Shear-wave (S-wave) refraction and compressional-wave (P-wave) reflection seismic surveys can detect seismic wave transmission differences expected between disturbed and undisturbed material. Variations in the phase, amplitude, frequency, and velocity of horizontally polarized shear waves are indicative of changes within the subsurface. The locations of these seismic differences can help differentiate pit boundaries, and can also help determine the volume of waste within a particular pit.

TECHNOLOGY NEEDS

Surface geophysical surveys are routinely used in many groundwater, geotechnical, and waste-site characterization projects. Often, however, only a few techniques are used because of limited experience, ill-perceived notions of a certain technique's usefulness, or cost and schedule considerations. An integrated approach using pertinent geophysical techniques offers data and interpretations not attainable by a single technique. To successfully integrate the data from various geophysical techniques, considerable experience is necessary to ensure that data of the highest quality are acquired at suitable spacings. Once sufficient high-quality data are acquired, modelling and an integrated interpretation of the data can be conducted. This integrated approach offers solutions that encompass numerous physical property contrasts, and is therefore more reliable than interpretations from a single geophysical technique.

ACCOMPLISHMENTS

- Seismic geophysical surveys were conducted at the MWLID test site at Sandia National Laboratories/New Mexico in Albuquerque.
- Locations of the known chromic acid and organics pits were interpreted at or near their historical boundaries, unknown pits were identified, and areas of disturbance possibly related to contaminants were interpreted outside the boundaries of both the known and unknown pits. Rudimentary waste types were identified and modelled where appropriate, and anomalies from recent activities were identified and discounted from further analyses.
- Pit boundaries and basic geometries (horizontal and vertical extent) were identified to less than 3 feet through integrated interpretation of complex galvanic resistivity, GPR, and S-wave seismic data.
- Indication of metallic debris within the identified pits was accomplished through

combined interpretation of all the data sets; the presence of nonmetallic debris was interpreted if an anomaly was indicated in the S-wave seismic, P-wave seismic, or GPR data but was not evident in the complex galvanic resistivity or TDEM data.

For further information, please contact:

James C. Hasbrouck
Principal Investigator
RUST Geotech Inc.
(303) 248-6714

David A. Emilia
Technical Program Manager
RUST Geotech Inc.
(303) 248-6417

1.11 ADVANCED IN SITU MOISTURE LOGGING SYSTEM

TASK DESCRIPTION

The objective of this task is to demonstrate and evaluate a self-contained nuclear moisture/density probe in directionally drilled access tubing (see Figure 1.11).

The neutron source/detector consists of an americium/beryllium combination (10 mCi). The source and detector are located in close proximity to each other, and the probe counts thermalized "slow" neutrons that have contacted hydrogen atoms. The Troxler count ratio is generally linear with respect to percent moisture. Its configuration allows for quantification of the moisture content to within plus or minus 2% volumetric water content when calibrated to a given soil, and has an approximate radius of influence of about 30 cm. The gamma source, for measuring soil density, is an 8 mCi cesium-137 configuration.

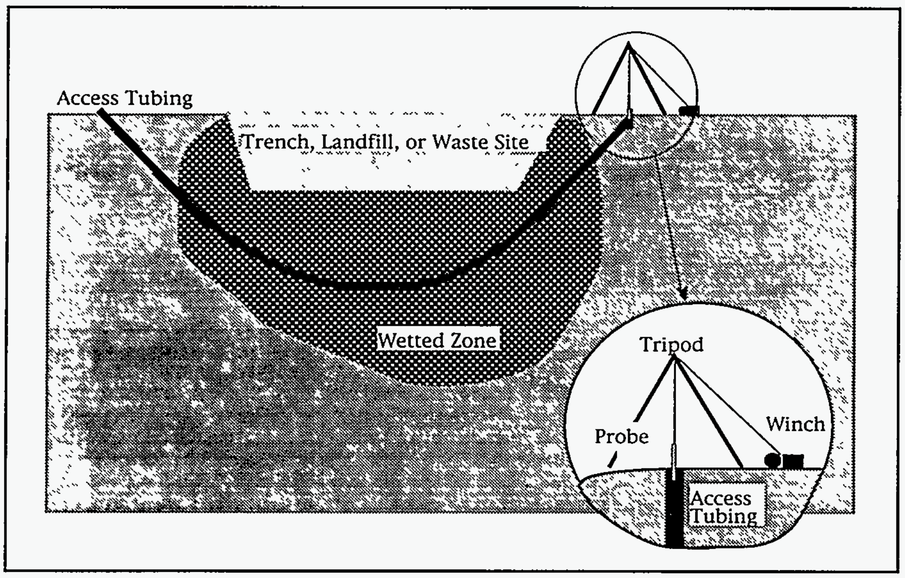

Figure 1.11. Moisture logging.

The conventional means of deploying such a probe is to lower a logging tool down an access tube to a depth ranging from several meters to tens of meters. The electronics to operate and process data from the probe are located in a housing that sits at the top of the access casing.

The cable used to lower the probe down the access tube serves as both support cabling and electronic communications. The increasing noise (background signal) may impair the data quality with increasing length of the cable; therefore, a practical limitation on hole depth exists.

The new Troxler probe is self-contained. In other words, the electronics required to take a reading and to program subsequent readings of moisture content and soil density are contained within the housing of the device itself. The probe is drawn through an access tube via a support cable and requires no electronic communications to the top of the casing; therefore, length of the access tubing is not prohibitive, and long horizontal tubes may be used if a delivery system is engineered properly. The proposed choice for a delivery system is to employ a constant velocity winch, or one which can be hooked up to a data logger or laptop computer to record cable take-up rate and time and/or length. Such a system has just become available from Mount Sopris Instrument Co. Inc., Golden, CO. Other devices exist to monitor in-situ moisture content and soil density, but are general point source devices.

The advantage of a downhole logging device is that continuous data collection along the length of the access tubing allows for greater spatial coverage. With the advent of the horizontal/directional drilling technologies, the application of the downhole self-contained monitoring devices becomes significantly enhanced. In addition, information from downhole logging devices is essential in evaluating the performance of such remedial alternatives as capping or soil venting strategies, and as input to risk assessment modelling methodologies. In deep vadose zone regimes, this type of device/monitoring system might be used in lieu of an expensive monitoring well. The tool being evaluated will provide a self-contained neutron/gamma moisture/density probe for use in vertical or horizontal access tubing of almost any length. The tool can be used at practically any waste site throughout the DOE Complex where moisture content and/or soil density data are needed, whether for leak detection or for performance of a facility.

TECHNOLOGY NEEDS

A self-contained nuclear moisture/density probe for use in directionally drilled access tubing beneath waste sites is needed for the purpose of leak/contaminant detection and post-closure monitoring.

ACCOMPLISHMENTS

- Evaluated and field tested the in-situ moisture logging system. Modifications to the system were made by the manufacturer, Troxler Electronics Laboratories, Inc., to ruggedize the system.
- Performed calibration experiments.
- Evaluated and procured a winch system.
- Constructed a field infiltration experiment.

COLLABORATION/TECHNOLOGY TRANSFER

This project involves collaboration with Troxler Corporation of North Carolina and the EPA out of Nevada

For further information, please contact:

Robert Knowlton
Principal Investigator
Sandia National Laboratories
(505) 848-0425

George Allen
Technical Program Manager
Sandia National Laboratories
(505) 845-7015

1.12 NEUTRON ACTIVATION LOGGING SYSTEM

TASK DESCRIPTION

The goal of this task is to demonstrate, test, and evaluate a neutron activation logging system for in-situ measurement of contaminant metals.

The system may provide information that can be used to directly estimate waste volumes, and to support or refute evidence of waste migration. This system potentially applies to both chemical and radioactive elements.

The logging system is self-contained and operates as a stand-alone. During field operations, the probe is lowered into a borehole and data is collected. This data is stored digitally, processed rudimentarily, and displayed to allow quality assurance and initial interpretation. At a later time, the data is processed in detail and interpreted.

To generate Multi-Element (ME) data, the instrument generates a short burst of neutrons using a linear accelerator in a sealed tube within the probe. Neutrons penetrate the soil and rock surrounding the borehole, which generates gamma rays from inelastic scattering, prompt capture, and delayed capture. These gamma rays are detected by a 10% efficient, high-purity, cryogenically-cooled germanium detector. The gamma ray spectrum can be gated to distinguish signatures from different elements in the material surrounding the borehole.

TECHNOLOGY NEEDS

An advantage to ME technology is that it can analyze a 1000-times larger volume of material than an individual sample. Furthermore, it can produce in-situ assay data in a fraction of the time that it takes to submit all of the samples from a borehole to an analytical laboratory and obtain results. With the ME system, a single gamma ray spectrum can be collected in a few minutes and results are available soon after. Logging, of course, provides the opportunity to repeat measurements in the same borehole year after year for monitoring purposes.

ACCOMPLISHMENTS

In FY93, this project was completed following a demonstration at the Sandia CWL in an area of chromium contamination. The system performed as predicted and chromium was not present at concentrations above the detection threshold for the system, on the order of 1000 parts per million by weight. Numerical computations were completed to confirm performance of the system for this one case. Detection thresholds for other elements are now being determined through work sponsored by the Characterization, Monitoring, and Sensor Technology Integrated Program.

For further information, please contact:

Dave George
Principal Investigator
Chem-Nuclear Geotech, Inc.
(303) 248-6699

David Emilia
Technical Program Manager
Chem-Nuclear Geotech, Inc.
(303) 248-6417

1.13 CROSS BOREHOLE ELECTROMAGNETIC IMAGING

TASK DESCRIPTION

Electrical properties such as resistivity, determined by electromagnetic methods, are unique among geophysical measurements, since the electrical property is directly related to chemical composition of the fluid passing through the geologic medium.

Fiber optic cables lower the tool, which is 2 in diameter and 6-12 in length, into boreholes to determine properties, such as the permeability, saturation, and water chemistry. Based on the attenuation and phase shift of radio frequency signals propagated between boreholes, mapping of electrical conductivity or permittivity between boreholes can be accomplished (see Figure 1.13).

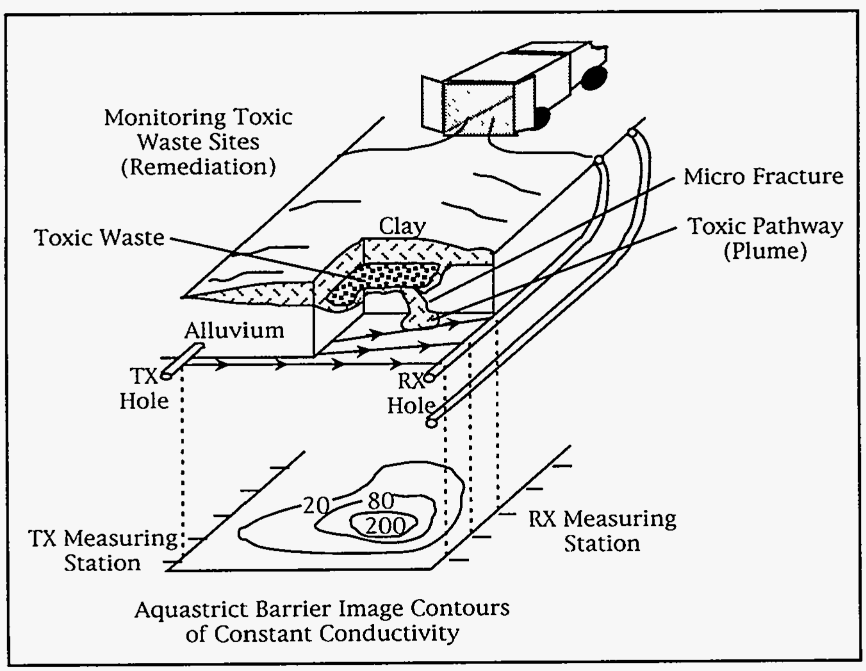

Figure 1.13. Cross Borehole Electromagnetic Imaging.

TECHNOLOGY NEEDS

In landfills containing metallic waste forms, the contrasts in electrical properties enhance the effectiveness of several electrical and electromagnetic methods. For the problem of source and plume detection at these landfill sites, the continuous wave and pulsed radar systems provide a means to image the subsurface for targets that may be uniquely suited for the method.

ACCOMPLISHMENTS

- Rocky Flats has requested that RIMtech, Inc. design a trial radio imaging survey of selected sites.
- Presented and published a paper on radio imaging of the unlined chromic acid pits at the 1993 Symposium on the Application of Geophysics to Engineering and Environmental Problems, San Diego, April 1993.
- Presented a paper on electromagnetic imaging of mixed waste landfills to Environmental Geology Section, Geological Society of America Annual Meeting, Boston, October, 1993.

- Completed three-dimensional surveys of the 60's pits at the Sandia Chemical Waste Landfill. This survey utilized the two slant drill holes with the transmitter in the borehole and the receiver roving on the surface. These surveys delineated the covered trenches and possible plumes associated with them.

- Completed borehole-to-borehole images using the three UNCAP boreholes. These images delineated the major soil units that influence contaminant transport under the pit. The images also detected high-concentration portions of the plume beneath the pit. Reproduced the surveys a year later in 1993 with data agreement within 5%.

- Completed borehole-to-borehole images utilizing the pulsed radar system in use for treaty verification work. This survey was completed in October 1993, and correlates to the radio frequency-based images from the same boreholes.

COLLABORATION/TECHNOLOGY TRANSFER

The commercialization plan for this technology has been developed and will be utilized in 1994. The technology will be commercially available in late 1994.

Collaboration is with:

Stolar Inc.
1030 Clayton Road
P.O. Box 428
Raton, NM 87740
Contact: Larry Stolarcyzk
Phone: (505) 445-3607

For further information, please contact:

David Borns
Principal Investigator
Sandia National Laboratories
(505) 844-7333

George Allen
Technical Program Manager
Sandia National Laboratories
(505) 845-7015

1.14 MAGNETOMETER TOWED ARRAY

TASK DESCRIPTION

The magnetometer towed array, also called Surface Towed Ordnance Locator System (STOLS™) was built by the U.S. Navy as a proof-of-principal, nonintrusive characterization system to locate and identify buried ordnance (see Figure 1.14). Sandia, in conjunction with the U.S. Navy and Geo-Centers, Inc., is furthering the magnetometer towed array system to meet the DOE need for rapid and noninvasive detection and quantification of subsurface waste forms.

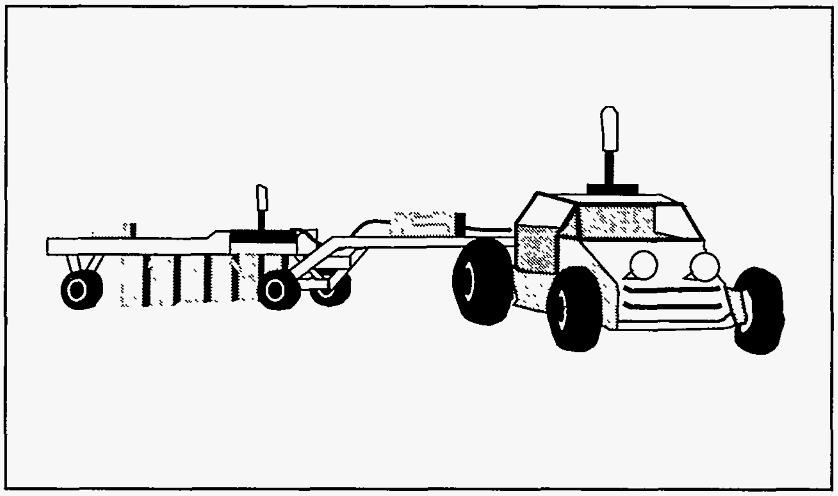

Figure 1.14. Magnetometer.

Current technology is based on walkover magnetometer surveys which provide low resolution data at the rate of an acre or two per day. STOLS™ has been commercialized by the Geo-Centers Inc. This vehicle-based system deploys a non-intrusive sensor platform containing seven total-field magnetometers with precise satellite positioning for locating the magnetic data. The acquired data sets are processed to produce high resolution magnetic maps of the surveyed area (on the order of 0.5-meter resolution).

The vehicle that tows the sensor platform is rugged, for handling the terrain variations in diverse field conditions. It enables the system to rapidly cover the survey area at a rate of at least fifteen acres per day. The vehicle has been designed to exhibit a low magnetic signature in order to minimize interference with the magnetometers. In addition, the sensor platform, itself composed of low-magnetic materials, has been designed to keep the sensors at a sufficient distance from any spurious magnetic sources. An onboard computer accepts directional information from an electronic compass, and position coordinate information is now updated once per second by the dynamic global positioning system. The on-board computer also provides real-time information to the driver.

The sensor platform contains the array of seven cesium-vapor magnetometers spaced at 0.5 meter intervals perpendicular to the direction of travel. Each of these magnetometers measure the total field strength at a rate of twenty points per second. This rate yields a total data-point density of 100,000 data points per acre.

The field strength at any point is determined by the sum of the Earth's field plus any local variations caused by the presence of ferrous materials. Data from a nearby reference station is used to remove the effects of the Earth's field from the sensor platform data. This step leaves behind only the variations due to local ferrous objects.

Precise positioning data is acquired simultaneously with the magnetic data. Based on a global positioning system, the location of the sensors is calculated at every instant to provide positions for every magnetic data point. After interpolating the positioned magnetic data to a regularly-spaced grid, magnetic maps of the survey area are readily produced and are repeatable from survey-to-survey. On these maps, the magnetic variations due to local ferrous objects are readily located through the use of appropriate color scales. In addition, areas that the system has yet to survey are clearly seen, and can be subsequently located and surveyed. Local landmarks and locations significant to a given survey can also be indicated.

Displayed on a video monitor, the magnetic map of a surveyed area provides the user interface to the STOLS™ semi-automated target analysis for small isolated targets. Using a mouse, the user selects an anomaly due to a given ferrous target. The target analysis then performs an iterative least-squares model matching to determine the best fit of magnetic moment and depth to the selected anomaly for small isolated targets. Detection ranges include small pieces of ordnance (containing a few pounds of iron) down to a maximum depth of 6.5 meters.

TECHNOLOGY NEEDS

The STOLS™ technology represents a capability to perform environmental cleanup competently and efficiently. With rapid and repeatable surveying capability, coverage of broad survey areas can be performed in a cost-efficient manner that can be reliably documented. Additionally, target analysis can begin the remediation procedure by providing estimates of the location and quantities on the subsurface targets, and providing needed guidance for the total environmental clean-up procedure.

ACCOMPLISHMENTS

- To aid in the evaluation and selection of a dynamic Geographic Positioning system (GPS), a navigation system test track was setup at the NRL Chesapeake Beach Detachment, Chesapeake Beach, MD. Field evaluations began the week of February 1, 1993.

- Eight vendors of locator systems demonstrated their ability to locate targets on the test track while driving through the test track at 5 MPH. Some vendors demonstrated real-time 100% accuracy at Û meter error, and 100% accuracy at Û 0.5 M error in post processing. Other vendors were less than 10% accurate. A report documenting the performance of the eight navigation systems and the test setup was written and distributed.

- Based on the field test results, a GPS system was selected and purchased for incorporation into the towed array. The $100K Trimble Navigation 4000 SSE dynamic GPS system was purchased with both MWLID and Navy funds.

- Two trial surveys were conducted at the RB-11 landfill to make sure the actual field demonstration would be successful. In April, a trial survey was conducted with hand-held magnetometers, and in

May, a trial survey was conducted using dynamic GPS navigation systems.

- During the week of September 7, 1993, the Magnetometer Towed Array was successfully demonstrated at the RB-11 landfill. Less than two hours were required to survey the test site.

COLLABORATION/TECHNOLOGY TRANSFER

This technology will be offered commercially in late 1994 and involves collaboration with the following commercial industries:

U.S. Naval Research Laboratory
560 Center Drive
Port Hueneme, CA 93043-4328

GeoCenters, Inc.
7 Walls Avenue
Newton Center, MA 02159

For further information, please contact:

John Cochran
Principal Investigator
Sandia National Laboratories
(505) 848-0415

George Allen
Technical Program Manager
Sandia National Laboratories
(505) 845-7015

1.15 POST-CLOSURE MONITORING

TASK DESCRIPTION

The objective of this task is to design, construct, install, field test, and evaluate an automated state-of-the-art soil moisture monitoring system for measuring the hydrologic performance of migration barriers and advanced surface covers for remediating landfills. The test will involve a comparison of automated state-of-the-art Time Domain Reflectometry (TDR) technology with the conventional neutron moisture gage. Three brands of TDR will be evaluated, including one manufactured in Germany, one by Campbell Scientific, and one manufactured in Logan, Utah. Performance, reliability, and cost of each of the technologies will be compared and documented. Radiation, volatile organic compounds, or other chemical detectors may also be evaluated as possible components of an integrated monitoring system.

ACCOMPLISHMENTS

Prepared draft evaluation of one brand of time domain reflectometry soil moisture system.

COLLABORATION/TECHNOLOGY TRANSFER

This project involves collaboration with the following commercial industries:

University of Houston
Dept. of Chemical Engineering
4800 Calhoun
Houston, TX 77204
Contact: Frank Kovarik
Phone: (713) 743-4351

Dupont Chemical Laboratory
Jackson Laboratory
Deep Water, NJ 08023
Contact: Mark Noll
Phone: (609) 540-3654

University of New Mexico
Dept. of Civil Engineering
Wagner Hall, Rm. 118
Albuquerque, NM 87131
Contact: Bruce Thomson
Phone: (505) 277-4729

For further information, please contact:

Ken Bostick
Principal Investigator
Los Alamos National Laboratories
(505) 667-8483

Bruce Erdal
Technical Program Manager
Los Alamos National Laboratories
(505) 667-5338

1.16 THERMAL ENHANCED VAPOR EXTRACTION SYSTEM

TASK DESCRIPTION

The objective of this technology is to demonstrate the combination of two soil heating methods (resistive and dielectric) with a vacuum vapor extraction system. The added heat will increase the mass removal rate of the soil contamination (see Figure 1.16).

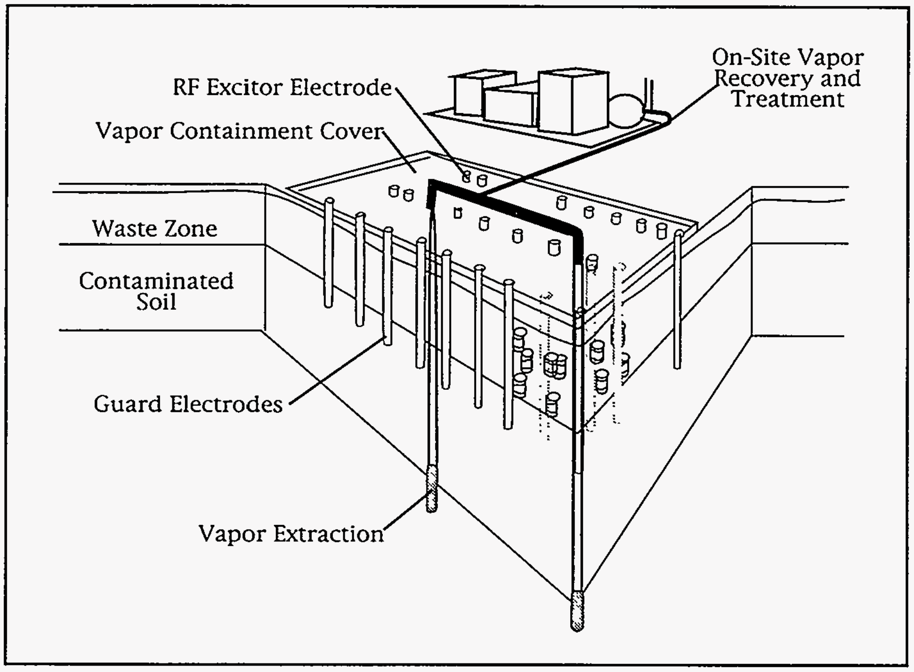

Figure 1.16. Thermal Enhanced Vapor Extraction System.

Three rows of electrodes are placed through an organic waste disposal cell (tri-plate array configuration) down to a depth of 25 feet. The center row electrodes are connected as the excitor (energy input) source and the two exterior rows are used as ground/guard electrodes to help contain the input energy to the treatment zone. Surface hardware connecting the electrodes are then installed. Two dual-purpose vacuum vapor extraction wells/ electrodes are installed as part of the excitor array. A vacuum blower and off-gas treatment system is provided for the removal of the heated soil contaminants.

Resistive heating technology passes powerline frequency (60 Hz) through the soil using the conductive path of the residual soil water. Powerline frequency energy input is controlled through a multi-tap transformer to allow for the changing impedance of the soil as soil water is removed. Voltages begin at ~200V and can be increased in steps up to 1600V. Water addition to the excitor electrodes is necessary to moderate the increased soil resistance caused by removal of the soil water. The soil heating technology vaporizes the added water into steam and also provides another mechanism for enhancing contaminant removal. When the temperature nears 100°C, the resistive heating energy input becomes constrained by the increased soil resistance (lack of residual soil water as a current conducting path). At this point, it is not effective to continue with the resistive heating mode, and switching to the radiofrequency heating is indicated.

Radiofrequency (RF) heating uses high-frequency microwaves (2-20 MHz) to heat the soil by a mechanism known as dielectric heating. The RF energy is transmitted through the soils without using residual soil water as the conductive path. Energy deposition is a function of the frequency applied and the dielectric features of the soil medium. Frequency selection is based on tradeoffs of wave penetration depth (lower frequencies penetrate further) and the dielectric constant of the soil profile. Typical frequencies used are around 6.78 MHz. The energy output from the radiofrequency transmitter is passed through a network of capacitors to match the impedance of the soil in the treatment zone to the output of the power transmitter. This hardware is necessary to minimize energy reflected from the soil and maximize the energy absorbed by the soil. By adjustment of the transmitter frequency and matching network, soil heating can continue up to 250°C or greater.

TECHNOLOGY NEEDS

Landfill disposal pits used for the disposal of a wide spectrum of organic chemicals are difficult to remediate by vacuum vapor extraction technology due to low mass removal rates. Innovative technologies that increase the mass removal rates of in-situ extraction technologies are needed to reduce the cost of in-situ remediation of difficult, high-boiling organic waste mixtures.

ACCOMPLISHMENTS

- Site characterization completed to collect soil contaminant information for engineering design efforts.

- Engineering design efforts began with a laboratory column treatability study of actual soil removed during site characterization. This effort concluded that a treatment design temperature of 200°C is needed. Air permeability tests were performed and identified a very highly permeable soil that is beneficial to the subsurface containment of vapor and steam expansion caused by soil heating. Subsurface containment modeling has shown that only a moderate soil vacuum is necessary to contain the thermodynamic gas expansion. A soil heating (electrical and RF) and subsurface instrumentation design report was completed which supported the submittal of a Resource Conservation and Recovery Act (RCRA) RD&D permit application to the New Mexico Environment Department.

COLLABORATIONTECHNOLOGY TRANSFER

This project involves collaboration with the following commercial industries:

Illinois Institute of Technology Research Institute
10 West 35th St.
Chicago, IL 60616
Contact: G. Sretsy
Phone: (312) 567-4232

Science & Engineering Associates
1570 Pacheco, Suite D-1
Santa Fe, NM 87501
Contact: William Lowry
Phone: (505) 983-6698

For further information, please contact:

James Phelan
Principal Investigator
Sandia National Laboratories
(505) 845-9882

George Allen
Technical Program Manager
Sandia National Laboratories
(505) 845-7015

1.17 MIGRATION BARRIER COVERS FOR MIXED WASTE LANDFILLS

TASK DESCRIPTION

The objective of this project is to provide field-tested capping alternatives, including the EPA RCRA cap, and calibrated water balance models that can be used in the assessment phase of the Remedial Investigation and as a component of the Corrective Measures Study for selecting remediation alternatives for the MWLID. The goal is to ensure that cost-effective capping technologies are available so that cap design can be selected based on the level of hydrologic control needed at the site.

Over the past eight years, parallel and collaborative research and development by LANL, PNL, Idaho National Engineering Laboratory (INEL), USDA-ARS, USGS, and the UMTRA program has explored several alternative long-term migration barrier cover technologies for interim stabilization and final closure of radioactive waste landfills in arid sites (see Figure 1.17).

These barrier technologies have addressed means to control erosion, deep percolation, and biological intrusion using engineered covers constructed of synthetic and/or natural geologic materials. A systems approach has been taken in some of this work, such that the underlying hydrological and biological phenomena was used to design barriers that control the fate of precipitation falling on the site. The spectrum of designs vary from simple soil barriers that have optimum configurations of soil, plant cover, and surface slope, to more complex multi-layered cover profiles incorporating engineered barriers that inhibit downward movement of soil moisture. The EPA's RCRA cap uses compacted clay as a hydraulic barrier, while others employ a capillary barrier to divert water laterally. Unfortunately, few of those designs, including EPA's RCRA cap, have been constructed in the field and monitored in a way that allows a complete evaluation of performance characteristics. Those few that have been field-tested have been evaluated under very specific climatic and environmental conditions.

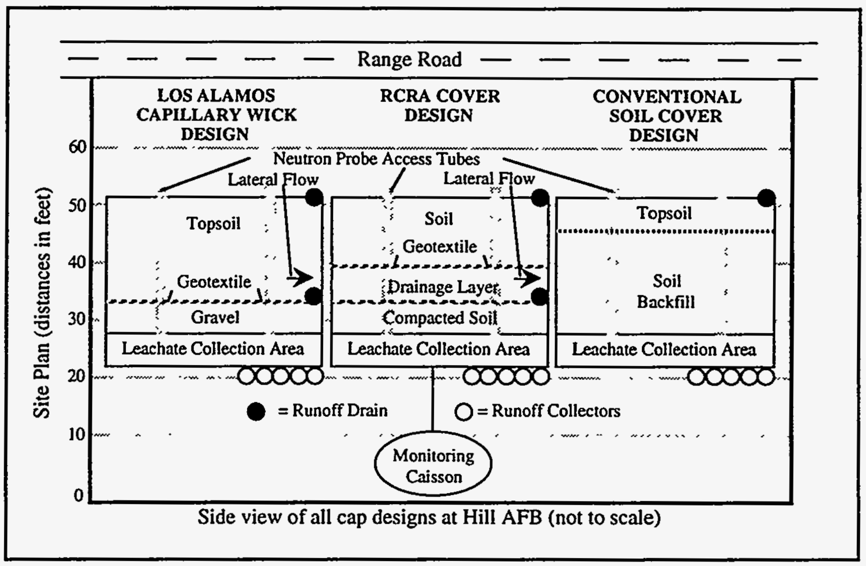

Figure 1.17. Migration Barrier Cover Systems.

LANL has conducted the basic research and begun to field test various landfill cover designs, and has had some success in reducing erosion and percolation of water into underlying waste under local climatic conditions. However, tests for some of these barrier concepts in other climatic conditions (i.e. at Hill Air Force Base in Utah) and for wastes other than radionuclides have just begun. Factors such as climate, soils, vegetation, and waste composition are important site attributes that affect both the design and the performance of migration barrier cover systems. Field testing will evaluate the performance levels of each cap in preventing water percolation into the waste and in preventing soil erosion.

TECHNOLOGY NEEDS

Field-tested migration barrier cover designs, tailored to the climate, can serve as the sole containment technology or as a component of an integrated barrier system that incorporates other barrier concepts, along with cover, to contain wastes. In addition, the hydrologic control exerted by the cover can be used to establish optimum moisture conditions in the waste backfill to improve performance of other treatment technologies such as in situ vitrification (ISV), vapor extraction, and other in-situ treatment technologies. Relative to the excavate and re-bury option, containment with field-tested migration barrier designs can reduce remediation costs 10-1000 times and still ensure regulatory compliance.

ACCOMPLISHMENTS

- Selected and delivered a report on the best barrier design based on performance data, from a demonstration at Hill Air Force Base.

COLLABORATION/TECHNOLOGY TRANSFER

This project involves collaboration with the following commercial industries:

USDA-ARS
SW Watershed Res. Ctr.
2000 E. Allen Rd.
Tucson, AZ
Contact: Leonard J. Lane
Phone: (602) 670-5566

Colorado State University
Dept. of Radiology and Radiation Biology
Ft. Collins, CO 80524
Contact: Ward Whicker
Phone: (303) 491-5343

For further information, please contact:

Ken Bostick
Principal Investigator
Los Alamos National Laboratories
(505) 667-8483

Bruce Erdal
Technical Program Manager
Los Alamos National Laboratories
(505) 667-5338

1.18 DECISION SUPPORT SYSTEM TO SELECT LANDFILL COVER SYSTEM

TASK DESCRIPTION

The objective of this technology is to provide risk managers with a defensible, objective way to select capping alternatives for remediating radioactive and mixed waste landfills. The objective will be achieved through a joint project between LANL and USDA-ARS by developing a multi-objective decision-making software system (DSS), with embedded simulation models, to design and evaluate engineered surface barriers for mixed waste landfills. The data collected from the Migration Barrier Covers for Mixed Waste Landfills project will be used to evaluate the DSS. The task includes testing the prototype DSS for remediation of waste disposal sites with migration barrier cover technology, using the designs and database from the existing cover barrier field demonstration at Hill Air Force Base in Utah. The objectives of the work include:

- Assembling the technical database to develop site-specific parameters for the knowledge-based system (KBS);
- Incorporating the multi-objective analysis tools into the existing DSS;
- Assembling the heuristic database and scoring functions for the DSS;
- Evaluating the DSS with monitoring data from Hill AFB, and selecting the best barrier cover design for meeting the regulatory requirements at a minimum cost;
- Using the DSS to design and evaluate migration barrier cover alternatives for mixed waste landfills; and
- Comparing DSS predicted performance with monitoring data from the planned MWLID barrier technology demonstrations at Hanford and SNL.

Applications of a DSS to natural resource management and to landfill cover remediation have been explored, and a prototype DSS has been partially developed by the USDA-Agricultural Research Service for water quality management. The DSS uses a computer model (a new version of the EPA's HELP model) to calculate water balance. The technical criteria include runoff erosion, percolation, interflow, and evapotranspiration, given the climate of the area. Other criteria are pertinent regulations and cost. All criteria go towards an overall score used to determine which cap is best for the site.

A PC-based prototype DSS software package, running with Windows 3.1, is under development. It will be a user-friendly coupling between symbolic processing and numerical near-surface hydrologic modelling. The embedded KBS will integrate confidence limits and exceedence probabilities from stochastic conjectural analyses of hydrologic variables in space and time, and the symbolic objects that influence landfill technology. The integration will result in a DSS that should improve long-range predictability of migration barrier performance, by incorporating complex environmental processes, along with the management issues, into the decision-making process.

Interpreting the output of the KBS applied to landfill design and remediation problems, particularly when multiple and sometimes conflicting objectives exist, requires the aid of decision analysis tools to simplify the decision-making process. For example, the hydrologic analysis from the KBS might identify a particular barrier design as "better" in controlling runoff (and erosion) from the site, but at the expense of increasing water infiltration into the landfill. A method to decide whether the increased infiltration will significantly enhance the potential of deep percolation and concomitant migration of solutes toward groundwater, and whether this enhanced migration has relevance in light of other factors, such as thickness of the unsaturated zone, potential use of the water, climate, etc. can be very useful.

The DSS will use dimensionless scoring or utility functions parameterized from the quantitative KBS output and expert judgment to convert the range of the decision variables to a unitless common range. This process allows one to combine the decision variables and rank the alternative designs. A major task of this project is to integrate a new decision-making methodology into the existing DSS in order to eliminate much of the subjectivity in existing multi-objective methods.

TECHNOLOGY NEEDS

Containment technologies, including surface caps, are essential to reduce the potential for contaminant migration from the landfill by an alteration of the surface and/or subsurface soils. The process of selecting containment cover technologies for landfills requires consideration of many complex and interrelated technical, regulatory, and economic issues. A decision support system is needed to integrate the knowledge of experts from scientific, engineering, and management disciplines to help in selecting the "best" capping practice.

ACCOMPLISHMENTS

Developed a prototype decision support system and delivered a report on barrier cover demonstrations to evaluate alternatives using a Knowledge-Based System.

COLLABORATION/TECHNOLOGY TRANSFER

This project involves collaboration with the following National Laboratories and commercial industries:

Idaho National Engineering Laboratory
200 S. Woodruff
Idaho Falls, ID 83401
(208) 526-2164

Pacific Northwest Laboratory EcoSystems Dept.
P.O. Box 999
Richland, WA 99352
(509) 376-5659

USDA-ARS
SW Watershed Res. Ctr.
2000 E. Allen Rd
Tuscon, AZ
(602) 670-5566

Westinghouse Hanford Operations
P. O. Box 1970
Richland, WA 99352
(509) 376-8506

For further information, please contact:

Ken Bostick
Principal Investigator
Los Alamos National Laboratories
(505) 667-8483

Bruce Erdal
Technical Program Manager
Los Alamos National Laboratories
(505) 667-5338

1.19 SUBSURFACE BARRIER EMPLACEMENT DEVELOPMENT

TASK DESCRIPTION

Subsurface barrier emplacement involves putting an impermeable barrier (composed of some kind of grouting material) in below a landfill (see Figure 1.19). It has to be emplaced without disturbing the landfill. There are two emplacement methods that are being tested. The first is permeation grouting, which uses a slight pressure to inject the grout and takes advantage of the natural porosity of the soil by letting it flow into the soil. The second is jet grouting by mixing, which takes a drill and rotates while injecting the grout. This intentionally fractures the soil and intermixes it with the grout. For both, the boreholes will be drilled approximately two to three meters apart.

Initially, feasibility of each technique will be evaluated, followed by evaluation of design parameters such as borehole separation, depth and arc limitations, etc.

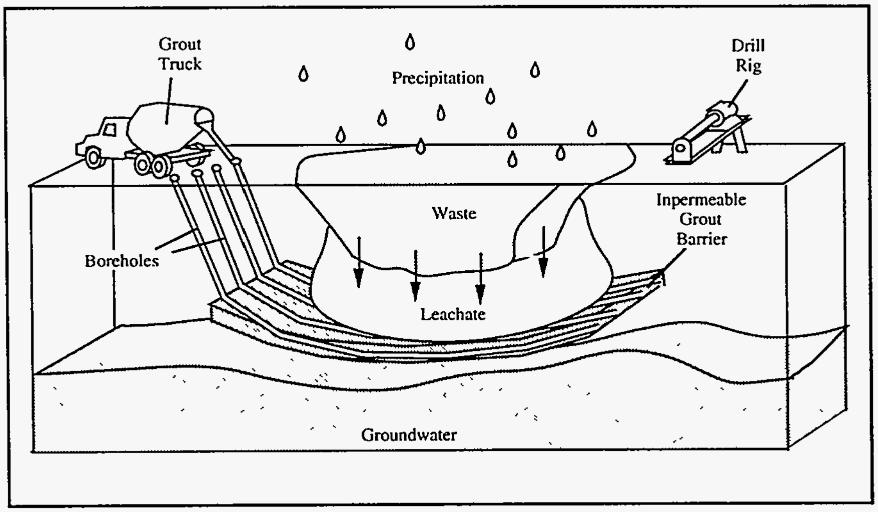

Figure 1.19. Subsurface Barrier Application.

TECHNOLOGY NEEDS

The current state-of-the-art for emplacement of subsurface barriers in near surface soils lies primarily with vertically emplaced barriers. Subsurface horizontal to sub-horizontal barriers that retard vertical mass movement are not currently employed in the civil engineering applications.

ACCOMPLISHMENTS

- Completed report/literature review summarizing the technological aspects of all system components required for demonstrating a subsurface barrier emplacement.
- Completed field-scale permeation grouting experiment. Field testing consisted of grouting in vertical and horizontal boreholes using four different barrier materials. The barrier materials used were two ultrafine cements, a mineral wax/ bentonite mixture, and a sodium silicate grout. Numerous non-intrusive geophysical techniques were used to identify where the grout flowed. Geophysical techniques used included: cross hole seismictomography, grout penetrating radar, electro-magnetic induction, neutron probe and downhole temperature

logs. Finally the cementitious grout site was excavated exposing the grout. Observations shall be compared with the crosshole tomography data when the analysis is complete.

For further information, please contact:

Brian Dwyer
Principal Investigator
Sandia National Laboratories
(505) 845-9894

George Allen
Technical Program Manager
Sandia National Laboratories
(505) 845-7015

1.20 DRY BARRIER APPLICATIONS FOR LANDFILLS

TASK DESCRIPTION

The objective of this project is to develop and demonstrate an air-enhanced dry barrier for application to landfills in arid environments (see Figure 1.20). This technology is based on the well-founded capillary barrier concept: the contrast in unsaturated hydraulic conductivity of a coarse layer (barrier) and an overlying finer layer that limits downward water flow. This technology goes beyond the conventional capillary barrier in that the coarse layer is dried with lateral air flow through the layer, preventing moisture accumulation in the layer and ensuring that its unsaturated hydraulic conductivity remains low. The drying of the barrier by air can be accomplished by passive or active means, in order to assure that the air flow is sufficient to load and transport any net recharge to the atmosphere. The dry barrier may also have application as a method for stripping gas-phase contaminants.

The air-enhanced dry barrier could assume numerous forms and functions. Most simply, it can be a component of a cap or cover system. The barrier would principally be used to limit vertical infiltration through the cap. Another application would be in engineered liner systems. The air-dried layer can be used as a final barrier to prevent leachate movement beyond the landfill, and to strip denser-than-air gas-phase constituents (e.g., TCE) as they migrate downward. This application does not rely on an engineered liner, but rather utilizes the existing heterogeneous soil beneath most landfill sites. Air flow through a highly air-permeable layer beneath the landfill can be induced with vertical or directional holes to supply and remove air. These schemes may be able to utilize the prevailing westerly winds to induce sufficient air flow through the layer without relying on blowers or vacuum pumps. For applications underneath landfills, the contaminant concentration of the air is likely to be low enough so as not to require treatment.

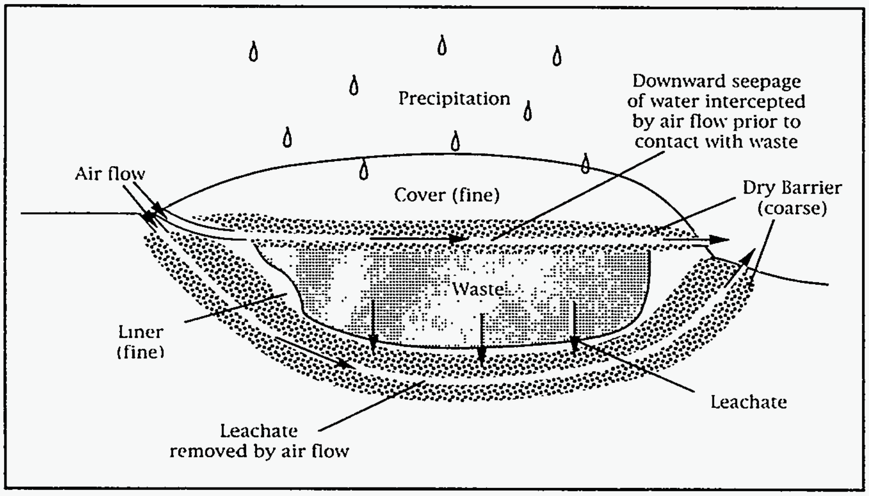

Figure 1.20. Dry Barrier.

This project will evaluate the feasibility of the dry barrier concept for applications at landfills in arid environments by a combination of laboratory, design and field efforts. First, a better understanding of unsaturated transport properties of both engineered and natural soils is needed to develop the dry barrier concept. A novel technique will be evaluated as a means of simultaneously obtaining gas permeability and unsaturated hydraulic conductivity. Small-scale testing of the dry barrier concept will utilize sandbox experiments as two-dimensional models of dry barriers. These experiments will evaluate the ability of lateral air flow to remove downward flowing water using soil types with various properties. Based on the laboratory studies, dry barriers for field demonstration will be designed. At this point, the feasibility of different applications of dry barriers will be assessed. This project will culminate with field demonstration of the dry-barrier concept at a local site.

TECHNOLOGY NEEDS

Most landfills require both above-ground and below-ground barriers. In arid environments, capillary barriers are often used in containment systems. Incorporating dry barriers into the containment systems would allow inexpensive isolation in many circumstances, and extend the probable life of the capillary barrier. The dry barrier concept addresses a number of issues associated with landfills. If a low-maintenance dry barrier can be incorporated into the design, the cover design can be improved, and perhaps its longevity can be extended. Dry barriers used as liner can serve as both a redundant barrier to liquid flow and as a means of stripping gas-phase contaminants. For existing landfills on alluvial deposits, it may be possible to use an existing coarse layer as a dry barrier.

ACCOMPLISHMENTS

- Demonstrated feasibility of the dry barrier concept in bench-top tests.
- Measured site-specific soil properties required for dry barrier design.
- Conducted numerical and analytical study of dry barrier performance.
- Completed an engineering assessment of an active dry barrier for Albuquerque, Los Alamos, and Salt Lake City.
- Conducted active and passive field measurements of dry barrier performance.

COLLABORATION/TECHNOLOGY TRANSFER

This project involves collaboration with the following commercial industries:

University of New Mexico
College of Engineering
Wagner Hall, Rm 118
Albuquerque, NM 87131
Contact: Bruce Thomson
Phone: (505) 277-4729

Stephens & Associates
6020 Academy Road
Albuquerque, NM 87109
Contact: M. Ankeny
Phone: (505) 822-9400

For further information, please contact:

John Stormont
Principal Investigator
Sandia National Laboratories
(505) 845-9347

George Allen
Technical Program Manager
Sandia National Laboratories
(505) 845-7015

1.21 LONG-RANGE ALPHA DETECTION

TASK DESCRIPTION

The objective of this program is to develop the Long-Range Alpha Detector (LRAD) soil monitor demonstrated at Fernald into a monitoring system useful for multiple environmental situations. An LRAD soil surface monitor is essentially a large, flat box whose open end is placed on top of the soil to be monitored. Radiation from the soil ionizes the air in the box. The amount of ionized air, which is proportional to the amount and type of radiation, is measured. This method is particularly sensitive to alpha radiation, which is emitted by uranium and transuranic elements. The primary advantage of an LRAD monitor is that it provides a real-time measurement in situ and is, therefore, much faster (10 - 15 minutes vs days or weeks), less expensive, and safer (no excavation or transport of contaminated material) than sample analysis. LRAD monitors are also more advantageous than hand-held alpha monitors because they are 10 to 100 times more sensitive, providing a quicker response to the operator as they move into a contaminated area.

TECHNOLOGY NEEDS

Detection of alpha contamination on soil surfaces has traditionally been limited by the short range of the alpha particles in soil, air and alpha detectors. This short range, coupled with the small size and poor sensitivity of traditional detectors, has made surface surveying a difficult and time-consuming process. The LRAD technique relies on detection of the air ions created by alpha particles rather than the alpha particles themselves. These ions can be carried over long distances (up to 10 meters) in a moving current of air, prior to detection by an ion detector. Alternately, as in the LRAD soil surface monitor, the ions can be collected by a directly applied electric field (Figure 1.21). The ability to monitor entire large and/or rough surfaces also makes LRAD monitors ideal for scanning large areas of soil surface.

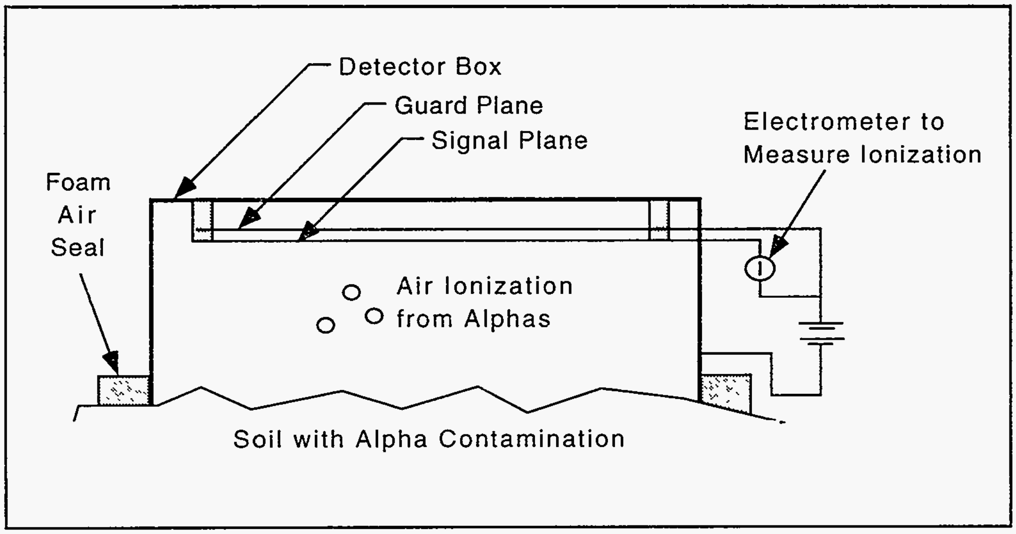

Figure 1.21. Schematic of Long-Range Alpha Detector Soil Surface Monitoring.

ACCOMPLISHMENTS

- Developed and built two, one-square meter, tractor-mounted LRAD soil surface monitors and a one-quarter square meter, handcart-mounted soil surface monitor.
- Monitored Fernald Soil Treatment Plant and Decontamination & Decommissioning Areas as part of the Uranium in Soils Integrated Demonstration.
- Monitored three active firing sites at LANL for LANL Health & Safety personnel.
- Monitored three inactive firing sites at LANL for LANL Environmental Restoration personnel.
- Monitored the outside of a 40-year-old uranium critical assembly building at LANL for the building's supervisory personnel.
- Monitored inactive firing site at Kirtland AFB for Sandia National Laboratories' Environmental Restoration personnel.
- Monitored calibration pads in both Grand Junction, CO and Grants, NM.

COLLABORATION/TECHNOLOGY TRANSFER

Eberline Instrument Corp
504 Airport Rd.
Sante Fe, NM 87504
(505) 471-3232

For further information, please contact:

Michael Malone
Program Manager
U. S. Department of Energy
Washington, D. C. 20585
(301) 903-7996

John Bounds
Los Alamos National Laboratory
MS J562, Group NIS-6
Los Alamos, NM 87545
(505) 665-0446

1.22 INTEGRATED SPECTROSCOPIC SYSTEM FOR CHARACTERIZING CONTAMINANT SPECIATION

TASK DESCRIPTION

The focus of this project is to develop a new approach to characterize contaminant speciation by directly probing molecular structure. The Integrated Spectroscopic System for Environmental Contaminant Speciation (ISSECS) is being applied mainly to soils contaminated with radioactive and/or toxic metals such as uranium, plutonium, and chromium. It is a laboratory-based approach consisting of four state-of-the-science spectroscopic techniques: X-ray absorption spectroscopy, pulsed-laser photoacoustic spectroscopy, pulsed-laser (time-resolved) and continuous-wave luminescence spectroscopy, and laser Raman spectroscopy (See Figure 1.22).

Applying these techniques in combination provides a greater level of information on contaminant speciation than do the techniques separately. The spectroscopies can determine average speciation at the bulk scale (1 to 2 cm), as well as more precise speciation at the microscopic scale (1 to 10 microns). By contrast, more conventional approaches rely on microscopic methods only, which can provide very accurate speciation data for small populations, but not for bulk samples.

ISSECS is both sensitive and adaptable to soils, sludges, and groundwater, and can be applied over a broad spatial range. ISSECS not only addresses all relevant spatial scales for contaminant heterogeneity, but because the characterization tools are all optically based, their application is noninvasive; the contaminated samples can be studied in the exact form as they existed in the environment without having to damage them. Once samples representing the contamination plume are collected, they are characterized in the laboratory. These data are provided to the site remediation personnel along with recommendations for candidate remediation

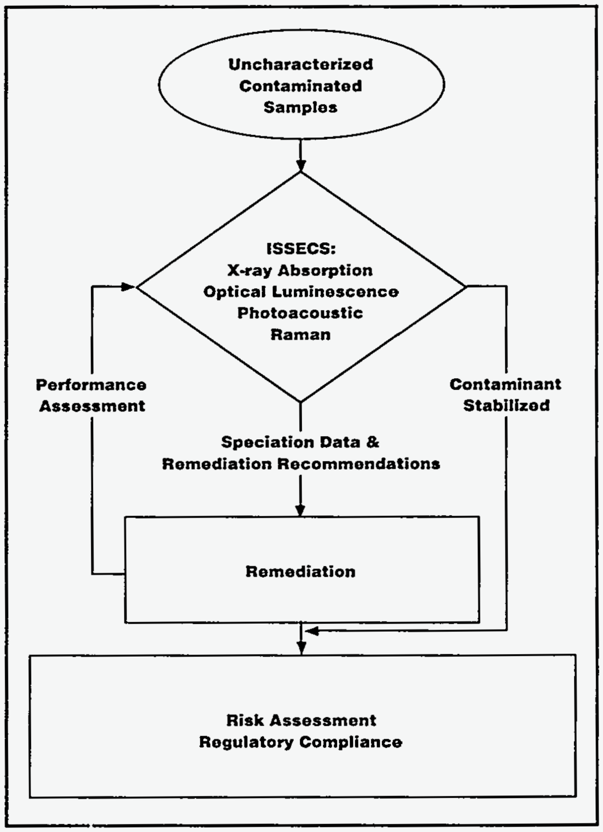

Figure 1.22. Integrated Spectroscopic System Process.

strategies based on the contaminant speciation. ISSECS also provides feedback on how well the remediation treatments perform, as well as post-treatment analyses.

Using ISSECS to do a complete analysis of one environmental sample costs $5,000 to

$7,000. Conducting a representative analysis of an entire plume would typically require 2 to 20 samples, assuming that a fully equipped laser laboratory is already in place. Estimated capital costs to develop the complete laser lab facility are $650,000 (not including physical plant). The x-ray absorption spectroscopy technique requires access to a synchrotron radiation facility, such as the Stanford Synchrotron Radiation Laboratory in California, but the negotiating or subcontracting costs are factored into the "per sample" estimate.

TECHNOLOGY NEEDS

When new remediation technologies are being developed and tested, analytical data are generally available on contaminant concentrations and the spatial extent of the contaminant plumes. However, the contaminants often exist in the environment in many different chemical forms or species, such as toxic and radioactive metals, which have many accessible oxidation states. Unless speciation information is factored into the characterization need early on, remediation development and testing strategies are strictly by trial and error, which is both costly and inefficient.

Some routine analytical approaches are currently used, including electron microscopies, x-ray, and electron diffraction. In principle, these methods can provide some contaminant speciation information, but in theory are limited because they cannot easily address sample and contaminant heterogeneity over spatial ranges from <1 micron to >1 cm.

ACCOMPLISHMENTS

Results of the project, intended to demonstrate a cradle-to-grave approach for remediating uranium from shallow subsurface soils, indicate that the majority of uranium (75% to 80%) in the contaminated soils exists in the hexavalent state as some form of the uranyl moiety.

This bulk, macroscopic finding could only be obtained using x-ray absorption spectroscopy. Later investigations of these same samples using laser-induced luminescence and Raman spectroscopies could identify the uranyl moieties, principally as microcrystalline mineral phases of uranyl hydroxides, silicates, phosphates, and carbonates. These results show that relatively mild soil washing should work well. However, remediation based on physical and magnetic separations does not offer much promise.

COLLABORATION/TECHNOLOGY TRANSFER

Federal and state government agencies would be the principal customers for this system, followed by metal manufacturing and processing industries. The entire suite of methods in this technology has been demonstrated only for uranium at this time, but subsets of the methods have also been tested for plutonium, thorium, and chromium. This technology can also be applied to other environmental contaminants that exist in two or more chemically different forms, such as the metals selenium, mercury, and lead, and simple, nonvolatile inorganic ions such as cyanide. ISSECS offers a very real potential for reducing remediation costs and minimizing secondary waste streams.

Use of ISSECS should be demonstrated on a case-by-case basis for each contaminant and should require only minimal development work. As ISSECS is shown to be viable for one contaminant, it can be commercialized before the system is tested for other contaminants. Market analyses need to be conducted to identify potential customers. Two possibilities for establishing private-sector access to a synchrotron radiation facility are university partnerships and joint-venture agreements with LANL.

For further information, please contact:

Michael Malone
Program Manager
U. S. Department of Energy
Washington, D. C. 20585
(301) 903-7996

Dr. David Morris
Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 665-6487

1.23 HEAP LEACHING OF URANIUM FROM SOIL

TASK DESCRIPTION

The objective of this task is to determine the performance and economics of uranium heap leaching for comparison with the batch-reactor method. Heap leaching is being simulated in the laboratory using leaching columns. Transparent columns in use permit researchers to observe soil and reagent conditions during the leaching process. Initially, small columns with 1 kg of soil (in lifts of 4-in dia. x 6-in tall) were chosen to minimize waste accumulation. However, work is progressing to larger columns (10-in dia. x 5-ft tall). Testing is being performed at room temperature using homogeneous soil samples from the Fernald storage pad and incinerator sites. This soil does not contain large rocks and humus. Column experiments are being designed and conducted so results from these experiments can be compared to results from batch work being conducted by Oak Ridge National Laboratory (ORNL).

Aqueous solutions of carbonate/bicarbonate of either potassium or sodium are being tested because they are the reagent of choice in the uranium mining and processing industry. Future reagents, however, may depart from carbonate/bicarbonate. During leaching tests, reagent is pumped from a dewar to the columns. After being introduced at the top of the column, the reagent flows downward by gravity, solubilizing and mobilizing the uranium from the soil.

Pilot-scale tests are envisioned where contaminated soil will be excavated and placed (heaped) on an impermeable pad on the surface of the ground. The pad will be sloped toward a sump at the bottom edge of the heap. Selected leaching reagent(s) will be pumped to and distributed on top of the heap with a drip irrigation system or aerial sprayers. Reagent will travel down through the soil, solubilizing and mobilizing the contaminant(s). The leachate will then be collected from the sump and pumped to a leachate treatment and regeneration system. This system will remove the contaminant(s) from the leachate and regenerate the leaching reagent for return to the top of the heap. The process will be continued nonstop until the contaminant(s) in the soil have been reduced to EPA standards.

TECHNOLOGY NEEDS

Economical, effective and safe methods are needed to remove contamination, especially metals, from massive amounts of soil, so that the soil may be returned to its original site and use. Heap leaching for soil cleanup is an adaptation of a proven mining method for removing precious and semiprecious metals from low-grade ore. In the mining industry, thousands of tons of ore are processed daily for less than \$100 yd^3. Metals remaining in the depleted ore are measured in parts per billion. The benefits of this form of soil remediation, when proven at field scale, would include:

- on-site cleanup;
- low-cost processing;

- conservation of expensive repository space; and

- elimination/reduction of long-term costs for monitoring, isolation, and habitat protection of disposal areas.

Additionally, the method would provide the ability to closely examine, sort, treat, and verify the cleanliness of the soil. This methodology will provide a permanent solution to the soil contamination problem, not just a relocation of the soil and cost for future care.

ACCOMPLISHMENTS

- Demonstrated that carbonate/bicarbonate is highly selective for uranium. The latest results indicate only negligible quantities of other compounds (non-uranium bearing) were removed from the soil during leaching.

- Demonstrated that it is not necessary to separate the soil into its size fractions (i.e., gravel, sand, clay, and silt) before it can be leached.

- Demonstrated that the liquid-to-solid ratio can be kept quite low (1 to 2 liters per kg soil per 24-hour day) to minimize (or eliminate) the need for dewatering of the soil after treatment.

- Demonstrated that electrical energy consumption is negligible.

- Demonstrated that uranium removal is a function of carbonate/bicarbonate concentration.

- In leaching soil contaminated with 387 mg of uranium/kg of soil using a .1M solution of $KHCO_3/K_2CO_3$ with leaching conducted 24 hr/day:

  - 42% of uranium was removed after 1 day; the liquid-to-solid ratio was 1:1.

  - 90% of uranium was removed after 10 days; the liquid-to-solid ratio was 10:1.

  - 97% of uranium was removed after 33 days; the liquid-to-solid ratio was 33:1.

  Remaining contamination levels in the soil were 164, 37, and 12 mg/kg, respectively.

- In leaching thirteen columns of soil contaminated with 470 mg uranium/kg of soil with various solution concentrations and times:

  - 81% of uranium was removed after 8 days using a .1M solution of $NaHCO_3/Na_2CO_3$; the liquid-to-solid ratio was 8:1.

  - 81% of uranium was removed after 6 days using a .25M solution of $NaHCO_3/Na_2CO_3$; the liquid-to-solid ratio was 6:1.

  - 92% of uranium was removed after 6 days using a .5M solution of $NaHCO_3/Na_2CO_3$; the liquid-to-solid ratio was 6:1.

  Remaining contamination levels in the soil were 90, 83 and 40 mg/kg, respectively.

COLLABORATION/TECHNOLOGY TRANSFER

Adrian T. Hanson
Civil, Agricultural, and Geological Engineering Department
New Mexico State University
Box 30001 Dept. 3CE
Las Cruces, New Mexico 88003
(505) 646-3032

Bruce M. Thomson
Department of Civil Engineering
University of New Mexico
Albuquerque, NM 87131
(505) 277-4729

Robert Spangler
Environmental Sciences Laboratory
RUST Geotech, Inc.
P.O. Box 14000
Grand Junction, CO 81502
(303) 248-6706

Nick Hazen (potential)
Hazen Research, Inc.
4601 Indiana St.
Golden, CO 80403
(303) 279-4501

For further information, please contact:

Michael Malone
Program Manager
U. S. Department of Energy
Washington, D. C. 20585
(301) 903-7996

Don York
Los Alamos National Laboratory
Los Alamos, NM 87544
(505) 667-8458

1.24 CHELATOR APPROACHES TO ACTINIDE REMOVAL FROM SOIL

TASK DESCRIPTION

The objective of this project is to develop effective extraction processes for the removal of uranium from contaminated soils. Important requirements for the process are that it should not destroy the soil or generate secondary waste streams that are difficult to treat. This approach is focused on the use of siderophores (microbial iron chelators) and biomimetic analogs as mobilizing agents for uranium. Based on the use of these chelators, together with redox chemistry, chemical extraction of the uranium can be performed under mild conditions. This process will produce an aqueous leach solution that will be treated to remove and concentrate the solubilized uranium. If required, the treated leach solution will be recycled.

Inputs for the process are contaminated soil and a neutral aqueous solution containing chelators and mild redox agents. In some cases, it may be beneficial to pretreat the soil with a physical separation process or another chemical leaching process to either preconcentrate the uranium or to remove a fraction of the uranium not ammenable to this process.

The outputs of the process are soil from which the majority (90 - 99%) of the uranium contamination will have been removed, and an aqueous leach solution containing the solubilized uranium. The final uranium concentration in the decontaminated soil has yet to be determined. Results obtained to date demonstrate that for certain specific soils at Fernald (e.g., Plant 1 storage pad soil), chelator approaches to decontamination can reduce uranium levels in treated soils to close to background (<10 ppm).

It is envisioned that this process will be used on soil that has been excavated from contaminated sites at Fernald. Both agitated vat leaching and heap leaching are under consideration for implementation. The pregnant leachate will be collected from the heap leach or separated from the soil in vat leach for subsequent uranium recovery and/or chelator recycle by pH adjustment and ion exchange. The recovered uranium will be immobilized for disposal and the decontaminated soil returned to the site.

To date, the best decontamination results in batch tests on soil treatability samples have been obtained using Tiron, a biomimetic chelator with extraordinary affinity for U^{4+}, and dithionite as a reductant, although good decontamination effectiveness has been obtained with Tiron alone.

TECHNOLOGY NEEDS

Many DOE sites have radionuclide and/or toxic metal contamination in soils and groundwaters. This project is primarily focused on the FEMP site where previous processing activities have resulted in uranium contamination. The precise extent of the contamination is unknown, but estimates suggest that 2,000,000 yd^3 of soil have unacceptable levels of uranium contamination.

Present technologies for remediation of radioactively contaminated soils involve immobilization of the radioactive metals in place, excavation of the site and transport of the contaminated soil to a secure repository, or separation (usually by density or size) of the more highly contaminated soil fractions. Immobilization approaches suffer from poor public acceptance and from high and continuous monitoring costs. Transport and storage of the entire volume of contaminated soil will be expensive. Physical separation methods are quite effective for contaminated soils in which a large fraction of the contamination is concentrated in a small volume of soil that can be separated by density or size. However, at Fernald the uranium contamination is as sociated with all size and density fractions of the soil. Consequently, it appears that traditional physical separation methods will not be applicable, and that any soil washing strategy will depend upon a chemical extraction process.

ACCOMPLISHMENTS

Fernald Site Soils:

- Reductive dissolution of uranium (VI) phases in the presence of strong chelators was shown to be an effective strategy for uranium decontamination.
- Residual uranium concentrations remaining in treated Plant 1 Storage Site soil samples ranged from 10 to 60 ppm.
- Residual uranium concentrations remaining in treated Incinerator Site soil samples ranged from 60 to 100 ppm.

For Primary Waste Stream:

- Primary waste stream of neutral aqueous solution containing uranium and other metals complexed to chelators.
- Method to dissociate uranium from the chelators for uranium recovery on ion exchange resins and chelator recycle.

COLLABORATION/TECHNOLOGY TRANSFER

Metallurgical and Biological Extraction Systems, Inc. (MBX)
325 S. Euclid Ave.
Suite 123
Tucson, AZ 85719

Hampshire Chemical Company
2 East Spit Brook Rd.
Nashua, NH 03061

Environmental Scientific, Inc.
P.O. Box 13486
Research Triangle Park, NC 27709

For further information, please contact:

Michael Malone
Program Manager
U. S. Department of Energy
Washington, D. C. 20585
(301) 903-7996

Dr. James Brainard
Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 667-0150

1.25 TIME DOMAIN REFLECTOMETRY AND FIBER-OPTIC PROBES FOR THE CONE PENETROMETER

TASK DESCRIPTION

SNL is fabricating, testing and evaluating a new cone penetrometer application for characterizing hydrogeologic parameters and subsurface contaminant concentrations with chemical specific fiber-optic probes and a TDR sensor. This development work should help DOE meet some of their needs for characterization and monitoring technologies. Because this technology is based on a cone penetrometer system, its deployment is minimally intrusive, and therefore supplies needed subsurface information without waste products. The data collected with this system will meet critical needs for performing fate and transport modelling, as well as risk assessment analyses.

The basic work to be accomplished under this Task Plan is as follows:

- Complete testing of the fiber-optic probe for pore pressure determinations in unsaturated porous media;

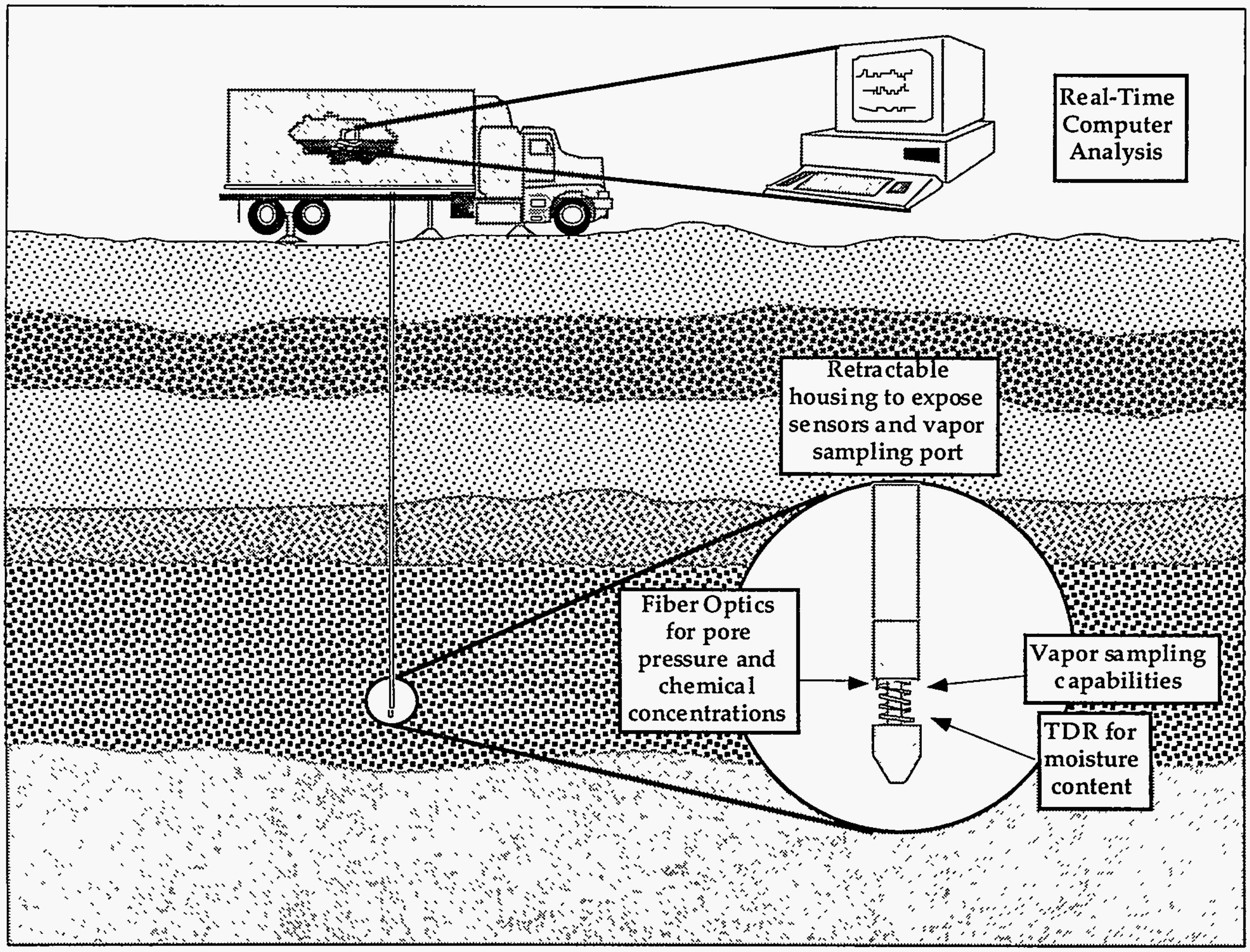

Figure 1.25. Cone Penetrometer Tip for Hydrologic Investigations.

- Design and fabricate a TDR probe to quantify soil-moisture content for downhole cone penetrometer deployment;

- Evaluate and test chemical-specific probes (e.g., fiber-optic) for possible inclusion in the cone penetrometer tip. This would include the evaluation of chemical-specific probes that might have adequate sensitivities for waste site characterization and/or monitoring purposes;

- Design and fabricate a cone penetrometer tip to incorporate the probes (see Figure 1.25); and

- Perform an in situ test of the new cone tip to evaluate its performance.

TECHNOLOGY NEEDS

As mentioned above, this technology will supply needed information to waste site investigators on hydrogeologic parameters and chemical specific concentrations in the subsurface. Moisture content and pore pressure measurements in unsaturated soils are critical parameters for inclusion in fate and transport modelling, and also in risk assessment evaluations. Whether a waste site poses a possible threat to human health and the environment is the ultimate driver for acceptability of a site or a remedial alternative. Risk assessment methods help to quantify whether a site poses a threat. Critical data needs for risk assessment are therefore critical characterization needs. The nature and extent of contamination is also very important in the risk assessment analysis. This new cone penetrometer system will supply many critical needs to these modelling efforts.

ACCOMPLISHMENTS

This is the first year of funding for this project. The initial stages of this project will be focused on design and testing of the sensor packages. The TDR sensor for quantification of soil-moisture content is under design. Previous TDR designs have given sensitivities of +/-1% moisture by volume. The fiber-optic pore pressure sensor is undergoing laboratory testing. This sensor should take the place of the conventional thermocouple psychrometer system for pore pressure measurements, which are quite cumbersome to apply. Other sensor packages are under investigation. Work is underway to define the applicable sensitivity levels desired for other chemical/radionuclide sensors for possible inclusion in the tip. It is preferable to have risk-based concentration thresholds driving the required sensitivities, and not the lowest achievable detection limit.

COLLABORATION/TECHNOLOGY TRANSFER

The opportunity for technology transfer and teaming with corporate entities is outstanding in this proposed work. First, the fiber-optic development of the capillary pressure sensor has been a collaborative effort to date between SNL and GeoCenters, Inc. GeoCenters will continue to support this development. The TDR probe may be solicited for technology transfer to the private sector. Also, the successful demonstration of chemical-specific probes would lead to increased commercialization of their product. Certainly, the procurement of the contract with a cone penetrometer logging company would facilitate the fabrication and use of this new cone penetrometer sensor tip. Given that there already exists a strong need for cone penetrometer applications, it would appear that the addition of sensor capabilities would greatly enhance the usefulness of the existing systems. Technology transfer would be quite welcome by all parties concerned in this project.

For further information, please contact:

Robert Knowlton
Sandia National Laboratories
MS 1348
Albuquerque, New Mexico 87185-1348
(505) 848-0425

George Allen
Technical Program Manager
(505) 845-7015

1.26 MINIATURIZED CHEMICAL FLOW PROBE SENSOR DEVELOPMENT

TASK DESCRIPTION

A small, reconfigurable, and real-time chemical analysis instrument could provide field technicians performing screening operations with on-the-spot data to allow for smart field characterization studies. The flow probe will use a flowing reagent chemistry with fiber-optic-based detection and speciation enhanced by modern chemometric techniques. Goals are to develop an architecture that can encompass a large class of chemical speciation through the use of modular functional blocks, a flexible membrane sampling block, interchangeable reagents, and multiwavelength, multivariate (possibly second order) statistical methods. The specific field demonstration will include metals and VOCs in aqueous matrices.

TECHNOLOGY NEEDS

Current methods for preliminary field analysis include: a) technicians taking samples, followed by transport to an off-site analytical laboratory for analysis, and b) technicians taking samples to an on-site mobile analytic laboratory. Both methods involve the high costs of analytic laboratory technicians and equipment, and the off-site method involves the long-time (up to months) delay of obtaining results. Flow probe research in the university environment has reached the point where the technology is ready to move into the commercial market. For this to happen however, significant engineering development is needed to produce a viable commercial instrument. This project provides the collaboration of the university scientist with the national laboratory engineer to perform this development in a pre-competitive setting.

ACCOMPLISHMENTS

Since the project's beginning in November 1993, performance specifications from a broad range of users have been received. The needs span the range from measuring trace organics in an organic matrix at 200°C to

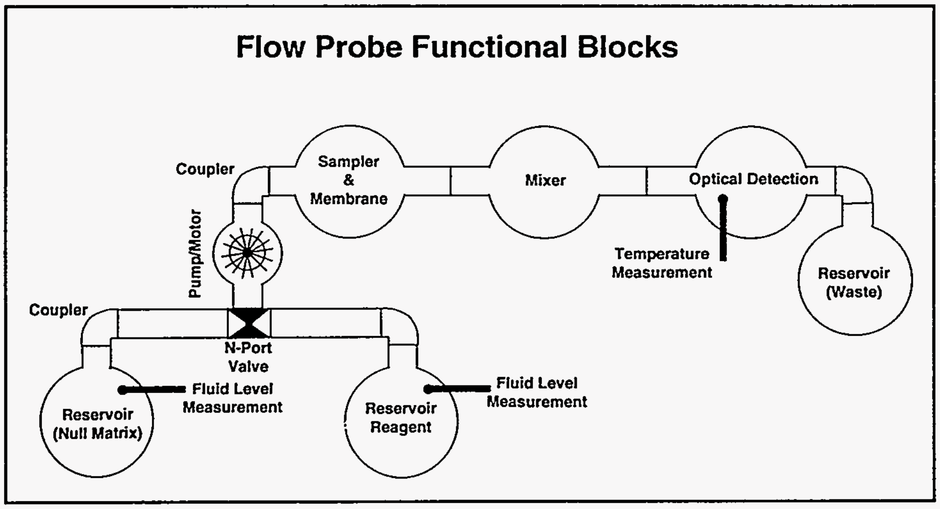

Figure 1.26. Schematic Representation of Functional Blocks for the Flow Probe in a Possible Pevice Arrangement.

measuring trace metals in an aqueous matrix at room temperature. A system model of flow probe functional building blocks was developed from these needs. The functional specifications for many of the functional building blocks needed for a generic instrument have been accomplished. A few of these functional blocks are shown in Figure 1.26 in one of many possible arrangements. The maximum size of the probe head and the minimum functions for this probe head were established. Two representations from the Center for Process Analytical Chemistry (CPAC) industry representatives attended a conceptual design meeting in January. Thus, the ideas and experience of the CPAC scientists, the SNL engineers, a LANL scientist and CPAC industrial members are working to produce a usable and commercially-viable flow probe.

Two functional constraints on the design are: 1) to maximize the chemometric information available for each analysis, and 2) to allow for additional reagent introduction into the analyte/reagent mixture in downstream functional blocks. Two fluid moving implementations are being investigated: a pulsed flow type and a volume mover type. For the pulsed flow type, there is fluid in a pipeline at all parts of the flow probe head. Through the use of timed fluid pumping, localized fluid segments contain analytes for the various functional modules to operate on. For the volume mover type, a segment of fluid is captured in a physical cavity and then moved from one module to the next module. In this implementation, fluid is present only in one module at a time. These two implementations each have their manufacturing and field use advantages and disadvantages.

COLLABORATION/TECHNOLOGY TRANSFER

The project is a 50/50 collaboration with the CPAC at the University of Washington and Sandia National Laboratories. The analytical chemistry aspects are worked upon by the CPAC scientists and the engineering for a fieldable instrument is worked upon by SNL. The project consists of three phases. The initial phase includes obtaining performance requirements from the various CPAC-sponsored chemical companies (i.e., users) and working with the CPAC instrument companies (i.e., suppliers) early in the development of the instrument. The middle phase is to demonstrate in the field the instrument at both DOE and commercial sites. The final project phase is to include an instrument partner to make a pre-commercial prototype. Collaboration with all parties is well underway with representatives from Amoco and Sippican joining the design team discussions during a 3-day design review meeting in January 1994.

Letters of interest from many CPAC companies have been received, which include in-kind support commitments that range from $200k (DOW USA) to $50k (Perkin-Elmer). Other companies expressing interest and in-kind support commitments include Amoco, Calgon, Chevron, Sippican, Goodyear, Hewlett-Packard, Proctor & Gamble, Shell, and ZymoGenetics.

For further information, please contact:

George R. Laguna
Sandia National Laboratories
Department 2337
P.O. Box 5800
Albuquerque, NM 87185-0503
(505) 844-5273

George Allen
Technical Program Manager
(505) 845-7015

1.27 PORTABLE, REAL-TIME MONITORING SYSTEMS FOR VOLATILE ORGANICS

TASK DESCRIPTION

The objective of this project is to develop, test, and demonstrate systems capable of real-time, on-line or in situ monitoring of volatile organic contaminants. As shown in Figure 1.27a, these systems use surface acoustic wave (SAW) devices that are extremely sensitive to changes in thin film properties (can detect the mass of a single particle with a diameter one-tenth that of the average human hair). This sensitivity enables them to be used for rapid chemical detection when they are coated with chemically-sensitive thin films. The PAWS systems being developed need to provide long-term, continuous, and accurate monitoring of contaminant concentrations. They also need to be robust enough to detect high contaminant concentrations and to work in the presence of corrosive vapors. These systems should be automated, easy to set-up and use, and have little or no maintenance requirements. Down hole probes should use existing monitoring, while aboveground systems should be small and portable with battery power for remote operation.

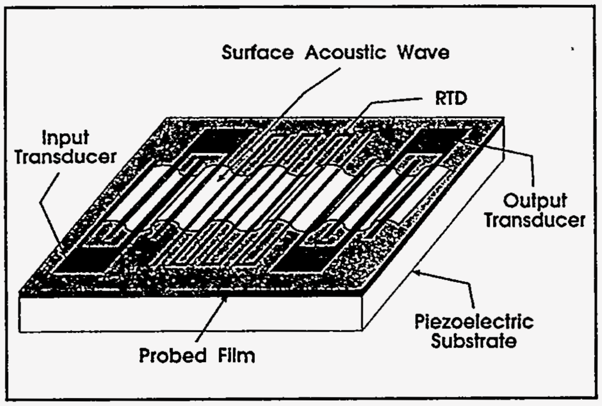

Figure 1.27a. Schematic of a Surface Acoustic Wave Sensor.

TECHNOLOGY NEEDS

There are a significant number of DOE sites that have been previously contaminated with large amounts of volatile organic species including chlorinated hydrocarbons. One example is the Hanford site, which is contaminated mainly with carbon tetrachloride (CCl_4). One key need for these sites is to effectively characterize the distribution of contamination and to be able to provide ongoing monitoring of down hole concentration changes to evaluate the effectiveness of the remediation effort. This characterization and monitoring can best be accomplished by in situ analysis of contaminant concentrations using sensitive, accurate, and robust sensors that will not be overloaded by the high concentrations (tens of thousands of ppm) that may be present in some locations. The PAWS technology has demonstrated these basic requirements. Since a common and effective technique for removing volatile organics from soils is to pull them out using large vacuum pumps and wells into the contaminated site, another need is to be able to provide real-time, on-line monitoring of contaminant concentrations in off-gas streams from these soil vapor extraction systems.

ACCOMPLISHMENTS

Efforts to date have resulted in the development and field demonstration of portable hand-carried instruments about the size of a shoe box and down hole probes small enough to be placed underground in monitoring wells (see Figure 1.27b). These systems can continuously detect and measure isolated volatile organic compounds in the vapor phase from 10 to 100,000 parts per million (ppm). Accurate analysis has been demonstrated with rapid (seconds) and reversible responses. Based upon a patented technique to monitor both the speed and power of the wave, chemical identification of isolated species is possible.

The first PAWS field test demonstrated on-line monitoring of exhaust stack concentrations at a DOE production facility. This real-time chemical information was used to rapidly evaluate alternative cleaning processes resulting in a 96% reduction in emissions. For environmental clean up activities, PAWS systems were demonstrated for continuous, on-line monitoring of contaminant concentrations from soil vapor extraction systems at both Savannah River Site and Hanford. The systems were shown to be accurate and easy to transport, setup, and operate. Real-time analysis of gas samples pulled to the surface as a cone penetrometer probe is pushed into the soil at a contaminated site has also been demonstrated. Current development of these systems is focused on instruments for monitoring residual contaminants in treated off-gas streams containing corrosive chemicals and on systems containing multiple sensors and a pattern recognition routine to provide analysis of multiple species in mixtures.

The PAWS down hole probe was evaluated at the Hanford site as part of the VOC-Arid Integrated Demonstration. The probe was placed in six different wells with diameters from 4" to 8". Concentrations from below 10 ppm to over 20,000 ppm were observed during the demonstration, illustrating the wide range of concentrations these systems can monitor. The probe provided accurate and continuous monitoring of contaminant concentrations. An aboveground PAWS system provided comparison analysis of a sample pushed to the surface by the probe. As shown in Figure 1.27c, agreement between the surface PAWS system and on-site analytical instrumentation was excellent (2%); however, differences between the probe and the aboveground systems were observed. These differences were found to be due to contaminant addition or loss in the sample line to the surface, demonstrating the advantage of in situ analysis for site characterization.

Figure 1.27b. Deployment of a down hole portable acoustic wave sensor system at the Hanford site in Washington State.

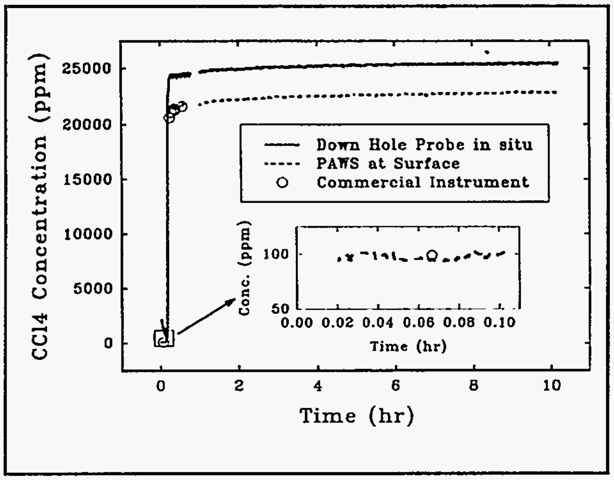

Figure 1.27c. Real-time monitoring of contamination at the Hanford Site using a down hole portable acoustic wave sensor system for in situ analysis.

COLLABORATION/TECHNOLOGY TRANSFER

A key component of this program is transferring this monitoring technology to DOE environmental restoration and to industry. An above ground PAWS system has already been provided to Hanford Environmental Restoration for their ongoing use and a down hole system will also be transferred to Hanford following a second field demonstration. Regarding commercialization, announcement of the availability of this technology has been made by public presentations, publications, a *Commerce Business Daily* announcement, and representation at the Sensors Expo '93 and at a DOE-sponsored industrial workshop. A mailing was sent to 175 identified companies of which 13 responded with an initial questionnaire expressing interest and four responded with full business plans. Negotiations are underway with these four companies to identify the optimum relationships for maximizing the impact of this technology development work.

For further information, please contact:

Gregory C. Frye
Principal Investigator
Microsensor R&D Department
1315, MS-0351
Sandia National Laboratories
Albuquerque, NM 87185-0351
(505) 844-0787

1.28 CHLORINATED AND AROMATIC HYDROCARBON THIN FILM CHEMICAL SENSORS

TASK DESCRIPTION

This task aims to develop compact, inexpensive, and robust SAW-based chemical sensors for remote, real-time sensing in air, groundwater, and possibly soil of chlorinated and aromatic hydrocarbons. The sensors will be system-integrated through co-development with Motorola and with the University of California at Berkeley. The initial success of others who have demonstrated ppm sensitivity to specific chlorinated hydrocarbons using spin-cast cyclodextrin as the selective layer of a SAW-based mass sensor will be built upon. Cyclodextrins form inclusion complexes with chlorinated hydrocarbons and aromatics, thereby allowing for reversible binding of the analyte and near real-time sensing. This novel approach incorporates promising new technology:

- the use of surface modification techniques to covalently bond (via siloxane linkages) cyclodextrins directly to the SAW transducer substrate, thereby mitigating the ubiquitous spin-casted film problems of adhesion, leaching, swelling, and stability (see Figure 1.28a);

- subsequent molecular engineering to control access to the cyclodextrins and further enhance molecular specificity, sensitivity, and reversibility;

- employment of Lamb-wave transducers with advantages for sensing in aqueous and hostile environments; and

- the use of thermal desorption rates as an additional mechanism for species differentiation.

While the focus of this task is directed toward mass transduction sensors, the surface modification approach and chemistry employed is equally applicable to fiber-optic and electrochemical transduction devices, and can likely be extended to sensing other toxic organics, inorganics, or trace metals. Specific benefits include reduced cost, time, and worker risk associated with site characterization and monitoring; improved performance; and adaptability to a wider range of environmental conditions.

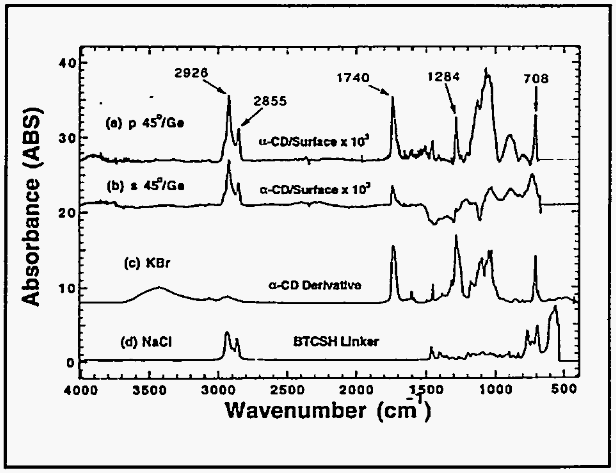

Figure 1.28a. Fourier-transform infrared-attenuated total reflection (FTIR-ATR) spectra of (a) a-cyclodextrin monolayer covalently bound to the native oxide surface of Si<100> with a kGe internal reflection element and p-polarized light incident at 45o, 1024 scans, 2cm-1 resolution; (b) s-polarized; (c) bulk a-cyclodextrin derivative (KBr disk), (d) neat linker on NaCl crystal.

TECHNOLOGY NEEDS

Sensors for continuous real-time monitoring of ambient air, ground and surfacewater, and contaminant plume migration will be needed for compliance with state and Federal regulations (the Clean Air Act, the National Environmental Policy Act, and RCRA, to mention a few). Moreover, the specific needs of the environmental restoration and waste management programs require a new generation of sensors and advanced fieldable instrumentation. Present technology is simply inadequate to address the multitude of monitoring needs in site characterization, cleanup verification, post-closure monitoring, and process diagnostics and control. There is a specific high-level need at a number of industrial sites for real-time sensors that will accommodate both air and down-hole aqueous phase sampling of chlorinated hydrocarbons (see Figure 1.28b).

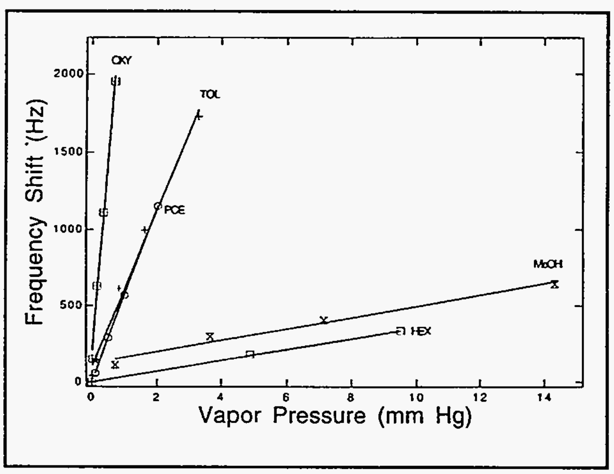

Figure 1.28b. Linear concentration dependent SAW response of various analytes to an a-cyclodextrin monolayer coated 200 HMz resonator: perchloroethylene, toluene, o-xylene, methanol, kand hexane.

ACCOMPLISHMENTS

Now beginning the second year of funding, a number of molecular surface building blocks have been synthesized covalently-bound self-assembled monolayer (CBSAM) thin films on various surfaces (e.g., Si wafers for infra-red analysis, and SAW resonators for sensor evaluation have been fabricated), and the CBSAM thin films have been characterized via polarized variable-angle internal attenuated total reflection infrared (PVAI-ATR-IR) techniques and surface acoustic mass transduction. More specifically, asymmetric a-cyclodextrin-2O,3O-dodecabenzoate and b-cyclodextrin-2O,3O-tetradecabenzoate have been synthesized by first reacting dried and purified cyclodextrins with benzoyl chloride to form cyclodextrin perbenzoate, and then selectively hydrolyzing the benzoate groups on the primary side of the cyclodextrin rim using isopropoxide. The resulting mixture usually consists of a few other cyclodextrin benzoate derivatives, which were removed by chromatography using silica gel and benzene:ethanol as an eluted solvent. The final products (structure and purity) were characterized by ^{1}H NMR, FTIR, and TLC.

Monolayers of both asymmetric a- and b-cyclodextrin benzoate derivatives can be successfully anchored on oxide surfaces through covalent bonds via a linker w-bis(trichlorosilyl)alkane. To form the cyclodextrin monolayer, the substrate was first exposed to the vapor of the linker+1,6-bis(trichlorosilyl)hexane, followed by binding subsequent cyclodextrin molecules through their primary hydroxyl groups. By blocking the secondary hydroxyl groups of a-cyclodextrin or b-cyclodextrin via functionalization of benzoate groups, these cyclodextrin surface building blocks can be easily linked to the surface with the cyclodextrin "bucket" facing upward. This desired

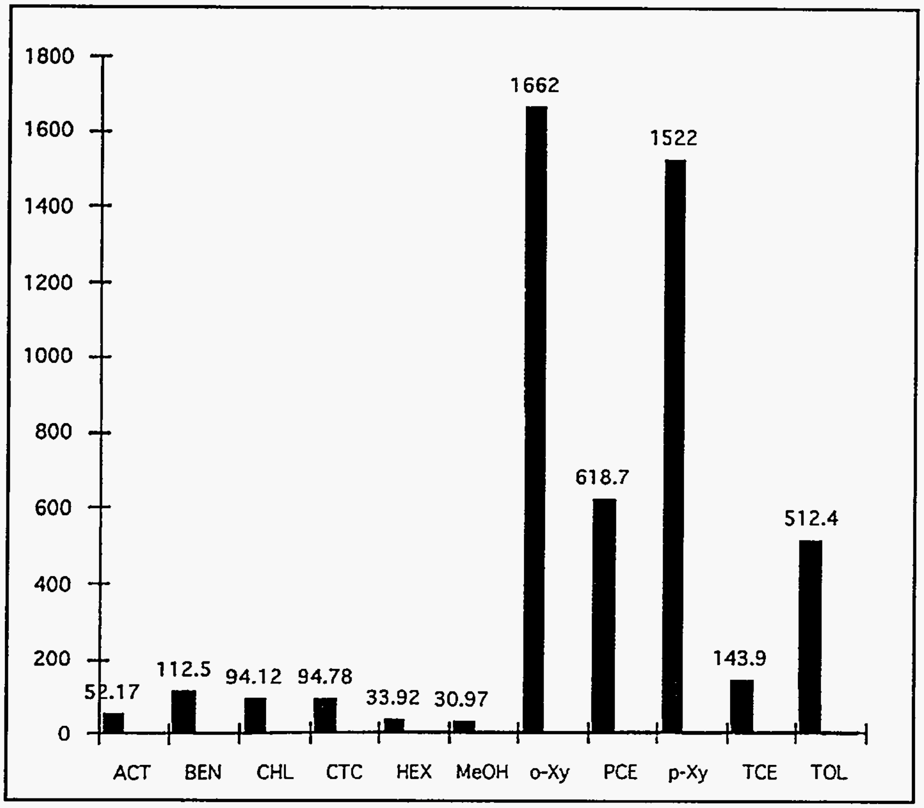

Figure 1.28c. Comparisons of the responses of the self-assembled a-cyclodextrin monolayer coated 200 MHz SAW resonator microsensors to a variety of analytes at unit organic vapor concentration (Hz/mmHg): Acetone, benzene, chloroform, carbon tetrachloride, hexanes, methanol, o-xylene (o-Xy, perchloroethylene, p-xylene, trichloroethane, and toluene. Note the a-cyclodextrin coated monolayer thin film is very selective to xylenes, PCE, and toluene.

molecular orientation results in an enhancement of the kinetic speed (i.e., response time) of the formation of inclusion complexes. Moreover, functionalities other than benzoates can be incorporated into the secondary hydroxyl group "tether" points. These functionalities include such alkyls as methyl, ethyl or aryl and serve to further control access to the cyclodextrin cavity by the analytes. In addition to covalent bonding to the oxide surface, this step-by-step supramolecular self-assembly technique offers molecular level manipulation of nano-structure such as cyclodextrin orientation.

CBSAM thin films were analyzed by PVAI-ATR-IR techniques, and the results suggest successful monolayer formation of cyclodextrin derivatives on the Si wafer surfaces. The vibrations of cyclodextrin benzoates at 1740 cm^{-1}, 1284 cm^{-1}, and 708 cm^{-1} and its linker at 2926 cm^{-1} and 2855 cm^{-1}, which are covalently attached to the Si surfaces, are clearly resolved. Monolayer thin films of both a- and b-cyclodextrin on actual surface acoustic wave devices have been fabricated. Results on 200 MHz resonators indicate that the b-cyclodextrin thin films do show significant affinity to target chlorinated organic toxins such as PCE while a-cyclodextrin monolayer thin films prefer toluene and xylenes. Further experiments underway are aimed at maximizing monolayer coverage for construction of densely packed monolayer thin films. Sensing layer efforts into other synthetic host molecules have recently been expanded and the initial results are extremely encouraging.

The extreme outer rim of cyclodextrins can be further modified to achieve better selectivity and sensitivity by blocking the primary hydroxyl groups with t-butyldimethylchlorosilane followed by substitution reactions at the secondary hydroxyl groups (see Figure 1.28c). This result opens up a number of opportunities to tailor the cyclodextrin-surface properties (hydrophilic versus hydrophobic) as well as its selectivity to various analytes. Cyclodextrins are also being synthesized for the construction of multilayer self-assembly using this step-by-step approach by alternating cyclodextrin layers and linker layers. Previous approaches have focused on linking host molecules via organic covalent bonds. A new inorganic approach that binds cyclodextrins or other synthetic hosts via a coordinative and/or ionic bond is being experimented with; to this end new molecular building blocks, such as a-cyclodextrin-2O,3O-dodecabenzoate-6O-hexaphosphate and other cyclodextrin phosphate compounds are being synthesized.

COLLABORATION/TECHNOLOGY TRANSFER

In the second fiscal year of this funding, Ames Laboratory and the University of California at Berkeley are collaborating to work on Lamb wave devices for aqueous sensing. A full-time graduate student and part-time student will be supported by part of this funding (~$50k). Motorola is interested in sponsoring and establishing a test facility for sensor systems at their Phoenix plant for waste stream monitoring and downhole sensing in aqueous media. Motorola will provide a path to technology transfer and commercialization, via integration of our sensor elements into a remote, real-time monitoring system. A formal CRADA between Motorola and LANL is currently under development. A number of companies including Tektronix, Tanknology, Berkeley MicroInstrument, Amtex, Geocenter, and TPL have expressed interest in how variants of the base technology might meet their needs for sensor technology. For instance, Tanknology is interested in developing a pentane sensor with low ppm sensitivity for monitoring the leaks of gasoline storage tanks. Tanknology has a great demand for these pentane sensors, as they currently sample around the tanks using a very expensive GC-MS procedure. Ways to leverage efforts on related sensor technologies for benefit to all programs, DOE, and industrial partners are currently being pursued.

For further information, please contact:

DeQuan Li
Los Alamos National Laboratory
P.O. Box 1663
Los Alamos, MN 87545
(505) 665-1158

Bruce Erdal
Technical Program Manager
(505) 667-5338

1.29 AIR QUALITY SITE BOUNDARY MONITORING FOR VOLATILE ORGANIC COMPOUNDS

TASK DESCRIPTION

This proposal describes a methodology in which a micromist air sampler (CMAS) developed at Los Alamos National Laboratory will be combined with a transportable gas chromatograph ion trap mass spectrometer (GC/ITD) for the field collection and detection of airborne VOCs (see Figure 1.29). Membrane sampling technology, developed at Purdue University, will be used to introduce the preconcentrated VOCs to the GC/ITD. Each of these individual technologies has proven successful. Sensitivities can be tailored to quite easily surpass any existing or realistically anticipated regulatory requirements for the lower limits of detection. This technology can provide both primary (fast screening) and secondary (slower) legally defensible GC/MS data to verify air quality at and around DOE facilities and remediation sites. Sampling can be done in near-real time (minutes); additional samples can be easily collected for verification by independent off-line analysis.

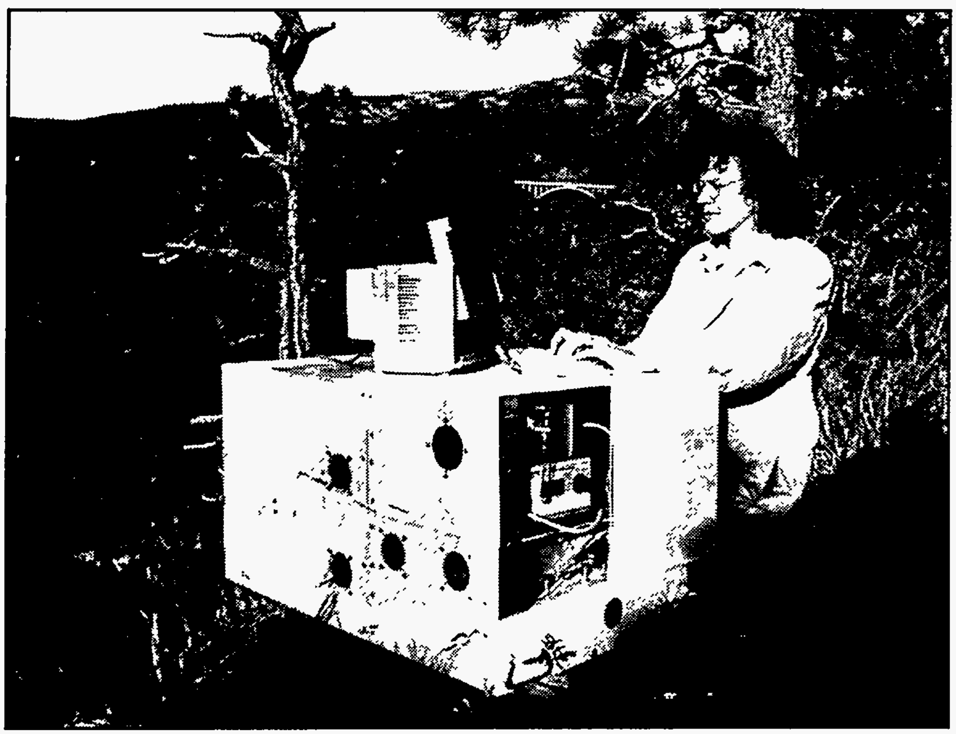

Figure 1.29. The Los Alamos transportable gas chromatograph ion trap mass spectrometer used for the field analysis of volatile organic compounds in the environment.

TECHNOLOGY NEEDS

This technology is needed at every DOE facility to monitor air quality at site boundaries. There are many scenarios that require high sensitivity detection of atmospheric volatile organic compounds:

- routine monitoring to establish baseline air quality at site boundaries;

- response monitoring to characterize and document atmospheric distribution of volatile chemical solvents from accidental releases or spills; and

- waste site monitoring to ensure worker and public safety during remediation activities. Specific Integrated Demonstrations that could be supported by this technology include those where remediation of VOC-contaminated soil is planned or underway (Savannah River A-1, Hanford A-4, and Sandia-Albuquerque A-9). The instrument could provide monitoring for accidental releases during waste exhumation at the Buried Waste ID (B-I) at INEL.

The proposed technology can support many other activities in the environmental arena:

- air monitoring at hazardous or mixed waste storage sites;

- air monitoring at DOE and private industrial areas to ensure worker safety and to document exposure; and

- detection of atmospheric tracers to provide data for global modelling efforts.

Finally, the instrument could be used to monitor chemical emanations that are signatures of military operations, drug processing, and other illegal or aggressive activities.

ACCOMPLISHMENTS

Significant accomplishments were made in two key areas: (1) air sampling, and (2) membrane sample introduction. The collection of VOCs with the CMAS is problematic due largely to the poor partitioning of organics from air into the aqueous mist. Dilute surfactant solutions in the CMAS improved collection of certain compounds. With a prototype CMAS, detection limits for many VOCs in air are about a part-per-billion by volume (ppbv), with some in the high parts-per-trillion range. A new CMAS specifically for VOC collection was designed and built and is being tested. The development of the membrane interface at Purdue University was very successful. The efficiency of the membrane introduction system was improved by a factor of 100. Organics in water can be detected at the low part-per-trillion by weight (pptw) level in near-real time with linearity spanning a 2000-fold concentration range. Although this system was designed as an interface between the CMAS air sampler and the ion trap mass spectrometer, the membrane sampling system could also be used for the direct analysis of VOCs in water, (e.g., as a waste stream monitoring technique).

COLLABORATION/TECHNOLOGY TRANSFER

This project is in collaboration with Purdue University. The Principal Investigators are remaining in close communication with Finnigan MAT, the commercial manufacturer of the ion trap mass spectrometer, and with the president of MIMS, a company founded to develop and market membrane separators for chemical analysis. In addition, a scientist from the National Center for Atmospheric Research is on sabbatical at the laboratory and will be working on improving the CMAS and developing new cryogenic methods of VOC collection.

For further information, please contact:

Philip Hemberger
Analytical Chemistry Group
Los Alamos National Laboratory
(505) 665-5735

Bruce Erdal
Technical Program Manager
Los Alamos National Laboratory
(505) 667-5338

1.30 MULTI-SPECTRAL NEUTRON LOGGING: A NEW GENERATION PULSED-NEUTRON INDUCED GAMMA-RAY MULTI-SPECTRA LOGGING SYSTEM FOR IN SITU MAPPING OF CONTAMINANTS

TASK DESCRIPTION

This project addresses two nuclear borehole logging techniques that are capable of identifying and mapping numerous contaminants and are nuclide specific.

- Neutron-induced spectral gamma-ray logging measures gamma-ray energy spectra during and/or after irradiation of the borehole environment with energetic neutrons, and can positively identify many nuclides, including chlorine and a number of RCRA metals (see Figure 1.30a).

- Passive spectral gamma-ray logging positively identifies gamma-emitting contaminants and is quite sensitive, but needs work to be made quantitative.

In the neutron-induced spectral gamma-ray part of this project, a contaminant-doped concrete test facility has been designed and is now under construction at Grand Junction, Colorado (see Figure 1.30b). Assembled through collaboration with an industry partner (Environmental Measurements Corp., Denham, TX), a hybrid test instrument composed of the pulsed-neutron source section of the existing commercial instrument along with a laboratory-grade cryogenic detector and multichannel analyzer will be assembled. Experiments will be performed in the test facilities using the hybrid test instrument to make direct assessments of instrument sensitivity to the contaminants in the test facilities. Ongoing computer simulations will allow extension of the experimental results to estimate detection thresholds for other contaminants of concern and determination of optimum design for a next-generation instrument.

In the passive spectral gamma-ray part of the project, experimental data provided by Westinghouse Hanford Company is being used, along with computer simulations to develop data correction and deconvolution algorithms to establish a quantitative basis for this technique. The FY94 effort is to determine the response of an existing DOE instrument to many environmental variables and adapt existing data processing techniques, including linear inverse theory, to correct for those conditions. The FY95 effort is to generalize

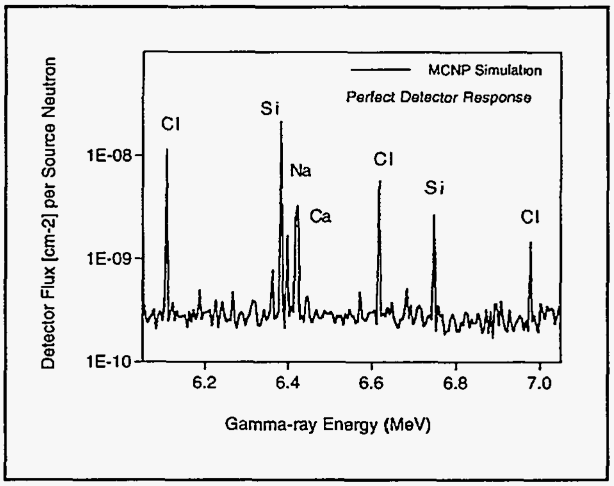

Figure 1.30a. Small portion of a simulated gamma-ray energy spectrum.

the data correction algorithms to less well-behaved geologic conditions, where the assumption of linear system behavior is not valid. A more general statistical approach will be developed to assure data quality in such environments.

TECHNOLOGY NEEDS

This project responds to a number of needs identified by the CMST-IP:

- field analysis equipment for real-time results;
- significantly improved analytical methods or sensors;
- improved in situ measurements of subsurface properties;
- instrumentation for deployment by cone penetrometers; and
- statistically guided sampling and data quality assurance tools.

Letters of support for this project have been received from environmental restoration groups at Westinghouse Hanford Company, Sandia National Laboratories, Los Alamos National Laboratory, and Westinghouse Savannah River Company.

ACCOMPLISHMENTS

- Contaminant-doped concrete test facilities have been designed and are being constructed at Grand Junction, CO.
- Contract negotiations with an industrial collaborator are in the final stages for

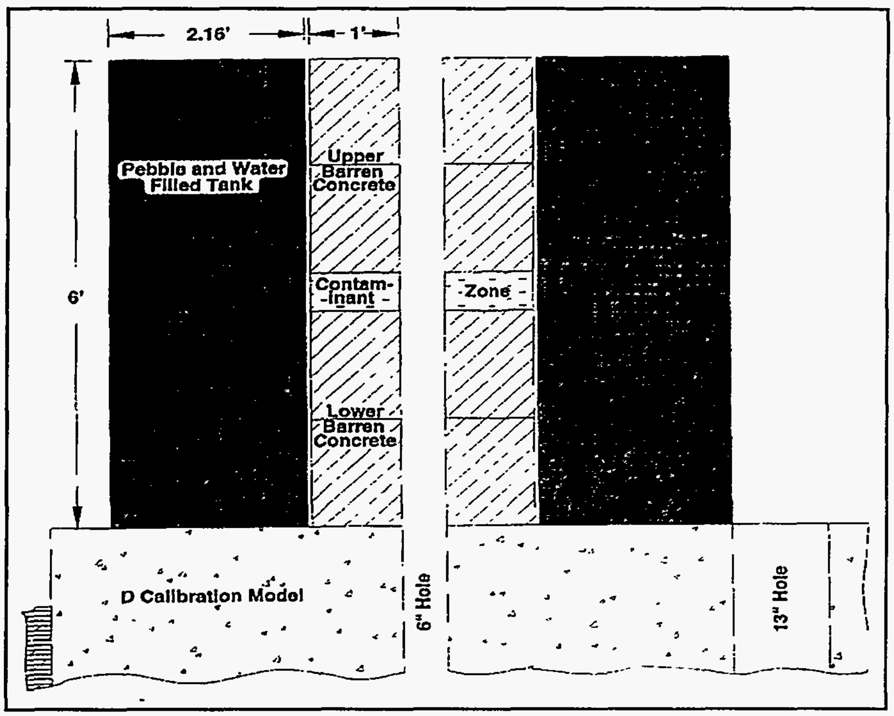

Figure 1.30b. Cross-section of contaminant-doped concrete test facility setting on an existing borehole calibration model at the Grand Junction Projects Office.

experiments using a hybrid commercial/experimental neutron-induced spectral borehole logging instrument.

- Computer codes for simulating neutron and gamma-ray transport problems have been installed and tested. Substantial improvements have been made to the codes for this project and other improvements are expected shortly that will greatly speed the simulation process. Simulations are now being performed successfully.
- For the passive spectral gamma-ray work, Westinghouse Hanford Company provided experimental data and details of their logging instrument. Simulation models are currently being tested.
- All work is on schedule and within budget.

COLLABORATION/TECHNOLOGY TRANSFER

This neutron-induced spectral gamma-ray work is being performed collaboratively by Los Alamos National Laboratory, RUST Geotech (site operator for the DOE Grand Junction Projects Office), and the U.S. Geological Survey, under separate Technical Task Plans. Westinghouse Hanford Co. is participating under EM-40 funding. Negotiations are in progress with a potential industry partner, Environmental Measurements Corp., who have been supportive and enthusiastic about collaborating on the project. The passive spectral gamma-ray work is primarily a Los Alamos project collaborating with Westinghouse Hanford Company under their own EM-40 funding. This part of the project is newer and the details of technology transfer are being worked out.

For further information, please contact:

John Conaway
Los Alamos National Laboratory
(505) 667-2683

David George
RUST Geotech
(303) 248-6699

Jon Mikesell
U.S. Geological Survey
(303) 236-1321

1.31 IN SITU RCRA METALS ANALYSIS

TASK DESCRIPTION

This task will develop field-deployable instrumentation for rapid determination of hazardous metals in soils at hazardous and mixed waste sites. The data quality is expected to be suitable for use of the instrumentation as a field analytical method during site characterization. Elements targeted specifically are those of primary concern at many DOE and industrial waste sites: Cr, Pb, As, Se, Sb, Cd, Zr, U, Be, and Th. The instrumentation will be based on laser-induced breakdown spectroscopy (LIBS). Using LIBS, it will be possible to determine rapidly both the concentration and location of elemental species in a waste site.

In LIBS, laser light is focused on a surface to vaporize a small amount of material. The vaporized material forms a short-lived plasma, which emits light that is collected, dispersed and analyzed. A schematic of a LIBS apparatus is shown in Figure 1.31a. LIBS instrumentation can be made quite compact and only requires line-of-sight access to a material. The method thereby lends itself to integration with other instruments and several instrument configurations. The working head of one portable instrument constructed at LANL is 4 inches in diameter and 8 inches long. Using a fiber-optic cable to guide the laser energy to soil will decrease the size requirements. Also, standoff analyses of at least fifty feet are anticipated to be achievable. The final form of the prototype instrumentation will either be designed to provide as general use as possible or will be determined by the instrument configuration and data requirements of any of a number of end-users.

Prototype instrumentation for hazardous waste sites will be available in mid-1995. Instrumentation for mixed-waste sites is planned for 1996. These programs all require a rapid field-screening method for site (or tank) characterization and real-time analysis for remediation and process monitoring.

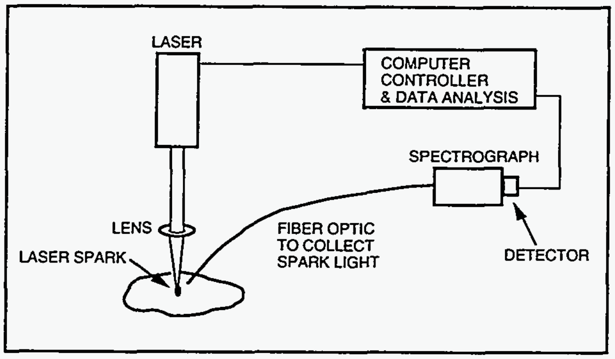

Figure 1.31a. Schematic representation of a basic laser-induced breakdown spectroscopy instrument.

TECHNOLOGY NEEDS

The need for a field method that can provide expedited site characterization of hazardous waste sites is critical. Site remediation often becomes mired in the site characterization step because of slow turn around time of sample analyses. In addition, once a sample is removed from a location, its chemical integrity is always of concern. A method that minimizes sample handling and transport is needed to better ensure data quality. The LIBS instrumentation to be developed and tested in this task is targeted to fulfill these needs for as many heavy metals as time permits.

In addition to increasing the speed and efficiency of analyses, this technology will decrease the costs associated with evaluating and remediating hazardous and mixed-waste sites. It is estimated that years will be saved in characterizing and remediating sites identified by EPA as falling under RCRA. Cost savings should include 80% of the sampling costs of using conventional laboratory techniques for all analyses as well as savings resulting from reduced crew downtime waiting for laboratory analyses. It is also anticipated that a reduction of 80-90% in transportation and 80-90% in the generation of new hazardous waste by sample analysis will occur. In addition, this instrumentation will eliminate the exposure of personnel to potentially hazardous wastes.

Another benefit is the larger number of samples that can be analyzed and the greater accuracy in determining the analyte distribution throughout a site. Analysis at a single position at a site should take one minute or less. Thus, a site can be surveyed in less time, with greater coverage, than achievable with conventional sample collection and analysis methods. Additionally, depth profiling by analysis of core samples is limited by the cost of analysis to one 10g sample taken for every five foot section. This is a very small fraction of the entire core, and choosing a representative sample is a difficult but critical task. Using an instrument based on LIBS to scan the entire length of the core sample, in the field, will be a cost-effective solution to this sampling problem.

ACCOMPLISHMENTS

This is the first year of this task. As scheduled for the first few months of this year, laboratory experiments have been conducted to:

- identify spectral interferences from elements typically found in soils for the analytes of interest.

- determine the detection limit, sensitivity and precision of the best analytical line(s) in soils spiked with single elements of interest. Instrument parameters used are those that can be translated to fieldable instrumentation.

A typical calibration curve is shown in Figure 1.31b.

Complete details of the results for detection limits of soils spiked with single elements will be available in the report due at the end of March 1994.

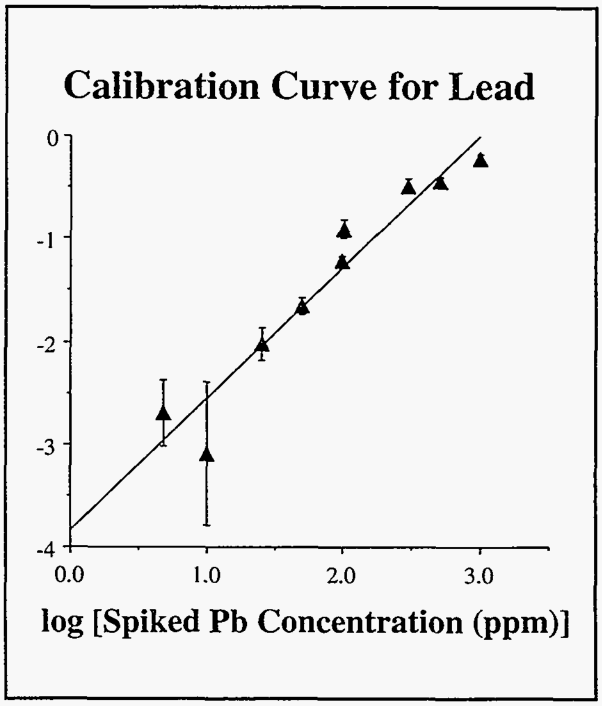

Figure 1.31b. Calibration curve for Los Alamos soil spiked with lead.

COLLABORATION/TECHNOLOGY TRANSFER

Perkin-Elmer, Inc., one of the largest analytical instrumentation manufacturers in the world, is interested in developing LIBS technology for heavy metals analysis of soils in the field. The principal scientist from Perkin-Elmer involved in this project has conducted experiments in the LIBS labs at LANL on several occasions. They have provided funds for the construction of a laboratory LIBS instrument to be delivered to Perkin-Elmer for evaluation. Construction of that instrument has begun.

For further information, please contact:

Aaron Koskelo
Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 665-4463

David Cremers
Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 665-4180

1.32 AIR-QUALITY MONITORING FOR ALPHA CONTAMINATION — LONG-RANGE ALPHA DETECTION

TASK DESCRIPTION

This project is developing detectors for airborne alpha contamination based on LRAD technology. The goals are to demonstrate the effectiveness of this technology when applied specifically to monitoring air quality and to compare these results with those generated by more traditional detectors. LRAD-technology-based detectors should exhibit better performance, as indicated by greater resolution and faster response at a lower cost than existing baseline detectors.

Detection of alpha contamination in air samples has traditionally been limited by the short range of alpha particles and the relative insensitivity of fieldable alpha monitors. The best currently available technology uses continuous air monitor (CAM) detectors. These detectors must sample a given volume for several hours in order to achieve ~0.1 pCi/liter resolution.

The general design of LRAD-technology-based Air-Quality Monitors (AQMs) is shown in Figure 1.32a. Air is drawn through electrostatic and particulate filters into a sample enclosure. Ions produced by alpha decays within the sample enclosure are then collected on a grid and the current generated is measured using a sensitive electrometer. This current is directly proportional to the concentration of airborne alpha contamination.

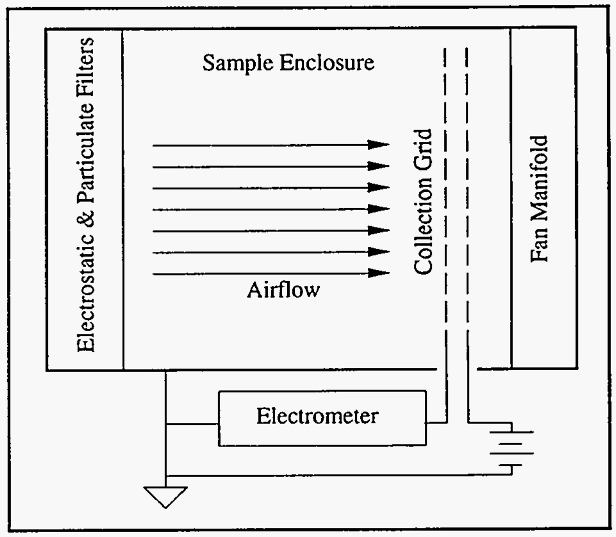

Figure 1.32a. Schematic of a long-range alpha detector, technology-based air-quality monitor.

TECHNOLOGY NEEDS

In the Decontamination & Decommissioning field, work involving sectioning and removing objects, such as walls, concrete floors, pipes and equipment, must be performed. Any alpha contamination attached to these objects can become airborne in the process. A real-time monitor capable of detecting alpha radiation levels ranging from the naturally occurring background of ~1 pCi/liter up to ~1000 pCi/liter would improve worker safety. Continuous real-time monitoring in plutonium processing facilities, waste storage areas and other places where the potential for airborne alpha contamination exists is also desirable.

ACCOMPLISHMENTS

Existing prototype LRAD detectors have been used to investigate whether the desired sensitivity to airborne alpha contamination can be achieved. Two detectors, originally designed as personnel hand monitors, were operated in the Radon/Radon Daughter Environmental Chamber operated by the Rust Geotech lab at the DOE Grand Junction Projects Office (GJPO). Concentrations spanning four decades, from 0.1 pCi/liter up to 320 pCi/Liter, were tested. Figure 1.32b shows current measured by the two LRAD

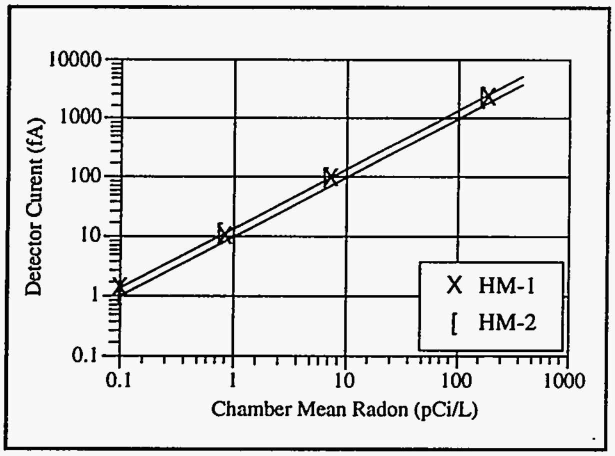

Figure 1.32b. Radon response of two long-range alpha detector, technology-based detectors, HM-1 and HM-2.

detectors (HM-1 & HM-2) versus the chamber mean radon concentration as measured by 10 continuous radon monitors, including a commercially-available Eberline RGM-2 and two Pylon AB-5s, operated by the Grand Junction Project Office staff.

After subtracting a constant background produced by cosmic ray ionization in the sample enclosure and leakage currents in the electrometer and collection grid standoffs, linear calibration coefficients of 9.25 and 11.38 pCi/L/fA were obtained for HM-1 and HM-2. Because detector HM-1 was equipped with a particulate filter while HM-2 was not, correlation coefficient for radon daughters attached to particulates were able to be measured. Figure 1.32c compares the GJPO data (10 detectors averaged over one hour intervals) to HM-2 data (averaged over 6 minute intervals) after applying the calibration and particulate corrections.

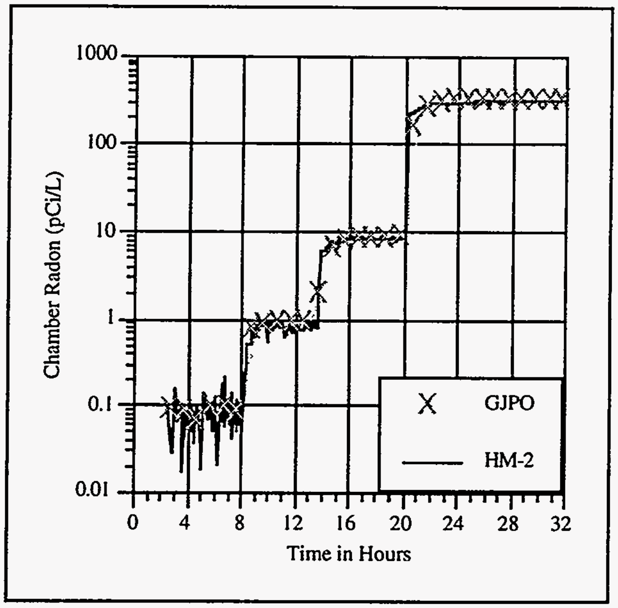

Figure 1.32c. An overlay of the particulate-corrected HM-2 and Grand Junction Project Office data.

These data show that LRAD-technology-based air-quality monitors will have a fast and linear response to airborne alpha contamination over the entire test range of 0.1 pCi/liter to greater than 320 pCi/liter. The speed of response to changes in concentration is determined by the rate of exchange between the sample enclosure and the surrounding air. This exchange rate is typically less than 10 seconds.

Rust Geotech Radon Laboratory has joined LANL personnel in analyzing and presenting these data as work in progress in a paper titled LRAD Radon Test Results at the Mid-Year Health Physics Society Meeting, Albany, NY (Feb. 13-16, 1994).

Two new prototype detectors (AQM-1 and AQM-2) have been fabricated in order to determine the optimum design for monitoring airborne contamination. While the HM detectors used airflow ion collection, these prototypes can easily be modified to operate in either the airflow or electrostatic ion collection mode.

Initial results obtained with the AQM prototypes indicate that the electrostatic ion collection method improves ion collection efficiency by ~30%. This increase in detection efficiency will translate into a smaller, more portable monitor.

Work is underway to optimize an electrometer for use with AQMs. All previous LRAD-technology-based detectors, including HM-1 and HM-2, used Keithley 617 electrometers. These cost ~$3500 each and are AC powered, large, heavy and subject to baseline fluctuations, due to temperature shifts, vibration or other environmental factors. In addition, since many of the potential applications of AQMs require operation outdoors or in facilities being decommissioned, battery operation is required. The current electrometer prototype has better performance than the Keithley unit, weighs only a few ounces, runs for ~60 days on a set of batteries and costs ~$100. Electrometers with additional improvements are under development.

COLLABORATION/TECHNOLOGY TRANSFER

Ames Laboratory is collaborating with personnel at the DOE GJPO and Rust Geotech Radon Laboratory on calibration and testing of LRAD-technology-based detectors. A second trip to this facility is planned for April, 1994 in order to calibrate and investigate the performance characteristics of the AQM prototypes.

A CRADA and licensing agreement between LANL and Eberline Instrument Corporation for the commercial development of LRAD-technology-based detectors already exists. Eberline has already commercially-produced an LRAD object monitor, the LRAD-1. As part of the technology transfer partnership, LANL continues to work with Eberline to evaluate and suggest incremental improvements to their existing design. LANL is working closely with Eberline and Commercialization Specialists to insure that transfer of the final AQM design and relevant technical information occurs at the appropriate moment. This transfer will most likely occur by mid- to late-summer. Once Eberline has a production unit available, based on the AQM design and technical input, the final part of this program, obtaining regulatory acceptance of AQMs as implemented by Eberline, can proceed.

For further information, please contact:

Richard Bolton
LANL, NIS-6, MS-J562
Los Alamos, NM 87544
(505) 667-8241

Bruce Erdal
Technical Program Manager
(505) 667-8914

1.33 DATA FUSION FOR CHARACTERIZATION AND MONITORING

TASK DESCRIPTION

The purpose of the this project is to successfully transfer Data Fusion technology developed for the Department of Defense (DoD) to the DOE environmental mission. Multi-sensor Data Fusion is a new discipline that seeks to combine data from multiple sensors to perform inferences that may not be possible from a single sensor alone. Most applications address military problems, such as automatic identification of targets, analysis of battlefield situations, and threat assessments (Hall 1992).

Coleman Research Company (CRC) is a developer of multi-sensor Data Fusion technology. Under DOE guidance, they have applied their DoD knowledge and experience to develop a Data Fusion workstation to combine environmental data sets. The technology is being demonstrated and tested for data collected at the Hanford site, in particular, at the Volatile Organic Compounds in Arid Soils Integrated Demonstration. During FY94, CRC collected multi-sensor data (surface geophysical data) and adapted their Data Fusion software. They transferred a Data Fusion workstation to PNL. This project will complete the adaptation of this technology, demonstrate its utility at the Hanford Site, and transfer the technology to the Westinghouse Hanford Company.

Initial efforts will be focused on insuring that the current software will perform efficiently. This task will focus on debugging the hardware and software, validating the results, and conducting sensitivity studies. The utility of the debugged software will be demonstrated through the development of a site conceptual model. Data Fusion technology will form the foundation of the site conceptual model. Transfer of the adapted workstation to Westinghouse Company will complete the task. It is anticipated that Data Fusion technology can be used to maximize the utility of the data that has been collected at Hanford and other DOE environmental sites. The fusion of disparate data sets will permit a "unified" method for the interpretation of characterization and performance assessment data.

TECHNOLOGY NEEDS

A significant amount of effort and money has been expended by the DOE community to support its environmental mission. Much of that money has been spent in the collection of surface and subsurface data for the characterization of active and inactive waste sites. This data comprises many different types, and much of it has not been interpreted in a "unified" manner. That is, individual data sets are typically interpreted individually, or, at best, other data types are examined in a non-numerical manner to assist the interpretation. The high cost of data acquisition and the significant increase in computer capabilities promise to maximize the current investment in characterization data.

Data Fusion technology, as developed by DoD, is designed to mathematically merge or fuse different data types into the development of a single, coherent interpretation. This technology is capable of fulfilling the following technology needs:

- Multiple data sets can be fused simultaneously. The average scientist is hard-pressed to manually combine more than three or four data sets. The data fusion workstation should only be limited by the number of related data sets available.
- The fused interpretation is repeatable. The files necessary for fusion are stored, and they can be easily rerun.
- Residuals are calculated for the final fused interpretation. Thus, a statistical validity is assigned to all interpretations, and this value can be used to consistently judge the results.
- The fused results can be readily displayed using three-dimensional visualization software.

ACCOMPLISHMENTS

Effective use of the Data Fusion workstation hardware has been difficult, due to problems in system stability, reliability, and the lack of disk space. The stability problems have been common to the model of workstation deliv ered to PNL. The vendor solved the problems by replacing most of the boards in December 1993. Additional disk space was installed in January. Hardware problems have delayed the onset of this task by three months.

PNL has been actively debugging the software since the hardware problems were resolved. Collaboration with CRC to debug the data fusion software has occurred. CRC has provided multiple patches to the software, and will deliver a new version in the upcoming weeks. As part of this debugging process, PNL has generated a series of artificial data sets to test the sensitivity of the data fusion software to variations in inputs and data quality. In addition, an attempt to fuse surface resistivity data from another site to extend the capabilities of the fusion software has been made. The Hanford data collected by CRC in FY93 has been successfully fused.

All FY93 data from the Volatile Organic Compounds in Arid Soils Integrated Demonstration and additional data from Hanford Environmental Information System (HEIS) is currently being loaded into the workstation. PNL will use this data to develop an alternative site conceptual model. The loading is currently on hold while PNL works with CRC to determine whether the Data Fusion database should be rewritten. If it is rewritten, this subtask will be a collaborative effort between PNL and CRC.

COLLABORATION/TECHNOLOGY TRANSFER

The final step in the development of the Data Fusion Workstation will be the physical transfer of the workstation hardware to the user community at Westinghouse Hanford Company (WHC). PNL will provide partial support for training WHC personnel in the use of the workstation. PNL has provided funding, from an independent source, for the purchase of a replacement workstation. The replacement workstation will provide PNL the capability to support WHC after the transfer.

Because PNL is providing interim support between the development of the Data Fusion workstation at CRC and its use at the WHC ER client, Ames Laboratory has been actively collaborating with scientists at both organizations. Currently, most of the dialogue has been with CRC to support the debugging effort and the exploration of new uses for data fusion technology.

For further information, please contact:

Stan Tomich
Pacific Northwest Laboratory
(509) 376-9645

Steven Slate
Technical Program Manager
Pacific Northwest Laboratory
(509) 375-3903

1.34 THREE DIMENSIONAL/THREE COMPONENT REFLECTION SEISMIC FOR SITE CHARACTERIZATION

TASK DESCRIPTION

This task will investigate the near-surface earth in a uniform three-dimensional manner through the acquisition, processing, and interpretation of three-dimensional, three-component (3D/3C) reflection seismic data. 3D/3C seismic surveys record data in three-dimensions (X and Y along the ground surface, and depth Z) and three-components (vertical and 2 orthogonal horizontal directions. See figure 1.34a). Data will be acquired with available instrumentation, processed with existing, adapted and/or developed computer software, and interpreted by a combination of existing and developed methodologies.

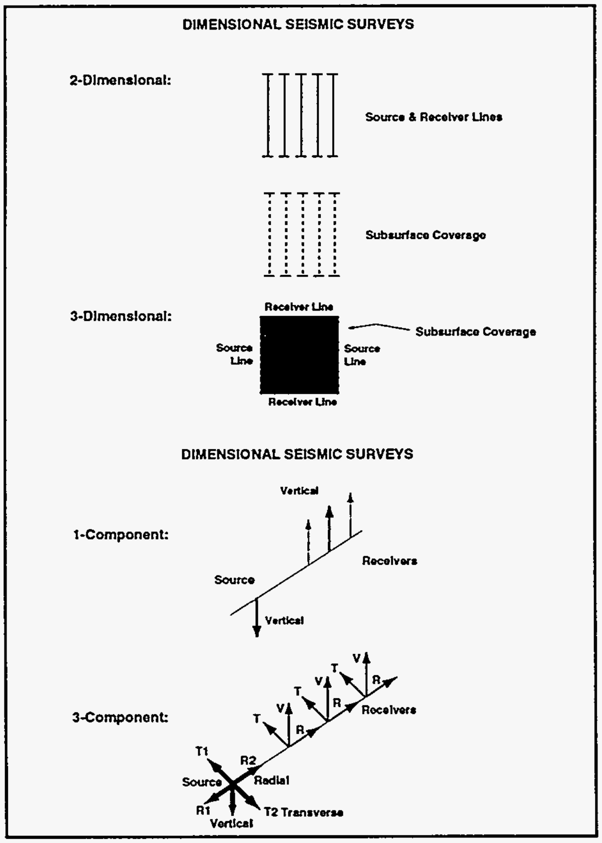

Figure 1.34a. Seismic survey definitions.

Seismic Survey Definitions. There are three primary objectives to this task. The short-term objective will be the acquisition of three-dimensional, one-component (3D/1C) and 3D/3C reflection seismic data sets of the highest quality given the local geologic conditions; the surveys will be designed such that data frequencies and spatial sampling are suitable for high-resolution of the shallow subsurface. The intermediate objective will be the processing and interpretation of the 3D/1C data, which will serve as a baseline comparison for the 3C data and will allow for a direct indication of improvement in characterization between 1C and 3C. All data processing will be designed to retain the high frequencies within the original data. The long-range objective will comprise the adaptation and/or development of software that will be used in the processing and interpretation of 3D/3C data, and the submittal of draft and final reports detailing the acquisition, processing and interpretation of the 3D/3C data. A Core Planning Group consisting of all the participants (RUST Geotech Inc., United States Geological Survey (USGS), Colorado School of Mines (CSM), and Resolution Resources , Inc.)) will be involved in all activities of this task.

TECHNOLOGY NEEDS

3D/3C seismic technology addresses the need to expedite site characterization by non-intrusive methods. The need may be divided into general depths of investigation from shallow, through intermediate, to deep, with inherent approximation of boundaries. The shallow need is primarily concerned with the definition/delineation of trench and pit boundaries, location of buried contaminants, and imaging of shallow structures. The intermediate need, while also concerned with those items of the shallow regime, concentrates more on hydrogeologic framework and subsurface geologic/physical properties measurement. The deep need is basically an extension of the intermediate with perhaps more emphasis on regional characteristics. Site-specific needs are detailed in the Technology Needs Assessment. In addition to DOE field sites, DoD, EPA and other government entities require technologies to conduct the best available characterization to produce data to be input into Records of Decision.

ACCOMPLISHMENTS

This is a newly funded project beginning in FY94. The field site selected for the demonstrations is south of the Old Burial Ground (OBG) in the F-Area Effluent Line (Creek) at the DOE Savannah River Site (SRS) (Figure 1.34b). This site was chosen in collaboration with EM-40 personnel at SRS. Three primary problems that will be addressed at this site with the 3D/3C seismic technology include 1) definition and/or description of preferential pathways for contaminant migration; 2) location of faults and/or fractures; and 3) location and/or detection of plumes (primarily TCE, mercury and tritium).

The field demonstrations will be separated into two parts: namely, an initial 3C noise analysis survey and a subsequent azimuthal 3D/3C survey. The results of the 3C noise analysis survey will be incorporated into the design of the azimuthal 3D/3C survey.

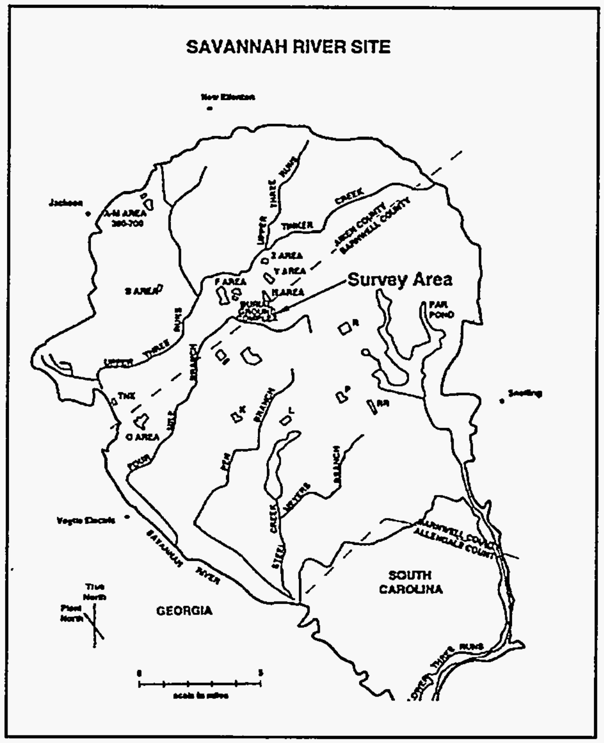

Figure 1.34b. 3D/3C seismic survey location.

3D/3C Seismic Survey Location. The preliminary 3C noise analysis survey will consist of 2 lines also used for the azimuthal survey (tentatively the north-south and east-west lines) plus 1 or 2 lines within the "fill" area (perpendicular to the old stream channel). These surveys will be conducted by the USGS with assistance by other members of the Core Planning Group. A sledgehammer source will be used for the surveys with 5 strikes (vertical, 2 radial and 2 transverse) into 3-components along a minimum of 6 spreads. Subsurface continuity, frequency content as a function of distance and anisotropy definition will be the primary objectives of these surveys. Processing and analysis of the data will be conducted primarily by the USGS, and by RUST Geotech to a lesser extent, using existing software.

The azimuthal surveys will consist of eight surface lines separated by 45° and centered around a borehole. Three-component receivers will be located along the surface lines and within the borehole. A minimum of 20 stations (with 3-component receivers at each station) along the surface plus 20 3-component receivers within the borehole (at an unspecified interval) are planned. The 3D/3C surveys will be conducted by Resolution Resources with assistance from other members of the Core Planning Group. Seismic sources may include the "mini-vibrator", sledgehammer and possibly the USGS "Rotator". An azimuthal array offers a multitude of angles and offsets, the inclusion of data from a borehole contributes to constraining solutions, and recording of all 3 components from a single source-impact reduces the number of variables within the experiment. Processing of the 3D/3C data will be conducted by CSM using Advance Geophysical Corporation's PROMAX software; it is envisioned that a subset of the data will be processed by RUST Geotech using Mercury International Technology or other software.

COLLABORATION/TECHNOLOGY TRANSFER

The joint participants within this task represent the DOE, private sector, academia and another government agency. The joint participants will collaborate towards the common goal to develop feasible near-surface 3D/3C seismic technology. Emphasis will be placed on providing technology to the private sector suitable for near-term application to specific EM programs. Resolution Resources, the private sector joint participant, will gain sufficient knowledge from this project to become a leader in the commercialization of the technology. The final reports will not only represent the work that has been done, but will be vehicles for the transfer of this technology.

For further information, please contact:

James C. Hasbrouck
RUST Geotech Inc.
P. O. Box 14000
Grand Junction, CO 81502
303-248-6714 (Voice)

David Emilia
Technical Program Manager
303-248-6417

1.35 CROSSHOLE COMPRESSIONAL AND SHEAR-WAVE SEISMIC TOMOGRAPHY

TASK DESCRIPTION

For the geologic characterization and monitoring of environmental remediation sites, methods are needed for imaging of the geology and subsurface properties with a minimum of intrusion. Crosshole seismic tomography is a semi-intrusive method for such sites. The output of this method is an image of the seismic-wave velocity structure between the boreholes obtained by measuring the seismic-wave travel times between a large number of source and receiver locations at various depths within the wells. This velocity structure can be interpreted in terms of geology. In addition, by combining the use of compressional (P) and shear (S) waves, other rock properties, such as saturation level, can be imaged for identifying perched water zones and monitoring remediation processes that change saturation levels, for example, air sparging (see Figure 1.35a). This technology will be developed into a commercializable field and processing system through the development and improvement of existing downhole source and receiver technology. At the same time, the imaging and property determination capabilities of the technology will be demonstrated and improved through a series of surveys at the Hanford site using existing boreholes.

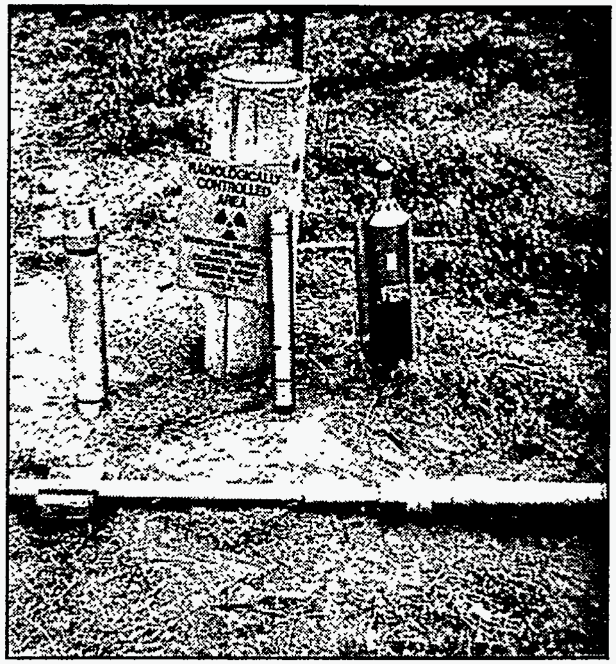

Figure 1.35a. Down hole equipment used in preliminary test at Hanford site. From left to right: Oyo-Conoco orbital vibrator, Bolt airgun, Oyo-Sandia downhole receiver. In front: Sandia pneumatic vertical vibrator.

TECHNOLOGY NEEDS

At the present time, subsurface characterization is restricted to extrapolation of point information from wells, surface geophysical methods, and newly-developed crosshole electromagnetic imaging methods. Crosshole seismic imaging is needed to improve the subsurface geologic interpretation by providing information between the boreholes to help in extrapolating the borehole-determined properties. It has advantages over surface methods in that it does not depend on seismic energy returning to the surface via reflection or refraction, but relies on one-way transmitted energy, eliminating the need for reflectors in the subsurface. It also has the advantage of placing the source and receiver nearer to the zone of interest, resulting in less attenuation of the high-frequency, high-resolution information and avoiding the typically highly attenuative near-surface layers.

Finally, seismic imaging provides a complementary imaging method to crosshole electromagnetic methods in that they respond differently to changes in rock properties and, used together, can provide a much more complete picture of the subsurface. When limiting the methods to existing wells, seismic has the advantage of being able to work in steel-cased wells, unlike presently available EM methods.

ACCOMPLISHMENTS

Although funding for this project only began this fiscal year, an initial fielding at Hanford was performed in February (see Figure 1.35b.). This test was to examine three existing sources for their capabilities to transmit sufficient energy between existing boreholes at the Hanford site. Two sites were chosen, one in the Hanford formation of open-framework gravels and silts, and one in the more cemented gravels and sands of the Ringold formation. Both sites used locations above and below the water table to test coupling in the vadose zone as well as the saturated zone. The three sources used were a commercially-available airgun, which generates primarily P waves from a high pressure air pulse; a Sandia-developed pneumatically-powered vertical vibrator, which generates vertically-polarized S waves; and a recently available eccentric mass orbital vibrator, which generates both P waves and horizontally-polarized S waves.

Preliminary results from this initial test showed that all three sources generated sufficient energy to be easily recorded in the geologic formations at Hanford in boreholes separated by up to 180 feet. In addition, surface geophones were recorded to test the possibility of recording reverse vertical seismic profiles. Although these results are not as unambiguous as the crosshole data, significant amounts of energy were recorded on the surface geophones, indicating that RVSP may be a viable exploration technique in these areas. Although this preliminary test was not a full tomographic survey to determine seismic velocity structure, definite changes in velocity were noted at various depths in the hole and corresponded to changes in lithology determined from drilling infor-

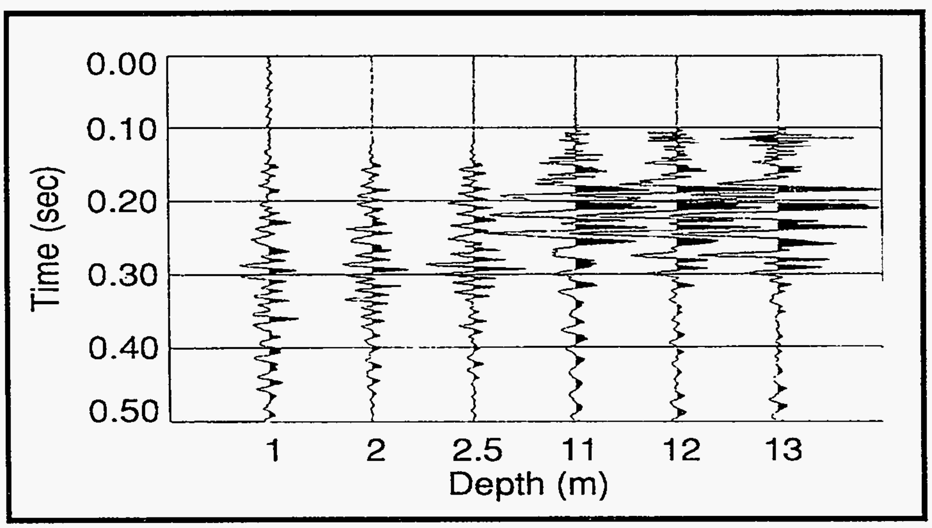

Figure 1.35b. Example of cross hole data collected with Bolt airgun at Hanford site.

mation. This correspondence indicates that seismic tomography will be a useful method for imaging the geology between the wells.

COLLABORATION/TECHNOLOGY TRANSFER

Negotiations have begun with Sandia Research Associates to enter into a cooperative agreement for the development of both new inversion processes for the seismic data and the development of a standard rapidly-deployable field system for collecting the seismic crosshole data. It is hoped that the final system will include both hardware and software for producing in-field preliminary velocity structure models. Sandia Research Associates is also actively pursuing additional industrial partners and plans to submit an SBIR proposal for additional funding next fiscal year.

Internal research funds through Sandia National Laboratory Directed Research and Development program have been used to develop a prototype of a new downhole source with higher frequency and energy output. It is hoped that FY95 funding for this project will allow the development of this source into a usable field tool to be employed at Hanford. Finally, discussions have begun with Stanford University on the possibility of bringing one of their graduate students to Sandia at Stanford's expense to help out with the collection and processing of the data, as well as provide hydrogeologic input to the interpretation of the tomography results.

For further information, please contact:

Greg Elbring
Sandia National Laboratories
Division 6231 MS-0750
P. O. Box 5800
Albuquerque, NM 87185-0750
(505) 844-4904

George Allen
Technical Program Manager
505-845-7015

1.36 RABBIT VALLEY GEOPHYSICS PERFORMANCE EVALUATION RANGE

TASK DESCRIPTION

Utilization of nonintrusive, investigative techniques represents a significant improvement over intrusive characterization methods, such as drilling or excavation, because there is no danger of exposing personnel to possible hazardous materials and no risk of releasing or spreading contamination through the characterization activity. Nonintrusive geophysical techniques provide the ability to infer near-surface structure and waste characteristics from measurements of physical properties associated with those targets.

The DOE (GJPO) was tasked by the DOE Office of Technology Development to develop a geophysics performance evaluation range (GPER) in the high-desert terrain of Rabbit Valley, west of Grand Junction, Colorado.

The purpose of the GPER is to provide:

- static physical models with fixed configurations to test geophysical instrument and method performance against baseline parameters; and
- dynamic physical models that can be reconfigured to simulate specific target parameters.

A subtask of this activity is to identify and catalog other geophysical test facilities within the DOE Complex and to solicit suggestions for test-cell design specifications for the Rabbit Valley GPER from the Offices of Waste Management, Environmental Restoration, and Technology Development; DOE Operations Offices; other Government agencies; and the private sector.

TECHNOLOGY NEEDS

The Rabbit Valley GPER will provide known parameters against which the performance of geophysical instruments or methods can be assessed. Comparison of the response obtained over undisturbed earth with the responses observed after the test facilities have been constructed determines the response contribution of the materials placed in the GPER cells. Quantification of this response contribution allows a direct assessment of precision and accuracy of geophysical instrumentation and provides performance criteria for development or adaptation of emerging geophysical methods and technologies.

ACCOMPLISHMENTS

GJPO solicited information on parameters of available geophysical test beds from DOE Program and Operations Offices, DOE contractors, National Laboratories, academia, and private industry. The results of the survey were presented in an initial report delivered in January 1994. The results of the survey will help catalog soil types, specific target parameters, measurement techniques, and instrumentation systems tested, as well as any lessons learned from successes and failures of equipment and techniques evaluated.

Geophysical background data was collected from over 20 acres to be used for the Rabbit Valley GPER, using a 4m by 4m survey grid. Radiometric, frequency-domain electromagnetic, very-low-frequency electromagnetic, magnetic total field, time-domain electromagnetic, resistivity data, and multi-coil airborne electromagnetic survey data were acquired. Additional, magnetic data were collected by a private industry user who has made the data available to the GPER project\.

COLLABORATION/TECHNOLOGY TRANSFER

The Rabbit Valley GPER is available to other Government agencies, universities, and private industry. To date, five organizations have utilized the site, including the DOE Special Technologies Laboratory in Santa Barbara, California, GeoCenters, in Boston, Massachusetts, Airborne Environmental Surveys, of Santa Maria, California, Coleman Research Corporation in Orlando, Florida, and Dr. Bill Hasbrouck, of the U.S. Geological Survey.

The results of the geophysical measurements will be of interest to Federal agencies and private sector organizations conducting characterization or monitoring investigations of buried wastes. Transfer of the results of this task will be accomplished through public announcement of the Rabbit Valley GPER in trade publications and through presentations to professional forums and at conferences and workshops. A Rabbit Valley Geophysics Performance Evaluation Range User's Guide will be prepared and disseminated that provides range specifications, structure of the GPER database, numerical modelling results, and logistics, field, and dynamic model reconfiguration support available from the GJPO, as well as details of other geophysical test sites.

For further information, please contact:

James W. Allen
RUST Geotech Inc.
P.O. Box 14000
Grand Junction, Colorado 81503
(303) 248-6715

Dan Varhus
U.S. Department of Energy
Grand Junction Projects Office
(303) 248-7768

1.37 RAMAN PROBE RADIATION STUDY

TASK DESCRIPTION

The detection and identification of molecular and ionic species in the underground waste tanks at Hanford is required in order to provide information concerning the content of energetic compounds, including ferrocyanide, as well as compounds that will determine the success of pretreatment methods, such as organics and nitrates. There are very few options that allow such measurements to be made both in the hot cells and in the tanks. Raman spectroscopy can provide fingerprint identification of molecular and ionic species through detection of their unique vibrational spectra. This approach, using fiber-optic-based probes, has been selected as the technology most likely to succeed for these measurements. However, many uncertainties remain for application, especially for measurements made in the highly hostile environments of the waste tanks themselves. Included in these uncertainties are the effects of the high gamma radiation environment on the optical components of the remote Raman probe. This task will take prototype probes and examine changes in the quality of a Raman spectrum as a function of radiation dose. It will include real-time measurements in gamma fields in order to observe the effects of both short-lived and permanent darkening of the optical components on the signal quality of the Raman spectrum.

TECHNOLOGY NEEDS

The application of Raman spectroscopy to remote hostile environments will require a firm understanding of the expected lifetime and degradation of performance over the period during which the probe is in place. To that end, a method to monitor this performance in situ, with the probe in gamma radiation environments of known levels, must be developed. This will require standardized sources and controlled probe geometries. In addition, careful measurements of performance at different wavelengths will allow selection of the best laser source for the probes. These wavelength choices are visible, either at 514 or 488 nm, and near-infrared, near 800 nm. While radiation effects will be less pronounced in the near-infrared, source power and stability are better in the visible. However, such preference for a visible wavelength source may be supplanted by the loss of throughput associated with radiation darkening of optical components in this region. While the probe includes fiber-optics, the placement of other materials and optical elements in the radiation environments requires that total system performance be evaluated. Included in these other elements are filters, adhesives and index matching gels. Thus, the technology needs require total system performance evaluation.

ACCOMPLISHMENTS

To date, a portable Raman spectroscopy system has been constructed and coupled to fiber-optic probes provided by other investigators in the Raman spectroscopy project. Some filters were evaluated for performance in radiation fields before the integrated system was constructed, simply in order to gauge the anticipated degree of failure of the filter quality. This work is displayed in Figure 1.37. The exposure experiments are now being arranged with custodians of gamma sources at Los Alamos National Laboratory as well as at EG&G in Las Vegas. The dose dependence of Raman signal will be measured by using a standard Raman scatterer, sodium nitrate, which is found both in solution and solid phases, in the Hanford tanks.

COLLABORATION/TECHNOLOGY TRANSFER

The transfer of the remote Raman probe technology will be pursued in other portions of the Raman development program. The measurements made as a function of irradiation will figure in the selection of possible industrial or government collaborators for this program.

For further information, please contact:

Robert J. Donohoe
Los Alamos National Laboratory
MS-C345
Los Alamos, NM 87545
(505) 665-6794

Bruce Erdal
Technical Program Manager
Los Alamos National Laboratory
(505) 667-5338

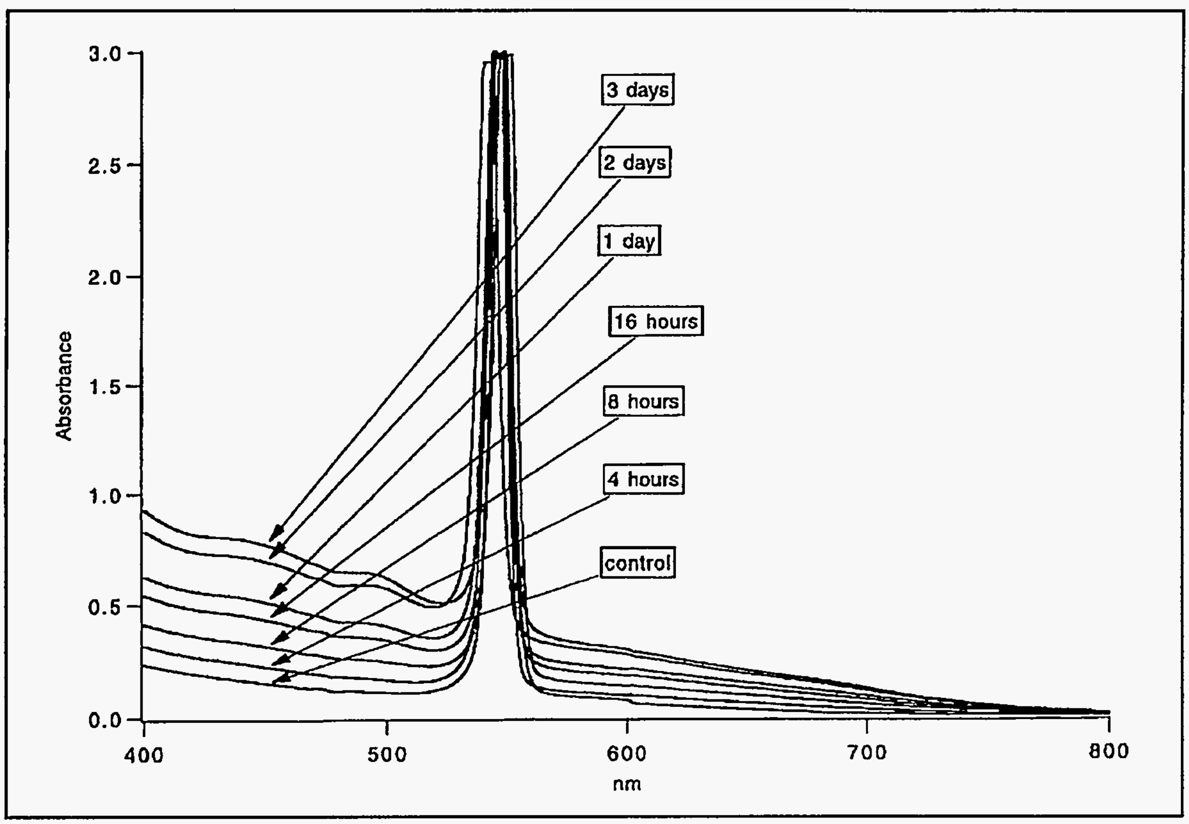

Figure 1.37. Absorption of holographic filters vs. exposure time at 435 Rad/min.

1.38 EVALUATION OF TWO NEW FLOWABLE GROUT TECHNIQUES

TASK DESCRIPTION

This project is examining the potential application of a bentonite/mineral wax formulation, developed in Germany, and an inorganic grout, developed in France, as barrier materials for DOE sites (see Figure 1.38). Because these materials have been used for grouting, bringing them to regulatory and public acceptability within the U.S. should be rapid.

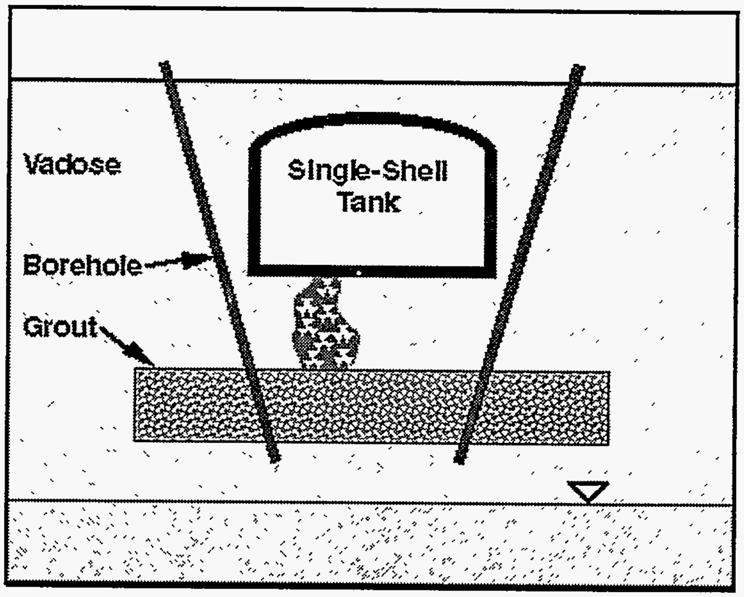

Figure 1.38. Evaluation of new grout barriers.

This investigation is examining the compatibility of these barrier formulations within the range of DOE soils and waste types. Technical challenges include lateral permeation of the soils, physical and hydraulic stability of the barrier over time, and the regulatory acceptance of the overall approach and grout materials.

TECHNOLOGY NEEDS

A groundwater control system that is injectable from the surface and forms within the aquifer removes the need to excavate trenches and construct barriers. A material that is resistant to deterioration from aquifer and contaminant chemistry would meet significant waste site remediation needs throughout the complex. Materials that do not contain synthetic compounds or have been used elsewhere may gain regulatory acceptance faster than those using unusual or manufactured substances.

This investigation is examining some currently available injectable grouts that have shown promise in Europe. Their application to the arid site conditions and resistance to waste components are the focus of this study.

ACCOMPLISHMENTS

- Final agreements between DOE and the technology vendor on licensing and non-disclosure have been secured.
- Grouts are being formulated to match the permeability of several soils.
- Sandia National Laboratory has agreed to a field test of the technology and has identified a drilling contractor.

COLLABORATION/TECHNOLOGY TRANSFER

This project is a cooperative effort of Golder Associates and the European licensees MIBRAG (Germany) and Societe Hoechst Francaise (France). The materials were identified through the International Technology Exchange Program. Results will be made available through this and other international efforts.

The Underground Storage Tank Integrated Demonstration sites at Hanford, Oak Ridge, Savannah River, Fernald, and INEL will all potentially benefit from these relatively advanced technologies. The Sandia Mixed Waste Landfill is the probable site for demonstration of effectiveness. Other potential users include a number of DoD sites with leaking underground storage tanks as well as industrial facilities such as refineries and fuel terminals.

With DOE's assistance this technology should mature rapidly. The German company is searching for an American affiliate to manage applications in North America. The French group has a U.S. division to manufacture and distribute its formulation. Speedy transfer to the private sector is expected.

For further information, please contact:

James L. Rea
Principal Investigator
Sandia National Laboratories
(505) 845-8728

Dennis L. Berry
Technical Program Manager
Sandia National Laboratories
(505) 844-5678

Charles Voss
Site Manager
Golder Associates
(206) 883-0777

1.39 CHEMICAL BARRIERS FEASIBILITY AND FIELD DEMONSTRATION

TASK DESCRIPTION

This research is examining the sorption and immobilization capacity of a natural iron mineral for a number of site contaminants, and its use in the formation in situ of a permeable barrier that removes target contaminants but does not impede groundwater flow.

Ferric oxyhydroxide or hydrated iron oxide is a naturally occurring non-hazardous substance that has sorption affinities for a number of inorganic contaminants found at DOE sites. Such contaminants as uranium, molybdenum, copper, lead, zinc and radium can potentially be removed from groundwater.

The iron is injected as a solution in water. Reaction underground with aquifer mineral alkalinity converts it to the sorbing phase. Precipitation within the aquifer pores coats the rock particles forming a barrier zone around the contaminated area. This coating extracts the contaminants moving with the groundwater and confines them in the barrier zone (see Figure 1.39).

The objectives of this investigation are:

- to determine the absorptive capacity of the iron mineral for target contaminants; and
- to design and field test a low-cost water-permeable, barrier system formed in situ.

TECHNOLOGY NEEDS

Construction of an impermeable barrier system can be expensive in terms of excavation, hazardous waste disposal, and groundwater management.

Important aspects being studied in this project include the sorption capacity for a variety of contaminants and the relative immobility of the sorbing phase under aquifer flow conditions.

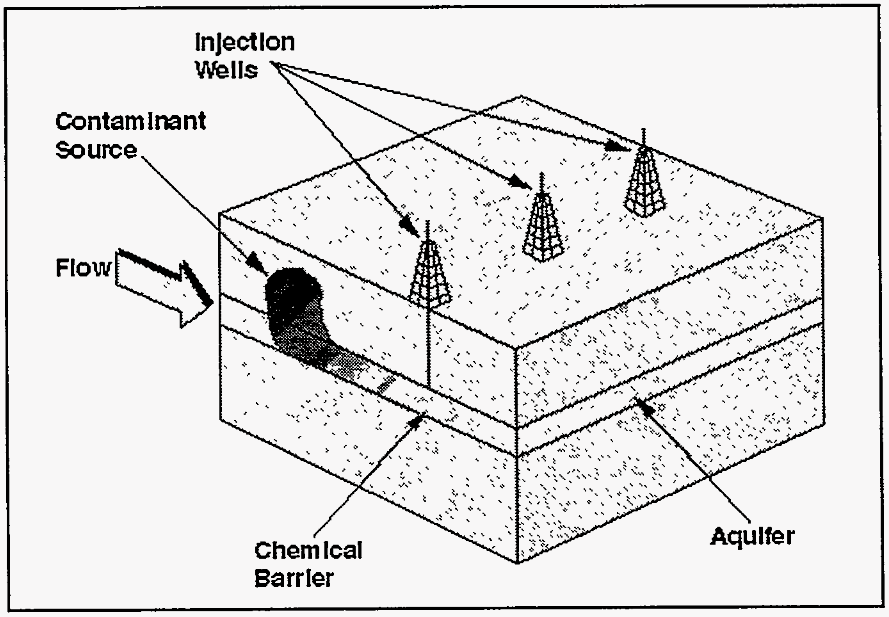

Figure 1.39. Chemical Barriers Feasibility and Field Demonstration.

ACCOMPLISHMENTS

- Ferric oxyhydroxide has been identified as an effective sorbent for such species as uranium, molybdenum, lead, copper, zinc and radium.
- The sorption characteristics of uranium and molybdenum at the Monticello Uranium Mill Waste site in Utah have been completed.
- Methods to enhance the attachment of ferric oxyhydroxide to the aquifer minerals have been examined.
- Laboratory studies on the use of this sorbent for uranium have been carried out under the Surplus Facilities Management Program, and the Grand Junction Project's Office of Research and Development Program.
- Preliminary acceptance from regulators has been received for an injection experiment at the Monticello field site.
- Laboratory column studies are underway to examine aquifer permeability changes.
- The rate at which the aquifer would accept fluid was determined in an injection test at Monticello using clean water.

COLLABORATION/TECHNOLOGY TRANSFER

This project is being carried out by Chem-Nuclear Geotech, Inc. (Rust International), with the cooperation of the Monticello Remedial Action Project of the DOE Office of Environmental Restoration.

This effort is directly applicable to remediation of uranium contamination at the Monticello Mill site. Because uranium contamination in groundwater is prevalent at many DOE sites, this technology has widespread application. Other DOE sites with uranium contamination include UMTRA facilities, uranium groundwater contamination at Pantex, Fernald, the Rocky Flats Plant, Nevada Test Site, Y-12, and the Gaseous Diffusion Plant at Oak Ridge.

In addition, the application of this type of barrier may be appropriate for many different metals at DOE, DoD, EPA, and numerous commercial and industrial waste sites.

For further information, please contact:

Stan J. Morrison
Principal Investigator
Chem-Nuclear Geotech, Inc.
(303) 248-6417

David A. Emilia
Technical Program Manager
Chem-Nuclear Geotech, Inc.
(303) 248-6417

1.40 DEMONSTRATION OF A FROZEN SOIL BARRIER AT AN ARID SITE

TASK DESCRIPTION

This investigation addresses the feasibility of using frozen soil barriers (ground freezing technology) to contain hazardous and radionuclide-contaminated soil in an arid setting (see Figure 1.40).

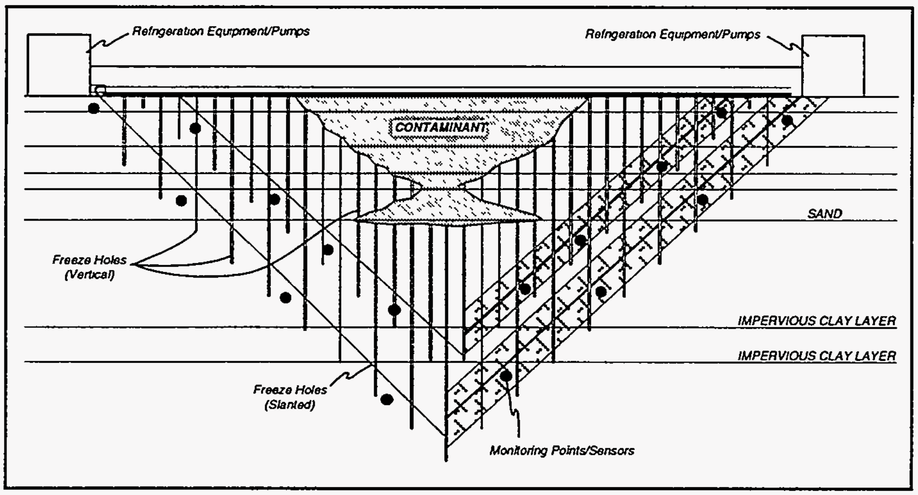

Figure 1.40. Cryogenic Barrier at an Arid site; cross-sectional view.

The first phase is a lab-based investigation of containment aspects of frozen water in soil, including the behavior of associated solutes, transport mechanisms through unfrozen water films or pockets, mechanical effects such as heave, and other freezing-related processes.

Assuming favorable results from the lab-scale investigation, a frozen soil barrier will be installed at an uncontaminated site. Installation involves drilling to install pipes through which refrigerant is circulated. The holes are positioned to create a confined subsurface volume as the soil around the boreholes freezes. A critical aspect of this project is the successful, controlled addition (and removal) of water to the unsaturated subsurface to create the barrier. Water movement in response to 1) the negative pore pressures of the unsaturated zone, and 2) thermal gradients around freeze pipes complicates barrier formation beyond that of a saturated site. Upon completion, the project must also be able to remove water to prevent contaminant migration, should that be a requirement in the technology's future use at unsaturated contaminated sites. Assuming the successful addition of water, barrier integrity/performance would then be evaluated by means of tracer tests, monitoring of thermal conditions, and other suitable methods.

Furthermore, the barrier would then be available as a test bed within which other investigators could conduct studies of hazardous waste treatment technologies.

TECHNOLOGY NEEDS

Many of DOE's contaminant sources (e.g., landfills, dry wells, evaporation ponds, etc.) are located in arid climates and are typically far above the natural groundwater level. Frozen soil barriers are thought to be useful in providing containment at these sites. However, most experience with their hydraulic performance is associated with natural, fully saturated environments. Under arid conditions, performance may be affected by the need to first create full saturation, (i.e., achieve near-zero air porosity), then maintain this condition under the frozen state. This project will examine potential performance factors arising from arid site conditions and evaluate specific measures to mitigate or minimize adverse effects.

ACCOMPLISHMENTS

- A series of technical workshops and planning sessions on frozen soil barrier formation and performance have been held, leading to an acceptable Technical Task Proposal.
- Procurement of services for various tasks within the project has begun.
- The project is working towards a Summer 1994 demonstration.

COLLABORATION/TECHNOLOGY TRANSFER

Overall project management is the responsibility of DOE's Grand Junction Projects Office. The lab-based investigation of the behavior of water and solutes in frozen soil will be awarded to a subcontractor in late FY93. The design of the field installation and the subsequent testing is the responsibility of Chem Nuclear Geotech, Inc., a contractor to Grand Junction Project Office. Soil freezing and associated equipment are available commercially, but a subcontractor has not yet been selected.

For further information, please contact:

Dave Durant
Stan Schweissing
Principal Investigators
Chem Nuclear Geotech, Inc.
(303) 248-6447

Tracy B. Plessinger
Project Manager
DOE-Grand Junction Projects Office
(303) 248-6197

1.41 ELECTROKINETIC REMEDIATION OF HEAVY METAL CONTAMINATED UNSATURATED SOIL

TASK DESCRIPTION

The ultimate goal of this project is to develop an in situ electrokinetic process for removing chromate contamination from unsaturated soil. After the technology is developed and tested at bench and pilot scale in FY93, a field test in clean soil will be run in FY94 to characterize the process and demonstrate in situ water control in unsaturated soil. Demonstration of the process in chromate contaminated soil at the Sandia Chemical Waste Landfill is scheduled for FY95 as part of the Mixed Waste Landfill Integrated Demonstration.

TECHNOLOGY NEEDS

A large portion of DOE's contaminated soil is unsaturated with water, especially in the western states. In regions where contaminated saturated soils are more common, there also exists a zone of contaminated unsaturated soil lying above the saturated zone. There currently are no viable in situ methods for remediating heavy metal contamination from these unsaturated soils. Excavation and processing or disposal at a licensed landfill (the baseline technology) will not always be feasible and will always be expensive.

This research is immediately directed at remediating chromate (CrO_4^{2-}) contamination in unsaturated soil in Sandia's Chemical Waste Landfill, where chromium contamination has been detected to a depth of 75 feet. Other DOE sites contaminated with mobile anions (e.g., MoO_4^{2-}, SeO_4^{2-}, $HAsO_4^{2-}$, $UO_2(CO_3)_3^{4-}$) should be treatable with this technology; anions are highly mobile in soil because they typically do not adsorb strongly on the soil surface.

ACCOMPLISHMENTS

Preliminary experiments at Sandia National Laboratories have demonstrated that electrokinetic processes can move large organic dye anions, as well as chromate anions, through unsaturated sands having moisture contents typical of subsurface soils found in arid regions (The minimum moisture content for observable migration to occur in the soils tested was 3.5 wt- %.). An electrode system has also been developed for extracting anionic contaminants from unsaturated soil without significantly changing the moisture content of the soil. Control of water introduction and removal of 95% of the chromate contamination have been demonstrated in bench-scale testing. This electrode system is presently under review by the Sandia patent office.

COLLABORATION/TECHNOLOGY TRANSFER

Characterization of Sandia soils for fundamental electrokinetic properties will be performed at the University of Washington. All potential additions to the subsurface will be identified and discussed with the New Mexico Environmental Department to ensure compliance with all applicable regulations. An industrial partner having prior field experience with electrokinetics, ElectroPetroleum, Inc., will assist with design review, installation, and operation of the field demonstration.

For further information, please contact:

Eric R. Lindgren
Principal Investigator
Sandia National Laboratories
(505) 844-3820

Dennis L. Berry
Technical Program Manager
Sandia National Laboratories
(505) 844-0234

Waste Retrieval and Processing Overview

Section 2.0

2.0 WASTE RETRIEVAL AND PROCESSING OVERVIEW

Waste retrieval and processing constitutes one of the largest DOE problems. 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.

DOE has identified more than 1 million 55-gallon drums and boxes of waste in storage, and 3 million m^3 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 m^3 have been buried, and 60,600 m^3 have been retrieved and stored. Mixed transuranic waste composes 58,000 m^3 of this inventory. High-level waste stored at four DOE sites represent another 381,000 m^3 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 m^3 are stored as granular calcined solids. Since most of the high-level waste is mixed with hazardous contaminants, it is considered mixed waste. The remainder of the stored waste, about 3,000,000 m^3, is low-level waste and includes 247,000 m^3 of mixed low-level waste. No effective treatment is known for 107,000 m^3 of this mixed low-level waste.

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.

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 m^3 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 a total present value cost of about $18.7 billion, and an annual cost of about $1.8 billion using available technologies. Furthermore, 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.

2.1 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 2.1a and 2.1b). 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.

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 these 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 facili-

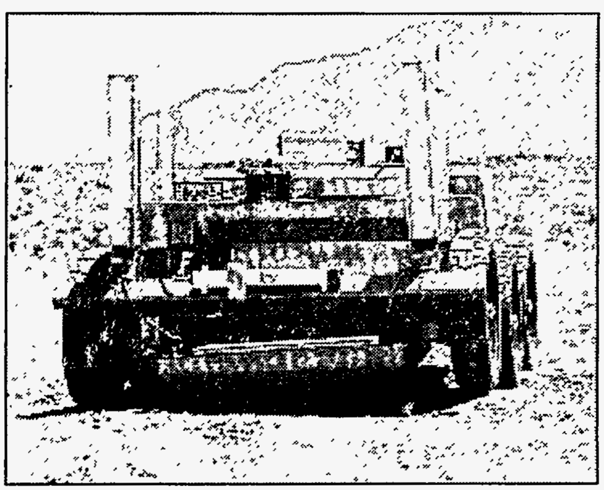

Figure 2.1a. Remote Characterization System at the INEL Cold Test Pit.

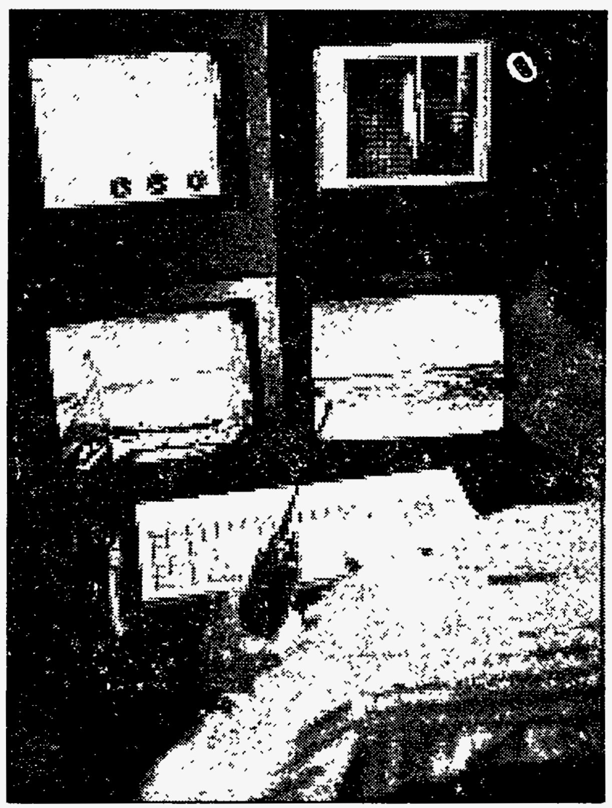

Figure 2.1b. Remote Characterization System Control Station.

ties that have buried hazardous and/or radioactive waste.

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, ORNL, SNL, LLNL AND PNL).

For further information, please contact:

Sandia National Laboratory
D. S. Horschell
(505) 845-9836

C. Q. Little
(505) 844-8366

2.2 BROAD BAND ELECTROMAGNETICS

TASK DESCRIPTION

The objective of the Broad Band Electromagnetics (BBEM) Demonstration was to adapt present broadband electromagnetic interpretation technologies used in mineral exploration to locate, in three dimensions, objects buried at shallow depths (see Figure 2.2). 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.

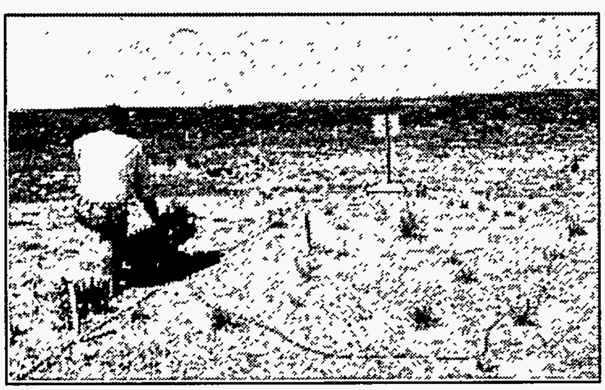

Figure 2.2. Broad band electromagnetic demonstration at INEL.

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.

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 Cold Test Pit and the RWMC with encouraging results when compared to historical information collected at the Cold Test Pit and Pit 9. Further development for this technology is necessary.

COLLABORATION/TECHNOLOGY TRANSFER

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

For further information, please contact:

H. D. MacLean
RUST Geotech, Inc.

L. Pellerim
U.S. Geological Survey
(303) 248-6702

2.3 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 2.3). 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.

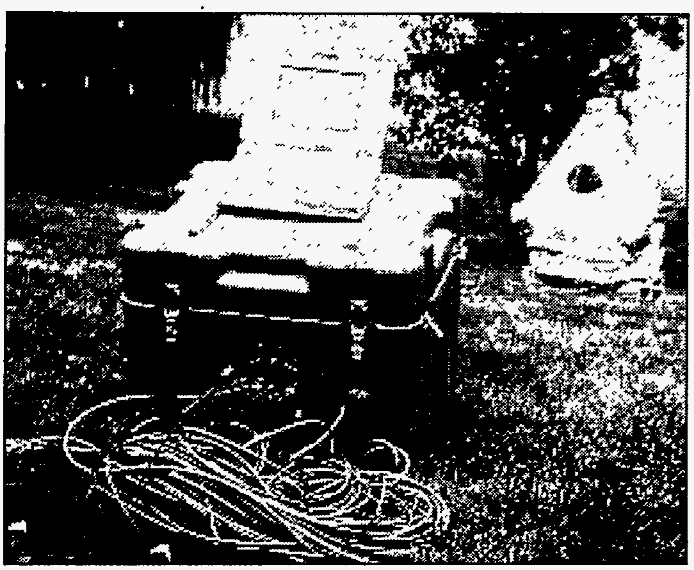

Figure 2.3. Tensor Magnetic Gradiometer.

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 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.

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.

For further information, please contact:

D. D. Snyder
RUST Geotech Inc.

L. Pellerim
U.S. Geological Survey
(303) 248-6702

2.4 REMOTE EXCAVATION SYSTEM

TASK DESCRIPTION

The objective of this project is to demonstrate and evaluate a system to remotely excavate radioactive waste, unexploded ordnances 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 2.4a). 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.

The Remote Excavation System (RES) is designed for relatively small excavations. (See Figure 2.4b). 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 not be able to achieve these rates because of protective equipment and monitoring requirements.

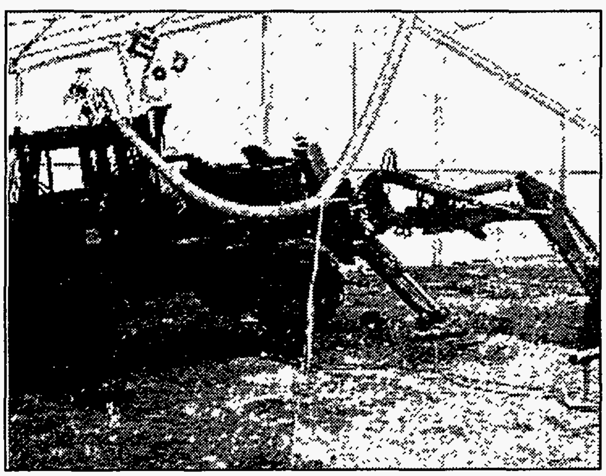

Figure 2.4a. Remote excavation operations at the INEL Cold Test Pit.

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.

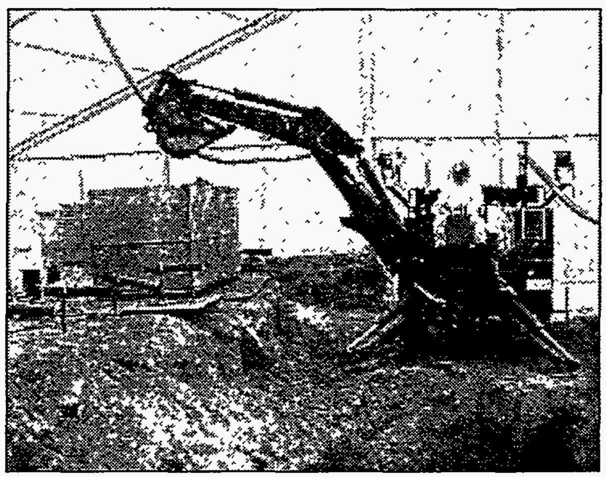

Figure 2.4b. Manual operation of the Remote Excavation System equipment.

TECHNOLOGY NEEDS

Several DOE sites have significant amount of buried waste and contaminated soil. The mixture varies 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 ordnances 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.

For further information, please contact:

S. Killough
Oak Ridge National Laboratory
(615) 574-4537

R. A. Hyde
EG&G Idaho, Inc.
(208) 526-0741

2.5 LIGHT DUTY UTILITY ARM SYSTEM

TASK DESCRIPTION

The LDUA is a remotely operated, mobile system to deploy end effectors for waste characterization and tank inspection (see Figure 2.5). This device brings together technologies developed within multiple DOE laboratories and industry into an integrated system for providing a spectrum of storage tank characterization capabilities. The technology will enhance existing capabilities which are limited to single axis deployment of instruments into tanks. The arm will provide seven degrees of freedom with a 4.5 m (13.5 foot) reach for positioning end effectors in multiple tank locations.

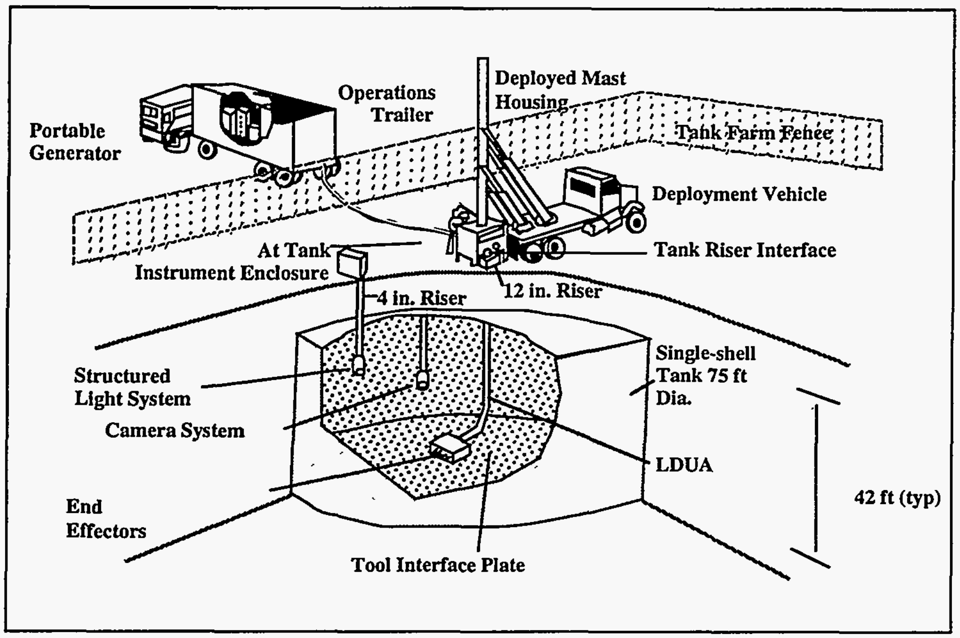

Figure 2.5. Light Duty Utility Arm System.

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.

For further information, please contact:

S. M. Gibson
Program Manager
U. S. Department of Energy
12800 Middlebrook Road
Germantown, MD 20874
(301) 903-7258

R. C. Eschenbaum
Characterization and Retrieval
Program Manager
Westinghouse Hanford Company
P.O. Box 1970, MS N1-21
Richland, WA 99352

2.6 HIGH PRESSURE WATERJET DISLODGING AND CONVEYANCE END-EFFECTOR USING CONFINED SLUICING

TASK DESCRIPTION

The underground storage tanks at Hanford contain three basic material types, both individually and in combination: liquid supernatant, sludge, and hard saltcake. Removal of the sludge and saltcake has presented a technological challenge. A high pressure waterjet can be used to cut up and dislodge the tenacious sludge and saltcake. Combined with a conveyance system operating simultaneously, this confined sluicing can be used to effectively remove and convey waste from the tanks (see Figure 2.6).

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

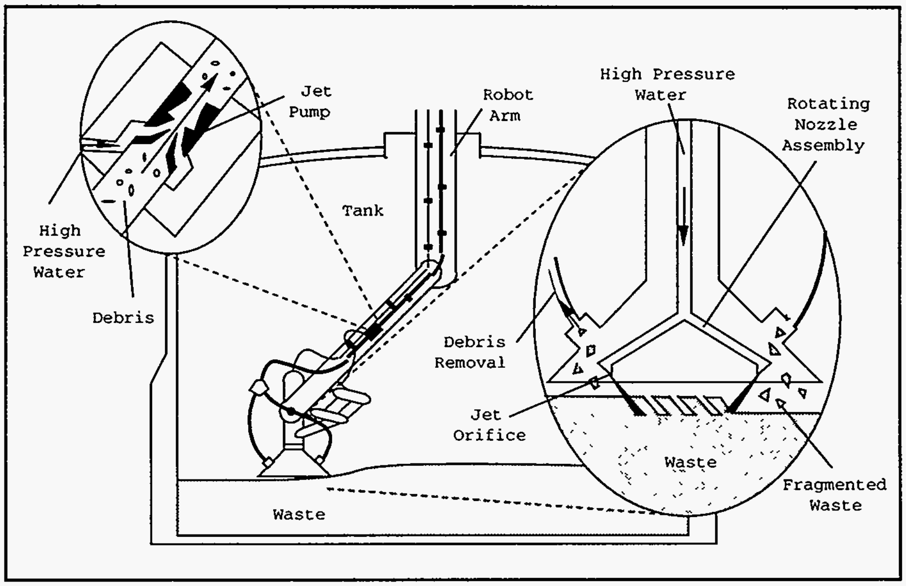

Figure 2.6. Water Jet Cutting.

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

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

COLLABORATION/TECHNOLOGY TRANSFER

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

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

For further information, please contact:

S. M. Gibson
Program Manager
U. S. Department of Energy
12800 Middlebrook Road
Germantown, MD 20874
(301) 903-7258

R. L. Gilchrist
Integrated Demonstration Coordinator
Westinghouse Hanford Company
P. O. Box 1970, MS L5-63
Richland, WA 99352
(509) 376-5310

2.7 SEPARATION OF CESIUM AND STRONTIUM FROM HIGH-LEVEL RADIOACTIVE WASTE

TASK DESCRIPTION

The objective of this investigation is to develop a separations system for removing cesium and strontium from radioactive aqueous waste using cobalt dicarbollide (CoD_2). The cobalt dicarbollide molecule was first synthesized in the United States in 1965, but investigations of its application as an extractant in nuclear waste management was first undertaken in the 1970's in the former Czechoslovakia and the former Soviet Union. Cobalt dicarbollide has been described as a nearly ideal hydrophobic anion for the extraction of cationic species from aqueous solutions into an organic solution, and the literature indicates that under the appropriate conditions cesium and strontium can be extracted with very high selectivity and yield. In addition, cobalt dicarbollide is believed to possess superior radiation stability. Most of the earlier work has focussed on the use of the molecule in solvent extraction systems. The thrust of this work is to explore the incorporation of cobalt dicarbollide (or its derivatives) into polymers to produce a material with the benefits of a solid-based sequestrant. (See Figure 2.7). This program builds on a considerable body of experimental and development work performed at the Nuclear Research Institute in Rez, the Czech Republic.

TECHNOLOGY NEEDS

Because of the short half-lives of Cs-137 and Sr-90 (30.17 and 28.6 years, respectively), as well as their high contribution to the radiation and thermal burden of fission products from nuclear waste (defense and commercial), these isotopes constitute a major concern to the safety of stored bulk waste. During the first 30 years after removal from the reactor, these two nuclides account for over 90% of the thermal energy and penetrating radiation of the waste. Separation of these nuclides for engineered surface storage or vitrification, in addition to reducing the immediate safety concerns of the waste storage tanks, not only allows isolation of these nuclides for potential future use, but reduces the structural concerns arising from the incorporation of high thermal loads on cementitious grout.

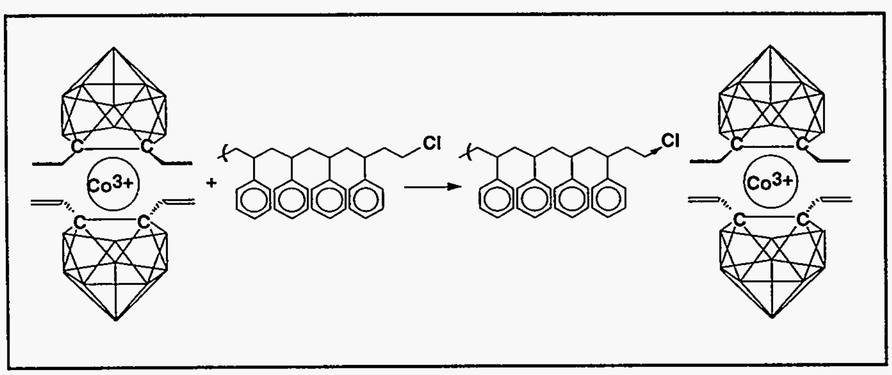

Figure 2.7. Incorporation of Dicarbollides onto Polymers.

ACCOMPLISHMENTS

Experiments on sorption of dicarbollide onto a macroporous resin have been carried out. The polymer swelled adequately and had poor solubility of the selected salt ($(CH_3)_4N^+$). There was limited amount of carbollide sorbed onto the resin (95 mg CoD_2^- /4 g resin). Some cesium was removed from solution with no Sr^{2+} being removed.

Other solid-supported dicarbollide experiments have also been carried out. A solution of cobalt dicarbollide (in the H^+ form) in acetone was evaporated from saturated filter paper. The column of filter paper showed no sorption of Cs from solution.

COLLABORATION/TECHNOLOGY TRANSFER

Nuclear Research Institute, Rez, Czech Republic; Dr. Jiri Rais.

For further information, please contact:

Moses Attrep
Principal Investigator
Los Alamos National Laboratory
(505) 667-0088

Hugh D. Murphy
Technical Project Manager
Los Alamos National Laboratory
(505) 667-8914

2.8 WASTE SEPARATION AND PRETREATMENT USING TITANATE ION EXCHANGERS

TASK DESCRIPTION

This project is focused on the development and demonstration of advanced, efficient separation technologies to selectively remove Cs-137 and other radionuclides from a wide spectrum of radioactive defense wastes. Crystalline silicotitanates (CST) and amorphous hydrous titanium oxide (HTO) ion-exchange technology will be developed and demonstrated for the removal of the radioactive materials from Hanford-type supernatant solutions and salt cake. The project objectives will be accomplished within four tasks:

- the evaluation of the ion exchange properties, especially the effects of pH and sodium content on the ability of crystalline silicotitanate to remove Cs-137;
- the assessment of the feasibility of regenerating the crystalline silicotitanate ion exchangers;
- the measurement of the radiation stability of the crystalline silicotitanate materials; and
- the delivery of the materials to PNL for testing on actual Hanford wastes.

TECHNOLOGY NEEDS

Within the DOE Complex there are currently more than 200 tanks being used for processing and storing radioactive waste by-products generated by weapons materials production facilities. These tanks contain tens of millions of gallons of highly radioactive supernate and grout feed liquid, salt cake, and sludges. The major radioactive constituents are isotopes of cesium, strontium, iodine, technetium, and transuranics. The technology developed and demonstrated in this work is needed to remediate radioactive wastes currently contained in defense waste storage tanks. Specifically, titanate ion-exchange materials and ion-exchange processes will be used to develop advanced, efficient radioactive waste separation technology.

ACCOMPLISHMENTS

A variety of CSTs have been synthesized to evaluate the effect of structure and composition on ion exchange properties. Transmission electron microscopy micrographs show cuboidal crystals ranging from 20 to 50 nm and preliminary X-ray structural studies indicate a tetragonal structure. Cs adsorption was measured at various pHs and the distribution coefficient (K_d) was calculated. From pH 2 to 10, the K_d exceeds 10,000 ml/g. However, at a pH of approximately 10 the K_d decreases markedly and drops to 100 mL/g at pH 14.

A second generation of CST ion exchangers was prepared and is undergoing testing and evaluation. The main effect of the structural and compositional modification has been to increase the K_d to 1000 ml/g in 2.5 N NaOH to pH 11. Stability tests have been conducted on CST in high pH solutions for 100 days at

40°C and ambient temperature by measuring the Cs concentration. No change in Cs concentration and the K_d for Cs adsorption was measured.

COLLABORATION/TECHNOLOGY TRANSFER

Pacific Northwest Laboratory
Texas A&M University

For further information, please contact:

Norm E. Brown
Principal Investigator
Sandia National Laboratories
(505) 845-8180

Dennis L. Berry
Technical Program Manager
Sandia National Laboratories
(505) 844-0234

2.9 SOLID SEQUESTERING AGENTS FOR THE REMOVAL OF TRANSURANICS FROM RADIOACTIVE WASTE

TASK DESCRIPTION

This project will develop a series of polymer supported, ion-specific, extraction systems for removing actinides and other hazardous metal ions from waste water streams. The work is initially focussed on the metal contaminants (especially plutonium and americium) in waste streams at the Waste Treatment Facility at LANL TA-50 and at the Rocky Flats Plant (RFP). Reducing the concentration of a target metal to extremely low levels will require that the chelating system have a high-binding strength for that ion, while also having a high-selectivity for the target ion in the presence of competing cations. To this end, the work involves testing and selection of ligands with the required selectivity and binding constant, incorporation of the chosen ligands into polymeric structures, evaluation of the separation properties (capacity, recycle and long-term stability) of the supported ligands, and a complete engineering assessment of the polymer systems in combination with complementary and competing technologies. Chelating ligands under consideration include polyhydroxamates, bis(acylpyrazolones), malonamides and water soluble polymers for ultrafiltration.

TECHNOLOGY NEEDS

There is an urgent need for alternative technologies for treatment of radioactive waste water to meet regulatory limits, decrease disposal costs, and minimize waste. In particular, this technology would address the need to replace sludge-intensive precipitation methods at LANL TA-50 and at the RFP, and to reduce the transuranic (TRU) wastes from batch processes for recovery of plutonium. More stringent discharge regulations from both DOE and the EPA are anticipated and these will require considerably lower metal ion concentrations in the effluent water from facilities such as LANL TA-50. This technology is also applicable to radionuclide-specific treatment of multiple aqueous waste streams at Hanford that would be generated by the cleanup of the storage tank wastes and various environmental contamination sites.

An important subset of the waste waters of concern are mixed wastes that contain radioisotopes and hazardous organics or toxic metals. Treatment of the mixed waste to reduce the amount of the toxic metals to levels below regulatory concern would generate separate waste streams that can be treated by other technologies that are better established from a regulatory viewpoint.

ACCOMPLISHMENTS

Investigation of chelators containing multiple hydroxamic acid functional groups has continued to yield new compounds with improved selectivity for binding actinide ions relative to potential competing metal ions. A systematic series of compounds has been investigated and a number of these chelators have shown a strong preference for binding tetravalent plutonium and thorium over trivalent ions. These new compounds show considerable promise for yielding extraction systems with improved selectivity for actinide metal ions over potential interfering ions, such as iron and aluminum that are commonly present in DOE process and waste streams. Even more selective compounds can be developed as the understanding of the complexation chemistry of this series of ligands is elucidated.

A series of five water-soluble polymers containing hydroxamic acid and acylpyrazolone chelating groups has been prepared in quantity. Testing with americium and europium gamma tracers has been performed and the binding of metal ions to the polymers is under evaluation as a function of pH, polymer concentration, concentration of potentially interfering metal ions, membrane material, and molecular weight cut-off of the membrane. Initial results with some polymers demonstrate removal efficiencies of greater than 99% with a single ultrafiltration operation.

COLLABORATION/TECHNOLOGY TRANSFER

Keith Motyl
Rocky Flats Plant

S. Alexandratos
University of Tennessee

A. Gopalan
New Mexico State University

For further information, please contact:

Gordon Jarvinen
Principal Investigator
Los Alamos National Laboratory
(505) 665-0822

Hugh Murphy
Technical Project Manager
Los Alamos National Laboratory
(505) 667-8914

2.10 ACTINIDE SEPARATIONS FOR ADVANCED PROCESSING OF NUCLEAR WASTE

TASK DESCRIPTION

The goal of this project is to develop actinide separations capabilities that could be used in an advanced processing flowsheet, such as the "Clean Option" for the Hanford Tank Waste Remediation System or some other alternative. Since there is a wide variety of waste streams needing treatment, (such as aqueous acid waste, aqueous basic waste, low-level neutral wastewaters, contaminated soils and handling materials), this project has several subtasks. These include investigation of selective inorganic precipitation of metals (molybdenum, technetium, ruthenium, palladium, cadmium, americium, and curium) to replace processes requiring the use of organic solvents, investigating the use of liquid ion exchangers (LIXs) as alternatives to Aliquot 336 for actinide processing, investigating diamides as alternatives to CMPO for TRU removal, developing soft ion donor extractants for the separation of trivalent actinides from lanthanides, investigating the use of water-soluble chelating polymers, and investigating microporous hollow-fibre membranes for dispersion free liquid/liquid extraction (see Figure 2.10).

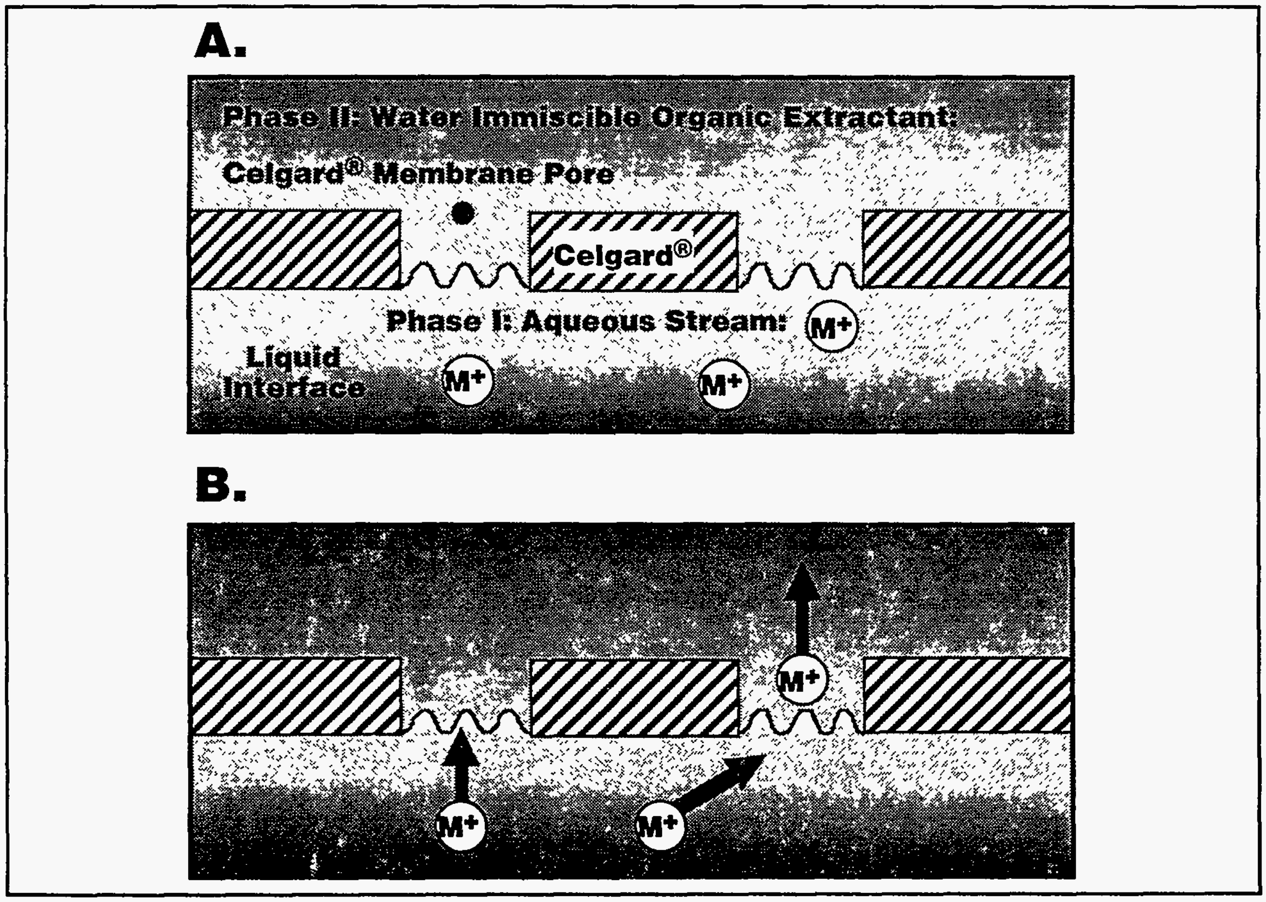

Figure 2.10. Liquid/Liquid Extraction.

TECHNOLOGY NEEDS

There is a general need for advanced actinide and fission product separations for a variety of applications, for example, tank waste remediation at Hanford, decontamination and decommissioning operations at all the DOE facilities, soil and sludge leaching, mixed waste treatment, processing for light-water reactors, and transmutation of actinide waste systems.

ACCOMPLISHMENTS

Precipitation and separation of the lanthanides and transition metals from the actinides through a process of complexing the actinides with carbonate and precipitating the other metals has been achieved. Interesting differences between tracer studies and higher loading studies were observed.

In the research into LIX alternatives to Aliquot 336, three new pyridinium compounds have been synthesized and preliminary thorium extraction studies are in progress.

Two new dialkyldithiophosphoric compounds have been synthesized and tested for trivalent actinide/lanthanide separations. Initial results indicate enhanced extraction of americium over europium.

A commercially available pyrazoylborate was tested and found to have potential for separation. The instability of the compound has led to synthetic modification studies to improve both organic solubility and stability.

Collation of data has begun on the investigation of water soluble chelating polymers for waste stream treatment.

Plutonium Uranium Extraction Process (PUREX) testing on available equipment for the dispersion-free liquid-liquid extraction modular unit has been completed and data is being evaluated for comparison with other engineered systems.

COLLABORATION/TECHNOLOGY TRANSFER

H. Freiser
University of Arizona

R. Paine
University of New Mexico

D. Ensor
Tennessee Tech University

R. Long
New Mexico State University

For further information, please contact:

Barbara Smith
Principal Investigator
Los Alamos National Laboratory
(505) 667-2391

Hugh D. Murphy
Technical Project Manager
Los Alamos National Laboratory
(505) 667-8914

2.11 FISSION PRODUCT CHEMISTRY

TASK DESCRIPTION

This work is divided into three separate initiatives addressing the separation needs for Tc-99, iodine-129 and nickel (both stable and nickel-63). For technetium separation, the approach being followed is a reexamination of the two baseline technologies, ion exchange and solvent extraction, in the light of recent work. In the former case, a new anion-exchange resin containing the pyridinium-functionality, Reillex™-HPQ, which has shown superior stability towards radiation and nitric acid and is being tested as a replacement for the baseline Dowex resin (see Figure 2.11).

For the solvent extraction, pyridinium-type extractants, or a liquid ion-exchange extractant, such as Aliquat 336, are under investigation. The use of water soluble chelating polymers containing quaternary amine functionalities specific to technetium will also be examined.

For iodine, the main effort will be to investigate the systems that would be needed if transmutation of waste were to become a disposal option.

For nickel, the three major objectives are to investigate the disposition of nickel in existing flowsheets, evaluate the technologies applicable to nickel removal from radioactive waste streams, and evaluate the behavior of nickel in the posited hydrothermal destruction of organic compounds (since much of the nickel present in Hanford wastes may be present as a nickel cesium ferrocyanide complex).

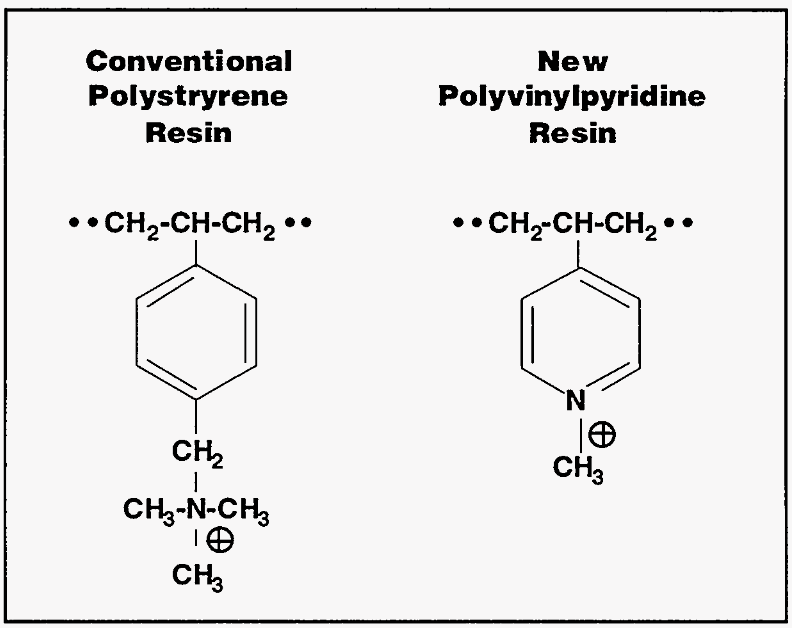

Figure 2.11. New resins have greatly improved chemical and radiation stability.

TECHNOLOGY NEEDS

Technetium is a major fission product resulting from nuclear reactors and by nuclear fission of plutonium. At the present rate of production, Tc-99 will reach 170,000 Kg by the year 2000. Tc, as TcO_4^-, is a very mobile species in the environment. This characteristic, along with its long half-life (213,000 years) causes technetium to be a major contributor to the long-term risk. Additionally, incorporation of technetium into currently planned waste forms may pose unusual chemical and engineering problems during vitrification. For example, the Hanford glass frit mix contains formic acid, which may reduce technetium to TcO_2. At processing temperatures, this can disproportionate into the metal (which runs the risk of shorting out the vitrifier's electrical heater) and volatile Tc_2O_7.

The amount of nickel in the Hanford single-shell tanks exceeds the goal set by the "Clean Option" strategy making it necessary to evaluate technologies for nickel removal from HLW streams.

ACCOMPLISHMENTS

For separation of technetium, the investigation of Reillex™-HPQ has progressed to the level that the behavior of interfering ions is being probed (uranium and chromate).

In addition to these studies, many experiments have been completed on the behavior of Reillex™-HPQ. Breakthrough experiments using a double-shell slurry simulant, containing 5 x 10^{-5}M technetium ion as pertechnate ion, have been carried out. The breakthrough for technetium for this system is highly flow-rate dependent and occurred at 50 bed volumes with slow flow rates. Several iodine transmutation design alternatives have been proposed to replace the original design that used an iodine-filled rods system. Calculations and engineering considerations for both a static-solid and dynamic gaseous system are being developed. Optimization considerations for thickness, heat transfer, etc., to develop figure of merits for transmutation conditions are being made. The literature survey for nickel removal technologies is nearly complete. First effort selection of technologies for nickel removal has been made. Some experimental work has been initiated where nickel removal from solutions is 99%.

For further information, please contact:

Moses Attrep
Principal Investigator
Los Alamos National Laboratory
(505) 667-0088

Hugh D. Murphy
Technical Project Manager
Los Alamos National Laboratory
(505) 667-8914

2.12 CHEMICAL/PHYSICAL TREATMENT: DETOX PROCESS DEMONSTRATION

TASK DESCRIPTION

This effort for MWIP involved a rigorous evaluation of the DETOX process based on completed work, and documentation of the ability of the process to meet mixed waste treatment needs.

The DETOX process uses iron (III) in an acid solution as the primary oxidant; the iron (II) formed in the oxidation process is converted back to iron (III) by a second catalyzed reaction with oxygen. The primary benefit of the DETOX process is the ability to catalytically oxidize organic constituents of a waste stream in a contained reactor. DETOX is potentially more convenient to use than other forms of wet oxidation because of its ability to accept a wide variety of waste streams and sizes; its lack of NOx, SOx, dioxin, or furan formation; its relatively low power usage; its containment and concentration of heavy metals and radionuclides; and its ability to operate at moderate temperatures (150°C to 225°C) and near atmospheric pressures (14 psig to 40 psig). The program began in FY91 when LANL requested that Delphi Research, Inc. conduct oxidation studies on simulated LANL mixed waste using their patented oxidation process. Vacuum pump oil, chlorinated solvents, and two scintillation cocktails were tested to determine the viability of the process for the destruction of hazardous organics. In FY92 work continued to measure the effects of high cation and anion concentrations, determine the effectiveness of the DETOX process in removing organics from vermiculite, determine the retention of heavy metals, obtain more accurate destruction efficiencies, and purchase a one-gallon stirred reactor to scale up the previous laboratory studies.

TECHNOLOGY NEEDS

Increasingly stringent regulations on the discharge of toxic and mixed wastes have stimulated the need to develop alternative waste treatment technologies that can be permitted with relative ease, allow regulations to be met, minimize waste, and decrease disposal costs. Also, most existing treatment systems are open to the atmosphere, leading to an inherent fugitive emissions problem and the need to treat the off-gas. The DETOX technology is an alternate to incineration for the destruction of organics within a contained system in which hazardous intermediates are not produced, and in which heavy metals and radionuclides can be contained and subsequently precipitated from solution for disposal.

ACCOMPLISHMENTS

These studies demonstrated that the DETOX solution oxidized the simulated wastes at practical rates with temperatures ranging from 200°C to 225°C. Reaction rate constants obtained in these preliminary studies indicated that a 100-liter DETOX reactor could oxidize 500-8000 grams per hour of these waste materials. It was found that the ratio of iron

(III) to iron (II) had little effect on the apparent reaction rate or the formation of reaction intermediates, and reaction intermediate compounds had no significant effect on oxidation reaction rates. The reaction rates increase with the addition of small amounts of sulfate and phosphate, decrease in the presence of ammonium ions, and decrease when the acidity of the DETOX solution exceeds 1M. Because acids will be formed when halogenated organics are oxidized, a pilot plant will require a neutralization system to maintain acidity levels. It was also found that the oxidation reaction rate of the DETOX process is dependent upon the surface area and organic concentration. The organic concentration in the present reactor configuration is limited by the amount of oxygen that can be preloaded into the reactor. Future development work should use a system that operates continuously with the ability to replenish oxygen.

The simulated waste destruction efficiencies (DE) measured after three hours of oxidation averaged 99.5% to 99.94% for the nonvolatile constituents and 99.75% to >99.9999% for the volatile constituents. The 99.75% DE for the volatile constituent was measured during the oxidation of TCE. The DE was lower than expected because of an unforeseen erosion/corrosion mechanism of the impeller and impeller shaft that consumed oxygen needed to completely oxidize the TCE. Further tests that subjected other metallurgies to the TCE DETOX conditions indicate that grade 7 titanium appears to be a suitable replacement for the grade 2 titanium used in the 1-gallon reactor.

COLLABORATION/TECHNOLOGY TRANSFER

This work has been performed in collaboration with Delphi Research, Inc.

For further information, please contact:

Kathryn Elsberry
Los Alamos National Laboratory
(505) 665-4686

Hugh Murphy
Los Alamos National Laboratory
(505) 667-8914

2.13 CHEMICAL/PHYSICAL TREATMENT: ELECTRON BEAM WASTE TREATMENT TEST BED

TASK DESCRIPTION

This effort for the MWIP involved an evaluation of the suitability of electron-beam technology for removal of organics (hydrocarbons and hazardous organics such as chlorocarbons) and nitrates from simulated wastes, based upon completed work. This included using data from removal tests on chlorocarbon and nitrate wastes, modelling results for the removal of chlorocarbons, and evaluating continuous-duty versus repetitively-pulsed electron accelerators for hazardous organic removal.

The process of irradiation in aqueous solutions produces sizable quantities of the free radicals eaq-, H., OH., and the more stable oxidant H2H2. These highly reactive species react with organic contaminants to produce CO_2, H_2O, and salts that are no longer hazardous. LANL has configured an existing electron accelerator, operating in a single-pulse mode (65-ns pulse width), for technology evaluation studies and demonstrated destruction of two hazardous organic compounds characteristic of priority mixed wastes. Computer-based chemical kinetic models have been developed to predict the expected removal efficiency and to compare standard electrostatic accelerators to pulsed accelerators in terms of free radical production.

Hazardous Chemical Compound	E-Beam Dose (kRads)	Removal Effect (%)
Trichloroethylene	500	>99
Toluene	650	97
Benzene	650	>99
Chloroform	650	83
Phenol	800	88
1,1,1-Trichloroethane	650	89
Methylene chloride	800	97
Trans-1,2-Dichloroethylene	800	93
Chlororobenzene	650	97
Carbon tetrachloride	150	>99

Table 2.13. FIU Experimental Removal Efficiencies.

Recently, an e-beam pilot plant, capable of treating an aqueous hazardous waste stream at a flow rate of 120 gpm, has been developed at Florida International University (FIU). This plant uses a 1.5 Mev continuous duty profile accelerator to produce doses in water approaching 1 Mrad. Studies at that plant used influent streams of potable water, and raw and secondary wastewater. Typical efficiencies for removing various organics at low and moderate e-beam doses are given in Table 2.13. Removal efficiencies range from 85% to greater than 99% for most common solvents.

Computer modelling shows that a continuously applied e-beam dose is more efficient in destroying waste than the same amount of pulsed dosage due to less radical-radical recombination, and that a repetitively pulsed machine can produce similar radical concentrations to those of a DC machine when pulsed at high repetition rates (e.g., 10 kHz). The model has also been modified to include radical scavengers normally occurring in potable and natural water (e.g., carbonates). Scavenger-included calculations are compared with FIU experimental results in Figure 2.13; this high correlation provides confidence in the models. Initial evaluations

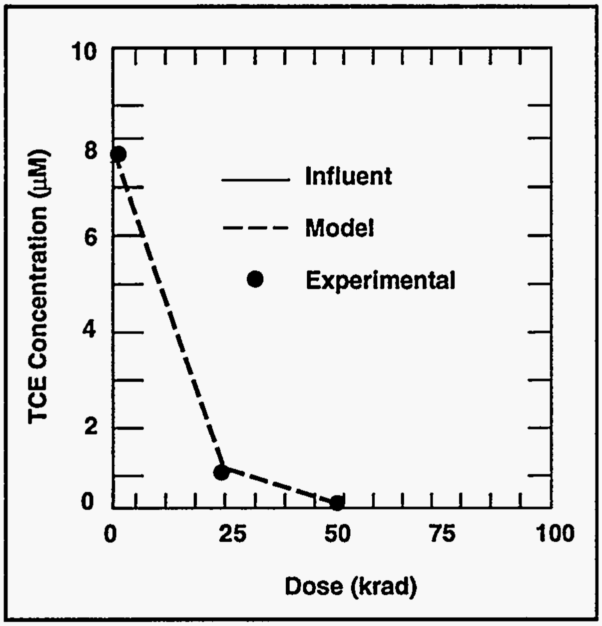

Figure 2.13. Simulated and Experimental Removal of 1 ppm TCE in Potable Water.

indicate that e-beam irradiation also holds promise for the treatment of nitrates in aqueous solution or sludges due to the production of large amounts of reductive, as well as oxidative, free radicals.

TECHNOLOGY NEEDS

DOE is faced with the disposal of large amounts of hazardous organic wastes in the form of aqueous solutions and sludges. The major wastes of concern are halocarbons and aromatics, most of which appear on the EPA Superfund list of toxic organics. Increasingly stringent regulations on the discharge of toxic and mixed wastes have stimulated the need to develop alternative waste treatment technologies that can be permitted with relative ease, allow regulations to be met, minimize waste, and decrease disposal costs.

ACCOMPLISHMENTS

The following conclusions have been made based on these efforts:

- Radical production efficiencies are lower for high-dose rates than for lower-dose rates (due to radical-radical recombination).
- A suitable application of repetitive, short-duration pulses (e.g., 10kHz, 100ns) gives radical concentrations and organic removals similar to a DC dose.
- The model predicts waste removals in agreement with potable water experiments, providing confidence in expanding the model to include nitrates.
- Electron beam treatment is presently cost-competitive with established commercial technologies for removing organics in water solution; new accelerator technology promises increased performance and reduced cost.

COLLABORATION/TECHNOLOGY TRANSFER

LANL is working with industry on potential applications and collaborations. Their existing collaboration with FIU and the University of Miami is continuing. They have also established collaborations with LLNL, INEL and SNL to promote radiolytic waste treatment technology.

For further information, please contact:

Louis Rosocha
Los Alamos National Laboratory
(505) 667-8493

Hugh Murphy
Los Alamos National Laboratory
(505) 667-8914

2.14 CHEMICAL/PHYSICAL TREATMENT: DEVELOPMENT OF POLYMERS TO REMOVE PLUTONIUM AND AMERICIUM FROM WASTEWATERS

TASK DESCRIPTION

This effort involves a rigorous technical assessment of the previous years' work and a report on that assessment. The primary objective of the polymer extraction task is to develop and demonstrate metal-ion-specific polymers as ligands to extract actinides from wastewater streams. These include both commercially available and experimental polymers. There are three aspects to this work: preconcentration of ultralow levels of actinides for analysis of trace concentrations, waste treatment with commercial resins, and cryptand binding studies with heavy metals.

Preconcentration of actinides uses water-soluble chelating polymers to selectively retain the metal ions of interest while the unbound metal ions are removed with the bulk of the aqueous solution as the permeate by membrane ultrafiltration. Water-soluble polymers have been evaluated for selective retention of americium(III) and plutonium(III) from dilute aqueous solutions high in salt content that simulate waste streams from the TA-50 treatment plant at LANL. The PEI phosphoric acid was chosen over other experimental polymers because of its high solubility over a wide pH range, ease of synthesis, high selectivity for actinides over other metal ions, and the ability to bind actinides at low pH.

The raw influent waste stream at the LANL TA-50 Waste Treatment Facility contains a variety of radionuclides and heavy metals in several forms, including those adsorbed onto small particles or colloids, or in solution as cations and/or anions. Several commercial resins were tested to evaluate the metal uptake and elution properties for subsequent treatment of this waste stream. Studies involving filtration were also performed since filtration is proving to be successful in removing colloidal particles in wastewater with adsorbed radionuclides. Factors such as filter pore sizes required for optimum performance, and the species (radionuclides, heavy metals) and colloidal particle size removed by filtration need to be determined for each waste stream, since there may be considerable variability.

New reagents and polymeric materials that exhibit selectivity for cations (Cd2+, Hg2+, Pb2+) are being designed and synthesized for potential use in treating mixed waste streams. The chelator is a potential binding agent for toxic metals found in mixed waste streams. Preliminary studies indicate that this chelator is very selective for mercury(II) with a binding constant of 1031; the lead binding constant is 1016.

TECHNOLOGY NEEDS

Selective separation and preconcentration techniques are required to analyze increasingly lower concentrations of elements often at levels below the detection limit. The use of water-soluble chelating polymers combined with ultrafiltration is an effective method for selectively removing metal ions from dilute aqueous solutions on both an analytical and process scale. New polymer materials can provide a cost-effective replacement for sludge-intensive precipitation treatments and yield effluents that meet more stringent discharge requirements. New waste treatment facilities using this technology could be downsized relative to facilities using precipitation/ flocculation, considerably reducing capital costs.

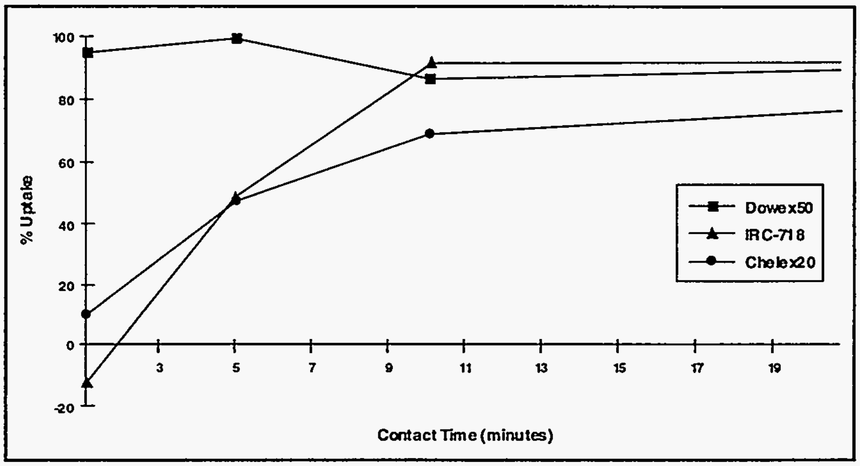

Figure 2.14. Americium 241 Uptake.

ACCOMPLISHMENTS

LANL has developed a method for the analysis for ultra-low level actinides in waste water by preconcen-tration through ultrafiltration. It consists of treating at least a 1 liter sample for oxidation state adjustment, pH adjustment, and silicate removal, followed by addition of a water-soluble chelating polymer for actinide retention. The actinides are selectively retained and concentrated from a salt solution by ultrafiltration. The method has been optimized to give a greater than 98% recovery and accountability for the actinides with an analysis time of approximately 3 hours.

The results of metal uptake studies performed on several commercial resins are shown in Figure 2.14. As expected, the Dowex 50, a sulfonated polystyrene, showed very fast metal uptake while the other resins reached the same level in 10 to 30 minutes. Filtration with a 1 micron pore size filter reduced the concentration of plutonium and americium by over 95%.

An efficient synthesis method for OAC has been developed, and binding constants for Hg and Pb have been determined. A polymeric form of the cryptand has been prepared in water soluble form, and it can be crosslinked to be insoluble, allowing ready removal of Hg and Pb. Mercury and lead can be eluted by changing the pH, the resulting concentrate evaporated, and the metals recovered.

COLLABORATION/TECHNOLOGY TRANSFER

Several of the principal investigators at Los Alamos work closely with Rocky Flats collaborators to identify the most cost effective technology for treating their waste streams. There have also been interactions with industries that are interested in commercial production of the polymers.

For further information, please contact:

Gordon Jarvinen
Los Alamos National Laboratory
(505) 665-0822

Hugh Murphy
Los Alamos National Laboratory
(505) 667-8914

2.15 WASTE DESTRUCTION AND STABILIZATION: DESTRUCTION OF ORGANIC MATERIALS AND DECOMPOSITION OF NITRATES IN MIXED WASTES BY STEAM REFORMING

TASK DESCRIPTION

SNL and Synthetica Technologies have been investigating application of Synthetica's steam reforming system for destruction of hazardous organic contaminants found in DOE wastes. This commercial steam reforming system uses a high temperature reactor (1200°C) called a Thermal Detoxifier (see Figure 2.15), equipped with several feed systems designed to gasify different waste forms (e.g., drummed wastes, liquid wastes, slurried wastes, medical wastes, low-level radioactive wastes, and contaminated soil). Wastes are gasified in the appropriate feed system by exposure to superheated steam, and then the gasified organic materials are fed to the Detoxifier, where they are destroyed by heat. When the organic materials in the waste contain substantial amounts of heteroatoms, acid removal is performed to prevent corrosion.

This project will address mercury processing, nitrate decomposition (aqueous processing), and organic destruction, and will demonstrate the use of a flexible treatment technology that could function as an alternative to incineration.

This project will use a commercial one ton/day steam reforming system, located in California, in trial destruction of the following mixed waste simulants: an adsorbed aqueous organic liquids simulant; a high organic

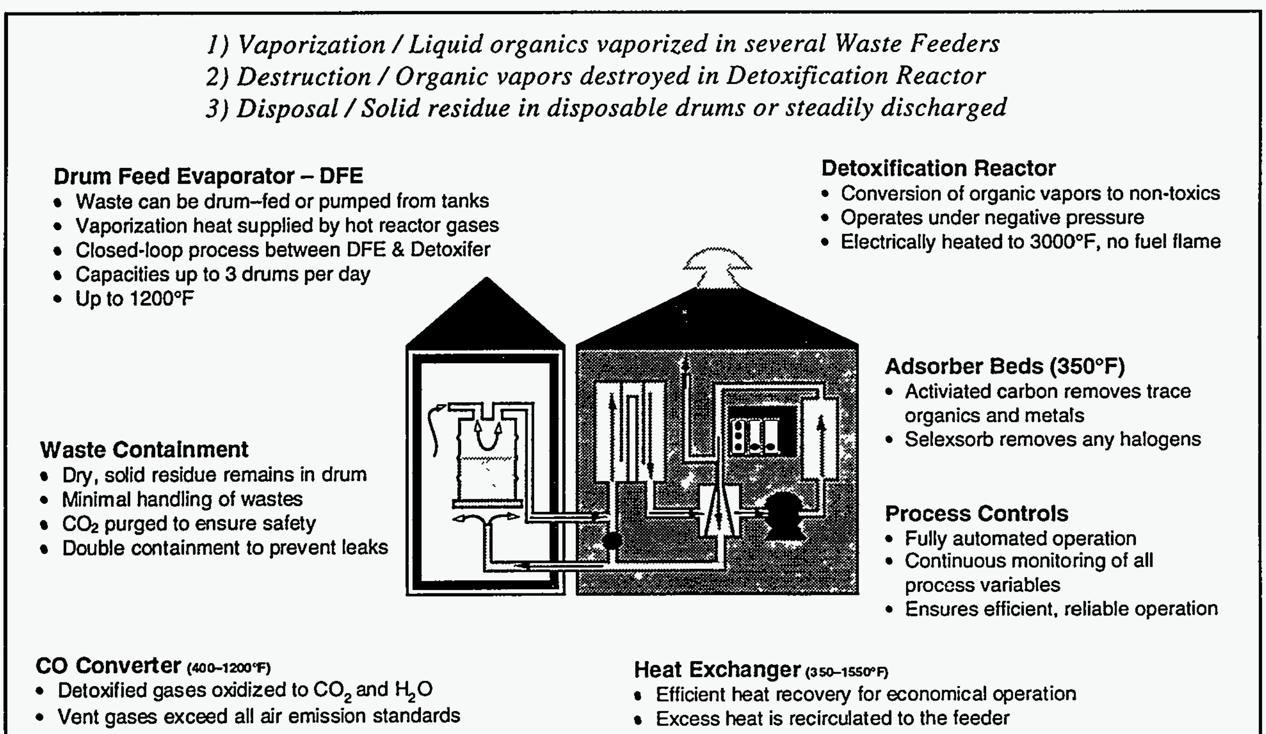

Figure 2.15. Synthetica® Detoxifier Three-Step Process.

content sludge simulant; a cemented sludges, ashes, and solids simulant; a heterogenous debris simulant; and a lab packs simulant. In addition, destruction of Trimsol coated on machining wastes will be demonstrated.

TECHNOLOGY NEEDS

This technology would be applicable for treatment of organic wastes addressed by Volatile Organic Compounds in Arid Soils ID, Volatile Organic Compounds in Non-Arid Soils ID, Underground Storage Tank ID, and the Waste Component Recycle, Treatment, and Disposal Integrated Program (WeDID). Steam reforming has already been shown to destroy many organic solvents found in typical mixed wastes with efficiencies greater than 99.99 percent, and to achieve destruction efficiencies in excess of 99 percent for most of the common polymeric organic components of mixed wastes. This project will demonstrate destruction of organic materials (e.g. paper, plastics, rubber, lumber, and organic solvents) and inorganic salts that decompose thermally (e.g. nitrites, nitrates, carbonates) using the steam reforming system of Synthetica® Technologies. In addition, scavenging of mercury vapor by molten sulfur coated on ceramic spheres will be studied to determine whether Synthetica's ceramic sphere packed moving bed evaporator liquid feed system can be used to scavenge mercury vaporized by steam gasification of mixed wastes.

COLLABORATION/TECHNOLOGY TRANSFER

This project will use the steam reforming system of Synthetica Technologies, Inc. Successful demonstration tests will lead to the near-term availability of a commercialized, easily transportable, publicly acceptable, economic steam reforming technology. The development of the Synthetica Detoxifier was partly funded by the California Hazardous Waste Reduction Grant Program.

For further information, please contact:

J. L. Sprung
Sandia National Laboratory
(505) 844-0234

D. L. Berry
Sandia National Laboratory
(505) 844-0234

2.16 WASTE DESTRUCTION AND STABILIZATION: LIQUID METAL MELT-SLAG TECHNOLOGY EVALUATION FOR MIXED WASTE INTEGRATED PROGRAM

TASK DESCRIPTION

Studies show that large quantities of metal, both ferrous and nonferrous, exist in the DOE inventory and that much more metal will be generated by future remediation efforts and by decontamination and decommissioning activities. Much of this metal waste is contaminated with both chemically hazardous and radioactive components. A metal melting treatment system could treat metal-bearing wastes, allowing for recovery of the contained metal, in addition to volume reduction of the waste stream and vitrification of the contaminants. Radioactive contaminants would be separated into a slag phase, and hazardous organic contaminants would be decomposed by the heat of the bath.

In FY93, this task evaluated state-of-the-art technologies for metal refining with specific reference to separation of radioactive contaminants and destruction of hazardous organics. Specific tasks included:

- Determining the most effective metal processing technology available and selecting industrial partner(s) to develop and implement the technology; and
- Recommending industrial partners and sources for contaminated metal processing technology. This task was a collaboration between PNL and LANL.

Based upon preliminary studies, melting technologies that were considered to be viable for treatment of mixed waste and thus justify further examination included:

- Fossil fuel melting (bath smelting, basic oxygen processes; process heat from carbon combustion with injected oxygen);
- Electric arc melting;
- Induction melting;
- Electron beam melting;
- Vacuum arc remelting; and
- Electro-slag melting.

TECHNOLOGY NEEDS

The MWTP flowsheet indicates that no conventional technology exists for metal processing. A metal melting treatment system could conceivably allow for the treatment of a wide variety of waste streams with necessary but minimal pretreatment. The type of treatment system sought would allow for recovery and reuse of the contained metal in addition to volume reduction of the waste stream and vitrification of the contaminants.

A metal melting system would allow DOE to meet legal requirements for treatment and disposal of these complex waste streams. Recent information amplifies the need of this technology in that recycled steel is needed for high level waste canisters.

ACCOMPLISHMENTS

A literature review was conducted to assess the current state-of-the-art metal melting technologies. Sources used in this effort included the chemical abstract data base (1968 to date), the metals abstract data base, and the national technical information data base. A broad range of metal refining technologies was evaluated in order to select a most promising technology. Induction melting was identified as the most viable technology for the treatment of DOE's mixed waste streams, based on the current state of development. Induction melting has already been demonstrated in the treatment and recycle of uranium contaminated metals, and requires no gas feed for process gas. Technology assessment reports incorporating the combined studies at LANL and PNL were completed. This establishes a sound basis for continued work in the arena of metal melting technology for mixed wastes.

COLLABORATION/TECHNOLOGY TRANSFER

An announcement was issued in the *Commerce Business Daily* to generate interest in metal melt/recycling of DOE mixed waste and locate potential industrial partners. Several industrial firms with experience in metal melting of hazardous wastes at the commercial scale expressed interest in future joint efforts to treat DOE mixed wastes.

A metal melting technology designed to treat mixed wastes would be applicable to many metal-bearing mixed waste streams in the DOE inventory and mixed wastes being generated by decontamination and decommissioning activities.

For further information, please contact:

Edward L. Joyce
Los Alamos National Laboratory
(505) 667-9954

Hurshal G. Powers
Pacific Northwest Laboratory
(509) 376-4973

2.17 FINAL WASTE FORMS: MICROWAVE SOLIDIFICATION AND TREATMENT SUPPORT FOR ROCKY FLATS

TASK DESCRIPTION

This task provided technical assistance to the MWIP and the Rocky Flats Plant (RFP) in support of the RFP Microwave Solidification Project and the Microwave Fluidized Bed Project at LANL. Support areas included microwave field measurements, theoretical modelling of microwave heating physics, and process control studies aimed at reducing or preventing process anomalies, such as arcing and non-uniform heating.

A bench-scale microwave solidification system was built and tested using surrogate waste formulations. The 3-dimensional microwave field generated within a 30 gallon drum by a microwave solidification applicator was measured, and a report submitted on improving process reliability and final waste form. Microwave applicator design can be easily modified with this system, and the process performance data, off-gas characterization, and final waste form obtained should be similar to those obtainable later when the process is scaled to larger sized units. In similar work, the processing of actual mixed waste streams will be conducted on mixed waste streams not previously considered for treatment by this process.

The Microwave Fuidized Bed is a thermal treatment process that uses microwave energy to heat a bed of silicon carbide particles (SiC) that is being fluidized by a water vapor stream containing hazardous organic liquids. The fluidized bed breaks down the liquid into less hazardous constituents. The precise mechanism is unknown, and trial and error approaches will be required to optimize the process.

TECHNOLOGY NEEDS

There is a need for solidification technologies in order to store and dispose of wastes in containers. There also is a need to develop alternatives to incineration and cementation to avoid the formation of incomplete combustion products that occur during incineration and large increases in waste volume due to cementation. Microwave solidification and microwave fluidized bed technologies achieve these needs.

ACCOMPLISHMENTS

Pilot-scale demonstration on surrogate hydroxide precipitation sludge was successfully completed and bench-scale tests were performed on actual radioactive waste. TCLP tests were performed on the surrogate waste to demonstrate acceptable leachability of the final waste form.

Microwave fluidized bed work in FY92 demonstrated a detoxification of 92 percent for 1,1,1-trichloroethane in a single pass through a fluidized bed of SiC heated with 0.915 GHz microwaves. FY93 funded generation of a letter report showing the ability of this technology to meet the needs of MWIP.

COLLABORATION/TECHNOLOGY TRANSFER

This task served as technical support to RFP Microwave Solidification Project and the Microwave Fluidized-Bed Detoxification Process being developed at LANL.

Development of the microwave solidification system at Rocky Flats has been carried out in collaboration with Microdry, Incorporated and RF Technologies.

Microwave fluidized bed technology at Los Alamos is collaborating with other microwave technology projects at LANL, which include microwave sintering and joining of materials.

For further information, please contact:

Terry White
Oak Ridge National Laboratory
(615) 574-0983

Greg Sprenger
Microwave Solidification
EG&G Rocky Flats
(303) 966-3159

Joel D. Katz
Microwave Fluidized Bed
Los Alamos National Laboratory
(505) 665-1424

2.18 OFF-GAS: REAL-TIME, CONTINUOUS MONITORS

TASK DESCRIPTION

Monitoring systems have been created to monitor and control trace amounts of gas particulate emission during off-gas treatment. In FY94, plans for these systems will follow a pattern of technology transfer of established monitoring systems to complete field demonstration. The radionuclide particles that need to be monitored include: ammonia, nitrogen oxides, halogen/sulfur species, VOC's, mercury, plutonium, uranium and americium.

Three technical task plans have been established to monitor these particles:

- Large-Volume Flow Through Detection Systems (LVFTDS) for radionuclide particles (see Figure 2.18a);

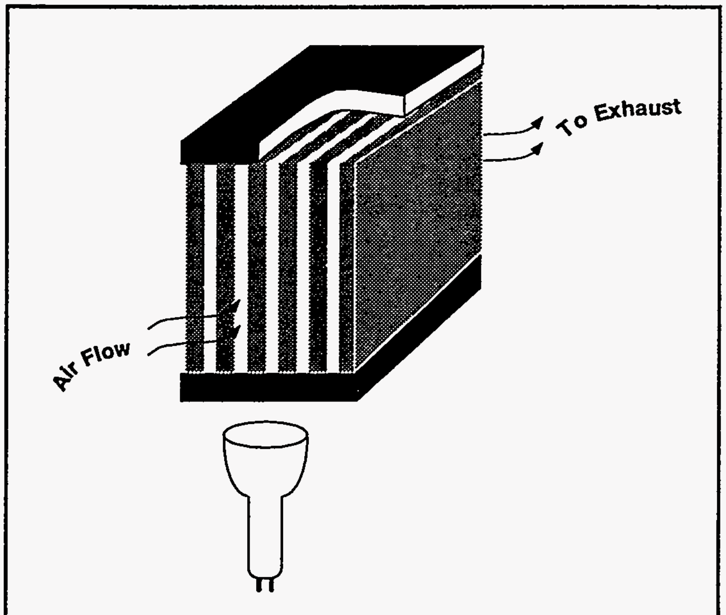

Figure 2.18a. The Large Volume Flow-Through Detection System Concept.

- Tunable Diode Laser (TDL) Spectroscopy for ammonia and other gas effluents; and
- continuous analyzers for mercury monitoring.

Plans for FY94 for the LVFTDS for alpha emission particles include:

- identify and secure an industrial partner for this technology;
- implement a full- scale detector and demonstration; and
- evaluate results.

Replacing the current monitoring system for transuranic waste with the LVFDS would improve the sensitivity by an order of magnitude while decreasing detection times. Additionally the detector is simple and reliable due to the lack of any type of filter that would need replacing (see Figure 2.18b).

Plans for near-infrared TDL spectroscopy include:

- field testing of ammonia monitor;
- proof of concept experiments on a halogen/sulfur species monitor;
- identification of performance specifications and instrument configuration for VOC monitor;
- construction and lab testing of VOC emissions monitor; and

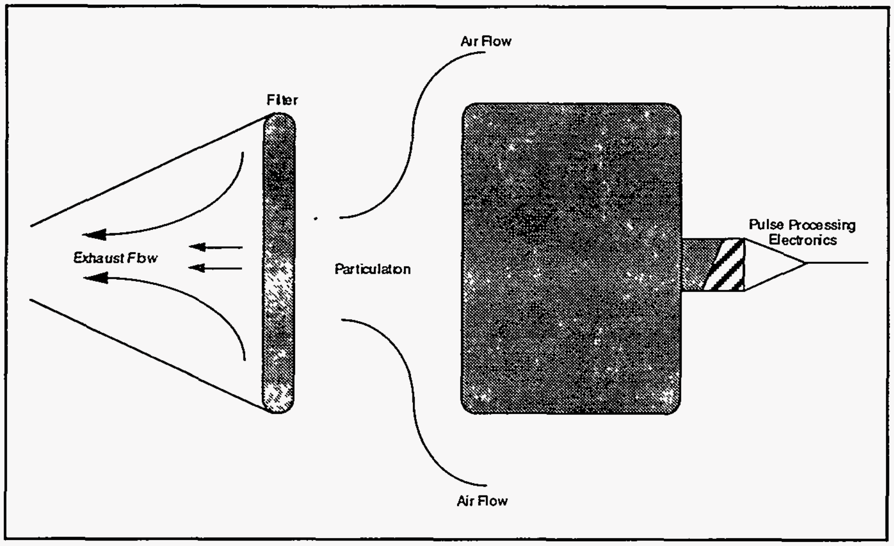

Figure 2.18b. Typical Stack Gas Alpha Detection System.

All of these instruments will provide sub-ppm detection limits for gas phase air toxic species, reliable operating lifetimes, in situ monitoring of species and environmentally hardened instrumentation with on-board calibration methods. They will also create increased public and regulatory confidence knowing that effluent streams are being continuously monitored, and will also save time and money.

- making the decision, based on lab results, for the construction of a field unit.

Benefits of TDL spectroscopy for waste stream monitoring are:

- low cost optical and electronic hardware for trace detection limits;
- physically robust components, which do not require cryogenic temperature control;
- unambiguous identification of individual gas-phase molecular species;
- rapid data acquisition and analysis for process control; and
- possibilities for in situ sampling.

Plans for a mercury monitor in gas effluents include:

- proof of principle for conversion of speciated mercury and achievement of 0.1 ppb mercury detection; and
- fabrication of a mercury monitor for tests on a lab scale.

TECHNOLOGY NEEDS

MWIP has identified a high priority need for real-time monitors for trace amounts of high toxicity gases to be field tested within two years. These monitors are also needed for air quality measurements of stack emissions before and after air pollution control processes.

ACCOMPLISHMENTS

A fully functional lab-scale prototype LVFTDS has been fabricated and will be available from the start of FY94 for progressional scale-up for field testing.

TDL spectroscopy/ammonia monitors are being tested at PSI Environmental Instruments Corporation and several utility test sites and will be available to be field tested at DOE sites early in FY94. Sub-ppm detection limits have been demonstrated in the laboratory for several small molecular gas species.

ADA Technologies has produced a spectroscopically based commercial continuous analyzer that examines elemental mercury in gas streams.

ADA Technologies will collaborate with SNL throughout the work on continuous mercury analyzers to provide expertise in instrumentation systems and field implementations.

COLLABORATION/TECHNOLOGY TRANSFER

LANL/Controlled Air Incinerator has been working on the LVFTDS for airborne emission particles and is a candidate for field testing. Past funding has been provided by Rocky Flats through the Federal Facility Compliance Act.

PSI Environmental Instruments Corporation will collaborate with LANL for field test studies on TDL spectroscopy units. Further technological development of tunable diode lasers at SNL will provide additional markets for these products. These monitors will be useful to all government and private sector organizations involved in combustion, gasification, and incineration. Process monitors based on this technology are also possible for medical applications in blood and oxygen monitoring and semiconductor manufacturing, which will broaden its government agency utilization.

For further information, please contact:

R. E. Gritzo
Large-Volume Flow Through Detector System/Airborne Particles
Los Alamos National Laboratory
(505) 667-0481

D. Ottesen
Tunable Diode Lasers/Ammonia Monitor
Sandia National Laboratory
(510) 294-3567

J. Wang
Mercury Analyzer
Sandia National Laboratory
(510) 294-2786

2.19 SYSTEMS ANALYSIS FOR MIXED WASTE INTEGRATED PROGRAM

TASK DESCRIPTION

The MWIP systems analysis coordinates potential alternatives to baseline technology (see Figure 2.19). Work focuses on safety risk assessment, performance systems analysis, and life-cycle costs for OTD-developed subsystems. This includes an analysis of technology subsystems that have the potential to improve baseline technologies. The MWIP systems analysis group is developing alternative flowsheet models for baseline processes, which were developed by the Mixed Waste Treatment Project (EM-30). The alternative flowsheet processes involve mass and energy balances, and could possibly improve baseline technology by analyzing replacement subsystems of the master model.

The MWIP performance systems analysis group will model the innovative technologies in FLOW (to gain knowledge in the new technology) and in ASPEN software packages. The ASPEN models will be used by EM-30 to analyze the potential improvements of the innovative technologies with respect to their baseline process model. Evaluation will consider criteria such as implementability; maintainability; technical risk; environmental health and safety risk; and costs.

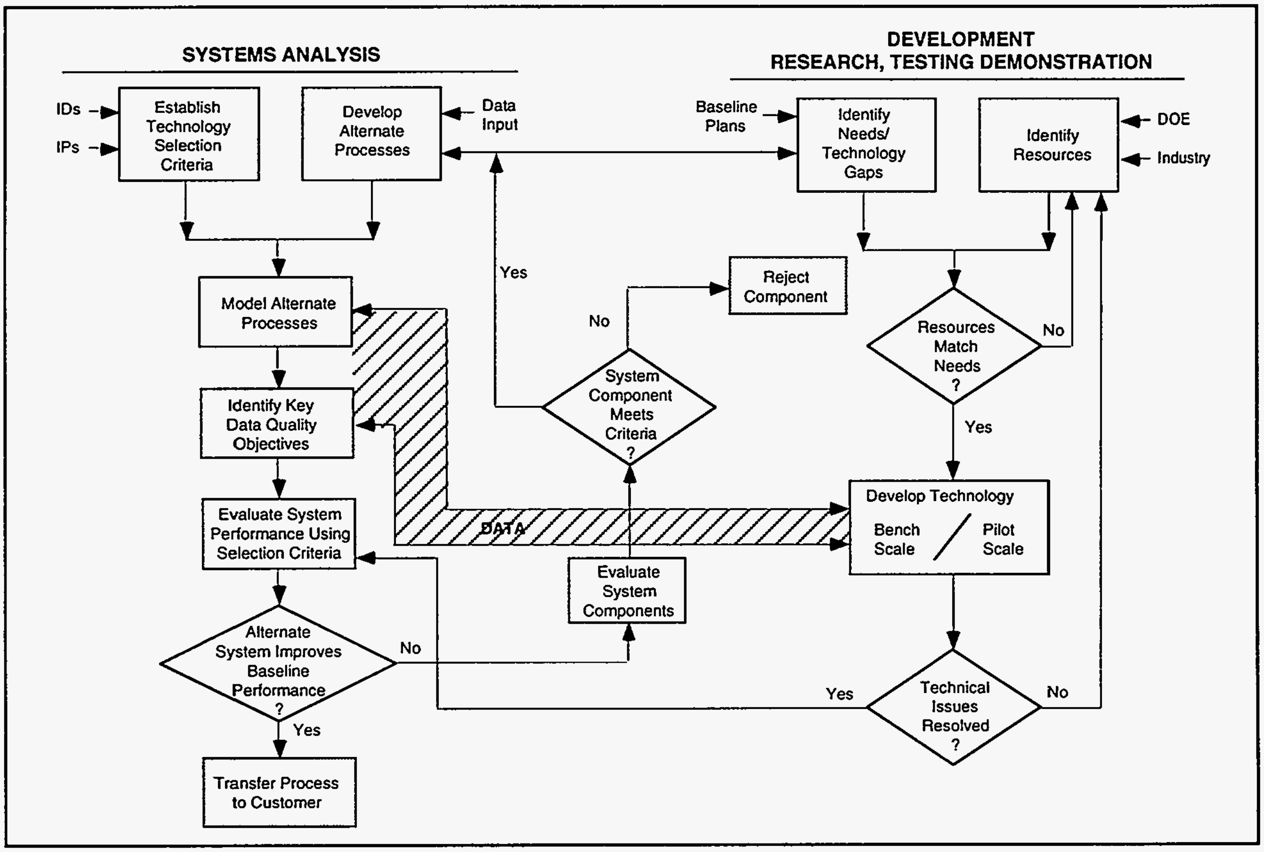

Figure 2.19. Systems Analysis.

TECHNOLOGY NEEDS

EM-30 requires that systems analysis be performed to assure that OTD-developed alternatives to baseline technologies are demonstrably superior to the original. MWIP is developing alternative technologies to fill technology gaps in mixed waste treatment plans, decrease characterization needs, and simplify treatment with versatile technologies.

ACCOMPLISHMENTS

The systems analysis group completed a preliminary hazard analysis of the plasma hearth process, and found that there will be no significant risk if the waste inventory is maintained below 100 drums. An evaluation criteria report has been drafted, and includes technical and social elements. A performance analysis report has been drafted and includes tools development, preliminary performance results, and an uncertainty analysis that indicates the study needs for pilot plant experiments. A life-cycle cost analysis has been drafted, and includes a cost comparison between the baseline process and the first alternative flowsheet based on the plasma hearth process.

COLLABORATION/TECHNOLOGY TRANSFER

Collaboration with Carnegie-Mellon University to perform uncertainty analysis has started. The computerized system being developed will run uncertainty analyses of innovative technologies. Actual work is directed to produce a computerized tool that works with the performance systems analysis tools to evaluate uncertainties in technology performance. Cost analysis has been developed by LANL, in conjunction with IT Corporation. The risk assessment has been conducted by LLNL in conjuction with Science Application Internation Corporation. Additional process engineering consultation is planned.

For further information, please contact:

Juan J. Ferrada
Oak Ridge National Laboratory
(615) 574-4998

Jeannette B. Berry
Oak Ridge National Laboratory
(615) 574-6907

2.20 INCINERATION ALTERNATIVES: PACKED BED REACTOR/SILENT DISCHARGE PLASMA

TASK DESCRIPTION

Silent Discharge Plasma (SDP), or "cold plasma", is a proven technology used extensively in water purification operations (see Figure 2.20). By applying a high-frequency electric field between two plates, short-duration electrical discharges produce a highly reactive substance that attacks gaseous organic molecules present between the plates. SDP is being investigated as an off-gas treatment for existing technologies.

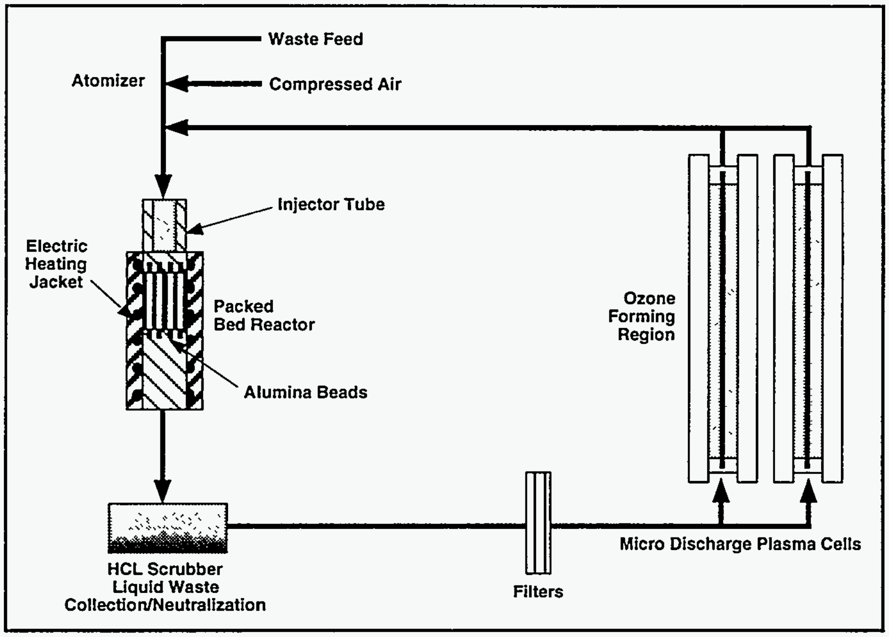

Figure 2.20. Silent Discharge Plasma.

In addition, SDP is being combined with an alumina (aluminum oxide) Packed Bed Reactor (PBR), a new thermal treatment unit, to expand its capabilities to destroy various waste forms. A liquid waste stream is mixed with oxygen and water and oxidized at 1100-2200°F in the PBR. The resulting vapors pass through the SDP cell.

TECHNOLOGY NEEDS

The PBR/SDP technology is being developed at the Los Alamos National Laboratory. High destruction efficiencies of liquid organic wastes have been separately demonstrated with both the PBR and SDP technologies. Although SDP could be used as a primary treatment unit, studies are in progress to evaluate integration of these two units to achieve higher overall destruction efficiencies. Approaches to treating solid wastes are also being explored; treatment of slurries appears promising. Scale-up issues are also being investigated.

SDP is also a candidate technology for off-gas treatment with other technologies serving as the primary treatment unit. Studies will be conducted to assess the ability of SDP to destroy the hazardous components in a variety of off-gas conditions and resolve other integration issues.

ACCOMPLISHMENTS

- Completed lab-scale tests and determined destruction efficiencies for surrogate (non-radioactive) FBI oil (liquid chlorinated organics).
- Completed lab-scale tests and determined destruction efficiencies for surrogate solid combustibles (e.g., paper, plastic).

COLLABORATION/TECHNOLOGY TRANSFER

The development of the PBR/SDP technology for Rocky Flats is being conducted at Los Alamos National Laboratory in collaboration with the Electric Power Research Institute.

Rocky Flats also continues to evaluate published reports and data on other incineration alternative technologies and to follow the development of these technologies throughout the DOE Complex.

Details on the results of these studies will be published in DOE technical reports and outside journal articles.

For further information, please contact:

Charles M. Brown
Principal Investigator
EG&G Rocky Flats
(303) 966-5277

Jerry L. Peterson
Technical Program Manager
EG&G Rocky Flats
(303) 966-5349

Louis Rososcha
Principal Investigator
Los Alamos National Laboratory
(505) 667-8493

Hugh D. Murphy
Technical Program Manager
Los Alamos National Laboratory
(505) 667-8914

Pollution Prevention Overview

Section 3.0

3.0 POLLUTION PREVENTION OVERVIEW

Manufacturing processes generate much of the hazardous waste within DOE, other Federal agencies, and U.S. industry. 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, 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 m^3 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 electro-manufacture process industry to develop manufacturing processes and 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 cleaning electronic components annually. EPA estimates indicate that contaminated soil, sediment, and sludges at sites listed on the National Priorities List (those with RODs) from electronic/electrical equipment alone approach 1.5 million cubic yards.

The Pollution Prevention program supports an integrated approach to pollution prevention and waste minimization by developing and demonstrating 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 may stimulate U.S. competitiveness and economic growth through the growth of a "clean" technology industry.

3.1 INTEGRATED ENVIRONMENTALLY COMPATIBLE SOLDERING TECHNOLOGIES

DESCRIPTION

The goal of this program is to characterize and demonstrate alternative soldering technologies that can be applied towards reducing solvent use and the subsequent volume of chemical waste generated during soldering of microelectronics assemblies. The Integrated Environmentally Compatible Soldering effort covers several technologies (materials and processes) that address the ozone depletion and waste stream problems.

Fluxless and "no clean" soldering covers a wide variety of technologies that utilize various "clean" or reducing atmospheres to either maintain or produce a solderable base surface. Vacuum, inert or reducing gas, reactive plasma, and activated acid vapor atmospheres have been applied to fluxless soldering. These atmospheres restrict the supply of oxygen to the work piece during the heating and soldering operations. The "no clean" solder concept typically couples controlled atmospheres with the use of a low-solids flux. Flux residues are generally negligible. Work being conducted at SNL has shown that the gas species (molecular, atomic, or ionic) has a significant effect on the rate of oxide reduction and subsequent solder wetability. Although thermodynamic data suggests that the reduction of metallic oxides in hydrogen or vacuum is feasible at typical soldering temperatures, 200-300°C, the rate of reaction is very low. Reactive gases have a greater potential for effectively reducing surface oxides. SNL has characterized the effect of reactive gases on directly soldering metallic substrates.

The use of protective coatings (metallizations and organic preservation/inhibitors) can reduce the need for a flux. Nonoxidizing surfaces, such as gold or other noble alloys, have a long history of being readily wet by solder without fluxing. A thick metallization layer is generally required to guarantee a nonporous surface barrier that will adequately protect the wettability of the underlying base metal. However, the thickness of gold must be carefully controlled when using tin-based solder alloys. Gold reacts with tin to form a brittle intermetallic that could consequently embrittle a solder joint if excess gold is applied. Conversely, a thin, porous layer of gold might expose the underlying metal that would be susceptible to oxidation or corrosion in a poorly controlled storage environment. These porous metallizations can be protected during storage by applying organic inhibitors. SNL has collaborated with the University of California at Berkeley to characterize the effects of disposition method, surface roughness, and micro-structure of gold, nickel and copper surfaces on fluxless wetting. The State University of New York at Stony Brook has studied the bonding behavior of organic inhibitors on metallic surfaces. Results from the two university programs have been used by SNL to design metallization and inhibitor systems that facilitate fluxless soldering or allow the use of more environmentally-compatible fluxes.

Laser ablative cleaning involves the use of very short pulses of high peak power laser radiation to rapidly heat and vaporize microscopically thin layers of oxidized metal surfaces in an inert gas environment. The vaporized material quickly condenses on contact with the cooler ambient gases forming submicron particles that are easily transported from the "clean" surface by a flowing gas stream. These waste particles can be collected with a submicron filter canister. A Q-switched pulsed laser beam can be mechanically scanned across the faying surface to not only ablate the surface, but to also directly wet it without fluxing. Secondary heating can be used to also make the solder joint. The cover gas prevents recontamination of the cleaned surfaces. SNL has recently developed a laser ablative fluxless soldering (LAFS) process that yields high quality metallurgical bonds without use of reactive chemicals. The combination of high spatial resolution and low thermal impact makes LAFS an attractive process for application on microcircuits and high density printed circuit boards (see Figure 3.1).

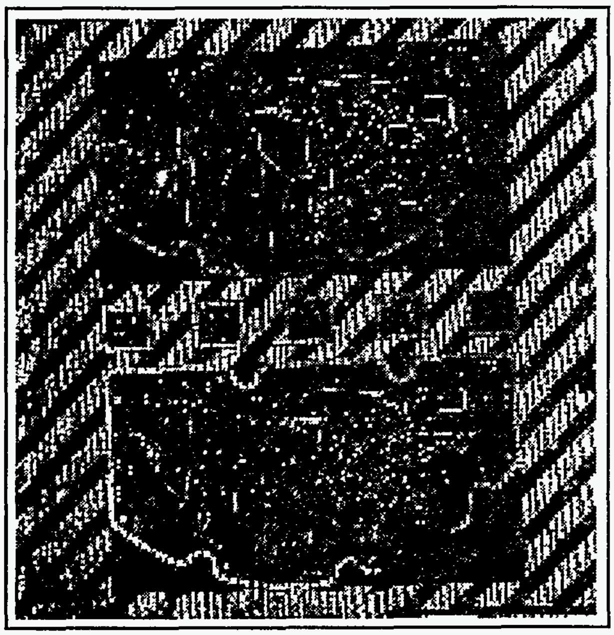

Figure 3.1. ECMID Printed Wiring Boards.

Wetting evaluations have been conducted with LAFS and the experiments have been highly successful. Aluminum, copper and nickel surfaces, typically difficult metals to wet without fluxing, were directly wet using LAFS.

Water soluble and low solids ("no clean") fluxes are alternatives to fluxless soldering processes. Although these fluxes require some level of cleaning after soldering, electronic assemblies can be cleaned by more environmentally compatible methods (e.g. alcohol or aqueous based cleaners). Since most soldering lines have been set up for rosin-based fluxes, work must be done to define the working limits of the alternative fluxes. The newer fluxes are generally more sensitive to the soldering parameters and have a narrower operating range. SNL has been working with Allied Signal to integrate water soluble and low solids fluxes into environmentally conscious manufacturing (ECM) practice. A nontoxic, nonflammable, citric acid based flux has especially demonstrated potential.

TECHNOLOGY NEEDS

Chemical fluxes are typically used during conventional electronic soldering to enhance solder wettability. Most fluxes contain very reactive, hazardous constituents that necessitate special storage, handling, and cleaning procedures. Corrosive flux residues can also compromise product reliability if left on the soldered part. The residues are generally removed with CFC or other hazardous solvents that have been linked to either ozone depletion or waste stream generation. Alternative materials and processes are being developed to lessen the dependence on these solvents, many of which are being phased out to meet environmentally-driven restrictions. SNL has developed a variety of soldering technologies that facilitate the reduction of solvent use and the subsequent volume of chemical waste generated during electronic soldering.

Since there is no single process that can be universally applied to the waste minimization problem, these technologies are intended as complements to each other and should not be viewed as competing processes under the given constraints.

ACCOMPLISHMENTS

- Demonstrated the feasibility of applying controlled atmospheres, metallizations, organic inhibitors, lasers, and ultrasonic soldering as fluxless or "no flux" soldering operations.
- Demonstrated pretinning process using laser ablative and ultrasonic soldering technique.
- Demonstrated water soluble and low- solid flux selection, laser soldering of an integrated circuit, and inert/activated atmospheres soldering.
- Selected water-soluble and low-solids fluxes for demonstration.
- Demonstrated laser ablative cleaning at the Kansas City Plant.

COLLABORATION/TECHNOLOGY TRANSFER

The technologies will be available to DOE design and production facilities, subcontractors, other government agencies, and the commercial sector. Technology transfer will be handled through SNL's Technology Transfer Center. Site visits, technical presentations, and documentation in open literature will also facilitate technology transfer.

For further information, please contact:

Michael Hosking
Principal Investigator
Sandia National Laboratory
(505) 845-8401

George C. Allen
Technical Program Manager
Sandia National Laboratory
(505) 844-9769

3.2 ON-LINE MONITORING OF VOLATILE ORGANIC COMPOUNDS

TASK DESCRIPTION

Sandia National Laboratory's program for on-line monitoring of volatile organics for waste minimization involves development, demonstration, and fielding of PAWS systems based on a technique for obtaining chemical discrimination using a single sensor by monitoring both the wave velocity and the wave attenuation (see Figure 3.2). Program activities include identification of high priority needs for chemical monitoring, development of selective and sensitive acoustic wave sensors for these applications,

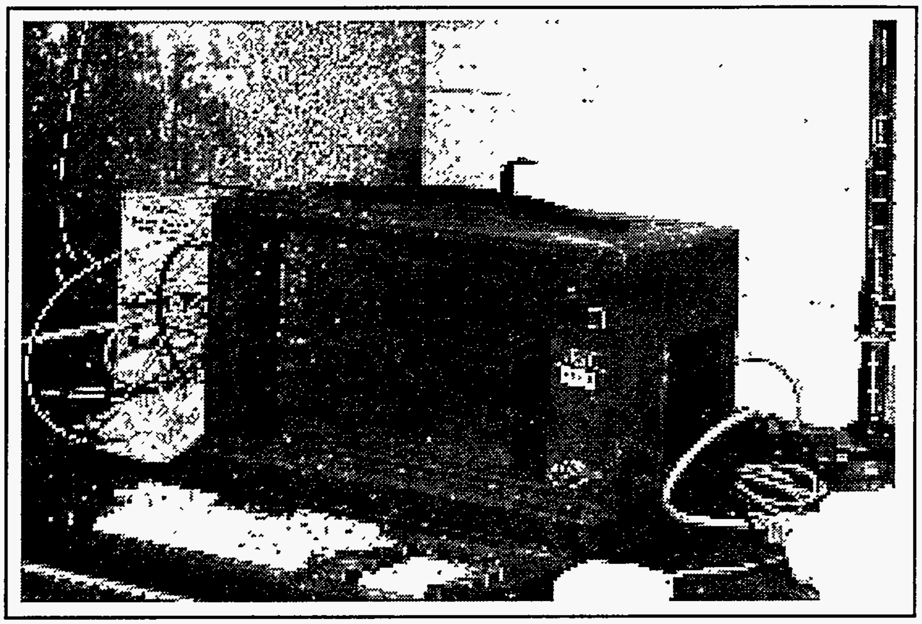

Figure 3.2. The portable acoustic wave sensor.

and integration of these sensors into systems containing automated data acquisition and analysis techniques, and real-time reporting of chemical concentrations. These capabilities are being applied to monitor process lines, exhaust systems, and work-place environments. The chemical information provided by these systems will be used to document emissions to the environment and prevent discharging above the EPA limits as well as to modify engineering parameters and improve process control to increase efficiency and minimize waste.

TECHNOLOGY NEEDS

Ratification of the Montreal Protocol will result in significant reductions in the production and usage of Chloroflurocarbons (CFC) and chlorohydrocarbons (CHC). EPA has indicated that most, if not all, halogenated solvents currently used in the DOE weapons complex will eventually be regulated. It is the goal of the production agencies to eliminate their use from weapons manufacturing. In addition, the new Clean Air Act and other Federal, state, and local regulations provide stricter regulations regarding all chemical emissions (e.g., volatile organic compounds) to the environment and emphasize the need to monitor and document these emissions.

ACCOMPLISHMENTS

- The portable acoustic wave sensor module was field tested at Allied Signal-Kansas City Plant which resulted in vital data concerning spray cleaning and alternative solvents.
- Sandia developed and is currently using PAWS for real-time, on-line monitoring of volatile organic chemicals in their process waste streams.

COLLABORATION/TECHNOLOGY TRANSFER

An integral part of the PAWS project is transferring the technology to Allied Signal at the Kansas City Plant through the integration of the systems into production lines and training of personnel for effective operations. Once successful transfer is made to Allied Signal, the systems should be available to any DOE facility and may be transferred to industry for wide spread application. Currently, SNL has two CRADAs with Mechanical Technology Inc. and Tektronix Laboratories for developing additional capabilities for the PAWS systems.

For further information, please contact:

Greg Frye
Principal Investigator
Sandia National Laboratory
(505) 844-0787

George C. Allen
Technical Program Manager
Sandia National Laboratory
(505) 844-9769

3.3 CLEANING ALTERNATIVE

TASK DESCRIPTION

Cleaning alternative activities are identifying cleaning processes which are environment, safety and health-friendly and produce zero or near zero waste discharge. The project began in FY90 by identifying and evaluating currently available cleaning technologies, including substitute solvents to be used to clean electronic assemblies. This selection was based on a cleaning efficacy study and an accelerated aging study of cleaned substrates. Six solvents were evaluated (two aqueous-based, one terpene-based, one alkyl acetate, one alcohol, and a trichloroethylene/ isopropyl alcohol baseline). The efficiency with which these solvents removed rosin flux and silicone mold release were determined using Auger electron spectroscopy, contact angle measurements, and ionic conductivity measurements on substrate rinse solutions. In addition, the use of water soluble organic acid fluxes that can be cleaned with distilled water rinses was similarly evaluated. Cleaned substrates were subjected to accelerated aging at elevated temperatures and humidities. Based on the evaluations, aqueous cleaners and d-limonene appear to be the most likely candidates for cleaners in the long term. Aqueous cleaners are inherently safe to use and under most current regulations are relatively easy to dispose. D-limonene, implemented as the immediate substitute cleaner for replacing halogenated cleaners for electronic assemblies at the Kansas City Plant, also offers potential as a long term solution since it may be able to be recycled through low temperature vacuum distillation.

TECHNOLOGY NEEDS

CFC and CHC solvents are used throughout the DOE weapons complex for cleaning processes. However, due to regulatory requirements, CFCs will be phased out by 1995. SNL and the Allied Signal Aerospace-Kansas City Division (AS-KCD) have committed to implement non-CFC cleaners by 1995. This task plan is an essential part of the ECMID at AS-KCD. Solvent substitution technologies will be evaluated and applied to the fabrication of selected demonstration components at AS-KCD.

ACCOMPLISHMENTS

- Established parameters to distill d-limonene from used cleaner, a mixture of d-limonene and isopropyl alcohol (IA).
- Fabricated ten "Pulse Width Modulator" boards for a Simple Firing Set with nonrosin flux and IA cleaned.
- Completed corrosion mechanism study on brass in alkaline medium.
- Successfully assisted RSM Electron Power to replace Freon cleaning using d-limonene and ethyl lactate.

COLLABORATION/TECHNOLOGY TRANSFER

Meetings, presentations, and conferences would be the media for technology transfer. Through the DOE Solvent Waste Stream Working Group, ideas and information are exchanged with the weapons complex on a quarterly basis. Technology transfer to SNL vendors and suppliers will be established by providing them with needed information to implement their own ODC reduction programs.

For further information, please contact:

Sally Hoier
Principal Investigator
Sandia National Laboratory
(505) 845-9749

George C. Allen
Technical Program Manager
Sandia National Laboratory
(505) 844-9769

3.4 SUPERCRITICAL CARBON DIOXIDE CLEANING

TASK DESCRIPTION

The overall goal of this program is to investigate the feasibility of replacing toxic and environmentally-objectionable volatile organic cleaning solvents with supercritical carbon dioxide (SC-CO_2) in the DOE Complex; develop an environmentally conscious cleaning process that does not add to the solvent waste stream and can therefore be used in the long term; and engineer cleaning systems that can be implemented within the Complex. The potential advantages of SC-CO_2 cleaning are enormous; CO_2 is non-toxic, recyclable, and relatively inexpensive. One of the positive aspects of SC-CO_2 is that it is recyclable. Figure 3.4 is a schematic of an ideal SC-CO_2 cleaning system. The parts to be cleaned are placed in the extractor and the CO_2 circulates through the pressure reducer and separator, and is recycled back to the extractor. Because the dissolving power of CO_2 generally decreases as the pressure is decreased (at constant temperature), the contaminant is collected in the separator. SC-CO_2 will prove most useful where parts having complicated geometry must be cleaned and no other method is adequate. The use of SC-CO_2 as a cleaner is consistent with DOE's stated goals regarding waste minimization, CFC elimination of worker exposure to toxic solvents, and compliance with environmental regulations.

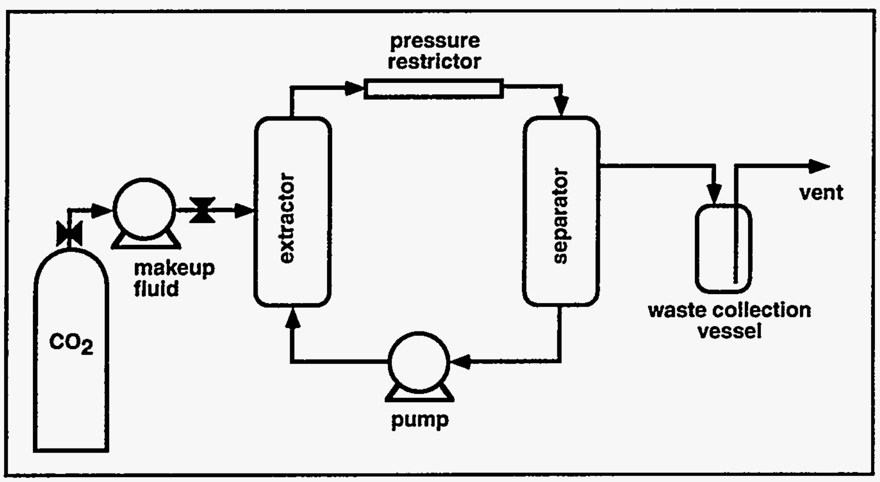

Figure 3.4. Ideal Supercritical Carbon Dioxide Cleaning System.

TECHNOLOGY NEEDS

Supercritical CO_2 cleaning features waste minimization through a recycle process, elimination of CFC and halogenated solvent usage, and reduced worker exposure to toxic chemicals. Parts are removed from the process dry and do not require bake-out to remove residual cleaning solvent. This technology would enable DOE, other government agencies, and U.S. industry in general, to comply with current Education, Safety, and Health regulations.

ACCOMPLISHMENTS

- Completed materials compatibility study with SC-CO_2.

- Completed parts (printed wiring boards, resistors, capacitors, diodes, transistors) testing with SC-CO_2.

COLLABORATION/TECHNOLOGY TRANSFER

Technology transfer between SNL and AS-KCD will occur naturally as a result of the nature of the ECMID. Participation in the Solvent Waste Stream Working Groups will also facilitate discussion and transfer among members of the DOE manufacturing complex. Technology transfer to members of private industry will occur as a result of technical presentations at meetings with the Joint Association for the Advancement of Supercritical Fluid Technology.

For further information, please contact:

Carol Adkins
Principal Investigator
Sandia National Laboratory
(505) 845-9119

George C. Allen
Technical Program Manager
Sandia National Laboratory
(505) 844-9769

3.5 LEAD FREE SOLDER PASTE

TASK DESCRIPTION

This activity recommends development of lead-free solder alloy pastes which may be used in environmentally acceptable circuit assembly by means of surface mound technology. The subtasks involve alloy design and selection, preparation of ultrafine solder alloy powders, conversion of powders to paste, evaluation of alloy wetting characteristics, solder assembly and performance evaluation of test vehicles, and demonstration of the feasibility of ECM on development hardware and transfer of this technology to U.S. industry and war reserve production. In addition to being environmentally safe, the ultrafine powders produced during this project will enable manufacture of printed wiring boards having considerably finer pitch to meet the challenge of today's shrinking microcircuit technologies. Successful completion of this project will ease public anxiety over lead use in manufactoring, and assist U.S. industry in being more competitive in world markets.

TECHNOLOGY NEEDS

Lead metal and its compounds are known toxins, and legislation in both Houses of Congress is staged to ban or heavily tax lead use in all commercial products. Since lead is a component of electronic solder alloys, U.S. electronic manufacturers are concerned that this legislation will unnecessarily burden the industry, which is already reeling from intense overseas competition. This program is developing lead free solder alloy pastes, which may be used in environmentally-acceptable circuit assemblies.

ACCOMPLISHMENTS

- Identified initial lead-free solder candidates by characterization of melting behavior and microstructure of small ingot samples.
- Characterized solder alloy performance in wetting, mechanical strength, ductility, and thermal fatigue.
- Optimized high-pressure gas atomization process for production of fine lead- free solder alloy powder.

COLLABORATION/TECHNOLOGY TRANSFER

The technologies will be available to DOE design and production facilities, subcontractors, other government agencies, and the commercial sector. Technology transfer will be handled through SNL's Technology Transfer Center. Site visits, technical presentations, and documentation in open literature will also facilitate technology transfer.

For further information, please contact:

Fred Yost
Principal Investigator
Sandia National Laboratory
(505) 844-5278

George C. Allen
Technical Program Manager
Sandia National Laboratory
(505) 844-9769

Iver Anderson
Principal Investigator
Ames Laboratory
Iowa State University
(515) 294-8252

J.P. Corones
Technical Program Manager
Ames Laboratory
Iowa State University
(515) 294-9636

3.6 VALIDATION OF ENVIRONMENTALLY CONSCIOUS MANUFACTURING INTEGRATED DEMONSTRATION

TASK DESCRIPTION

Technologies and materials developed in the laboratory are transferred to the Kansas City Plant (KCP) for integration into a manufacturing pilot operation, prior to introducing changes to the factory floor, to evaluate product quality and manufacturing system issues. Technologies selected for a specific application affect many elements of the product and the total manufacturing process. A technology cannot be isolated as its application depends on the product design and upstream manufacturing processes, and its implementation affects downstream processes.

Technology demonstration activities at the KCP are designed to insure applicability of a technology to the production process. Aspects of the substitute process that require evaluation include worker exposure to new chemicals; safety and reliability of the new process; new waste streams in terms of toxicity and volume; material compatibility; component functionality, quality and long-term reliability; and component manufacturability including throughput and cost.

Aging, corrosion and compatibility is being evaluated to insure residues left by a new cleaning method does not react unfavorably with the substrate or encapsulant thereby decreasing component reliability. Manufacturability is tested in a system context with regard to throughput, quality, and subsequent processing capability (i.e., can a cleaned substrate be properly welded, soldered, encapsulated, etc.). The finished component is functionally tested to insure proper operation after being subjected to various environments it may be exposed to during its lifetime including humidity, thermal cycling, shock, and vibration. Without qualification of these materials and processes, and insurance of long term functionality and reliability of war reserve weapons, they will not be used in manufacturing and no benefit will be gained from the program.

TECHNOLOGY NEEDS

The validation of ECM hardware effort is necessary to ensure that the electronic components manufactured using environmentally clean manufacturing techniques and materials will perform their design function in the same manner as the original design.

ACCOMPLISHMENTS

- Completed all Tool Made Sample (TMS)-type testing.
- Completed statistical analysis of ECMID data versus TMS data.

COLLABORATION/TECHNOLOGY TRANSFER

The technologies will be available to DOE design and production facilities, subcontractors, other government agencies, and the commercial sector. Technology transfer will be handled through SNL's Technology Transfer Center. Site visits, technical presentations, and documentation in open literature will also facilitate technology transfer.

For further information, please contact:

Bill Ross
Principal Investigator
Allied Signal Kansas City Division
(816) 997-4151

David L. Jordan
Technical Program Manager
Allied Signal Kansas City Division
(816) 997-3318

3.7 B61/6/8 ELECTRONIC ASSEMBLY

TASK DESCRIPTION

The manufacturing techniques required to fabricate large-scale electronic assemblies differ somewhat from the techniques used to fabricate lower scale assemblies. This project builds on the knowledge obtained during the MC4138 Programmer study in FY92 by including those processes used at the higher assembly levels that are not used at the lower levels, and further studying those processes used at both levels.

The B61-6/8 electronic assembly (programmer) was the prototype assembly manufactured with no hazardous materials and minimal waste generated (see Figure 3.7). It is the first ECM unit manufactured with ECM materials and processes. Criteria for materials selected for the prototype programmer were printed wiring boards (non-MDA cured), polymers (non-isocyanate and non-MDA), solvents (non-CHC/CFC), and plating (non-cyanide, non-hexavalent chromium). Processes that generate minimal waste were used to manufacture the assembly to prove the feasibility and capability of the component. If ECM materials and processes prove to function as designed, the technology will be transferred to other electronic hardware and assemblies until all weapon systems components are manufactured using ECM technologies.

The information gained on this project will greatly assist in the goal of developing processes and materials necessary to enable the manufacture of environmentally clean systems at the KCP. Both electronic and mechanical assemblies will be included in this project in addition to the cleaning methods required for both. The techniques and processes validated on this project will then be available to other programs to assist in elimination of CFCs, CHCs and other hazardous materials from all aspects of manufacturing and assembly.

TECHNOLOGY NEED

The electronic assembly effort is necessary to ensure that the programmers manufactured using environmentally clean manufacturing techniques and materials will perform their design function in the same manner as the original design.

Figure 3.7. The B61/6/8 Electronic Assembly.

ACCOMPLISHMENTS

- Implemented ECM technologies in the manufacture of three functional demonstration B61 programmers at Allied Signal-Kansas City Division.
- Identified all hazardous product/process materials.
- Identified non-hazardous substitutes.

COLLABORATION/TECHNOLOGY TRANSFER

The technologies will be available to DOE design and production facilities, subcontractors, other government agencies, and the commercial sector. Technology transfer will be handled through SNL's Technology Transfer Center. Site visits, technical presentations, and documentation in open literature will also facilitate technology transfer.

For further information, please contact:

Bill Ross
Principal Investigator
Allied Signal Kansas City Division
(816) 997-4151

David L. Jordan
Technical Program Manager
Allied Signal Kansas City Division
(505) 997-3318

3.8 FORGE HAMMER

TASK DESCRIPTION

The forge hammer is a pretreatment technology designed to rapidly rubblize nuclear weapon components (see Figure 3.8). This rubblization process allows for easier chemical characterization and subsequent treatment, or separation of metals. However, there is a desire, for waste minimization reasons, to ensure that dissimilar materials are not rubblized. Therefore, it will include an interlock system using bar-coding to identify components, and prevent creating mixed waste by not rubblizing components containing radioactive material and heavy metals. Remote operation and dust control systems have been installed to address worker safety and health problems.

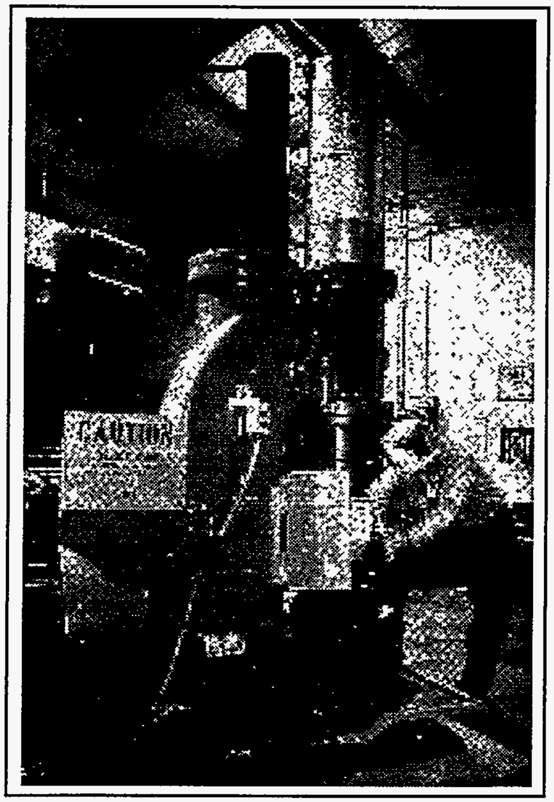
Figure 3.8. Forge Hammer.

TECHNOLOGY NEEDS

Approximately 2,000 weapons per year will be decommissioned, requiring treatment of approximately 230 cubic meters of weapons components and associated declassifications per year. Nuclear weapon components cannot legally be disposed of in conventional landfills without pretreatment or extensive characterization because they contain leachable toxic substances, like lead and cadmium. Weapons components also routinely contain radioactive, explosive, and toxic materials that are not easily separated or characterized. In addition, regulations are becoming increasingly stringent in terms of disposal options, necessitating environmentally sound practices. Chemical characterization of weapon components is prohibitively expensive. With the increasingly stringent regulatory environment, there is a need for treatment technology systems that can meet all regulatory requirements now and in the future. At the same time, these treatment technology systems must reduce front-end characterization activities, and, wherever possible, provide significant recycling opportunities. Technologically robust technology systems can save DOE both money and time in the treatment and disposal of nuclear weapons components or electronic materials.

ACCOMPLISHMENTS

- Three forge hammers procured from DoD surplus at essentially no cost (only cost for shipping) to DOE.
- Forge hammers delivered to Allied Signal-Kansas City Division, Pantex Plant, and Sandia National Laboratory.
- New rubblization box demonstrated, including dust control system.
- Forge hammer material rubblization and cryogenic fracture demonstrated.
- Developed test plans for forge hammer, interlock, and dust control system.

COLLABORATION/TECHNOLOGY TRANSFER

Technology transfer has occurred between the Sandia National Laboratory, the Pantex Plant, and the Allied Signal Kansas City Plant. This has benefitted the WeDID program by collaborating among the facilities and integrating the program elements/technologies into a systems approach to maximize program coordination. Further, the forge hammer interlock and dust control systems are likely to be able to be patented as process patents. This would allow transferring of the technology to private industry through CRADAs.

For further information, please contact:

W. Ted Wheelis
Principal Investigator
Sandia National Laboratory
(505) 845-9298

George C. Allen
Technical Program Manager
Sandia National Laboratory
(505) 844-9769

3.9 HAZARDOUS SEPARATION SYSTEM

TASK DESCRIPTION

It is advantageous to separate waste streams as early as possible in a process to minimize the amount of a particular material (i.e., waste minimization) for subsequent processing and to keep one material from contaminating other recovery or processing steps. Standard cutting procedures, like bandsaws or shears, when used on nuclear weapon components, are generally difficult to use, are slow, and are not very accurate (i.e., wide cutting margins are required to account for errors or failures of the cutting devices), and, therefore, do not minimize waste. To overcome these disadvantages, WeDID is demonstrating the use of water-jet cutting techniques. Specifically, water-jet cutting can cut through thick, heterogeneous materials quickly, does not appreciably heat up the material being cut (important for potting that may evolve carcinogens when heat up), is essentially vibration free, and can cut intricate patterns within thousandths of an inch of a target material. In addition, because the cutting medium is water and garnet (i.e., sand), cleanup is straightforward (i.e., mechanical filtration). This technology has been demonstrated in the WeDID program for the removal of thermal batteries from potted components and for the demilitarization of a parachute (see Figure 3.9).

For example, it took just a few minutes to remove the thermal batteries and to cut through a 12-inch diameter section of nylon/Kevlar parachute. Water-jet cutting lends itself to small, enclosed systems that recycle the water used for cutting and could be used for explosive or radioactive materials removal where containment boundaries are needed. The water-jet system will be combined with an x-ray system to ensure the location of hazards to be removed is accurately known (critical information since potting can cause items to shift positions in nuclear weapon components). Eventually, a full-scale weapon component hazard separation system (including water-jet, x-ray, visual, and control systems) will be demonstrated.

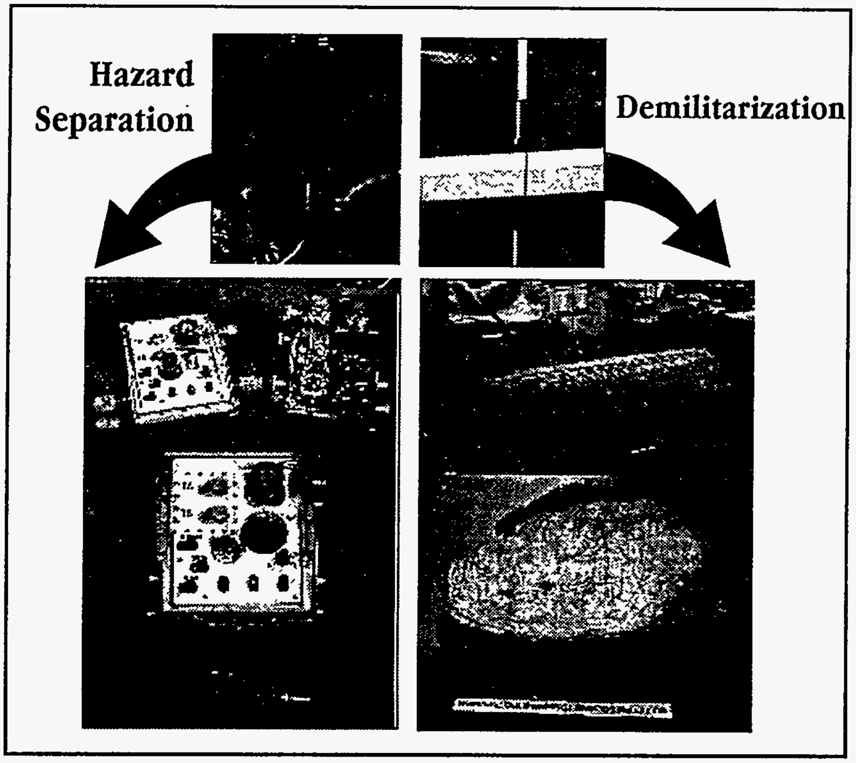

Figure 3.9. Demilitarization.

TECHNOLOGY NEEDS

Nuclear weapon components cannot legally be disposed of in conventional landfills without pretreatment or extensive characterization because they contain leachable toxic substances, like lead and cadmium. Weapons components also routinely contain radioactive, explosive, and toxic materials that are not easily separated or characterized. In addition, regulations are becoming increasingly stringent in terms of disposal options, necessitating environmentally sound practices. Technologically robust treatment systems can save DOE both money and time in the treatment and disposal of nuclear weapons components or electronic materials.

ACCOMPLISHMENTS

- Procured water-jet cutting system, X-ray system, and control hardware.
- Demonstrated hazard separation by water-jet cutting system removal of thermal battery from pre-flight control unit.
- Provided parachute demilitarization/disposal guidance to Pantex Plant.
- Demonstrated parachute water-jet cutting demilitarization.
- Demonstrated water-jet cutting technique for kevlar recycling and identified commercial recycler for kevlar.
- Identified recycle industry drivers of separation, aluminum, and organics.
- Identified precious metals recovery options in weapon components.
- Demonstrated the feasibility of using digitized X-rays to drive a water-jet cutting system for removal of hidden hazards, like radioactive gap tubes.
- Developed test plans for hazard separation system.

COLLABORATION/TECHNOLOGY TRANSFER

Collaboration and technology transfer has occurred between the Sandia National Laboratory, the Pantex Plant, and the Allied Signal Kansas City Plant. This has benefitted the WeDID program by collaborating among the facilities and integrating the program elements/
technologies into a systems approach to maximize program coordination. Further, the water-jet cutting system is likely to be able to be patented as a process patent. This would allow transferring of the technology to private industry through CRADAs.

For further information, please contact:

W. Ted Wheelis
Principal Investigator
Sandia National Laboratory
(505) 845-9298

George C. Allen
Technical Program Manager
Sandia National Laboratory
(505) 844-9769

3.10 ADVANCED TREATMENT TECHNOLOGIES

TASK DESCRIPTION

Plasma arc is one of the advanced treatment technologies in the WeDID. It demonstrates the destruction of organic materials and recycling of the metals (precious and bulk) found in the weapons (see Figure 3.10a). Plasma arc operates at extremely high temperatures and is able to destroy any hazardous organic material. A natural product of a plasma arc system is a metal ingot. The ingot is typically made up of a high concentration of copper which collects precious metals like gold, silver, and palladium. Another product of the process is a glassified "slag" which in turn collects undesirable metals, such as cadmium and arsenic, and other materials, like asbestos.

Steam reforming is an advanced treatment technology that demonstrates destruction of organic materials found in weapons by using a steam reforming unit (see Figure 3.10b). After organic destruction, the residues, typically metals and ceramics, can be further recycled using separation techniques to increase the value of the recyclable material. This method is principally being used for organics destruction; therefore, other items, such as classified foams, will also be examined as another use for the process.

Mining separation technologies are advanced treatments using commercial mining techniques demonstrating the selective removal of material from weapon components to maximize the recyclable/sellable potential of the metals. In this process, the weapon component material is partitioned into fractions of aluminum, ferromagnetic, precious metal bearing and organic combinations, and predominantly organic fines. This method is concentrating on

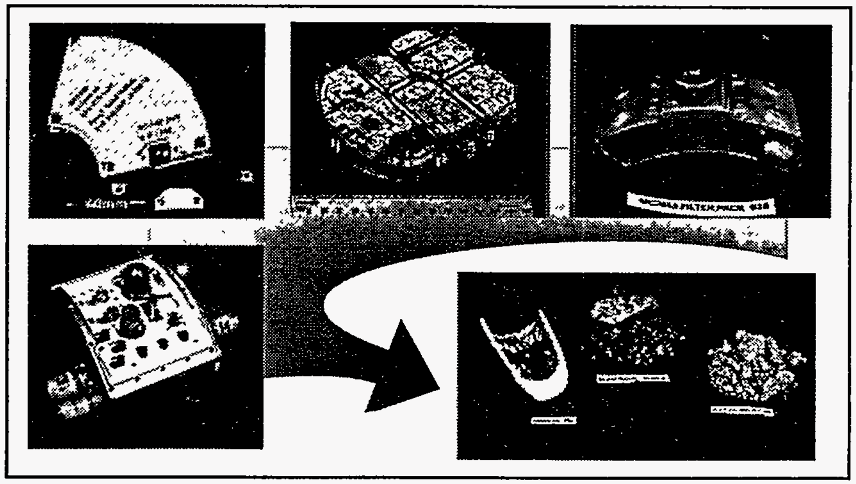

Figure 3.10a. Electronic components before and after thermal treatment processes.

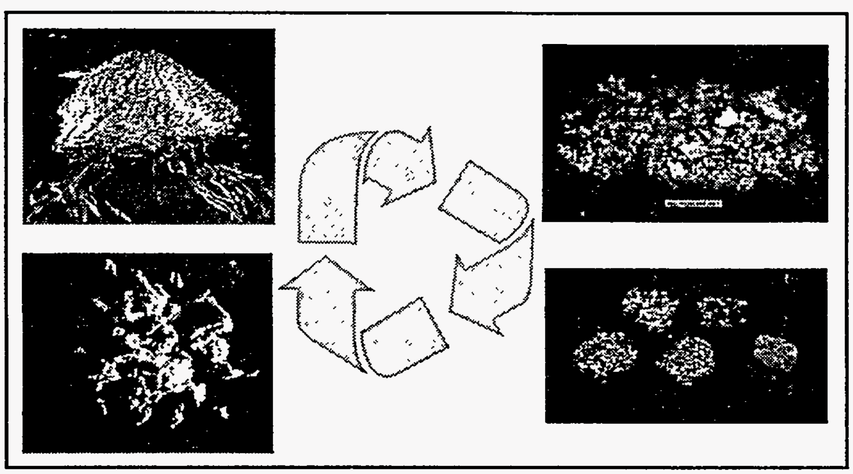

Figure 3.10b. Recycling potential of weapon.

showing separation of the valuable fractions of a weapon component, as well as providing actual data on the assayed economic value of the precious metals recovered.

Molten metals is an advanced treatment technology that is demonstrating destruction of organics for recovery of precious and bulk metals. Molten metals operates on the principle of a molten bath of a metal such as iron, although it can be customized to include copper or aluminum. Material for treatment is injected through the molten bath to ensure good mixing as well as optimum heat transfer. Metal found in weapon components goes into the metal bath and can be drained off into ingot form for further processing or recycling. Molten metals is also being evaluated as to its capability to treat explosives found in weapons.

Chemical depotting is an advanced treatment technology being used to declassify protected volume parts and classified electronic weapon components containing recyclable metals and either radioactive gap tubes or other types of hazardous components. The process dissolves or attacks a wide range of organic adhesives, sealants, coatings and potting compounds (encapsulants), is non-corrosive and biodegradable. The process is being used at the Kansas City Plant to facilitate removal of radioactive gap tubes from units which presently would constitute mixed waste.

TECHNOLOGY NEEDS

Approximately 2,000 weapons per year will be decommissioned, requiring treatment of approximately 230 cubic meters of weapons components and associated declassifications per year. Chemical characterization of weapon components is prohibitively expensive. With the increasingly stringent regulatory environment, there is a need for treatment technology systems that can meet all regulatory requirements now and in the future. Technologically robust treatment systems can save DOE both money and time in the treatment and disposal of nuclear weapons components or electronic materials.

ACCOMPLISHMENTS

- Completed printed circuit board treatment technology demonstrations using acid digestion, steam reforming, vitrification, and plasma arc.
- Demonstrated treatment of four weapons components (fire set, radar, filter pack, and pre-flight control unit) by steam reforming.
- Established independent treatment technology support group from industry and academic personnel.
- Demonstrated steam reforming destruction of kevlar/nylon parachute.
- Completed bench-scale demonstration of approximately 5 pounds of weapon components at Molten Metals Technology.
- Developed test plans for the advanced treatment technologies.
- Completed demonstration of plasma arc on thermal battery containing asbestos.
- Developed cost effectiveness methodology for treatment technologies.
- Completed draft regulatory framework document.

- Completed analysis of current disposal methods versus vitrification over a ten year life cycle.

- Demonstrated destruction by steam reforming of surrogate classified foam.

- Developed test plans for advanced treatment technologies.

COLLABORATION/TECHNOLOGY TRANSFER

Collaboration and technology transfer has occurred between the Sandia National Laboratory, the Pantex Plant, and the Allied Signal at the Kansas City Plant. This has benefitted parachute demilitarization at Pantex, and demonstration destruction of classified waste surrogate using steam reforming for Kansas City Plant. Steam reforming is being demonstrated by Synthetica Technologies, Inc., a commercial firm in San Francisco. Molten metals activities are being conducted by Molten Metal Technology in Massachusetts. Plasma Arc is being demonstrated by Mason & Hanger PEAT in Huntsville, Alabama. Mining technology is being conducted by the U.S. Bureau of Mines.

For further information, please contact:

Dale M. Blankenship
Principal Investigator
Sandia National Laboratory
(505) 844-9694

James D. Lutz
Principal Investigator
Sandia National Laboratory
(505) 844-9082

Innovation Investment Area Overview

Section 4.0

4.0 INNOVATION INVESTMENT AREA OVERVIEW

The mission of OTD's Innovation Investment Area 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 (PRDA), Research Opportunity Announcements (ROA), CRADAs, Financial Assistance Awards (Grants), Interagency Agreements (IAG), and DOE National Laboratory Technical Task Plans (TTPs). Activities procured through these contracting devices can be promptly moved to other RDDT&E programs that identified the need for research and development, or to the private sector for commercialization.

4.1 LASER SPARK SPECTROSCOPY FOR CONTINUOUS METAL EMISSIONS MONITORING

TASK DESCRIPTION

The objective of this task is to develop an instrument, using Laser Spark Emission Spectroscopy (LASS) as a continuous monitor, to measure metal emissions from offgas of thermal treatment units (see Figure 4.1).

LASS is a commercially available in-situ optical diagnostic technique, developed to investigate in real-time the chemical properties of deposits formed on the surfaces of materials exposed to combustion processes and gas cleanup flows.

In LASS, a high-energy pulsed laser is used to vaporize a particle or a portion of a solid deposit to produce a plasma or laser spark that contains excited-state ions. As the plasma cools, the excited state species relax and emit optical energy as frequencies that are characteristic of the emitting elements. Specifically resolved measurements of the emissions can then be used to identify and quantify the elements present.

To accomplish this, a two-phase approach will be implemented. Phase I will encompass laboratory development of the technique (proof-of-principle experimentation), while phase II will include fabrication and demonstration of a prototype field instrument.

TECHNOLOGY NEEDS

There are many industrial situations, such as monitoring gaseous effluents, perimeter monitoring, and stack gas analysis, where it is important to be able to identify and analyze small amounts of impurities. The primary difficulty of incineration and other thermal treatment technologies centers around operation without a means to assure continuous compliance. The EPA has singled out metal emissions as a priority development area in waste incineration. The metals covered under the new Clean Air Act are highly toxic even in small amounts, and represent the most serious health risk of any emissions from a thermal treatment unit.

Present modes of monitoring metal emissions, i.e. sample extraction and laboratory analysis, are cumbersome, expensive, and sub-

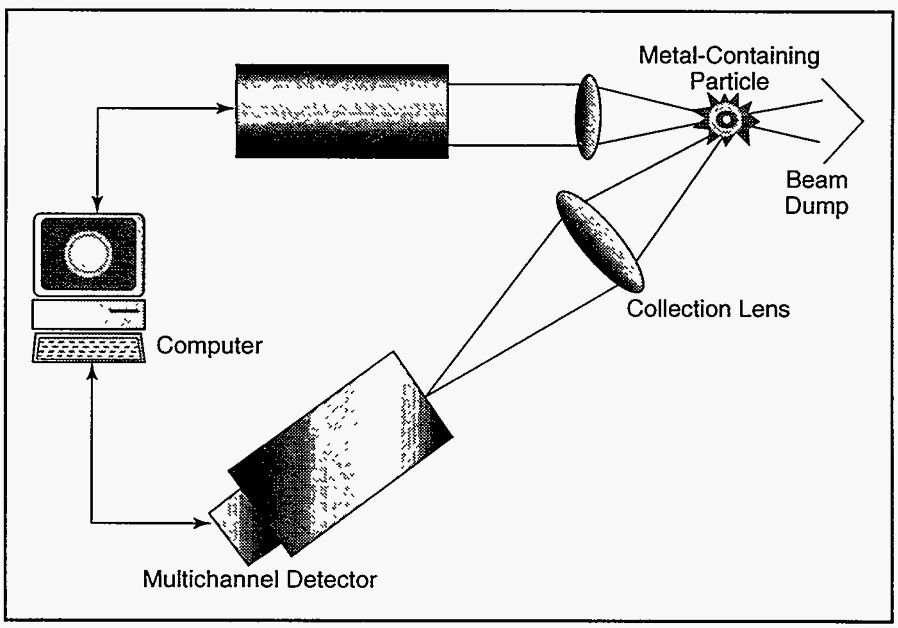

Figure 4.1. Schematic of the Laser Spark Technique measuring atomic species.

ject to human error. In addition, current monitoring methods are not real-time - often it takes three to four weeks between the time of sampling and the laboratory results. Innovative technologies are needed to ease siting, permitting and operations constraints of thermal heatwork units. LASS might be able to fill that need.

ACCOMPLISHMENTS

- Evaluated the detectability of 11 Clean Air Act metals and initiated quantitative measurements of metal emissions typical of those found in the field.

- Installed and began evaluation of chemometric software to determine contributions of individual atomic species to complex emission spectra.

- Discussed possible field demonstrations with INEL and the Mixed Waste Integrated program. Associated discussions focused on defining "typical" effluents of interest for laboratory simulation.

COLLABORATION/TECHNOLOGY TRANSFER

This project was contracted to SNL at Livermore to demonstrate the feasibility of using LASS as a continuing monitoring device for metal emissions.

Discussions were held between SNL and Perkin-Elmer to collaborate on experiments that will be used to asses data analysis procedures. An agreement was reached with the industrial partner, ADA Technologies, on roles and responsibilities. ADA will be responsible for designing and fabricating extraction hardware and a sample calibration device.

For further information, please contact:

Bill Flower
Principal Investigator
Sandia National Laboratories
Org. 811
Livermore, CA 94551
(510) 294-2046

Dennis Berry
Technical Manager
Sandia National Laboratory
Org 8113
Livermore, CA 94551
(510) 844-6101

Isiah Sewell
Program Manager, IIA
U.S. Department of Energy
Office of Technology Development
(301) 903-8459

Robotics Technology Development Program Overview

Section 5.0

5.0 ROBOTICS TECHNOLOGY DEVELOPMENT PROGRAM OVERVIEW

The Robotics Technology Development Program is a "needs-driven" effort. A lengthy series of presentations and discussions at DOE sites considered critical to the DOE's EM 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 (Cross Cutting) to each of these robotics application areas, e.g., computer control and sensor interface protocols. Further, the OTD approach to the RDDT&E process urged an additional organizational breakout between short-term (1-3 years) and long-term (3-5 years) efforts (Advanced Technology). The RDTP is thus 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 EM 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 EM 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 EM. 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 Headquarters 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 management 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 Contaminant Analysis Automation (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 loading. 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 LLW and TRU mixed wastes. The Team, led by the Savannah River Technology Center, 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 the Savannah River Technology Center, 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 modeling/simulation. Coupling of sensor-based modelling with automated programming of robot operations is a key approach to developing faster, safer, and less expensive waste cleanup systems.

FY94 Activities Funded Through the Albuquerque Operations Office

Section 6.0

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

VOC IN NON-ARID SOILS ID

AL121109	COLD PLASMA DESTRUCTION OF SR OFF-GAS VOCS
AL201101	GROUNDWATER FLOW SENSOR/SEISMIC IMAGING

VOC IN ARID SOILS ID

AL141002	ARID BAROMETRIC FLUCTUATION-SOIL MICROSCALE
AL231005	ARID SONIC DRILLING

MIXED WASTE LANDFILL ID

AL121211	MIGRATION BARRIER COVERS FOR MIXED WASTE
AL131001	PROTOTYPE DECISION SUPPORT/COVER SYSTEM
AL141001	POST CLOSURE MONITORING TECHNOLOGY
AL221107	LANDFILL CHARACTERIZATION SYSTEM
AL221110	TECHNOLOGY INTEGRATION FOR THE MWLID
AL221112	MIXED WASTE LANDFILL INTEGRATED DEMONSTRATION - PROGRAM DIRECTION AND SUPPORT
AL221114	ADVANCED IN-SITU MOISTURE LOGGING SYSTEM
AL221115	SEAMIST APPLICATIONS FOR HEAVY METAL
AL221116	HYBRID DIRECTIONAL BORING AND HORIZONTAL LOGGING
AL221120	REMEDIAL OPTIONS EVALUATION
AL221121	THERMAL ENHANCED VAPOR EXTRACTION SYSTEM
AL221123	CROSS BOREHOLE EM IMAGING
AL221206	FIELD SCREENING LABORATORY SYSTEM
AL231002	DRY BARRIER APPLICATIONS FOR LANDFILLS
AL231003	MAGNETOMETER TOWED ARRAY
AL231004	SUBSURFACE BARRIER EMPLACEMENT DEVELOPMENT
AL231006	MW LANDFILL ID/QA AND ES&H COMPLIANCE
AL241001	ELECTROKINETICS DEMONSTRATION
AL241003	ADVANCED LANDFILL COVER DEMONSTRATION
AL241004	ENVIRONMENTAL DECISION SUPPORT SYSTEM
AL241007	MEASUREMENT WHILE DRILLING

URANIUM IN SOILS ID

AL121121	SELECTIVE EXTRACTION/LEACHING
AL231007	COST/RISK PERFORMANCE ASSESSMENT OF CHARACTERIZATION TECHNOLOGIES

CHARACTERIZATION, MONITORING & SENSOR TECHNOLOGY

AL031001	MULTI-SPECTRAL NEUTRON LOGGING
AL131004	MULTI-SPECTRAL NEUTRON LOGGING
AL131006	CHLORINATED AND AROMATIC HYDROCARBON THIN FILM SENSORS
AL131007	AIR QUALITY BOUNDARY MONITORING FOR VOLATILE ORGANIC COMPOUNDS
AL141004	TECHNICAL SUPPORT
AL141005	RAMAN PROBE RADIATION STUDY
AL141006	IN SITU RCRA METALS ANALYSIS
AL141007	AIR QUALITY MONITORING FOR ALPHA CONTAMINATION
AL141008	TECHNICAL SUPPORT
AL221104	PORTABLE ACOUSTIC WAVE SENSOR
AL241002	CROSSWELL COMPRESSIONAL/SHEARWAVE SEISMIC TOMOGRAPHY
AL241009	MINATURIZED CHEMICAL FLOW PROBE SENSOR DEVELOPMENT
AL241010	CONE PENETROMETER CHARACTERIZATION
AL241011	APPLICATION OF SYNTHETIC APERTURE RADAR (SAR)
AL931001	MULTI-SPECTRAL NEUTRON LOGGING
AL932003	GEOPHYSICAL TEST PIT AT RABBIT VALLEY
AL941001	3D/3C SEISMIC

IN-SITU REMEDIATION TECHNOLOGY DEVELOPMENT IP

AL141003	GEL BARRIERS
AL231008	EVALUATE TWO NEW FLOWABLE GROUT TECHNOLOGIES FOR IN SITU BARRIER CONSTRUCTION
AL231009	ELECTROKINETIC REMEDIATION OF HEAVY METAL CONTAMINATION IN UNSATURATED SOIL
AL931002	CHEMICAL BARRIERS FEASIBILITY AND FIELD DEMONSTRATION

OTHER TECHNOLOGIES - GROUNDWATER & SOILS CLEANUP

AL124103	MAGNETIC SEPARATION CRADA

INTERNATIONAL TECHNOLOGY EXCHANGE

AL223301	IDENTIFICATION OF FOREIGN TECHNOLOGY
AL223302	ENVIROTRADE INFORMATION SYSTEM
AL234302	RUSSIAN SEPARATIONS PROGRAM

LIAISON AMD COMMUNICATIONS

AL048501	TRAINING AND POLICY STUDIES

PROGRAM DIRECTION

AL026001	PROGRAM DIRECTION - SALARIES AND OTHER EXPENSES
AL026002	SUPPORT SERVICES

PROGRAM SUPPORT

AL125002	TPM SUPPORT
AL225001	TPM SUPPORT
AL245001	TECHNICAL SUPPORT
AL425001	TPM SUPPORT
AL925001	TPM SUPPORT

RDDT&E SUPPORT AND NEW INITIATIVES

AL043501	SAN ILDEFONSO
AL101201	COST SAVINGS ANALYSIS
AL243501	TECHNICAL SUPPORT
AL333501	MONITORING AND CONTROL OF METAL EMISSIONS/DOE HMWTTU
AL722001	BIODEGRADATION OF LIQUID SCINTILLATION COCKTAIL/BTX

ROBOTICS

AL113204	ROBOTICS CONTAMINANT ANALYSIS AUTOMATION (LANL)
AL138201	ROBOTICS CROSSCUTTING AND ADVANCED TECHNOLOGY
AL143502	ROBOTICS CONTAMINANT ANALYSIS AUTOMATION (LANL)
AL213204	TECHNOLOGY DEVELOPMENT PROGRAM ROLLUP (SNLA)

TECHNOLOGY INTEGRATION

AL134102	TECHNOLOGY INTEGRATION/TECH TRANSFER SUPPORT
AL214103	TECHNOLOGY INFUSION FOR ID PROGRAM
AL344101	CALIFORNIA ENVIRONMENTAL ENTERPRISE

DOE/AIR FORCE MOA

AL243001	POLLUTION PREVENTION ACTIVITIES AT SNL
AL443001	CONTAMINANT REMOVAL FROM SOLID WASTE/SSC02

BURIED WASTE ID

AL132012	IMPROVED TRU WASTE ASSAY - CTEN
AL142002	SECONDARY TREATMENT OF BWID OFF GASES
AL911201	BWID NON-INTRUSIVE SENSING

UNDERGROUND STORAGE TANKS ID

AL232001	LDUA-COMPUTER INTERFACE

EFFICIENT SEPARATIONS ID

AL121217	SOLID SEQUESTERING AGENTS/REMOVAL OF TRU
AL132010	FISSION PRODUCT CHEMISTRY
AL142001	VACUUM DISTILLATION SEPARATION OF PLUTONIUM WASTE STREAMS
AL232004	WASTE SEPARATION & PRETREATMENT USING TITANATE ION EXCHANGE
AL932002	COBALT DICARBOLLIDE SUPPORT

HAZARDOUS & MIXED WASTE DESTRUCTION IP

AL121219	COST/BENEFIT ANALYSIS
AL142003	DEVELOPMENT OF A REAL-TIME MONITOR FOR ALPHA
AL221207	OFF GAS TECHNOLOGY SPECIFICATION
AL242001	STEAM REFORMING MIXED WASTE
AL342002	CONTROL & RECOVERY OF VAPOR PHASE MERCURY USING GOLD-PLATED SURFACES
AL342003	CONTINUOUS MONITOR TUNABLE DIODE LASER FOR NITRITES
AL342004	CONTINUOUS MONITOR FOR MERCURY IN GASES AND ON SOLIDS

ROCKY FLATS FFCA COMPLIANCE

AL121215	SUPPORT FOR ROCKY FLATS, NMWP

OTHER TECHNOLOGIES - WASTE RETRIEVAL

AL101202	COST SAVINGS ANALYSIS
AL132007	FFCA OF 1992 REPORT
AL232005	USE OF DU IN STORAGE/DISPOSAL CASKS

SUPERCRITICAL WATER OXIDATION

AL342001	DESIGN MODELS FOR SCWO CORROSION STUDIES
AL342005	JOINT DOE/ARMY SCWO BENCH SCALE PLATELET REACTOR DEMONSTRATION

How To Get Involved

Section 7.0

7.0 HOW TO GET INVOLVED

WORKING WITH THE DOE OFFICE OF ENVIRONMENTAL 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 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 Development Agreements

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

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

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

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

Licensing of Technology

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

Technical Personnel Exchange Assignments

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

Consulting Arrangements

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

Reimbursable Work for Industry

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

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

EM Small Business Technology Integration Program

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

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

CONTACT

David W. Geiser, Acting Director
International Technology Exchange Division
EM-523
Environmental Restoration and Waste
Management Technology Development
U.S. Department of Energy
Washington, D.C. 20585
(301) 903-7940

EM Central Point of Contact

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

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

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

Office of Research and Technology Applications

Office of Research and Technology Applications 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:

Claire Sink, Director
Technology Integration Division
EM-521
Environmental Restoration and Waste
Management Technology Development
U.S. Department of Energy
Washington, D.C. 20585
(301) 903-7928

Acronyms

Section 8.0

8.0 ACRONYMS

AFB	Air Force Base
AQMs	air quality monitors
BBEM	Broad Band Electromagnetics Demonstration
CAM	continuous air monitor
CBSAM	covalently-bound self-assembled monolayer
CFC	chloroflurocarbons
CHC	chlorohydrocarbons
CMAS	micromist air sampler
CMST-IP	Characterization, Monitoring and Sensors Technology Integrated Program
CPAC	Center for Process Analytical Chemistry
CRADA	Cooperative Research and Development Announcements
CRC	Coleman Research Company
CSM	Colorado School of Mines
CST	Crystalline silicotitnates
CWL	Chemical Waste Landfill
D&D	decontamination and decommissioning
DE	destruction efficiencies
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DSS	decision-making software system
ECM	environmentally conscious manufacturing
EM	Office of Environmental Management
EPA	U.S. Environmental Protection Agency
FIU	Florida International University
FTIR-AIR	Fourier-transform infrared attenuated total reflection
GAC	grandular activated carbon
GC/ITD	gas chromatograph ion trap mass spectrometer
GCMS	gas chromatograph/mass spectrometer
GJPO	Grand Junction Operations Office
GPER	geophysics performance evaluation range
GPR	ground-penetrating radar
GPS	Geographic Positioning System
HEIS	Hanford Environmental Information System
HTO	hydrous titanium oxide
INEL	Idaho National Engineering Laboratory
ISSECS	Integrated Spectroscopic System for Environmental Contaminant Speciation
ISV	in situ vitrification

KBS	knowledge-based system
KCP	Kansas City Plant
LAFS	laser ablation fluxless soldering
LANL	Los Alamos National Laboratory
LASS	laser spark emission spectroscopy
LCMS	Landfill Characterization and Monitoring System
LCS	Landfill Characterization System
LIBS	laser-induced breakdown spectroscopy
LIXs	liquid ion exchangers
LLNL	Lawrence Livermore National Laboratory
LRAD	Long-Reach Alpha Detector
LVFTDS	Large-Volume Flow Through Detection Systems
ME	multi-element
MWIP	Mixed Waste Integrated Program
MWLID	Mixed Waste Landfill Integrated Demonstration
ORNL	Oak Ridge National Laboratory
OTD	Office of Technology Development
PAWS	Portable Acoustic Wave Sensor
PBR	packed bed reactor
PNL	Pacific Northwest Laboratory
PUREX	Plutonium Uranium Extraction Process
PVAI-ATR-IR	polarized variable-angle internal attenuated total reflection infrared
PVC	polyvinylchloride
RCRA	Resource Conservation and Recovery Act
RCS	Remote Characterization System
RDDT&E	Research, Development, Demonstration, Testing, and Evaluation
RES	Remote Excavation System
RF	radiofrequency
RFP	Rocky Flats Plant
SAWS	surface acoustic wave sensor
SDP	silent discharge plasma
SEAMIST™	Science and Engineering Associates Membrane Instrumentation and Sampling Technique
SEE	Small Emplacement Excavator
SNL	Sandia National Laboratory
SP	spontaneous potential
SRS	Savannah River Site
STOLS™	Surface Towed Ordnance Locator System
SVE	soil vapor extraction
TCE	tricholorthylene
TDEM	time domain electromagnetic
TDL	tunable diode laser
TDR	time domain reflectometry

3D/3C	three-dimensional/three-component
TMG	Tensor Magnetic Gradiometer
TMS	tool made sample
TRU	transuranic (waste)
UNCAP	Unlined Chromic Acid Pit
USGS	U.S. Geological Survey
VOCs	volatile organic compounds
WDC	Water Development Corporation
WeDID	Waste Component Recycle, Treatment, and Disposal Integrated Demonstration
WHC	Westinghouse Hanford Company
XRF	X-ray fluorescence