DECONTAMINATION & DECOMMISSIONING FOCUS AREA

Technology Summary
August 1996

The information in this book represents information available and current through February 1996.

Decontamination and Decommissioning Focus Area Technology Summary

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FIGURES

INTRODUCTION

The Office of Environmental Management (EM) is responsible for cleaning up the legacy of radioactive and chemically hazardous waste at contaminated sites and facilities throughout the U.S. Department of Energy (DOE) nuclear weapons complex, preventing further environmental contamination, and instituting responsible environmental management. Initial efforts to achieve this mission resulted in the establishment of environmental restoration and waste management programs. However, as EM began to execute its responsibilities, decision makers became aware that the complexity and magnitude of this mission could not be achieved efficiently, affordably, safely, or reasonably with existing technology.

Once the need for advanced cleanup technologies became evident, EM established an aggressive, innovative program of applied research and technology development. The Office of Technology Development (OTD) was established in November 1989 to advance new and improved environmental restoration and waste management technologies that would reduce risks to workers, the public, and the environment; reduce cleanup costs; and devise methods to correct cleanup problems that currently have no solutions.

In 1996, OTD added two new responsibilities—management of a Congressionally mandated environmental science program and development of risk policy, requirements, and guidance. OTD was renamed the Office of Science and Technology (OST).

THE EM ORGANIZATION

OST is one of seven Deputy Assistant Secretarial Offices within EM. Each Deputy Assistant Secretarial Office is discussed here, with the exception of OST (EM-50), addressed in detail later in this Introduction.

Office of the Assistant Secretary for Environmental Management (EM-1)
The Office of the Assistant Secretary for Environmental Management provides centralized direction for waste management operations, environmental restoration, and related applied research and development programs and activities within DOE. The Office of the Assistant Secretary develops EM program policy and guidance for the assessment and cleanup of inactive waste sites and facilities, and waste management operations; develops and implements an applied waste research and development program to provide innovative environmental technologies to yield permanent disposal solutions at reduced costs; and oversees the transition of contaminated facilities from various departmental programs to environmental restoration. The Assistant Secretary provides guidance to all DOE Operations Offices. Organizational relationships are shown in Figure A.

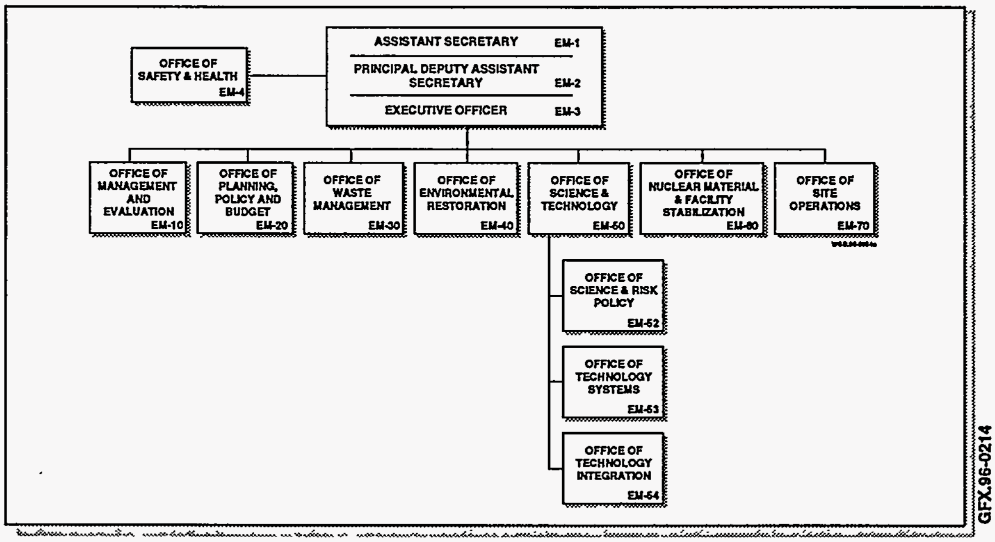

Figure A. Office of Environmental Management Organization Chart.

The Office of Management and Evaluation (EM-10)

The Deputy Assistant Secretary for Management and Evaluation serves as the Assistant Secretary's principal advisor on all administrative functions and activities for EM line offices. Responsibilities include personnel administration; training and career development; total quality management; organization and manpower management; cost and performance management; space and logistics management; acquisition, procurement, and contracts management; general administrative support services; and automated data processing, automated office support systems, and information resources management.

The Office of Planning, Policy, and Budget (EM-20)

The Office of Planning, Policy, and Budget analyzes and provides support on policy and planning issues associated with environmental compliance and cleanup activities, waste management, nuclear materials and facilities stabilization, overall budget and priority setting analyses, nuclear nonproliferation policy practices, and the ultimate disposition of surplus materials and facilities. This Office is also responsible for the review, coordination, and integration of inter-site, interagency and international planning activities related to these issues. The Office coordinates policy and procedural issues associated with the external regulation of the environmental restoration, waste management, and nuclear materials and facility stabilization programs.

The Office of Waste Management (EM-30)

The Office of Waste Management provides an effective and efficient system that minimizes, treats, stores, and disposes of DOE waste as soon as possible in order to protect people and the environment from the hazards of those wastes. The Office carries out program planning and budgeting, evaluation and intervention, and representation functions associated with management of radioactive high-level, transuranic, and low-level waste; hazardous and sanitary waste; and mixed waste.

The Office of Environmental Restoration (EM-40)
The Office of Environmental Restoration remediates departmental sites and facilities to protect human health and the environment from the risks posed by inactive and surplus DOE facilities and restores contaminated areas for future beneficial use. This Office provides program direction for and management of environmental restoration activities involving inactive sites and facilities, including the decontamination of surplus facilities.

The Office of Nuclear Material and Facility Stabilization (EM-60)
The Nuclear Material and Facility Stabilization program mission is to protect people and the environment from the hazards of nuclear materials and to deactivate surplus facilities in a cost-effective manner. The Office provides program planning and budgeting, evaluation and intervention, and representation functions associated with the stabilization of nuclear materials and the deactivation of surplus facilities.

The Office of Site Operations (EM-70)
Acting to eliminate barriers and ensure that field concerns are recognized in major EM decisions, the Office of Site Operations acts as a focal point and champion for the Operations Offices and field sites, serving as facilitator, coordinator and ombudsman for crosscutting issues and topics raised by the various EM elements. The Office of Site Operations provides Headquarters policy direction for landlord planning and budgeting and sets policy and guidance to improve the effectiveness of crosscutting environment, transportation management, and waste minimization activities.

The Office of Science and Technology (EM-50)

OST manages and directs focused, solution-oriented national technology development programs to support EM by using a systems approach to reduce waste management life-cycle costs and risks to people and the environment. OST programs involve research, development, demonstration, testing, and evaluation of innovative technologies and technology systems that meet end-user needs for regulatory compliance. Activities include coordination with other stakeholders and the private sector, as well as collaboration with international organizations. In 1994, the EM program identified five major problem areas on which to focus its technology development activities (later two were combined), and implemented Focus Areas to address these problems. In addition, some needs were identified that were common to all the Focus Areas, and three Crosscutting Programs were created to address them.

OST programs establish, manage, and direct targeted, long-term research programs to bridge the gap between broad fundamental research that has wide-ranging application and needs-driven applied technology development research. OST expects to produce technologies to answer the needs of its major customers within EM for innovative science and technology through

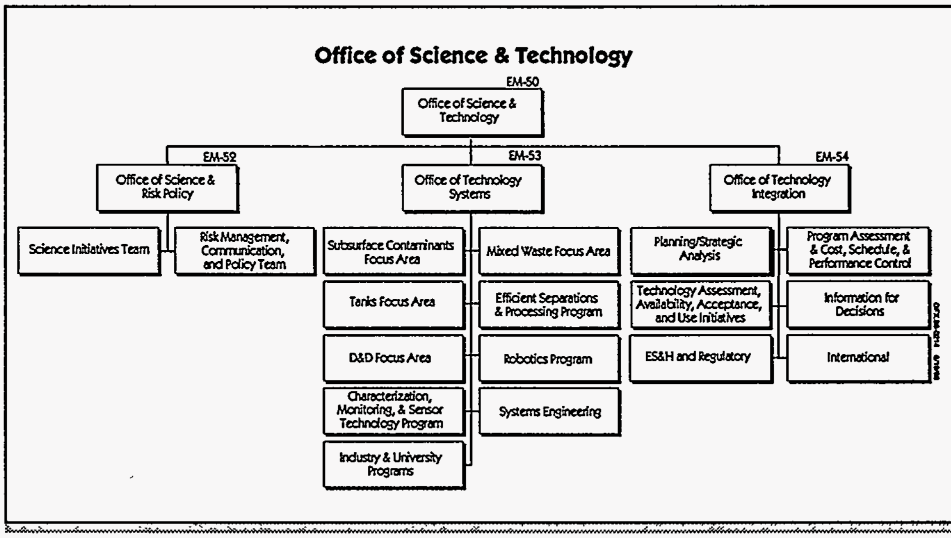

Figure B. Organization Chart of the Office of Science and Technology.

integration of basic research programs, applied research programs (Focus Areas and Crosscutting Programs), industry partnerships, and technology transfer activities.

Three offices comprise OST: the Office of Science and Risk Policy, the Office of Technology Systems, and the Office of Technology Integration. The organization for OST is shown in Figure B.

Office of Science and Risk Policy (EM-52)

The Office of Science and Risk Policy manages EM's Science Program and the formulation of risk policy. The mission of this office includes the development of a targeted, long-term basic research agenda for environmental problems so that "transformational" or breakthrough approaches can lead to significant reduction in the costs and risks associated with the EM Program. This Office also bridges the gap between broad fundamental research that has wide-ranging applicability, such as that performed in DOE's Office of Energy Research, and needs-driven applied technology development that is conducted in EM's Office of Technology Systems. This Office was designed to focus the country's science infrastructure on critical national environmental management problems.

The Science Program draws on information from its DOE customers to identify necessary basic research. The Science Program concentrates its efforts on the characterization of DOE's wastes and contaminants, interactions of radioactive elements with biosystems in various natural media and waste forms, extraction and separation of radioactive and hazardous chemical contaminants, prediction and measurement of contaminant movement in DOE facilities' environments, and formulation of scientific bases for the risks associated with DOE-based contaminants.

Risk policy activities within this Office involve the development of policies, procedures, and guidance to ensure that EM activities in preventing risks to the public, workers, and the environment are within prescribed, acceptable levels. Risk evaluation methods and event and consequence analyses provide DOE with a basis for assessing both the risk and any actions being considered to reduce that risk. The Office of Science and Risk Policy ensures that advances in risk evaluation methods are integrated into coherent decision-making processes regarding risk acceptability. Decision-making processes must meet DOE missions while protecting public health, worker health and safety, ecosystem viability, and cultural and national resources.

Office of Technology Systems (EM-53)

OST programs involve research, development, demonstration, testing, and evaluation activities designed to produce innovative technologies and technology systems to meet national needs for regulatory compliance, lower life-cycle costs, and reduced risks to the environment. To optimize resources, OST has streamlined technology management activities into a single focus team for each major problem area. To ensure programs are based upon user needs, these teams include representatives from user offices within EM. There are four major problem areas upon which technology development activities are focused.

- Mixed Waste Characterization, Treatment, and Disposal
- Radioactive Tank Waste Remediation
- Subsurface Contaminants
- Decontamination and Decommissioning

Mixed Waste Characterization, Treatment, and Disposal Focus Area

DOE stores 167,000 cubic meters of mixed low-level and transuranic waste from over 1,400 mixed radioactive and hazardous waste streams at 38 sites. The Mixed Waste Characterization, Treatment, and Disposal Focus Area provides an integrated, multi-organizational, national team to develop treatment systems for the department's inventory of mixed radioactive and hazardous waste and to dispose of these low-level and transuranic waste streams in a manner that fulfill regulatory requirements.

This Focus Area plans to demonstrate three technologies to treat at least 90 percent of DOE's stored mixed waste inventory by the end of FY97. The outcome will be waste forms that are reduced in volume, as compared to the volume of stored mixed waste, and meet regulatory requirements for safe, permanent disposal. Technology development is being conducted in the areas of thermal and nonthermal treatment emissions, nonintrusive drum characterization, material handling, and final waste forms.

Radioactive Tank Waste Remediation Focus Area
The Radioactive Tank Waste Remediation Focus Area develops technologies to safely and efficiently remediate over 300 underground storage tanks that have been used to process and store more than 90 million gallons of high-level radioactive and chemical mixed waste. Technologies are needed to characterize, retrieve, and treat the waste before radioactive components are immobilized. All this must be done in a safe working environment. Emphasis is placed on in situ or remotely handled processes and waste volume minimization.

Research and development of technologies in this area is aimed at enabling tank farm closure using safe and cost-efficient solutions that are acceptable to the public and that fulfill Federal Facility Compliance Act requirements of site regulatory agreements.

Subsurface Contaminants Focus Area
The Subsurface Contaminants Focus Area is developing technologies to address environmental problems associated with hazardous and radioactive contaminants in soil and groundwater that exist throughout the DOE complex, including radionuclides, heavy metals, and dense, nonaqueous phase liquids. More than 5,700 known DOE groundwater plumes have contaminated over 600 billion gallons of water and 50 million cubic meters of soil. Migration of these plumes threatens local and regional water sources, and in some cases has already adversely impacted off-site resources. In addition, the Subsurface Contaminants Focus Area is responsible for supplying technologies for the remediation of numerous landfills at DOE facilities. These landfills are estimated to contain over 3 million cubic meters of radioactive and hazardous buried waste, some of which has migrated to the surrounding soils and groundwater. Technology developed within this specialty area will provide effective methods to contain contaminant plumes and new or alternative technologies for remediating contaminated soils and groundwater. Emphasis is placed on the development of in situ technologies to minimize waste disposal costs and potential worker exposure by treating plumes in place. While addressing contaminant plumes emanating from DOE landfills, the Subsurface Contaminants Focus Area is also working to develop new or alternative technologies for the in situ stabilization and nonintrusive characterization of these disposal sites.

Decontamination and Decommissioning Focus Area
The Decontamination and Decommissioning Focus Area is developing technologies to solve the department's challenge of deactivating 7,000

contaminated buildings and decommissioning 700 contaminated buildings. It is also responsible for decontaminating the metal and concrete within those buildings and disposing of 180,000 metric tons of scrap metal. Technology development for decontamination and decommissioning focuses on large-scale demonstrations, each of which incorporates improved technologies identified as responsive to high-priority needs. All technologies will be considered for eventual deployment, and side-by-side comparisons of improved technologies are being performed using existing commercial technologies as baselines.

CROSSCUTTING PROGRAMS

In addition to work directed to specific Focus Areas, EM is engaged in research and development programs that cut across these problem areas. Technologies from these Crosscutting Programs may be used within two or more of the Focus Areas to help meet program goals. These programs complement and facilitate technology development in the Focus Areas as shown in Figure C. The Crosscutting Programs are:

- Characterization, Monitoring, and Sensor Technologies,
- Efficient Separations and Processing, and
- Robotics Technology Development Program.

Characterization, Monitoring, and Sensor Technologies Crosscutting Program

DOE is required to characterize more than 3,700 contaminated sites, 1.5 million barrels of stored waste, 385,000 m^3 of high-level waste in tanks, and from 1,700 to 7,000 facilities before remediation, treatment, and facility transitioning commence. Monitoring technologies are needed to ensure worker safety and effective cleanup during remediation, treatment, and site closure.

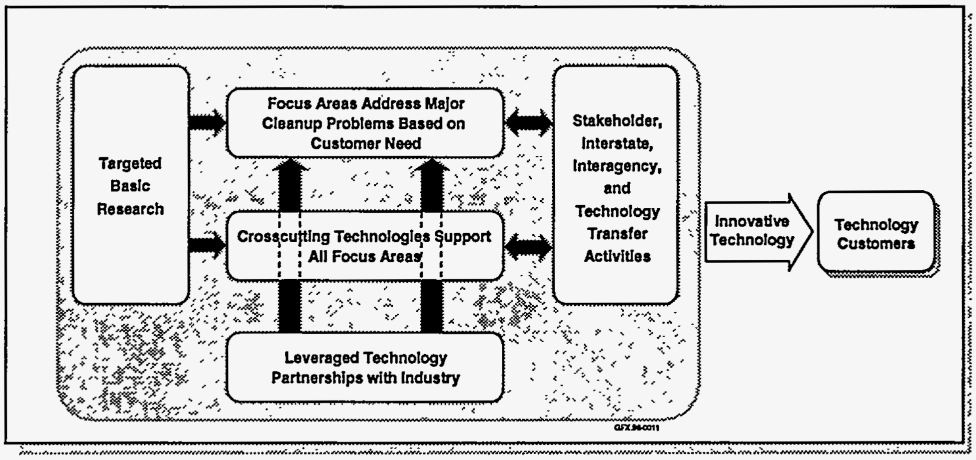

Figure C. Relationships between Focus Areas and Crosscutting Programs.

Efficient Separations and Processing Crosscutting Program

Separations and selected treatment processes are needed to treat and immobilize a broad range of radioactive wastes. In some cases, treatment technologies do not exist; in others, improvements are needed to reduce costs and secondary waste volumes and to improve waste form quality. This Crosscutting Program concentrates efforts on specific high-priority needs as defined by the Focus Areas, then evaluates and adapts the technologies for other applicable Focus Areas.

This program is working to meet Federal Facilities Compliance Act milestones and other regulatory requirements, and to develop separations and treatment technologies that minimize risk, the volume of waste requiring deep, geological disposal, and secondary waste volumes.

Robotics Technology Development Crosscutting Program

Existing technologies are often inadequate to meet EM's mission needs both at a reasonable cost and under conditions that promote adequate worker safety. Robotic systems reduce worker exposure to the absolute minimum while providing proven, cost-effective, and, in some cases, the only acceptable approach to problems.

Robotics remote systems development work occurs in three areas. Remote systems for decontamination and dismantlement of facilities will reduce or eliminate extensive worker radiation protection requirements and increase productivity. Robotic systems for characterization and retrieval of stored tank waste will allow work to proceed within the radiation fields in the waste storage area. Automated chemical/radiological analysis systems are estimated to provide a cost benefit of $10.5 billion from FY96 through FY00.

INDUSTRY AND UNIVERSITY PROGRAMS

Industry and University programs provide to the Focus Areas and the Crosscutting Programs the capability to involve private industry, universities, and other interested parties in their program through direct procurement with DOE. The public-private partnerships that are established encourage the enhancement and commercialization of technologies developed by the private sector through pilot- and field-scale demonstration at DOE sites. The integration of industry, academia, and the DOE laboratories allows all aspects of the technology to be evaluated, including worker safety and health, commercial potential, and technical merit.

Industry and University activities support more than 100 agreements with the private sector. These agreements include the Small Business Innovative Research (SBIR) program, international activities, stakeholder activities, worker safety and health activities, and commercialization initiatives, as well as the direct support to the Focus Areas. For information on how to participate in these programs, see the "DOE Business Opportunities" section at the end of this book.

OFFICE OF TECHNOLOGY INTEGRATION (EM-54)

The Office of Technology Integration addresses issues that affect the involvement of critical external entities such as production/waste sites, users, the public, tribes, regulators, and commercial parties. The office is involved in the assessment, acceptability, availability, and use of improved technical solutions by providing uniform guidance, tools, and initiatives to support the Office of Technology Systems. This office also sponsors efforts to encourage and promote the involvement of affected parties' in regulatory issues.

In addition, the Office of Technology Integration sponsors domestic and international technology transfer programs within OST and coordinates planning and cost-benefit analyses with other EM organizations.

Decontamination and Decommissioning Focus Area Overview

In January 1994, the U.S. Department of Energy Office of Environmental Management (DOE EM) formally introduced its new approach to managing DOE's environmental research and technology development activities. The goal of the new approach is to conduct research and development in critical areas of interest to DOE, utilizing the best talent in the Department and in the national science community. To facilitate this solutions-oriented approach, the Office of Science and Technology (EM-50, formerly the Office of Technology Development) formed five Focus Areas to "stimulate the required basic research, development, and demonstration efforts to seek new, innovative cleanup methods." In February 1995, EM-50 selected the DOE Morgantown Energy Technology Center (METC) to lead implementation of one of these Focus Areas: the Decontamination and Decommissioning (D&D) Focus Area.

The D&D Focus Area is responsible for developing, demonstrating, and implementing cost-effective and safe technologies to deactivate approximately 7,000 contaminated buildings, and decommission approximately 700 contaminated buildings that are currently on DOE's list of surplus facilities. Deactivation refers to ceasing facility operations and placing the facility in a safe and stable condition to prevent unacceptable exposure of people or the environment to radioactive or other hazardous materials until the facility can be decommissioned. Typically, deactivation involves removal of fuel and stored radioactive and other hazardous materials and draining of systems. Decommissioning is the process of decontaminating or removing contaminated equipment and structures to achieve the desired end state for the facility. Desired end states include complete removal and remediation of the facility, release of facility for unrestricted use, or release of facility for restricted use.

In general, commercial technologies exist to deactivate and decommission the DOE surplus buildings, structures, and their contents. Many of these technologies have been developed by the nuclear utility industry, which has similar problems to those found within the DOE complex, or the D&D firms that service this industry. In addition, other countries with nuclear weapons and/or nuclear utility programs have developed technologies to handle their D&D problems. However, these technologies are often labor intensive, time consuming, expensive, and can unnecessarily expose workers to radioactive and other hazardous materials. Many of the commercial technologies also generate secondary waste beyond those of the building materials and their contents.

The D&D Focus Area is addressing these problems by developing, demonstrating, and implementing technologies that generate lower quantities of waste materials, are lower in cost, require less labor, reduce exposure of personnel to radioactive and other hazardous materials, and improve worker safety. Innovative technologies are being developed for characterization of contamination, decontamination of buildings and materials, dismantlement of buildings and equipment systems, reuse or recycle of materials, waste minimization, and worker protection and safety.

Ultimately, the end goal of any technology development program is to commercialize the technology. A key phase of technology development in the D&D Focus Area is "demonstration" of the technology to potential end users. Technologies reaching the demonstration stage should have customer support for the demonstration; firm cost-sharing arrangements and partnership agreements; and resolution of technical, safety, regulatory, public, and licensing issues. It is the intent of the D&D Focus Area to conduct technology demonstrations in end users' facilities at a scale and test duration that is convincing to end users. Data from demonstration testing of the technology should provide end users with pertinent information needed in making decisions regarding subsequent use of the technology. Primary end users for D&D Focus Area technologies are the DOE EM-40 (Environmental Restoration) and EM-60 (Office of Nuclear Materials and Facilities Stabilization) organizations. In general, EM-40 is responsible for decommissioning DOE surplus facilities, while EM-60 is responsible for deactivation of the facilities. EM-30 (Waste Management) is also an end user. EM-30 is the beneficiary of waste minimization and recycling technology.

The D&D Focus Area has observed that its EM-40 and EM-60 customers are often unwilling to accept the risk and liability associated with the first time use of a new technology. In order to fairly evaluate the cost and performance of new technologies, the D&D Focus Area has embarked upon a strategy to sponsor these first-time, full-scale demonstrations within the DOE complex, whether the technology originates with the D&D Focus Area or outside the complex. The only requirement is that such demonstrations be performed on real D&D projects, and that the problem-holder commit to deploy the technology within that project if its cost and performance merit such deployment.

Implementing D&D Focus Area's "New Strategy" of Large-Scale Demonstrations

The key indicator to a successful technology development program is applicability and end use. In order to facilitate this process, the D&D Focus Area has recently begun a new strategy to provide hands-on demonstration of D&D technologies at DOE facilities currently being deactivated or decommissioned. The large-scale demonstration projects are the "cornerstone" of this new strategy. In the large-scale demonstration projects, innovative D&D technologies are demonstrated during ongoing deactivation or decommissioning of a DOE surplus facility. The intent of the large-scale demonstration projects is to show that using a combination of innovative and commercial D&D technologies has substantial cost and other benefits over using only commercial D&D technologies to deactivate or decommission a DOE surplus facility. This approach provides a unique opportunity to test innovative D&D technologies side-by-side with commercial technologies in an active D&D project.

The D&D Focus Area has several goals for the large-scale demonstration projects. These goals include the following:

- Achieve a significant impact, such as visible skyline changes and reduction in cost, time, and safety and health risks for the project.
- Prove significant benefits of using a suite of innovative technologies compared to baseline technologies. The suite of technologies should address technology needs in characterization, deactivation, surveillance and maintenance, decontamination, dismantlement, and material disposition and recycling of the DOE surplus buildings, structures, and their contents.
- Conduct a large-scale demonstration at a scale that is convincing to potential users of the innovative technologies, and will serve to assist DOE Operations Offices in accomplishing their ongoing and planned deactivation and decommissioning activities.
- Manage and conduct large-scale demonstration projects through a D&D Integrating Contractor Team who will transfer the experience and expertise to similar D&D jobs at other DOE facilities and commercial plants.

Thus far, the D&D Focus Area has three ongoing large-scale demonstration projects. These projects, described in detail in Section 1.0, are the decommissioning of the Chicago Pile 5 research reactor at Argonne National Laboratory-East near Chicago, Illinois; decommissioning of the Plant 1 uranium processing complex at the Fernald Environmental Management Project site near Cincinnati, Ohio; and deactivation of the C production reactor on the Hanford Reservation near Richland, Washington. Each project is managed by an Integrating Contractor Team, consisting mainly of industrial D&D firms. These Teams will promote commercialization of the proven innovative technologies by including them in bids for D&D work at other DOE sites and commercial nuclear facilities.

The D&D Focus Area plans to select an additional five large-scale demonstration projects. The last project is expected to be completed by the end of calendar year 1999. Technology demonstrations in the eight large-scale demonstration projects are expected to address at least 90 percent of the technology problems identified by the EM-30, EM-40, and EM-60 organizations. Therefore, it is necessary that the eight facilities selected be broadly representative of the 7000+ surplus facilities in the DOE complex. To categorize this large number of facilities and to bring logic and order to the selection process, the Focus Area has devised Product Lines to ensure that the 90 percent goal is met.

D&D Focus Area Product Lines

The D&D Focus Area Product Lines are centered around the three main areas of surplus facilities: Reactor Facilities, Processing Facilities, and Laboratory Facilities. In addition to these three main areas, the Focus Area categorizes products in a fourth Product Line: Infrastructure and Supporting Activities.

Reactor Facilities

Facilities within this Product Line include production, test, and research reactors, and their associated buildings. These facilities represent a significant portion of DOE's D&D mortgage. Furthermore, decontamination and dismantlement of the reactors, using currently available technologies, present high levels of exposure risk to the workers. These are the principal reasons the Focus Area has chosen these facilities as a Product Line.

Processing Facilities

This Product Line encompasses a number of facilities including plutonium, fuel, uranium, tritium, and lithium processing, and gaseous diffusion plants. Each type of facility requires its own applications, given the nature of contaminants, but similarities in the infrastructure provide the basis for this Product Line. The objectives for development in this Product Line are to demonstrate in situ characterization and analysis, less restrictive and less costly disposal options, automated systems for containment and dismantlement, and recycling resultant materials.

Laboratory Facilities

Hotcells and gloveboxes, among other laboratory facilities, are found throughout the DOE complex and represent a significant problem area for D&D. Hotcells and gloveboxes have a high-radiation environment with highly contaminated equipment. The D&D Focus Area chose this Product Line to demonstrate improved technologies for performing D&D in a highly radioactive environment. Improved technologies are demonstrated for characterization, decontamination, dismantlement, and waste disposal. This development will improve techniques in debris removal, dry/wet decontamination, segregation volume reduction, and remote/robotic dismantlement.

Infrastructure and Supporting Activities

In addition to the main Product Lines, the D&D Focus Area supports technology development to improve infrastructure and supporting activities. This includes innovative development in the areas of personal protective equipment, concrete and metal recycling, waste minimization, pollution prevention, and final waste form.

D&D Focus Area's Approach to Technology Research and Development

The D&D Focus Area strategy is to look first to commercially available technologies, which are unproven in a DOE setting or in a D&D application, before developing innovative alternatives to baseline technologies currently used in the DOE complex. Only if an effective solution does not exist, will the D&D Focus Area move to develop a new technology. Where innovative solutions do not exist, the D&D Focus Area works in collaboration with EM-50's three Crosscutting Programs (Characterization, Monitoring and Sensor Technologies; Efficient Separations and Processing; and Robotics), as well as with Industry Programs, to conduct the necessary research and development to satisfy these technological gaps.

The Focus Area's structure for technology development is organized into three main areas: facility deactivation, facility decontamination, and facility dismantlement and material disposition. Facility deactivation addresses problems such as separating plutonium from process solutions, separating tritium from water, improving worker productivity and protection, sampling/mapping surfaces and locating contaminants, and removing sludge and water from reactor pools. Facility decontamination addresses problems such as remotely cleaning and decontaminating surfaces, and extracting contaminants from concrete and metal. Facility dismantlement and material disposition addresses problems such as dismantling concrete and metal structures using delivery/manipulator/tooling systems, remotely reducing sizes of cut metal and concrete, remotely disassembling and removing material, containing work areas, demolishing buildings, immobilizing asbestos, and recycling.

These problem areas are addressed through technology research and development conducted by D&D, Crosscutting, and Industry Programs. Once mature, full-scale demonstration of these technologies will be supported by the D&D Focus Area as part of the large-scale demonstration projects, as depicted in Figure D.

The D&D Focus Area will complete its research and development activities on existing projects during Fiscal Year 1996 (FY96). Beginning in FY97, the D&D Program will focus on large-scale demonstration projects. Research and development activities will be performed by the Crosscutting and Industry Programs.

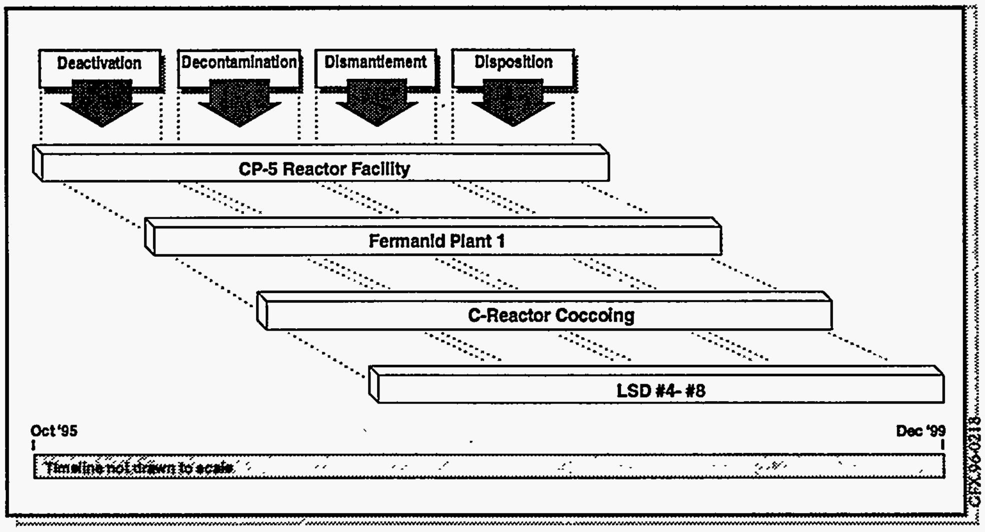

Figure D. Technology Development and Implementation Framework.

About This Document

Given the nature of D&D technology development activities, the technology development structure described earlier is accustomed to group activities, rather than Product Lines. Most technologies being developed within this structure have applications in each Product Line. Therefore, this document is organized according to this structure. Information in this document reflects ongoing activities being conducted by the D&D core program, Crosscutting activities that have applications to D&D projects throughout the complex, and the Focus Area's program status and accomplishments as of January 31, 1996. The information on Characterization, Monitoring, and Sensor Technologies; Efficient Separations and Processing; and Robotics Technology Development was provided by these programs. The information is the same in their books. It is included here to give the reader a complete picture of the EM-50 D&D technology development initiatives.

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1.0 Demonstrations and Industry Approaches

In July 1995, the Decontamination and Decommissioning (D&D) Focus Area issued a competitive Request-for-Letter Proposal to all U.S. Department of Energy (DOE) Operations Offices, requesting they offer facilities to host a large-scale demonstration project. In August 1995, eight letter proposals were received by the D&D Focus Area. The letter proposals were evaluated using four major criteria: significance of demonstration, readiness of demonstration, site commitment, and project management.

In October 1995, the D&D Focus Area selected three DOE facilities to host the large-scale demonstration projects. These facilities are the Chicago Pile 5 (CP-5) research reactor at Argonne National Laboratory-East near Chicago, Illinois; the Plant 1 uranium processing complex at the Fernald Environmental Management Project site near Cincinnati, Ohio; and the C production reactor at the Hanford Reservation near Richland, Washington. Each of these projects is scheduled to complete its technology demonstrations within 18 months after the start of the project.

These large-scale demonstration projects represent the cornerstone of the D&D Focus Area's technology development program. In the large-scale demonstration projects, innovative D&D technologies will be demonstrated as part of DOE's ongoing deactivation or decommissioning efforts. The large-scale demonstration projects will use a combination of commercial and innovative D&D technologies to deactivate or decommission the DOE surplus facilities. The intent of these projects is to show that by using the combination of innovative and commercial D&D technologies, compared to using only commercial D&D technologies, significant cost savings and other benefits can be achieved. This approach provides a unique opportunity to test innovative D&D technologies side-by-side with commercial technologies in an active D&D project.

Each large-scale demonstration project is managed and conducted by an Integrating Contractor Team. This Team coordinates and oversees the work of subcontractors who own the innovative and commercial D&D technologies. Typically, three or more experienced D&D firms comprise this Team. Management of the large-scale demonstration project by multiple D&D firms ensures a balanced approach to D&D of the DOE surplus facility, since different firms may use different commercial and innovative technologies and may have different perspectives on the risks associated with the use of innovative technologies. The Integrating Contractor Team and its subcontractors will be able to use the technologies in performing future D&D

work at other DOE sites and commercial nuclear facilities. In addition, knowledge of the technologies used in the large-scale demonstration project will be directly transferred to more D&D firms.

The Integrating Contractor Team is responsible for evaluating innovative technologies for possible demonstrations during the large-scale demonstration project. Major criteria include applicability to the technology needs of the project, applicability of the technology to other DOE surplus facilities, maturity of the technology, potential benefits of the technology, and cost to demonstrate the technology. The Integrating Contractor Team works closely with the technology vendor to develop demonstration test plans and performance goals for the technology. Data collected during the demonstrations are analyzed by the Integrating Contractor Team, and the results of the analyses are documented in a manner consistent with DOE Office of Environmental Management (EM) requirements.

Through an interagency agreement, the D&D Focus Area has acquired the services of the U.S. Army Corps of Engineers to provide an independent cost-benefit analysis of all the large-scale demonstration projects. First, the Corps of Engineers will estimate the cost to decommission or deactivate the DOE surplus facility using only commercial, baseline D&D technologies. They will then evaluate the cost to accomplish the same D&D end state using the proposed combination of innovative and baseline technologies. Lastly, they will evaluate the actual cost of using the combination of innovative and baseline technologies based on work performed during decommissioning or deactivation of the facility. Based on the performance data collected during demonstration of the innovative technologies, they will project the cost and benefits of the innovative technologies, when available, as commercial, baseline technologies. The cost and benefits of the innovative technologies will be compared to the commercial, baseline technologies in a life-cycle cost-benefit analysis of the entire large-scale demonstration project.

The cost of the large-scale demonstration projects is shared by the D&D Focus Area, the vendors of innovative technologies, and EM-40 for decommissioning projects or EM-60 for deactivation projects. In general, costs associated with demonstration of innovative technologies are provided by the D&D Focus Area. Costs associated with the use of commercial, baseline technologies are provided by EM-30, EM-40, or EM-60. Vendors are expected to share the costs of their demonstration, since successful demonstration of a technology in a large-scale demonstration project provides a rapid avenue to commercialization and acceptance by end users, regulators, and other stakeholders.

The D&D Focus Area plans to issue additional Requests-for-Letter Proposals to the DOE Operations Offices, leading to selection of an additional five large-scale demonstration projects. The last large-scale demonstration project is expected to be completed in 1999. Technology demonstrations in the eight large-scale demonstration projects are expected to address at least 90 percent of the technology problems identified by the EM-30, EM-40, and EM-60 organizations.

This section provides a more detailed description of the three ongoing large-scale demonstration projects. Section 1.4 provides a detailed description of a computer-based tool being developed by the D&D Focus Area. This tool will assist decision makers and program managers in planning and executing future large-scale demonstration projects and other D&D projects at commercial nuclear facilities and at facilities throughout the DOE complex.

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1.1 Chicago Pile 5 Research Reactor at Argonne National Laboratory - East

Technology Need

The CP-5 research reactor, as shown in Figure 1.1-1, is a heavy-water moderated and cooled, highly enriched, uranium-fueled, thermal reactor designed to supply neutrons for research. The reactor had a thermal-power rating of 5 megawatts and was continuously operated for 25 years until its final shutdown in 1979.

The containment building is an upright cylinder, 70 feet in diameter and 42 feet high. The walls are made of approximately 1-foot thick, reinforced concrete. The reactor biological shield is an octagon, 15 feet high and 20 feet across, located in the center of the reactor floor. It is estimated that there is an inventory of radioactive material inside the biological shield of greater than 100,000 Ci. Much of this activity is Co^{60}, Fe^{55}, and Ni^{63} from the activation of a steel tank located adjacent to the concrete biological shield and other structural steel components. The remaining activity consists of mostly C^{14}, Eu^{152}, and Eu^{154} from the activation of the graphite reflector that surrounds the reactor tank. High levels of Cs^{137} are possible.

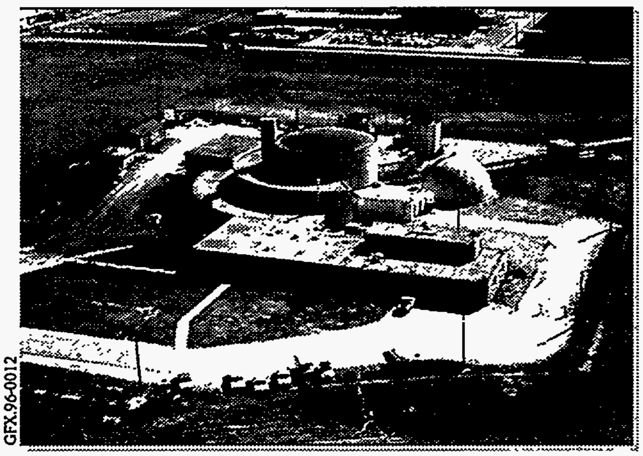
GFX.96-0012

Figure 1.1-1. Chicago Pile 5 Research Reactor.

Included in the facility is a fuel-rod storage area with storage tubes built into the floor to house highly radioactive materials. The tubes have been emptied of their contents, with some decontamination completed. However, some of the tubes still remain highly contaminated. A fuel pool and hotcell facility were added to the original building. Currently, the fuel pool contains approximately 50 shield plugs from the fuel module which are still highly radioactive and are classified as a mixed waste. The fuel-pool water is contaminated with Cs, Co^{60}, and trace amounts of H^3.

With small exception, the general exposure rates inside the containment shell are less than 1 millirem per hour. However, numerous locations throughout the facility have much higher readings and are controlled-access locations. More importantly, once the reactor vessel area is opened for full-scale D&D

operations, levels of radiation are expected to exceed 250 rems per hour. These high exposure rates will necessitate the use of remote dismantlement equipment and personnel protective equipment to reduce worker exposure during D&D activities.

Technology Description

The scope of the large-scale demonstration project will be to integrate technology demonstrations and management approaches within the ongoing D&D of CP-5. This includes a supportive, project focus on technologies emphasizing characterization, worker protection, robotics and remote systems, concrete decontamination, and storage-pool filtration. The approach complements the existing CP-5 effort which includes removal of the reactor internals and biological shield; decontamination of the fuel-rod storage area and radioactive material storage and handling facilities, including the fuel pool; and D&D of the building.

The current large-scale demonstration project schedule includes six demonstration "sets." Demonstration of technologies is scheduled to occur over a three-week period beginning April 1, 1996, for the first demonstration set. This initial set of demonstrations has been labeled the "Validation Set" in that the overall planning, execution, assessment, and reporting process will be fine-tuned during the demonstrations. The remaining five demonstration sets are scheduled to begin the final quarter of Fiscal Year 1996 (FY96) and end early FY97. Recommendations for adding technologies to these demonstration sets will be made in March 1996. Demonstration set number five has been set aside for the dismantlement of the research reactor and will include demonstration of the Mobile Work System, "Rosie;" the Dual Arm Work Module (DAWM); and a number of innovative and commercially available end effectors and tools.

Benefits

A successful large-scale demonstration project will achieve meaningful technology demonstrations that qualify for commercialization and field application throughout the DOE complex. The practical approach of this project is the expedited deployment of needed D&D technologies to meet specific customer needs while meeting DOE EM-50 Office of Science and Technology (OST) established return-on-investment guidelines, and to identify technology activities that should be reviewed for continued DOE support or termination. Additionally, this project introduces commercial business practices to technology deployment and illustrates DOE's commitment to performance-based strategies and contracting reform.

COLLABORATION/TECHNOLOGY TRANSFER

The Integrating Contractor Team is led by Duke Engineering and Services and includes 3M Corporation, Commonwealth Edison, Duke Power, ICF Kaiser, Florida International University, and Argonne National Laboratory. It is anticipated that technology transfer will be accomplished through multiple pathways. In coordination with DOE EM-50 and the D&D Focus Area, the CP-5 large-scale demonstration project will examine potential application of qualified technologies to other DOE sites with similar needs, or to private industry such as Commonwealth Edison's Dresden 1 facility in Morris, Illinois, which is currently in the early stage of D&D.

ACCOMPLISHMENTS

- Assessed 10 technologies for insertion in the second and third quarters of FY96. Eight technologies were recommended for demonstration. The Technology Assessment Team identified five major D&D problem areas for which technical subteams were developed. These teams were charged with developing comprehensive needs/problem descriptions, technology evaluation and performance review parameters, and draft demonstration requirements/test processes in the areas of characterization and monitoring, worker protection, contaminated concrete, robotic systems, and fuel-storage pool.
- Developed a draft revised baseline and presented to the Integrating Contractor Team for its review and comments. This effort is scheduled to be completed by the end of March. As part of this effort, work packages will be developed for each of the primary D&D activities in order to capture the cost of these activities. Argonne personnel are currently working to incorporate exposure and waste volume parameters into the baseline effort.

TTP INFORMATION

Chicago Pile 5 Research Reactor at Argonne National Laboratory - East technology development activities are funded under the following technical task plan (TTP):

TTP No. CH06DD23, "Large-Scale Demo, CP-5 Reactor Decommissioning"

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Wright, C., M. Weiner, and D. Reisenweaver. "Decommissioning Cost Estimate for the Full Decommissioning of the CP-5 Reactor Facility," prepared by Nuclear Energy Services for Argonne National Laboratory (June 1992).

"Decommissioning Plan for the CP-5 Reactor," Argonne National Laboratory, p. 1.1-05 (October 1995).

1.2 PLANT 1 COMPLEX AT FERNALD ENVIRONMENTAL MANAGEMENT PROJECT SITE

TECHNOLOGY NEED

The Fernald Environmental Management Project Plant 1 complex, as shown in Figure 1.2-1, consists of Building 1A and six other buildings. Building 1A was used to receive all enriched-uranium materials that were processed at Fernald. Additionally, nonenriched ore concentrates and recycled materials were milled in this plant prior to distribution to other process facilities. This four-story building contains asbestos insulation; transite; large, contaminated process equipment; and utilities. Other smaller buildings in the Plant 1 complex include two storage sheds, two drum-storage buildings, a drum-reconditioning building, and a thorium warehouse. Decommissioning the Plant 1 complex will consist of decontaminating and dismantling the buildings and their contents. Technologies that will enhance safety, efficiency, and cost effectiveness during the decommissioning process are needed.

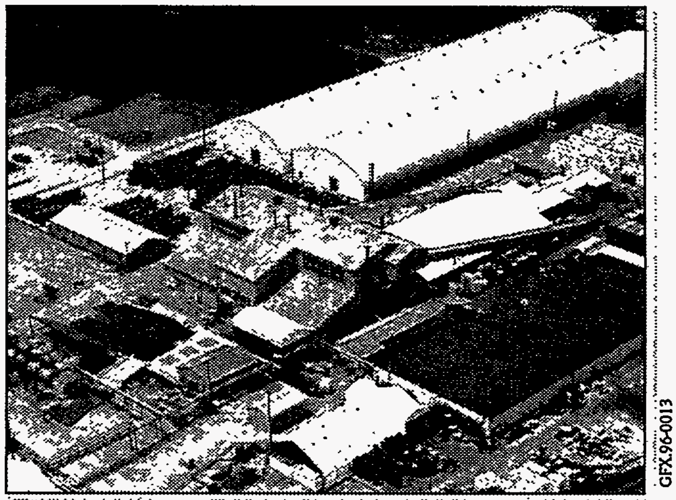

Figure 1.2-1. Fernald Plant 1 Uranium-Processing Facility.

TECHNOLOGY DESCRIPTION

This project provides for the integration of multiple technology demonstrations into the Fernald Environmental Management Project's ongoing Plant 1 D&D project. A suite of technologies will be demonstrated in the areas of characterization, worker protection, demolition, and decontamination. The demonstrations will be new technologies or developed technologies from other industries that are being integrated into nuclear D&D projects for the first time. The intent of the large-scale demonstration project is to quantify the derived benefits (i.e., cost, schedule, and/or safety) achieved through the use of each of the D&D technologies relative to its corresponding baseline technology. In order to preclude the need to scale up technologies, full-scale, commercial D&D demonstrations will be conducted.

The Plant 1 D&D project being performed by Babcock and Wilcox Nuclear Environmental Services, Incorporated commenced in October 1995, and is scheduled for completion in July 1997. The planning and execution of this large-scale demonstration project is scheduled for an 18-month period that commenced in January 1996. Technology selection is scheduled to begin in early February, and the first demonstration should begin in June 1996.

Benefits

This project allows selected technologies to be fully evaluated under an actual commercial-scale application. This will preclude the need to scale up the results of the demonstration, which on occasion, can produce misleading conclusions. This information will be beneficial to D&D contractors in employing the technology on future D&D projects. With respect to addressing similar problems/needs across the complex, this large-scale demonstration project will provide proof of the benefits (or deficiencies) of each new D&D technology.

Collaboration/Technology Transfer

The Integrating Contractor Team is composed of Fernald Environmental Restoration Management Corporation; Fluor Daniel; Halliburton Nuclear Utility Services; Jacobs Engineering; Babcock and Wilcox Nuclear Environmental Services, Incorporated; and Foster Wheeler Environmental Corporation.

The results of the large-scale demonstration project at Fernald Environmental Management Project Plant 1 will be transferred throughout DOE and to private industry through four separate avenues: Babcock and Wilcox Nuclear Environmental Services, Incorporated, the D&D contractor for the Plant 1 D&D Project; technology suppliers involved in the demonstrations of new technologies; Integrating Contractor Team and its members who are actively involved in environmental remediation and D&D projects; and performance evaluation reports prepared on each of the demonstrated technologies. These reports and conference presentations will provide for the wide dissemination of information on the proven technologies. Issues that may influence the future use of any of the demonstrated technologies (e.g., regulatory issues, special training requirements, and availability from suppliers) will be addressed in these reports.

Accomplishments

- Conducted a kick-off meeting at the Fernald Environmental Management Project site on January 25 and 26, 1996. The meeting was attended by representatives from the DOE Morgantown Energy Technology Center (METC), DOE Fernald, U.S. Army Corps of Engineers, Fernald Environmental

Restoration Management Corporation, and Babcock and Wilcox Nuclear Environmental Services, Incorporated. A management plan and a timeline for the demonstration were developed. During this visit, D&D Focus Area representatives met with project stakeholders, including individuals from the Ohio Environmental Protection Agency and local citizens' organizations.

TTP Information

Plant 1 Complex at Fernald Environmental Management Project Site technology development activities are funded under the following TTP:

TTP No. OHO6DD21, "Large-Scale Demonstration"

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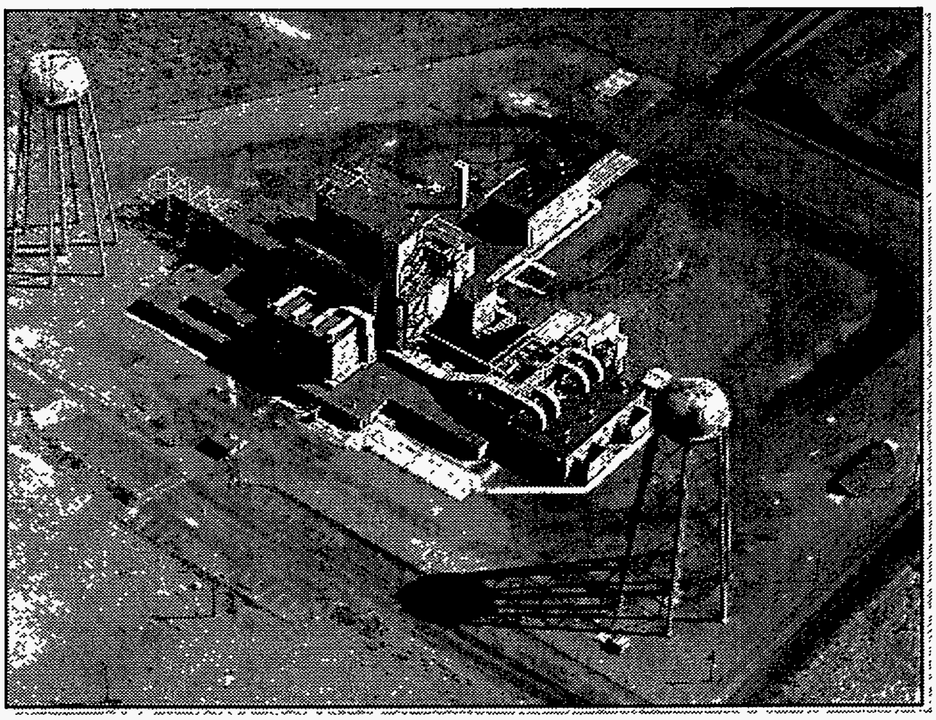
U.S. DOE Fernald Field Office. "Operable Unit 3: Remedial Design/Remedial Action Work Plan for Interim Remedial Action," Fernald Environmental Management Project, Fernald, Ohio (March 1995).

1.3 C-Reactor at Hanford Reservation

Technology Need

To reduce the costly burden of maintaining and cleaning up DOE's aging inventory of former weapons production facilities, it is critical that DOE successfully demonstrate the concept of low-cost, interim, safe storage (cocooning) of a major facility. The C-Reactor, as shown in Figure 1.3-1, is a full-scale surplus production reactor that was scheduled to be the first of eight reactors at Hanford to be dismantled. Cocooning the Reactor facilitates its safe storage during the period before final dismantlement, reducing risks and costs of prolonged surveillance and maintenance.

The C-Reactor facility is located in the 100 B/C Area of the Hanford Site. The 105-C building is 105.5 meters by 45.7 meters by 36.6 meters. Except for reinforced sections, the building can be classified as a light, nonairtight, industrial structure. The lower levels of the building and the central portions surrounding the Reactor are constructed of reinforced concrete. The massive reinforced concrete walls surrounding the Reactor are 0.9 to 1.5 meters thick.



The upper portions of the building are enclosed with corrugated asbestos cement (transite). Other exterior walls are concrete block. The roof is mainly cast-concrete panels.

A record of decision was issued by DOE subsequent to a National Environmental Policy Act evaluation of the decommissioning alternatives for the surplus production reactors at Hanford. The record of decision states that the preferred alternative is to place the reactors into a safe-storage condition for up to 75 years and then move the reactors in one piece to a specially prepared burial facility in the 200 West Area of the Hanford Site.

TECHNOLOGY DESCRIPTION

This large-scale demonstration project will provide DOE a major opportunity to demonstrate progress in accomplishing highly visible D&D cleanup activities. The technologies associated with this new approach will include the following: characterization, decontamination, dismantlement, demolition, waste minimization, facility monitoring and surveillance, and radiological and industrial safety enhancements.

The main tasks include an extensive removal of the contaminated surfaces. Some contaminated areas, such as the outer rod rooms and metal storage rooms, can be cleaned by conventional wiping technologies. Other areas, such as the fuel-storage basin, fuel-examination facility, and fuel-transfer pits, will require aggressive surface-removal techniques.

The baseline plan for the safe storage of the C-Reactor includes removal of the fuel-storage basin, the adjacent fuel-examination facility, and the fuel-transfer pits. The proposed baseline technique for surface removal from these facilities is scabbling (mechanical removal of contamination from concrete). However, whether or not to remove any or all surfaces would be decided on the basis of a cost-benefit analysis. It may be cheaper to fix the contamination and remove the components as low-level waste rather than expend time and resources to remove the surfaces only.

BENEFITS

This large-scale demonstration will show that the improved technologies will have significant benefits over the use of baseline technologies in the following areas:

- Lower facility life-cycle costs
- Lower health and safety risks to the worker and the public
- Lower risks for detrimental impact to the environment
- Reduced amount of secondary waste

- Reduced hazard level and category of waste
- Increased reuse of materials within DOE and/or free release of materials for recycle by the private sector
- Less time required for characterization, deactivation, decontamination, dismantlement, and disposition of facilities
- Reduced amount of residual contamination in materials following decontamination
- Reduced cost and worker exposure in surveillance and maintenance of facilities

This project will also result in the identification of technologies that will be optimal for preparing the other seven surplus production reactors at Hanford for similar low-cost, interim, safe storage.

COLLABORATION/TECHNOLOGY TRANSFER

The D&D Integrating Contractor (Bechtel Hanford, Inc.) will transfer the experience and expertise gained on the C-Reactor interim storage activities to similar D&D jobs at Hanford, other DOE facilities, and commercial jobs. The technical performance data collected will be transferred to DOE Headquarters, EM-50 OST for evaluation and shared with other federal agencies and private utilities in need of the various technologies.

ACCOMPLISHMENTS

- Initiated planning activities for this large-scale demonstration. The draft Conceptual Design Report for long-term storage was received from the engineering subcontractor in late December. The draft has been reviewed with the Environmental Restoration Contractor, and comments were informally forwarded to the subcontractor for resolution. The conceptual cost estimate has been completed by the subcontractor and is being reviewed by the Environmental Restoration Contractor estimating staff. The Environmental Restoration Contractor, DOE Richland team, presented the Value Engineering Concept to the Hanford Site D&D Site Technology Coordination Group subgroup at their monthly meeting. The Environmental Restoration Contractor, DOE Richland team, will use the D&D subgroup as the Value Engineering team to get regulatory, Native American, and local business input for technology identification and selection.

TTP Information

C-Reactor at Hanford Reservation technology development activities are funded under the following TTP:

TTP No. RL06DD21, "Large-Scale Demonstration: C-Reactor Cocooning at Hanford"

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Bibliography of Key Publications

None at this time.

1.4 PHOENIX: A COMPUTER-BASED, DECISION-MAKING TOOL FOR DECONTAMINATION AND DECOMMISSIONING OF NUCLEAR FACILITIES

TECHNOLOGY NEED

The objective is to design, develop, and demonstrate a prototype, computer-based tool that assists decision makers and program managers in planning and executing D&D projects at nuclear facilities. Specifically, the tool will facilitate the following activities: programmatic decision making, project planning, detailed cost estimating, D&D technology selection, and waste management.

TECHNOLOGY DESCRIPTION

Phoenix, the computer-based tool, will assist in determining the safest and most cost-effective process to decommission a given facility and whether the work should be done immediately, in phases, or at a later date. Considerations include cost, health risk, governmental policies, and waste issues. The tool will also identify, collect, and organize data required to plan a D&D project, and provide an accurate cost estimate. The database will include information on commercial and innovative technologies applicable to D&D. This information will include applicability of technology, cost and other attributes, along with related advantages and disadvantages. Key components of the tool will be a geographical information system and a suite of algorithms that are based on D&D-related data. An example screen from Phoenix is illustrated in Figure 1.4-1.

In June 1996, a prototype of the operational Phoenix system will be demonstrated. This demonstration will be based on the Fernald Plant 1 D&D large-scale demonstration project. It will serve as a baseline to show potential users the system's capabilities and enable users to critique the system. The demonstration will be a point of departure for design of a commercial, operational Phoenix software.

BENEFITS

Phoenix will assist program managers and D&D decision makers with the selection of optimal technologies for specific applications or entire projects. It will provide detailed cost estimates as well as compute the amount and type of waste that will be generated from the selected technology or approach. The tool also selects the safest and most cost-effective waste container and storage location; determines the quantity of waste to store in a specific area;

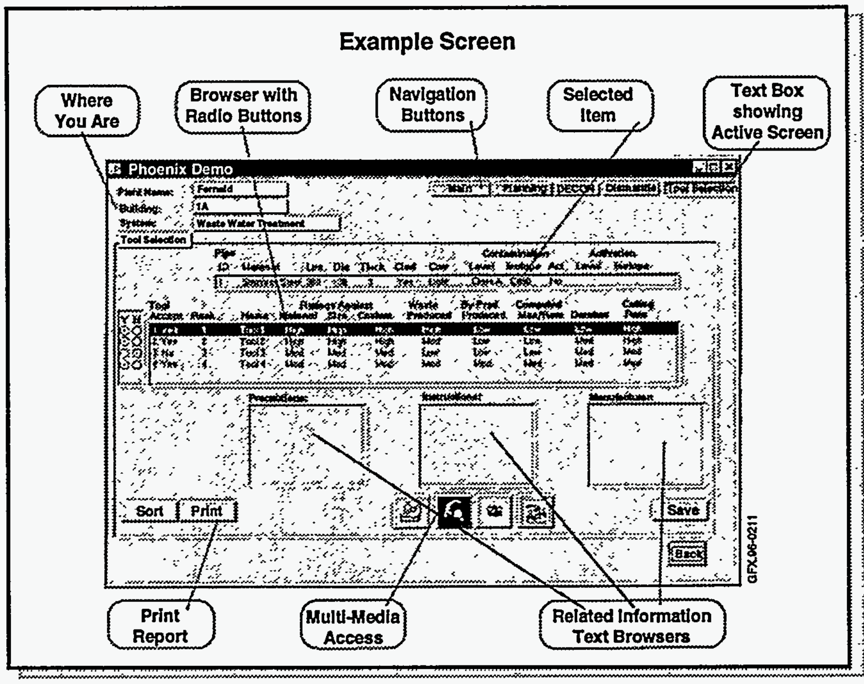

Figure 1.4-1. Phoenix Example Screen.

recommends handling procedures; and estimates packaging, storage, transportation, and disposal costs.

Collaboration/Technology Transfer

Arrey Industries and its subcontractors (Arrey Team: Nuclear Expertise and MRJ) are currently working on several project tasks in parallel. Nuclear Expertise is providing the domain expertise in D&D planning, technology selection, and cost estimation. MRJ is providing engineering and software design expertise to program the domain expertise into Phoenix.

Accomplishments

- Initiated development of evaluation criteria for technologies. The evaluation criteria will include, for example, speed of operation, decontamination factors, waste generation, operational costs, capital costs, radiation exposure, and many other factors.
- Developed menu screens for the Phoenix user interface, and designed and integrated D&D sequence and technology selection constraints.
- Created Site-Independent databases containing D&D data applicable to a wide range of nuclear facility types. Databases were created in Access and

are being populated. Links to hypermedia and Internet information have been incorporated into the Site-Independent data tables, assuring a continual updating of available data such as catalogs, procedures, regulations, photographs, and video clips.

- Developed Site-Dependent database, in Access, to contain facility-specific data.
- Selected Microsoft Visual Basic as the Phoenix system executor, since it can handle all commercial off-the-shelf software planned for the demonstration, and has the newest object-linking and embedding features needed for the demonstration.

TTP Information

Phoenix: A Computer-Based, Decision-Making Tool for Decontamination and Decommissioning of Nuclear Facilities technology development activities are funded under the following TTP:

TTP No. ME06DD23, "Phoenix"

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"Phoenix Progress Report," Presentation by the Arrey Team (January 23, 1996).

2.0 FACILITY DEACTIVATION

Facility deactivation refers to the process of placing a facility in a safe and stable condition to minimize the long-term cost of a surveillance and maintenance program that is protective of workers, the public, and the environment until decommissioning is complete. Actions include the removal of fuel and stored radioactive and other hazardous materials, and draining and/or de-energizing nonessential systems. As a bridge between operations and decommissioning, deactivation can accomplish operations-like activities such as final process runs, characterization activities, and also decontamination activities aimed at placing the facility in a safe and stable condition.

The U.S. Department of Energy Decontamination and Decommissioning (DOE D&D) Focus Area has identified a number of broad technological needs that can reduce surveillance and maintenance costs incurred throughout the Department due to delays in decontamination and decommissioning of facilities. These needs include real-time characterization and sampling techniques for characterizing contaminants on concrete and metal, as well as inside pipes; improved worker protection systems; improved techniques for separating radioactive contaminants from sludge, process equipment, and other media; and improved techniques for the disassembly and removal of contaminated process equipment. This section highlights the current D&D portfolio of technology development activities addressing these needs.

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2.1 Advanced Worker Protection System

Technology Need

Many D&D activities require difficult tasks to be completed by workers in protective suits and respirators. The suit essentially encapsulates the wearer's body, preventing the evaporation of perspiration, and thereby preventing the heat generated by the worker's activity from leaving the suit. As a result, the average worker cannot tolerate exposure to the hot and humid atmosphere for more than approximately 45 minutes, after which the worker has to cool down. Time required for donning and doffing a suit and respirator, along with decontamination time, makes for a work day that is, at best, less than 50 percent efficient, and frequently only 25 percent efficient. New protective equipment and systems are needed to improve performance.

Technology Description

The Advanced Worker Protection System (AWPS), as shown in Figure 2.1-1, is a self-contained, extended service-time, personnel-protection system that uses a liquid-air backpack to provide air to workers for both breathing and cooling. Breathing air is provided to a pressure-demand respirator worn by the worker. Air is also used to cool water that is circulated in a liquid cooling garment worn against the worker's skin. The worker can wear either a two-piece, splash-protection suit (Level B protection) or a totally encapsulating suit (Level A protection).

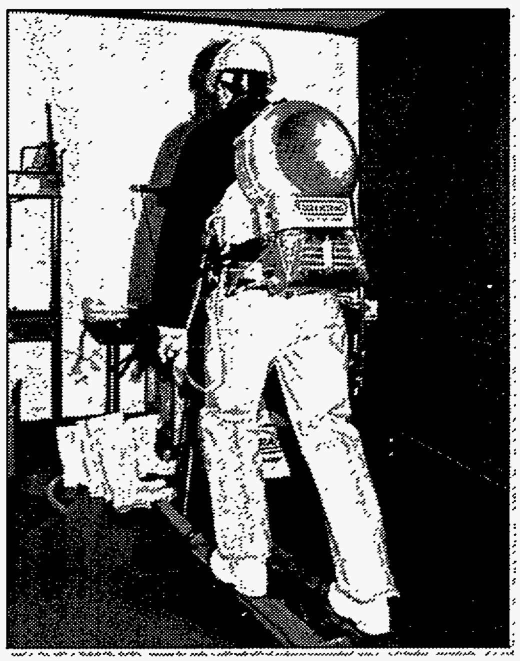

Figure 2.1-1. Advanced Worker Protection System.

The backpack includes the vacuum-jacketed dewar which contains the cryogenic liquid air. The liquid air is fed through a heat exchanger that uses the water warmed by the wearer's body to vaporize the cryogen for breathing, while it cools the water to control body temperature. The air is regulated to the appropriate pressure and delivered to the respirator. The cooled water is delivered to the liquid cooling garment. The amount of cooling can be controlled by the wearer.

A recharge station is required to fill the dewar on the AWPS with the liquid air. The present design allows this recharge station to be retrofitted to current self-contained breathing apparatus charging units. Workers can wear the AWPS for more than two hours without the need for a forced break or cool-down period.

Complete development of the AWPS involves two phases of work. Phase I, which has been completed, included the development and testing of the AWPS prototype, including preliminary assessment of the apparatus by the National Institute for Occupational Safety and Health. Phase II, currently underway, will optimize the design using information gained from the Phase I testing and assessment. Phase II development of the preproduction units will conclude with certification by the National Institute for Occupational Safety and Health, U.S. Department of Transportation, and Los Alamos National Laboratory, and a field demonstration at one of the DOE facilities.

BENEFITS

Firefighters from Manhattan, Kansas, were the subjects of human performance tests conducted at the Institute of Environmental Research at Kansas State University. Participants walked on a treadmill at 3 miles-per-hour for up to 90 minutes wearing three different types of apparel. The three different types of apparel were shorts and t-shirt, the AWPS, and standard clothing and self-contained breathing apparatus worn by firefighters. The test subjects were monitored for heart rate, blood pressure, and body temperature. Firefighters were able to walk on the treadmill for 90 minutes when wearing the AWPS, compared to only 20 to 30 minutes when wearing the standard firefighting suit.

COLLABORATION/TECHNOLOGY TRANSFER

This project is funded through the Morgantown Energy Technology Center (METC) via an Industry Program Research and Development Announcement (PRDA) award. Oceaneering Space Systems, a division of Oceaneering International, Inc., is the prime contractor for the AWPS. The AWPS is one of many life-support and cryogenic technologies being developed by Oceaneering Space Systems.

ACCOMPLISHMENTS

- Developed a full-scale prototype AWPS, for both Level A (vapor protection) and Level B (liquid-splash protection)
- Completed human performance testing of the AWPS at the Institute of Environmental Research at Kansas State University (see Benefits section)

- Scheduled a demonstration of the prototype AWPS at the International Union of Operating Engineers Human Factor Facilities in Beaver, West Virginia

TTP Information

Advanced Worker Protection System technology development activities are funded under the following technical task plan (TTP):

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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"Kansas State University Testing Report - AWPS," *Phase I Topical Report* (June 15, 1995).

2.2 PROTECTIVE CLOTHING BASED ON PERMSELECTIVE MEMBRANE AND CARBON ADSORPTION

TECHNOLOGY NEED

Decontamination workers at DOE sites face potential contamination from a variety of hazardous compounds including asbestos, mercury and other heavy metals, toxic organic compounds such as polychlorinated biphenyls (PCBs) and chlorinated solvents, and radioactive metals and salts. For many activities, they must wear protective garments that are impermeable to particulates, aerosols, and organic vapors, and provide protection from toxic contaminants. These garments are heavy, time consuming to put on and remove, and impermeable to water vapor. Because perspiration cannot evaporate, body heat is not dissipated. Therefore, the potential for workers to become heat-stressed is high. Frequent, lengthy rest periods are needed. Use of existing protective garments greatly reduces worker and process efficiency.

TECHNOLOGY DESCRIPTION

The objective of this work is to develop and demonstrate improved protective clothing made of an innovative fabric that combines an ultra-thin, permselective outer membrane with a sorptive inner layer. This protective clothing is illustrated in Figure 2.2-1. The outer membrane layer is extremely permeable to water vapor escaping from the wearer, but highly impermeable to hazardous compounds. The sorptive inner layer captures any hazardous compounds that may breach the membrane layer.


Figure 2.2-1. Protective Membrane Clothing.

BENEFITS

This protective clothing will provide protection equivalent to current garments, but is lighter weight to improve comfort. It is breathable, therefore allowing water vapor to escape, and reducing heat stress. In laboratory tests, water-vapor-transmission rates of 600 to 900 grams per square meter per day have been measured through the fabric. This water-vapor-transmission rate is far superior to butyl rubber suits with a water-vapor-transmission rate of 0 to 10 grams per square meter per day. Chemical vapor transmission rates have been equal to, or lower than, the fabrics of commercial suits. Membrane Technology and Research, Inc. (MTR) compared the economics of using a suit made from their fabric with a Saranex-coated Tyvek and Barricade suit. Results indicated that although the MTR suit is more expensive ($53 versus $31 to $45), the life-cycle cost of using the MTR suit is less than for Saranex-coated suits because of increased worker productivity when wearing the suit.

COLLABORATION/TECHNOLOGY TRANSFER

This project is funded through METC via an Industry PRDA award. MTR was founded in 1982 as a membrane research company with the long-term goal of developing marketable membrane technologies. MTR's programs have focused on gas separation and pervaporation, and have ranged from fundamental development to full-scale demonstrations. Uretek is conducting the lamination of the MTR permselective fabric onto the sorptive layer. Kappler Systems manufactures the suits from the laminated fabric.

ACCOMPLISHMENTS

- Completed development of fabric materials and the layering configuration.
- Produced rolls of laminated fabric to conduct laboratory tests and to send samples of the fabric to Uretek for lamination.
- Received two laminated rolls of fabric from the Uretek. One roll of fabric (90 meters by 30 inches) uses rip-stop nylon as both inner and outer layers. The second roll (40 meters by 30 inches) uses the rip-stop nylon on the outside and a flexible, lightweight, nonwoven fabric on the inside.
- Received prototype suits manufactured by Kappler Systems. These included: 13 suits from MTR 1 fabric (rip-stop on both sides), five suits from MTR 2 fabric (rip-stop/nonwoven), six suits from Saranex-coated Tyvek fabric, and six suits from uncoated Tyvek fabric. Saranex and Tyvek suits were produced so that identical suits made from conventional fabrics were available to compare with suits made from the MTR fabrics.

TTP INFORMATION

Protective Clothing Based On Permselective Membrane and Carbon Adsorption technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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BIBLIOGRAPHY OF KEY PUBLICATIONS

Gottschlich, Douglas, and R. Baker. "Protective Clothing Based on Permselective Membrane and Carbon Adsorption," *Proceedings of the Environmental Technology Through Industry Partnership Conference*, DOE/METC-96/1021, Vol. 1, p. 65 (October 1995).

2.3 Characterization of Radioactive Contamination Inside Pipes With The Pipe-Explorer™ System

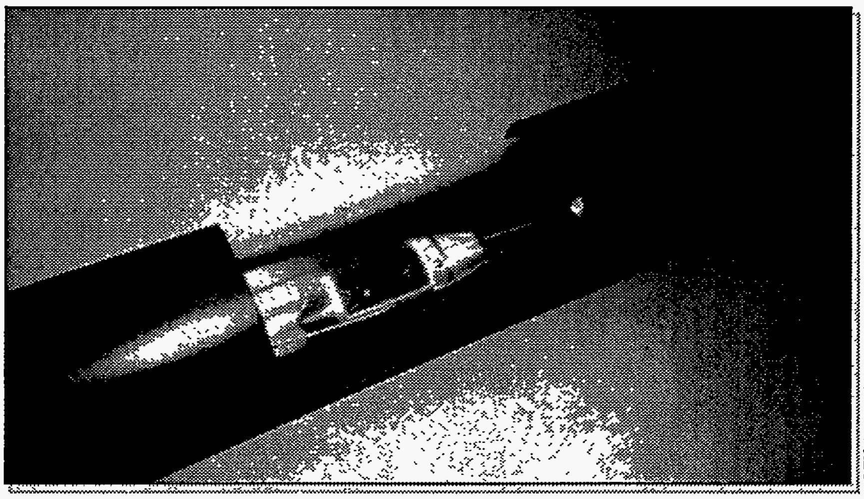
Technology Need

Pipes and ducts that are potentially contaminated are difficult to access and characterize. Buried drainlines, or those encased in concrete, must often be excavated to satisfy survey requirements. Therefore, characterization efforts require significant additional effort and cost.

Standard internal detection methods, such as pipe crawlers and push rods which become contaminated, can lead to ambiguous results. There are additional limitations associated with these alternative methods. For example, pipe crawlers are typically limited to larger diameter pipes (greater than 4 inches). They are also cumbersome to operate around elbows, and have a difficult time in pipes with slippery surfaces. Push-rod methods are limited in length and are often unreliable when trying to get a detector around elbows.

Technology Description

The objective of this effort is to develop and demonstrate the Pipe-Explorer™ System, a remotely operated system for surveying radiological contamination in pipes. The Pipe-Explorer™ System, shown in Figure 2.3-1, integrates standard radiation detectors with a unique inverting-membrane deployment method (originally developed for sensor deployment in boreholes and known as SEAMIST™), which tows instruments through a long, tubular membrane inside pipes. The initial deployment system consists of sodium-iodide and cesium-iodide scintillation detectors coupled to photomultiplier tubes.



GFX.96-0031

Figure 2.3-1. The Pipe-Explorer™ System.

Electrical pulses proportional to radioactivity are transmitted through a cable back to the data acquisition system. Pulses are either counted for gross contamination or analyzed with a multichannel, pulse-height analyzer to determine their energy and the specific radioisotope. Based on end-user requests, alpha and beta detection and visual capabilities have also been developed.

BENEFITS

DOE's Formerly Utilized Sites Remedial Action Program co-funded a demonstration of the gamma and beta activity-detection system at a Program site in Adrian, Michigan. The Pipe Explorer™ was used to characterize over 1,000 feet of suspect contaminated drainline at the site. Program personnel estimate that the Pipe-Explorer™ System saved DOE over $1.5 million. This estimate is based on the cost to dig up and characterize the suspect pipes and includes the costs of shutting the facility down for 90 days, which would have been required to do the work. A second demonstration at an operating DOE research facility saved an estimated $500 thousand because piping suspected of contamination did not have to be excavated to be characterized. Instead, after the aging piping was determined to be uncontaminated, it was allowed to remain in place and could be structurally upgraded with a low-cost, slip-lining technique.

The use of Pipe Explorer™ offers many technical benefits including:

- Enables 100 percent gamma, beta, and alpha surveys of pipe interiors, even in buried pipes
- Prevents detector from becoming contaminated
- Eliminates spread of contamination along pipe
- Reduces personnel exposure
- Provides ability to operate around elbows

COLLABORATION/TECHNOLOGY TRANSFER

This program is funded through METC via an Industry PRDA award. Science Engineering Associates develops, builds, and commercializes radiological and chemical characterization technologies for application to DOE needs.

ACCOMPLISHMENTS

- Demonstrated the viability of the Pipe-Explorer™ System at the Idaho National Engineering Laboratory on a drainline mockup (with calibrated Cs^{137} sources mounted to the pipe's exterior) and on sections of suspect contaminated scrap pipe in July 1994. In the drainline mockup tests, the Pipe Explorer™ unambiguously detected the Cs^{137} sources ranging in activities from 0.449 pCi to 0.047 pCi.
- Completed a successful characterization of 175 feet of drainlines at a Program site in April and May 1995 (see Benefits section).
- Evaluated scintillating materials for alpha detection. ZnS(Ag) was the scintillator of choice. Due to the fact that it has high light output (large number of photons emitted per alpha particle), it is a good spectral match with existing high sensitivity photodetectors, is relatively inexpensive, easily incorporated into a thermoplastic such as polyethylene, and is a nonhazardous material.
- Completed the second full-scale demonstration of the Pipe-Explorer™ System in November 1995. A major milestone in this demonstration was the inclusion of a video survey with the System. It was found that very clear, good resolution pictures could be obtained through the membrane. Further, the camera was well protected by the Pipe-Explorer™ membrane. The video pictures were used by site personnel to assess the structural integrity of the drainline, assess the level of buildup in the pipe, and to verify configuration of the drainline system. Beta and gamma activity characterization was also accomplished.
- Selected an optimum model photomultiplier tube for a prototype detector package for 4-inch pipe geometry and placed an equipment order.

TTP INFORMATION

Characterization of Radioactive Contamination Inside Pipes with the Pipe-Explorer™ System technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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BIBLIOGRAPHY OF KEY PUBLICATIONS

Cremer, C. David, W. Lowry, E. Cramer, and D.T. Kendrick. "Characterization of Radioactive Contamination Inside Pipes with the Pipe-Explorer™ System," *Proceedings of the Environmental Technology Through Industry Partnership Conference*, DOE/METC-96/1021, Vol. 1, p. 204 (October 1995).

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2.4 COHERENT LASER VISION SYSTEM

TECHNOLOGY NEED

Robotic systems require detailed position and orientation data throughout the area in which they operate. Systems do not exist that can provide that data accurately and reliably. As a result, the full capability of robotic operations is typically hampered. Existing three-dimensional, vision technologies lack both resolution and sensitivity to ambient lighting conditions and surface shading. Various techniques, including world models and simulations, exist to work around these difficulties; but the challenges become even more severe if the work area itself is dynamic (i.e., other objects are moving, or the scene is changing).

TECHNOLOGY DESCRIPTION

The objective is to develop and demonstrate a sensor that can provide timely, accurate, and reliable three-dimensional position and orientation data in a dynamic environment. The Coherent Laser Vision System (CLVS), as illustrated in Figure 2.4-1, is a lightweight, compact, robust sensor that provides scanned images of 256 by 256 pixels at a rate of 1 frame per second. The radar uses the relatively large tuning range of injector laser diodes to achieve greater precision than available with other techniques. An eye-safe laser source is used. An acousto-optic scanner is used to steer the laser beam and enable addressability of all pixels.

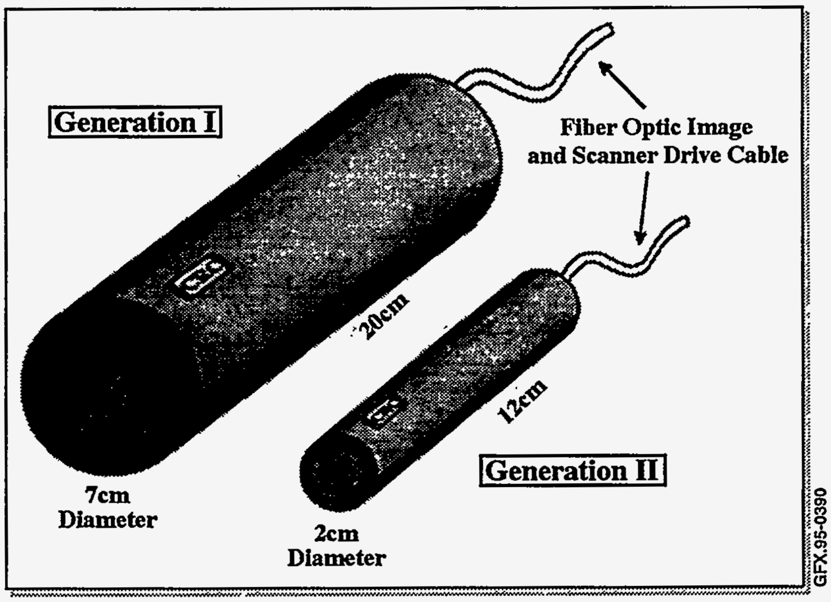

Figure 2.4-1. Coherent Laser Vision System.

The project is planned in two phases. Phase I includes the development of a prototype system with a two-dimensional scanner, a frame density of 128 by 128 pixels at 1 frame per second, and a 1.5 meter depth of range. In Phase II, the receiver will be upgraded; the frame density increased to 256 by 256 pixels; and the operating range increased to beyond 5 meters.

Benefits

Benefits of the CLVS include:

- Reduces need for humans to conduct simulations or remote operation
- Provides ability for robots to function in a dynamic environment
- Offers ability to detect low-contrast features and those of minor surface distortions
- Enables true robotic operations functioning on a real-time basis

Collaboration/Technology Transfer

Coleman Research Corporation is the prime contractor for this project which is funded through METC via an Industry Research Opportunity Announcement (ROA) award. Coleman Research Corporation designed the transmitter and receiver modules and is assembling the transmitter. Designs for the acousto-optic scanner were prepared by the University of Colorado and Essex Corporation, subcontractors to Coleman Research Corporation. The University of Colorado scanner design was selected for the CLVS, and they are now building the scanner. Sciteq Electronics supplied the direct digital frequency source to the University of Colorado for driving the scanner, and NEOS supplied the University of Colorado with the Bragg cell.

Accomplishments

- Completed design of the transmitter, scanner, and receiver
- Initiated assembly of the transmitter module
- Selected acousto-optic scanner designed by the University of Colorado, subcontracted to the University to build the scanner, and completed the optimization software
- Selected Sciteq Electronics to supply the direct digital frequency source that will drive the scanner and compensate for internal doppler shifts caused by the coherent frequency shifts of the laser interacting with the acoustic wave

TTP Information

Coherent Laser Vision System technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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Barry, R.E., M. Beckerman, B.E. Bernacki, T.W. Burgess, B.L. Burks, and O.H. Dorum. "A Preliminary Analysis of Metrology Techniques Related to ITER Mapping Requirements," Oak Ridge, Tennessee, Oak Ridge National Laboratory (1994).

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Sebastion, R.L. "Coherent Laser Vision System," *Proceedings of the Environmental Technology Through Industry Partnership Conference*, DOE/METC-96/1021, Vol. 1, p. 70 (October 1995).

2.5 THREE-DIMENSIONAL, INTEGRATED CHARACTERIZATION AND ARCHIVING SYSTEM

TECHNOLOGY NEED

Characterization sampling and analysis is a time-consuming, expensive process that requires workers to wear protective garments and equipment to guard against potential exposure to radioactive and other hazardous materials. After use, protective garments and equipment represent a secondary waste that requires disposal. Their use also increases the time required to accomplish the characterization task because of the time needed to don and remove the clothing and equipment. Additional costs are incurred for handling and transporting potentially hazardous samples. Off-site laboratory analysis is also expensive and time-consuming, necessitating delay of further activities until results are received.

TECHNOLOGY DESCRIPTION

The objective of this project is to develop a remote system that can perform rapid in situ analysis of hazardous organic and radionuclide contaminants on structural materials. This remote system is the Three-Dimensional, Integrated Characterization and Archiving System (3D-ICAS), depicted in Figure 2.5-1. The 3D-ICAS configuration consists of a mobile sensor platform and a mobile mapper platform that operate in contaminated areas, and an integrated

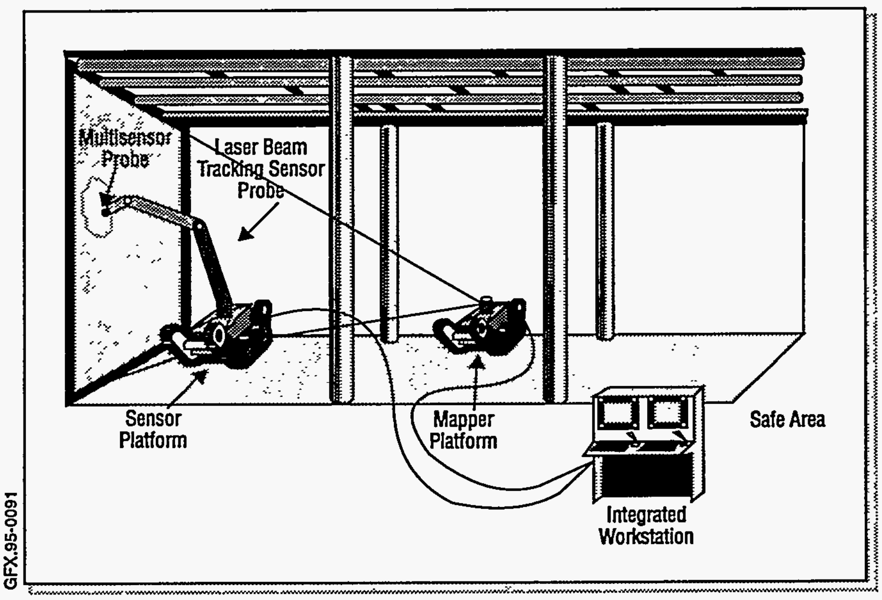

Figure 2.5-1. Three-Dimensional, Integrated Characterization and Archiving System.

2.6 Interactive, Computer-Enhanced, Remote-Viewing System

Technology Need

Remediation activities conducted using remote robotic systems can be expensive and slow due to the time needed to analyze geometric information regarding the site scene and task, and to provide the robotic operator with that information in a form that can be efficiently used.

Technology Description

The objective is to develop and demonstrate an Integrated, Computer-Enhanced, Remote-Viewing System (ICERVS) to provide a reliable geometric description of a remote environment. Figure 2.6-1 displays how ICERVS works. Development of ICERVS is planned in three phases. The majority of the work in Phase I involves development of the basic analysis software and demonstration of the data library and tool-kit subsystems. Phase II includes development of a subscale model of ICERVS. Phases I and II have been completed. The result of Phase II was a system that demonstrated topographical mapping by a structured light subsystem, video display of a workspace by a remote-viewing subsystem, software simulation of other sensor subsystems, software that provided enhanced data analysis and visualization tools, software that provided enhanced geometric-modeling capabilities, and an integrated

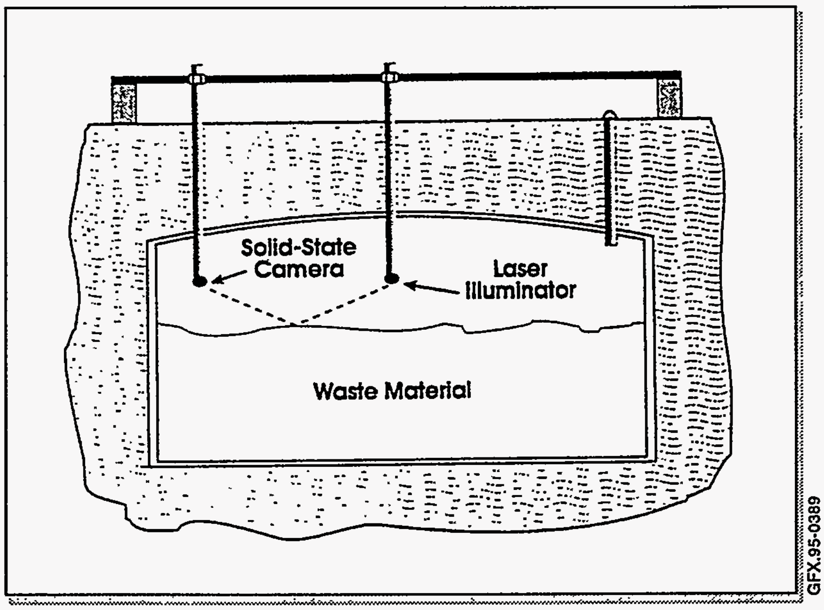

Figure 2.6-1. Interactive, Computer-Enhanced, Remote-Viewing System Deployment.

user interface. The project is currently in Phase III of development, which is designed to achieve a full-scale, integrated system and demonstrate this system at a DOE site.

Benefits

The ICERVS will serve as a critical subsystem that will allow robotic remediation tasks to be conducted more effectively and economically than with the present system. ICERVS will help an operator to analyze a scene and generate additional geometric data for automating significant portions of the remediation activity by using the following features: storage and display of empirical sensor data, ability to update segments of the geometric description of the task space, and side-by-side comparison of a live TV scene and a computer-generated view of the same scene.

Collaboration/Technology Transfer

This project is funded through METC via an Industry PRDA award. Mechanical Technology, Inc. designs and develops intelligent, custom systems with measurement and data acquisition capabilities for both DOE and commercial customers.

Accomplishments

- Completed final system design and the initial volumetric-data software to display views of data sets that have been finished.
- Initiated development of the full-scale, Release B version, visualization and analysis software. The major effort is focusing on updating the ICERVS data set to incorporate capabilities for storing and displaying "nonscaler" data, specifically images, text, and numerical arrays.

TTP Information

Interactive, Computer-Enhanced, Remote-Viewing System technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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BIBLIOGRAPHY OF KEY PUBLICATIONS

Mechanical Technology, Inc. "Integrated, Computer-Enhanced, Remote-Viewing System (ICERVS)," *Phase II Topical Report* 95TRI (November 1994).

Tourtellott, J.A., and J.F. Wagner. "Integrated, Computer-Enhanced, Remote-Viewing System (ICERVS)," *Proceedings of the Environmental Technology Through Industry Partnership Conference*, DOE/METC-96/1021, Vol. 1, p. 254 (October 1995).

2.7 PORTABLE SENSOR FOR HAZARDOUS WASTE

TECHNOLOGY NEED

Many DOE sites have areas, buildings, and waste materials that are contaminated with hazardous chemicals, including organics, heavy metals, and radionuclides. Current hazardous waste site characterization and compliance monitoring methods generally involve sample retrieval, packaging, transportation, and off-site analysis. This process is both time consuming and expensive. Better methods are needed to accelerate site characterization, improve compliance assurance, and reduce site cleanup costs. New technologies are needed that are capable of rapid and sensitive detection of hazardous compounds for a variety of applications, while maintaining portability for field use.

TECHNOLOGY DESCRIPTION

The objective is to develop and demonstrate a compact, portable, real-time, analytical instrument based on the principle of active-nitrogen-energy-transfer technique to quantify concentrations of specific hazardous components, including polychlorinated and nonchlorinated hydrocarbons; transuranics; uranium; thorium; and heavy metals, including mercury, chromium, cadmium, arsenic, and lead. Contaminated samples will be prepared and injected into a stream of active nitrogen, which causes fluorescence to occur. This fluorescence is detected conventionally, using simple optical detectors. Figure 2.7-1 illustrates the potential applications of the portable sensor for detecting hazardous waste.

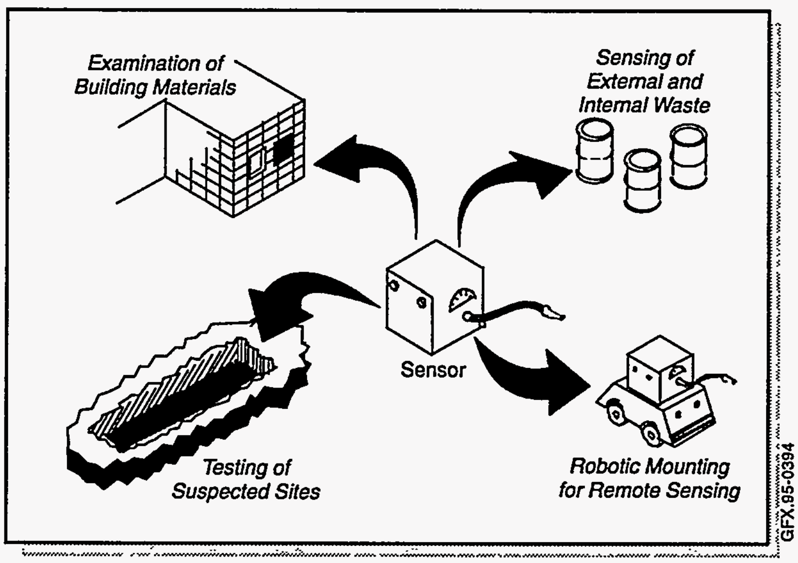

Figure 2.7-1. Portable Sensor for Hazardous Waste.

Benefits

This system's relative absence of interferences, combined with strong fluorescence signals, allows for simultaneous, real-time, multicomponent detection with high sensitivity. The system's field portability will reduce sampling and analysis costs.

Collaboration/Technology Transfer

This project is funded through METC via an Industry PRDA award. Physical Sciences, Inc. is a small business dedicated to producing new commercial products and entities through research and development.

Accomplishments

- Demonstrated the detection of the heavy metals mercury, chromium, and selenium. The detection limit for selenium and mercury was well below part-per-billion levels, while that for chromium appeared to be just below part-per-million levels.
- Demonstrated that organic species evinced strong emissions from cyanide radicals at 388 and 420 nm. Detection limits for the organic species were approximately 5 parts-per-billion at both 278 and 388 nm.
- Demonstrated that chlorinated organic species displayed chlorocarbon emissions at 278 nm.
- Completed efforts to detect oxygenated organics by observing emission from hydroxyl radicals at 283 or 308 nm. No detection was observed.
- Prepared, and circulated to various DOE sites, a questionnaire to develop a better understanding of the characterization problems posed by the contaminants found at each site. The questionnaire requests information on contaminants, analytical techniques currently employed, limitations and cost of current analytical technology, and attributes of importance in technology (i.e., sensitivity, reliability, accuracy, portability, etc.).
- Completed in-house experimental facility and began investigation of active-nitrogen-energy-transfer excitation of lead.

TTP INFORMATION

Portable Sensor for Hazardous Waste technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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Piper, L.G., M.E. Fraser, and S.J. Davis. "Portable Sensor for Hazardous Waste," *Proceedings of the Environmental Technology Through Industry Partnership Conference*, DOE/METC-96/1021, Vol. 1, p. 47 (October 1995).

2.8 Rapid-Surface Sampling and Archive-Record System

Technology Need

Current wipe-test-type methods for characterizing the extent of organic contamination, such as oils, chlorinated hydrocarbons, polynuclear aromatic hydrocarbons (PAHs), and PCBs on building surfaces, are inefficient, expensive, subject to operator variability, give nonreproducible results, and expose workers to added health and safety risk of solvent vapors. Improved methods for sampling and sample handling are needed to cost-effectively deal with the extremely large areas requiring characterization at DOE sites.

Technology Description

The objective is to develop and demonstrate an instrument to cost-effectively sample concrete and steel surfaces in order to provide a near real-time, "quick-look" measurement for the presence or absence of semi-volatile organic contaminants. When fully developed, the Rapid-Surface Sampling and Archive-Record system, as shown in Figure 2.8-1, will have the capability to trap up to 50 separate samples in a convenient manner and transfer them to a modified, commercially available, thermal-desorption autosampler for subsequent analysis. The fully integrated, laboratory-scale system will be constructed, with each component engineered for direct integration into a functional, portable prototype suitable for field operations.

Benefits

DOE's potential benefits from using this technology include improved reliability and reproducibility, reduction of worker health risk, cost reduction over current sampling methods, and more efficient qualification for material recycle or disposition.

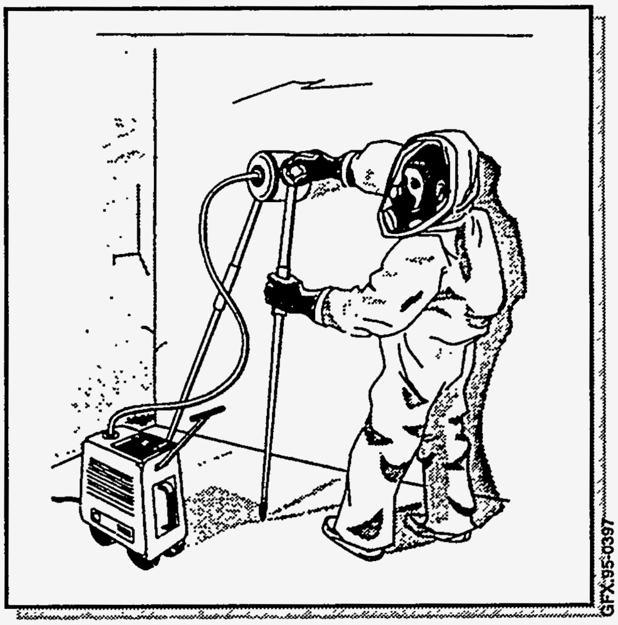

Figure 2.8-1. Rapid-Surface Sampling and Archive-Record System.

COLLABORATION/TECHNOLOGY TRANSFER

This project is funded through METC via an Industry PRDA award. General Electric Corporate Research and Development conducts research in a wide variety of disciplines. Their Environmental Laboratory develops cost-effective technology to address remediation, pollution prevention, and product stewardship needs. EAI Corporation will design and assemble the multisample trapping module. A meeting was held in late 1995 between EAI and General Electric Corporate Research and Development to discuss plans for the commercialization of Rapid-Surface Sampling and Archive-Record technology.

ACCOMPLISHMENTS

- Completed the design, construction, and testing of Rapid-Surface Sampling and Archive-Record system components such as the concrete sampler head, the bulk sampler head, and near-vacuum ultraviolet detector
- Optimized sampling-flow-rate conditions using the bulk sampler head by measuring sampling efficiencies using model compounds representing three major classes of pollutants: oil, PCBs, and PAHs
- Demonstrated a commercially available photoionization detector as a "quick look" indicator of surface contamination
- Demonstrated the feasibility of using Surface-Enhanced Raman Spectroscopy as an analytical tool for detecting PCBs in the presence of large quantities of oil
- Initiated design and fabrication of the multitube, sample-trapping module that will house solid-phase sorbent tubes and will allow for simple, automated, subsequent analysis of samples while providing direct transfer of sampling data for data-handling simplification
- Initiated design and assembly of a steel sampler head

TTP INFORMATION

Rapid-Surface Sampling and Archive-Record System technology development activities are funded under the following TTP:

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BIBLIOGRAPHY OF KEY PUBLICATIONS

Barren, E., D.R. Berdahl, C.M. Penney, and R.B. Sheldon. "Rapid Surface Sampling and Archival Record System," *Proceedings of the Environmental Technology Through Industry Partnership Conference*, DOE/METC-96/1021, Vol. 1, p. 44 (October 1995).

2.9 HIGH-SENSITIVITY MONITOR FOR RADIONUCLIDES

TECHNOLOGY NEED

Improved radiation-detection techniques are needed to reduce the time and cost required for many site characterization and environmental monitoring tasks.

TECHNOLOGY DESCRIPTION

The objective of this project is to demonstrate the applicability of a recently developed charged-particle, radiation-imaging technique for fast, cost-effective characterization of radionuclides at contaminated sites and in environmental samples. Initial studies have shown that this new technique, originally developed for biomedical applications, can be applied to detect all types of radioactivity, including alpha, beta (including tritium), gamma or x-rays, and neutrons. The technique uses storage photostimulable phosphor (SPP) sensors to detect radiation. This new type of sensor exhibits high sensitivity with excellent linearity over a wide, dynamic range for quantitative analysis. These reusable SPP sensors have an active area of up to 35 centimeters by 43 centimeters in size and a spatial resolution as fine as 50 microns. Multiple sensor plates can be deployed simultaneously to cover larger areas of interest.

BENEFITS

Using this technique, the "exposure" time for mapping radioactivity in environmental samples may be in terms of minutes, and offers spatial resolution not obtainable with counting equipment used at this time.

COLLABORATION/TECHNOLOGY TRANSFER

NeuTek is developing this system with funding made available through METC via an Industry ROA award.

ACCOMPLISHMENTS

- Applied the SPP technology to measure radioactivity strength and distribution of the following National Institute of Standards and Technology standard reference sources:
  - Alpha: Gd^{148}, Po^{208}, Th^{229}, U^{232}, U^{235}/U^{238}, Pu^{239}, Am^{241}, Cm^{243}
  - Beta: P^{32}, Sr^{90}, Pm^{147}, Tl^{204}
  - Gamma: Co^{60}

- Obtained soil samples from Oak Ridge and Rocky Flats for comparison testing. These soil samples were spiked with Pu and U in the range from 6.9 pCi/g to 340 pCi/g.
- Completed comparison testing between the SPP detection process and other detection processes, including an electret ionization chamber, a proportional counter, and a gamma spectroscopy system, with favorable SPP performance.
- Prepared several thin soil test samples for a Rocky Flats, National Institute of Standards and Technology, spiked sample. Measurements of the soil sample with SPP sensor plates indicate an alpha activity of 0.49 Bq/g. This compared very favorably to 0.47Bq/g obtained by radiochemistry method.

TTP Information

High-Sensitivity Monitor for Radionuclides technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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Bibliography of Key Publications

NeuTek. "Development of a High Sensitivity Monitor for Radionuclides Characterization," *Base Phase Draft Final Report* (revised February 7, 1996).

2.10 Multisensor Inspection and Characterization Robot for Small Pipes

Technology Need

The decontamination and decommissioning of shutdown plants require upfront characterization for planning and prioritization of activities, as well as to determine optimal waste separation and disposal scenarios. Across DOE, there are miles of small diameter pipes (less than 2 inches) that require characterization; however, no system currently exists to complete the task in a cost-effective, nonintrusive manner. Systems do exist for inspection of large diameter pipes, but do not have a full suite of instruments available.

Technology Description

The objective of this project is to develop an operational, commercial system for real-time, multisensor, characterization and mapping of small diameter, contaminated process pipes. Figure 2.10-1 displays the Multisensor Inspection and Characterization Robot for Small Pipes (MICROSPI) in its current stage of development. The product of this effort will be a semi-autonomous device with onboard miniature sensors and a remote operator interface with integrated data system. The display will be capable of inspecting pipes for radiation (alpha, beta, gamma), organics (solvents and PCBs), and metals (mercury, lead, arsenic, etc.), and capable of determining and mapping the locations of unknown pipes. This system will operate in both a moving, survey mode and a stationary, detailed-analysis mode.

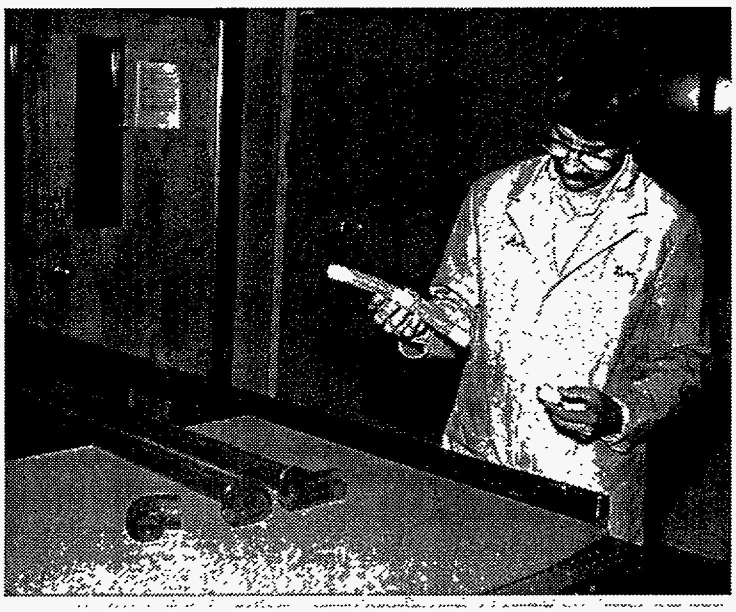

Figure 2.10-1. Multisensor Inspection and Characterization Robot for Small Pipes Deployment System .

Benefits

This system is in an early stage of development. Therefore, actual cost and benefit data are unavailable. Early estimates suggest that this robotic system can reduce the cost per inspection hour by a ratio of 12:1 over conventional characterization methods. In general, the benefits of this technology include:

- Reduced time to perform overall D&D, both during characterization and remediation
- Reduced waste generation since less disposable protective garments are required
- Improved waste segregation since accurate characterization allows appropriate level of planned work effort for different types of contamination
- Minimized airborne and localized spread of contaminants released by opening pipes and sampling
- Reduced overall D&D costs by eliminating the need for D&D, if no contamination is detected

Collaboration/Technology Transfer

Lockheed Martin Astronautics is developing this system with funding made available through METC via an Industry ROA award. The miniature sensors developed by this task complement and enhance existing and planned work within the DOE technology development community, such as efforts to develop a 3-inch pipe crawler, duct-crawling robots, and other mobility bases for 1-inch pipes.

Accomplishments

- Began investigating field demonstration opportunities at the Idaho National Engineering Laboratory, Los Alamos, and Rocky Flats.
- Initiated development of a conceptual design package. The basic concept for most of the elements has been selected; details of the exact configurations and interface issues are currently being addressed to complete the conceptual design.
- Selected initial approaches for three of the four basic sensing modules: visual, metal (element) detection, and radiation detectors. The organic characterization module has four concepts under review: a modified gas chromatograph, an ultraviolet spectrometer, a simplified photoionization detector for volatiles, and a gas field-effect transistor for volatile halogenated solvents and aromatics.

- Initiated an investigation of an interface issue involving the allocation of electronics. The most recent area of study is a Lockheed Martin proprietary fabrication technique called High Density Interconnect. This is as inexpensive as hybrid circuit construction and is more easily hardened against environmental hazards. Use of High Density Interconnect fabrication techniques could lower production costs by at least an order of magnitude without increasing development costs.

TTP Information

Multisensor Inspection and Characterization Robot for Small Pipes technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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Bibliography of Key Publications

None at this time.

2.11 A Robust Radiation Detector for Rapid Waste Characterization

Technology Need

This project directly addresses several needs for radiation detection including: portable sensors for use on robotic systems for waste and facility characterization; and field deployable equipment for rapid characterization of radionuclides in soil, groundwater, debris, equipment, and process effluents. The chemical vapor deposition (CVD) of a diamond coating on a Cadmium Zinc Telluride (CZT) solid state detector yields a sensor that is impervious to extremely hazardous environments such as corrosive chemicals and high radiation fields. The thin diamond coating detectors are excellent for measurement of alpha and low energy beta particles. Since diamond has very low dark currents, it can be expected to operate in ambient light. Standard use of separate handheld gamma ray and alpha particle detectors are inadequate due to excessive worker exposure, high expense of operating these detectors due to long times to cover large areas, and the labor costs. Commercial solid state detectors are available for alpha particle measurements, but these devices are not solarblind or impervious to corrosive chemicals and high radiation fields.

Figure 2.11-1 displays pulse height distributions measured by a Brookhaven National Laboratory/Northrop-Grumman (N-G)-made CVD Diamond Detector under 60-second exposure to 400 microCurie Am^{241} alpha radiation.

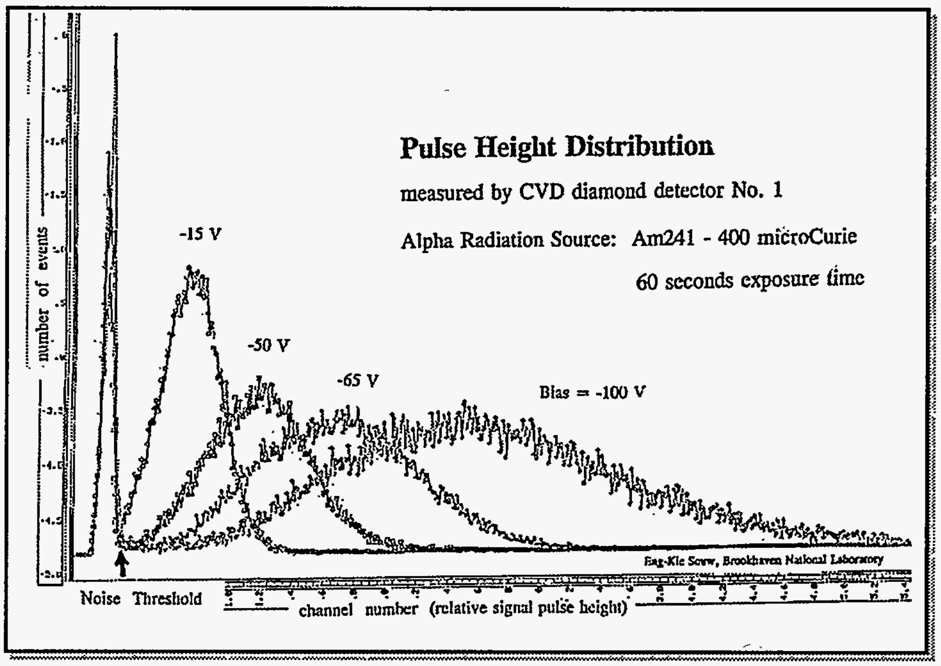

Figure 2.11-1. Pulse Height Distributions.

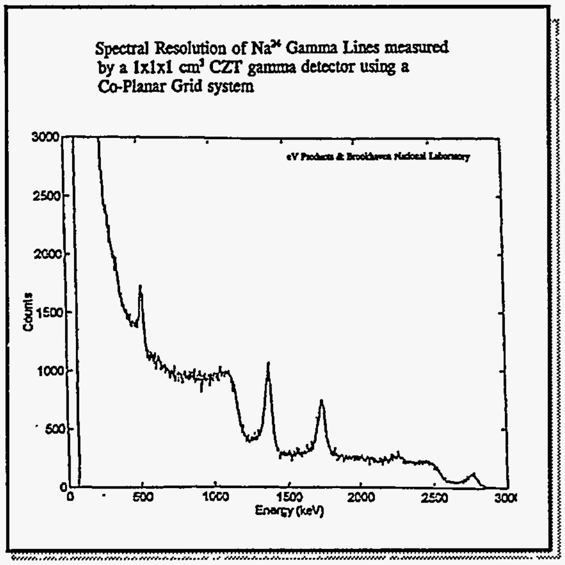

Figure 2.11-2. Spectral Resolution of Na^{24} Gamma Lines.

Figure 2.11-2 illustrates the spectral resolution of Na^{24} gamma lines measured in a 1x1x1 cm^3, eV-manufactured CZT detector with co-planar grid system. The gamma line at 1.3686 MeV is fully developed; the second gamma line at 2.7540 MeV is too energetic for a 1-cm-thick CZT wafer (hence, the low efficiency/peak intensity); the pertaining pair-production & double-escape peak appears prominently at 1.734 MeV.

TECHNOLOGY DESCRIPTION

To take advantage of the superior properties of diamond in this project, the conventional front electrode of the Standard Solid State detector is replaced by a p-type, boron-doped CVD diamond layer, so that only the diamond, and no metal layer or coating, is exposed to harsh environments.

CZT has been identified recently as being ultimately superior to CdTe with regard to gamma detection properties. To improve spectral resolutions at higher gamma energies, a recently invented co-planar grid (CPG) technology may be applied.

BENEFITS

Robust, miniaturized radiation sensors can be engineered to robotic systems to eliminate worker exposure during surveying of walls, floors, ceilings, process equipment, or debris.

Radiation sensors engineered to robotic systems are expected to lower surveying costs by more than a factor of ten by eliminating the need for survey and survey support team in the field and by cutting the time for characterizing large areas by over a factor of five by running robotic systems 24 hours a day.

Chemically robust and radiation-hardened sensors can be deployed into highly restricted facility areas and directly into waste and debris, allowing unique determination of the radiation levels at these sites.

Collaboration/Technology Transfer

This collaborative project is making use of N-G's plasma-enhanced CVD diamond reactor, as well as their expertise in diamond-growing and vacuum-brazing of diamond films to other materials. The project will also benefit from a collaboration with the N-G radiation detector group and the company's potential for nuclear detector commercialization.

The project (NJIT) is taking advantage of an existing BNL-New Jersey Institute of Technology collaboration between the BNL Principal Investigator and a NJIT Professor in photoluminescence and radiation damage in microelectronics, while making use of a BNL-owned laser and Charged-Coupled Device (CCD) camera installed at NJIT for that purpose.

As soon as the persistent problem with bulk polarization is resolved, a patent application will be filed for a CVD diamond alpha dosimeter. A second patent application on a complete alpha-beta-gamma detector system is planned, pending a successful development of a composite CVD-diamond/CZT device. These patents provides a basis for technology transfer to private industry, with N-G holding the primary license right.

Accomplishments

- Experimental results indicate that the distribution broadening occurs primarily due to a polarization effect which seems to stop, or at least to slow down substantially, after 11 minutes of continuous exposure under 150 V bias voltage while the pulse height distribution remains well-isolated from the noise background. If results prove reproducible, a diamond detector can be readily used as an alpha particle dosimeter.
- Analysis of gamma spectroscopic performance, with and without the CPG technique, has been conducted on CZT wafers manufactured by three different companies.
- Analysis of current transport and carrier trapping in CVD diamond from photo conductive current measurements has been carried out at BNL to improve the diamond detector performance and, in particular, to suppress the polarization effect.

TTP Information

Robust Radiation Detector for Rapid Waste Characterization technology development activities are funded under the following technical task plan (TTP):

TTP No. CH353001 "A Robust Radiation Detector for Rapid Waste Characterization"

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2.12 Airborne and Ground-Based Laser-Induced Fluorescence Imaging

Technology Need

Laser-induced fluorescence (LIF) addresses the need for rapid survey tools for monitoring sites remotely, identifying contaminant "hot spots," assisting in cleanup activities, and monitoring remedial progress. Future efforts may include verification of site cleanup if regulatory sensitivity can be achieved and verified through field tests. Development and field testing of an airborne survey tool for fluorescence and reflectance signature detection promises area coverage of sites that are either spread out geographically, such as uranium firing sites, or sites that have poor access, such as clay cap areas. The concept of detecting plant stress as an indication of subsurface contamination is an active area of research at a number of federal agencies, as well as many universities. The EPCOT Land Pavilion research and development (R&D) work brings researchers together from many institutions in an effort to better understand and scope the applicability of LIF as a remote sensing tool. Laser-induced fluorescence imaging (LIFI) applications include the detection of: uranium (as uranyl oxides) during D&D activities; surficial heavy metals and volatile organic compounds (VOCs) (solvents, polyaromatics, and fuels) associated with landfills; and vegetation stress as an indicator of subsurface contaminant plumes.

Technology Description

LIF is an optical technique that exploits the detection of fluorescent compounds irradiated with laser light or filtered conventional light sources. Fluorescence is the prompt luminescence of a material caused by an external stimulus — in this case, a laser. When the stimulus ceases, so does the fluorescence. Common compounds which fluoresce include such organics as chlorophyll in plants and hydrocarbon fuels. When uranium is excited by an ultraviolet laser, its peak fluorescence is persistent (phosphorescent), lasting much longer than the laser pulse. Operationally, the prompt fluorescence of compounds which may mask the presence of uranium can be removed by delaying the activation of a photon detector 60 nsec after a laser pulse. This precise delay ensures the extinction of prompt fluorescence, effectively isolating the presence of uranium.

A variety of techniques to exploit LIF in several environmental applications are being explored. Techniques include aerial remote sensing (Figure 2.12-1)) and hand-held portable survey tools (Figure 2.12-2) for detecting uranium on surfaces and subsurface contaminants via vegetation stress. This task has required the development of hardware, software, and analysis methods for ground-based and airborne LIFI systems. The current LIFI configurations

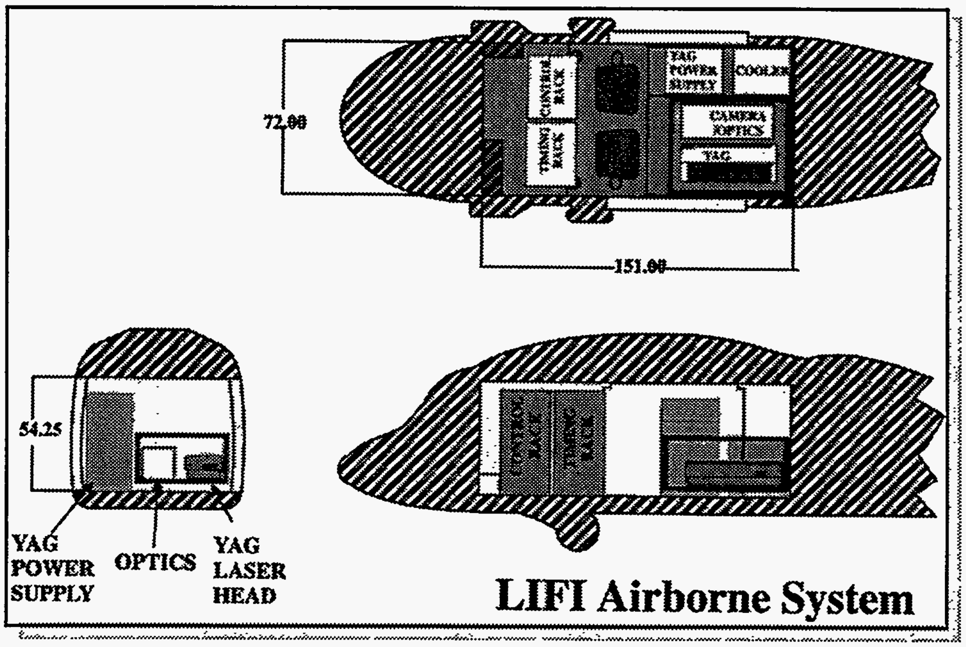

Figure 2.12-1. Blackhawk Helicopter System.

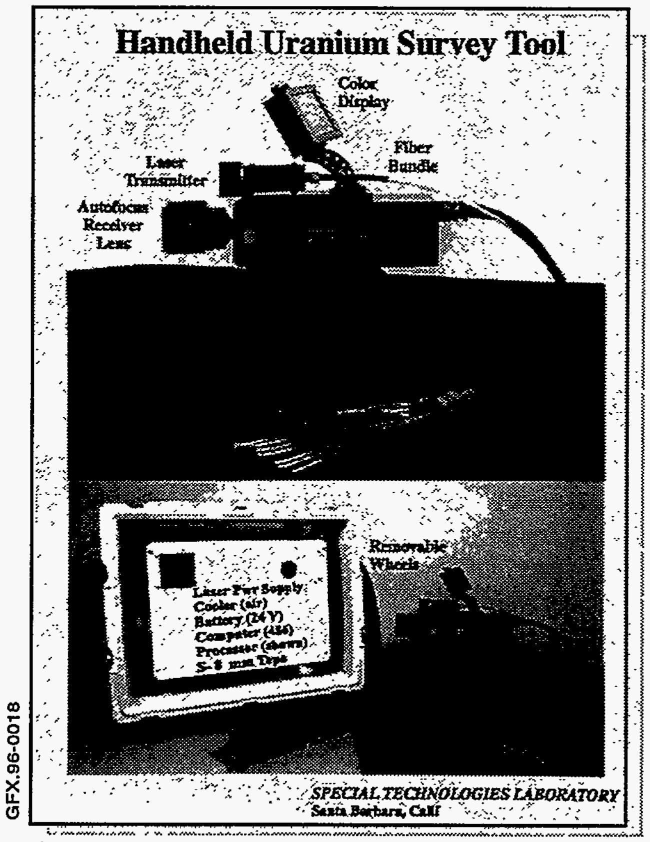

Figure 2.12-2. Hand-Held Laser-Induced Fluorescence Imaging System.

include ultraviolet and visible laser source (355 nm and 532 nm wavelength), intensified CCD cameras, and video monitors for instantaneous viewing. Video images can also be electronically stored for further analysis and display.

Current activities include: (1) completion of customer requested upgrades and fielding of the portable uranium survey tool at DOE sites for characterizing facility walls, floors, equipment, and surface soils; and (2) completion and flight testing of the airborne LIFI system. The hand-held uranium survey tool will be fielded in cooperation with EM-40 personnel for D&D applications at the Oak Ridge Gaseous Diffusion Plant (K-25) and the Fernald Facility. It will also be deployed at EPCOT Center's Land Pavilion to collect data on plant stress. The airborne LIFI system was configured last year for the DOE Convair 580T aircraft. The system has been reconfigured for helicopter usage, so that deployment is now possible on a variety of platforms, including the U-60 class (Blackhawk, Seahawk, and Pavehawk), Chinooks, and SH-3s.

BENEFITS

Fluorescence techniques have the ability to detect signatures that are not observable by traditional remote sensing methods. The high spatial resolution of intensified CCD cameras and the time-resolved phosphorescence emission characteristic of the uranyl ion allow one to obtain a digital picture of the extent of surface contamination. This allows mitigation efforts to be focused on specific areas, which speeds the survey and lowers overall costs. The real-time image processing of the data into a false color composite on gray scale background allows the operator to quickly distinguish the uranium signature. Since the data is recorded on video tape, they can be reviewed for planning and evaluation of D&D activities.

The advantages of airborne systems for remote sensing are well documented. Airborne operations allow one to survey large areas in a cost-effective manner. Many DOE sites are located in remote areas, with practical access obtained only from the air. An aerial view allows identification of subtle changes and patterns that are not apparent from ground-based operations. High resolution imaging techniques under development allow one to obtain a picture of the extent and location of surface contamination. This allows mitigation efforts to be concentrated on specific local areas.

Participation with EPCOT Center in plant studies affords the opportunity to collaborate with world class plant physiologists to study the effects of plant pathogens and contamination. A variety of sensors will be used and compared to evaluate the concept of plant stress. EPCOT Center will act as a focal point for collaboration across agency boundaries and act as a site for continued collaboration. The development of robotic systems will provide platforms for testing the concept of LIF on sites of agricultural interests.

Collaboration/Technology Transfer

The LIF project has often used the leverage of collaboration to control costs, especially in joint agency field exercises. Efforts with EPCOT scientists have involved scientists from the DOE Remote Sensing Laboratory, DOE Special Technologies Laboratory, Army Topographic Engineering Lab (Army Corps of Engineers), and Rochester Institute of Technology. Field tests have been performed in collaboration with the above-mentioned federal agencies, members of EM-50 and EM-40 at the Oak Ridge reservation, and EM-50 personnel at Savannah River. FY96 field tests at the Oak Ridge Gaseous Diffusion Plant will be completed in collaboration with EM-40 at K-25.

An agreement with Aerodyne to conduct sensor research and development for plant stress detection at EPCOT has been developed. FY96 technology transfer activities include the commercialization of a disk interface card with SYSTEMWARE, a disk manufacturer in Westlake Village, California.

Accomplishments

- Deployed the hand-held LIFI system at the K-25 Gaseous Diffusion Plant in Oak Ridge, Tennessee, to detect uranium during D&D operations; the K-25 uranium cylinder storage yards (E and K) to detect uranium on surfaces; and EPCOT Land Pavilion to detect chromium induced stress in plants. The system will also be deployed at the Fernald Facility for a D&D demonstration this year.
- Incorporated significant improvements to the hand-held system, including the addition of removable hard drives for increased data storage, expansion of digital LIFI data to 16 bits for greater radiometric resolution, integration of a companion analysis system for rapid data evaluation, and addition of a variable gate and delay laser control for greater flexibility of adjustments by the user.
- Reconfigured the airborne LIFI system for flight testing on a U.S. Army Blackhawk helicopter at the Yuma Proving Grounds and the Los Alamos National Laboratory late in 1996. All equipment pallets have passed preliminary flight approval from the Army. A lidar system has been added for altitude correction measurements. The final camera configuration is in progress and will be completed prior to the flight tests.
- Completed laboratory facilities and initiated plant experiments at the EPCOT Land Pavilion. A DOE scientist is at EPCOT full-time conducting experiments. The hand-held LIFI system was deployed at EPCOT in March, with a second data collection scheduled for April. Plans were approved for

a robotic system to automatically detect plant stress in the Land Pavilion. The robot has been selected and ordered, and the initial sensor suite has been determined.

TTP Information

Airborne and Ground-based Laser Induced Fluorescence for Environmental Monitoring technology development activities are funded under the following TTP:

TTP No. NVO5C253 "Airborne and Ground-based Laser Induced Fluorescence for Environmental Monitoring"

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2.13 SECONDARY ION MASS SPECTROSCOPY ANALYSIS

TECHNOLOGY NEED

DOE has many contamination problems requiring the determination of contaminants that adhere tightly to waste, environmental, and industrial surfaces. There is a critical need in DOE and industry for characterization technologies that are fast, inexpensive, and can address surface contamination. An excellent example of this need is the detection of mercury on soil samples, and equally important, the identification of mercury species present. The mercury speciation issue is important because differing environmental mobility among the species alters risk assessment associated with mercury contamination. For example, mercury present as $Hg(NO_2)_3$ is highly mobile and would require containment; on the other hand, mercury present as HgO strongly adsorbs to soil and poses a much lower risk. At the present time, there is no facile means to make a distinction between these species on soil samples. See Figure 2.13-1.

Another example of this need is characterization of core and particulate samples from radioactive waste in underground storage tanks, which currently costs an average of $750,000/core analysis. Technologies capable of determining chemical speciation are needed to reduce the number of analyses needed, and to improve the estimation of tank energy content (critical for risk assessment associated with tank characterization and remediation activities).

Figure 2.13-1. Depiction of Secondary Ion Mass Spectroscopy Bombardment of Hg-Contaminated Soil.

TECHNOLOGY DESCRIPTION

Fast, inexpensive, and nonpolluting instrumentation for the detection of surface contaminants is being developed at the INEL using advanced Secondary Ion Mass Spectroscopy (SIMS) technology. The attributes of this technology make it extremely attractive for waste and environmental characterization:

- No sample preparation is required.
- No waste is generated.
- Analysis is rapid and simple.

- It is capable of speciation, "fingerprinting."
- The technology is amenable to almost any sample type.
- It is amenable to involatile organics, salts.

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

The objective of the SIMS analysis program is to develop instrumentation and chemical applications for: (1) detection of chemical species; and (2) identification of semivolatile, involatile, or adsorbed contaminants on the surfaces of soils, minerals, salts, rocks, and other difficult-to-handle sample types. During the course of the SIMS Analysis program, detection applications and instrument development were accomplished. In FY96, the objective of the program is to transfer technology to end users and to instrument manufacturers.

Benefits

New analytical capability, reduced analysis cost, and technology transfer are among the benefits of the SIMS Demonstration Program. Since the technology requires no sample preparation, is rapid, and generates no waste, lower analytical cost can be realized. The technology also provides a facile approach toward the analysis of involatile contaminants that are difficult to analyze using current methods and instrumentation. Organophosphate and hazardous metal species are examples of classes of chemicals that are amenable to the SIMS characterization approach. The program has also resulted in the transfer of software components to instrument manufacturers, and the transfer of hardware components is expected in the near future. The development of the transportable ion trap SIMS instrument has resulted in a device which can be used in the field for on-site characterizations. Instruments that are based on the prototype are being constructed for other government users.

Collaboration/Technology Transfer

Technology transfer has been pursued with three vendors. Given the nature of the technology, the focus of technology transfer activities has been on transfer of SIMS components, instead of a complete instrumental package that would require the manufacturer to engineer its instrument from scratch. A license was completed for data acquisition and instrument control software with Extrel (Pittsburgh, Pennsylvania). Transfer of the primary ion gun technology to Phi-Evans, Inc. (Redwood City, California) has been actively pursued. This activity requires a head-to-head comparison of existing ion guns with the INEL ReO_4^--gun. It is expected that this activity will be completed by May 1996, and negotiations for transfer of ion gun technology will be renewed with Phi-Evans.

Figure 2.13-2 is a schematic diagram of a prototype ion trap SIMS instrument being developed at INEL. The instrument is capable of anion and cation acquisitions, and enhanced selectivity and sensitivity will result from MS/MS and selective ion storage capability. The capability of the instrument has resulted in a U.S. Department of Defense (DOD) end user (U.S. Army Chemical Material Destruction Agency, Non-Stockpile Program), who is funding fabrication of second generation prototype ion trap SIMS instruments. This development has motivated negotiations with Teledyne (Mountain View, California, ion trap vendor), for the purpose of transferring SIMS components, thereby providing the end user with a commercial technology vendor.

ACCOMPLISHMENTS

The rapid analysis of simulated salt cake samples was demonstrated using the laboratory-based SIMS instrument located at the INEL. The analysis required no sample preparation, and hence required less than 10 minutes; in addition, no waste was generated. A unique attribute of the 100 Award-winning, pulsed-extraction SIMS instrument is the ability to analyze anions and cations at the same time. This attribute is especially valuable for salt cake analyses because the salt samples contain both anion and cation species. Nitrite, nitrate, cyanide, and hydroxide anions; and iron, sodium, potassium, and nickel complexes were detected.

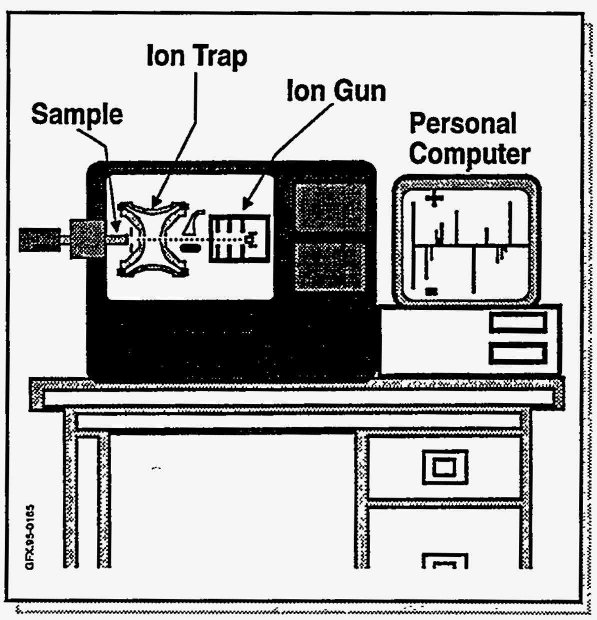

Figure 2.13-2. Prototype Ion Trap Secondary Ion Mass Spectroscopy Instrument.

Since demonstrating SIMS for the characterization of salt cake, the SIMS analysis has been redirected toward the determination of metal speciation on soil samples. Research conducted in FY95 using SIMS showed that different mercury species could be distinguished by forming surface derivatives, which is easily accomplished using simple organic acids and bases. The mercury surface derivatives were specific for the inorganic mercury species originally present, and were easily detected using an ion trap SIMS instrument (see Figure 2.13-2).

Instrument transportability, and improved sensitivity and selectivity are desired attributes of the instrumentation that will be constructed in this program. An ion trap mass spectrometer (ITMS) satisfies these requirements. Therefore, an ion trap SIMS instrument was constructed in FY95. Using this instrument, it is possible to observe fragile, but species-diagnostic organometallic ions, that cannot be observed using other types of instrumentation. The instrument is also smaller in size: the current version resides on a cart that has a footprint of approximately 2 by 3 feet.

TTP Information

Secondary Ion Mass Spectroscopy Analysis technology development activities are funded under the following TTP:

TTP No. ID72C241 "Secondary Ion Mass Spectroscopy Analysis"

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2.14 Inductively Coupled Plasma-Mass Spectrometry for Analysis of Microliter Samples and Solids

Technology Need

This project will provide analytical technology needed to support a wide variety of remediation problems, such as: (1) real-time measurement of transuranic elements and other radionuclides, (2) rapid measurement of Resource Conservation and Recovery Act (RCRA) metals in a wide variety of aqueous or organic solutions, and (3) the general need for sample dissolution for accurate quantitative determination of metals. The overall cost of such analyses will also be reduced because the amount of radioactive waste samples will be reduced to microliter quantities or less, which greatly simplifies containment concerns.

Technology Description

Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) is already a highly sensitive and selective method for elemental and isotopic analysis. This project includes investigation of the ability of a microscale nebulizer, called a monodisperse dried microparticulate injector (MDMI), to improve the sensitivity; speed; accuracy; and precision of ICP-MS for determination of stable elements and radionuclides.

Essentially, a micropump creates uniform wet droplets that are dried carefully and then introduced into the plasma for conversion into atomic ions. There is little or no waste solution, and 100 percent of the sample reaches the plasma. Exposure to radioactivity and waste cleanup problems during analysis will also be greatly reduced because the nebulizer requires only nanoliter to microliter volumes of solution.

Specifically, two related projects are under study: (1) direct analysis of very small solution volumes, and (2) on-line calibration for laser ablation ICP-MS, so that solids can be analyzed directly with better accuracy than is now achievable.

The analytical capabilities of MDMI-ICP-MS, such as detection limits and tolerance to concentrated sample matrices, will be evaluated thoroughly for real samples of interest in waste remediation. This sample introduction technology is potentially applicable to existing ICP-MS devices used for analyses that support waste cleanup. It should also be suitable for field use with a mobile ICP-MS device in a van.

Benefits

The major benefits are more sensitive measurement of radionuclides and stable elements with little waste solution, and direct analysis of solids with simple, accurate calibration procedures that do not require matrix-matched standards.

Collaboration/Technology Transfer

The MDMI is an advanced prototype donated by Perkin-Elmer SCIEX. They intend to offer the MDMI as a commercial product and are eager to collaborate on evaluation of its suitability for these special applications. The Principal Investigator has been associated with SCIEX since the early days of ICP-MS (since approximately 1982).

Accomplishments

- Achieved detection limits of approximately 0.1 fg of uranium in a solution volume of 0.1 nL, representing 250,000 atoms of uranium
- Improved precision from approximately 2 percent to 0.1 percent relative standard deviation for measurement of ion ratios in solids by laser ablation ICP-MS
- Implemented substantial operational improvements in the reliability and consistency of MDMI-ICP-MS and achieved fundamental characterization of matrix interferences
- Initiated feasibility experiments on calibration of laser ablation ICP-MS with solution aerosols

TTP Information

Inductively Coupled Plasma-Mass Spectrometry for Analysis of Microliter Samples and Solids technology development activities are funded under the following TTP:

TTP No. CH15C241 "Inductively Coupled Plasma-Mass Spectrometry for Analysis of Microliter Samples and Solids"

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2.15 PORTABLE X-RAY, K-EDGE HEAVY METAL DETECTOR

TECHNOLOGY NEED

Cleanup of many DOE facilities requires dismantling equipment that was used to process hazardous materials such as uranium, plutonium, and mercury. Using existing techniques, such as passive neutron and gamma measurements and neutron activation analysis, it is difficult and time consuming to detect and quantify these hazardous materials when they are contained within heavy equipment (i.e., steel pipes with 1/2-inch thick walls). The gaseous diffusion plant at the K-25 Site at Oak Ridge contains over 100 acres of heavy equipment used for separating uranium isotopes. Similarly, the Fernald Site has buildings and equipment used in processing uranium ore. Rapid in situ analysis of these types of equipment for hazardous elements is needed to improve the efficiency and safety of D&D efforts.

TECHNOLOGY DESCRIPTION

The K-edge technique provides an improved method for detection and quantification of heavy metals, such as Hg, U, Pu, located inside containers and equipment. An X-ray transmission measurement of the K-shell absorption edge of these materials is implemented in this task. This method provides accurate quantification of these elements regardless of container material and geometry. Typical accuracy of 10 percent for 10 mg/cm^2 of heavy metals in one inch of steel (100 ppm) is achievable. Figure 2.15.1 shows an example

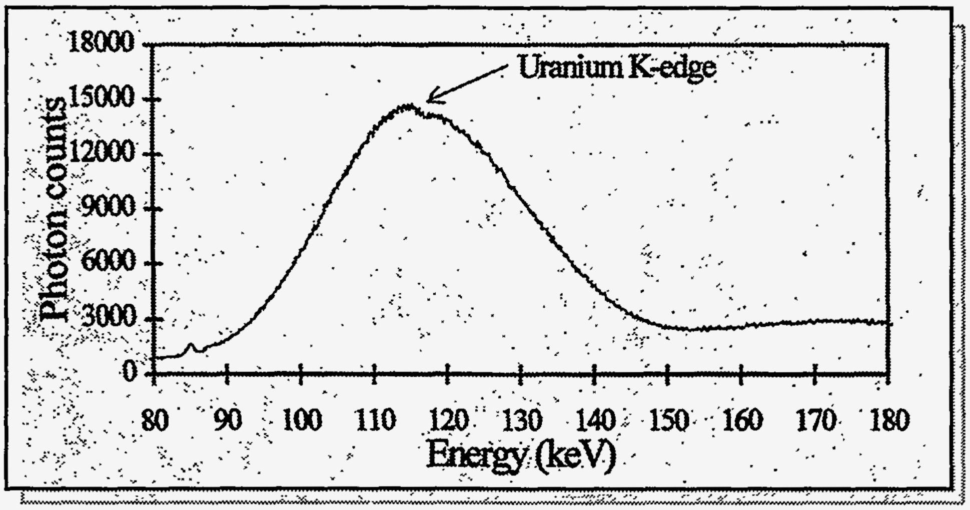

Figure 2.15-1. K-edge Absorption Spectrum for Uranium in a Steel Pipe.

of a K-edge absorption spectrum for 11 mg/cm^2 U inside a steel pipe with 1/2-inch thick walls. A fieldable prototype instrument is being developed, and will be tested at DOE sites in support of the D&D Focus Area.

Benefits

A fast in situ method for quantifying the presence of uranium, plutonium, and RCRA-listed heavy metals inside closed containers would greatly enhance the safety and efficiency of D&D efforts. In particular, there are residual deposits of uranium found in gaseous diffusion plant equipment and in ore refining facilities. Not having to dispose of process equipment as high-level waste would yield significant savings. Accurate determination of the level of hazardous metals present would enhance the safety of dismantling operations.

Collaboration/Technology Transfer

This project is currently being carried out at Iowa State University and Ames Laboratory, taking advantage of existing expertise at the Center for Nondestructive Evaluation. In development of the prototype instrument, we have worked with several companies to produce specialized components. Based on this work, we anticipate further collaboration with industry to optimize equipment to meet the needs of the technique.

Accomplishments

- Achieved measurement of 1.3 μm (2.5 mg/cm^2) gold in 1/2-inch steel
- Produced measurement of 2 μm (4 mg/cm^2) uranium in 1-inch steel
- Achieved measurement of plutonium in vitrified sample
- Designed prototype fieldable instrument

TTP Information

Portable X-ray, K-edge Heavy Metal Detector technology development activities are funded under the following TTP:

TTP No. CH15C251 "Portable X-ray, K-edge Heavy Metal Detector"

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2.16 Accelerated Facility Characterization Process Description

Technology Need

With the increased needs of federal agencies and regulators to accelerate the facility characterization activities and final D&D across the DOE complex, there is a growing need to broaden the approach to facility characterization. The objective of the Accelerated Facility Characterization (AFC) process is to provide a more efficient, scientific, innovative, and integrated approach to characterize nuclear and nonnuclear facilities.

Technology Description

An innovative approach to facility characterization that integrates all appropriate scientific disciplines and characterization approaches to provide more cost- and time-effective characterization of facilities is being developed. Fundamental to the AFC process is a multi-disciplinary team approach to problem solving. Facility characterization is accelerated by working smarter to address the characterization problem efficiently by using all available information and decision tools to avoid blindly collecting unneeded data. Efficient decision making implies an intimate working relationship between the planner, sampler, analyst, data interpreter, and decision maker. The AFC process encompasses the following elements and general flow: (1) identifying and assembling team; (2) defining the problem; (3) developing dynamic work plan for each characterization element; (4) executing characterization; and (5) reporting.

Benefits

The application of the AFC process will significantly reduce costs and time; obtain more accurate, rapid information; and allow better planning of facility D&D activities.

Collaboration/Technology Transfer

Argonne's role is to provide technical expertise and guidance in the application and implementation of the AFC process to characterize facilities across the DOE complex. Collaboration with other sites and private sector D&D contractors is also ongoing. The Characterization, Monitoring, and Sensor Technology Crosscutting Program and the D&D Focus Area jointly fund and closely coordinate this project.

Accomplishments

- Completed and delivered the project work plan
- Developed the AFC process and conducted demonstration activities

TTP Information

Accelerated Facility Characterization Process Description technology development activities are funded under the following TTP:

TTP No. CH26C251 "Accelerated Facility Characterization Process Description"

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None at this time.

2.17 DEFINING REQUIREMENTS FOR RADIOLOGICAL SENSORS AND ROBOTIC PLATFORM TECHNOLOGIES SPECIAL TECHNOLOGIES LABORATORY CHARACTERIZATION, MONITORING AND SENSOR TECHNOLOGY SUPPORT

TECHNOLOGY NEED

Task 1: The establishment of standards of quality for Office of Science and Technology (OST) programs will provide principal investigators, DOE customers, and DOE program reviewers with guidelines that can be used to evaluate existing and future OST proposals for quality and relevance.

Task 2: Identification of D&D measurements to be made, the platform and sensor problems associated with those measurements, and monitoring the appropriate sensor and platform technologies to ensure mutual compatibility will maximize the specificity of each to D&D measurements.

TECHNOLOGY DESCRIPTION

There is no single technology directly associated with this program. There are several varied technologies that are associated with programs currently being monitored and assisted. As a result, the technology description is better replaced with a task description.

Task 1: A document for each new program is prepared in association with the principal investigator. It includes a detailed set of performance specifications for use in reviewing proposals for new and future projects, with each examined for both technical and management contents. New, experimental plans are evaluated for overall technical merit by matching proposed capabilities with requirements to estimate the probability of success. Similar proposals are screened for duplication.

For existing programs, low profile, on-site visits are made to increase the accuracy of technical assessments. Evaluation criteria for each of the programs are established to provide standards for performance comparisons. Sensors and related instrumentation are evaluated for performance expectation, while data processing algorithms are examined for technical merit.

Proposed experimental plans, which include schedules, milestones, cost estimates, objectives, and performance specifications, are reviewed for reality and consistency. These criteria are then used to determine if the measured values meet regulatory requirements, projected milestones have been reached, data are both reasonable and realistic, and the system is performing as expected.

Task 2: Reductions and cessations of activities at nuclear weapon production facilities have generated a need for D&D activities at those sites. Selections of appropriate sensors and sensor systems depend strongly on measurements to be made and robotic platforms under development. This program will monitor the progress of radiological sensor technology development as it applies to D&D requirements.

Results of measurements at selected sites are monitored to evaluate the effectiveness of the sensors in meeting requirements. Deficiencies are noted and analyzed to determine if new and different sensor systems may be required. The results are communicated to OST for review.

Because the D&D requirements are constantly changing, measurement technologies will have to respond accordingly. This program assists OST in monitoring the progress of design, development, and availability of new and innovative sensors and sensor systems. It also assists in testing and evaluation for reliability and applicability. Visits are made to D&D sites to observe measurements to be made and sensor systems to be used. Robotics/sensor system communications are evaluated and monitored to ensure coordinated development. Sensor developments are also monitored to assess their utility in current and future measurements.

BENEFITS

Task 1: The enhanced quality of the OST programs will provide DOE with improved guidelines for evaluating existing and future research and development (R&D) proposals. Improvements in data quality will provide savings in cost and time, and reductions in human risk and waste generation.

Task 2: The enhanced quality of the radiological sensors in D&D applications will provide DOE with improved cleanup capabilities. Depending on the specific programs under evaluation, these improvements will contribute to savings in cost and time, and reductions in human risk and waste generation.

COLLABORATION/TECHNOLOGY TRANSFER

Not applicable for either task.

Accomplishments

- Developed the radiological sensor for Site Characterization and Analysis Penetrometer System to the level where it is ready for a full-scale demonstration.

TTP Information

Defining Requirements for Radiological Sensors and Robotic Platform Technologies Special Technologies Laboratory CMST Support technology development activities are funded under the following TTP:

TPP No. NV05C261 "Defining Requirements for Radiological Sensors and Robotic Platform Technologies Special Technologies Laboratory CMST Support"

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None at this time.

3.0 FACILITY DECONTAMINATION

Decontamination refers to the removal or reduction of radioactive or other hazardous contamination from facilities, including both structural (e.g., volumetric and surface-contaminated concrete and steel) and nonstructural (e.g., asbestos insulation and transite) materials and equipment. Decontamination techniques include chemical or electrochemical techniques, thermal techniques, mechanical cleaning and washing, or other techniques to achieve a stated objective or end condition.

The U.S. Department of Energy Decontamination and Decommissioning (DOE D&D) Focus Area has identified a number of deficiencies associated with baseline decontamination technologies including:

- Generation of airborne contaminants and/or secondary wastes
- Inefficiencies and expense of labor intensive, time consuming, and costly operations
- High risk of worker exposure
- Inability to efficiently decontaminate components having complex geometries or surface irregularities (e.g., welds in steel and concrete cracks and crevices)

Solutions to these problems include the development of remote techniques that reduce the risk of worker exposure, in situ decontamination methods that reduce the generation of secondary wastes or reduce the requirement for waste handling and/or waste processing, and methods for decontaminating inaccessible areas and equipment with complex geometries and surface irregularities. This section highlights the current D&D portfolio for the development of innovative decontamination technologies.

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3.1 DEMONSTRATION AND EVALUATION OF THE CORPEX™ NUCLEAR DECONTAMINATION PROCESS

TECHNOLOGY NEED

The removal of plutonium from equipment and systems is often costly in terms of dollars, personnel resources, personnel exposure, protective clothing and equipment requirements, and waste disposal. Surplus plutonium-contaminated facilities are located at Savannah River, Hanford, Los Alamos, and Rocky Flats. Technology that will enable safer, more efficient removal of plutonium in a cost-effective manner is needed.

TECHNOLOGY DESCRIPTION

The objective of this project is to demonstrate and evaluate the CORPEX™ Nuclear Decontamination Process for the decontamination of plutonium-contaminated facilities and equipment. The CORPEX™ chemical process is a nondestructive cleaning method that removes only the contaminant and the matrix that fixes the contaminant to the surface; it does not damage the substrate. The chemistry of the cleaning agent is destroyed by the addition of proprietary oxidizers, leaving only water, carbon dioxide, nitrogen gases, and the secondary waste sludge. The glovebox line in the old Metallography Laboratory in Building 235-F at Savannah River is the selected site for the CORPEX™ demonstration. The surfaces of the glovebox line have both removable and fixed contamination. The glovebox provides a highly contaminated area that is difficult to decontaminate, and also provides a containment to reduce the possibility of airborne contamination during the demonstration. A typical glovebox facility in which the CORPEX™ technology would be applicable is illustrated in Figure 3.1-1.

BENEFITS

A successful demonstration of the CORPEX™ process will likely result in widespread DOE use. Benefits include reduction of cost, schedule, and personnel exposure; waste minimization; and the possible free-release of decontaminated components.

COLLABORATION/TECHNOLOGY TRANSFER

Hanford, Los Alamos, and other appropriate DOE sites will be invited to view the demonstration when final arrangements are complete. The final report and recommendations will be evaluated for use on other systems and contaminants.

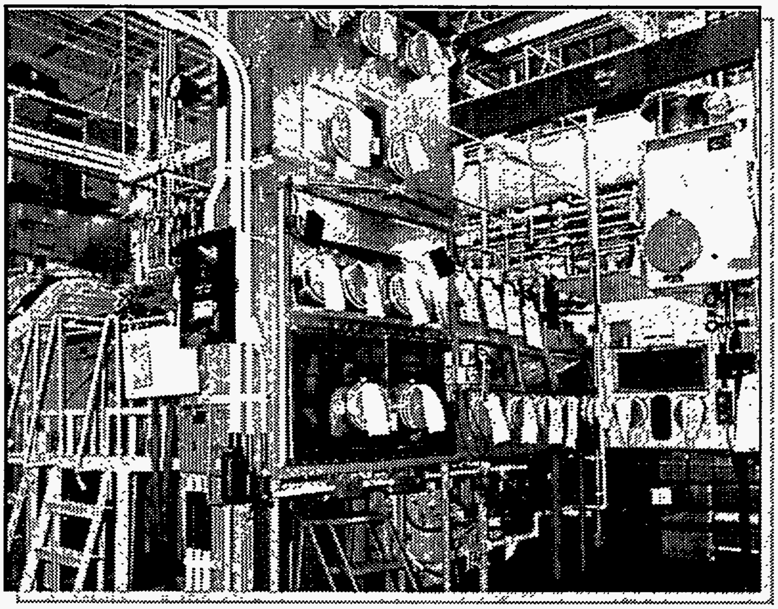

Figure 3.1-1. Glovebox Facility.

Accomplishments

- Awarded contract to Mele Associates (November 16, 1995) to implement the CORPEX™ decontamination process
- Received approval from DOE Savannah River (on December 15, 1995) on the Baseline Change Proposal to revise the 235-F facility Fiscal Year 1996 (FY96) work scope to accommodate the CORPEX™ demonstration
- Initiated facility preparation tasks, including sealing the glovebox seams, characterizing contaminants, formulating safety documentation, obtaining waste approvals, and equipping the glovebox room
- Initiated equipment and process design effort

TTP Information

Demonstration and Evaluation of the CORPEX™ Nuclear Decontamination Process technology development activities are funded under the following technical task plan (TTP):

TTP No. SR06DD21, "Demonstration of Improved Technologies At Ongoing Decommissioning Project"

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3.2 Gas-Phase Decontamination Process Demonstration

Technology Need

A 1993 DOE study reported that there are approximately 600,000 tons of radioactive scrap metal that is anticipated from the dismantlement of the Department's three gaseous diffusion plants. Consequently, the traditional disassembly/wet decontamination technique for decontamination of diffusion cascade equipment will be time consuming, labor intensive, and costly. In addition, wet decontamination results in the production of uranium oxide, which must be stored for an indefinite period of time because no oxide conversion facility is currently available. Health physics, environmental, and safety concerns associated with disassembling and handling contaminated equipment are numerous.

Technology Description

The objective of this project is to demonstrate the effectiveness of the long-term, low-temperature (LTLT) technique for in situ decontamination of diffusion-cascade equipment. This demonstration will have two phases: (1) a full-scale test on a shutdown diffusion cell, and (2) removal, disassembly, and characterization of a centrifugal compressor from the test cell after completion of the full-scale test. The process is illustrated in Figure 3.2-1. If proven effective, this technique could be applied to the decontamination of diffusion equipment across the complex.

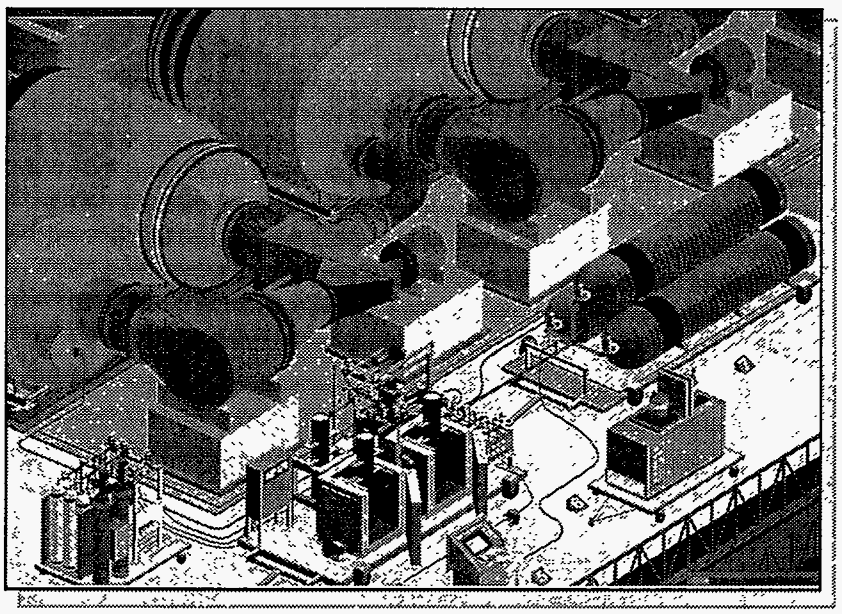

Figure 3.2-1. Artist Rendition of a Gaseous Diffusion Plant.

The LTLT process is an in situ technique that uses a mixture of treatment gases to decontaminate diffusion-cascade equipment. The treatment gases are injected into the diffusion cell at low pressure and allowed to react with the solid uranium deposits. Once the reactions have progressed to the desired level, the cell gases are removed and either returned to the operating cascades where recovered uranium hexafluoride is eventually withdrawn as low-enriched uranium product, or passed through cold traps to remove recovered uranium hexafluoride.

Benefits

Since multiple cells can be decontaminated simultaneously using the LTLT process, this technique is less time consuming and labor intensive than the conventional disassembly/wet decontamination alternative. In addition, since the LTLT process is an in situ process, decontamination does not involve disassembly and handling of contaminated equipment. This greatly reduces the cost of decontamination. The uranium hexafluoride recovered from this process can be converted into low-enriched uranium product, as opposed to the uranium oxide produced in the wet-decontamination process, which must be stored indefinitely for lack of an operating oxide-conversion facility.

Collaboration/Technology Transfer

Personnel from all the three DOE gaseous diffusion plant sites (Oak Ridge K-25, Paducah, and Portsmouth) have consulted on this project and have provided technical review of the demonstration test plans. This test effort will be integrated with ongoing laboratory investigations of the LTLT process at K-25, as well as other planned decontamination technology investigations.

Accomplishments

- Completed laboratory-scale testing of the LTLT process at K-25. Solid uranium deposit material was successfully removed from copper, monel, nickel barrier, and cast-aluminum substrates to surface contamination levels less than the release limits specified in U.S. Nuclear Regulatory Commission Guide 1.86.
- Prepared and approved engineering drawings needed to install instruments at the test cell local-control console.
- Received and prepared all analytical equipment needed to conduct the full-scale test. It is anticipated that the full-scale test can begin March 1, 1996, or sooner.

TTP Information

Gas-Phase Decontamination Process Demonstration technology development activities are funded under the following TTP:

TTP No. OR15DD41, "Demonstrate Gas-Phase Decontamination Process"

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Riddle, R.J. "Operational Strategy for Handling Safety Concerns During the LTLT Full-Scale Test," POEF-771-95-14.

Simmons, D.W. "The Stability of ClO_2 as a Product of Gas-Phase Decontamination Treatment," K/TCD-1116.

3.3 Concrete Decontamination By Electro-Hydraulic Scabbling

Technology Need

Contamination of concrete structures by radionuclides, hazardous heavy metals, and organic substances occurs at many DOE sites. In many instances, the contaminants penetrate into the concrete to such depths that surface cleaning is not sufficient. However, complete demolition of the concrete structure results in the generation of a large volume of contaminated and/or mixed waste, which requires regulated disposal. The problems of cost and logistics of the regulated disposal of such large quantities of mixed waste are significant.

Technology Description

The objective of this project is to develop and demonstrate a cost-efficient, rapid, controllable, concrete electro-hydraulic scabbling (EHS) process to remove surface layers of contaminated concrete while generating minimal secondary waste. This process is displayed in Figure 3.3-1. The EHS device delivers powerful shock waves to the concrete surface originated by a pulsed, high-voltage electric discharge between two electrodes. The hydraulic shock wave propagates through water between the discharge channel and the concrete, causing the concrete to crack and peel. The depth of scabbling is controlled by changing the pulse energy, shape, and electrode position. Water not only provides efficient transfer of energy, but also acts as a debris retainer and transport medium. The consumption of water in the EHS is much lower than in conventional high-pressure, water-jet decontamination techniques.

Benefits

The EHS process can be used to decontaminate deeply contaminated floors, walls, or ceilings. Benefits of the EHS process include reduction of waste volume subject to regulated disposal; reduction of health and environmental hazards associated with decontamination and demolition processes; and reduction of decontamination costs due to lower energy consumption, higher processing rates, lower labor requirements, and lower mixed-waste disposal costs.

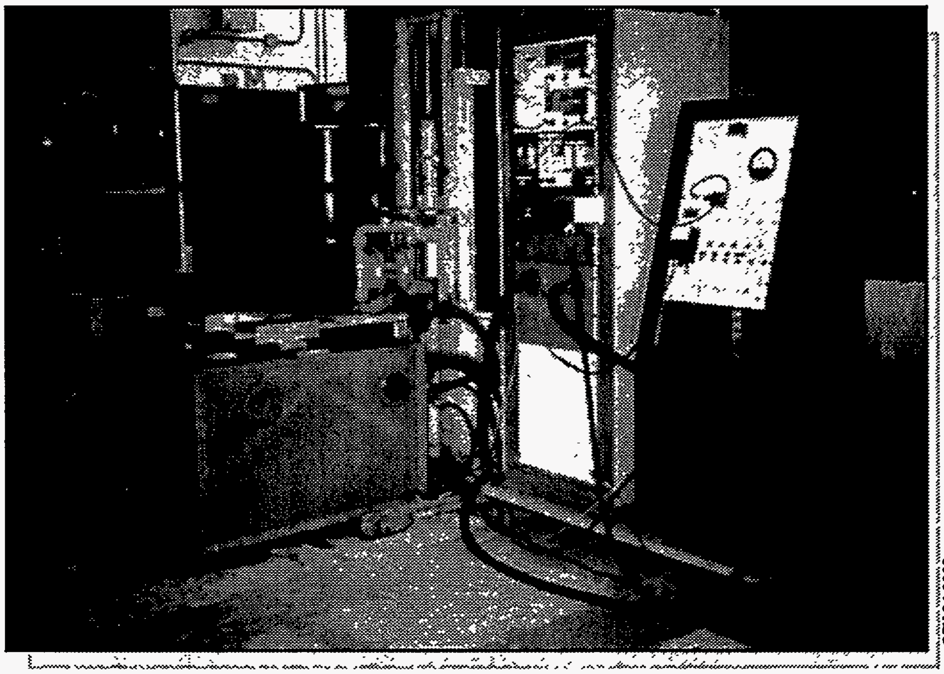

Figure 3.3-1. Electro-Hydraulic Scabbling System.

Collaboration/Technology Transfer

Textron Defense Systems has developed a variety of applications of high-voltage, pulsed discharge and pulse radiation technologies in lasers and treatment of gases and services. The EHS technology is being developed by Textron with funding through the Morgantown Energy Technology Center (METC) via an Industry Program Research and Development Announcement (PRDA) award.

Accomplishments

- Demonstrated concept feasibility in the laboratory; concrete surface layers were removed in a single pass with the EHS head creating a 1.5-to-2.5-inch-wide path.
- Developed a prototype unit and tested it on a nonradioactive concrete floor at the Textron facility during July 1995. A 2-feet-wide path was scabbled.
- Demonstrated EHS process at Fernald Plant 6 during September 1995, on a contaminated concrete floor. The system performed well, with no breakdown of any key component. Preliminary data indicate that scabbling depths of up to 0.75 inches and an average level of uranium removal of 83 percent were achieved.

TTP Information

Concrete Decontamination by Electro-Hydraulic Scabbling technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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Textron Systems Division. "Concrete Decontamination by Electro-Hydraulic Scabbling (EHS)," *Topical Report Phase* II (December 1995).

3.4 Electrokinetic Decontamination of Concrete

Technology Need

Concrete surfaces contaminated by radioactive isotopes, heavy metals, and organics create severe problems for conventional decontamination methods. Surface cleaning by mechanical scabbling or physical abrasion can result in the generation of large quantities of secondary wastes and highly toxic fine particles. Use of these methods also makes it necessary to employ stringent precautions to protect working personnel during the actual procedure. Disposal of large volumes of contaminated concrete and other wastes is expensive, requiring large portions of limited resources.

Technology Description

ISOTRON® Corporation has developed an electrokinetic process for in situ removal of contaminants from porous concrete. This method provides a viable alternative to scabbling or physical abrasion. The technology developed for electrokinetic decontamination of concrete surfaces applies an electric field to induce migration of ionic contaminants from within the porous concrete into the ISOTRON® decontamination unit.

The system, exhibited in Figure 3.4-1, has the following components: a proprietary Surface Electrokinetic Extraction Concept (SEEC) pad, electrolyte solution, and electrode. The electrolyte solution contains various complexants, as well as other materials to promote formation of a soluble ionic complex of each specific contaminant present. The electrolyte solution is in contact with the concrete surface through the SEEC pad, which consists of a fabric or carpet-like material that partially removes contaminants from the electrolyte solution and limits the solution's flow. All contaminants are collected in either the aqueous electrolyte solution and/or in the SEEC pad. Both of these can be treated and disposed of by conventional technologies. ISOTRON® is evaluating alternative configurations of the system to enhance the removal of specific contaminants from concrete.

Benefits

The electrokinetic decontamination process provides an in situ alternative to concrete decontamination, thereby eliminating physical or mechanical damage of the concrete, allowing for reuse of the structure or facility. This process generates minimal secondary waste and no airborne particulates common to conventional scabbling or physical abrasion techniques. Furthermore, compared to these conventional systems, the ISOTRON® process is capable of removing contaminants diffused deeply into concrete.

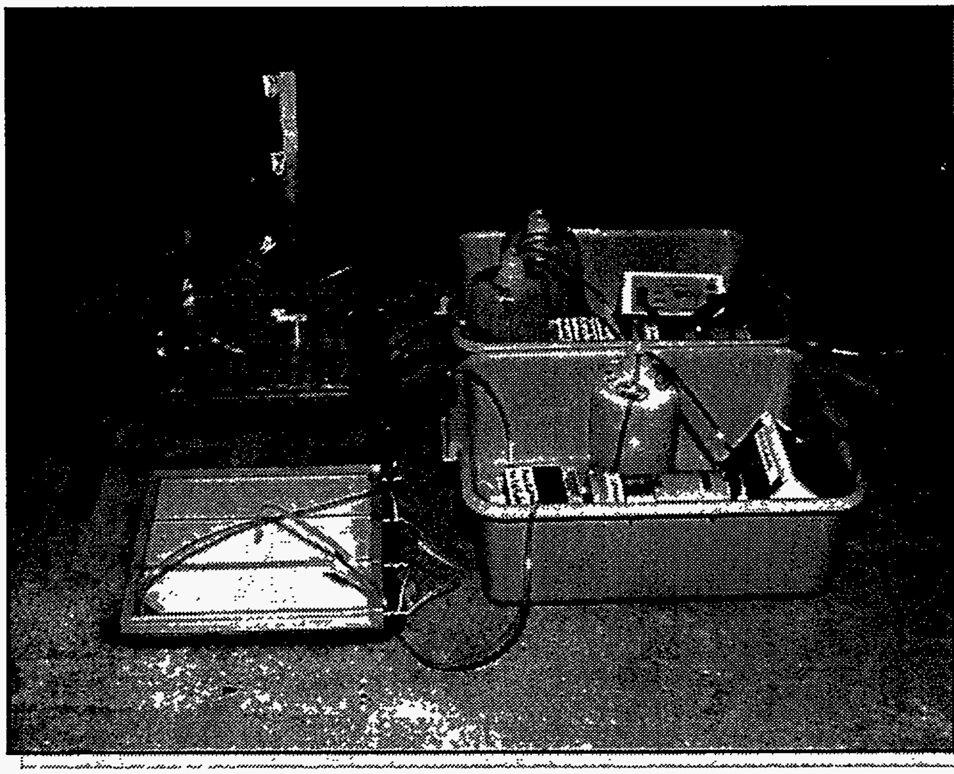

Figure 3.4-1. Electrokinetic Decontamination System.

Collaboration/Technology Transfer

This project is funded through METC via an Industry PRDA award. ISOTRON® Corporation develops innovative, environmentally safe, and energy and cost-efficient approaches for environmental restoration.

Accomplishments

- Completed laboratory-scale testing and procedures to verify the design
- Completed functional testing on the 4-feet-by-6-feet SEEC pad and various components of the electrokinetic extraction module
- Initiated design changes to the service module that is used with the SEEC pad to extract the contaminants
- Scheduled continuing testing of the electrokinetic extraction module which will remove thorium from the working solution so that the electrolyte can be continuously recycled

TTP INFORMATION

Electrokinetic Decontamination of Concrete technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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3.5 Laser Ablation of Contaminants from Concrete and Metal Surfaces

Technology Need

Over the years as buildings and equipment surfaces became contaminated with dust or spills from uranium and other radioactive materials, or became contaminated with hazardous materials like polychlorinated biphenyls (PCBs), the surface contamination was stabilized in situ by applying coats of paint, and in some cases, strippable coatings. Most of the earlier paint used was lead-based. More recently, hydrocarbon-based and latex paints have been used. Many facilities have been repainted many times, resulting in several coats. These coats not only vary in thickness, but often vary in types from one location to the next. For facility D&D, it is desirable to remove these coatings rather than having to remove walls and floors. Chemical paint strippers are messy, become contaminated, and result in an increased bulk of mixed hazardous waste. Sand, walnut-shell, water, metal or plastic-pellet blasting also adds to the bulk of contaminated waste. Dry-ice pellet blasting or liquid nitrogen cryofracture does not add to the bulk, but workers must wear air-breathing apparatus. None of these processes does an effective job of cleaning out surface pores of the substrate being decoated. Other techniques, such as microwave, cannot be used on metal surfaces nor on other substrates where heating cannot be tolerated. For all cleaning techniques, it has been found that filter clogging is a big problem, requiring frequent filter changes and the need to develop on-line recleanable filters.

Technology Description

The objective of this work is to modify and demonstrate high-power, high-repetition-rate industrial lasers to ablate coatings from metal and concrete surfaces in a controlled manner. Figure 3.5-1 displays the laser-ablation system. The laser uses the proper combination of wavelength, pulse duration, energy, power densities on target, pulse repetition rate, and scan rate. This not only yields efficient removal of coating material from the surface and surface pores, but also ablates material faster than a thermal wave can propagate into the substrate, preventing entrainment of surface contamination in molten substrate, and leaving behind a cool surface. This characteristic also avoids damage to the substrate and reduces potential volatilization of contaminants. A gas, vapor, and particulate suction device captures the ablated material. A vacuum system draws the mixture of entrained air and gases, vapors, and particulates from ablation through filtering stages.

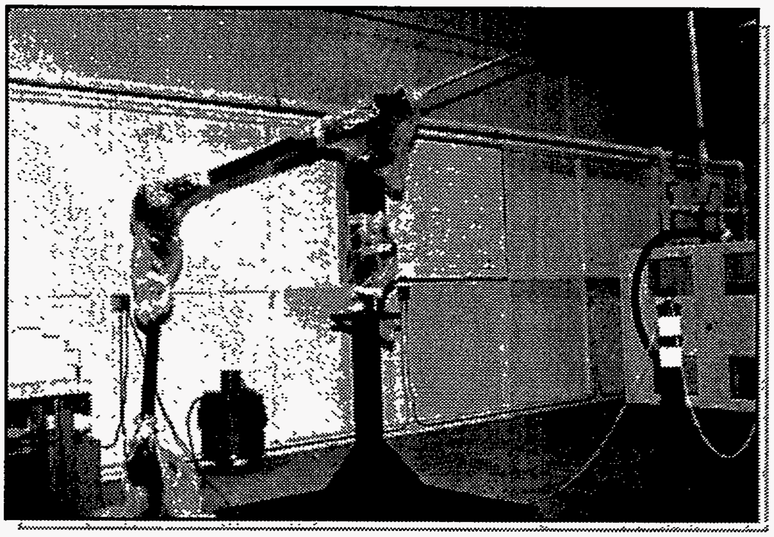

Figure 3.5-1. Laser-Ablation System.

BENEFITS

Benefits of the F2 Associates' laser ablation system include pore cleaning, waste volume reduction, negligible substrate damage to maximize salvage or recycle value, reduced worker exposure, one-step final containerization, no wet chemistry for cleaning or for processing residuals, and possible on-line assay.

COLLABORATION/TECHNOLOGY TRANSFER

This project is funded through METC via an Industry PRDA award. F2 Associates, through its Research and Development Division, is engaged in product improvement and innovative product development for both DOE and the Department of Defense. The market for nuclear D&D is quite large, involving both DOE and commercial nuclear facilities. In addition, the market for environmentally safe, nonradioactive, lead-based paint removal is huge for ships, bridges, and other facilities and structures. There is also a potentially large market for other applications, such as aircraft cleaning. Therefore, the technology being developed by F2 Associates is not only "dual use," but "multiuse."

ACCOMPLISHMENTS

- Demonstrated a 600-watt, laboratory-instrumented system, successfully removing paint and epoxy from concrete and metal surfaces.
- Initiated procurement of the equipment and materials for fabrication of the full-scale (6,000-watt), mobile-integrated, laser-ablation system. Several major assembly activities involving the mounting skid, modulator, pulse-power, controls, and output window have been completed.

TTP INFORMATION

Laser Ablation of Contaminants from Concrete and Metal Surfaces technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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3.6 REMOTE-OPERATED VEHICLE, DRY-ICE PELLET DECONTAMINATION SYSTEM

TECHNOLOGY NEED

Concrete surface contamination inside buildings is one of the most serious problems at DOE facilities. Contamination typically consists of various radionuclides, heavy metals, and organic deposits resulting from leaks and spills. New technologies are required to remove concrete surface contamination so that buildings can be reused; or, if they are to be dismantled, to permit disposal of the majority of the concrete as nonhazardous, nonradioactive waste.

TECHNOLOGY DESCRIPTION

The objective of this project is to develop a concrete decontamination system that integrates two demonstrated technologies: a remote-operated vehicle (ROV) and a dry-ice (CO_2) blasting system. This combined system, ROVCO_2, as portrayed in Figure 3.6-1, is based on an ANDROS remotely operated, six-wheeled vehicle designed for nonnuclear applications. The vehicle provides transport and power for all vehicle-mounted subsystems, which include the CO_2 XY orthogonal end effector (COYOTEE), cryogenesis dry-ice blasting system, and the vacuum/filtration/containment subsystems. The COYOTEE manipulates a specially designed vacuum containment workhead with the cryogenesis blasting nozzle to cover every point within a rectangular workspace.

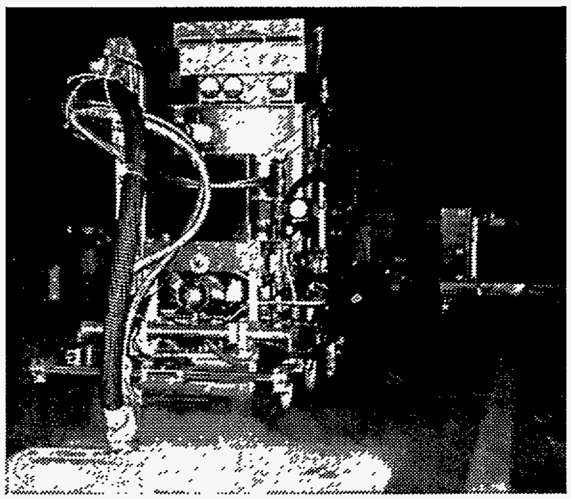

Figure 3.6-1. Remote Dry-Ice Blasting System.

BENEFITS

Since ROVCO_2 utilizes CO_2 gas, it has the potential to eliminate process waste resulting from the blasting material. Additionally, since the system is remotely operated, personal protection requirements, as well as worker exposure risks, are reduced.

Collaboration/Technology Transfer

The $ROVCO_2$ technology is being developed as a result of a PRDA award between METC and Oceaneering Technologies, Inc. Through its Research and Development Division, Oceaneering Technologies, Inc. is engaged in product improvement and innovative product development, and has teamed with two subcontractors for this project. Waste Minimization and Containment Services, Inc., inventors of the patented cryogenesis dry-ice blasting system, will adapt and enhance the system for remote operation. NSS Numanco, Inc. will be used for its expertise in the area of nuclear industry D&D.

Accomplishments

- Developed a prototype ROV using CO_2 pellet blasting to decontaminate concrete surfaces. Critical subsystems, including the CO_2 blasting base vehicle, work arm manipulator, and operator controls, were developed, tested, and integrated. Concept testing of the prototype system was performed on floors coated with a concrete sealant and with an epoxy paint.
- Completed reliability testing at the Oceaneering Technologies, Inc. laboratory. During these tests, the $ROVCO_2$ system was tested without operation of the cryogenesis subsystem, a minimum of 1,000 hours to determine its reliability and productivity. The full $ROVCO_2$ system, with operation of the cryogenic subsystem, was tested approximately 100 hours to gather data and establish the functional operating limits and sealing capacity for infiltration of contaminants from the blasting. Overall, the system performed very well, meeting most design criteria. Unfortunately, the commercial workhead was not as effective in containing the blasting debris as required.
- Selected an improved workhead with four critical orifice nozzles that surround and contain the blasting nozzle.

TTP Information

Remote-Operated Vehicle, Dry-Ice Pellet Decontamination System technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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BIBLIOGRAPHY OF KEY PUBLICATIONS

Resnick, A.M. "Remote Operated Vehicle with Carbon Dioxide Blasting," *Proceedings of the Environmental Technology Through Industry Partnership Conference*, DOE/METC-96/1021, Vol. 1, p. 239 (October 1995).

4.0 FACILITY DISMANTLEMENT AND MATERIAL DISPOSITION

This section highlights U.S. Department of Energy Decontamination and Decommissioning (DOE D&D) technology development in the technical areas of facility dismantlement and material disposition. Dismantlement activities include the disassembly or demolition and removal of any structure, system, or component during decommissioning. Material disposition refers to the satisfactory interim or long-term storage of the residual materials generated during decommissioning activities.

Current baseline technologies for dismantlement include manual and hydraulic tools used to cut, shear, lift, and move structural materials and process equipment. These tools include overhead cranes, high-pressure water jets, saws, laser cutters, and plasma and acetylene torches. Though these methods are versatile and easy to control, they tend to generate secondary wastes, require manual intervention/operation, and expose workers to industrial and radiological safety hazards. The most meaningful solution to the problems associated with using baseline technologies is the development of viable robotic or automated dismantlement systems that can perform repetitive tasks while generating minimal secondary waste. Specific dismantlement applications will require the development of systems that are capable of lifting, disassembling, and moving large, heavy objects or equipment. In addition, remote systems that can operate in confined or limited-access areas are needed.

Current material disposition alternatives include burial and storage. Both methods require continuous surveillance and maintenance, and their long-term viability under current and future regulations (e.g., increasingly restrictive environmental and landfill regulations) is questionable. Size reduction of materials prior to burial or storage is expensive, labor intensive, and produces secondary waste. Even after size reduction, contaminated materials require disposal. The most meaningful solutions to the problems associated with the current material disposition alternatives include the development of decontamination and dismantlement techniques that minimize the generation of materials and secondary wastes destined for disposal, improvement of waste management and pollution prevention practices, and the development of viable recycle and reuse programs and/or techniques.

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4.1 Stainless Steel Beneficial Reuse Demonstration

Technology Need

DOE possesses about 1 million tons of radioactively contaminated stainless steel and other contaminated metals, including nickel, which is the high-cost feedstock for stainless steel. Most of this metal is only slightly contaminated or may only be "suspect." The current options for disposal of this material within the complex are storage in on-site scrap storage yards and burial at disposal sites. Concern over the potential runoff from contaminated metal storage yards flowing into surface waters or groundwater aquifers is significant at many sites. This concern is aggravated by the fact that some storage yards are located in flood plains. Burial is often the chosen option because of the low cost of burial, compared to decontamination and long-term storage. The reclamation of valuable materials, such as stainless steel, is clearly a preferable option over storage or burial when the economics of recycling and the avoided storage and disposal are taken into account.

Technology Description

This demonstration uses developed technology to melt stainless steel radioactive scrap metal (RSM) and refabricate the metal into storage containers. The RSM to be recycled is type 304 stainless steel coming from several sources, such as heat exchangers, as shown in Figure 4.1-1, primary piping, damaged heavy-water containers, and contaminated transfer equipment. All RSM will qualify as "low specific activity" items, as defined by the U.S. Department of Transportation regulations. The 304 stainless steel finished products will be 100-cubic-feet boxes and 55- or 85-gallon drums.

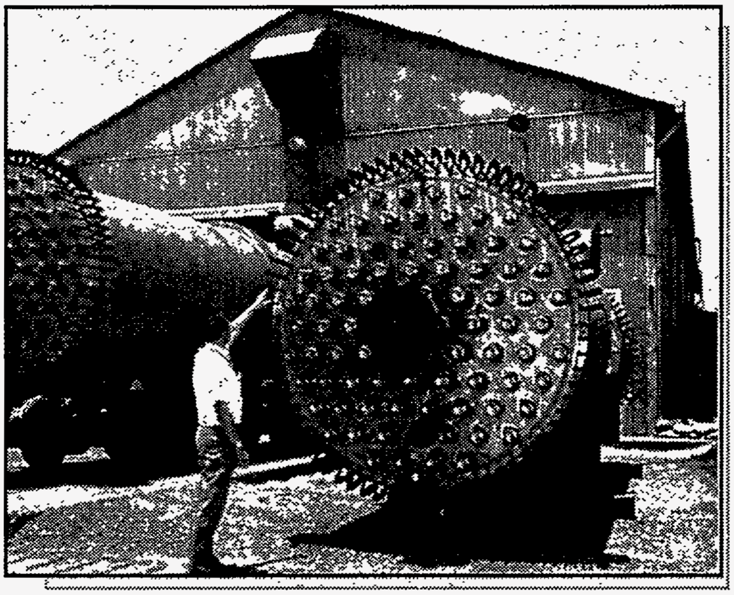

Figure 4.1-1. Heat Exchangers from Savannah River Used in the Recycle Process.

Up to 200 tons of RSM will first be processed and packaged at DOE sites. Next, the metal will be shipped to private industry for the melting and fabrication steps. The finished products will be shipped back to the DOE sites for use as containers for long-term, temporary, or above-ground storage of mixed waste, transuranics, or other appropriate materials.

Benefits

The use of RSM to fabricate containers to store waste, rather than introducing virgin metal containers to the process, is environmentally sound. This initiative establishes and promotes recycling and reduces the amount of waste destined for burial.

One analysis, recently conducted by Westinghouse Savannah River Company for DOE Headquarters (HQ), estimated the cost effectiveness of fabricating stainless steel, heavy-water storage drums from recycled stainless steel RSM. At the Savannah River Site, low-level radioactive waste is required to be disposed by placing the waste into a B-25 disposal box. The box is then placed in a disposal vault. The Savannah River Site has a number of damaged stainless steel drums that, if not recycled, would be declared low-level waste and disposed in virgin metal containers. If the disposal of a crushed drum can be avoided by beneficially reusing (recycling) its metal, then the potential cost savings, accounting for avoided burial costs and the cost of a virgin steel waste container, is about $100 per drum. Additional benefits are discussed in the Collaboration/Technology Transfer section.

Collaboration/Technology Transfer

This project has involved close collaboration with two metal recycling and fabrication subcontractors: Carolina Metals, Inc. of Barnwell, South Carolina; and Manufacturing Sciences Corporation of Oak Ridge, Tennessee. Both companies operate licensed commercial facilities and are recycling RSM into beneficially reusable products.

In Fiscal Year 1996 (FY96), this project leveraged its work with the Mixed Waste Focus Area's Transportable Vitrification System (TVS) project at Oak Ridge. The TVS project needs stainless steel containers for its vitrified glass waste stream. This need has provided an opportunity for the Beneficial Reuse program to manufacture the TVS containers from recycled stainless steel. This project between two Focus Areas (D&D and Mixed Waste) furthers the Department's industrialization/commercialization efforts, will produce a product needed by the Department, and will provide additional financial data for comparison with commercial costs. The cost of the TVS containers is expected to be closer to commercially produced products (than the original demonstration boxes and drums), since the start-up costs have already been borne by the initial production activities.

Accomplishments

- Completed firm documentation showing overall cost reduction when using high-integrity containers made from recycled, contaminated stainless steel.
- Continued to progress in production of TVS boxes with delivery scheduled in April 1996.
- Continued to progress with production of 55-gallon drums and 85-gallon overpacks at Manufacturing Sciences Corporation in Oak Ridge. Distribution of these containers is scheduled for May and June.
- Continued efforts with reactor operations at the Savannah River Site to produce recycled, heavy water, stainless steel 55-gallon drums. An additional 3,000 drums will be required in support of the future heavy-water storage needs.

TTP Information

Stainless Steel Beneficial Reuse Demonstration technology development activities are funded under the following technical task plan (TTP):

TTP No. SR14DD51, "Stainless Steel Beneficial Reuse Demonstration"

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Boettinger, W., et al. "Beneficial Recycling of Contaminated Stainless Steel," SRS draft document, unpublished (September 25, 1992).

Logan, J.A., and M.M. Larsen. "Development of a Facility for Fabricating Nuclear Waste Canisters from Radioactively Contaminated Steel," *Conference Proceedings, Waste Management* 1994.

"Radioactive Scrap Metal Recycling - A DOE Assessment," EM-40 draft, unpublished (1991).

4.2 Advanced Technologies for Decontamination and Conversion of Scrap Metal

Technology Need

The decontamination and decommissioning of DOE facilities will generate large quantities of RSM from process equipment, utilities, and structures. Nickel makes up about 19 percent of the total expected scrap volume, but may carry more than 80 percent of the total value based upon current scrap prices. The nickel recovered from DOE applications is often contaminated with uranium or fission products, including technetium-99 and trace amounts of neptunium, plutonium, and americium. The contamination cannot be completely removed by surface decontamination methods. Cost-effective technologies are needed to remove or reduce the contamination in order to permit recycle or reuse of this valuable resource.

Technology Description

The objective of this task is to develop and successfully demonstrate a technically effective and cost-efficient process to remove and/or reduce the radioactive contamination of nickel. The scope also includes the study of options to recycle the nickel by using the nickel as a constituent in alloys to produce new metal products.

This process for decontamination of nickel RSM and conversion of the metal to useful new products, as portrayed in Figure 4.2-1, will be developed in four phases. Phase I has been completed. It included laboratory-scale investigation of process conditions, demonstration of stainless steel production from the decontaminated metal, determination of process economics, and a study of the market for products from the recycled nickel. Goals in Phase II, currently ongoing, include developing a cost-effective method to analyze the isotopic content of incoming nickel, as well as products made from that material; removing technetium from nickel by bulk and/or surface decontamination techniques; and manufacturing metal products using alloy made with contaminated nickel. Phase III will encompass integrated testing of the process. Phase IV will include full-scale testing and evaluation of the technology for decontamination and conversion of RSM to high-value products.

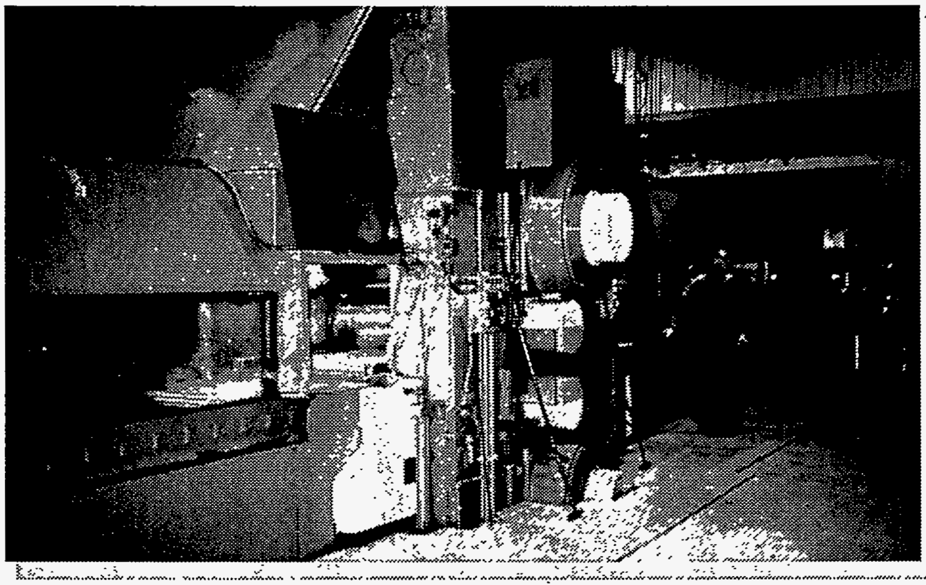

Figure 4.2-1. Rolling Mill for Fabrication of Recycled Metal.

BENEFITS

Recycling RSM provides an environmentally sound alternative to storage and disposal. Moreover, much of the metal is strategic in nature and no longer economically recoverable in this country. Therefore, recycling of RSM provides both economical and national defense benefits.

COLLABORATION/TECHNOLOGY TRANSFER

Manufacturing Sciences Corporation is involved in numerous projects with DOE that focus on the recycle and reuse of contaminated metal. This project is funded through the Morgantown Energy Technology Center (METC) via an Industry Program Research and Development Announcement (PRDA) award. It includes a partnership with Covofinish, Inc. to develop an electrodescaling process for stainless steel. Manufacturing Sciences Corporation currently has contracts for products in place with Westinghouse Savannah River Company, Lockheed Martin Energy Systems, and the Atomic Energy of Canada Limited Chalk River Laboratory. Deliveries of stainless steel and carbon steel drums and boxes are already underway. Manufacturing Sciences Corporation is also working with DOE in a three-year cooperative agreement as the contractor for the National Conversion Pilot Project at Rocky Flats. This project will convert four former nuclear weapons buildings into a scrap metal recycling facility to manufacture waste storage containers and other products. The project includes cleaning more than 200,000 square feet of manufacturing space and equipment.

Accomplishments

- Demonstrated inducto slag refining experiments for reducing technetium contamination in nickel. Experiments were performed both with technetium and with a surrogate rhenium as the contaminant in nickel. The predicted level of decontamination was not achieved in any of the experiments.
- Produced a total of 11 ingots of 304 stainless steel in the Manufacturing Sciences Corporation vacuum induction melting furnace. Machining, rolling, heat treating, welding, forming, corrosion testing, and mechanical property testing confirmed that the stainless steel produced from technetium-contaminated nickel was metallurgically identical to stainless steel produced in a similar manner with uncontaminated nickel.
- Performed a comprehensive review of available RSM at DOE sites. Markets for potential end-use products were also investigated. Potential restricted end-use products include: multipurpose canisters for the containment of spent reactor fuel, high-level waste vitrification flasks, and boxes and drums for waste disposal.
- Received nearly 3,000 pounds of contaminated nickel for full-scale testing from the Oak Ridge K-25 facility in January 1996. Because the nickel was in a classified configuration, it was shipped in sacrificial drums and declassified by melting the nickel and the drum together in an induction furnace. One of the nickel ingots was sectioned into 50-pound chunks to be used as feed for casting stainless steel ingots.
- Conducted laboratory-scale testing of the electrorefining process to decontaminate bulk-contaminated nickel in January 1996. Results demonstrated the effectiveness of the displacement reaction process to decontaminate technetium-contaminated nickel anodes.
- Initiated full-scale testing of the electrodescaling process in January 1996. Testing is under way to optimize the procedures and equipment used to cast stainless steel in the vacuum induction melting furnace.

TTP Information

Advanced Technologies for Decontamination and Conversion of Scrap Metal technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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Muth, T.R., K.E. Shasteen, A.L. Liby, B. Mishra, D.L. Olson, and G. Hradil. "Advanced Technologies for Decontamination and Conversion of Scrap Metal," *Proceedings of the Environmental Technology Through Industry Partnership Conference,* DOE/METC-96/1021, Vol. 1, p. 233 (October 1995).

4.3 Reuse of Concrete from Contaminated Structures

Technology Need

Restoration of the Department's surplus nuclear facilities will result in the dismantlement of a large number of these contaminated structures, and the generation of enormous quantities of concrete rubble or refuse. Due to the porous nature of concrete and its exposure to contamination sources, much of this concrete is extensively contaminated. Contaminants include polychlorinated biphenyls (PCBs), hazardous chemicals, and radionuclides including uranium, plutonium, and fission products. Most of the concrete is bare, but some is covered with paint, epoxy, or tile. Although most contamination is near the surface, some contaminants (e.g., tritium, PCBs, and mercury) may have penetrated deeply into the concrete. The cost of disposal of this material in radioactive-waste facilities will be a significant drain on DOE Environmental Management (EM) resources. If this material could be cost-effectively reused after decontamination, in ways that low levels of contamination would not endanger humans, it would greatly lessen the cost burden of DOE's cleanup efforts.

Technology Description

The objective of this research is to analyze the current and proposed disposition of the large quantities of contaminated concrete, as shown in Figure 4.3-1, resulting from the environmental restoration of the Department's nuclear facilities. The research is subdivided into four major task areas: economic analysis, legal/regulatory consideration, environmental risk assessment, and social/political implications. An analysis of a specific facility that has undergone D&D will be conducted. The analysis will compare the costs of entombment with that of concrete and rebar reuse. It will also evaluate legal and regulatory obstacles and restrictions, as well as the risks associated with the reuse of concrete and rebar. In addition, the research will explore public acceptance and the policy implications of reusing concrete from the Department's facilities.

Benefits

This study will result in a more accurate estimate of the nature and extent of concrete contamination throughout the complex, and the array of commercial and emerging technologies available to address this problem. In addition, a clearer understanding of regulatory and social issues, as well as the

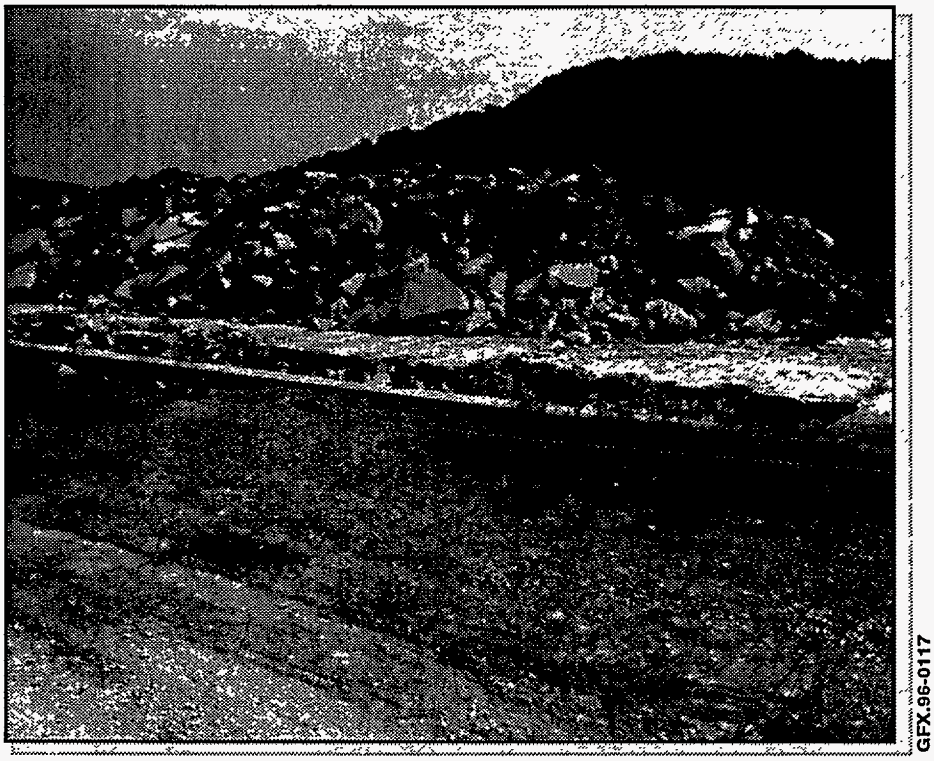

Figure 4.3-1. Contaminated Concrete Rubble Pile.

environmental risk associated with the reuse of concrete, will facilitate the implementation of cost-effective treatment and recycling of contaminated concrete.

COLLABORATION/TECHNOLOGY TRANSFER

This analysis is being conducted by masters and Ph.D. degree candidates at Vanderbilt University in collaboration with the Vanderbilt Center for Environmental Management Studies. This Center is a Vanderbilt University system-wide initiative to promote and develop partnerships between industry, government, and academia concerning the relationship of environmental policy to business management and operations.

ACCOMPLISHMENTS

- Established a database for all literature collected on technologies and costs associated with the potential reuse of contaminated concrete.
- Identified and grouped feasible technologies for decontaminating and recycling concrete and rebar. Treatment trains based on the identified

technology groups have been developed for the various D&D scenarios. These treatment trains will serve as the basis for the economic analysis and risk determinations.

- Continued work to quantify the volumes of concrete available for recycling and the associated levels of contamination.

TTP Information

Reuse of Concrete from Contaminated Structures technology development activities are funded under the following TTP:

TTP No. OR05DD51, "Reuse of Concrete from Contaminated Structures"

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Bibliography of Key Publications

This is a newly funded project; however, papers on the general topic include:

Dickerson, K.S., M.J. Wilson-Nichols, and M.I. Morris. "Contaminated Concrete: Occurrence and Emerging Technologies for DOE Decontamination," DOE/ORO/2034, U.S. Department of Energy, Oak Ridge (August 1995).

Parker, F.L. "Building Consensus Through Risk Assessment and Management of the Department of Energy's Environmental Remediation Program," *National Research Council* (1994).

Parker, F.L. "Risk Analysis as Applied to Mill Tailings Piles and Hazardous Wastes," *Proceedings Remedial Actions Program Annual Meeting*, CONF-87041 15, U.S. Department of Energy (1987).

4.4 Decontamination and Recycle of Concrete

Technology Need

The technical, regulatory, environmental, and economic considerations associated with the D&D of DOE facilities provide strong drivers for waste minimization. Technologies are needed that provide effective separation of hazardous constituents from structural and process equipment in a manner that minimizes their volume and allows for safe and economical disposal. The need to dispose of an enormous quantity of structural concrete at various DOE facilities requires innovative technology solutions to reduce time, cost, and potential safety and environmental risks.

Technology Description

The objective of this project is to develop and demonstrate a concrete treatment and reuse system that integrates decontamination and separation technologies proven in other applications. This system, called AWD-CON™, has two major subsystems: one for decontamination, and the other for separation, including collection and treatment of all waste streams. System flow is delineated in Figure 4.4-1. The decontamination subsystem includes:

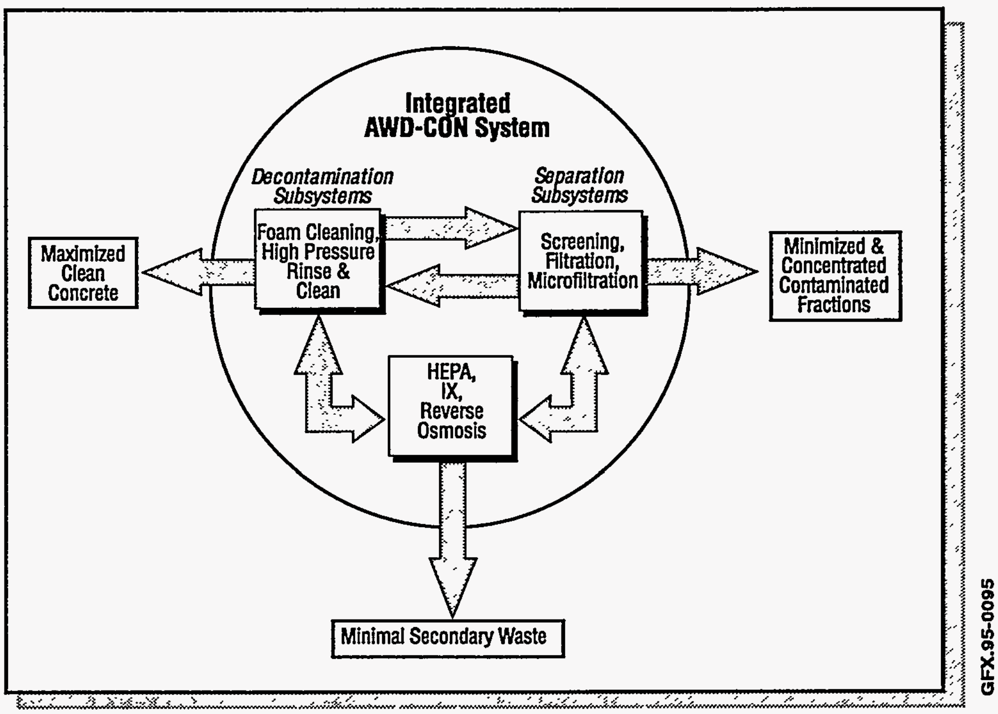

Figure 4.4-1. Integrated AWD-CON™ System Process Flow Diagram.

dry vacuum cleaning with high-efficiency particle-air filtration, dust collection, foam-cleaning agent application, low- and high-pressure surface rinsing, and surface concrete removal using high-pressure water. The separation subsystem provides coarse solids screening, oil and grease collection, fine solids removal, and organic compounds removal using activated carbon.

Development of this treatment and reuse system includes two phases. Phase I involves assembly of the integrated AWD-CON™ system, and the testing of individual component parts and subsystems. Phase II involves demonstration of the units at a DOE facility.

Benefits

If successful, the AWD-CON™ system has the potential for efficient in situ removal of a variety of contaminants from concrete, including uranium, technetium, PCBs, and chromates. In addition, the system will reduce both primary and secondary wastes, cleanup time, and costs due to lower disposal requirements.

Collaboration/Technology Transfer

This project is funded through METC via an Industry PRDA award. The integrated system is a proprietary process of Dow Environmental, Inc., a subsidiary of the Dow Chemical Company. Dow Environmental offers remediation services and develops commercial applications for Dow technologies. Current plans are to demonstrate this technology at full-scale at the Oak Ridge K-25 facility in late FY96.

Accomplishments

- Completed development of the system process flow diagram
- Initiated equipment sizing, material balance, and preliminary system cost estimates
- Initiated bench-scale testing for several of the alternative subsystems for removing uranium and technetium from the concrete
- Initiated preparation of the sampling plan, analytical procedures, and testing protocol for the full-scale demonstration at the Oak Ridge K-25 facility

TTP Information

Decontamination and Recycle of Concrete technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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Bibliography of Key Publications

None at this time.

4.5 DEPLETED URANIUM RECYCLING/PRODUCTS

TECHNOLOGY NEED

DOE is responsible for managing 550,000 metric tons of depleted uranium hexafluoride generated during the uranium enrichment process. Currently, about 90 percent of the depleted uranium (DU) is stored in cylinders at the three gaseous diffusion plant sites. The unique properties of uranium hexafluoride, such as its high purity and density, as well as its large volume, make it appropriate to assess and determine its fate. DOE is currently assessing a number of options, including disposal, long-term storage as an energy resource for future breeder reactors, and reuse, primarily for shielding in spent nuclear fuel and high-level waste containers.

TECHNOLOGY DESCRIPTION

The initial objective of this project was to perform an assessment of the feasibility and economic incentives of alternative management options for storing, recycling, and/or disposing of the large DU reserves within the DOE system. Three economic options were developed in FY94. Costs of disposal were found to range from $4 to $12 billion. As an alternative to disposal, the Idaho National Engineering Laboratory (INEL) developed a concept for converting DU into an oxide aggregate (DUAGG) material for use in cement. The FY95 work scope continued to perform experimental tasks to improve on the concept and to develop manufacturing processes for fabrication of the DUAGG concrete material known as DUCRETE for use as a shielding material, as shown in Figure 4.5-1. In FY96, the major work effort is directed toward a pilot-scale demonstration of the low-cost briquetting process selected for development of DUAGG, and optimization of the DUCRETE formulation. Specific process variables to be optimized include DUCRETE mechanical properties, thermal conductivity, and gamma and neutron attenuation.

Figure 4.5-1. Concrete Shielding from Recycled Depleted Uranium.

BENEFITS

Studies conducted in FY94 have shown that a high-density waste form can produce a minimum savings of $100 million to more than $500 million in disposal costs at Nevada Test Site and Hanford, respectively. These saving are derived directly from disposal of the DUAGG material, which has a greater uranium density compared to that of the bulk oxide used in the baseline disposal options study. The higher-density material will essentially reduce the transportation, container, and disposal cost inversely to the density. Thus, approximately two-thirds of the cost can be saved if the aggregate is disposed, rather than the bulk powder in containers.

If the depleted uranium aggregate can be successfully incorporated into the concrete product DUCRETE and used for high-level waste or spent fuel storage containers, disposal as a waste is eliminated entirely, and the savings to DOE will be measured in billions of dollars.

COLLABORATION/TECHNOLOGY TRANSFER

Information gained from this project will provide guidance to the DOE Manager of Uranium Programs in DOE's Office of Nuclear Energy and EM managers concerning the feasibility and economic incentives to pursue any of the DU management options: continued storage as is, disposal, or recycling. The findings will also provide input to the Programmatic Environmental Impact Statement, initiated by the Office of Nuclear Energy, to evaluate DU management options, as well as complement the Office of Civilian Radioactive Waste Management spent nuclear fuel storage, transport, and disposal cask development activities. A patent application has been filed for the process to develop the aggregate and its use as a shielding material.

ACCOMPLISHMENTS

- Completed testing to examine the leaching characteristics of 80, 90, and 93 volume percent uranium oxide aggregates using the standard ANSI/ANS-16-1-1986 test procedures. After normalizing the results on an area basis, the samples have rates similar to iron-enriched basalt, and two orders of magnitude better than borosilicate glass.
- Received fabrication equipment including a 1.5-gallon attrition mill and an 18-inch disk pelletizer.
- Completed 120-hour interval leach testing of DUAGG. The leaching values were very low, comparable to good glass and glass ceramics.
- Continued leach testing on the iron-enriched basalt DUAGG and metallography activities to characterize the DUAGG microstructure.

TTP Information

Depleted Uranium Recycling/Products technology development activities are funded under the following TTP:

TTP No. ID75DD51, "Depleted Uranium Recycling and Products"

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Hopf, J.E. "Conceptual Design Report for a Transportable DUCRETE Spent Fuel Storage Cask System," INEL-95/0167 (August 1995).

Lessing, P.A. "Development of DUCRETE," INEL-94/0029 (March 1995).

Powell, F.P. "Comparative Economics for DUCRETE Spent Fuel Storage Cask Handling, Transportation, and Capital Requirements," INEL-95/0166 (April 1995).

4.6 DEMONSTRATE IMMOBILIZATION OF ASBESTOS USING MINERALOGICAL CONVERSION

TECHNOLOGY NEED

Asbestos waste generated at Hanford and other federal sites across the United States is becoming more expensive to package, handle, and dispose. A major disadvantage associated with committing asbestos waste to landfill dumping is that the owner of the asbestos waste indefinitely retains all legal liability associated with the waste. The landfill at Hanford designated for asbestos waste can only hold 10 percent of the remaining asbestos planned for removal under the Hanford Site Asbestos Abatement Plan. The remaining 90 percent of the estimated 22,000 cubic yards is destined for a public landfill. By converting asbestos waste into an inert, recyclable end-product, future liability concerns and the need for additional landfill space are virtually eliminated.

TECHNOLOGY DESCRIPTION

The Asbestos Conversion System thermally converts the asbestos in asbestos-containing material (ACM) into a totally nonhazardous substance. The ACM, as shown in Figure 4.6-1, is introduced to the process via a mechanical conveyor system. The asbestos drops from the conveyor into a shredder for size reduction to 1-inch diameter or less. From the shredder, the asbestos is introduced into a soak tank of heated, 7 percent borax solution

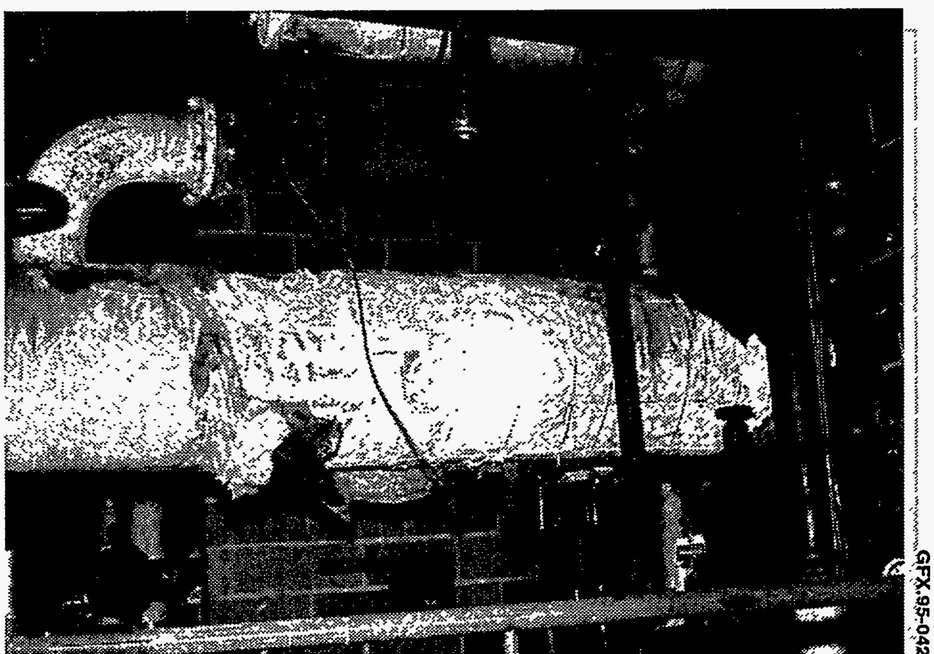

Figure 4.6-1. Contaminated, Asbestos-Piping Insulation.

(nonhazardous) and is fed via a dewatering screw press into the rotary hearth furnace. In the furnace, the asbestos is subjected to temperatures of 2,200 degrees Fahrenheit for a period of one hour. The converted asbestos-free material is then removed from the furnace by means of a discharge system where the material drops by gravity into a solids quench tank filled with clean water.

BENEFITS

Currently, radioactively contaminated asbestos is segregated from other radioactive waste and is packaged separately for disposal. Successful implementation of the Asbestos Conversion System for contaminated asbestos would result in a substantial volume reduction (up to 80 percent) and would eliminate the asbestos portion of the waste stream. At Hanford, approximately 10,000 cubic yards of contaminated asbestos remain to be packaged and disposed. At a cost of $10 million (1994 dollars), a conservative estimate of 50 percent volume reduction would result in a $5 million savings.

COLLABORATION/TECHNOLOGY TRANSFER

This project is jointly funded by EM-50 and EM-40. Bechtel Hanford, Inc. has negotiated a "pay-for-performance" subcontract with Asbestos Recycling, Inc. to develop and operate a full-scale Asbestos Conversion System at the Hanford site.

ACCOMPLISHMENTS

- Selected 400 Area at Hanford for the full-scale, nonradioactive demonstration site.
- Commenced mobilization of the Asbestos Conversion Unit after its arrival at the Hanford 400 Area on December 5, 1995.
- Verified the Asbestos Conversion Unit as ready for service on December 21, 1995. Rotary Hearth Furnace heat rampup commenced on December 22. Furnace temperatures above 2,000 degrees Fahrenheit needed for asbestos conversion were reached on December 26, 1995.
- Began actual asbestos conversion on December 27 when 930 pounds of thermal systems insulation (pipe lagging) were introduced into the Asbestos Conversion Unit. Results of the conversion revealed that no asbestos fibers were present in the end-product captured in the Asbestos Conversion Unit discharge bin. The volume of material was 3 cubic yards weighing 930 pounds at input. The converted volume equaled 3.5 cubic feet (95.5 percent reduction) and 216 pounds (78 percent reduction).

TTP Information

Demonstrate Immobilization of Asbestos Using Mineralogical Conversion technology development activities are funded under the following TTP:

TTP No. RL05DD52, "Implement Mineralogical Conversion of Asbestos Waste Technology"

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Foltz, A.D. "Asbestos Conversion Systems," Asbestos Recycling, Inc., Kent, Washington (April 20, 1994).

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4.7 ELECTROMAGNETIC MIXED-WASTE PROCESSING SYSTEM FOR ASBESTOS DECONTAMINATION

TECHNOLOGY NEED

DOE sites contain a broad spectrum of asbestos materials (cloth, pipe, lagging, sprayed insulation, and other substances) that are contaminated with a combination of hazardous wastes. These wastes consist of cutting oil, lubricants, solvents, PCBs, heavy metals, and radioactive contaminants. The radioactive contaminants are the activation, decay, and fission products of DOE operations. The asbestos must be converted by removing and separating radioactive and other hazardous materials to prevent the formation of mixed wastes and to allow for both sanitary disposal and effective decontamination. Currently, no technology exists that can meet these sanitary and other objectives.

TECHNOLOGY DESCRIPTION

The objective of this work is to develop and demonstrate a multistage process to remove and separate radioactive and other hazardous materials from asbestos and destroy the asbestos fibers. In the process, shown in Figure 4.7-1, radiofrequency heating is used to volatilize, or destroy, organic

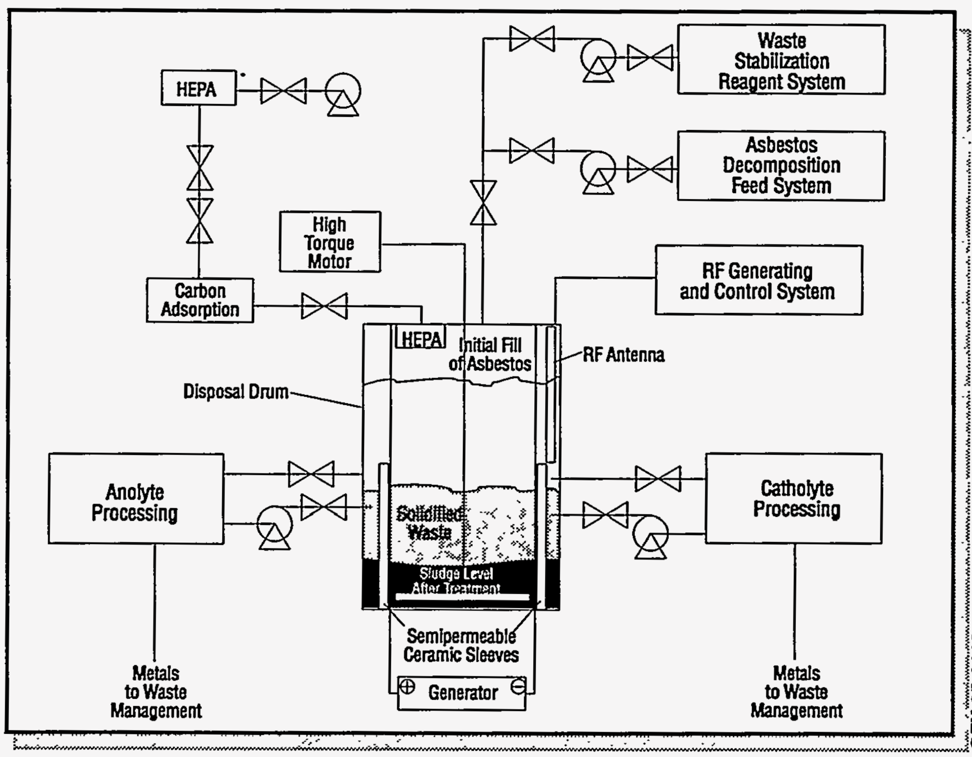

Figure 4.7-1. Electromagnetic Conversion Process Flow Diagram.

contaminants. Radionuclides in the resulting solution are separated by physical methods and ion exchange. The radionuclide and organic-free asbestos is treated by the acid-based ABCOV technology to destroy the asbestos fibers. The amorphous silica containing heavy metals resulting from this treatment is solidified with lime, sodium silicate, and possibly other reagents for disposal as sanitary waste.

BENEFITS

Benefits of the electromagnetic mixed-waste processing system include:

- Conversion of over 99 percent of asbestos for sanitary disposal
- Prevention of mixed wastes through separation of radioactive and hazardous components
- Stabilization of hazardous waste according to the Resource Conservation and Recovery Act and radionuclide material requirements of the U.S. Environmental Protection Agency and the U.S. Nuclear Regulatory Commission
- Minimization of public, worker, and environmental risks through the closed system process
- Reduction of operating costs compared to state-of the-art alternatives such as plasma-fired, thermal destruction combined with molten salt separation

COLLABORATION/TECHNOLOGY TRANSFER

This project is funded through METC via an Industry PRDA award. With their electromagnetic mixed-waste processing system, KAI Technologies, Inc. employs three patented technologies from three separate companies to convert asbestos to a nonhazardous, radionuclide-free, sanitary waste. These technologies are: (1) acid decomposition of asbestos (ABCOV method from DSI Industries), (2) physical separation/ion exchange to remove radionuclides (Westinghouse Science and Technology Center), and (3) radiofrequency heating to remove organics (KAI Electromagnetic Process).

Westinghouse Science and Technology Center is reviewing the materials at the Fernald Environmental Restoration Management Corporation that could be used in the bench-scale testing. The selection criteria is based on the amount and kind of radioactive contaminated asbestos material available now for laboratory testing. Necessary documents are being developed for transfer of this material to Westinghouse Science and Technology Center.

ACCOMPLISHMENTS

- Demonstrated the individual process steps and optimized the process flow diagram.
- Conducted laboratory tests to demonstrate process viability for asbestos conversion, organics removal, and radionuclide removal. All criteria for the laboratory tests were met.
- Demonstrated (by DSI Industries) greater than 99 percent asbestos conversion to amorphous solids using commercial ABCOV process.
- Demonstrated (by KSI) 90 percent removal of organics from the asbestos suspension.
- Achieved (by Westinghouse Science and Technology Center) 92 percent removal of uranium from solution, resin loadings of 0.6 equivalents per liter, and greater than 50 percent regeneration of resin in laboratory scale tests.
- Completed design of the test facility and received approval to begin construction. Phase II tests will investigate the removal of uranium from asbestos, in the presence of lead and mercury.

TTP INFORMATION

Electromagnetic Mixed-Waste Processing System for Asbestos Decontamination technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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KAI Technologies, Inc. "Electromagnetic Mixed-Waste Processing System," *Phase I Topical Report*, DOE/MC/29249-4074, DE95009720 (December 12, 1994).

Kasevich, R.S., W.G. Vaux, and T. Nocito. "Electromagnetic Mixed-Waste Processing System for Asbestos Decontamination," *Proceedings of the Environmental Technology Through Industry Partnership Conference*, DOE/METC-96/1021, Vol. 1, p. 11 (October 1995).

4.8 Demonstration of Conversion of Asbestos-Containing Material Into A Nonregulated Material

Technology Need

ACM, used as fireproofing insulation and for other purposes in building construction, represents a significant fraction of the hazardous materials inventory requiring D&D at all DOE sites. As a national and worldwide concern, asbestos-abatement techniques, as they are currently practiced, are likely to account for expenditures of $80 to $100 billion over the next 25 years. Analyzing these costs in greater detail reveals that the largest single expense is the erection of a negative pressure confinement around the site to be remediated. Other significant costs are associated with the removal and transport of the ACM from the site. Nonasbestos fireproofing or thermal insulation must be applied in place of the original ACM to complete the project. Avoiding these steps would result in significant savings within the DOE complex as well as in the public sector.

Technology Description

Brookhaven National Laboratory and its industrial partner have shown that in a laboratory environment, as pictured in Figure 4.8-1, chrysotile asbestos in ACM can be fully converted in situ. Based upon these findings, research to fully define and field demonstrate the in situ process was initiated in FY94, as a Cooperative Research and Development Agreement (CRADA) between DOE EM-50, Energy Research, and an industrial partner. In FY95, the technology will be demonstrated under cold conditions and under full-scale radioactive conditions at a decommissioning site.

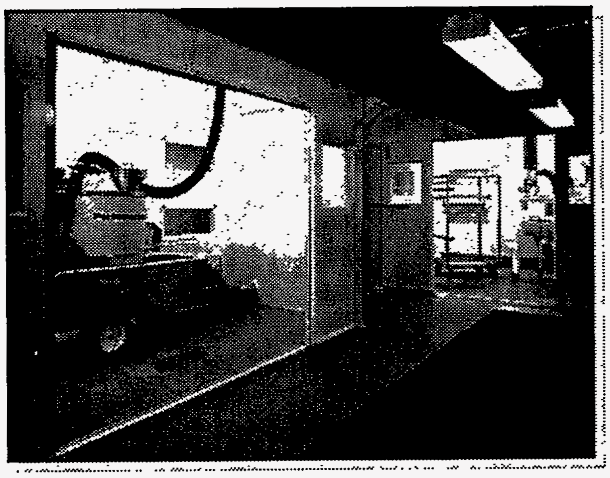

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Figure 4.8-1. In Situ Asbestos Conversion System.

BENEFITS

The greatest cost savings is derived from the avoidance of tenting procedures. Other cost savings are associated with the avoidance of material transport and disposal. Finally, the costs associated with the reapplication of fireproofing or insulating materials are avoided. The aggregate of these avoided expenses could amount to a 50 percent cost reduction in the estimated $80 billion mitigation needs.

COLLABORATION/TECHNOLOGY TRANSFER

Brookhaven National Laboratory and its industrial partner are transferring the technology developed via the existing DOE CRADA (BNL-C-94-24). The partnership intends to test this new technology in the field at a DOE site such as Brookhaven National Laboratory. Projected cost savings using this technology will allow DOE-allocated remediation dollars to cover more identified projects.

ACCOMPLISHMENTS

- Completed commissioning of the Inhalation Toxicology Facility at Brookhaven National Laboratory and conducted initial experiments to verify equipment performance capabilities
- Received all New York State permits required to use the Inhalation Toxicology Facility with ACM and notified the Environmental Protection Agency of the planned start date for the initiation of engineering-scale experiments
- Completed an Operational Readiness Review and commenced full operation of the Inhalation Toxicology Facility in FY95
- Confirmed in late November and early December 1995 that each of the steps in the in situ conversion process can be performed safely within the Inhalation Toxicology Facility, and at a scale sufficient to verify engineering practicability
- Conducting further design, procurement, construction and testing efforts to fabricate a conversion system sized for use in larger-scale field demonstrations scheduled for late FY96

TTP Information

Demonstration of Conversion of Asbestos-Containing Material Into A Nonregulated Material technology development activities are funded under the following TTP:

TTP No. CH34DD52, "Conversion of Asbestos-Containing Material Into Nonregulated Material"

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Hriljac, J.A., C. Eylem, Q. Zhu, R. Sabatini, L. Petrakis, R. Hu, and J. Block. "On the Use of X-Ray Powder Diffraction for Determining Low Levels of Chrysotile Asbestos in Gypsum-based Bulk Materials: (II) Use of a Synchrotron Source," submitted to *Analytical Chemistry*.

Hriljac, J.A., C. Eylem, R. Sabatini, R. Hu, Q. Zhu, and L. Petrakis. "Quantifying the Level of Chrysotile in Pure and Gypsum-based Materials: A Comparison of Synchrotron and Laboratory X-Ray Diffraction Techniques," R. L. *Perkins* EIA *Journal*, 5-10 (1994).

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4.9 ASBESTOS PIPE-INSULATION REMOVAL SYSTEM

TECHNOLOGY NEED

Most of the steam and process piping in DOE facilities is clad and insulated with ACM, which must be removed before any decontamination and dismantling activities occur. Manual removal is expensive and time consuming because of the carcinogenic nature of asbestos fibers, radiological contamination, and the associated abatement regulation requirements from the Environmental Protection Agency and Occupational Safety and Health Administration.

TECHNOLOGY DESCRIPTION

The objective of this task is to develop and demonstrate a mechanical, asbestos-removal system that can be remotely operated without a containment area. This system is illustrated in Figure 4.9-1. The technology, known as BOA, consists of a pipe-crawler removal head and a boom vehicle system with dual robots. BOA's removal head can be remotely placed on the outside of the pipe and can crawl along the pipe, removing lagging and insulation. The lagging and insulation is cut using a hybrid endmill water-jet cutter and then diced into 2-inch cube sections of ACM. These ACM sections are then removed from the pipe using a set of blasting fan-spray nozzles, vacuumed off through a vacuum

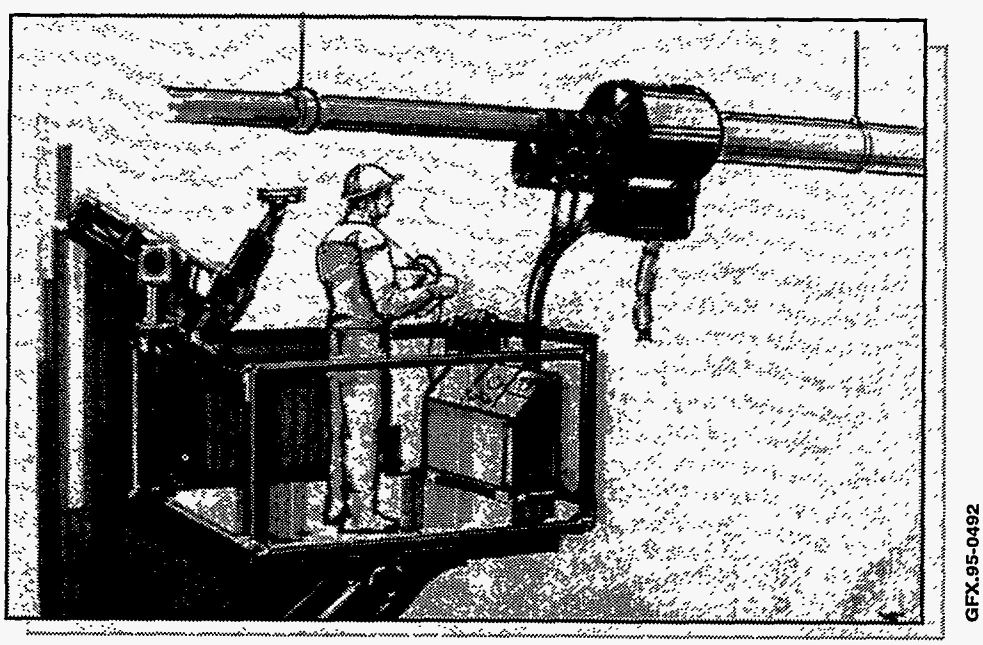

Figure 4.9-1. Artist Rendition of the Mechanical Asbestos Removal System.

hose, and bagged. Careful attention to vacuum and entrapment air flow ensures that the system can operate without a containment area while meeting local and federal standards for fiber count.

BENEFITS

The system is capable of operating on 4-to-8-inch diameter pipes from 8 to 60 feet off the ground. The removal head cuts through various types of cladding such as plaster tape, aluminum lagging, wire mesh, plastic boots, and pipe clamps, and can adapt to differences in cladding thicknesses.

A recent analysis conducted on this technology found that the robot system has a substantial cost-benefit for DOE and private industry, with relative cost savings ranging from 25 to 30 percent for indoor piping (comparison based on manual glovebagging technique), and as high as 40 to 50 percent for outdoor piping (comparison based on full-containment technique).

COLLABORATION/TECHNOLOGY TRANSFER

This technology is being developed through a Research Opportunity Announcement (ROA) award between METC and the Field Robotics Center at Carnegie Mellon University's (CMU's) Robotics Institute. The Field Robotics Center has been developing field robot prototypes for remote and hazardous environments for over 10 years and currently performs contract work for DOE, the National Aeronautics and Space Administration, Advance Research Projects Agency, and the Department of Defense.

ACCOMPLISHMENTS

- Developed and demonstrated the prototype BOA pipe-crawler robot at CMU
- Completed a market study, cost-benefit analyses, and regulatory analyses (see Benefits section)
- Developed nozzle types and manufacturing methods for optimal cutting, based on the preliminary demonstration of the hybrid endmill/water-jet cutter
- Completed the design of the prototype endmill cutter/jet/gearbox/motor assembly and initiated fabrication
- Reconfigured the remover section of the robot to simplify and reduce the cost of the overall design while maintaining the productivity of the robot

- Finalized machine drawings and placed a purchase order to fabricate a 4-inch system for testing at the K-25 site in October 1996

TTP Information

Asbestos Pipe-Insulation Removal System technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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Carnegie Mellon University. "BOA: Asbestos Pipe-Insulation Removal Robot System," *Topical Report Phase* I (February 28, 1995).

Schempf, H., J. Bares, et al. "BOA: Pipe-Asbestos Insulation Removal Robot System," *Proceedings of the Environmental Technology Through Industry Partnership Conference*, DOE/METC-96/1021, Vol. 1, p. 294 (October 1995).

4.10 Mobile Work System for Decontamination and Dismantlement

Technology Need

Work tasks for transitioning of DOE facilities include equipment disassembly and dismantling; size reduction, packaging, and removal of materials; decontamination of structures and building surfaces; and sensor surveys and mapping to assure reduction of contamination and regulatory compliance. To keep within as-low-as-reasonably-achievable standards and minimize worker exposure to radiation and other hazards, these tasks have to be performed with robots and other remote equipment, to the maximum extent possible.

Technology Description

The objective of this task is to develop and demonstrate a mobile work system capable of performing a wide range of decommissioning tasks in nuclear facility environments. The Remote Work Vehicle, an existing tele-operated work system built originally for nuclear accident recovery at Three Mile Island, will be upgraded through introduction of a more sophisticated control system, fabrication of new tooling, and simultaneous enhancement and simplification of the operator control. These upgrades will result in the next generation of a mobile work system for decontamination and decommissioning, called "Rosie II." This development phase also includes a semi-automatic, task-space, scene-analysis system, "Artisan." Both systems were designed to work with, and complement, other robotic D&D technologies to execute selective equipment re-moval scenarios in which some part of an apparatus is extricated

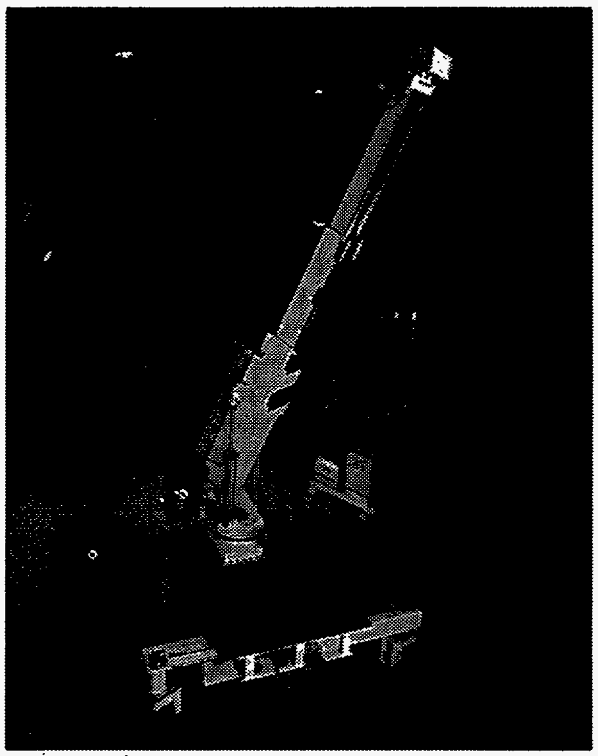

Figure 4.10-1. Rosie Mobile Work System.

while minimally disturbing the surroundings. The Rosie Mobile Work System is shown in Figure 4.10-1.

This work system is being designed to reliably and safely withstand the rigors of heavy work over periods of years. Because this system will go from worksite to worksite, it must be decontaminated upon exit. Seals, finishes, and materials are designed to resist contamination and to be amenable to decontamination procedures such as wash-down, wipe-down, and chemical treatment.

BENEFITS

Benefits of this robotics system include:

- Features remote capabilities to operate tools, manipulate and package contaminated objects, and position sensors
- Provides dexterity combined with high strength to accomplish complex tasks throughout a large work volume
- Offers mobility to make the worksystem self-deploying and increase the work envelope beyond that of a fixed base
- Supplies a power and signal tether that provides reliable communications and allows unlimited work duration
- Contributes computer control for precise positioning, motion coordination, and status monitoring
- Furnishes workspàce geometry modeling to enhance remote viewing, and improve robot control and speed of task execution

COLLABORATION/TECHNOLOGY TRANSFER

This project is a collaboration of CMU's Robotics Institute and RedZone Robotics, Inc. Both organizations are distinguished for their abilities and records of integrating complex robot technologies into systems that prove themselves in both research and real-world contexts. Funding for this project is through METC via an Industry PRDA award.

ACCOMPLISHMENTS

- Rehabilitated and upgraded Remote Work Vehicle that was previously developed by CMU for use in D&D operations at Three Mile Island
- Developed a mobile work system, "Rosie," and a semi-automatic, task-space, scene-analysis system, "Artisan"

- Demonstrated Rosie and Artisan at RedZone's facility in Pittsburgh and at the Oak Ridge National Laboratory (ORNL) in September 1995
- Conducted capability/endurance testing of the Rosie system at ORNL in preparation for the system's demonstration at the Chicago Pile 5 (CP-5) research reactor scheduled for the fall of 1996, and perfomed two consecutive weeks of daily operations deploying available tooling in concrete demolition exercises
- Initiated development of dismantling scenarios and candidate tools for using Rosie and the Dual Arm Work Module (DAWM) in the CP-5 reactor decommissioning project

TTP Information

Mobile Work System for Decontamination and Dismantlement technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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4.11 DEMONSTRATION OF STANDARD DISMANTLEMENT SYSTEM FOR DECOMMISSIONING

TECHNOLOGY NEED

The CP-5 Reactor at Argonne National Laboratory-East is currently undergoing D&D using DOE EM-40 funds. The initial work on removal of nonnuclear system components has been completed, and work is proceeding on the dismantlement of the reactor block. Current plans are to demonstrate and evaluate, at CP-5, three major systems developed through the EM-50 Robotics Program. The first system is the Selective Equipment Removal System. This System is designed to perform a variety of D&D tasks using a new DAWM. The second system to be demonstrated is the Mobile Automated Characterization System (MACS). MACS is a full-scale remote mapping and data acquisition system. In addition, a smaller version, the Reduced Access Characterization System (RACS), may also be demonstrated. The last system to be demonstrated is a new version of the mobile work system for decontamination and decommissioning (i.e., Rosie II), which is specially designed to perform D&D tasks (see Section 4.10).

TECHNOLOGY DESCRIPTION

The objective of this project is to demonstrate and field test, at CP-5, the three systems listed earlier. Coordination activities include developing preliminary data packages describing CP-5, which include significant photographs (see Figure 4.11-1), figures, and drawings for distribution to all of the organizations involved in these demonstrations; defining and designing D&D sequencing tasks; task sequencing; developing waste handling, characterization, segregation, and packaging procedures; specifying tooling requirements for each task; ensuring proper space and utilities are provided for equipment operation and maintenance; training operators;

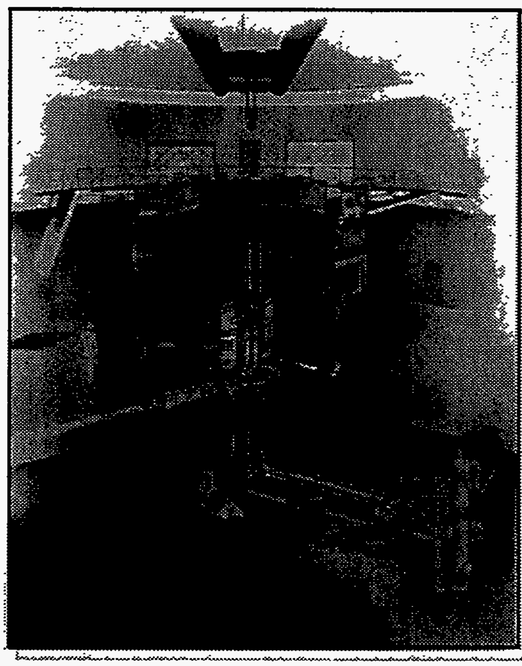

Figure 4.11-1. Cut-Away View of the Chicago Pile 5 Research Reactor.

and assuring all regulatory and permitting documents relative to the robotic demonstrations are accurate and up-to-date.

BENEFITS

In addition to the actual lessons learned from field testing, a great deal of information about the cost effectiveness of performing operations remotely will be made available. This information will be fed back into risk, cost, and dose-reduction analysis methodologies. Also, the information from these demonstrations will be used to determine what further testing should be performed at CP-5 or other facilities. The successful completion of these demonstrations will provide both DOE and the D&D community with a suite of robotic tools that can be selected with confidence for future applications.

COLLABORATION/TECHNOLOGY TRANSFER

The current project involves five different organizations, separately funded, to participate with ANL-E in the demonstrations at CP-5. The first four of these five organizations are funded through the EM-50 Robotics Program. The Robotics and Process Systems at ORNL will be responsible for the planning and mockup testing of the equipment that will be demonstrated. The Intelligent Systems and Robotics Group at Sandia National Laboratories (SNL) has been selected to do three-dimensional modeling of the required demonstration tasks. In order to deploy some of the robotic equipment, the CP-5 building crane will be converted to swing-free operation. This task will be handled by the Robotics Group of the Westinghouse Savannah River Company. A new DAWM, and the fixtures required for deployment, will be designed and procured by Lockheed Martin Idaho Technology Company. The fifth organization, RedZone Robotics, Inc., is the developer of the new Rosie II vehicle. Procurement for the design and fabrication of this system is funded through METC via an Industry PRDA award.

ACCOMPLISHMENTS

- Initiated development of the robotic dismantlement scenario and identified and addressed interface issues.
- Initiated development of waste-handling procedures that will outline the characterization, segregation, and packaging requirements.
- Completed a survey (final draft) of commercially available robotic arms, end-effectors (i.e., tools), and delivery systems that are applicable to D&D activities. More than 70 vendors have been referenced, and their equipment is described with figures and in tables for easy comparison.

- Developed robotics tasks required for horizontal and vertical thimbles and identified preliminary locations for equipment and controls after reviewing the conceptual plan for the deployment of a dual-arm work platform on the CP-5 reactor block.
- Completed National Environmental Policy Act review. DOE determined that the proposed robotics work falls within the original Finding of No Significant Impact for the CP-5 D&D.
- Completed identification and definition of the CP-5 reactor block dismantlement tasks to be performed remotely by robotic equipment. This activity allows robotic equipment design and procurement activities to proceed and mockup activities to begin.

TTP Information

Demonstration of Standard Dismantlement System for Decommissioning technology development activities are funded under the following TTPs:

TTP No. CH24DD51, "Standard Dismantlement System for Reactor Decommissioning/Rosie II"

TTP No. ME06DD51, "Standard Dismantlement System for Reactor Decommissioning/Rosie II"

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4.12 Reconfigurable In-Tank Mobile Robot

Technology Need

The retrieval of radioactive, chemical, and other wastes stored in DOE above and underground waste storage tanks is a hazardous and geometrically challenging task that defies strictly manual methods or existing remote technology. The use of remote equipment has been identified as the necessary mode of tank waste removal. Mobile worksystems are attractive for in-tank operations because they provide flexible tool deployment platforms. However, existing mobile worksystems with sufficient work capability are too large to be deployed through existing tank openings.

Technology Description

This project will develop a mobile worksystem for the specific application of retrieving Fernald K-65 silo waste. The system will also be useful at other DOE sites. The proposed system, named Houdini, will perform waste retrieval, waste mobilization, waste reduction, and other decommissioning tasks. Houdini, displayed in Figure 4.12-1, is a tethered, hydraulically powered, track-driven worksystem with an expandable frame chassis. When fully deployed, Houdini measures 4 feet by 5 feet; but the system can be collapsed to fit through confined entries as small as 24 inches in diameter. Houdini's reliable actuation systems, low voltage servo-valving, inherent spark-proof hydraulic

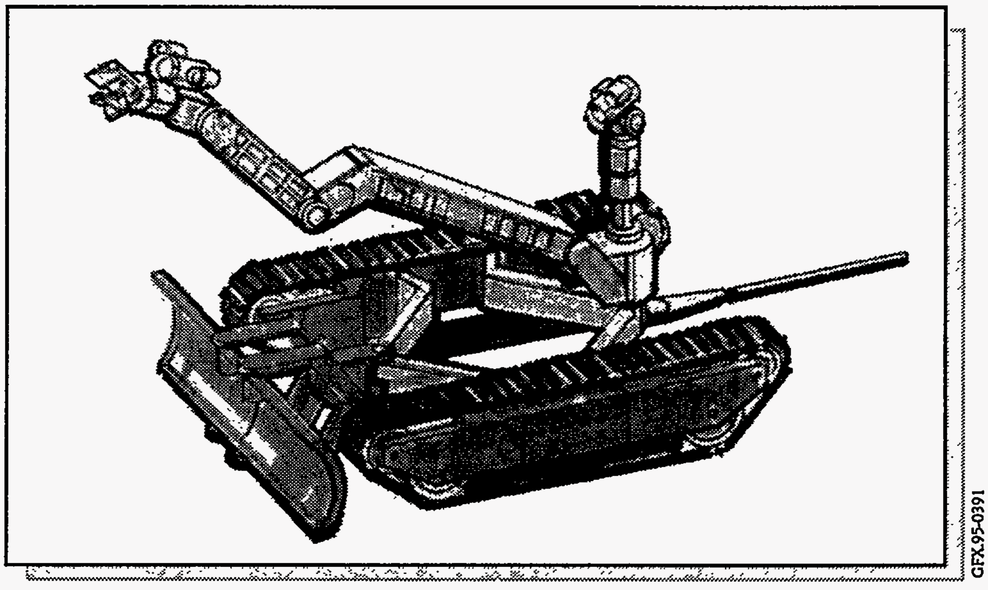

Figure 4.12-1. Artist Rendition of the Houdini System.

operation, environmentally-safe hydraulic fluid, self-collapsing capability, hand-operable winch, and hard-wired suitcase control console make for a system that is safe and efficient to operate. The development program will include the core applied research activities and result in demonstration of the Houdini system in an uncontaminated tank mockup at RedZone Robotics, installation at the Fernald site, and full-scale functional testing in a nonradioactive tank-remediation demonstration at Fernald.

Benefits

Houdini can be used to retrieve waste from tanks for treatment and long-term storage, as well as perform heel and debris removal from waste storage tanks during and after bulk materials removal by other means. The benefits of Houdini include tracked locomotion, which enables travel on, over, and through various materials; smooth surfaces and no entrapment corners, which allow for easy system decontamination by spray washdown; and a sealed system for spray washdown and operating fully submerged.

Collaboration/Technology Transfer

This project is funded through METC via a ROA award and is a collaboration of RedZone Robotics, Inc. and CMU's Robotics Institute. Both organizations are distinguished for their abilities and records of integrating complex robotic technologies into systems that prove themselves in both research and real-world contexts.

Accomplishments

- Conducted a site visit at Fernald and examined the K-65 silos, cold-test tank, and superstructure.
- Initiated (by CMU) complete analysis and design of a pre-prototype crawler frame and locomotive systems, as well as the experimental test-pit.
- Completed construction of the uncontaminated tank mockup. The mock-up consists of a 20-feet-by-25-feet area with full walls (cinder block) on two sides and a 3-feet high wall on two sides. The mockup will be filled with surrogate waste material for testing the Houdini prototype and final system.
- Completed initial testing of the CMU prototype in the surrogate. Test results revealed the tread design was inadequate, especially in runny, soft material. The material jammed into the tread elements and stopped the machine. Removal of every other tread element improved performance significantly.

TTP Information

Reconfigurable In-Tank Mobile Robot technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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White, D.W., et al. "Houdini: Reconfigurable In-Tank Robot," *Proceedings of the Environmental Technology Through Industry Partnership Conference*, DOE/METC-96/1021, Vol. 1, p. 305 (October 1995).

4.13 Diagnostics and Data Fusion of Robotic Sensors

Technology Need

Within DOE's environmental restoration and waste management programs, extensive use of robotic equipment is planned for safely and efficiently cleaning up hazardous and radioactive waste. Some of the more formidable remediation tasks will necessitate complex robotic assemblies, such as long-reach articulated manipulator arms. These assemblies will be exposed to a variety of life-limiting environmental and operational conditions. Equipment failures during operation can expose humans to hazardous wastes and significantly increase the cost and time to remediate the site. The technology to detect impending failures in robotic manipulators and accurately predict remaining life is near, but not yet available.

Technology Description

There are two primary objectives for this project. One objective is to develop a data fusion software module that combines data from multiple surface-mapping sensors and sensor poses to reduce effects of errors in individual data points for robotic remediation systems, and also to provide a metric to estimate the confidence attributed to a set of sensor data. The data fusion will result in three-D maps that can be interpreted to create or verify a computer-aided drafting model of a task space. The second objective is to search, review, and integrate monitoring technologies into a package to detect and predict failures in robotic manipulators used in facility D&D efforts.

Benefits

It is too early to quantify the benefits of this technology. However, potential benefits include:

- Reduces risk of catastrophic in-tank robot failures
- Produces warning of degradation before failure occurs
- Provides data trending and has built-in diagnostics and prognostics
- Enables faster, safer, and less-costly cleanup of hazardous waste
- Facilitates better planning of equipment resources, maintenance, and spare parts
- Offers flexibility of application to other robotic systems

Collaboration/Technology Transfer

This project is funded through METC via an Industry ROA award. Mechanical Technology, Inc. develops advanced technology for new commercial products, performs contract research and development, and provides technical services to government and commercial clients. Business Focus Areas include custom monitoring and diagnostic systems, advanced measurement systems, unique power and energy systems, and specialty machinery components.

Accomplishments

- Initiated an investigation of available registration algorithms/software and monitoring and diagnostic techniques for robotic sensors.
- Conducted project kick-off meeting in Morgantown, West Virginia, in January 1996. A key objective of the meeting was to ensure the developers' plans matched users' needs, and that the plans were integrated with the DOE Robotics Program.

TTP Information

Diagnostics and Data Fusion of Robotic Sensors technology development activities are funded under the following TTP:

TTP No. ME06IP01, "METC Industry Programs Technology Development Projects"

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Bibliography of Key Publications

None at this time.

4.14 Surveillance and Maintenance Risk and Cost Reduction Evaluation Methodologies

Technology Need

A methodology is needed to assist in evaluating the level of activities being performed during facility deactivation and ongoing surveillance and maintenance to properly address the combination of risk and cost associated with various activity scenarios. As part of those activities, use of robotic or remote systems needs to be properly represented to understand the true potential impact and payoff. The development cost, operational cost during deactivation and surveillance and maintenance, and the potential for ultimate use during final D&D are parameters that are included in evaluations relative to the use of robotic and remote systems for these tasks.

Technology Description

The surveillance and maintenance Risk and Cost Reduction Evaluation Methodologies activity provides the development of analysis tools for the evaluation of risk and cost/benefit tradeoffs associated with the use of robotic systems for surveillance and maintenance and deactivation work. This task supports working with a vendor to develop a commercially available application illustrated by Figure 4.14-1, useful for the evaluation of robotic systems during the facility deactivation and continuing surveillance and maintenance. To accomplish this task, assessment of methodologies will be performed and a final strategy will be selected for use in candidate facilities to test and refine the methodology.

Benefits

This methodology will provide a fairer representation of the impact of robotic technology for facility surveillance and maintenance and D&D. It will account more appropriately for costs and risks that have not been factored into the analyses in the past. In addition, the methodology will assist in the direction of research and development for surveillance and maintenance and D&D.

Collaboration/Technology Transfer

This technology is being jointly developed by ORNL, the Savannah River Technology Center (SRTC), SNL, INEL, and JBF Associates, Inc.

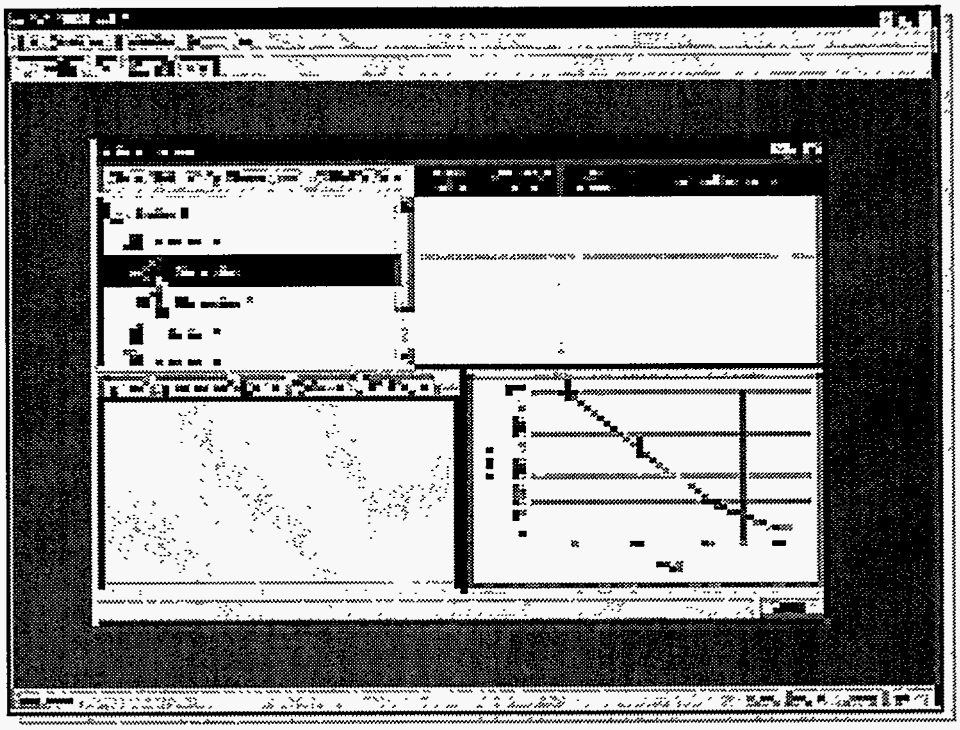

Figure 4.14-1. Comparison of Weighted Scores for Alternatives.

ACCOMPLISHMENTS

- Through collaboration with JBF Associates, Inc., existing risk analysis methods were surveyed, the best-suited approaches were determined, and a prototype computer code was written that served as an analysis tool for implementing the methodology.
- The methodology was demonstrated at INEL on September 7-8, 1994. The demonstration goal was to remove dirt and loose material from the offgas cell floor at a waste calcining facility. The preferred cleanup option was found to be remote liquid decontamination.
- The JBF Associates, Inc., DECIDE software is now commercially available as part of a training course on risk and cost-benefit analysis.

TTP INFORMATION

Surveillance and Maintenance Risk and Cost Reduction Evaluation Methodologies work is funded under the following TTPs:

TTP No. OR15C141, "Robotics ORNL Rollup"
TTP No. SR16C151, "Robotics SRTC Rollup"
TTP No. ID75C121, "Robotics INEL Rollup"

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Bibliography of Key Publications

Guthrie, Vernon H., and David A. Walker. *Risk-Based Robotic Planning: Phase I - Methodology Development*, JBF Associates, Inc., Document No. JBFA-235-94. Knoxville, Tennessee (1994).

Haire, M. J., Vernon Guthrie, and David A. Walker. "Practical Risk-Based Decision Making: Good Decisions Made Efficiently," presented at the 1995 ASME *International Mechanical Engineering Congress and Exhibition*, San Francisco, California (November 1995).

4.15 INTERNAL DUCT CHARACTERIZATION SYSTEM

TECHNOLOGY NEED

Across the DOE complex there are numerous facilities identified for D&D that have been placed on the contaminated list because of the risk of internal contamination in duct work. Most of this duct work is inaccessible because it is buried underground, encased in concrete, or runs through hot cells. Duct work characterization is extremely difficult because of airflow control devices, varying sizes and geometry of the work, and numerous changes in duct direction. Characterization of this work is essential before, during, and after D&D activities. The identification and mapping of contaminants is a major concern during facility deactivation. An understanding of the types and extent of contamination will be primary drivers for decisions regarding decontamination and/or dismantlement. These decisions will affect initial deactivation cost, ongoing surveillance and maintenance risk and cost, and eventual D&D strategy and costs. Identifying sections of the ducts that are not contaminated can greatly reduce the amount of material sent to waste handling facilities for decontamination/disposal. Conventional methods have been applied to the characterization of duct work with some success, but this has been at the risk of human exposure to high levels of contamination. Commercially available remote duct work characterization systems are limited in their capabilities. A robotic/remote duct characterization system with extended travel capability that can perform chemical and radiological contaminant characterization and selected hot spot decontamination or partial duct work dismantlement is needed.

TECHNOLOGY DESCRIPTION

The Internal Duct Characterization System (IDCS) activity provides for the design, fabrication, procurement, and demonstration of a remotely operated system for visually inspecting ventilation duct work and characterizing selected chemical and radiological contaminants that are internally located in ventilation duct work. The IDCS, as shown in Figure 4.15-1, consists of a control station, a reel-mounted tether for data communication, and a pipe crawling vehicle. The IDCS vehicle can travel over 200 feet in round ducts 6 inches in diameter and larger, and in rectangular ducts 6 inches square and larger. The vehicle visually inspects the interior condition of ducts using a high-resolution color video camera, and has an integrated radiation sensor to detect significant levels of radioactivity. The entire vehicle is made from stainless steel and is designed to be decontaminated. The IDCS system also provides limited contaminant sampling and decontamination capabilities.

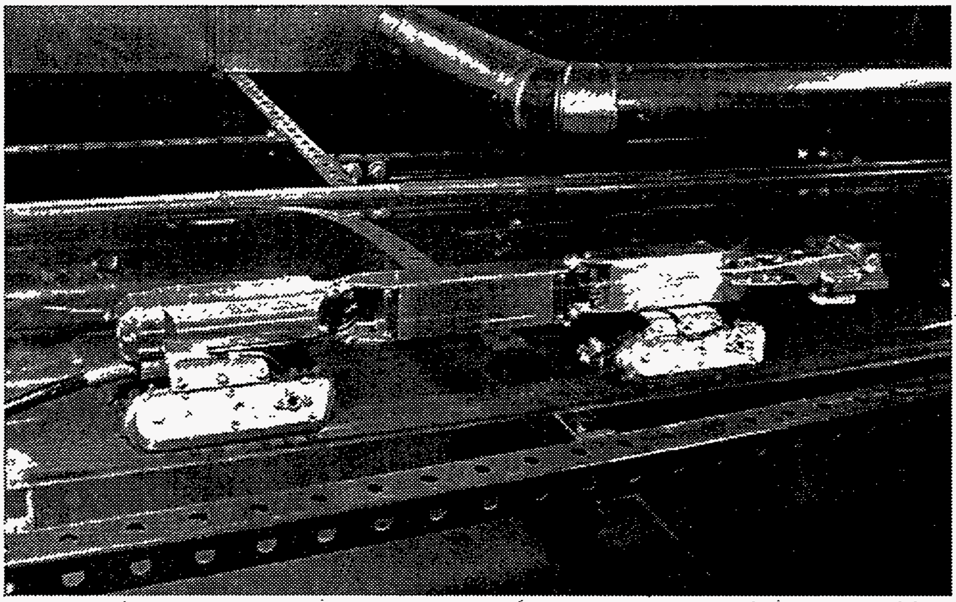

Figure 4.15-1. Internal Duct Characterization System in 8-inch Round Duct.

Benefits

This technology allows characterization of duct work that otherwise could not have been characterized. Determining the absence or presence of contamination and the extent of contamination in duct work will reduce the costs of D&D activities by allowing the duct work to be handled appropriately as opposed to treating all work as contaminated. It will also reduce the amount of secondary waste generated since uncontaminated duct work will not need to be decontaminated. It will reduce human health risk because sections of duct work that pose health risks will have been identified prior to exposure. Using this technology to perform in situ decontamination would provide additional benefits in the areas listed above.

Collaboration/Technology Transfer

This technology has been developed by INEL in collaboration with private industry. Performance requirements for this task were developed at INEL, but much of the design and fabrication was performed by a team of two Canadian companies: Inuktun Services, Ltd., and Automation Systems Associates, Ltd., both located in British Columbia. All the technology developed under this activity is now commercially available, with the patent rights for everything except the drive reconfiguration mechanism held by the industrial partners.

Accomplishments

- The IDCS was used to inspect over 200 feet of contaminated offgas ducting at an operating DOE facility.
- The IDCS control system was upgraded to provide for the addition of sensors and motors.
- A drive reconfiguration mechanism was designed, built, and installed to allow "on the fly" adaptation to varying duct sizes and geometries.
- A vertical travel carriage was designed and built through an industrial procurement.
- The improved IDCS was demonstrated at a major programmatic technology demonstration.

TTP Information

The Internal Duct Characterization System is funded under the following TTPs:

TTP No. ID75C121, "Robotics INEL Rollup"
TTP No. OR15C141, "Robotics ORNL Rollup"

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4.16 SMALL PIPE CHARACTERIZATION SYSTEM

TECHNOLOGY NEED

Across the DOE complex, there are numerous facilities identified for D&D with piping that have been placed on the contaminated list because of internal contamination risk. Much of this piping is inaccessible because it is buried, embedded in concrete, or runs through hot cells. Identification and mapping of contaminants in piping is a major concern during facility deactivation. An understanding of the types of contaminants present and the extent of contamination are primary drivers for decisions regarding decontamination and/or dismantlement, all of which affect initial deactivation cost, ongoing surveillance and maintenance risk and cost, and eventual D&D strategy and cost. Currently, there are no robotic/remote systems capable of characterizing pipe in the 2-to-3-inch size range. Characterization of this piping is essential before, during, and after D&D activities. Identifying those sections of the piping that are actually contaminated can greatly reduce the amount of material sent to waste handling facilities and/or the amount of secondary waste generated performing unneeded decontamination.

TECHNOLOGY DESCRIPTION

The Small Pipe Characterization System (SPCS) activity provides for the design, procurement, fabrication, integration, demonstration, and technology transfer of a system for characterizing contaminants in pipes with internal diameters between 2 and 3 inches. The SPCS, as shown in Figures 4.16-1 and 4.16-2, consists of a control computer, a tether for data communication, and a pipe crawling vehicle. The pipe crawler is driven by DC-motor-powered wheels arranged in a triangular configuration and sprung against the sides of the pipe for traction. The configuration of the wheels allows the pipe crawler to maneuver through radiused elbows and to adapt to changing pipe diameters "on the fly." Live color video is transmitted from the camera on the front of the pipe crawler to the control computer. The SPCS is also capable of deploying small sensors such as radiation detectors; however, appropriately sized sensors have not yet been developed.

BENEFITS

This technology makes it possible to characterize previously inaccessible piping. Determining the absence or presence of contamination and the extent of contamination in piping will reduce the costs of D&D activities by treating only the affected areas. It also reduces the amount of generated secondary waste from uncontaminated piping. Personnel exposure can then be limited only to areas with uncontaminated piping.

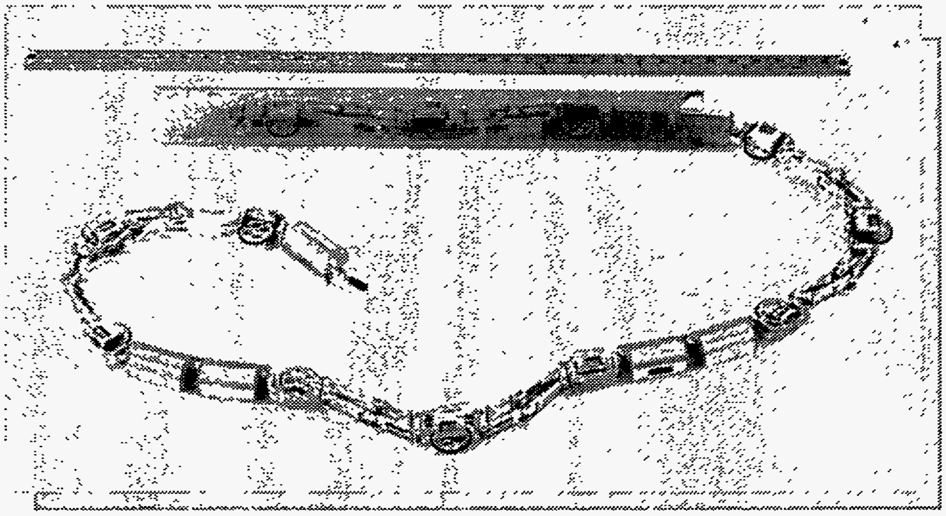

Figure 4.16-1. Close-up of Front Section of Small Pipe Characterization System Vehicle.

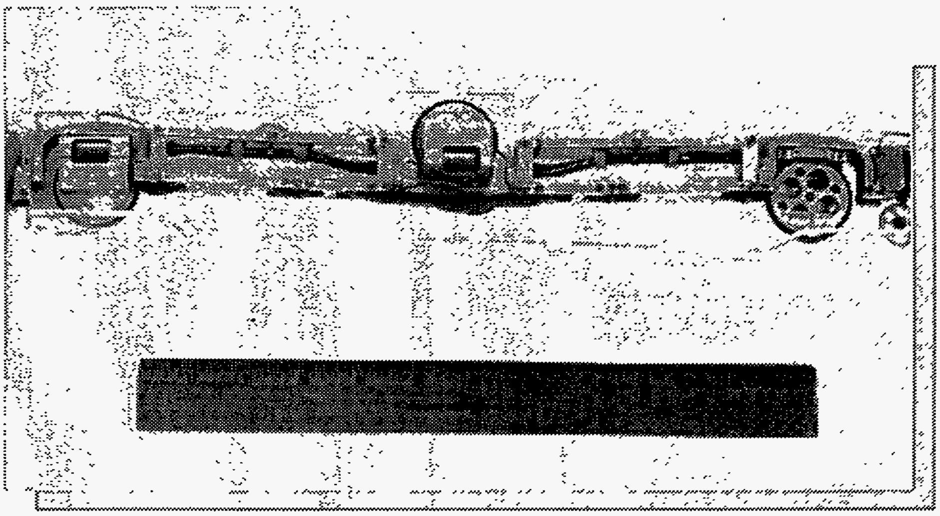

Figure 4.16-2. Small Pipe Characterization System Inserted Into 2-Inch Pipe.

COLLABORATION/TECHNOLOGY TRANSFER

A Cost Share Agreement was negotiated with Foster-Miller, Inc. in FY95, to provide design enhancements and facilitate transfer of the SPCS technology to Foster-Miller for potential commercial development. Under the Cost Share Agreement, Foster-Miller has been granted nonexclusive rights to the SPCS technology.

Accomplishments

- Significant modifications were made to the prototype system to improve maneuverability, increase travel range, and minimize tether diameter.
- A Cost-Share Agreement was placed with a commercial partner for much of the modification work.
- The modified SPCS was demonstrated at a major programmatic technology demonstration. Demonstrated features included video inspection, horizontal and vertical travel, selective steering, cornering, and the ability to transition between 2- and 3-inch pipe "on the fly."

TTP Information

The Small Pipe Characterization System activities are funded under the following TTPs:

TTP No. ID75C121, "Robotics INEL Rollup"
TTP No. OR15C141, "Robotics ORNL Rollup"

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Bibliography of Key Publications

None at this time.

4.17 REDUCED ACCESS CHARACTERIZATION SUBSYSTEM

TECHNOLOGY NEED

Many facilities exist in the DOE complex that have become radiologically contaminated through years of research and service. These facilities include hot cells, gloveboxes, fuel-storage buildings, and process buildings. As many of these facilities are prepared for D&D, the need arises for surveillance and characterization before, during, and after cleanup activities. Characterization is currently being performed in these areas by having a radiation control technician manually monitor radiation levels with hand-held instruments. Although this method is effective for small or hard-to-reach areas, automated floor characterization systems can be much more effective in larger buildings such as the 300+ acre K-25 facility located at ORNL. During the past two years, MACS has been developed jointly by the SRTC and ORNL. The MACS platform is designed to carry multiple radiation sensors and perform automatic floor characterization of large areas. During the development of MACS, it was found that a significant floor area exists in most facilities that is not readily accessible by a large-floor characterization system. RACS is being developed to operate as a subsystem of MACS and provide characterization of areas inaccessible to MACS.

TECHNOLOGY DESCRIPTION

The RACS activity provides for the development and demonstration of a stand-alone robotic floor characterization system that can work cooperatively with MACS to perform tedious floor characterization and provide superior radiological data collection and storage. The RACS system, as shown in Figure 4.17-1, consists of the RACS robot, which is based on a commercially available robot, and a homing/repeater beacon called TRACS. In a typical inspection, RACS and TRACS will be carried on a platform onboard MACS. When MACS arrives at a limited access region, the MACS operator will send a

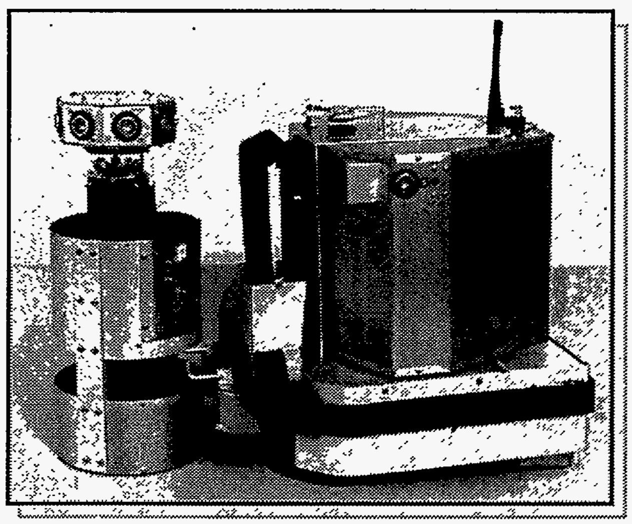

Figure 4.17-1. Reduced Access Characterization Subsystem Robot and TRACS Homing/Repeater Beacon.

deploy command to RACS, which incorporates current global position of the MACS robot and coordinates of the area RACS is to survey. RACS then leaves MACS, drops the TRACS beacon, and surveys the area specified while MACS continues its survey. RACS will transmit radiation and position data back to MACS via TRACS where it is incorporated into the facility map. When RACS has completed its survey, it will retrieve the TRACS beacon and wait until MACS returns. When MACS is in position, RACS will receive a stow command and board its carrying platform on MACS. RACS can also be used as an independent system, if necessary.

Benefits

This technology will allow automated characterization of floor areas that could not have been characterized by larger automatic floor characterization systems. Automated floor characterization, particularly of large areas, can be done much more quickly than manual methods. In addition, the data obtained from automated floor characterization will be more detailed and accurate than manual methods, and can easily be integrated into an overall facility map. The use of automated systems will remove radiation control technicians from potentially hazardous areas and reduce overall personnel exposure by identifying areas that pose health risks prior to possible personnel exposure.

Collaboration/Technology Transfer

This technology has been developed at INEL in collaboration with private industry. All the robotic equipment used in the development of RACS has been procured to INEL specifications from IS Robotics, Inc.

Accomplishments

- The RACS robot and TRACS beacon were procured from industry.
- RACS behaviors for deployment and surveying a rectangular area have been written and incorporated into the system.
- The interface to the radiation sensor was completed and radio transmission of RACS data back to MACS was accomplished.
- RACS was demonstrated at a major programmatic technology demonstration.

TTP Information

Reduced Access Characterization Subsystem activities are funded under the following TTPs:

TTP No. ID75C121, "Robotics INEL Rollup"
TTP No. OR15C141, "Robotics ORNL Rollup"

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Bibliography of Key Publications

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4.18 Selective Equipment Removal System

Technology Need

Hazards associated with contaminated hot cells, canyons, gloveboxes, and reactor facilities at DOE sites are radiation, radiological contamination of the equipment being removed, and hazardous chemicals associated with the processes performed at the facilities. Because of these hazards, deactivation, surveillance and maintenance, and ultimate D&D will have to be performed remotely. D&D operations include disassembly of process equipment, cutting pipes, size reduction of equipment to be removed, transport of pipe and equipment out of the facilities, decontamination of equipment before removal from a facility, and decontamination of floors, walls, and remaining equipment in facilities to be refurbished. Robotics may also be needed to dismantle the facility structure. Hardened robotic systems for facility D&D can provide capabilities to accomplish these operations safely with workers away from the work site. Facility deactivation activities place emphasis on selective D&D in order to minimize the risk and costs associated with potentially long-term surveillance and maintenance activities and final D&D. For pre-surveillance and maintenance facility preparations, or ongoing surveillance and maintenance activities, a remote system capable of being deployed for selective D&D can eliminate high risk or high surveillance and maintenance cost contaminants or equipment.

Technology Description

The Selective Equipment Removal System (SERS) has been developed to demonstrate and evaluate a mobile telerobotic system suitable for performing selective D&D functions applicable to pre-surveillance and maintenance facility preparations. The SERS uses a reconfigurable DAWM to demonstrate inspection, decontamination, and equipment removal operations. DAWM has been deployed from an overhead transporter, as shown in Figure 4.18-1, for initial SERS demonstrations. Evaluations will be performed in FY96 for the development of a mobile work system through interaction with the Office of Science and Technology-funded PRDA contract with Carnegie Mellon University/RedZone Robotics, Inc. SERS tasks have included development of operator control console capabilities, development of scene generation and analysis capabilities, and a study of a remote tool set.

Benefits

Development of SERS will afford the opportunity to demonstrate and evaluate a mobile telerobotic system suitable for performing selective D&D

functions applicable to pre-surveillance and maintenance facility preparations. Overhead transporter, overhead crane, and vehicle-based deployment of the DAWM system provide the mobility options for SERS operation in pre-surveillance and maintenance and eventual D&D telerobotic tasks. Remotely deployable telerobotic systems remove workers from direct exposure to contaminants and industrial hazards.

Collaboration/Technology Transfer

This technology is being jointly developed by ORNL, SNL, and INEL and entails interaction with the University of Tennessee and Carnegie Mellon University.

Accomplishments

Initial SERS subsystem fabrication, modification, and integration has been completed. Specific subsystems include a DAWM, deployment from an overhead transporter, operator control console, task space scene analysis system, and high and low-level control system capabilities required to provide teleoperation, telerobotic operation, and robotic operation. The overhead transporter deployed SERS began task demonstration in the fourth quarter of FY94 at ORNL. Human-machine interfaces and automation enhancements will be developed to support various modes of mobile deployment.

- For FY95, Carnegie Mellon University/RedZone Robotics, Inc., delivered their SERS/DAWM mobile platform deployment option "Rosie" vehicle, developed under a DOE METC PRDA. Testing began in the Robotics Technology Assessment Facility at ORNL.
- Future direction indicates deployment of both Rosie and the DAWM in the dismantlement of the CP-5 research reactor at Argonne National Laboratory.

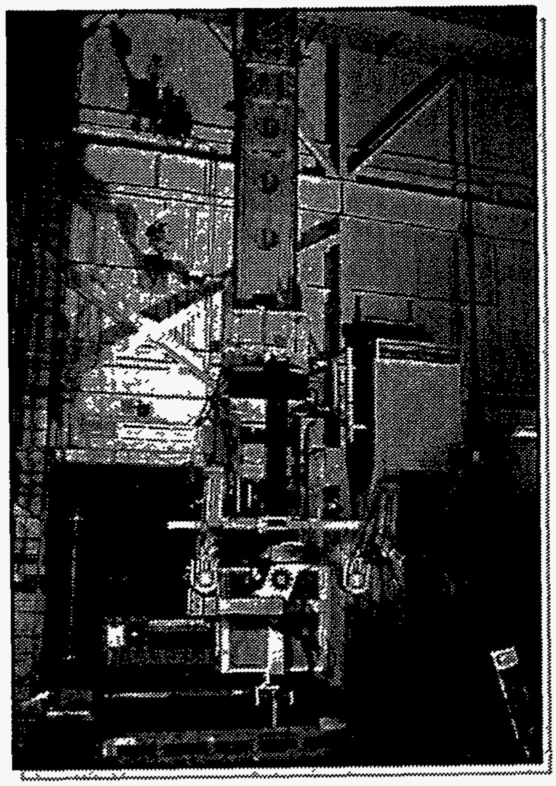

Figure 4.18-1. Dual-Arm Work Module (in lower third of picture) on Overhead Transporter.

TTP Information

The Selective Equipment Removal System is funded under the following TTPs:

TTP No. OR15C141, "Robotics ORNL Rollup"
TTP No. AL25C161, "Robotics Technology Development Rollup" at SNL
TTP No. ID75C121, "Robotics INEL Rollup"

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4.19 Technetium and Actinide Solvent Extraction

Technology Need

Efficient processes for the removal of technetium, strontium, and cesium from highly radioactive waste are priority needs of the Efficient Separations Program, the Tank Focus Area Program, and the Tank Waste Remediation System Program. How to safely dispose of the large volumes of radioactive wastes stored in underground tanks is one of the largest problems facing DOE. The general goal being pursued is overall cost savings through both reducing the volume of waste that must be committed to a geologic repository, and minimizing secondary waste streams.

Several promising technologies as separate unit operations have been under development in DOE programs to remove technetium, strontium, and cesium from alkaline tank supernate. These technologies would presumably be employed in series and would each entail separate process requirements, consumption of materials, effluent streams, stripping (if applicable), and impacts on vitrification.

Although the emerging technologies individually remove their target contaminants effectively, there may be compelling advantages to a single extractant that could remove technetium, strontium, and cesium together and transfer them to water, which can then be simply evaporated to produce a minuscule effluent volume. The overall process would be simpler in that a single technology is involved, and the space requirements could significantly shrink. Chemical consumption and new waste production would be minimal, limited essentially to replacement of extractant. Stripping would be accomplished with water, allowing the high-level effluent to be reduced to a minimal volume in a simple manner and leading to little chemical impact on vitrification processing.

Technology Description

Tank wastes at the Hanford Site and elsewhere [e.g., Melton Valley Storage Tanks (MVST) at Oak Ridge] are typically strongly alkaline and contain technetium, strontium, cesium, and other radioactive contaminants. In proposed treatment processes, these contaminants may be found in the aqueous supernates, or may be solubilized from the sludge during sludge washing or leaching. Because these aqueous streams will contain compli-cated and variable mixtures of salts, highly efficient separation methods are needed.

The purpose of this task is to develop an efficient solvent-extraction and stripping process to remove the fission products technetium-99, strontium-90, and cesium-137 from alkaline tank wastes, such as those stored at Hanford and Oak Ridge. As such, this task expands on FY95's successful development of a solvent-extraction and stripping process for technetium separation from alkaline tank-waste solutions. This process now includes the capability of removing both technetium and strontium simultaneously. In this form, the process has been named SRTALK and will be developed further in this program as a prelude to developing a system capable of removing technetium, strontium, and cesium.

Such a system could potentially simplify and improve fission-product removal from tank waste. In addition, it would possess advantages already inherent in our technetium solvent-extraction process: no required feed adjustment, economical water stripping, low consumption of materials, and low waste volume.

Whereas it has been commonly thought that applicable separation methods must also be selective for individual species, this work addresses the question of making a practical group selection for technetium, strontium, and cesium. Such a disparate trio of elements would ordinarily seem to have little chance of simultaneous extraction, but our tests together with available literature reveal that crown ethers may well offer this ability.

Because of its high selectivity and good mass-transfer properties, solvent extraction is a potentially attractive vehicle for combined technetium, strontium, and cesium removal from tank waste. The high ionic strength of the feed promotes good phase separation and minimizes (by "salting out") the solubility of organic solvent components in the aqueous phase. Centrifugal contactors should provide efficient recycling of the solvent, minimizing inventory requirements, solvent entrainment losses, and solvent radiation degradation. Solvent extraction has proven to be effective in many nuclear separations, establishing a good foundation for application to tank waste.

In FY96 we plan to develop the process flowsheet for the solvent extraction of technetium from alkaline supernatant and water stripping as needed by potential users. For example, Pacific Northwest National Laboratory (PNNL) has proposed to test the process on simulated and actual Hanford supernatant in 2-cm centrifugal contactors. We plan to continue investigating appropriate extractants, diluents, and modifiers for the combined extraction of technetium, strontium, and cesium. Key issues are achieving high extraction and stripping ratios for all of these, as some factors that enhance cesium extraction might suppress technetium stripping. This may additionally involve some combined effort with optimizing cesium and strontium extractants.

First, we will define a workable solvent, then we will begin process cycle development and seek ways to optimize the process. Intermediate stages will include demonstration of processes capable of combined technetium and strontium (SRTALK) extraction and combined cesium and technetium extraction from alkaline tank supernate.

BENEFITS

The Tank Focus Area and Tank Waste Remediation System will receive the primary benefit from this program. By removing and concentrating fission products directly from tank waste, increased safety and effectiveness in processing tank wastes, and large cost savings will be obtained because of reducing the high-level waste volume that must be committed to a geologic repository.

Compared with a sequence of three fixed-bed technologies, a combined technetium, strontium, and cesium extraction process could simplify processing and reduce space requirements. An effluent of these contaminants in water alone allows manyfold concentration by simple evaporation or sorption onto known solid materials.

The proposed technology offers the following major advantages: (1) direct treatability of the waste; (2) safe, economical, and efficient stripping using only water; (3) no additions of chemicals to the extraction or stripping cycle; and (4) use of diluents with high flash point, low toxicity, and low water solubility.

Collaboration/Technology Transfer

Industrial partners will be needed to supply crown ethers and other extractants in large quantities at reasonable cost. Eichrom Industries has a proven record in the production and sale of a key crown ether for solvent extraction of strontium and technetium. Further development of large-scale manufacturing procedures is still needed to reduce the cost of these expensive materials. In addition, the assistance of industry will prove valuable in designing and fabricating the appropriate contacting equipment for pilot and plant-scale use.

Both PNNL and ANL have expressed interest in testing the technetium solvent-extraction process for the Tank Focus Area. Interaction with Ben Hay at PNNL has provided insight into conformational effects and design of crown ethers.

Accomplishments

- A solvent-extraction and stripping process was defined for removing technetium from alkaline tank waste.
- A highly effective solvent for the process contains 4,4',(5')-di-t-butyldicyclohexane-18-crown-6 dissolved in TBP-modified isoparaffinic kerosene. The solvent has been tested on actual tank waste from ORNL's MVST; performance was equivalent to that obtained with waste simulants. Extraction and stripping efficiencies of 98 percent or better are attainable with two-stage extraction and two-stage stripping at unit phase ratio using waste simulants.
- The SRTALK process is under development to simultaneously extract technetium and strontium from alkaline tank-waste supernate. Results using a MVST simulant have shown that combined extraction and stripping efficiencies of 96 percent and 99 percent for technetium, respectively, and 62 percent and > 99 percent for

strontium, are attainable with two-stage extraction and two-stage stripping at unit phase ratio. Work toward increasing the extraction efficiency for strontium has produced excellent results from simple alkaline sodium nitrate solutions.

- Results to date reveal cesium extraction and stripping efficiencies from actual MVST W-29 waste of 89 percent and > 99 percent, respectively, following four equal-volume cross-current extraction contacts, and four equal-volume cross-current stripping contacts using only water. Combined technetium and cesium extraction and stripping results from MVST W-29 simulant have shown that combined extraction and stripping efficiencies of respectively 96 percent and 83 percent for technetium, and 37 percent and 93 percent for cesium, are attainable with two-stage extraction and two-stage stripping at unit phase ratio.

TTP Information

The Technetium and Actinide Solvent Extraction technology development activities are funded under the following TTP:

TTP No. OR16C341 "Technetium and Actinide Solvent Extraction"

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4.20 HIGH-TEMPERATURE VACUUM DISTILLATION SEPARATION OF PLUTONIUM WASTE SALTS

TECHNOLOGY NEED

There are 16 metric tons of salts at Rocky Flats Plant containing approximately 1 metric ton of plutonium. Most of these salts (11 tons) are composed of a sodium chloride-potassium chloride matrix. The remainder consists of a calcium chloride matrix. These salt residues are the product of past plutonium processing operations. The Defense Nuclear Facilities Safety Board has expressed concern (in Recommendation 94-1) about possibly unstable residues resulting from suspension of weapons-related activities in the DOE complex. These concerns include residue salts stored at Rocky Flats.

DOE responded with commitments to mitigate the hazards associated with these residues, including mitigating the problems associated with 6,000 kg of high-hazard pyrochemical salts at Rocky Flats by May 1997, and an additional 4,000 kg by December 1997. The high-hazard salts are stored in drums in buildings where workers need routine access and are in proximity to the drums. These residues may pose a safety risk if the reactive metals in the residues come into contact with water, creating hydrogen gas that could cause container pressurization.

The full 16-ton inventory is to be made safe by May 2002. In addition to mitigation of hazards, these residues must also be made acceptable for eventual disposal. An additional 2 tons of these salt residues exist at Los Alamos National Laboratory (LANL) and require stabilization by May 2002.

TECHNOLOGY DESCRIPTION

In this task, high-temperature vacuum distillation separation is being developed for residue sodium chloride-potassium chloride salts resulting from past pyrochemical processing of plutonium. This process has the potential of providing clean separation of salt from the actinide content with minimal amounts of secondary waste generation. The process could produce chloride salt that could be discarded as LLW or low actinide content TRU waste, and a concentrated actinide oxide powder that would meet long-term storage standards (DOE-3013-94) until a final disposition option for all surplus plutonium is chosen.

Distillation separation is based on the large difference in vapor pressures at high temperature between most chloride salts that constitute pyrochemical residues and the actinide oxides. However, the plutonium content in these salts is usually a form of plutonium trichloride. Vapor pressure differences between alkali and alkaline earth chlorides and plutonium trichloride are too small to effect a good separation, therefore $PuCl_3$ must be converted to an oxide through an oxidation process. Staff at LANL have developed a process that uses carbonate salts to act as an oxidant. This process has proven very effective in converting all plutonium species into plutonium dioxide. This oxidation process can be ultimately combined with a distillation separation process.

Uncontaminated salts have been used to verify the feasibility of the salt distillation process. These tests employed existing equipment and have been used to determine distillation rates as a function of temperature. A target rate of 3 kg per unit per day had been established. Results for sodium chloride-potassium chloride indicated that such a rate was easily achievable. Distillation rates for calcium chloride were found to be too slow below 11,000 degrees Celcius. Tests with uncontaminated salts have also been used to provide input for equipment designed expressly for the salt distillation process. This equipment is being fabricated and will be tested to verify expected performance, then transferred to a DOE EM-60-funded project that will process LANL residues to serve as a pilot demonstration for processing at Rocky Flats.

The high temperatures needed for calcium chloride distillation require extensive modification and redesign of equipment that could be used for sodium chloride-potassium chloride processing. The high temperatures and resulting complications make vacuum distillation of calcium chloride salts a less attractive process than that for the alkali metal chloride salts. Other physical processes, such as filtering solid plutonium dioxide from either the molten salt or aqueous salt solution will also be explored. Chemical conversion of plutonium species into a liquid metal alloy will also allow physical separation of the immiscible phases.

Existing pyrochemical processing equipment at LANL is being used with plutonium contaminated salts to test the separation achievable by the salt distillation process. A variety of feed sources and pretreatments are being used. These tests also establish the ability to carry out the process in a plutonium glovebox environment.

Other methods are being examined for separating calcium chloride residue salts. These alternatives include vacuum distillation at higher temperatures than sodium chloride-potassium chloride salts, molten salt filtration, recovery of actinides as metal alloys, and a combined aqueous-pyrochemical separation process.

BENEFITS

Separating the plutonium from the waste salts will lead to a large reduction in the cost of disposal, even if the salts do not meet LLW disposal criteria. Present Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria (WAC) would result in a maximum plutonium loading per 55-gallon drum of 23 g. In the best possible circumstance this would lead to more than 50,000 drums. Efforts are underway to modify the WIPP WAC to allow 200 g of plutonium per drum. This would still result in 8,000 drums.

If the plutonium in the salts can be reduced to less than 100 parts per million, a drum could be filled with salt without impacting even the present 25g of plutonium limit. In this case, approximately 200 drums would be generated for WIPP disposal. At a cost of $10 thousand per drum, the cost savings realized could total several tens of millions of dollars. The separated plutonium, consisting of 1 metric ton of plutonium dioxide, could be packaged for long-term storage per DOE-STD-3013-94. Plutonium oxide storage costs would be greatly offset by savings realized from WIPP disposal. Recent estimates of the total costs of processing by distillating the salt inventory at Rocky Flats are $71 million, compared to $103 million for disposal at WIPP with modified WIPP WAC, and $534 million with the current WIPP WAC.

Collaboration/Technology Transfer

After receipt and testing of new full-scale equipment, the technology and equipment will be transferred to personnel supported by DOE EM-60 to conduct a processing campaign with residue salts at LANL.

Accomplishments

- Experiments with both uncontaminated and plutonium contaminated salts have unequivocally established that kilogram quantities of alkali metal chloride salts can be distilled per unit operation per day. Excellent mass balance has been achieved with both distilled salt (> 99.5 percent) and distillation heel (> 99.9 percent).
- Tests with salts (approximately 50 kg) containing plutonium have successfully separated alkali metal chloride salts from the actinide content of the residue. The plutonium concentration of the salts was reduced from the tens of percent level to the parts-per-million level.
- Salts pretreated by a molten carbonate oxidation process were found to be excellent feed for the distillation separation process. These results led to funding by DOE EM-60 for design and procurement of full-scale, production capable equipment. This equipment is scheduled to begin processing salt residues at LANL in March 1996. The processing campaign will serve as a pilot-scale demonstration for Rocky Flats.

TTP Information

The High-Temperature Vacuum Distillation Separation of Plutonium Waste Salts technology development activities are funded under the following TTP:

TTP No. AL16C321 "High-Temperature Vacuum Distillation Separation of Plutonium Waste Salts"

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None at this time.

4.21 Separation of HTO Using Membranes Tritium Membrane Test

Technology Need

Although processes to remove tritiated water (HTO) are available (e.g., combined electrolysis-catalytic exchange), most require intensive capital or energy expenditures. Thus, the proposed remediation of HTO from DOE sites frequently involves migration with time through geologic formations. Although this is logical because of tritium's short half-life (12.3 years), regulatory agencies have requested more emphasis on separation technology because of concerns about groundwater movement; that is, the rapid groundwater flow that allows a plume of HTO quicker access to a river and ultimately to human and animal ingestion. Sites currently having either a point source or groundwater containing HTO are Hanford, Savannah River, INEL, Lawrence Livermore National Laboratory (LLNL), Brookhaven National Laboratory (BNL), and Mound Laboratory.

Technology Description

Polymeric composite membranes are being developed to remove tritium from contaminated water at DOE sites. Industrial membrane systems are being developed that have proven to be energy efficient, and membrane technologies such as reverse-osmosis have been well developed for desalination and other industrial/municipal applications. Aromatic polyphosphazene membranes are being investigated because they have excellent radiological, thermal, and chemical stability. The FY96 effort is directed toward delineating a potential mechanism, providing a statistical approach to data acquisition, refining a mass balance, and designing a staged array module. The major milestones of this project are directed at several issues, including a statistical approach to experimental design and mass balances, calculations from a designed module staged array, and a determination of the mechanism of the HTO separation.

In FY95, we showed that the poly[bis(phenoxy)phosphazene]-based membrane can consistently achieve 30 percent reduction in a single pass, from 3 µCi/L (K-East Basin water). The FY96 work is directed primarily at a basic understanding of the HTO separation. Thus, a series of mass balance experiments will be conducted to confirm the preliminary FY95 results. Experiments will follow statistically designed parameters. The designed experiments will examine factors that might impact the HTO separation, such as pH, ion type/concentration, and temperature.

Staff at the University of Idaho and the University of Washington will provide spectroscopic data on the possible mechanism of the HTO separation. SpinTek

Membrane Systems (Huntington Beach, California) will assist in the study of water permeation through the membranes. Several critical factors must be determined if the system is to be implemented. We expect to examine N-Basin water (39 μCi/L) during FY96 as well as water with a much higher tritium content. Experiments with water in the milliCurie per liter or higher range will require coordination with regulatory and technical personnel and possibly other DOE sites. The data from this experiment is crucial because it will allow us to determine further design parameters for the staged array system. Once most of the mechanism information and membrane property data are obtained, we will calculate the hypothetical separation of the HTO from water in the cascade.

Benefits

Waters containing unacceptable tritium concentrations (above environmental release limits or drinking water standards) are released at DOE sites, including Hanford, Savannah River, INEL, LLNL, BNL, and Mound. One example involves the C-O18H Treatment Facility at Hanford (to treat 242A evaporator waste water), which will discharge (1.4 million gallons) of treated condensate containing tritium averaging 6.3 μCi/mL through the year 2015. Currently, water from some test wells at Hanford contain tritium concentrations approaching 6×10^7 pCi/L. The Tri-Party Agreement requires that the HTO in the K-East Basin (spent nuclear fuel storage) be treated or relocated. Currently, there are no acceptable removal options for tritium remediation other than migration with time through geologic formations. This work will reduce the risk to the environment and public, reduce the costs for ultimate disposal for the tritium-containing water, and provide a way to recover the tritium in a concentrated form for disposal or use.

Tritium is also found in nuclear power plants in Canada and the United States, as well as at the Savannah River Site, as a result of neutron capture within the heavy water moderator/coolant. Light water coolant also contains increasing concentrations of tritiated water (HTO and related species) in a similar part-per-million range due to neutron emission/capture (uranium fission). This technology would go far to mitigate HTO as a point source pollutant for light water reactors. Also, there is a possibility that this membrane separation process would be of use in the future fusion effort.

Collaboration/Technology Transfer

This work is a collaborative effort between PNNL, Westinghouse Hanford Company, and SpinTek Membrane Systems. Atomic Energy Canada, Limited, has also expressed interest in the membrane process and has entered into a proprietary agreement with PNNL. Two meetings with Ontario Hydro personnel have been conducted.

PNNL has expanded the involvement of interested industries, including collaboration with Desalination Systems, Inc., during FY95. Liumar Technologies Corporation has examined the polyphosphazene membranes for their proprietary applications and continue to provide information about aqueous permeation. Separation Systems Technology, Inc. (San Diego, California) has also provided considerable information concerning membrane properties needed for module design. Scientific Ecology Group in Oak Ridge has discussed their need for this technology for application to commercial nuclear power facilities.

Information concerning deuterium and tritium physical properties has been obtained from both the All Russian Institute of Chemistry/Murmansk and the Association of Advanced Technologies/MINATOM (Russia). DOE is also collaborating with the University of Idaho and the University of Washington (Center for Process Analytical Chemistry) to help further define the HTO separation mechanism spectroscopically.

To promote interest in this technology, the work was presented to the Canadian Nuclear Society and the American Nuclear Society. A major publication is in press, and a patent was also issued.

ACCOMPLISHMENTS

- A statistical design of experiments was completed, and work toward providing the necessary information is under way.
- Ten gallons of K-East Basin water (3 µCi/L) have been deionized, distilled, and used as a source of HTO for initial experiments. Twenty gallons of N Basin water (39 µCi/L) will also be prepared for similar use.
- Experiments were conducted with 10 percent carboxylated poly(diphenoxy) phosphazene, unannealed, using distilled K-East Basin water (3 µCi/L). The experiments indicated that HTO separation is quite variable and reached 18 percent depletion with only one carboxylated membrane under deionized water conditions. This confirms the variability from many previous experiments with unannealed membranes.
- The annealed membranes were also examined under similar conditions (4°C and distilled K-East Basin water), but the scintillation results indicate little, if any, HTO depletion. However, the pressure stability required to maintain permeation with the annealed membranes was more consistent in contrast to the continual pressure fluctuations needed for the unannealed membranes.
- The same set of experiments (2 membranes and 4°C) was performed with distilled K-East Basin HTO containing 0.001 M Na_2SO_4. Both membrane types provided HTO separation, with the carboxylated membrane showing up to 17 percent HTO depletion, after four hours of operation. Membrane experiments with 0.01 M and 0.1 M Na_2SO_4 solutions, as well as with similar calcium salt

concentrations, are currently being conducted. Although the initial experiments have not been completed, the current data suggest that hydration shell involvement may be a significant part of the HTO separation mechanism.

- Liumar Technologies Corporation of Ottawa, Ontario, is determining the coating conditions of the poly(diphenoxy)phosphazene with material from Ethyl Corp. They are also attempting to establish the nanofiltration characteristics of the membrane using various molecular weight polyethylene oxides.

TTP Information

The Separation of HTO Using Membranes and Tritium Membrane Test technology development activities are funded under the following TTPs:

TTP No. RL36C311 "Separation of HTO Using Membranes"

TTP No. RL46C311 "Tritium Membrane Test"

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4.22 Water-Soluble Chelating Polymers for Removal of Plutonium and Americium from Waste Water

Technology Need

Alternative technologies are needed to treat radioactive waste water to meet regulatory limits, decrease disposal costs, and minimize waste. Currently, most DOE sites handle substantial volumes of dilute aqueous streams that must be treated before they are discharged into the environment.

In particular, this project addresses the need to replace precipitation methods that generate large volumes of radioactive sludge at LANL and other DOE sites and to reduce TRU wastes that will be generated from processing the large volume of plutonium-containing residues at DOE facilities.

Sludge handling and disposal is becoming more expensive as burial requirements increase and approved burial sites become less available. More stringent discharge regulations have been enacted by DOE, EPA, and the states in recent years that require considerably lower metal ion concentrations in the effluent water from facilities such as the LANL Waste Treatment Facility. Precipitation technology cannot consistently meet current discharge limits for some metals. Even lower discharge limits are anticipated in the future. The longer-term goal of moving to closed-loop, zero-discharge systems for water handling will require new approaches and new combinations of technology.

An important subset of the waste waters of concern are mixed wastes that contain radioisotopes and toxic metals on the Resource Conservation and Recovery Act (RCRA) list. Treating the mixed waste to reduce the amount of toxic metals to levels below regulatory concern could generate a much smaller mixed-waste stream. These can be treated by other technologies that are better established from a regulatory viewpoint. Developing technology to treat mixed wastes is being driven at most DOE sites by schedules established in the various Federal Facility Compliance Agreements between EPA and DOE.

Technology Description

Polymer filtration is a technology being developed to recover valuable or regulated metal ions selectively from process or waste waters. Water-soluble chelating polymers are specially designed to bind selectively with metal ions in aqueous solutions. The polymers' molecular weight is large enough so they can be separated and concentrated using available ultrafiltration technology. Water and smaller unbound components of the solution pass freely through the ultrafiltration membrane. The polymers can then be reused by changing the solution conditions to release the metal ions, which are recovered in concentrated form, for recycle or disposal.

The basis for metal ion separation involves the retention of metal ions bound to the chelating groups of the water-soluble polymer while smaller unbound species and water pass freely through the ultrafiltration membrane. Figure 4.22-1 illustrates that metal ions bound to the chelating water-soluble polymer are retained by the ultrafiltration membrane; water and other small solute species pass through freely. The polymer filtration process allows for the selective concen-tration of dilute solutions of metal ion contaminants. The reduced volume containing the polymer/metal ion complex can go directly to disposal or the metal ions can be recovered by a stripping reaction and the polymer can be recycled for further metal ion recovery. The advantage of this separation technology for dilute metal ion solutions is its rapid kinetics, which result from the homogeneity of the process. In addition, by careful selection of the chelating functionality, selective metal ion complexation can be obtained.

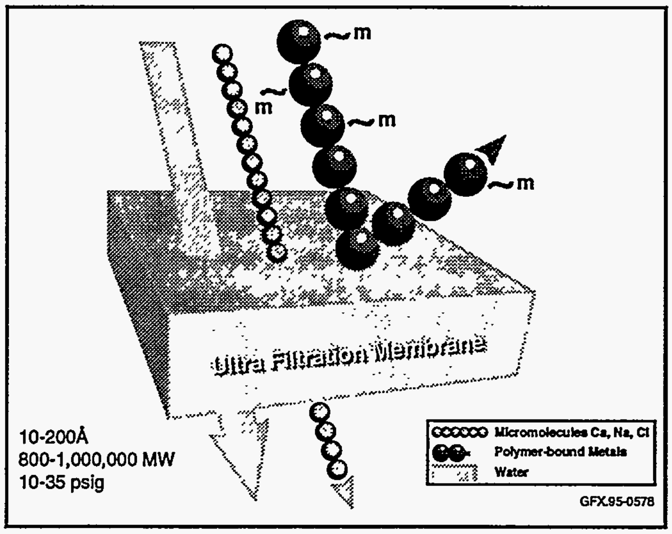

Figure 4.22-1. Metal Ion Separation.

Advantages of polymer filtration relative to technology now in use are rapid binding kinetics, high selectivity, low energy and capital costs, and a small equipment footprint. Some potential commercial applications include electroplating rinse waters; photographic processing; cooling water in nuclear power plants; remediating contaminated soils and groundwater, removing mercury contamination; and producing textiles, paint, and dyes.

The purpose of this project is to evaluate this technology to remove plutonium, americium, and other regulated metal ions from various process and waste streams found in nuclear facilities. The work involves preparing the chelating water-soluble polymers; small-scale testing of the chelating polymer systems for the required solubility, ultrafiltration properties, selectivity and binding constants; and an engineering assessment at a larger scale for comparison to competing separation technologies. This project focuses on metal-ion contaminants in waste streams at the Plutonium Facility and the Waste Treatment Facility at both LANL and Rocky Flats. Potential applications at other DOE facilities are also apparent.

This project involves preparation of the chelating water-soluble polymers and small-scale testing of the chelating polymer systems for the required solubility, ultrafiltration properties, selectivity and binding constants followed by a large-scale engineering assessment for comparison to competing separation technologies. Reducing the concentration of a target metal ion to extremely low levels will require the water-soluble chelating polymer to have a high binding strength that can accomplish the desired separation. However, in the presence of other cations, the ligand will require a large selectivity for the target metal ion to overcome competition from other cations for the ligand binding sites. In many of the waste streams to be addressed, the target actinide ion is present in very low concentration relative to metals such as sodium, potassium, calcium, and magnesium. Phosphonic acid, hydroxamic acid, and acylpyrazolone groups have a demonstrated affinity for high-valent metal ions, such as the actinides, relative to low-valent metal ions such as magnesium, calcium, or sodium. Therefore, the water-soluble polymers prepared in this project have employed these functional groups.

A systematic series of water-soluble chelating polymers has been prepared in this project. Some of these polymers are based on commercially available polymer backbone structures, and some are prepared from monomer units by polymerization reactions. The polymer backbone has been functionalized with phosphonic acid, acylpyrazolone, and hydroxamic acid groups for the reasons described above. The polymers have been characterized for solubility, stability, and retention during ultrafiltration in the pH range 1 to 9. The polymers with the best characteristics are tested for metal binding properties.

BENEFITS

This technology can provide a cost-effective replacement for sludge-intensive precipitation treatments and yield effluents that meet increasingly stringent discharge requirements. At LANL, we are working to save millions of dollars in capital and operating costs for renovating the Waste Treatment Facility by using improved extraction technology to greatly reduce the transuranic content of waste streams from the Plutonium Facility.

The polymer filtration technology is one of the advanced extraction technologies under evaluation in this effort. Polymer filtration systems can also be used at Rocky Flats to address Interagency Agreement requirements to develop and evaluate radionuclide treatment technologies, including treatment of environmental surface waters. Applications for these systems at INEL, Hanford, and other DOE facilities are also apparent.

We also see potential application for the water-soluble polymers to decontamination and decommissioning work. The polymer solution can be used to wash surfaces and remove contaminating metal ions. The metal ions would then be concentrated and recovered through the ultrafiltration operation and the polymer reused for further cleaning. Water-soluble polymers related to those prepared for this project have already shown promise for removing lead from soils at Superfund sites, and this work is proceeding to the demonstration phase. Other polymers have been developed for removing mercury contamination, controlling acid-mine-drainage, and removing technetium from groundwater. Demonstration sites for these applications are currently being sought.

COLLABORATION/TECHNOLOGY TRANSFER

Specific immediate customers for this technology are EM-30's Waste Treatment Facility at LANL and Defense Program's projects at LANL that cannot operate fully without the operations at the Waste Treatment Facility.

While application of the polymer filtration technology to electroplating operations is nearest to commercial deployment, we expect the prototype equipment that has been developed for these markets to be readily transferable to operations within the glovebox environment at the LANL Plutonium Facility. The effort within EM-60 to stabilize residues and wastes at DOE facilities as a result of the Defense Nuclear Facility Safety Board's Recommendation 94-1 may also require this technology in the near term.

Potential commercial applications beyond electroplating and plutonium processing operations include water cleanup, silver recovery from photographic and jewelry processes, leaching of toxic metals from soils, and decontamination and decommissioning operations. A number of these opportunities are being persued with industrial partners.

ACCOMPLISHMENTS

- A series of water-soluble polymers functionalized with phosphonic acid, acylpyrazolone, and hydroxamic acid chelating groups were prepared for evaluation and tested for metal ion retention at pH values from 1 to 6 and ionic strengths from 0.1 to 4.0 (sodium nitrate/nitric acid or sodium chloride/hydrochloric acid) with tracer amounts of americium and plutonium. Polymer concentration is generally about 1 wt percent, and the solution is filtered through an ultrafiltration membrane with the appropriate molecular weight cutoff.
- To date, the phosphonic acid derivatives have shown the best properties for removing plutonium and americium in the target solutions. Therefore, FY96 demonstration tests will concentrate on using the phosphonic acid-containing polymers.

- A polymer filtration apparatus was deployed for tests on actual waste solutions in the LANL Plutonium Facility. We tested the polymer filtration process on 7 L of wash solutions with initial pH of 1.5. The water-soluble chelating polymer was added, and the pH was adjusted with potassium hydroxide to the range of 5 to 6. The final permeate volume was approximately 6.75 L and the retentate volume was approximately 0.25 L. The alpha activity due to plutonium and americium was reduced from 75,400 cpm/mL in the original solution to 333 cpm/mL in the permeate (well below the discard limits for the industrial waste line).
- Ten L of nitric acid distillate (approximately 1 N) was run from an evaporator being tested to recycle nitric acid. About 1 L of 10 N potassium hydroxide solution was added to neutralize the acid and give a final pH of 8 to 8.5. The final permeate volume was approximately 10.5 L and the retentate volume was approximately 0.5 L. Permeate rates were in the range of 1 L every 12 to 16 minutes. The alpha activity was reduced from 4,288 cpm/mL to 97 cpm/mL. A demonstration unit will be designed, built, and tested in FY96 on waste water produced in LANL's Plutonium Facility.
- Four patent applications were filed in May 1995 that cover a variety of polymer filtration applications including the removal of radioactive metal ions from waste water streams.

TTP Information

The Water-Soluble Chelating Polymers for Removal of Plutonium and Americium from Waste water technology development activities are funded under the following TTP:

TTP No. AL16C322 "Water-Soluble Chelating Polymers for Removal of Plutonium and Americium from Waste Water"

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DOE Business Opportunities for Technology Development

Working with the DOE Office of Environmental Management

The Office of Environmental Management (EM) provides a range of programs and services to assist private sector organizations and individuals interested in working with DOE in developing and applying environmental technologies. Vehicles such as research and development contracts, subcontracts, grants, and cooperative agreements enable EM and the private sector to work collaboratively. In FY95, 39 percent of Office of Science and Technology (OST) funding went to the private sector, universities and other federal agencies. EM's partnership with the private sector is working to expedite transfer of newly developed technology to EM restoration and waste management organizations, industry, and other federal agencies.

Several specific vehicles address institutional barriers to effective cooperation and collaboration between the private sector and DOE. These mechanisms include contracting and collaborative agreements, procurement provisions, licensing of technologies, consulting arrangements, reimbursable work for industry, and special consideration for small businesses.

Information on EM

The EM Center for Environmental Management Information provides the most current facts and documents related to the EM program. Through extensive referrals, the Center connects stakeholders to a complex-wide network of DOE Headquarters and Operations Office contacts.

To obtain information from the EM Center for Environmental Management Information, write or phone:

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The Cooperative Research and Development Agreement

The Cooperative Research and Development Agreement (CRADA) is a written agreement between one or more federal laboratories and one or more nonfederal parties through which the government provides personnel, facilities, equipment, and other resources, with or without reimbursement, to support a shared research agenda. The nonfederal parties may also provide funds, personnel, services, facilities, equipment, intellectual property, or other resources to support the research. DOE developed a modular CRADA to be responsive to the needs of participants while protecting the interests of the government and its taxpayers. DOE also has issued the small business CRADA to expedite agreements with small businesses and other partners that meet DOE's requirements. During FY95, EM entered into more than 60 CRADAs.

The Research Opportunity Announcement

The Research Opportunity Announcement (ROA) is a solicitation for industry and academia to submit proposals for potential contracts in basic and applied research, ranging from concept feasibility through proof-of-concept testing in the field. This mechanism is used when EM is looking for multiple solutions for a given problem. ROAs are issued annually by EM. The EM ROA provides multiple awards and is open all year. ROAs are announced in the *Commerce Business Daily*, and typically published in the *Federal Register*.

For questions on ROAs, contact:

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To learn about EM Technology business opportunities, connect to the METC Homepage:
http://www.metc.doe.gov/business/solicita.html

The Program Research and Development Announcement

EM uses the Program Research and Development Announcement (PRDA) to solicit proposals from nonfederal parties for research and development in areas of interest to EM. The PRDA is used for projects that are in broadly defined areas of interest where a detailed work description might be premature. It is a tool to solicit a broad mix of applied research, development, demonstration, testing, and evaluation proposals.

For questions on PRDAs, contact:

Robert Bedick
U.S. Department of Energy
Morgantown Energy Technology Center
P.O. Box 880, D01
Morgantown, WV 26507
(304) 285-4505

To learn about EM Technology business opportunities, connect to the METC Homepage:
http://www.metc.doe.gov/business/solicita.html

THE SMALL BUSINESS INNOVATION RESEARCH PROGRAM

The Small Business Innovation Research (SBIR) Program promotes small business participation in government research and development programs. This legislatively mandated program is designed for implementation in three phases from feasibility studies through support for commercial application. DOE publishes solicitation announcements through the Small Business Innovation Research Office each year to define research and development areas of interest.

For further information about SBIR programs, contact:

SBIR Program Manager
U.S. Department of Energy
Small Business Innovation Research Program
ER-33
19901 Germantown Road
Germantown, MD 20874-1290
(301) 903-5707
sbir_sttr@mailgw.er.doe.gov

BUSINESS AGREEMENTS

Cost-Shared Contracts

Nonfederal parties working under DOE contract can agree to share some of the cost of developing a technology for a nonfederal market. This arrangement may involve cash, in-kind contributions, or both.

Grants and Cooperative Agreements

These contractual arrangements provide the recipient with money and/or property to support or stimulate research in areas of interest to DOE. DOE regularly publishes notices concerning grant opportunities in the *Commerce Business Daily*.

Research and Development Contracts

This acquisition instrument between the government and a contractor provides supplies and services to the government. DOE may enter directly into research and development contracts, and DOE laboratories and facilities can subcontract research and development work to the private sector. Announcements on requests for proposals are published in the *Commerce Business Daily* and are available through the EM Homepage on the Internet: *www.em.doe.gov*

Licensing Technologies

DOE contractor-operated laboratories can license DOE/EM-developed technology and software. In situations where DOE retains ownership of a new technology, the Office of General Counsel serves as licensing agent. Licensing activities are conducted according to existing DOE intellectual property provisions and can be exclusive or nonexclusive, for a specific field of use, for a geographic area, United States or foreign usage. Information on licensing technologies may be obtained by contacting the Office of Research and Technology Applications (ORTA) representatives listed later in this section.

Technical Personnel Exchange Arrangements

Personnel exchanges provide opportunities for federal or DOE laboratory scientists to work together with scientists from private industry on a mutual technical issue. Usually lasting one year or less, these arrangements foster the transfer of technical skills and knowledge. These arrangements require substantial cost-sharing by industry, but DOE has an advanced class patent agreement in place for this provision and the rights of any resulting patents become the property of the private industry participant. Contact an ORTA representative for more information.

Consulting Arrangements

Consulting arrangements are formal, written agreements in which a DOE laboratory or facility employee may provide advice or information to a nonfederal party for the purpose of technology transfer, or a nonfederal party may consult with the laboratory or facility. Laboratory/facility employees participating in this exchange of technical expertise must sign a nondisclosure agreement. Contact an ORTA representative for more information.

Reimbursable Work for Industry

This concept enables DOE personnel and laboratories to perform work for nonfederal partners when laboratories or facilities have expertise or equipment not available in the private sector. Reimbursable Work for Industry is usually termed "work for others." An advanced class patent waiver gives ownership of any inventions resulting from the research to the participating private sector company. Contact an ORTA representative for more information.

Office of Research and Technology Applications

Each federal laboratory has an Office of Research and Technology Application. These offices serve as technology transfer agents for the federal laboratories. They coordinate technology transfer activities among laboratories, industry, and universities. ORTA offices license patents and foster communication between researchers and technology customers.

ORTA Representatives:

Ames Laboratory
Todd Zdorkowski
(515) 294-5640

Argonne National Laboratory
Paul Eichemer
(708) 252-9771/(800) 627-2596

Brookhaven National Laboratory
Margaret Bogosian
(516) 344-7338

Fermilab
John Vernard
(708) 840-2529

Idaho National Engineering Laboratory
Jack Simon
(208) 526-4430

Lawrence Berkeley National Laboratory
Cheryl Fragiadakis
(510) 486-7020

Lawrence Livermore National Laboratory
Rodney Keifer (510) 423-0155
Allen Bennett (510) 423-3330

Los Alamos National Laboratory
Pete Lyons
(505) 665-9090

Morgantown Energy Technology Center
Rodney Anderson
(304) 285-4709

National Renewable Energy Laboratory
Mary Pomeroy
(303) 275-3007

Oak Ridge Institute of Science and Education
Mary Loges
(423) 576-3756

Oak Ridge National Laboratory
Bill Martin
(423) 576-8368

Pacific Northwest National Laboratory
Marv Clement
(509) 375-2789

Pittsburgh Energy Technology Center
Kay Downey
(412) 892-6029

Princeton Plasma Physics Laboratory
Lew Meixler
(609) 243-3009

Sandia National Laboratories
Warren Siemens
(505) 271-7813

Savannah River Technology Center
Art Stethen
(803) 652-1846

Stanford Linear Accelerator Center
Jim Simpson
(415) 926-2213

Westinghouse Hanford Company
Dave Greenslade
(509) 376-5601

PERIODIC TABLE

Of the Elements

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII	VIII	VIII	IB	IB	IIIA	IVA	VA	VIA	VIIA	0
1	1 H Hydrogen																	2 He Helium
2	3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
3	11 Na Sodium	12 Mg Magnesium											13 Al Aluminum	14 Si Silicon	15 P Phosphorous	16 S Sulfer	17 Cl Chlorine	18 Ar Argon
4	19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
5	37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
6	55 Cs Cesium	56 Ba Barium	57 *La Lanthanum	72 Hf Hafnium	73 Ta Tantalum	74 W Wolfram	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
7	87 Fr Francium	88 Ra Radium	89 +Ac Actinium	104 Rf Rutherfordium	105 Ha Hahnium	106 Sg Seaborgium	107 Ns Nielsbohrium	108 Hs Hassium	109 Mt Meitnerium	110 110								

*Lanthanide Series	58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
+Actinide Series	90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

GFX.96-0215

Acronyms

ACM	Asbestos-Containing Material
AFC	Accelerated Facility Characterization
AWPS	Advanced Worker Protection System
BNL	Brookhaven National Laboratory
CCD	Charged-Coupled Device
CLVS	Coherent Laser Vision System
CMU	Carnegie Mellon University
CO_2	Carbon Dioxide (Dry Ice)
COYOTEE	CO_2 XY Orthogonal End Effector
CP-5	Chicago Pile 5
CPG	Coplanar Grid
CRADA	Cooperative Research and Development Agreement
CVD	Chemical Vapor Deposition
CZT	Cadmium Zinc Telluride
D&D	Decontamination and Decommissioning
DAWM	Dual Arm Work Module
DOE	U.S. Department of Energy
DU	Depleted Uranium
DUAGG	Depleted Uranium Aggregate
EHS	Electro-Hydraulic Scabbling
EM	Environmental Management
EPA	U.S. Environmental Protection Agency
FY	Fiscal Year
HQ	Headquarters
HTO	Tritiated Water
ICERVS	Integrated, Computer-Enhanced, Remote-Viewing System
ICP-MS	Industry Coupled Plasma-Mass Spectrometry

IDCS	Internal Duct Characterization System
INEL	Idaho National Engineering Laboratory
ITMS	Ion Trap Mass Spectrometer
LANL	Los Alamos National Laboratory
LIF	Laser-Induced Fluorescence
LIFI	Laser-Induced Fluorescence Imaging
LLNL	Lawrence Livermore National Laboratory
LLW	Low-Level Waste
LTLT	Long-Term, Low-Temperature
MACS	Mobile Automated Characterization System
METC	Morgantown Energy Technology Center
MDMI	Monodisperse Dried Microparticulate Injector
MICROSPI	Multisensor Inspection and Characterization Robot for Small Pipes
MTR	Membrane Technology and Research, Inc.
MVST	Melton Valley Storage Tanks
N-G	Northrop-Grumman
NJIT	New Jersey Institute of Technology
ORNL	Oak Ridge National Laboratory
ORTA	Office of Research and Technology Applications
OST	Office of Science and Technology
OTD	Office of Technology Development
PAHs	Polynuclear Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PNNL	Pacific Northwest National Laboratory
PRDA	Program Research and Development Announcement
R&D	Research and Development
RACS	Reduced Access Characterization System
RCRA	Resource Conservation and Recovery Act

ROA	Research Opportunity Announcement
ROV	Remote Operated Vehicle
$ROVCO_2$	Combined System of Remote Operated Vehicle and Carbon Dioxide (Dry Ice)
RSM	Radioactive Scrap Metal
SEEC	Surface Electrokinetic Extraction Concept
SERS	Selective Equipment Removal System
SIMS	Secondary Ion Mass Spectroscopy
SNL	Sandia National Laboratories
SPCS	Small Pipe Characterization System
SPP	Storage Photostimulable Phosphor
3D-ICAS	Three-Dimensional, Integrated Characterization and Archiving System
TRU	Transuranic
TTP	Technical Task Plan
TVS	Transportable Vitrification System
VOCs	Volatile Organic Compounds
WAC	Waste Acceptance Criteria
WIPP	Waste Isolation Pilot Plant