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Buried Waste Integrated Demonstration

Technology Summary

MASTER

March 1994

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BURIED WASTE INTEGRATED DEMONSTRATION (BWID)

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OFFICE OF TECHNOLOGY DEVELOPMENT OVERVIEW

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

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

Figure A. DOE Organizational Structure as of June 1993.

In an effort to focus resources and address opportunities, EM-50 has developed **Integrated Programs (IP)** and **Integrated Demonstrations (ID)**.

An *Integrated Program* focuses on technologies to solve a specific aspect of a waste management or environmental problem and it can be either unique to a site or common to many sites. An Integrated Program supports applied research to develop innovative technologies in key application areas organized around specific activities required in each stage of the remediation process (e.g., characterization, treatment, and disposal).

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

The Buried Waste Integrated Demonstration (the subject of this report) is part of EM-552, Waste Management.

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

BURIED WASTE INTEGRATED DEMONSTRATION OVERVIEW

The Buried Waste Integrated Demonstration (BWID) supports the applied research, development, demonstration, and evaluation of a suite of advanced technologies that offer promising solutions to the problems associated with the remediation of buried waste. BWID addresses the difficult remediation problems associated with DOE complex-wide buried waste, particularly transuranic (TRU) contaminated buried waste. BWID has implemented a systems approach to the development and demonstration of technologies that will characterize, retrieve, treat, and dispose of DOE buried wastes. This approach encompasses the entire remediation process from characterization to post-monitoring. The development and demonstration of the technology is predicated on how a technology fits into the total remediation process. To address all of these technological issues, BWID has enlisted scientific expertise of individuals and groups from within the DOE Complex, as well as experts from universities and private industry.

The BWID mission is to support development and demonstration of a suite of technologies that, when integrated with commercially-available technologies, forms a comprehensive, remediation system for the effective and efficient remediation of buried waste throughout the DOE Complex. BWID will evaluate and validate demonstrated technologies and transfer this information and equipment to private industry to support the Office of Environmental Restoration (ER), Office of Waste Management (WM), and Office of Facility Transition (FT) remediation planning and implementation activities.

To test and evaluate technologies considered for remediating buried waste sites, a simulated cold test pit was created by the Idaho National Engineering Laboratory (INEL) in 1988. It consisted of five cells with various simulated waste configurations. Three test cells were added in 1992 to encompass other waste location configurations. See Appendix A for a description of the Cold Test Pit.

BWID subscribes to the clarion call that "Implementation is Success." Therefore, the BWID's success will be determined by its ability to address the needs of the ER, WM, and FT and provide technologies and technology systems in time for inclusion into the record of decision (ROD) process and other required remediation activities. BWID works closely with private industry and universities to ensure the commercialization of developing technologies, while working with stakeholders and regulators to ensure the acceptability of developing technologies.

THE PROBLEM

The amount of buried waste located throughout the DOE Complex as of 1990 is estimated at approximately 3.1 million cubic meters. The DOE sites where this waste is predominantly located are:

- the Hanford Site, in Richland, Washington;
- the Savannah River Site (SRS), near Aiken, South Carolina;

- the Idaho National Engineering Laboratory (INEL), near Idaho Falls, Idaho;
- the Los Alamos National Laboratory (LANL), in Albuquerque, New Mexico;
- the Oak Ridge National Laboratory (ORNL), in Oak Ridge Tennessee, and
- the Rocky Flats Plant (RFP), near Denver, Colorado.

The wastes at these various sites have been buried or stored in several types of structures, including trenches, pits, buildings, and storage pads.

Approximately half of all DOE buried waste was disposed of before 1970 in accordance with the regulations of that time. Disposal regulations at that time permitted the commingling of various types of waste (TRU, low-level radioactive (LLW), and hazardous). As a result, much of the buried waste throughout the DOE Complex is presently believed to

be contaminated with both hazardous and radioactive materials. DOE buried waste typically includes TRU-contaminated radioactive waste, LLW, hazardous waste per 40 CFR 261, greater-than-class-C (GTCC) waste per 10 CFR 61.55, mixed TRU waste, and mixed LLW. Interstitial soils are also believed to be contaminated as a result of these disposal practices, which significantly increases the volume of materials requiring remediation.

Typical buried waste includes construction and demolition materials (lumber, concrete blocks, steel plates, etc.), laboratory equipment (hoods, desks, tubing, glassware, gloves, etc.), process equipment (heat exchanger, valves, ion exchange resins, high efficiency particulate air filters, etc.), maintenance equipment (hand tools, cranes, oils and greases, etc.), and decontamination materials (paper, rags, gloves, plastic bags).

The waste and site characteristics of the INEL Radioactive Waste Management Complex (RWMC) are generally representative of other

DOE buried waste sites; therefore, remediation technology demonstrations performed at INEL should be transferable for potential applications at other DOE buried waste sites. Approximately 0.3 million cubic meters of waste is buried at the INEL RWMC. A variety of containers were used for the disposal of buried waste. Typical containers used for waste shipment such as those used at INEL included steel drums (30-, 40-, and 55-gallon),

Figure C. Buried Waste Integrated Demonstration Implementation Schedule.

cardboard cartons, and wooden boxes (up to 105 X 105 X 214 in.). Larger individual items were disposed of separately as loose trash. Degradation of the waste containers is believed to have resulted in contamination of the immediately surrounding soil. Estimates of contaminated soils at INEL are on the order of 0.9 million cubic meters.

In the past, incomplete records were kept, and as a result, the exact nature of the contamination is uncertain. Through the years, some of the waste-containing drums and boxes have leaked and the contents have mixed, creating another kind of problem. Some have potentially spread and migrated to the groundwater.

Figure D. Random disposal of drums at the Idaho National Engineering Laboratory in 1969.

Figure E. Early trench burial practices at Oak Ridge National Laboratory.

These waste disposal sites must be remediated or cleaned up within the constraints of the existing and evolving statutory and regulatory requirements. These requirements include the Federal Facility Agreement and Consent Order (FFA/CO), as well as other interagency agreements with legally binding milestones.

THE NEEDS

DOE buried wastes present significant remediation challenges, particularly the waste buried prior to 1970. DOE is committed to resolving the issues and problems resulting from past disposal practices. The Office of Technology Development supports these efforts to ensure that appropriate technological solution options are available to accomplish remediation objectives. The following paragraphs describe BWID's objectives in its effort to fulfill the technological needs in the broad categories of Site Characterization, Retrieval, Waste Assay/Characterization, and Treatment.

A detailed systems study was initiated during 1992 and is on-going. EM assisted in the development of the system approach, which has resulted in the identification of high-level systems for the remediation of buried waste (see Appendix B).

BWID is exploring four high-level systems for the remediation of buried waste: the characterization/retrieve/ex-situ treat system, characterization/in situ treat/retrieve system, characterization/in situ treat/monitor system, and characterization/contain/stabilize/monitor system. Each technology process is integrated with and dependent upon its surrounding processes. These processes must perform to their expected levels for the overall system to be successful in achieving its remediation objectives (see Figure F).

The characterization/retrieval/ex situ treatment system involves exhuming and subsequently treating the retrieved waste. Characterization is required to define waste boundaries, increase safety in the exhumation process, and provide the necessary information for the treatment process. Retrieved waste and soil need to be packaged and transported to a treatment facility.

Waste streams will eventually need to be treated. To date, the Program's emphasis has been high-temperature thermal treatments, but

other treatment techniques are also being investigated. Pretreatment, such as size reduction and metal sorting, may also be required. Final waste forms will be assayed to determine their compliance with disposal requirements. Packaging and ultimate disposal complete this system option.

The primary objective of the characterization/*in situ* treatment/retrieval system is to use *in situ* treatment processes to minimize the potential spread of contamination before and during buried waste retrieval. The combination of *in situ* treatment and subsequent retrieval provides the potential for significantly reducing contamination spread versus the retrieval of untreated waste.

The objective of the characterization/*in situ* treatment/monitoring system is to treat, *in situ*, radiological and/or hazardous buried waste so that the subsequent waste form can be left in place. The performance characteristics of the treated waste must provide for the destruction of hazardous waste and immobilization of radiological waste constituents in

both waste and interstitial soils. This treatment must represent a solution in which long-term hazardous and radiological releases to groundwater, surface soils, or air are eliminated. In addition to TRU and non-transuranic radionuclides, the system must include identification, treatment, and monitoring capabilities for hazardous organics and metals.

Figure F. Systems approach encompasses entire remediation process.

The objective of the characterization/contain/stabilize/monitor system is to emplace engineered barriers that retard and prevent radionuclide and hazardous substance migration from buried waste sources. Depending on the level of hazards, this option provides long-term or interim remediation measures and allows mitigation of the immediate hazard.

ACCOMPLISHMENTS

- BWID has demonstrated and evaluated a number of technologies in characterization, retrieval, contamination control, and treatment areas. In the characterization area, the manual Rapid Geophysical Surveyor (RGS) demonstrated its technical value by performing geophysical surveys 30-300 times faster than hand-held instrument surveys and for a cost of 25¢ versus \$5.00 per data point. Since the successful demonstration of the RGS, it has been used to address remediation problems at Los Alamos National Laboratory, Pits 9 and 7 at the Idaho National Engineering Laboratory, and at Camp Pendelton Marine Base.
- In the technology area of retrieval, the Cryogenic Retrieval method was investigated in 1992 as a way to control windblown contaminated dust during excavation and retrieval. In a full-scale, proof-of-principle demonstration, the test areas were frozen with liquid nitrogen through a series of pipes inserted into the Cold Test Pit soil. A gantry robot equipped with shears, grapple, jackhammer, hydraulic jack, and a video system broke up and removed chunks of frozen soil/waste from the test area with negligible dust dispersal. This technology has demonstrated, via retrieval of simulated waste, that cryogenic applications during the retrieval process can significantly reduce dust contamination.
- In the contamination control area, the Contamination Control Unit (CCU) is a trailer-mounted system developed to control dust generated during buried waste excavation and retrieval. The system can dispense dust control products, including chemical soil fixants and water mist, 100 feet from the trailer. The nuclear-grade vacuum system removes dust and soil debris from equipment, assisting in decontamination. This technology was successfully demonstrated in FY93 and proved to reduce dust generation significantly. The success of this technology is made more evident through its use by Environmental Restoration at the Idaho National Engineering Laboratory and Hanford to assist in remediation activities on contaminated sites.
- In the treatment area, the Ice Electrode project uses a novel approach to removing heavy metals from solutions. Bench-scale tests of this experimental technology showed that heavy metal contaminants in solution can be captured in an ice coating on a metal electrode, then recovered by allowing the ice to melt. Metals tested include copper, silver, zinc, cobalt, cadmium, lead, and chromium. Preliminary work with metals that do not electrodeposit on conventional electrodes, such as uranium and tungsten, suggests that oxides of such metals can be recovered with an ice electrode. With further development, this technology can be used in conjunction with chemical oxida-

tion technology, to destroy organics and remove various inorganic hazards and radioactive constituents.

- BWID has established a public participation policy with the goal of providing stakeholders with timely and accurate information and meaningful opportunities for involvement in the technology development and demonstration process. During 1993, presentations were made to civic, educational, and technical groups; displays and posters were viewed nationally; regular media contacts were established; and video teleconferences were held to enhance communication. A Technology Exhibition and Equipment Display was held on July 29-30, 1993, with presentations, poster sessions, site tours, and equipment displays available to participants.

The above examples represent a fraction of the many BWID accomplishments. The following pages outline the full range of technologies and BWID accomplishments to date in support of the four remediation systems being explored at INEL.

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Section 1.0

1.1

RAPID GEOPHYSICAL SURVEYOR

TASK DESCRIPTION

The objective of this project is to design, construct, and demonstrate a device to quickly and inexpensively characterize buried waste sites by collecting high quality, dense sets of magnetic data. The Rapid Geophysical Surveyor (RGS) is a hand-pushed, nonferrous vehicle that carries multiple cesium total field magnetometers, a data logger, and data storage hardware and software (see Figure 1.1). The unit can be easily adapted to accommodate different magnetic sensors. Magnetic data are collected automatically and stored at user-specified intervals as close as 2 inches apart as the unit is pushed along survey profile lines. The resulting database is very high resolution and can identify individual metallic objects, and object orientation, shape, and depth of burial.

The RGS can perform geophysical magnetic surveys quicker (30 - 300 times faster) and more economically (20 times cheaper per data point)

than hand-held instruments. The RGS can be easily and quickly deployed at any DOE or commercial facility where a high resolution magnetic survey is required.

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

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

Straightforward interpretation principles were applied to the magnetic data, which provided reliable detection of all the isolated ferrous objects in the Cold Test Pit Characterization Cell, a general depiction of the Retrieval Cell and an accurate definition of the overall waste pit. The RGS can collect spatially denser data sets than previously possible, thereby

Figure 1.1. Rapid Geophysical Surveyor at the INEL Cold Test Pit.

providing a much higher resolution picture of the buried waste site. The surveyor was developed for less than \$200,000.

**COLLABORATION/TECHNOLOGY
TRANSFER**

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

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1.2 RAPID TRANSURANIC MONITORING LABORATORY

TASK DESCRIPTION

The focus of this project is to develop a field deployable laboratory that can continuously monitor airborne TRU concentration and rapidly analyze soil, smear, and air filter samples for TRU isotopes and fission and activation products in a cost-effective manner. The Rapid Transuranic Monitoring Laboratory (RTML) is contained in two trailers (8 x 24 feet and 8 x 48 feet). The smaller trailer houses a sample preparation laboratory (see Figures 1.2a and 1.2) and the larger trailer contains:

- one terminal that controls and displays spectral data from four alpha continuous air monitors;
- two Ordela large-area ionization chamber alpha spectrometers;
- a thin-window gamma-ray spectrometer and automatic sample changer;

- a VAX 4000 Model 100 computer; and
- computer terminals and two printers used to display and generate reports of analysis results.

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

The RTML is appropriate for use at any TRU-contaminated waste site being excavated.

The RTML provides rapid on-site sample analysis at a lower cost per analysis than conventional methods. The main advantage is that samples can

be processed in under one hour for about \$30 per sample using a technician-driven system. This compares to fixed-laboratory results with radiochemists analyzing several samples per day at \$200-\$300 per sample.

Figure 1.2a. Rapid Transuranic Monitoring Laboratory.

TECHNOLOGY NEEDS

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

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

ACCOMPLISHMENTS

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

Figure 1.2b. Interior of Rapid Transuranic Monitoring Laboratory: Loose Surface Contamination Counting Area.

analyze any gamma or alpha emitting radionuclides with near radiochemistry LLD.

COLLABORATION/TECHNOLOGY TRANSFER

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

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1.3

REMOTE CHARACTERIZATION SYSTEM

TASK DESCRIPTION

This project demonstrates the feasibility of remote, high-precision characterization of buried waste by deploying and operating multiple geophysical sensors over a waste site. The Remote Characterization System (RCS) consists of a vehicle, multiple geophysical radiation and/or chemical sensors, on-board video cameras, data communication equipment, a Global Positioning System, and a control base station (see Figures 1.3a and 1.3b). The vehicle was designed and fabricated specifically for the RCS to minimize the amount of ferrous metal in the vehicle, which would interfere with the operation of the sensors.

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

Figure 1.3a. Remote Characterization System at the INEL Cold Test Pit.

The RCS allows simultaneous use of multiple sensors, thereby reducing remediation cost by rapidly characterizing waste sites. The RCS also improves safety by not requiring workers at hazardous waste sites to enter 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 facilities that have buried hazardous and/or radioactive waste.

TECHNOLOGY NEEDS

Current non-intrusive subsurface mapping techniques are labor intensive and time consuming.

Figure 1.3b. Remote Characterization System Control Station.

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

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1.4 MAGNETIC AND ELECTROMAGNETIC GEOPHYSICAL SURVEYING

TASK DESCRIPTION

This project is designed to demonstrate how efficiently airborne magnetic and electromagnetic devices can map buried waste sites and characterize subsurface waste objects. The airborne geophysical surveying system is a helicopter-mounted set of standard mineral exploration sensors including magnetic and electromagnetic sensor packages and ancillary electronic interrogation packages (see Figures 1.4a and 1.4b). The total magnetic field of the test areas is measured passively with a dual magnetic gradiometer system, which consists of two split-beam, optically pumped, cesium magnetometers and two optically pumped helium magnetometers. This allows the vertical and horizontal gradient of the total magnetic field to be computed.

The electromagnetic active method uses three horizontal coplanar coil pairs and two vertical coaxial pairs. The accuracy of the sensor platform positioning system is plus or minus 2 meters

Figure 1.4a. Helicopter-mounted standard mineral exploration sensors including magnetic and electromagnetic sensor packages.

when mapped against the actual location of an anomaly. Complete interpretation of the position tagged data will provide detailed information for characterizing buried materials and geologic information that can be used for hydrogeological modelling of the waste area. Data interpretation for each site is based on locating magnetic and electromagnetic anomalies, determining the amplitude of each anomaly above the total magnetic background reading, and correlating these anomalies with their most probable source.

Initial demonstration of these surveying techniques indicate that they can be used to provide the initial field screening of large DOE and industrial waste sites. Questionable areas can be quickly screened for possible burial sites. Thorough characterization of a site, however, will require combining land-based sensor technologies that obtain high resolution data.

TECHNOLOGY NEEDS

There are many sites where the documentation of the buried waste is not complete. There are questions about the accuracy of the data that does exist. The sites are very large, and there is a need to establish a method that more quickly screens these areas and identifies potential buried waste sites.

ACCOMPLISHMENTS

Airborne geophysical surveys were flown over the INEL's Naval Ordnance Disposal Area, the

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

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COLLABORATION/TECHNOLOGY TRANSFER

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

Figure 1.4b. Isometric display of INEL Cold Test Pit.

TASK DESCRIPTION

The objective of this project is to demonstrate an airborne infrared (IR) sensor method to detect and map ordnance and buried waste, and determine the feasibility of using automatic image processing algorithms to detect objects of interest (see Figure 1.5). Martin Marietta's helicopter-mounted imaging system, demonstrated in 1992, consisted of a gyro-stabilized IR detector of the mercury-cadmium-telluride type consisting of four elements with a spectral range of 8 to 12 μ m and with closed cycle cooling, control electronics, a time code generator for time tagging of sensor images, and a video system. A ground station included an advanced thermographic image processor with the ability to process images in real-time. Image processing algorithms used morphological filters, edge-based detection approaches, multiple feature computations, linear classifiers, and other algo-

rithms for object rejection, classification, and reporting. The data collected consisted of time tagged IR "photographs" with position information contained in "landmark" features. These "photographs" were enhanced using the advanced IR image processing algorithms.

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

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

Figure 1.5. Helicopter-mounted infrared sensor imaging system.

COLLABORATION/TECHNOLOGY TRANSFER

This work was done in collaboration with Martin Marietta.

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TASK DESCRIPTION

The objective of the Broad Band Electro-magnetics (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 1.6). The BBEM Demonstration device is an asymmetric two-coil induction system using a large 5-meter diameter transmitting loop to generate the equivalent of a three-decade frequency spectrum. When current flow is interrupted, a transient magnetic field may be briefly observed. This transient decay is analyzed to determine the magnitude of the induced field at systematic intervals. This information provides conductivity information at various delay intervals that may be equated to different penetration depths. The system may be used in either a traverse/profile configuration or as a vertical electric expander, or "sounding" device. For this reason it is easily adapted to use in describing three dimensional bodies

Conventional equipment and interpretation software provide demonstrated capability to characterize buried waste sites by obtaining a frequency spectrum (approximately 64 values) at a spatial

Figure 1.6. Broad band electromagnetic demonstration at INEL.

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.

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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 1.7). Using all of the spatial gradients of the earth's magnetic field significantly improves the applicability and efficacy of magnetic methods for subsurface detection and mapping. The technique offers an improved method for simple object location called "dipole mapping", in which small isolated magnetic targets can be accurately located and characterized by only a few measurements. In fact, this omnidirectional gradient information is sufficient to permit a simple quantitative interpretation from a single station.

Figure 1.7. 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
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TASK DESCRIPTION

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

Geophysical, chemical, and radiological sensors are being deployed by a robotic system. The sensors scan over the surface being remediated. As waste retrieval proceeds, the sensors are continuously deployed to characterize the remaining

waste. The remediation process proceeds in a stepwise manner in which the characterization data is interpreted on-line to support the retrieval process (see Figures 1.8a and 1.8b).

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

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

Figure 1.8a. Robotic gantry crane system for deploying the dig-face sensors.

Figure 1.8b. Pilot-scale deployment of dig-face sensors using a soilbox to simulate the dig face.

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

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

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

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

COLLABORATION/TECHNOLOGY TRANSFER

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

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Section 2.0

2.1

CRYOGENIC RETRIEVAL

TASK DESCRIPTION

A full-scale Cryogenic Retrieval demonstration was completed at the INEL Cold Test Pit in FY92. A series of carbon and stainless steel 2-inch schedule 40 freeze pipes, approximately 10 feet to 12 feet in length, were driven into 3 areas of soil and simulated buried waste. For the field demonstration, about 65 pipes were driven into each of 3 areas that measured 9 feet x nine feet x ten feet (810 ft³). Liquid nitrogen (LN₂) was circulated through the pipes, and small quantities of water were injected to promote cohesion of the soil and simulated waste particles (see Figure 2.1a). Besides freezing the test pit, the perimeter of an adjacent access pit was also frozen. Once the area to be removed was frozen, the center of the access pit was excavated (the

access pit was in clean soil). The access pit served to create a dig area from which excavation of the waste could proceed. A gantry with a remotely operated jackhammer, a hydraulic jack, shears, and a grapple was moved over the frozen area to be retrieved.

With the gantry and tools in place, the tools were remotely operated and the frozen soil and simulated waste were excavated and loaded into transport boxes (see Figure 2.1b). The jackhammer was used to break up the soil and debris. The shears cut and sized the material, and the grapple picked up the debris and loaded it into the transport boxes.

The prototype system is scalable to support 80 cubic yards of buried waste retrieval per 8-hour

Figure 2.1a. Liquid nitrogen injection pipes inserted in the INEL Cold Test Pit.

Figure 2.1b. Remotely operated retrieval equipment.

day. The retrieval can be accomplished with minimal contamination spread as evidenced by a lack of surrogate tracers on air sampling systems during the proof-of-principle tests.

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

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

[REDACTED]

TASK DESCRIPTION

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

[REDACTED]

ACCOMPLISHMENTS

This technology was successfully demonstrated at the Cold Test Pit in the summer of 1992. The Cryogenic Retrieval full-scale demonstration showed a positive proof of principle for remote retrieval of simulated buried TRU waste while containing contaminant spread. During the test, approximately 200,000 gallons of LN₂ were used to freeze 4500 ft³ of soil and debris. The spread of respirable particles was minimized by the freezing process. This technology was successfully

demonstrated as mature enough to be considered for actual waste site applications to reduce contamination spread during retrieval operations.

[REDACTED]

COLLABORATION/TECHNOLOGY TRANSFER

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

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TASK DESCRIPTION

The purpose of this project is to demonstrate Cryofracture™ technology as a pretreatment for processing retrieved and/or stored containerized waste (see Figure 2.2).

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

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

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

Cryofracture™ enhances the chances for success for post-retrieval treatment of buried waste and stored waste and results in a more homogenous waste for passive and active assay systems. The hazards and

risks associated with the conventional shredding of pyrophorics and other explosives are eliminated with the Cryofracture™ process.

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

The Cryofracture™ facility was developed by General Atomics. The demonstration showed a positive proof of principle for reducing the size of containerized waste. The demonstration showed that cryofracture was an effective size reduction

Figure 2.2. Cryofracture process description.

process. Containerized waste volumes were reduced by up to 47%. On the average, 90% of the material (containerized waste in 55-gallon drums or 4x4x4-foot boxes) was fractured to less than 6 inches in size, making this processed waste more compatible with most waste treatment options.

[REDACTED]

COLLABORATION/TECHNOLOGY TRANSFER

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

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2.3

RETRIEVAL DEMONSTRATION

TASK DESCRIPTION

The objective of the Retrieval Demonstration is to determine the effectiveness of full-scale, commercially-available excavation equipment and end-effectors for the retrieval of simulated buried waste forms typical of DOE sites. Manually-operated commercially-available equipment was evaluated for its suitability for buried waste retrieval. This equipment and its operation were also evaluated in terms of its remotization capability (see Figures 2.3a and 2.3b). The equipment and end-effectors evaluated in this study included a 325L excavator with Balderson thumb end-effector, 935C track loader with multipurpose bucket, EL200B excavator with front shovel, an IT28B integrated tool carrier with a grip and grab end-effector, and 235B excavator outfitted with a pair of Allied-Gator shears.

The average production (retrieval) rate of this equipment was determined to be 400 yd³/day (8-hour day). This rate far exceeded the target goal of 80 yd³/day. The 325L excavator with Balderson thumb proved to be the most versatile machine evaluated, operating effectively (simi-

lar production rates) both above and below grade. It was capable of handling 1 yd³ loads of heterogeneous waste with no spillage. It could selectively grab small 1 in. diameter cables, as well as handle large objects such as a 6 foot metal cube.

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

TECHNOLOGY NEEDS

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

Figure 2.3a and 2.3b. Full-scale retrieval demonstrations at Caterpillar Cold Test Pit site, Illinois.

ACCOMPLISHMENTS

A full-scale retrieval demonstration was conducted in June 1993 at the Caterpillar, Inc. Edwards Training Center near Peoria, Illinois. The demonstration was performed at a simulated waste pit constructed on this site. The simulated waste pit (overall size 70 x 32 x 13 feet) was comprised of three separate cells; a stacked drums and boxes cell (35 x 32 x 13 feet), an earth separation berm (10 x 32 x 13 feet), and a random dumped drums and boxes cell (25 x 32 x 13 feet). Excavation of the pit occurred in four passes, each 8 feet wide, moving lengthwise along the pit. The first two passes were excavated from the belowgrade position and the last two from abovegrade. Various equipment was tested during the demonstration. The demonstration provided information on retrieval rates at a buried waste site. The average production (retrieval) rate of this equipment was determined to be 400 yd³/day (8-hour day). This rate far exceeded the target goal of 80 yd³/day. The 325L excavator with Balderson thumb proved to be the most versatile, operating effectively both abovegrade and belowgrade. It was capable of handling 1 yd³ loads of heterogeneous waste with no spillage and could selectively grab small 1-inch-diameter cables, as well as handle large objects, such as a six-foot metal cube.

[REDACTED]

COLLABORATION/TECHNOLOGY TRANSFER

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

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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. 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. Remote operation of the system demonstrated a retrieval rate of approximately 2.4 ft³/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.

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.

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.

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

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.

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

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2.5

CONTAMINATION CONTROL UNIT

TASK DESCRIPTION

This project designs, constructs, and tests an easily deployed, mobile unit to efficiently and inexpensively suppress contaminated dust during excavation of buried waste. The Contamination Control Unit (CCU) is a 9 by 26-foot trailer outfitted with a powerful waste vacuuming system and three dust suppression systems (see Figure 2.5). The vacuum, a nuclear-grade system, with a High-Efficiency Particulate Air (HEPA) filter and a critically-safe 55-gallon waste container, can pull one inch debris through 100 feet of hose. The dust suppressing system applies a water mist, a soil fixant and a dust suppressant. The water misting system, DryfogSM (manufactured by Sonics, Inc.), uses compressed air to force demineralized water through four nozzles. The nozzles discharge a mist curtain that captures and removes aerosolized soil. The concentrated soil fixant, FoamerSM (manufactured by 3M Inc.), is combined with a stabilizer and water pumped from a trailer-mounted 325-gallon tank. The stabilizer and concentrate are stored in 5-gallon cans near the nozzle and are delivered by suction to the nozzle. The dust

suppressant, FlambinderSM (calcium lignosulfate manufactured by Flambeau Corporation), is commonly used on forest service roads to suppress dust. This product is mixed with water, stored in a 325-gallon tank and pumped to a nozzle via a hose and reel system. FlambinderSM cures in a few hours, and can withstand traffic of hundreds of vehicles without reapplication.

In a field-deployable setting, the unit is capable of fixing 500 ft²/minute with a total encapsulated (3M-Foamer), or apply 1000 ft²/15 minutes of dust suppressant (flambinder) while simultaneously providing 2 gpm mist from 4 misting nozzles. The vacuum system can be operated continuously during the spray operation. In an emergency response situation, the system is capable of spraying dust suppressant at a rate of 1000 ft²/3 minutes.

The CCU provides a reliable, easy to use, easily deployable system to control dust and wind-blown contamination at DOE and industrial buried waste sites during excavation and retrieval operations. Use of the CCU improves personnel safety and reduces the risk of contamination spread by airborne dust. Furthermore, all the dust

control products are nonhazardous, and can be disposed of in sanitary landfills.

Figure 2.5. Contamination Control Unit.

TECHNOLOGY NEEDS

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

[REDACTED]

ACCOMPLISHMENTS

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

[REDACTED]

COLLABORATION/TECHNOLOGY TRANSFER

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

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2.6 **FIXATION OF SOIL SURFACE CONTAMINATION USING NATURAL POLYSACCHARIDES**

TASK DESCRIPTION

The purpose of this demonstration project is to evaluate inexpensive dust suppression materials that will not adversely impact subsequent soil treatment processes such as soil washing. Natural polysaccharides, beet starch and potato starch, were tested for their ability to fix surface soil and suppress dust generation (see Figure 2.6). The test showed that the natural polysaccharides are generally economically favorable to synthetic products, have the potential to fix soil contaminants in a soluble matrix, and can be easily broken down during soil treatment processes.

Figure 2.6. Applying natural polysaccharides to an incline at the INEL Cold Test Pit retrieval site.

These products can be easily applied to areas where it is desirable to suppress dust generation and contamination spread without affecting subsequent soil treatment processes. Using simple tanks and pumps, the natural polysaccharide products can be dispensed by field-deployable applicators with minimal clogging of nozzles. 100 ft² of surface area can be treated in 15 minutes.

TECHNOLOGY NEEDS

DOE, Environmental Protection Agency (EPA), the Department of Defense (DoD) sites need to develop products that can easily be applied during retrieval operations to suppress dust generation and contamination spread, specifically in cases where there is a need to reduce generation dust on large, disturbed areas where synthetic chemicals are not permitted.

ACCOMPLISHMENTS

A large-scale demonstration was conducted at the Cold Test Pit in conjunction with the remote excavation and contamination control demonstrations. Each product was applied to the area of excavation with a spray system borrowed from the Hanford Vegetation Management Organization. The liquid sugar-beet product with additives (XDCA) decreased contamination by at least 95% over untreated Hanford soil. Potato starch on concentrated XDCA gave some protection to

Idaho soil up to 14% over untreated soil. A fermented potato waste (FPW) gave intermediate results for all soil types. Long-term applications favor synthetic products, although removal of any products from silty soil is difficult.

Large-scale demonstration of XDCA, FPW, and potato starch to excavated areas at both Hanford and Idaho allowed application rates to be determined and verified findings of the laboratory tests.

COLLABORATION/TECHNOLOGY TRANSFER

The markets for commercial products have been established and all but one product are commercially available.

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TASK DESCRIPTION

The objective of the Overburden Removal project was to demonstrate that discrete thicknesses of overburden soil can be removed with precision and accuracy and that fugitive dust can be controlled during excavation. The overburden removal system is a Caterpillar EL300B excavator fitted with an innovative end-effector (see Figures 2.7a and 2.7b). The end-effector is specially designed to remove incremental layers of soil from the area of excavation. Two vacuum ports were installed on the end-effector's front edge and two on the rear to remove much of the dust generated while cutting. The vacuumed dust is routed through hoses into a knock-down box. The vacuum system reduces potential contamination risks to the operators by reducing the generation of dust. A laser referencing system provides a constant grade reference by transmitting radio signals to a display in the operator's compartment to indicate if the end-effector is above, below, or on grade.

Figure 2.7a. Overburden removal demonstration at the INEL Cold Test Pit.

By using this system, one can accurately skim layers of "clean" overburden soil or surficial contamination from a waste site to minimize the amount of waste soil that needs to be treated. The system can remove clean or contaminated soil in controllable layers using 3", 4", or 6" cuts with an accuracy of ± 1 ". The system can remove 6 feet of soil over 1 acre in 10 8-hour days. This system can be used at any site requiring the removal of incremental layers of soil without dust generation or contamination spread.

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

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

A demonstration was completed at the Cold Test Pit. The equipment removed the layers of soil with a cut precision of ± 0.57 inches, and an average cut accuracy of only ± 0.08 inches. The target cut precision and average cut accuracy was set at ± 1 inch. The dust collection system functioned efficiently; the air monitor analysis results proved that the soil could be excavated without

spreading contamination. An experienced, proficient operator is essential.

COLLABORATION/TECHNOLOGY TRANSFER

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

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Figure 2.7b. Sonsub-developed end effector for overburden removal.

TASK DESCRIPTION

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

The Electrostatic Curtain uses grounded conducting plates to form the walls of an inner containment structure to capture charged contaminated dust particles (see Figure 2.8). The grounded conducting plates are also used in a ventilation system upstream from a HEPA filter to neutralize charged dust particles entrained in an air stream drawn from within an enclosure. A double enclosure with a ventilation system was used for the experiments.

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

The electrostatic curtain technology minimizes dispersal of contaminated dust during excavation and retrieval. This technology maintains a

Figure 2.8. Engineering-scale electrostatic curtain enclosure walls with ventilation system.

safer work environment in contaminated environments, and can be used at other DOE and industrial waste disposal sites.

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

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

COLLABORATION/TECHNOLOGY TRANSFER

Full-scale demonstration of this technology has not been completed. An opportunity exists for private industry that would be interested in further development and commercialization. In

addition, this opportunity may involve the demonstration of a full-scale unit in concert with the BWID FY95 full-scale integrated demonstration.

[REDACTED]

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Section 3.0

3.1

ICE ELECTRODES

TASK DESCRIPTION

The objective of this project is to develop and test an ice electrode to remove heavy metals from waste streams and recover valuable metals and minerals. An ice electrode is a conventional electroplating electrode coated with a thin sheath of ice produced by liquid nitrogen-cooled nitrogen gas flowing through an electrode (see Figure 3.1). Bench-scale tests indicate that metals that can be electrodeposited on a conventional electrode can also be electrodeposited on an ice electrode. Preliminary work with metals that cannot be recovered by conventional electrodeposition, including oxides of uranium and tungsten, suggests that they can be retrieved and easily recovered as an ice electrode. In addition, the ice electrode minimizes waste generation because the electrode is not destroyed due to the presence of the ice sheath.

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

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

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

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

Figure 3.1. Bench-scale demonstration of ice electrode technology at the INEL Research Center.

COLLABORATION/TECHNOLOGY TRANSFER

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

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3.2

PLASMA CENTRIFUGAL FURNACE

TASK DESCRIPTION

This project will demonstrate the applicability of the Plasma Centrifugal Furnace (PCF) for the treatment of mixed (hazardous and radioactive) wastes and contaminated soil into an extremely durable waste form for disposal (see Figure 3.2). The PCF is a rotating hearth plasma torch technology used for the refining of titanium and is now being developed for treatment of hazardous and mixed wastes and contaminated soils. The PCF has been demonstrated to be a very all-consuming waste treatment process during past testing for the EPA, DOE, and DoD. In the PCF, waste is fed to a rotating hearth such that the waste and molten material are held to the side through centrifugal force. During the rotation, the waste moves through plasma generated by a torch that does not rotate. To remove the molten material from the PCF, the rotation of the hearth is slowed and the slag flows through a central bottom opening.

The PCF has a nominal feed rate of over 150 lbs/hr of buried waste type feeds and soil. However, this technology should be scalable to larger capabilities using multiple plasma torches and larger hearth sizes. The feed system of the current melter is capable of feeding objects as large as 4 inches in diameter. The current system can handle limited quantities of hazardous (non-radioactive) materials. The processing of radioactive materials is being planned.

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

Successful implementation of the PCF will render hazardous and radioactive wastes and soils into a highly durable, glassy slag, with hazardous inorganic waste components being vitrified and stabilized into the slag. Reduced off-gas flows,

high organic destruction efficiency, high waste volume reduction, and the ability to treat almost any type of waste in a single step process are significant advantages of the plasma process.

Figure 3.2. Plasma Centrifugal Furnace at the MSE test facility, Butte, Mt.

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

The operating envelop, operating procedures, and process rate of the PCF has been established for feeds processed to date (mainly INEL soil).

The first test provided a shakedown of the PCF equipment and a reference base (known composition) for future test matrix comparisons. Three other tests involved surrogate waste (INEL soil) spiked with ceric oxide (a plutonium surrogate). Preliminary results of the mass balance from the three tests indicated that less than 0.05 percent of the cerium surrogate was volatilized into the off-gas treatment system. It appears that 99.95% of the plutonium surrogate was retained in the final vitreous waste form.

COLLABORATION/TECHNOLOGY TRANSFER

This furnace has been developed through an industrial partnership with MSE, Butte, MT.

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3.3

PLASMA FIXED HEARTH PROCESS

TASK DESCRIPTION

This project involves the demonstration and performance evaluation of the Plasma Hearth Process (PHP), a fixed hearth plasma arc treatment technology for the treatment of mixed (radioactive hazardous) wastes and soil to produce a durable waste form for disposal (see Figure 3.3).

This is not new technology, rather an application of an existing and commercially available technology that has been used for many years for metals processing. Mixed waste treatment in a PHP furnace has several potential benefits, including:

- efficacy of organic destruction;
- versatility of application;
- a high-integrity vitrified final waste form that reduces leachability of both hazardous and radioactive contaminants; and
- waste volume reduction.

The plasma furnace can process a wide variety of waste types including paper, cloth, plastics, metal, glass, concrete, soil, and sludge.

Performance testing with simulated wastes has been conducted in a pilot-scale PHP facility (3-4 barrels of waste per hour). A new generation PHP is being constructed in FY94 by the Mixed Waste Integrated Program for further testing.

The currently near pilot-scale PHP unit is expected to process a nominal 3-4 drums/hr (130 to 550 lbs/hr) of buried waste type feeds and soil. However, this technology should be scalable to larger capabilities using multiple plasma torches and larger hearth sizes. The feed system of the current melter is capable of feeding objects as large as a 35-gallon drum. A full-scale system

would be capable of feeding objects larger than a 55-gallon drum. The current system can handle limited quantities of hazardous (non-radioactive) materials. The processing of radioactive materials is being planned.

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

A high-temperature plasma technology is particularly effective in the treatment of mixed wastes. Advantages of plasma treatment include:

Figure 3.3. Fixed hearth and plasma torch at Retech test facility.

- high efficiency destruction of organics;
- separation of metal from slag in the molten state, with TRU components partitioning to the slag phase;
- encapsulation of heavy metals and radionuclides in the final waste matrix;
- high-integrity, vitrified final waste form;
- improved criticality control;
- maximum volume reduction;
- smaller off-gas rates minimize particulate entrainment and carryover;
- higher energy density and smaller gas rates allow smaller process equipment;
- one-step treatment process (no pre- or posttreatment required); and
- capability to process many waste types.

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

A total of six performance tests has been conducted. Simulated waste materials consisted of the following: mixed metals (ductile iron, cast iron, steel, aluminum, copper, and brass), metal oxide sludge, combustible solids (paper, polyethylene and polyethylene terephthalate, cloth, wood, rubber, etc.), and a combustible sludge. All waste materials were contained in a soil matrix, simulating retrieved waste. Each test consisted of feeding two 30-gallon drums containing a simulated waste.

The test series demonstrated the PHP can process a range of material types and compositions with no pretreatment.

The tests demonstrated successful processing of all waste categories; processed at a rate of 130 to 550 lbs/hr; demonstrated a thorough processing of combustibles, noncombustibles, and mixtures of both; and demonstrated the production of a high integrity final product in a single processing step. The test series also demonstrated effective destruction (greater than 99.99%) of organics; production of a highly durable and leach-resistant (properties comparable to glass) vitreous slag; and formation of two distinctly separate phases (metal and slag) in the molten pool.

COLLABORATION/TECHNOLOGY TRANSFER

The PHP evaluation is being conducted with Science Applications International Corporation (SAIC) and Retech, Inc. of Ukiah CA. SAIC is planning and conducting the testing at the Retech facility in Ukiah, CA. Planning for radioactive testing is underway.

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3.4

ARC MELTER VITRIFICATION

TASK DESCRIPTION

The Arc Melter Vitrification project is an extension of an in-progress U. S. Bureau of Mines (USBOM) and American Society of Mechanical Engineers (ASME) demonstration concerned with fly ash vitrification (see Figure 3.4a). This project will evaluate the applicability of a small commercial-scale arc melter to treat mixed TRU-contaminated wastes and buried or stored soils.

ASME/USBOM test system is a 1.5 MVA, 1.5 ton/hr (nominal) electric arc furnace with three carbon electrodes, cooled sidewalls for skull operation, a continuous feed system, off-gas treatment system, and slag and metals tapping capability (see Figure 3.4b). The existing off-gas system components will be modified if required to be more suitable for TRU surrogates and heavy metals. Experiments will include analysis of slag and metal phases, off-gas, and off-gas system residues. Surrogate wastes, including

soils, metals combustibles, and sludges, will be prepared and separately incinerated, as appropriate, in preparation for melter processing.

The currently near field-scale unit can process a nominal 1.5 ton/hr of buried waste type feeds and soil. However, this technology has been used in the steel industry at scales in excess of 105 tons per day. Feed capabilities in the ASME/USBOM melter are currently limited to a screw feed system, but are being upgraded to handle larger diameter objects (up to 6 inches). A full-scale system would be capable of feeding objects larger than a 55-gallon drum. The current system can handle limited quantities of hazardous (non-radioactive) materials. Approximately 20 to 30 metric tons of simulated waste will be processed in each melt campaign, or about 4 to 6 metric tons per day.

The technology has application to the treatment and vitrification of hazardous, radioactive (both

low-level and TRU), mixed wastes, and contaminated soils. This includes buried waste types of debris. These types of buried and stored waste are found at all DOE sites.

Figure 3.4a. U. S. Bureau of Mines three-phase arc melter furnace at the Albany Research Center, Oak Ridge, TN.

TECHNOLOGY NEEDS

A treatment technology is needed that can handle a wide variety of waste mixtures (radioactive and non-ra-

radioactive), significantly reduce the waste volume, and provide a stable, long-lasting, final waste form.

ACCOMPLISHMENTS

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

Figure 3.4b. Continuous tapping of slag to the slag mold.

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

COLLABORATION/TECHNOLOGY TRANSFER

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

This technology has also been developed in collaboration with the U. S. Bureau of Mines.

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3.5

GRAPHITE DC PLASMA ARC MELTER

TASK DESCRIPTION

The objective of this project is to design, fabricate, demonstrate, and evaluate a graphite-electrode DC arc furnace for its effectiveness in treating hazardous, radioactive (both low-level and TRU), and mixed wastes and soil, both buried and stored. An engineering-scale furnace, the Mark I, was tested in FY92 at MIT's Plasma Fusion Center to gain preliminary information on the treatability of buried waste surrogates using DC arc technology. The Mark II furnace was designed and fabricated in FY93, based on the results of the earlier tests. The newer design incorporates many of the features required for a semi-remote or remotely operated furnace, including prototype provisions for alpha containment, and the ability to process waste

continuously at power levels of more than 1 MVA and a processing rate of 500 to 700 lb/hr (see Figure 3.5). The Mark II furnace was designed with the capability to separate the glass phase from the metal phase.

The Mark II furnace is a refractory lined carbon steel vessel 23 feet (7 m) high and 7 feet (2.1 m) in diameter with four soft patch panels around the circumference to provide access for waste feed, glass discharge, and diagnostic equipment. The off-gas system incorporates components that will probably be used in the full-scale production furnace.

The electrode assembly has a unique coaxial arrangement. The outer graphite electrode is 14 inches (356 mm) outer diameter and 10 inches (254 mm) inner diameter. The inner electrode is a solid 6-in. (152-mm) piece of graphite. The electrode assembly can be operated in the transferred arc mode or the nontransferred arc mode to allow the furnace to be easily started. In the nontransferred mode, the waste material is initially heated, then, when the molten material becomes sufficiently electrically conductive, the electrode assembly is switched to the transferred mode.

The current Mark II near pilot-scale unit is expected to process a

Figure 3.5. Mark II DC Arc Furnace at Massachusetts Institute of Technology test facility, Cambridge, MA.

nominal 0.5 to 1.5 ton/hr of buried waste type feeds and soil. However, this technology has been used in the steel industry at scales in excess of 105 tons per day. The feed system of the Mark II melter is capable of feeding objects as large as a 35-gallon drum. A full-scale system would be capable of feeding objects larger than a 55-gallon drum. The current system can handle limited quantities of hazardous (non-radioactive) materials. Systems capable of processing radioactive materials are being planned.

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

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

The concept of this technology has been demonstrated in the Mark I furnace. Design improvements are on-going in the Mark II, including development of improved diagnostics.

The Mark II has been constructed and has begun shake-down testing. The diagnostic development has resulted in patents pending on the Millimeter Wave Radiometer and the Microwave Plasma Spectrometer. The radiometer will spatially resolve measurements of the furnace and melt temperatures. The spectrometer will provide on-line measurements of exhaust emissions, both in

the furnace chamber and in the off-gas. Both instruments will be implemented on the Mark II upon bench-top test completion.

COLLABORATION/TECHNOLOGY TRANSFER

This technology has been developed by MIT and EPI, Inc., and presently a contractual agreement is being negotiated with a large company for licensing of the furnace and diagnostic technology.

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How To Get Involved

Section 4.0

4.0

HOW TO GET INVOLVED

WORKING WITH THE DOE OFFICE OF ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

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

Cooperative Research and Development Agreements (CRADAs)

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

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

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

Procurement Mechanisms

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

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

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EM Central Point of Contact

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

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

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

Office of Research and Technology Applications

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

**For more information about these programs and services,
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Acronyms

Section 5.0

5.0

ACRONYMS

ASME	American Society of Mechanical Engineers
BBEM	Broad Band Electromagnetics Demonstration
BWID	Buried Waste Integrated Demonstration
CEMS	Continuous Emissions Monitoring System
CCU	Contamination Control Unit
CTP	Cold Test Pit
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
EM	Office of Environmental Restoration and Waste Management
ER/WM	Environmental Restoration and Waste Management
FFA/CO	Federal Facility Agreement and Consent Order
GTCC	greater-than-class-C
HEPA	High-Efficiency Particulate Air [filter]
ID	Integrated Demonstration
INEL	Idaho National Engineering Laboratory
IP	Integrated Program
IR	infrared
LANL	Los Alamos National Laboratory
LLW	low-level waste
LN2	liquid nitrogen
NODA	Naval Ordnance Disposal Area
ORTA	Office of Research and Technology Application
PCF	Plasma Centrifugal Furnace
PHP	Plasma Hearth Process
PNL	Pacific Northwest Laboratories

PRDA	Program Research and Development Announcement
RCS	Remote Characterization System
RDDT&E	Research, Development, Demonstration, Testing, and Evaluation
RES	Remote Excavation System
RGS	Rapid Geophysical Surveyor
ROA	Research Opportunity Announcement
RTML	Rapid TRU Monitoring Laboratory
RWMC	Radioactive Waste Management Complex
SAIC	Science Applications International Corporation
SBIR	Small Business Innovation Research
SB-TIP	Small Business Technology Integration Demonstration
SDA	Subsurface Disposal Area
SEE	Small Emplacement Excavator
SITE	Superfund Innovative Technology Evaluation
TCLP	Total Concentrate Leachate Procedure
THC	Total Hydrocarbon monitoring system
TMG	Tensor Magnetic Gradiometer
TRU	transuranic
USBOM	U.S. Bureau of Mines
USGS	U.S. Geological Survey

Appendix A

Cold Test Pit

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Section 6.0

APPENDIX A

COLD TEST PIT

An area 40 feet (12 m) wide, 150 feet (46 m) long, and about 10 feet (3 m) deep was excavated in 1988 about 200 yards (183 m) south of the Subsurface Disposal Area (SDA) in the Radioactive Waste Management Complex. The Cold Test Pit was initially divided into five cells, each cell representing a different configuration of the waste. The cells contain random dumped barrels, random dumped barrels and boxes, stacked barrels, stacked boxes, and the large objects pit (the waste seam is about 8 feet thick with a 4 5 foot soil cap). Each of the barrels and boxes was filled with simulated waste in specific, marked cells and backfilled in the same manner as the SDA waste pits were constructed between 1953 and 1970. Items such as metals, tools, plastics, concrete, asphalt, wood, and simulated sludge were placed in each container.

Cardboard containers were used to hasten deterioration of the barrels and boxes—a condition most likely to be encountered at the SDA. Water was also sprayed on the containers just prior to burial to accelerate the deterioration.

In order to roughly simulate the presence of radioactive waste for migration and detection purposes, rare earth tracers were placed into each container. These tracers are valuable when measuring the effectiveness of contamination control technologies. Only one kind of tracer was placed in each cell. No tracers were placed in the large objects pit. The following kinds of tracers were placed in each of the cells:

• Random dumped barrels	Dysprosium
• Random dumped barrels and boxes	Ytterbium
• Stacked barrels	Terbium
• Stacked boxes	Neodymium

Three additional test cells were added in 1992 to support BWID's characterization and retrieval demonstrations (see Figures A1, A2, and A3). Total size of the new cells is 40 feet (12 m) wide, 47 feet (14 m) long, and 12 feet (3.7 m) deep. The third cell contains the boxes retrieved during the Cryogenic Retrieval demonstration in FY92.

The Cold Test Pit is being used as a simulated waste disposal area to test and demonstrate characterization, retrieval, and treatment technologies. It provides known "targets" and waste forms for accurate evaluation/calibration of procedures, technologies, and equipment tested. Testing at the Cold Test Pit reduces hazards to personnel and the environment otherwise unavoidable in an actual disposal area.

Figure A1. Cold Test Pit Characterization and retrieval cells constructed during 1988 and 1992.

Figure A2. Aerial photograph of the INEL Radioactive Waste Management Complex. The Cold Test Pit is located to the right of the upper right quadrant of the Subsurface Disposal Area.

Figure A3. Characterization cell constructed at the INEL Cold Test Pit during 1992.

Appendix B

Configuration Options

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Section 7.0

Figure B-1. Detailed Integrated Logic Diagram for Characterization/Retrieval/Treatment.

Figure B2. Characterization/Retrieval/Ex-Situ Treatment Configuration Option (Pt. 1).

Figure B-3. Characterization/Retrieval/Ex-Situ Treatment Configuration Option (Pt.2).

Figure B-4. In-Situ Treatment Monitoring Configuration Option.

Figure B-5. In-Situ Treatment Retrieval Configuration Option.

Figure B-6. Containment/Stabilization Configuration Option.

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