Office of Environmental Management

Technology Development

MIXED WASTE CHARACTERIZATION, TREATMENT, AND DISPOSAL FOCUS AREA

Technology Summary

June 1995

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Mixed Waste Characterization, Treatment, and Disposal Focus Area Technology Summary

TABLE OF CONTENTS

Introduction iii

The Mixed Waste Characterization, Treatment, and Disposal Focus Area Overview ix

1.0 WASTE CHARACTERIZATION 1

1.1 Pulsed Fast Neutron Analysis/Thermal Neutron Capture 3

2.0 THERMAL TREATMENT PROCESSES 7

2.1 Plasma Hearth Process Development 9
2.2 Plasma Hearth Process Slag Chemistry and Slag/Metal Processing 14
2.3 Steam Reforming 16
2.4 Vitrify to Dispose Technology Development 18
2.5 Studies on Waste Streams Containing Difficult to Vitrify Components 21
2.6 Waste Stream Pretreatment for Mercury Removal 23
2.7 Microwave Solidification 25

3.0 NON-THERMAL TREATMENT PROCESSES 29

3.1 Low Temperature Thermal Desorption 31
3.2 Biocatalytic Destruction of Nitrate and Nitrite 34
3.3 Freeze Crystallization Technology 37
3.4 Catalytic Chemical Oxidation 40
3.5 Supercritical Carbon Dioxide Extraction 43
3.6 Polymer Encapsulation 45
3.7 Phosphate Bonded Ceramic Final Waste Forms 48
3.8 Final Waste Form Performance 51
3.9 Pilot Plant Demonstration 53
3.10 HTO Corrosion and Precipitation Control 57
3.11 HTO Alternative Reactor Designs 60

4.0 EFFLUENT MONITORS AND CONTROLS 63

4.1 Tunable Diode Laser and Mercury Monitor 65
4.2 Waste Stream Diagnostics and Control 68
4.3 Cleanable High Efficiency Particulate Air Filter Development and Demonstration 70
4.4 Capture and Release Off-Gas System 72

4.5 Mercury Removal and Recovery from Flue Gas 75
4.6 X-ray Fluorescence Spectrometry for Real-Time Monitoring of Slag Phase 77
4.7 HTO Process Monitoring Sensors 79

5.0 DEVELOP ON-SITE INNOVATIVE TECHNOLOGIES (DOIT) 83

6.0 DOE BUSINESS OPPORTUNITIES 87

7.0 ACRONYM LISTING 93

8.0 APPENDIX 99

Figures

A. The EM Organizational Structure as of May 1, 1994 vii
B. The OTD Organizational Structure as of May 1, 1994 viii
1.1 Principles of PFNA 3
2.1 PHP Prototype Design 9
2.3 Synthetica Detoxifier Three Step Process 16
2.4a EnVitCo Cold Top Melter Furnace 18
2.4b Stir Melter Furnace 19
2.7 Microwave Solidification Process 25
3.1 Low Temperature Thermal Desorption System 31
3.2 Biocatalytic Destruction Process Description 34
3.3 Bench-Scale Freeze Crystallizer 37
3.4 Catalytic Wet Chemical Oxidation Process 40
3.5 Supercritical Carbon Dioxide Extraction 43
3.6 Polymer Encapsulation System 45
3.7 Material Development and Waste Form Development 48
3.8 Approach to Assessing and Ensuring Long-term Performance of Mixed Waste Forms 51
3.9 Test Bed System Design 54
3.10 Ceramic Coating After 108 Hours of Exposure 58
3.11 Boundary Layer Protection in Platelet Reactor 60
4.1 The Large-Volume Flow-Through Detection System 65
4.3 Cleanable HEPA Off-Gas Treatment 70
4.4 Plasma Incineration Controlled Emissions System 72
4.7 Test Apparatus Showing Ultrasonic Transducer 79

INTRODUCTION

THE NEW APPROACH

PURPOSE

Although positive steps have been taken during the past three decades to remedy the world's environmental problems, the nation's ability to respond to many current and future environmental and economic challenges depends on technological advances produced by a well-organized and productive federal research and development program.

To ensure that such programs focus on the most pressing environmental restoration and waste management problems at the U.S. Department of Energy (DOE), the Assistant Secretary for the Office of Environmental Management (EM) established a Working Group in August 1993 to implement a new approach to environmental research and technology development. The goal of DOE's new approach is to conduct a research and technology development program that will overcome major obstacles in the cleanup of DOE sites. Integral to this new, solutions-oriented approach is an up-front awareness of program needs obtained from customers, users, regulators, and stakeholders. These needs can then be disseminated to the developers of technological solutions.

The key features of the new approach are:

- establishing five focus areas to address DOE's most pressing problems;
- teaming with the customers in EM to identify, develop, and implement needed technology;
- focusing technology development activities on major environmental management problems;
- coordinating management of scientific and development activities in support of EM;
- focusing resources in national laboratories more effectively;
- involving industry in developing and implementing solutions, including technology transfer into DOE and from DOE to the private sector;
- coordinating basic research by involving academia and other research organizations to stimulate technological breakthroughs; and
- enhancing involvement of regulators and stakeholders in implementation of technology development.

DOE has established a framework and strategy for coordinating efforts among DOE organizations, Management and Operations (M&O) contractors, the national laboratories, other government agencies, the scientific community, industry, academia, and the affected public. Full implementation of the new approach is planned for the FY 95/96 timeframe. The new strategy will build upon existing programs and will seek continual improvement of all EM operations and processes.

Prior to implementation of the new approach, EM's Office of Technology Development (OTD) carried out an aggressive national program of applied research and development to meet environmental restoration and waste management needs based on the concepts of Integrated Programs (IP) and Integrated Demonstrations (ID). These concepts, introduced in 1989, were engineered to manage the research, development, demonstration, testing and evaluation (RDDT&E) activities within EM.

An IP was the cost-effective mechanism which assembled a group of related and synergistic technologies to evaluate their performance to solve a specific aspect of a waste management or environmental problem. The problem could be unique to a site or common to many sites. An IP supported applied research to develop innovative technologies in key application areas organized around specific activities required in each stage of the remediation process (e.g., characterization, treatment, and disposal).

An ID was the cost-effective mechanism that assembled a group of related and synergistic technologies to evaluate their performance individually or as a complete system to correct waste management and environmental problems from cradle to grave.

BENEFITS

A keystone for implementation of the new approach is to encourage development of technologies that are better, faster, safer and more cost-effective than those currently available. More importantly, the new approach has been adopted to foster implementation of new and innovative environmental technologies, facilitating the national commitment to long-term environmental, energy, and economic goals.

An important benefit to the new approach is the creation of investment returns for developing new technologies — technology dividends. These technology dividends result from partnerships and leveraging within government and between government and the private sector. The partnerships can consist of technology developers, technology users, problem holders, and problem solvers.

EM technology dividends will include:

- Employment opportunities with new businesses and existing businesses;
- Cleanup of sites posing the greatest threats to human health, safety, and the environment;
- Materials reused and recycled, instead of thrown away or freshly contaminated;
- Pollution prevented;
- More effective and efficient industrial processes, leading to greater U.S. competitiveness globally; and
- Technology transfer to other countries.

By implementing the new approach for the unique environmental problems associated with DOE sites, EM/OTD, scientists, and engineers at the national laboratories stand at the threshold of opportunity to develop new technologies. This work will enhance quality of life through a cleaner environment, improved global competitiveness, and ensure job opportunities for American workers.

FOCUS AREAS

Five major remediation and waste management problem areas within the DOE Complex have been targeted for action on the basis of risk, prevalence, or need for technology development to meet environmental requirements and regulations. Other areas may be added or currently identified areas further partitioned to ensure that research and technology development programs remain focused on EM's most pressing remediation and waste management needs. These major problem areas, termed "Focus Areas," are described below.

Contaminant Plume Containment and Remediation. Uncontained hazardous and radioactive contaminants in soil and ground water exist throughout the DOE Complex. There is insufficient information at most sites on the contaminants' distribution and concentration. The migration of some contaminants threatens water resources and, in some cases, has already had an adverse impact on the off-site environment. Many current characterization, containment, and treatment technologies are ineffective or too costly. Improvements are needed in characterization and data interpretation methods, containment systems, and in situ treatment.

Mixed Waste Characterization, Treatment, and Disposal. DOE faces major technical challenges in the management of low-level radioactive mixed waste. Several conflicting regulations, together with a lack of definitive mixed waste treatment standards hamper mixed waste treatment and disposal. Disposal capacity for mixed waste is also expensive and severely limited. DOE now spends millions of dollars annually to store mixed waste because of the lack of accepted treatment technology and disposal capacity. In addition, currently available waste management practices require extensive, and hence costly waste characterization before disposal. Therefore, DOE must pursue technology that leads to better and less expensive characterization, retrieval, handling, treatment, and disposal of mixed waste.

High-Level Waste Tank Remediation. Across the DOE Complex, hundreds of large storage tanks contain hundreds of thousands of cubic meters of high-level mixed waste. Primary areas of concern are deteriorating tank structures and consequent leakage of their contents. Research and technology development activities must focus on the development of safe, reliable, cost-effective methods for characterization, retrieval, treatment, and final disposal of the wastes.

Landfill Stabilization. Numerous DOE landfills pose significant remediation challenges. Some existing landfills have contaminants that are migrating, thus requiring interim containment prior to final remediation. Materials buried in retrievable storage pose another problem. Retrieval systems must be developed to reduce worker exposure and secondary waste quantities. Another high-priority need is in situ methods for containment and treatment.

Decontamination and Decommissioning. The aging of DOE's weapons facilities, along with the reduction in nuclear weapons production, has resulted in a need to transition, decommission, deactivate, and dispose of numerous facilities contaminated with radionuclides and hazardous materials. While building and scrap materials at the sites are a potential resource, with a significant economic value, current regulations lack clear release standards. This indirectly discourages the recovery, recycling, and/or reuse of these resources. The development of enhanced technologies for the decontamination of these materials, and effective communication of the low relative risks involved, will facilitate the recovery, recycle, and/or reuse of these resources. Improved material removal, handling, and processing technologies will enhance worker safety and reduce cost.

Crosscutting Technologies

Crosscutting technologies are those which overlap the boundaries of the focus areas while providing simultaneous benefits. These technologies may be used in several or all focus area testing and evaluation programs, and include:

Characterization, Monitoring, and Sensor Technology. DOE is required to characterize more than 3,700 contaminated sites, 1.5 million barrels of stored waste, 385,000 m3 of high-level waste in tanks, and from 1,700 to 7,000 facilities before remediation, treatment, and facility transitioning commence. During remediation, treatment, and site closure, monitoring technologies are needed to ensure worker safety and effective cleanup. Cost-effective technologies are needed for all EM characterization requirements.

Efficient Separations and Processing. Separation and treatment technologies are needed to treat and immobilize a broad range of radioactive wastes. In some cases, separations technologies do not exist. In others, improvements are needed to reduce costs, reduce secondary waste volumes, and improve waste form quality. Separations technologies are also needed for environmental restoration of DOE sites, for groundwater and soils cleanup, and for decontamination and decommissioning of facilities. Many separations agents developed for waste treatment can be adapted for environmental restoration needs.

Robotics. DOE's waste disposal efforts have particular issues—access, safety, final disposal, and cost efficiency. Due to hazardous radiation, massive waste loads, and restricted entry ways, many sites are inaccessible for human labor. It is unsafe to expose humans to radiation, harmful chemicals, and injurious mechanical objects. Human labor requires higher compensation, the need for expensive protective clothing, and stringent decontamination procedures. Robotics systems are safe, efficient, and cost-effective means to automate the handling and processing of mixed waste and characterizing and/or retrieving storage tank waste. Systems can also be designed for surveillance, characterization, cleanup, and decommissioning of retired DOE facilities.

Innovative Investment Area. DOE has set aside funding to foster research and development partnerships within the public and private sector, and to introduce innovative technologies into OTD programs. The Innovative Investment Area supports two types of technologies: (1) technologies that show promise to address specific EM needs, but require proof-of-principle experimentation, and (2) proven technologies in other fields that require critical path experimentation to demonstrate feasibility for adaptation to specific EM needs.

Pollution Prevention. DOE and the Department of Defense (DoD) have similar waste stream pollution problems and common environmental concerns. By combining their resources, these agencies can develop a coordinated interagency environmental research and technology development program that produces cost-effective technological solutions, particularly in the areas of process change or in-process recycling.

TECHNICAL TASK PLANS

Technical Task Plans (TTPs) are used to identify and to summarize work funded and managed by OTD at headquarters, the field, and the national laboratories. These plans include a project summary, technical task description, budget schedule, and milestone schedule. The EM-50 FY 1994 Program Summary (DOE/EM-0216) lists TTPs current as of the date of this document.

All tasks require a TTP number. Each TTP number contains information on the fiscal year in which the task is first funded, the DOE Operations Office funding allotment code, and the laboratory/contractor/university designator. See appendix for further details.

EM ORGANIZATIONAL STRUCTURE

The Office of Environmental Management (EM) is responsible for managing the cleanup of DOE wastes from past nuclear weapons production and current operations. The EM mission is to bring DOE sites into compliance with all environmental regulations while minimizing risks to the environment, human health and safety posed by the generation, handling, treatment, storage, transportation, and disposal of DOE waste. The EM organization was established to provide focus, accountability, and visibility for DOE's waste management and remediation efforts. See Figure A.

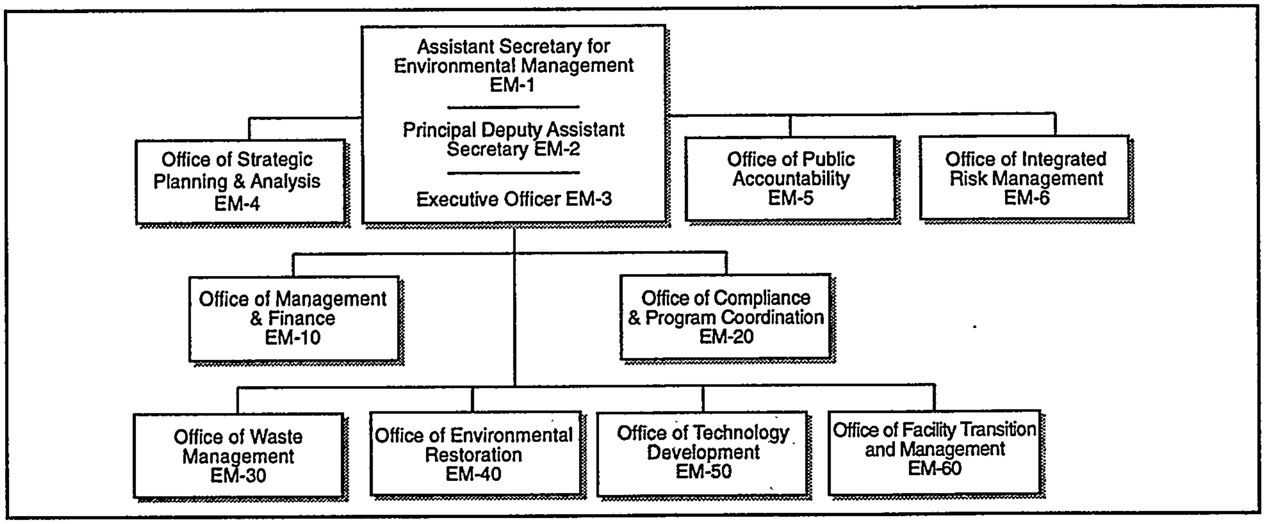

Figure A. The EM Organizational Structure as of May 1, 1994.

OFFICE OF TECHNOLOGY DEVELOPMENT

The Office of Technology Development (EM-50) has the overall responsibility to develop technologies to meet DOE's goals for environmental restoration. OTD works closely with EM-30, -40, and -60 in identifying, developing, and implementing innovative and cost-effective technologies. Activities within EM-50 include applied research and development, demonstration, testing, and evaluation (RDDT&E), technology integration, technology transfer, and program support. See Figure B.

EM-50 ORGANIZATION

The Office of Technology Transfer and Program Integration (EM-52) provides management, financial, and internal program support to line organizations that comprise EM-50. It also provides efforts to encourage and to facilitate the infusion and diffusion of innovative environmental technologies for internal and domestic application through collaborative partnerships with U.S. and foreign industry or organizations, the national laboratories, other federal agencies, and universities. Technology transfer and technology leveraging are important program components. Enhanced communication to internal and external stakeholders is a goal of this Office.

The Office of Research and Development (EM-53) is responsible for establishing applied research and development (R&D) program at DOE sites nationwide. Programs are designed to identify operational needs in environmental restoration, waste operations, and corrective activities, and to provide solutions to key technical issues that, if not solved in a timely manner, would adversely affect DOE's ability to meet its cleanup goal.

The Office of Demonstration, Testing, and Evaluation (EM-54) is responsible for identifying environmental management technologies in the research and development stage that are ready for transition to the demonstration arena. Those technologies are complete systems to demonstrate a solution to a specific problem area. Programs are conducted to advance selected technologies so they can be utilized by DOE to meet its cleanup goal in a cost-effective manner.

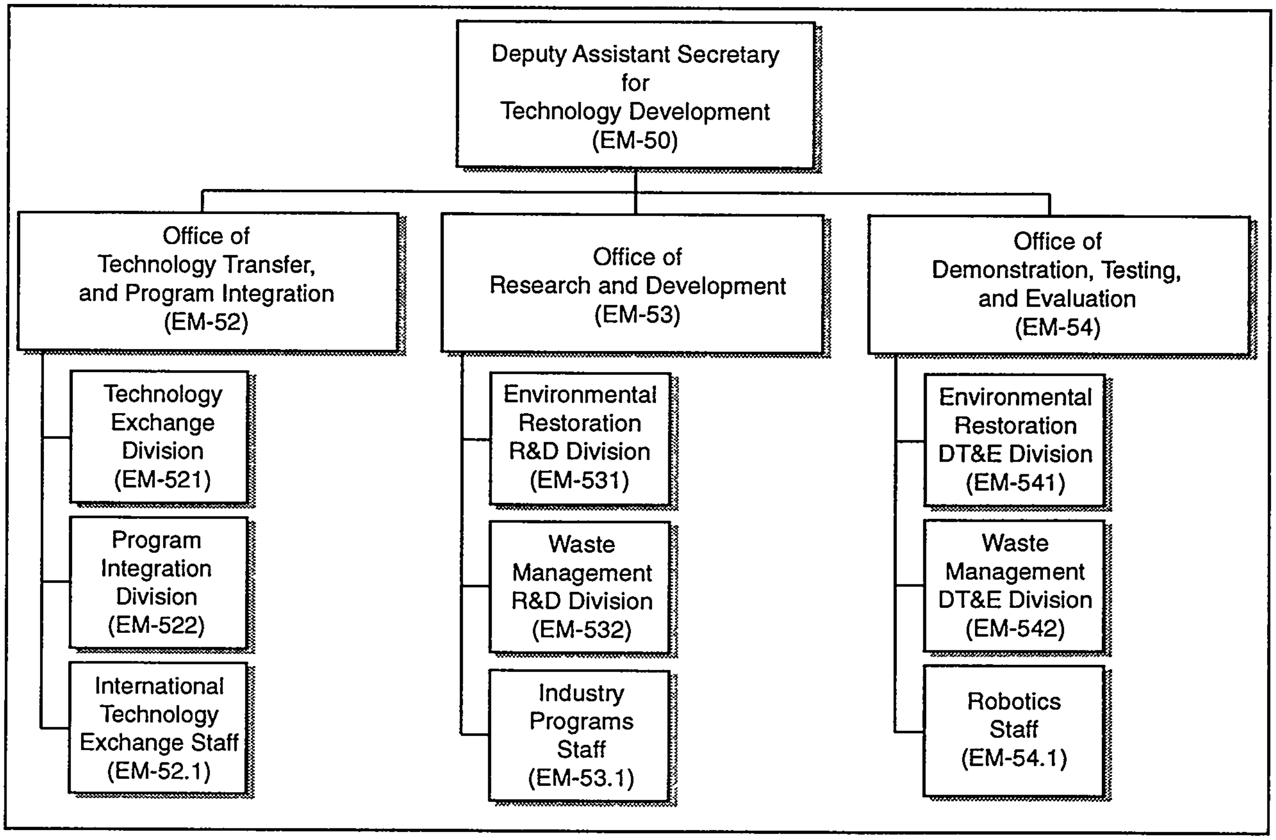

Figure B. The OTD Organizational Structure as of May 1, 1994.

OTHER EM ORGANIZATIONS

The Office of Waste Management (EM-30) has program responsibilities for managing waste generated at all DOE sites during weapons processing and manufacturing, research activities, and site cleanup activities. This includes the treatment, storage, transportation, and disposal of several types of waste: transuranic, low-level radioactive, mixed, and solid sanitary wastes. EM-30 is also responsible for the storage, treatment, and processing of defense high-level radioactive waste (HLW), waste minimization efforts, and corrective activities at waste management facilities.

The Office of Environmental Restoration (EM-40) has program responsibilities for assessment and cleanup of inactive hazardous and radioactive facilities and waste sites at all DOE installations and some non-DOE sites. EM-40 oversees program activities to reduce or eliminate risks to human health and the environment.

The Office of Facility Transition and Management (EM-60) has the responsibility to ensure that shut-down facilities are brought to a deactivated state, are properly maintained, and are eventually decontaminated and/or decommissioned or released for other uses.

Mixed Waste Characterization, Treatment, and Disposal Focus Area Overview

The Office of Environmental Management has established the New Approach to managing environmental technology research and development in critical areas of interest to DOE. The Mixed Waste Characterization, Treatment, and Disposal Focus Area (referred to as the Mixed Waste Focus Area or MWFA) is one of five focus areas and three cross-cut areas targeted for implementation of the new approach[1]. The MWFA deals with the problem of eliminating mixed waste from current and future storage in the DOE complex. Mixed waste is various forms of waste that are contaminated by both hazardous and radioactive constituents. It includes mixed low-level waste (MLLW) and mixed Transuranic (TRU) waste. DOE has been storing mixed waste, mainly in steel drums, for years in violation of the Resource Conservation and Recovery Act (RCRA), because treatment capacity in the DOE complex or the private sector has been inadequate or non-existent. The Federal Facility Compliance Act (FFCAct) waived sovereign immunity for the DOE and required DOE to develop plans and facilities for achieving RCRA compliance. In many cases this compliance will be achieved by eliminating the hazardous constituents in the waste and stabilizing the waste for final disposal. The MWFA is charged with developing the needed treatment system technologies to meet FFCAct goals. These systems require characterization of the waste prior to treatment, treatments that can handle a wide range of waste streams, off-gas and secondary waste treatment, waste handling, and waste disposal technologies.

The New Approach requires active involvement and input by representatives from the DOE/EM Offices of Technology Development (EM-50), Environmental Restoration (EM-40), and Waste management (EM-30). By working together, these technology developers and users will insure that the needed technologies are developed, demonstrated, and commercialized to meet DOE goals. As such, the MWFA is lead by a headquarters-based core management team (with team members from EM-30, EM-40, and EM-50) which interacts routinely with an implementation team which is comprised of representatives from the DOE-Idaho Field Office, personnel from the Idaho National Engineering Laboratory, and waste-type managers from across the DOE complex. Various groups from across the complex provide input and oversight to the focus area to guide the technology development activities.

One of the major goals of the MWFA is to solicit participation form persons involved with basic and applied research, technology transfer and implementation, the various regulatory communities, and stakeholders in setting objectives, prioritizing projects, and evaluating results. The stated mission of the MWFA is to develop, demonstrate, and deliver technologies and treatment systems for treating and disposing of MLLW and MTRU in a safe, timely, and cost-effective manner.

The MWFA will integrate and guide DOE-sponsored technology development activities, ranging from bench-scale basic research to field-scale radioactive demonstration. Problem holders (i.e., waste owners), regulators, and stakeholders will collaborate in defining problems/needs to be addressed, while the MWFA management team will select, prioritize, and develop projects and programs to fill those needs and solve the stated problems. Technologies developed under the MWFA will be transferred to industry for commercial use and application to the clean-up of DOE sites. The MWFA will identify opportunities to replace or

[1]The five focus areas are supported by three crosscutting programs which study specific problems which are common to more than one focus area. The crosscutting programs are described in detail elsewhere in similar documents.

enhance existing technologies with those that cost less, are more effective, and/or which reduce risk to the public, workers and the environment.

The MWFA will conduct a minimum of three pilot-scale demonstrations of mixed waste treatment systems using actual mixed waste by 1997. Cumulatively, these three pilot-scale demonstrations will be capable of treating a minimum of 90% of the current MLLW inventory of over 129,000m^3. This focus area will ensure that emerging technologies and future technology developments are considered and evaluated with the Federal Facility Compliance Act (FFCAct) process. It is anticipated that site treatment plans and resulting consent orders will have flexibility to evolve with time to include new environmental management options offered by advances in technology. This document presents an overview of the activities of the MWA during the past year, and provides insight into where major programs are headed over the Next several years.

The Mixed Waste Focus Area has developed a matrix approach for managing the development of new technologies. This approach divides the technologies into five categories which include, thermal treatment, non-thermal treatment, effluent monitoring and control, crosscut technologies, and post treatment. These technology development activities will be managed by waste-type managers who run programs that cut across the technology categories. Each waste-type manager oversees a program that includes technologies form the various categories that make up a system to treat a group of related waste streams. There are five waste type managers covering the waste type designations of: inorganic waste water/slurries, combustible organics, sludges/soil, solids/debris/soil, and special waste types. In this book, technologies are organized by technology categories which are further described in the following paragraphs.

THERMAL TREATMENT

The current baseline thermal treatment system for the destruction of organics is incineration. Incinerators are effective for organic destruction but have problems with stakeholder and regulator acceptance due to a perception that incinerators emit toxic off-gasses. Therefore, the MWFA is developing several alternatives to incineration. The Plasma Hearth Process (PHP) is a mixed waste thermal treatment technology which can accept a wide variety of containerized waste. Since the process is capable of treating many different waste streams, up-front waste characterization requirements are greatly reduced. The solid effluents from the PHP are metals which may be recyclable, and glass-like slag which has been shown to pass the EPA's Toxicity Characteristic Leaching Procedure (TCLP), allowing for disposal. The MWFA is also studying the application of vitrification to the stabilization of MLLW and MTRU. Vitrification involves converting waste into glass, and has been accepted as the Best Demonstrate Available Technology (BDAT) for the treatment of high-level radioactive waste. MWFA studies are developing not only the MLLW vitrification technology itself, but also is developing a plan using actual test data, modeling algorithms, and an extensive database of waste glass formulations to convince regulators to accept an up-front delisting petition for the technology itself. Another MWFA thermal treatment project is developing the Steam Reforming process of the destruction of organics in mixed waste.

NON-THERMAL TREATMENT

In the case of waste streams fro which thermal treatment could cause problems (such as those streams containing volatile metals, for example), the MWFA is investigating non-thermal treatment options. The non-thermal treatment of mixed waste alleviates regulatory and stakeholder concerns over the effluent streams from thermal treatment systems. Processes being investigated include a low temperature thermal desorption process, the catalytic chemical oxidation process, freeze crystallization, biocatalytic destruction of nitrate and nitrite, and supercritical carbon dioxide extraction. Other non-thermal treatment technologies being developed within the MWFA are used for stabilization of the waste or disposal and include polymer encapsulation, microwave solidification, and chemically-bonded (phosphate) ceramics.

EFFLUENT MONITORING AND CONTROL

In using a systems approach to the characterization, treatment, and disposal of mixed waste, the MWFA has initiated studies in controlling the gaseous releases form mixed waste treatment processes. A dedicated test bed has been set up at the Western Environmental Technology Office (WETO) in Butte, MT to study several different approaches to the problem. Projects include the development of a cleanable HEPA filter system, a regenerable mercury capture technology, a capture-test-and-release system, and others. Eventually, this work will be expanded to incorporate the monitoring instrumentation mentioned above to achieve a fully integrated process monitoring, process control, and controlled effluent release system. In order to ensure that mixed waste treatment processes are operating at peak efficiency while minimizing effluent generation, the MWFA is studying several advanced technologies for process monitoring and control. The emphasis is on developing real-time, on-line instrumentation which can be integrated into a complete system for controlling not only the process, but the releases form the processing as well.

CROSSCUT TECHNOLOGIES

This technology area coordinates with the crosscut areas to insure that the mixed waste treatment needs for characterization, robotics and efficient separations are being addressed by technology development activities in those areas. It also arranges for the demonstration of those technologies under treatment system demonstrations being conducted by the MWFA.

Waste characterization, is currently the most active area and involves the development of methods and equipment for assessing the properties of mixed waste prior to treatment to ensure that the treatment process is optimized for the waste. These characterization technologies involve the non-destructive assay of radioactive materials as confined within containers (such as the standard 55-gal. drum). Advanced imaging techniques gives information on the physical contents of drums as well. The evaluation of drum contents without requiring the opening of the container is advantageous for a process like the Plasma Hearth Process which is capable of treating whole, unopened drums of MLLW and MTRU.

POST TREATMENT

Post treatment technologies include technologies for handling final wastes, packaging wastes, shipping wastes to final disposal, treatment processes for secondary waste streams, recycling and reuse. There are currently no technology development activities in this area.

WASTE CHARACTERIZATION

Section 1.0

1.1 PULSED FAST NEUTRON ANALYSIS/ THERMAL NEUTRON CAPTURE

TASK DESCRIPTION

Pulsed Fast Neutron Analysis (PFNA), and Thermal Neutron Capture (TNC), are non-intrusive inspection technologies originally developed to detect contraband explosive and hazardous materials. They will be demonstrated as non-destructive analysis (NDA) tools to inspect 55-gallon drums containing MLLW. PFNA/TNC has a demonstrated ability to produce three dimensional maps of the distribution of many elements within a closed container. TNC will quantitatively detect the presence of hazardous elements such as mercury (Hg) and chlorine (Cl). In addition, hazardous compounds such as polychlorinated biphenyls (PCBs) may be determined. The system, shown in Figure 1.1, operates as follows: one-nanosecond pulses of non-energetic neutrons are directed toward a drum. Collimators are used to form a narrow beam that is rastered sequentially through all positions in the barrel. The neutrons in the collimated beam are highly penetrating, and are therefore able to interact with materials at all depths along the beam trajectory. Gamma rays are emitted when the neutrons in the pulsed beam interact with nuclei in the sample. Their intensity and energy spectra are analyzed to determine the elements that are present in the sample.

Although the speed and elemental specificity of PFNA/TNC measurements are very important, the most unique aspect of the system is its ability to determine the three-dimensional distribution of elements within even very large and heterogeneous samples. This spatial resolution is achieved principally by (1) collimating the neutron beam, and (2) performing time-of-flight (TOF) measurements. The collimators determine two dimensions of the system's spatial response transverse to the beam axis. By accurately measuring the time that elapses between production of a neutron pulse and the detection of induced gamma rays, it is possible to determine the third dimension (sample depth) from which the gamma rays are emitted. A spatial resolution in the range of several centimeters is typical.

TECHNOLOGY NEEDS

Over 130,000 cubic meters of MLLW are stored at 48 DOE sites in 22 states. Much of this waste is highly heterogeneous and over 40 percent has insufficient process knowledge to adequately judge the contents of individual waste containers.

Characterization is needed to safeguard the environment and worker health and safety, to design, protect, and optimize the treatment processes; to meet environmental regulations, and to satisfy the waste acceptance criteria of various disposal sites. PFNA/TNC technologies will allow for the mapping of elemental concentration of nitrogen, oxygen, chlorine, silicon, aluminum, iron, and other ele-

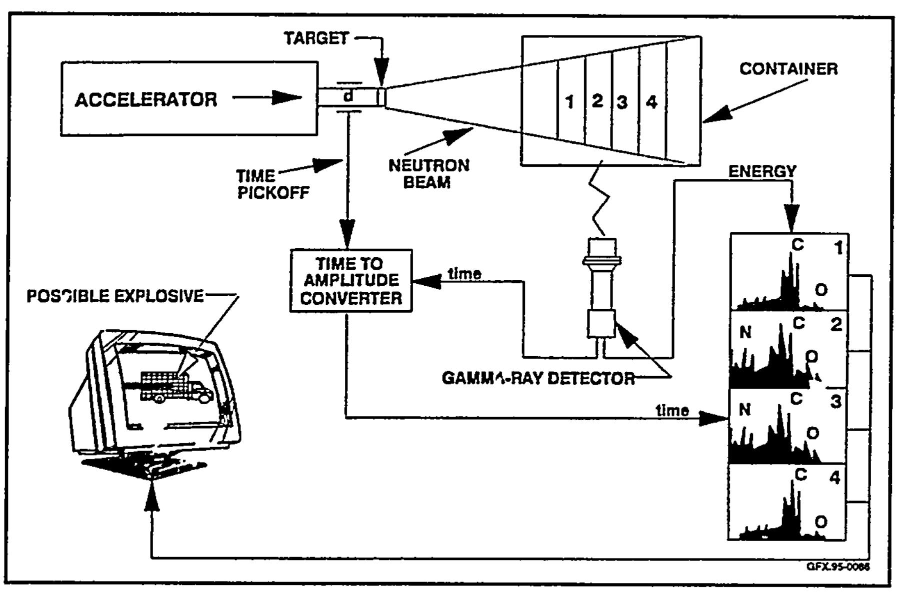

Figure 1.1. Principles of PFNA.

ments of interest. By examining the ratio of the elements detected, it may be possible to screen for particular hazardous materials. This in turn can significantly reduce overall characterization costs associated with screening different types of MLLW.

ACCOMPLISHMENTS

- Completed draft test plan for demonstration on MLLW.
- Initiated modifications of existing PFNA/TNC unit to optimize sensitivity for DOE MLLW.

BENEFITS

The PFNA/TNC procedure is non-intrusive and therefore human exposures and risks are minimized. Current plans already call for NDA radiological and x-ray evaluation of all drummed MLLW. The PFNA/TNC procedure can provide data supplemental to that already planned for.

Drums showing high levels of Hg, Cl, and possibly other elements could be easily segregated for separate handling and processing, whereas drums showing minimal amounts of particular hazardous wastes might be sent directly to treatment without additional analyses.

COLLABORATION/TECHNOLOGY TRANSFER

These technologies are being utilized commercially in the inspection of aircraft luggage and truck cargo trailers. Technology enhancements provided by DOE could expand the utility of the system to include analysis of hazardous wastes of industrial origin. Commercial waste treaters, each of which have their own unique criteria for acceptance of industrial waste, could use this technique to screen and confirm the accuracy of shipping manifests coming from their multiple customer base.

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Thermal Treatment Processes

Section 2.0

2.1 PLASMA HEARTH PROCESS DEVELOPMENT

TASK DESCRIPTION

The fixed hearth plasma arc thermal treatment unit uses a direct current (DC) arc plasma transferred torch generated in a gas flowing between two electrodes. The term "plasma" refers to a highly ionized electrically conductive gas. Plasmas can be generated by a variety of techniques, over a wide range of pressures and energy levels. The type of plasma produced in the Plasma Hearth Process (PHP) application is a dc arc-generated thermal plasma and is created by a device known as a "plasma torch". The plasma torch used in the PHP operates in the transferred arc mode. See Figure 2.1.

The transferred arc torch uses a flow of gas to stabilize an electrical discharge (arc) between a high voltage electrode (inside the torch) and a molten pool of waste (maintained at ground potential). Because of the very high resistance to electrical current flow through a gas, electrical energy is converted to heat. Additionally, energy is converted as the electric current passes through the melt, creating a Joule-heating effect in the molten pool.

Processing begins as complete drums of waste are fed to the plasma chamber, where heat from the plasma torch initiates a variety of chemical and physical changes. Complex organic compounds break down into non-complex gases that are drawn from the chamber, while the remaining inorganic material melts and separates into two phases: slag and metal. Actinides and oxidized heavy metals migrate to the slag phase which, after being removed, cools and solidifies into a glass-like, or vitrified, material. This high-integrity final waste form, similar to that selected for high-level radioactive wastes, has repeatedly shown the ability to meet or exceed disposal requirements instituted by the RCRA.

PHP thermal treatment technology is characterized by high-efficiency destruction of organics, encapsulation of heavy metals and radionuclides in the vitrified final waste matrix, maximum reduction of

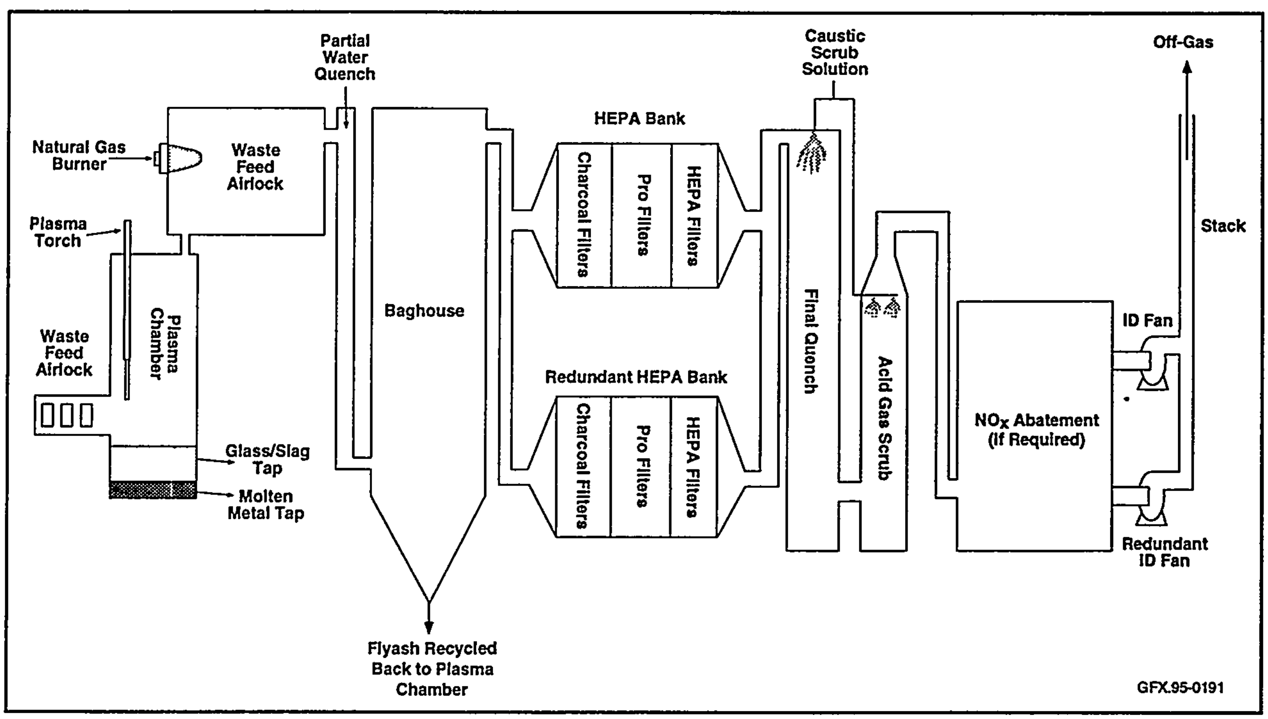

Figure 2.1. PHP Prototype Design.

waste volume, low off-gas rates, and the capability of processing many waste types in a single-step process.

The PHP program has been established to develop, test, and evaluate a new concept for treating mixed waste. The program is split into non-radioactive and radioactive activities. The non-radioactive testing involves two separate PHP research systems. The first system, a proof-of-principle system is a simplified version of the PHP concept that was designed and built in 1992. The system operates in a batch mode and has the capacity to process two 30-gallon drums per batch. Testing on the proof-of-principle system was completed in FY94. The second system is a pilot-scale PHP system which is a follow-on to the proof-of-principle system. The pilot-scale system is being designed to be a more complete version of the PHP concept. While it is being called a "pilot-scale" project, the hardware being designed and tested is essentially full-scale in size. This will lower the technology performance risk when implementing the large-scale hardware of the field-scale PHP project. In addition, SAIC operates a 200 KW nonradioactive system at its Science and Technology Applications Research (STAR) Center in Idaho.

The second activity is comprised of a radioactive bench-scale unit and a radioactive field-scale unit. The bench-scale unit will be built and tested in parallel with the non-radioactive pilot-scale unit. The bench-scale will be a batch process, capable of feeding up to eight 1-gallon cans of material per test. The plasma chamber is designed to closely model the pilot-scale plasma chamber so that comparisons of radionuclide/surrogate behavior can be obtained. The final activity in the PHP demonstration program will be the construction and operation of a production sized PHP system for treating actual INEL mixed waste. Installed at the ANL-W Transient Reactor Test (TREAT) facility, the unit will have a 1.2 MW torch and a throughput of two 55-gallon drums per hour.

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

The radioactive bench-scale PHP system design, construction and installation in the ANL-W TREAT facility will be completed in FY95, with radioactive testing to begin in the first quarter of FY96. The pilot-scale non-radioactive PHP system will be constructed at Retech, Inc. in Ukiah, CA, with testing to begin in mid FY96. The radioactive field-scale system Conceptual Design Report will be completed in FY95 procurement and construction will be completed in FY96, and radioactive testing will begin in FY97.

TECHNOLOGY NEEDS

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

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

ACCOMPLISHMENTS

Non-Radioactive Proof-of-Principle

Completed the final tests using the proof-of-principle demonstration PHP unit:

- Established treatability of different surrogate mixed waste categories.
- Achieved volume reduction ranging from 5:1 to 11:1.
- Generated a final waste form that was within RCRA limits for each of the spiked components using the TCLP.
- Proved that destruction and removal efficiency (DRE) for the principal organic hazardous constituent spiked into the feed was above the required DRE.
- Showed that the stack particulate loading was below both the existing standard and the proposed new standard.
- Conducted eight test runs for advanced design concepts testing for the following areas of concern:

  - Phase separation,
  - Feed transition,
  - Material Removal, and
  - Materials of construction.

Non-Radioactive Pilot-Scale

- The second generation pilot-scale PHP system Title I design has been completed and Title II design has been initiated.

Radioactive Bench-Scale

- Completed Radioactive Demonstration Project Plan, Quality Assurance Project Plan, Regulatory Compliance Plan, and a Bench-Scale Test Plan.
- Completed melter system Title I design review and initiated the Title II design.

BENEFITS

The PHP has the potential in a wide range of applications to vitrify a wide variety of mixed wastes currently stored at sites throughout the DOE Complex. The features that make the PHP particularly attractive include: the ability of the process to accept whole drums of waste; little or no special front-end handling requirements, feed preparation, or pretreatment; reduced waste characterization requirements; the ability to destroy organic compounds, including hazardous organics; partitioning of the TRU components to the slag phase; and a stable, nonleaching end-product that complies fully with all RCRA regulations.

COLLABORATION/TECHNOLOGY TRANSFER

This program is a collaboration between Lockheed Idaho Technologies Company (LITCO), Argonne National Laboratory-West (ANL-W), Science Applications International Corporation (SAIC), and Retech, Inc. Patent rights are being investigated and both SAIC and Retech are interested in commercialization of the technology as appropriate. Retech is supplying the plasma torch equipment and the melter chamber.

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2.2 PLASMA HEARTH PROCESS SLAG CHEMISTRY AND SLAG/METAL PROCESSING

TASK DESCRIPTION

The PHP is a high-temperature, fixed-hearth plasma-arc technology that has been used for many years in the processing of specialty and other metals. The type of plasma being used in this application is referred to as a thermal plasma. An electric torch is used to generate the plasma. A variable mixture of nitrogen, argon, and helium gases is used to stabilize the plasma. The goal of the plasma hearth process concept, when applied to waste treatment, is to produce a final waste product that is in full conformance with LDR and low level waste disposal requirements. Materials that are not converted to a chemically benign phase by the plasma process will be converted into either a molten vitreous slag or a molten metallic phase. When these are removed separately from the furnace, they solidify into a physically and chemically stable compact waste form.

The purpose of this task is to define the design basis and validate the final design of the slag and metal removal and handling system to be built for the field-scale radioactive plasma hearth process system by SAIC and Retech, Inc. This task will ensure that the system design will meet DOE nuclear facility design and safety requirements for plutonium processing, will allow an actual facility to operate in a production mode making acceptable slag and metal products, and will reflect the best applicable practices from the primary metal production industries with particular emphasis in the steel making processes.

TECHNOLOGY NEEDS

There are a number of DOE mixed wastes that require elaborate treatments prior to disposal. Many of these wastes contain a mixture of hazardous organics, and toxic and actinide metals in some heterogeneous matrix, for which available treatment technologies are limited. Disposal of these mixed wastes is driven by the U.S. Environmental Protection Agency's (EPA's) Land Disposal Restrictions (LDRs) which require treatment to defined levels of allowable concentrations of toxic metals in leachates from a standardized test prior to final disposal. The presence of radioactive contaminants further complicates the treatment procedure with respect to regulatory and safety concerns. There is currently no proven, commercially available technology that will treat a majority of these wastes, especially the alpha-contaminated wastes. Many technologies rely on extensive segregation and pretreatment of the waste, which increases handling, radiological exposure to personnel and cost.

ACCOMPLISHMENTS

- A detailed survey of industrial practice and its relevance to the slag and metal removal techniques for the PHP system was evaluated.
- Review of industrial practices with regard to safety of design and operations of the PHP system was completed.
- The validation process for the slag and metal handling design concept was finalized.
- Preparation of the draft requirements for the design of the plutonium confinement system was completed.
- Proof-of-principle testing of slag and metal separation and slag pouring concepts was completed by SAIC at facilities in Ukiah, CA and Idaho Falls, ID.

BENEFITS

The expected benefit of this task is to condense the time required for DOE to develop the PHP slag and metal handling system for the field-scale radioactive system as well as for a production waste treatment facility. Industrial experience will be evaluated to identify and correct potential design flaws that would negatively impact project schedule, cost, treatment capacity, availability, maintainability, and safety. It will also help ensure that the system will be able to meet DOE requirements for facilities handling of plutonium contaminated waste.

COLLABORATION/TECHNOLOGY TRANSFER

The present task is a part of the larger and ongoing task of the overall development of the PHP system. This larger program is composed of three industry partners and DOE contractors who have been working with ANL-W. These industrial partners include SAIC, LITCO, and Retech, Inc.

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TASK DESCRIPTION

The objective of this project was to demonstrate the steam reforming system developed by Synthetica Technologies to destroy organic and inorganic salts that decompose thermally (e.g., nitrates, nitrites, and carbonates) which are present in the following:

- An adsorbed aqueous organic liquid waste simulant,
- A high organic content sludge simulant,
- A cemented sludge/ash/solids simulant,
- A heterogeneous debris simulant,
- A laboratory pack simulant, and
- Trimsol coated machining waste.

In addition, scavenging of mercury vapor by molten sulfur coated on ceramic spheres was studied to determine whether a Synthetica ceramic sphere, in a packed moving bed evaporator liquid feed system can be used to scavenge mercury vaporized by steam gasification of mixed wastes.

Wastes are destroyed by this system in two steps. First, the organic components of a waste are gasified in the appropriate feed system by exposing the waste to superheated steam. Then, the gasified organic materials are destroyed by passage through the resistively heated high-temperature reaction chamber of the detoxifier, in which the mixture of steam and gasified organic fragments is heated to more than 1,200°C. See Figure 2.3.

TECHNOLOGY NEEDS

Large quantities of organic materials in mixed wastes stored or being generated at DOE sites must be destroyed in order to remediate these wastes. In addition, nitrate contaminants in the wastes must be destroyed before the final low-level radioactive wastes are entombed in permanent storage vaults.

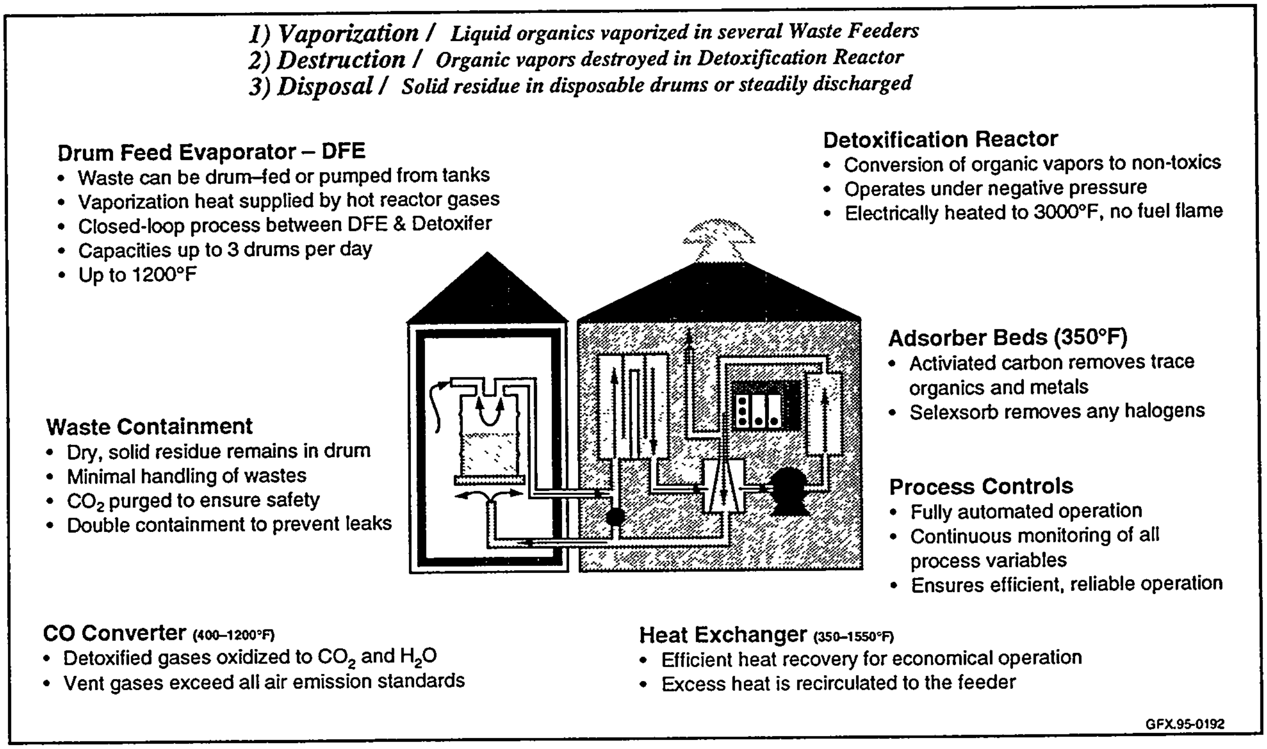

Figure 2.3. Synthetica Detoxifier Three Step Process.

Accomplishments

Two tests were conducted by Thermo Chem on a surrogate mixed waste containing chlorinated hydrocarbons. Both tests yielded greater than 99 percent DRE.

Benefits

The Synthetica system is suitable for a wide variety of waste streams (solid, liquid, or gaseous), such as solvent wastes, aqueous wastes with high or low concentrations of toxic organic contaminants, paint, printing ink, glues, and sealants, medical infectious wastes, spent adsorbents and loaded activated carbon, spent filters, pharmaceutical wastes, pesticides, chemical warfare agents and some explosives, printed circuit boards, and other organic materials. Since the detoxifier operates at high temperatures and does not combust the hazardous wastes, it avoids production of SO_x, NO_x, dioxins, and furans.

Collaboration/Technology Transfer

This technology has been proven commercially on various types of hazardous waste streams by Thermo Chem and Synthetica Technologies.

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2.4 Vitrify-to-Dispose Technology Development

Task Description

The purpose of this project is to further develop the "Treat-to-Dispose" vitrification technology. Vitrification involves converting wastes that are primarily inorganic in nature into glass. This is accomplished by using the Reactive Additive Stabilization Process (RASP), in which carefully chosen additives react chemically with potential glass-formers within the waste. The result of the RASP approach to vitrification is higher waste loadings and increased final waste-form homogeneity, which leads to decreased leachability.

Emphasis has been placed on broadening the number of waste streams applicable to vitrification by establishing the processing envelopes for specific representative waste streams. Four specific wastewater treatment sludges (Oak Ridge Y-12 WETF sludge, LANL sludge, Rocky Flats precipitate sludge, and SRS M-area sludge) and several flyash streams (including Oak Ridge TSCA flyash and LANL CAI flyash) have been identified for treatment. The study is also investigating advanced glass-making processes utilizing the expertise and pilot-scale resources at Clemson University. Two state-of-the-art joule-heated, slurry-fed glass melters are available at the Clemson University Environmental Systems Engineering Department. One is a cold-top design and the other is a stirred melter. See Figures 2.4a and 2.4b. The environmental impact of the glass making process (e.g., air emissions), as well as the environmental impact of the finished product, is being investigated. Data derived from this work will be used to formulate a delisting plan that will be used to establish vitrification as an acceptable technology for the delisting of MLLW.

The culmination of this work is a field-scale radioactive demonstration of vitrification technology which is being initiated in FY95. The demonstration will utilize a fully integrated system including material handling, glass melting, off-gas treatment, and process control subsystems, all of which will be transportable in nature. The demonstration using the Compact Vitrification System (CVS) has been scheduled to begin in late FY95 with Oak Ridge K-25 Plant being the host site. The actual mixed waste stream selected for treatment is the Oak Ridge Y-12 Plant WETF sludge.

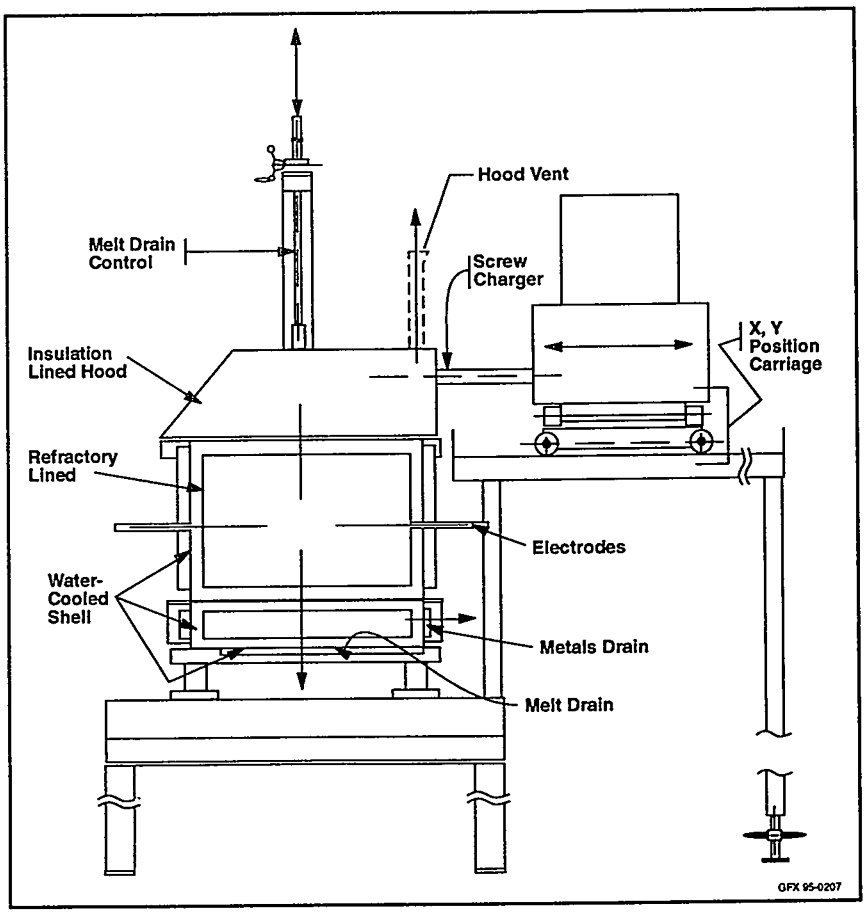

Figure 2.4a. EnVitCo Cold Top Melter Furnace.

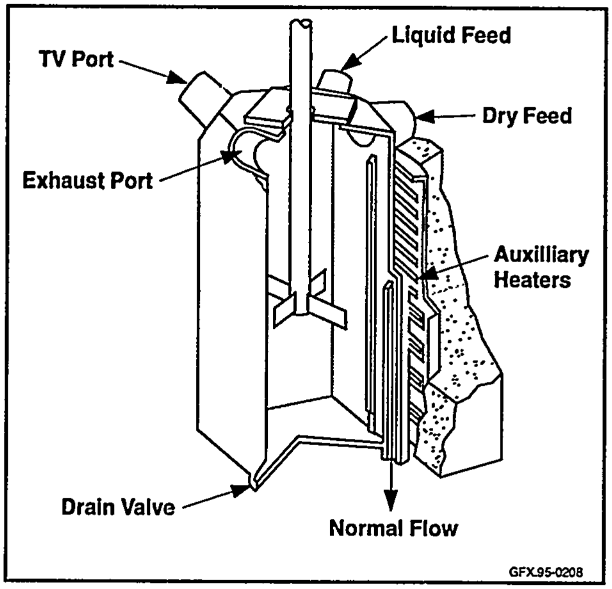

Figure 2.4b. Stir Melter Furnace.

Technology Needs

The goal of the vitrify-to-dispose approach to waste stabilization is to treat approximately 75 percent of the mixed waste in inventory can be effectively treated for disposal. A radioactive demonstration of the vitrification of the Oak Ridge Reservation (ORR) WETF sludge in a fully transportable, complete melter system is scheduled for accomplishment in FY95.

The treat-to-dispose vitrification technology development effort has as one of its goals production of the data necessary for regulators to approve the delisting of RCRA-regulated constituents bound within the glass matrix so that the final waste form can be land disposed. This effort is ongoing.

Accomplishments

The SRS has teamed with EM-50 and Clemson University to create the DOE/Industrial Laboratory for Vitrification Research. The laboratory has completed its second year of operation and has logged over 3000 hours of pilot-scale operation with the Stir-Melter system and over 4000 hours operating the EnVitCo cold-top melter system.

The Compact Vitrification System is currently being constructed. EnVitCo is supplying the melter and is also integrating the system. The off-gas treatment sub-system is being procurred from Anderson 2000, and the transportable process control/analytical trailer is being assembled by Calumet Coach.

Crucible-scale studies of actual Y-12 WETF sludge have been performed at Oak Ridge. The glass system chosen for this waste is soda-lime-silica (Na_2O-NaO-SiO_2). Waste loadings of up to 70 percent have been achieved with actual waste. Scoping tests are being performed at Clemson using an EnVitCo melter similar to that which will be used in the CVS. The scoping tests using surrogate WETF sludge will be used to determine important operational parameters to be used during the actual CVS demonstration.

Benefits

The successful production of a non-leachable glass waste form from MLLW will allow the land disposal of the waste at a lower cost than if the baseline technology (cementation) were used to stabilize the waste. This cost savings is due primarily to the large volume reductions realized during vitrification as opposed to the small volume reductions (or even volume increases) resulting from grouting or cementation. In addition, glass final waste forms have been shown to have decreased leachability and increased structural stability than the baseline waste form.

Collaboration/Technology Transfer

This project is a collaboration among SRS, Clemson University (which operates the DOE/Industry Laboratory for Vitrification Research), ORNL, and private companies that are providing equipment and technical support. EnVitCo, Inc. has a high waste loading, transportable melter, and StirMelter, Inc. has a high-rate, low-cost melter. RUST Remedial Services is providing chemical analysis services, waste form characterization, and engineering support. SRS is contributing its expertise on how the glass should be made using the Reactive Additive Stabilization Process (RASP). This project is being supported by EM-50, SRS's High-Level Waste Program, the Savannah River Economic Development Program, and the DOE Office of Waste Management.

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2.5 STUDIES ON WASTE STREAMS CONTAINING DIFFICULT TO VITRIFY COMPONENTS

TASK DESCRIPTION

This task is intended to investigate several waste streams that contain constituents known to be problematic for glass making. The constituents in question are organics, mercury, reduced metals, chloride, nitrate, and sulfate salts. The difficulties arise by either the constituent being insoluble in the glass melt (such as organics and reduced heavy metals) resulting in unacceptably low waste loadings, or by causing glass corrosion that over time reduces the structural stability of the glass and allows leaching from the glass matrix.

The vitrification processing envelopes are being defined for three waste streams: Hanford 183H solar pond sludge, Rocky Flats Saltcrete residues, and Oak Ridge TSCA incinerator residues. In addition, the application of direct vitrification of combustible material (rather than incineration followed by vitrification) has been studied.

TECHNOLOGY NEEDS

The stabilization of mixed waste by converting it into a glass final form (e.g., vitrification) is complicated by the existence of certain "bad actors" in a given waste stream. One of the major advantages of a glass final waste form as compared to a grouted or cemented waste form is the decreased leachability of the glass final form. Glasses are also expected to be more physically stable over much longer periods of time than grouted or cemented forms, probably due to the excellent corrosion resistance of good glasses.

"Bad actors" for glass production do exist in many DOE mixed waste streams. Examples are the 183-H Solar Evaporation Pond sludge from Hanford (containing high levels of copper, sodium, and sulfur), and the Rocky Flats Saltcrete waste (this waste is an example of the failure of cementation), which contains nitrates, sulfates, and chloride salts of sodium and potassium. This task is concerned with dealing with those "bad actors" in a manner that does not require their removal by pretreatment. Rather, the process involves the investigation of alternative glass systems in which the "bad actors" are acceptably soluble. Two other approaches to stabilizing problematic mixed wastes are presented below in the sections on phosphate-bonded ceramics and polymer encapsulation.

ACCOMPLISHMENTS

Both silicate and phosphate glass formulations have been developed for each of the referenced waste streams. Phosphate glasses are preferred, however, for two main reasons. Increased solubility of chloride ion in the phosphate glass melt has been observed, and the phosphate system allows evolution of sulfur oxide, which can be handled in an off-gas treatment train (sulfate typically is found in a separate molten phase on the surface of silicate glass melts, and upon solidification becomes available for leaching).

The glasses produced by this study on the crucible scale have been shown to be producible in joule-heated melters as a result of measurements of melt viscosity and electrical conductivity.

Proof-of-concept testing on the bench-scale has shown the viability of the direct vitrification of combustible materials. A bench-scale unit was fabricated at Washington State University-Tri-Cities Branch Campus, and was tested using wood as the test combustible material.

BENEFITS

As a result of this work, the number of mixed waste streams for which stabilization by vitrification is recommended has been broadened to include those containing combustible matter and/or high levels of nitrate, chloride, and sulfate salts. This was accomplished by adoption of the phosphate glass system $AlPO_4$-SiO_2-CaO-Fe_2O_3.

COLLABORATION/TECHNOLOGY TRANSFER

Joint participants include the Pacific Northwest Laboratory (PNL), Clemson University, Pacific Nuclear, MIT, and Washington State University. This project complements the treat-to-dispose vitrification technology development effort at SRS. Battelle-PNL is working with Vectra Technologies, Inc. in marketing vitrification technology for treating low-level waste produced in the commercial sector.

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TTP Numbers: RL332009, SR132004

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2.6 WASTE STREAM PRETREATMENT FOR MERCURY REMOVAL

TASK DESCRIPTION

As an important activity related to the "Treat-to-Dispose" effort, this task investigates waste stream pretreatment methods for removing mercury and speciated mercury. Two of the methods are appropriate for leaching mercury from solid waste matrices and involve acid leaching in one case, and the patented GE KI/I_2 leaching process in the other. For the removal of mercury from liquids, two processes have been studied. The liquid technologies are sulfur-impregnated activated carbon and a process involving ion exchange resins and membrane technology.

TECHNOLOGY NEEDS

A number of sites across the DOE Complex have mixed waste streams containing mercury compounds in various waste matrices. For an example of solid matrices, the Oak Ridge Y-12 site has approximately 363,000 kg of storm sewer sediments that were found to be not only radioactive, but to contain approximately 19,000 ppm of elemental mercury as well. Crushed fluorescent tubes and lamps are found at all sites (Oak Ridge alone has over 25,000 kg in storage). Examples of mercury-bearing liquids are the ICPP sodium-bearing acid waste (with approximately 1.5 million gallons in storage at Oak Ridge) and various leach solutions containing mercury as Hg^{2+} derived during this study from the acid-leaching of solid mixed wastes.

There is a need to separate mercury from the remainder of the mixed waste matrix when the waste is going to be treated thermally. The volatility of mercury is such that pretreatment for removal is needed in order to prevent the potential escape of the volatilized mercury from the off-gas treatment system. An alternate approach is to devise a process for capturing any volatilized mercury in the off-gas treatment system. This approach is being investigated under TTPs AL342002 and AL342004, presented elsewhere in this text.

ACCOMPLISHMENTS

- Laboratory studies have shown that the KI/I_2 leaching solution is able to reduce the mercury concentration in contaminated soils by as much as 99 percent regardless of mercury speciation.
- Of eight different leaching solutions evaluated for treatment of mercury-contaminated glass, only three (KI/I_2, NaOCI, and NaBrt acid) were able to remove any mercury from the glass.
- Several conceptual process flowsheets have been drafted for the complete mercury leaching/capture process, including: mercury removal, solid/liquid separations, I_2 recovery, and leaching solution recycle.

BENEFITS

The successful removal of mercury and/or speciated mercury from waste streams will allow their treatment in thermal processes. Operators of thermal treatment units are reluctant to treat mercury-bearing wastes due to the problems presented by having to capture volatilized mercury.

COLLABORATION/TECHNOLOGY TRANSFER

This project involves researchers at ORNL and has participation by Nucon International, 3M Corporation, and the General Electric Corporation. 3M Corporation is providing services to the MWFA through their existing contract with the Efficient Separations and Processing Crosscutting Program.

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2.7 MICROWAVE SOLIDIFICATION

TASK DESCRIPTION

Microwave solidification is a mixed waste treatment process being developed at the Rocky Flats Environmental Technology Site (RFETS). The process is applicable to homogeneous, wet or dry, inorganic solids. The process dries the waste, mixes it with a slice source and matrix modifier, transfers it to a processing container, and subjects the mixture to microwave energy to melt the materials. See Figure 2.7. The processed waste form then cools and solidifies. The RFETS process begins by connecting a 30-gallon drum to the microwave unit. Waste and glass frit are placed in the drum while a turntable moves continuously to ensure even distribution of the contents. Microwave energy is transmitted to the drum to raise the internal temperature of the material to 1,000°C. The resulting waste form is a vitreous material that contains no free liquids, has limited releasable particulates, and is highly leach-resistant due to its vitreous nature.

Bench- and pilot-scale tests have been performed on both actual and surrogate wastes. The basic design of the current microwave system has been demonstrated with bench-scale tests on actual waste materials. Test results indicate that volume reductions of up to 80 percent are achievable over some other solidification technologies.

TECHNOLOGY NEEDS

The generation of nearly 1,200 cubic feet of it per year, coupled with a backlog inventory of 18,000 cubic feet, makes it one of the largest waste streams at RFETS. Radioactive and heavy metal components contained in liquid effluent are removed during a hydroxide co-precipitation process, and an insoluble sludge coagulates and is collected.

The current treatment of this waste material is accomplished by cement stabilization. Microwave

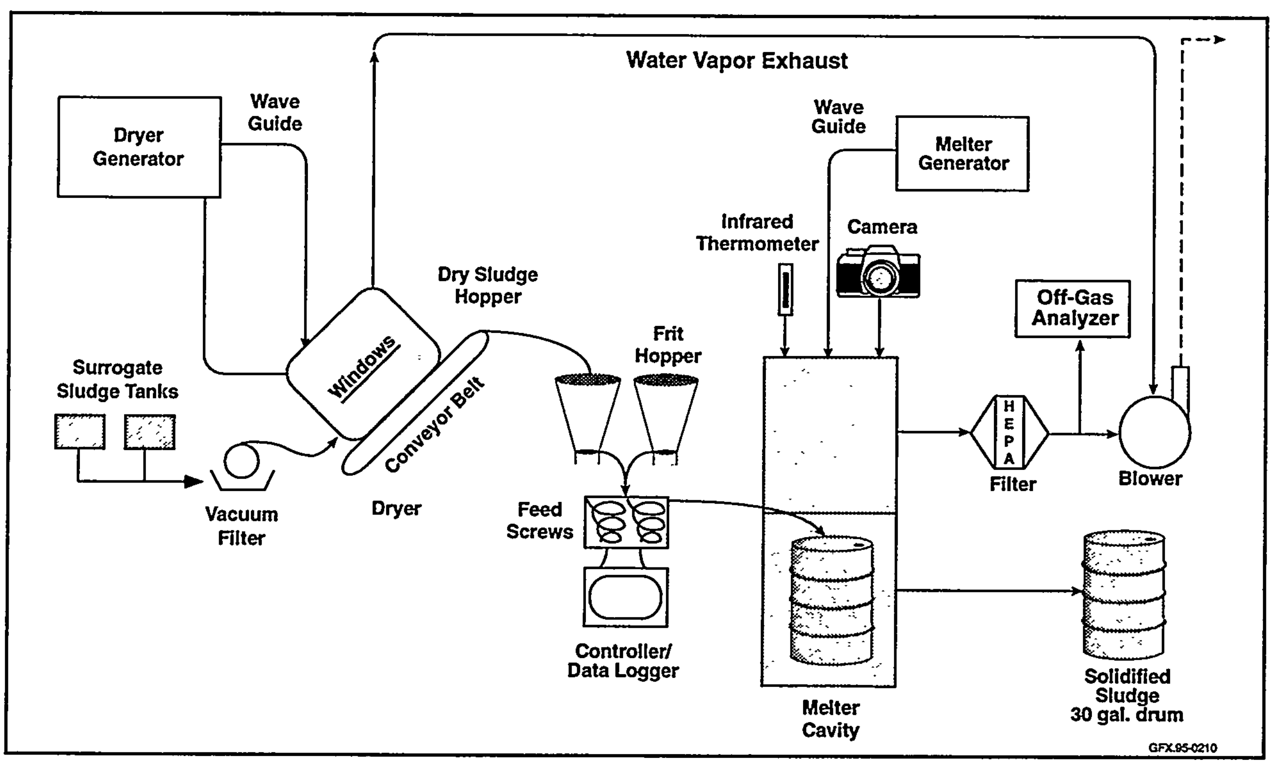

Figure 2.7. Microwave Solidification Process.

solidification was identified as a potential replacement for cement stabilization and was selected for utilization on a variety of inorganic wastes.

In addition to the hydroxide co-precipitation sludges currently under investigation, several other waste streams have been identified as potentially amenable to microwave solidification. These wastes include incinerator ash, nitrate salts, solar pond sludge, remediation soils, asbestos, and materials from foundry operations. Potential for application of this treatment technology also exists at other DOE facilities. Transfer of the technology to the facilities and to private enterprise will be pursued through the implementation of a technology transfer strategy and action plan.

ACCOMPLISHMENTS

Numerous studies have been conducted in bench-, pilot- and full-scale demonstration systems at RFETS. A majority of this work was completed using a non-radioactive, non-hazardous surrogate that represented the bulk chemical and physical properties of the hydroxide co-precipitation sludge. These studies were focused at obtaining information for preliminary recipe formulation, selection of operating parameters, equipment specification, and economic analysis of the process.

The feasibility of production implementation of the microwave solidification process has been proven using a full-scale demonstration system in operation since 1989. The test results from this facility indicate that the technology can be easily scaled from bench to production operations. Waste loading levels of 60 percent were easily achieved and may be pushed as high as 100 percent by combining waste streams to achieve appropriate glass formulations. One possibility is the use of spent rashig rings from solution storage tanks as a silica source in the operation. As a result of the success of the program, production implementation efforts have been initiated. The process should be brought into full production operations in 1998.

BENEFITS

- Volume reductions of up to 97 percent have been observed. This characteristic favorably impacts the life-cycle costs for the process and relieves storage limitations at the final waste interment facility.
- Due to its vitreous nature, the solidified waste product offers a leach resistant, stable matrix especially suited for hazardous and radioactive waste.
- The equipment is inexpensive and easy to maintain.
- Efficient energy transfer is achieved due to direct coupling between the microwave energy and the waste material.
- The process can be brought to operational temperature in a matter of minutes, compared to competing thermal processes, which can take hours.
- Because the material is being processed in-drum, it does not have to flow from a melting crucible to a shipping container. This eliminates viscosity concerns, allowing much higher waste loading and product density.

COLLABORATION/TECHNOLOGY TRANSFER

RFETS has developed a multi-faceted approach for technology transfer to possible customers in DOE, other public institutions, and private sector industries.

Several treatability study proposals are being formulated for RFETS wastes, such as the treatment of residues, solar pond sludge, and remediation soils from Operable Unit Number 2. Opportunities for the treatment of other DOE site wastes include the inventoried wastes at ORNL, the buried wastes at INEL, liquid waste treatment sludges from Technical Area 50 at LANL, and the remediation wastes at the Hanford Site.

The microwave solidification technology can also be applied to private-sector waste materials, including sludges from steel manufacturing, superfund remediation soils, ash from hazardous waste incinerators, and fly ash from commercial power facilities. The potential for application of this technology has been acknowledged by the Western Governors' Association, which selected the technology for participation in the Develop On-site Innovative Technologies (DOIT) program. Potential technology transfer participants and customers are being identified.

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NON-THERMAL TREATMENT PROCESSES

Section 3.0

3.1 LOW TEMPERATURE THERMAL DESORPTION

TASK DESCRIPTION

Thermal desorption is a cost-effective way to treat smaller volumes of organically contaminated soils, sludges, and other solid matrices, and is being demonstrated at the Rocky Flats Environmental Technology Site (RFETS). The objective of the Low Temperature Thermal Desorption (LTTD) effort is to desorb and separate the hazardous contaminants without combustion of the waste matrix. Hazardous contaminants are separated from the mixed waste by heating the materials to temperatures no greater than 120° C. The waste is prepared and sized in a chilled environment to control the volatilization of the organic contaminants and to more accurately determine the separation efficiency of the process. The waste material is then loaded into an indirectly heated, vacuum dryer equipped with agitator vanes. See Figure 3.1. A heated nitrogen carrier gas is injected into the dryer and blankets the waste as it is agitated and brought to operating temperatures. When the desired temperature is reached, the waste is subjected to a vacuum for a predetermined period of time (residence time). Organic contaminants are driven off as vapors, which are either condensed and collected as liquids or are destroyed by flowing the gas stream through a non-thermal plasma (NTP) gas treatment system. The NTP reaction cells use electrical micro-discharges to break up organic molecules. The resulting LTTD/NTP products include decontaminated solids, organic condensate, and nitrogen-rich vapor. The vapor stream is further cleansed using a HEPA filter and granular activated charcoal (GAC) adsorption system prior to venting.

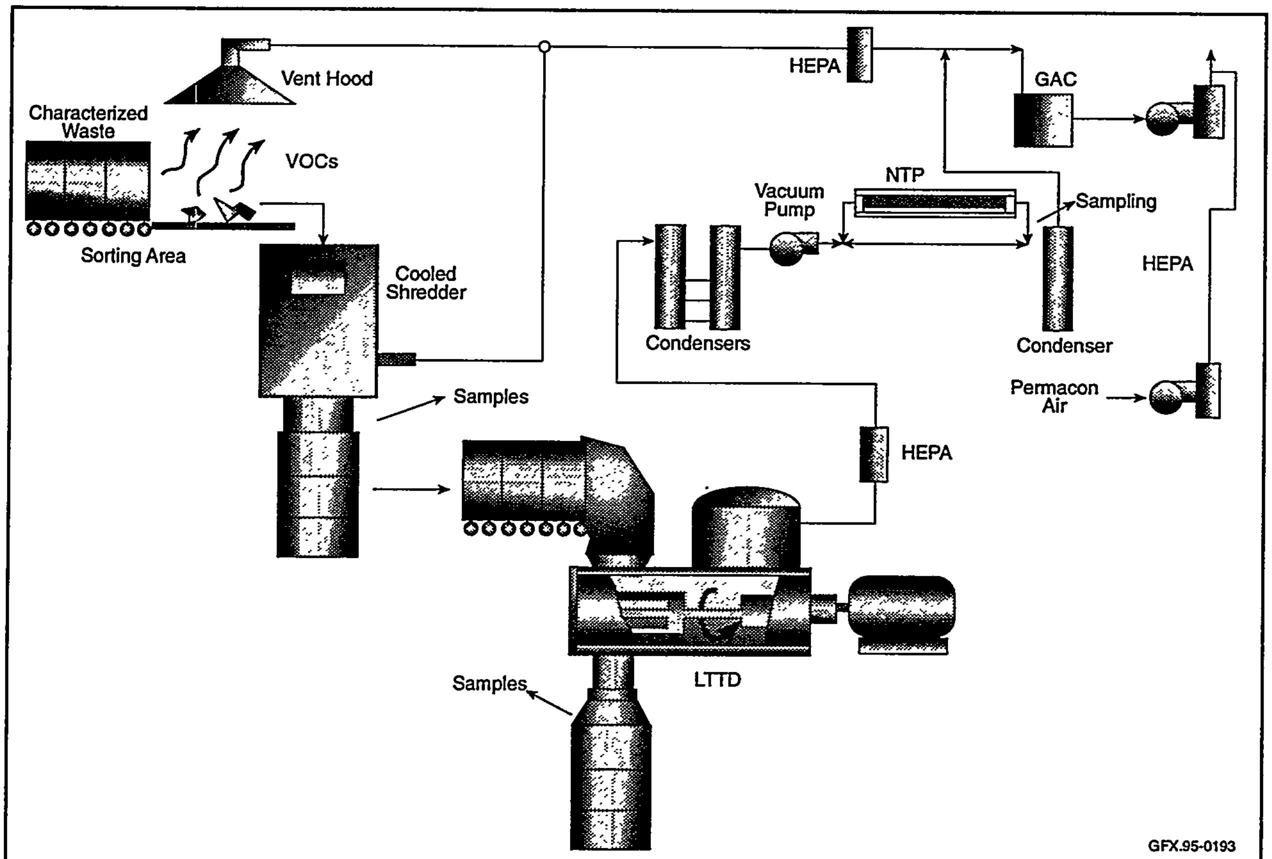

Figure 3.1. Low Temperature Thermal Desorption System.

The LTTD technology being tested at RFETS is the VAC*TRAX unit, developed by Rust Federal Services. The NTP technology to be tested is the Silent Discharge Plasma/Non-Thermal Plasma system developed by LANL. The process will be demonstrated on several wastes including low-level mixed combustibles, soils, clean-up debris and used absorbent material. LTTD will be demonstrated at RFETS in three phases: 1) coordinated treatability studies, 2) a coordinated demonstration, and 3) implementation and waste treatment. Treatability studies have been conducted at several vendor facilities on bench- and pilot-scale systems. A demonstration of the technology on actual MLLW was conducted in FY95 on the VAC*TRAX demonstration unit, which is capable of processing batches of approximately 50 kg. Engineering data for scale-up will be obtained in the demonstration.

TECHNOLOGY NEEDS

Development of this system was initially funded through a Programmatic Research and Development Announcement (PRDA) sponsored by the DOE Morgantown Energy Technology Center (METC). The objective of the development was to fill a need that exists both commercially and at DOE facilities for a thermal desorption system for treating small volume, solvent contaminated waste streams. Further pilot-/full-scale development and demonstration efforts are planned for FY95 and FY96. RFETS became part of this development process when Rust Federal Services conducted treatability studies on RFETS RCRA waste in October, 1993. Legal milestones set forth in the 1991 Federal Facilities Compliance Agreement II, a binding agreement between RFETS, EPA, and the Colorado Department of Public Health and Environment, called for the on-site demonstration of LTTD on RFETS waste.

ACCOMPLISHMENTS

- Treatability Study Exemption permits have been awarded by EPA and the state of Colorado environmental regulators.
- LTTD equipment was installed, and tested in preparation for on-site demonstrations at Rocky Flats.
- On March 8, 1995, an initial demonstration of LTTD using non-radioactive surrogate wastes was performed for Rocky Flats personnel and Colorado regulators.
- On March 23, 1995, a second LTTD demonstration was performed for EPA officials, the Colorado governors office, the Western Governors Association, and environmental regulators from several states outside Colorado.
- On April 6, 1995, a third LTTD demonstration was performed for local stakeholders.

BENEFITS

Removal of hazardous solvents from transuranic mixed waste and MLLW streams simplifies disposal of treated waste forms, and the corresponding volume reduction achieved separating out the hazardous compounds results in lower overall disposal costs. As a pretreatment system, LTTD renders solid waste more amenable to a final stabilization process, such as vitrification or polymer encapsulation. LTTD operates at a low temperature, typically around 120°C. Since the nitrogen atmosphere is inert, no combustion of organic material takes place.

COLLABORATION/TECHNOLOGY TRANSFER

Commercial organizations involved in the development program include EG&G Rocky Flats, Rust Remedial Services/Clemson Technical Center, and LANL. The Federal Advisory Committee to Develop On-Site Innovative Technologies (DOIT Committee), a joint federal-state partnership including the Western Governors Association, DOE, EPA, and various stakeholder groups, selected LTTD as a candidate demonstration to provide value-added enhancements to the demonstration process. Special emphasis is placed on achieving regulatory acceptance in states outside Colorado via a cooperative multi-state permitting effort.

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3.2 BIOCATALYTIC DESTRUCTION OF NITRATE AND NITRITE

TASK DESCRIPTION

This project is developing an enzyme-based reactor system that uses naturally-occurring reductase enzymes, to reduce nitrate and nitrite present in various aqueous wastes to nitrogen and hydroxide ions. The process involves a three-step reduction process: 1) reduction of nitrate to nitrite, 2) nitrite to nitrous oxide, and 3) nitrous oxide to nitrogen. The overall process requires three separate reductase enzymes, one for each reduction step. The reductase enzymes are co-immobilized along with electron-transfer mediators, such as functionalized bipyridinium complexes, onto the surface of an electrode. The enzymatic reactions proceed rapidly under mild conditions near ambient temperature and at redox potentials less than that required to electrolyze water (i.e., -0.828 V). The reducing equivalents are provided by a low-voltage electrical current, which transfers electrons from the cathode to the enzymes via the electron-transfer mediator. The immobilized enzymes are confined to the polyethylene glycol-rich phase of an aqueous biphase system to protect them from denaturization and inactivation due to the high ionic strength and radionuclide content of the mixed waste streams. This aqueous biphase system allows selective partitioning of nitrate and nitrite from the waste stream to the polyethylene glycol-rich phase of the reaction chamber. Most other anions, such as hydroxide, carbonates, and sulfates and most of the cations present in the mixed waste stream remain in the aqueous phase. The use of enzymes enables high specific catalytic activity to be obtained without the need for additional chemical reagents or the production of secondary waste streams. See Figure 3.2.

TECHNOLOGY NEEDS

A wide variety of high nitrate-concentration aqueous mixed wastes are stored at various DOE facilities. The presence of nitrates and nitrites in these wastes presents several problems for many pretreatment and immobilization processes currently being considered for treatment of these wastes, including vitrification. These problems include an increase in final waste form volume or reduction in waste form integrity; generation of off-gases, such as nitrous oxides or ammonia, which will require expensive scrubbing facilities; the potential for unstable exothermic reactions during processing in the presence of organics; and the need to meet EPA guidelines on nitrate levels in aqueous discharges. Thus, nitrate destruction before solidification of the waste will generally be beneficial from the standpoint of cost and waste form performance. Biocatalytic nitrate

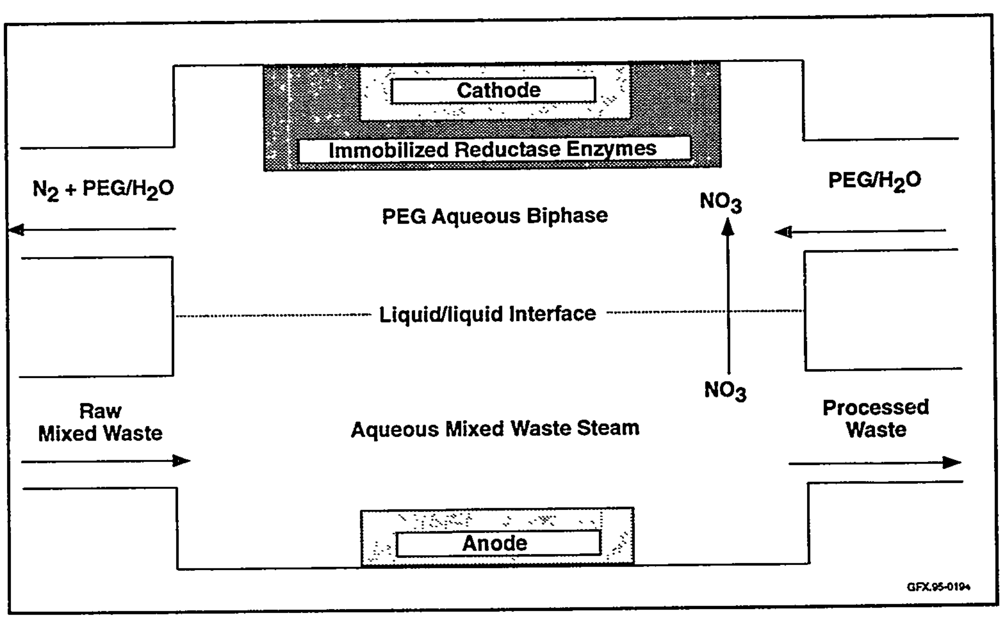

Figure 3.2. Biocatalytic Destruction Process Description.

destruction is applicable to a wide range of aqueous nitrate bearing wastes across the DOE Complex with highly variable composition and specifically to the Hanford tank wastes.

Further development is needed to co-immobilize the nitrite and nitrous oxide reductase enzymes, along with the nitrate reductase enzymes and the electron-transfer mediator, onto the electrode surface. Once this has been completed and the immobilization techniques optimized to provide maximum enzyme activity, a pilot-scale unit capable of reducing nitrate and nitrite to nitrogen gas should be demonstrated.

ACCOMPLISHMENTS

Work completed to date has focused on the reduction of nitrate to nitrite, which is the first step in the overall reduction of nitrate to nitrogen gas. A nitrate reductase enzyme (either the ferrocytochrome form of *Aspergillus* or the NAD form of *Escherichia coli*) has been co-immobilized with an electron-transfer mediator (a functionalized bipyridinium complex) onto the surface of a gold electrode. These immobilized enzymes can reduce nitrate to nitrite at a potential of -0.6 to -0.75 V, a potential that will not normally reduce nitrate to nitrite. The enzymes have been shown to work in polyethylene glycol solutions containing concentrations of nitrate in excess of 0.25 M and to retain their activity over extended periods of time - on the order of several months. Currently, other electron-transfer mediators, such as functionalized viologens, are being investigated to enhance the charge transfer to the active enzyme, a step that is believed to be rate limiting under the current conditions.

BENEFITS

This process could provide a compact, low cost reactor to treat aqueous mixed waste streams containing nitrates or nitrites, eliminate the need for chemical reagents, and minimize or eliminate secondary wastes such as NO_2, and secondary products such as NH_3, H_2, and O_2 that are prevalent with other nitrate destruction processes. By removing nitrates and nitrites from waste streams before they are sent to high temperature thermal destruction and vitrification, production of NO_x can be decreased with the attendant decrease in off-gas system requirements.

COLLABORATION/TECHNOLOGY TRANSFER

The reactor tests using simulated feeds were carried out jointly between ANL and the University of Iowa. Work at ANL focused on development of a biphasic extraction system and process integration. Researchers at the University of Iowa provided support in developing enzyme immobilization techniques and assays of activities.

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3.3 FREEZE CRYSTALLIZATION TECHNOLOGY

TASK DESCRIPTION

Freeze crystallization processes are based on the difference in component concentrations between solid and liquid phases that are in equilibrium. As an aqueous solution is cooled, ice usually crystallizes as a pure material, and dissolved components in the aqueous waste stream are concentrated in the remaining brine thereby reducing the volume of waste. See Figure 3.3.

Freeze crystallization technology is capable of separating organic and inorganic contaminants in an aqueous waste stream by removing the bulk of the water as ice, and concentrating the contaminants in the remaining brine. This is a flexible technology that can be designed and operated for specific site needs for removal of inorganics, organics, heavy metals, and radionuclides from aqueous wastes.

In this project, engineering studies have evaluated the technical and economic benefits of freeze crystallization technology as it pertains to mixed waste (i.e., a cost/benefit analysis). Treatability studies and process development were performed on surrogate waste streams at a vendor's small-scale pilot plant.

TECHNOLOGY NEEDS

INEL has expressed an interest in the technology, and supplied a surrogate (a simulated acidic waste) for testing. They are in the process of contracting with RUST Clemson Technical Center to perform bench-scale freeze crystallization studies on radioactive surrogates. Additional tests are required at lower pH, and separation of precipitated salts from the ice slurry before separation of the ice from the mother liquor is needed to prevent contamination of the melt. Evaluation of heat transfer surfaces is required to select the best type of surface for MWFA wastes to prevent fouling, crystallization, and corrosion on the surfaces.

ACCOMPLISHMENTS

- The engineering study demonstrated the pros and cons of applying freeze crystallization to removal of contaminants from aqueous waste streams compared to evaporation and membrane technologies. It was determined that the membrane process has the lowest capital and operating cost, followed by evaporation. Freeze crystallization is complex, requiring several unit operations, and therefore has the highest capital and electrical operating costs. However, membrane technology is not suited for waste streams with high (>25 percent) dissolved solids, and evaporation condensate may become contaminated with organics. Therefore, regardless of the cost, it appears that freeze crystallization may be the best choice for some waste streams.

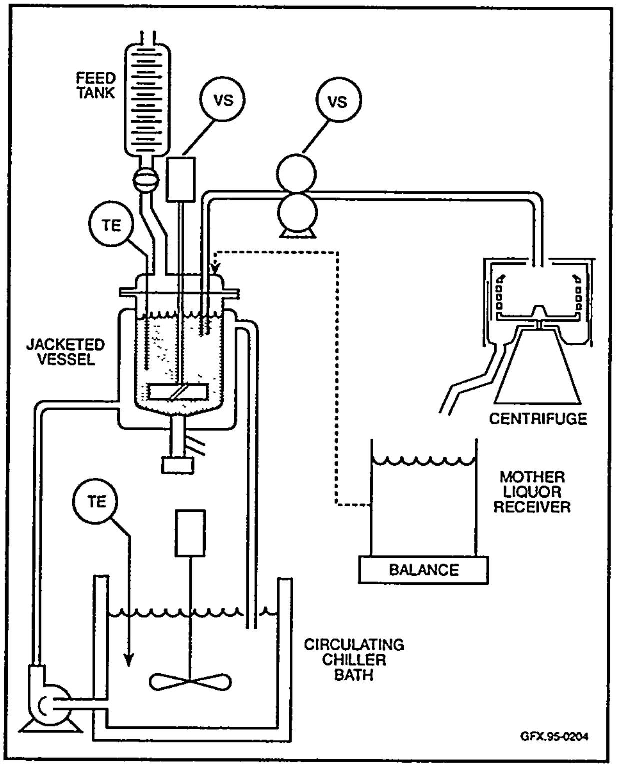

Figure 3.3. Bench-Scale Freeze Crystallizer.

- Tests of indirect-contact freeze crystallization on a concentrated acid waste demonstrated that it was possible to remove sodium nitrate, but the freezing point depression was very high, so other crystallization technologies are recommended.
- Tests on a more dilute surrogate demonstrated a low freezing point depression, and that the ice crystals did not scale the heat transfer surfaces. The melt water was contaminated with calcium, sulfate, and phosphate, but preliminary analysis indicates that the organics remained in the mother liquor, suggesting excellent separation.

BENEFITS

The primary benefit of freeze crystallization is that it can produce a higher purity water than other processes, such as evaporation and membrane technologies, from aqueous solutions containing high percentages of organics and inorganics. Thus, this technology may be beneficial in applications where water recovered from a waste containing RCRA waste and radionuclides must be discharged directly to the environment. Based on previous tests, decontamination factors are expected to be in the range of 100 to 1,000. In addition, off-gas issues will not be as significant for freeze crystallization as with evaporation, because the low operating temperatures will keep volatile organics from vaporizing.

COLLABORATION/TECHNOLOGY NEEDS

The engineering evaluation was performed by J.L. Humphrey and Associates, Austin, TX, an independent consultant in the field of separation technologies.

Laboratory-scale and bench-scale tests have been performed by Wheelabrator HPD, Inc. in Naperville, IL. Wheelabrator HPD, Inc. is a manufacturer of chemical process equipment including evaporators, membrane systems, and freeze crystallization equipment. The company has a research and development laboratory in which they can develop and evaluate heat transfer surfaces, and test the freeze crystallization process on non-radioactive waste streams. Wheelabrator HPD has indicated an interest in working with Westinghouse Hanford Company (WHC) in a cooperative manner, and possibly entering into a CRADA. They have also identified a commercial market for this treatment technology.

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A final report describing the results of the engineering evaluation and the Wheelabrator HPD tests has been published and distributed.

3.4 CATALYTIC CHEMICAL OXIDATION

TASK DESCRIPTION

Chemical oxidation systems use the reaction of oxygen, or an alternate oxidizing agent, to destroy the organic constituents of a waste in an aqueous solution. In catalytic chemical oxidation (CCO), one or more chemical species are added, which act to increase the rate at which the oxidation reactions proceed. See Figure 3.4.

The CCO system uses both an iron catalyst and co-catalysts to degrade the organics in a strong acid solution. The system operates at temperatures much below those used in incineration and uses moderate pressures (expected operating conditions are approximately 150 °C and 70 psig). Both solid and liquid wastes can be treated, and most metals are dissolved and concentrated in the reaction solution.

Delphi Research, Inc. has developed and patented a CCO system, called DETOX, which destroys hazardous organics at practical rates. This DETOX technology has been demonstrated at the bench-scale, with destruction efficiencies of 99.999 percent achieved for liquid hydrocarbons (including some chlorinated organics). Due to the strongly acidic nature of the reaction mixture, engineering development is focused on materials of construction, along with scale-up issues. Treatment of the spent reaction solution and system integration are also being studied.

TECHNOLOGY NEEDS

In a DOE project at METC, the application of the DETOX technology to soil remediation has been examined. Additional studies with other surrogates (non-radioactive) for RFETS wastes, including solid combustibles, are also under way. METC is currently sponsoring the development of a field-scale system to be tested with hazardous waste at SRS and with actual MLLW at Weldon Springs.

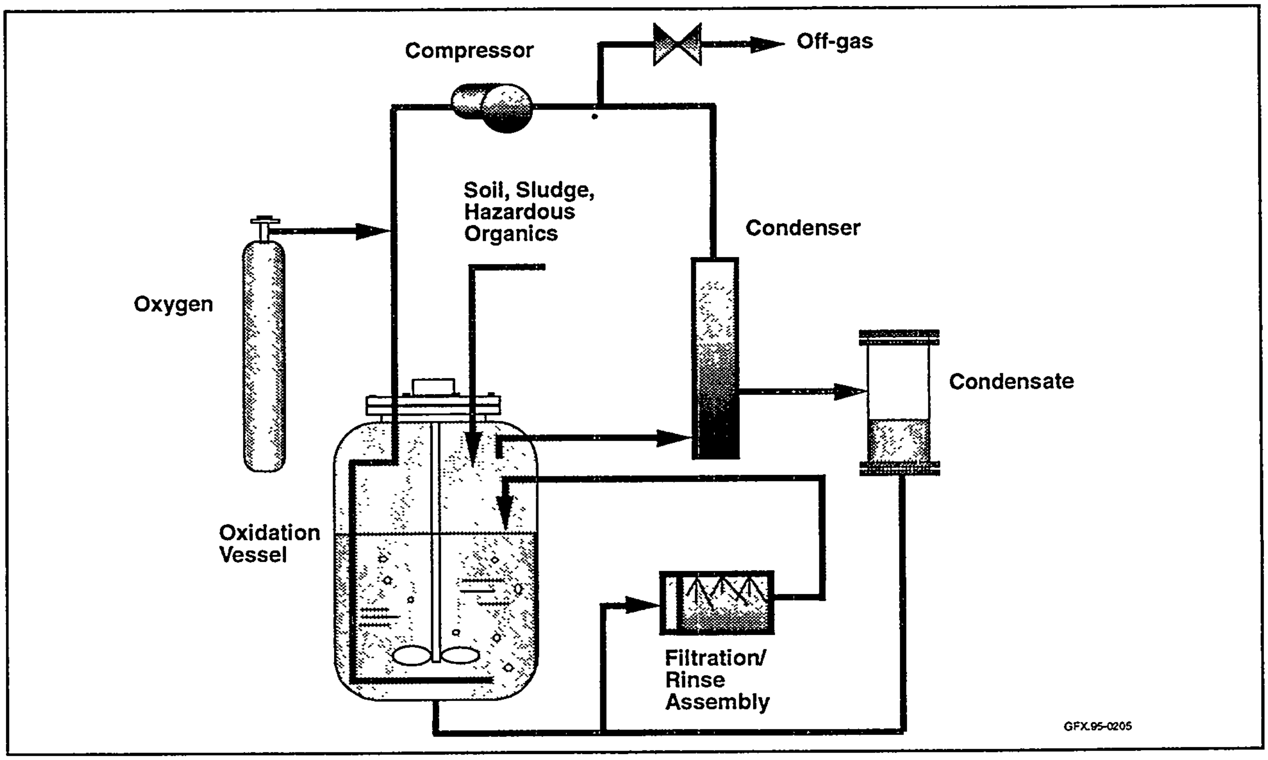

Figure 3.4. Catalytic Wet Chemical Oxidation Process.

ACCOMPLISHMENTS

- Completed laboratory and bench-scale tests and determined destruction efficiencies for surrogate (non-radioactive) FBI oil (liquid chlorinated organics).
- Completed laboratory and bench-scale tests and determined destruction efficiencies for surrogate solid combustibles (e.g., paper, plastic).
- Completed initial materials evaluation to identify materials of construction for a demonstration system.
- Completed initial solidification studies of the spent reaction solution.

BENEFITS

Catalytic Chemical Oxidation offers an alternative to incineration for the treatment of combustible MLLW. DETOX can treat combustible waste at a rate comparable to incineration and reduce the bulk volume of waste without the temperatures and off-gas associated with incineration. This technology has been selected for demonstration-scale development to provide information necessary to design and fabricate a production system.

COLLABORATION/TECHNOLOGY TRANSFER

The development of the DETOX process is being conducted by Delphi Research, Inc. RFETS also continues to evaluate published reports and data on other alternative to incineration technologies and to follow the development of these technologies across the DOE Complex. Development of this technology is expected to provide opportunities for commercial application outside DOE. This work is being coordinated with waste operations at LANL.

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3.5 SUPERCRITICAL CARBON DIOXIDE EXTRACTION

TECHNOLOGY DESCRIPTION

Supercritical Carbon Dioxide Extraction (SCDE) is a process that employs a flowing, non-combustible, non-toxic, environmentally safe fluid as a solvent. This process takes advantage of the enhanced ability of carbon dioxide to dissolve organic contaminants once it has been heated and compressed above 90° F and 1,080 psig. In waste cleanup applications, SCDE is used to dissolve the hazardous components and extract them from the substrate material. By lowering the temperature and pressure at the expansion vessel, the contaminants can be precipitated out of solution to allow separation and recycling of the carbon dioxide. See Figure 3.5. This process is capable of producing a dry residual waste form that can be treated as radioactive, rather than mixed waste.

TECHNOLOGY NEEDS

The laboratory-scale test unit for SCDE has been installed at the University of Colorado at Boulder. Treatability tests have been completed and tests with surrogate wastes have been started. The need for conducting a pilot-scale demonstration in FY96 will be evaluated based on the results of laboratory-scale tests and comparison with thermal desorption results in FY95. Additional studies are being conducted with an emphasis on separation/destruction of the extracted contaminants from the carbon dioxide stream. Extraction of the hazardous components from combustible waste and partitioning them from the host material is a key pretreatment to an incineration alternative process.

ACCOMPLISHMENTS

- Conducted feasibility tests on several thermal desorption systems at vendor facilities.
- Demonstrated feasibility of SCDE for light oils and solvents from steel and uranium substrates in laboratory tests at Rocky Flats.
- Installed laboratory-scale SCDE equipment at the University of Colorado and initiated surrogate waste testing.

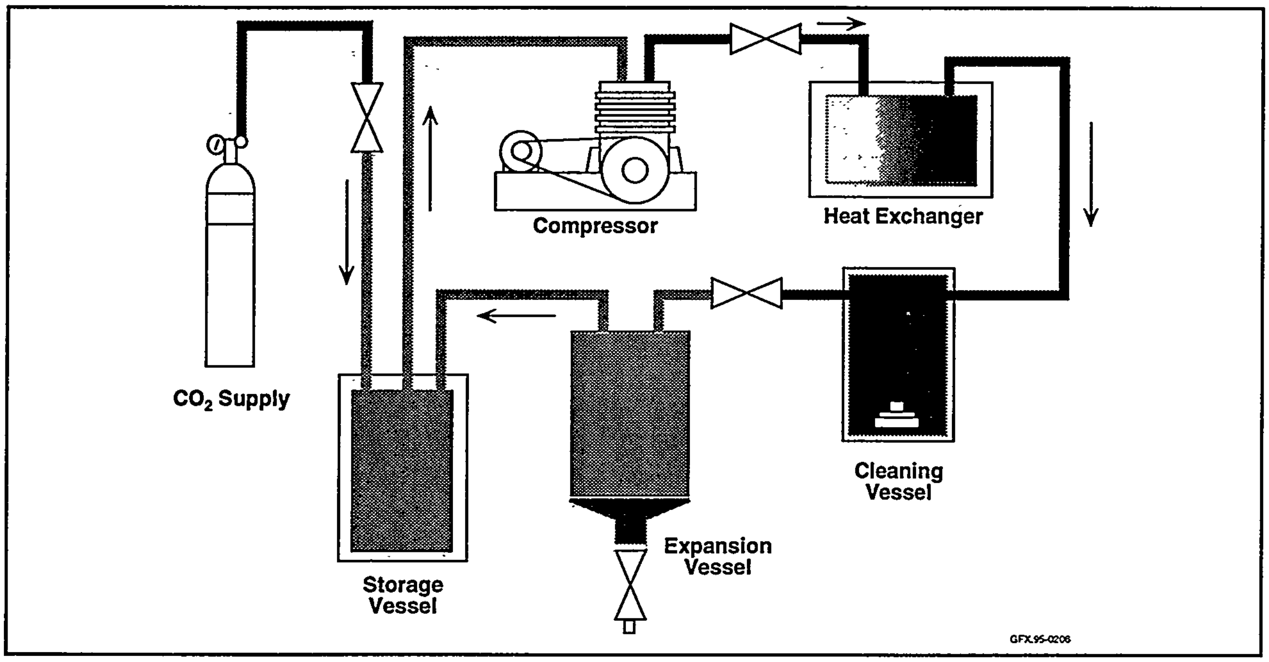

Figure 3.5. Supercritical Carbon Dioxide Extraction.

- Demonstrated feasibility of SCDE for both volatile and semi-volatile compounds from a variety of substrate materials.

BENEFITS

Successful development and implementation of organic removal technologies could remove selected waste streams from LDR status. Removal of hazardous solvents from TRU mixed and LLM wastes would simplify disposal of treated waste forms and result in cost savings. SCDE employs a noncombustible, nontoxic, environmentally safe fluid as the solvent.

COLLABORATION/TECHNOLOGY TRANSFER

Studies of SCDE at Rocky Flats are being conducted in collaboration with the University of Colorado Cooperative Institute for Research in Environmental Sciences (CIRES). Substantial industrial participation in studies of selected volatilization technologies is anticipated.

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TASK DESCRIPTION

Polymer encapsulation of mixed wastes encloses waste products in thermoplastic or thermosetting materials using commercially-available processing technologies. See Figure 3.6. Two primary polymer processes are being tested for DOE mixed wastes.

In one process, micro-encapsulation, thermoplastic polymers such as polyethylene (a commonly-used plastic that is resistant to chemicals and moisture), are combined with dried waste in a commercially-available extruder, which melts the polyethylene and mixes it with the waste. The waste encapsulated in polyethylene is extruded into a drum, where it solidifies upon cooling. The process operates at a low temperature, requires no off-gas treatment, and generates no secondary waste. Since high loadings of waste may be incorporated into the polymer, a substantial reduction in volume may be possible relative to cementation, which has been used to immobilize wastes in the past.

A second process, macro-encapsulation, in which bulk materials (i.e., lead and "debris") are suspended in a drum and encapsulated with molten or liquid plastic, is also being investigated. The solidified polymer surrounds the waste and immobilizes hazardous contaminants. The use of recycled polyethylene is being investigated for this application. Thermosetting plastics (resins combined with hardeners, similar to epoxy) have also been evaluated for encapsulating wastes.

Polyethylene and modified sulfur cement encapsulation are two thermoplastic encapsulation processes developed at Rocky Flats Environmental Technology Site (RFETS) and Brookhaven National Laboratory (BNL) with demonstrated applicability to a wide range of mixed waste types. Bench-scale R&D has been completed for both processes, including application of waste form test criteria recommended by the U.S. Nuclear Regulatory Commission (NRC) in support of 10 CFR 61.

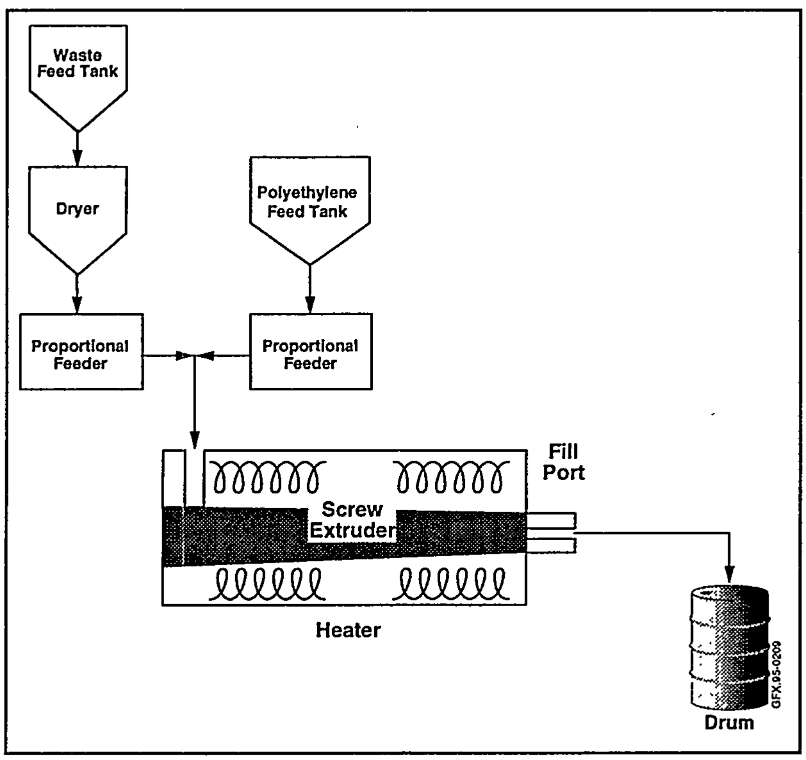

Figure 3.6. Polymer Encapsulation System.

TECHNOLOGY NEEDS

Research efforts focus primarily on the development of a polyethylene extrusion process to stabilize low-level nitrate salt waste. Pilot-scale studies and an integrated system demonstration are planned to obtain the operational data and design criteria necessary to implement a polymer solidification system for this waste stream. Laboratory-scale studies have demonstrated the process using actual (radioactive) nitrate salt waste. Treatability studies have also been completed on macro- and micro-encapsulation of several other radioactive waste streams.

Scale-up tests using surrogate (non-radioactive) materials are being conducted to identify the optimum method of encapsulating bulk wasteforms, such as lead metal. Full-scale treatment of several drums of debris and lead wastes is planned in FY95.

ACCOMPLISHMENTS

- A full-scale technology demonstration at BNL for polyethylene encapsulation of nitrate salt (Rocky Flats Plant surrogate) was conducted in FY94.
- Confirmed extrudability of spray-dried nitrate salts at laboratory and pilot scale.
- Demonstrated acceptable heavy metal leach rates in tests with surrogate and actual nitrate salt clarifier underflow wastes.
- Initially confirmed radioactive and thermal stability of polyethylene encapsulated nitrate salt.
- Demonstrated use of recycled plastic for macroencapsulation.

BENEFITS

These technologies will provide improved waste form performance and result in reduced risk to human health and the environment. Polyethylene encapsulation of nitrate salt waste compared favorably with Portland cement grout solidification—both technically and economically. For example, use of polyethylene at Rocky Flats was estimated to result in up to 70 percent fewer waste drums for storage, transport, and disposal, resulting in annual net costs savings between $1.5 and $2.7 million. The Tanks Focus Area has estimated cost savings of $200 million over the life of the single shell tanks remediation project at Hanford. Similarly, modified sulfur cement and polymer-impregnated concrete can accommodate high-waste loadings, and thus reduce overall costs.

COLLABORATION/TECHNOLOGY TRANSFER

Polymer solidification development at RFETS is being conducted with the collaboration of researchers at the Colorado School of Mines and WHC. Drying and extrudability studies are also being performed by several equipment vendors. Investigators at BNL are also participating in the development of this technology in conjunction with Pacific Nuclear Services.

Because polymer solidification has been demonstrated for the immobilization of other radioactive wasteforms (e.g., for nuclear power plants in Japan), data and results will be available to designers and engineers of these waste management systems.

Researchers from Vectra Technologies and the Ames Laboratory are developing subsystems for the single-screw extruder process for polyethylene encapsulation of problematic mixed waste streams. Vectra Technologies has developed a complete material handling system that includes feed material drying, size reduction, and blending/feeding into the extruder. Ames Laboratory is developing a technology for product monitoring which will also be applied to process control in future work. The technology is referred to as Transient Infrared Spectroscopy, and can measure the infrared emission spectrum of opaque materials in a non-contact fashion.

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3.7 PHOSPHATE BONDED CERAMIC FINAL WASTE FORMS

TASK DESCRIPTION

The purpose of this project is to exploit the attractive features of chemically bonded phosphate ceramics (CBCs) and develop superior waste forms for MLLW streams that cannot be handled by other established methods. Guidelines and assessments will be set up based on the waste stream with the best treatability performance, and that stream will be scaled up for pilot study. See Figure 3.7. These include waste streams containing liquid mercury, mercury-contaminated aqueous liquids, toxic and heavy metal containing materials, salt cakes and processing salts, beryllium wastes, and pyrophorics.

Phosphate-bonded ceramics are a subclass of CBCs and have several advantages over other systems for stabilization and encapsulation. These advantages are summarized below:

- Phosphates are natural analogs of radioactive and rare earth elements.
- They are extremely insoluable.
- Phosphates can be processed in a solid cement form at room temperature.
- Phosphate bonded ceramics are non-flammable inorganic polymers. Since they are non-flammable, there is no danger of fire during transportation and storage.
- Minimum generation of secondary waste streams. (Due to the low-temperature synthesis of the final waste form, there is no risk of volatilization. Furthermore, because there is no thermal treatment of the waste streams, the fabrication steps are minimal and contamination of equipment used during fabrication is relatively low).
- Overall processing costs are low.

Calcined MgO can be reacted with dilute phosphoric acid or dibasic phosphates (amonium or sodium dibasic phosphate respectively) to form a stable ceramic form. Similarly, zirconium phosphates can be formed by reaction of zirconium hydroxide with phosphoric acid solution. These reactions occur at room temperature to form a dense ceramic that sets into a hard product--sometimes in a few hours. Surrogate ash waste streams, salt compositions, and cemented sludge were incorporated in phosphate ceramics with loadings up to 50 percent. These waste streams were spiked with RCRA metal nitrates (Cd, Cr, Ni, Pb, and CsCl). TCLP leaching tests were used to evaluate the performance of the final waste form.

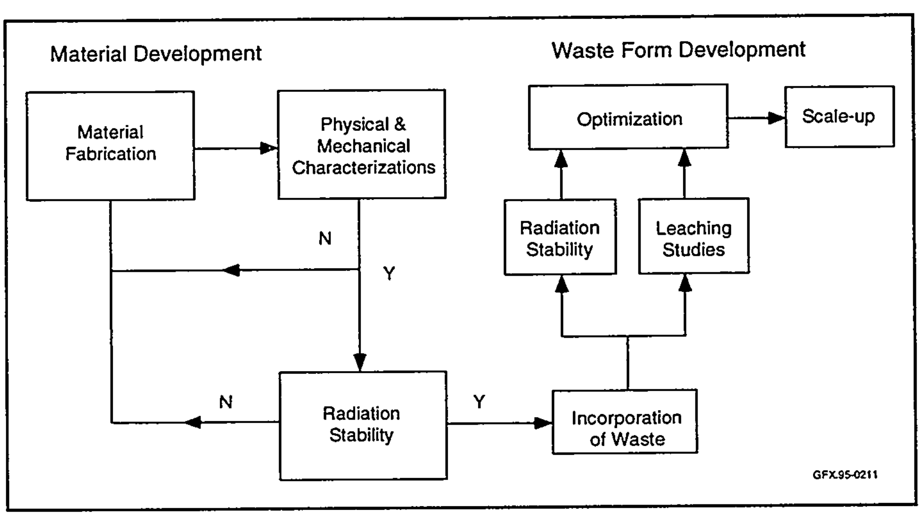

Figure 3.7. Material Development and Waste Form Development.

TECHNOLOGY NEEDS

Many waste streams exist for which vitrification is not technically feasible due to interferences by problematic species or high cost. An example of this would be a waste stream for which some constituent has a low solubility in the glass melt, resulting in a lower than acceptable waste loading.

Alternative waste stabilization processes are needed to allow the MWFA to meet its goal of demonstrating at least three technologies in the next three years, which cumulatively will have the capability of treating at least 90 percent of the mixed waste in current DOE inventory.

ACCOMPLISHMENTS

- Magnesium phosphate ceramics have been produced having the following properties:
  - The ceramics set at room temperature into dense, hard cements at controllable set rates.
  - Ash loadings (e.g., from incinerators) up to 70 percent can be incorporated.
  - Up to 0.5 weight degrees Cd, Cr, Ni, or Pb can be incorporated into the ceramic and it will still pass the EPA TCLP test.
  - The ceramic products have compressive strengths up to 7,000 psi at 70 degrees waste loadings.
- Zirconium phosphate ceramic can capture cesium chloride up to 1 percent without leaching by water.

BENEFITS

CBCs have the potential for stabilizing several problem mixed-waste streams that have been identified by DOE. They are attractive for applications such as solidification and stabilization of these waste streams because the final waste forms can be fabricated at room temperature. The phosphate CBCs are pore free, insoluble in ground water, and stable at elevated temperatures. They form solid solutions with actinides and rare earths. In general, metals and metal oxides react with phosphoric acids to form stable CBCs at low temperatures. This method of stabilization can be exploited to incorporate various components of the mixed waste into solid monolithic forms of CBCs. The presence of highly volatile contaminants and pyrophorics in a waste stream makes it very difficult to stabilize these wastes with currently available technologies. Chemically-bonded ceramics, on the other hand, can accommodate these waste streams.

COLLABORATION/TECHNOLOGY TRANSFER

This work was performed in collaboration with the Center for Advanced Cement-Based Materials at the University of Illinois, Urbana-Champaign and the University of Dayton Research Institute.

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3.8 FINAL WASTE FORM PERFORMANCE

TASK DESCRIPTION

Uniform final waste form performance criteria and testing and evaluation methods will allow comparison of alternate technologies for treatment systems and comparisons of waste forms. This will ensure long-term waste form safety and stability in storage and disposal, and demonstrate compliance with existing orders and regulations. Standardized test methods will improve QA/QC, and testing would generate performance data that could also be used as input to models for site performance assessment (PA) as required by DOE orders. See Figure 3.8.

TECHNOLOGY NEEDS

Testing procedures have been established by several government and non-government organizations: NRC, EPA, IAEA, ASTM. These have been evaluated for their applicability to mixed waste. Uniform waste form performance criteria are needed to demonstrate that newly-developed technologies meet applicable standards and support delisting petitions.

Historically, DOE has considered waste form characteristics to be of secondary importance, compared to the hydrogeochemical characteristics of the disposal site. Experience gained in operating LLW disposal sites has shown that waste forms play an important role in the isolation of radioactivity and toxic components of the waste. The lack of uniform waste form performance criteria across the DOE Complex has resulted in large volumes of solidified waste that have failed due to chemical incompatibility between the waste and solidification materials or poor mechanical properties. These wastes are unacceptable for disposal and are presently being stored at the sites for eventual reprocessing at additional cost.

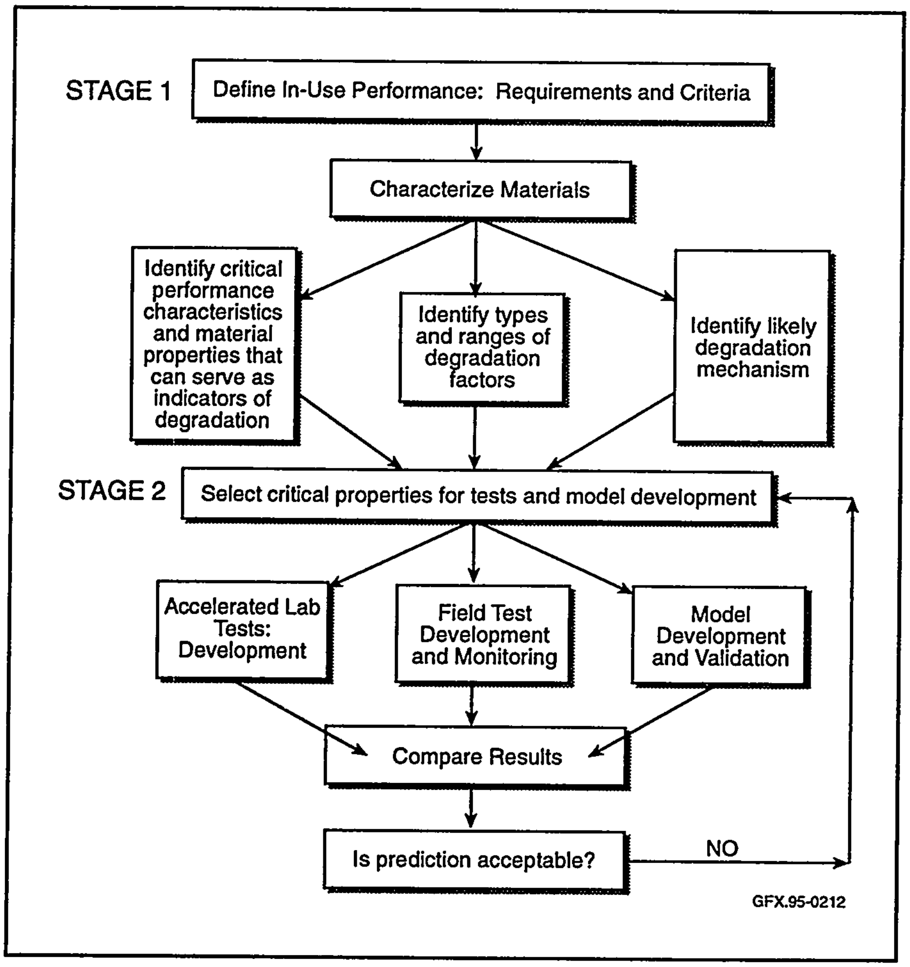

Figure 3.8. Approach to Assessing and Ensuring Long-term Performance of Mixed Waste Forms.

ACCOMPLISHMENTS

The full report on final waste form performance criteria has been published. The report recommends and supports the recommendations for the proposed criteria and testing methods. The performance criteria specifically examine glass compressive strength and resistance to the release of radionuclides under wet conditions. Further work is recommended, and several important areas of standard practice have been shown to be inadequate. Recommendations for test development include: the development of a thermal cycling (freeze/thaw) test with associated measurements of interest; modification of ASTM D-4842 to judge pass/fail of waste forms; and development of a standard method of irradiating waste forms. Recommendations also include the need for: a non-destructive testing (NDT) regimen to replace the compressive strength test in qualifying a final waste form; pass/fail specifications for acceptable dimensional changes and loss-of-material by spalling, as a result of stresses placed on the waste by testing, need to be based on a more rigorous technical foundation; and finally, for silicate glasses, a standardized method of converting PCT leach data to fractional release rates.

For the assessment of long-term behavior of waste forms, the report recommends first obtaining information on the solidification process used, including materials, and the site-specific disposal environment. Once this is accomplished, the report recommends experimental studies be performed to determine the mechanisms of degradation, the degradation products, and the relationship of these two things to the disposal environment.

BENEFITS

This work helps to provide uniform test procedures so that distinction can be made among various final waste forms in determining the adequacy of final waste forms produced, and in helping to predict their performance over time.

COLLABORATION/TECHNOLOGY TRANSFER

This work is being done in collaboration among BNL, INEL, and PNL, with BNL as the lead.

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3.9 PILOT PLANT DEMONSTRATION

TASK DESCRIPTION

The scope of work covered under this task is for the design, fabrication, permitting, operation, testing, and evaluation of the Hazardous Waste Pilot Plant (HWPP) and Mixed Waste Pilot Plant (MWPP) for treating DOE hazardous and mixed wastes. The HWPP demonstration will focus on identifying Hydrothermal Oxidation (HTO) technology development needs; providing technology improvements required to demonstrate that HTO is a safe, cost-effective technology; and demonstrating currently-available HTO technology using hazardous and surrogate mixed wastes of interest to DOE. Data generated in the HWPP demonstration will provide the basis for the decision of whether to proceed with the design basis of MWPP and the demonstration of the MWPP.

The MWPP will generate data to confirm the behavior of radionuclides during HTO treatment, confirm the disposability of wastes from a HTO unit treating mixed wastes, and demonstrate the shielding, additional control, and safety features required for a mixed waste facility. Data generated in the MWPP demonstration will provide the basis for the decision of whether to proceed with the design basis of a production-scale mixed waste treatment facility.

DOE mixed waste streams are unique since they include radioactive material and a wide variety of hazardous compounds. Many of these compounds corrode most reactor materials at HTO processing conditions. In addition, sticky salts can be formed during the HTO process that can plug the reactors. Recently, several researchers have proposed alternate designs that may solve or substantially alleviate these problems. Currently, some of these designs are being evaluated in small, bench-scale HTO systems. In FY95, the HWPP (Test Bed) will be constructed to evaluate these different reactor designs at pilot-plant scale for DOE simulated mixed waste. This will provide the most technically consistent, cost-effective, and timely evaluation of the alternate designs for DOE.

TECHNOLOGY NEEDS

HTO technology holds promise for treating approximately 15 percent of DOE's mixed waste inventory. While this technology has been successfully demonstrated at the bench- and pilot-scales for a more limited number of wastes, numerous questions and risks remain in applying the process to DOE mixed wastes. To successfully design, construct, permit, and operate a mixed waste facility, data is required on scaling factors, materials, technology and corrosion, thermodynamics and reaction kinetics for constituents of DOE wastes, and operational hazards. Data is also needed on performance of different process configuration, operational hazards, performance of different process configuration, performance for the wide range in type and compositions of DOE mixed waste, chemistry and disposition behavior of radionuclides at HTO processing conditions, and reliability and maintainability of the process for extended operating times.

The HWPP will provide much of this data without investing the substantial funds required to meet the requirements and regulations for a unit capable of treating mixed waste. Building on the data gained from the HTO HWPP, the MWPP will be designed and will then be used to obtain the additional data required to evaluate, permit, design, and operate a full-scale facility to process DOE mixed waste.

Extensive research has been conducted over the past 15 years to develop HTO systems that can destroy organic waste. Until recently, this research has focused on two types of reactors: tubular and vessel. Most of the research has been conducted in small bench-scale systems for specific compounds. DOE has contributed to this research by supporting the primary developers of this technology through cooperative agreements. The objectives of these agreements was to develop a HTO plant that could process mixed waste having high organic content.

ACCOMPLISHMENTS

- Completed the design of the HWPP. See Figure 3.9.
- Completed National Environmental Policy Act (NEPA) Documentation for the Hazardous Waste Pilot Plant.
- Completed safety documentation for the HWPP.

BENEFITS

DOE has stored significant inventories of mixed waste on its sites. This waste falls under EPA's Land Disposal Restrictions (LDRs). The total volume of DOE MLLW in storage facilities has been estimated at nearly 129,000m^3. In addition, DOE's decontamination and decommissioning (D&D) and other related activities will continue to generate significant volumes of mixed waste each year; some estimates say as much as 60,000m^3 could be generated annually.

HTO involves bringing together organic waste, water, and an oxidant (e.g., air, oxygen, etc.) to temperatures and pressures above the critical point of water (374° C, 22.1 MPa). Under these conditions, the waste is treated at high-organic-destruction efficiencies of over 99.99 percent and the resulting effluents, which consists primarily of water and carbon dioxide, is relatively benign. In addition, HTO has the potential of being a highly cost-effective treatment process when compared to conventional technologies such as incineration. To date, some of the candidate DOE mixed waste streams for HTO treatment include: spent solvent, oils, and other organic or aqueous liquids, sewage and organic-laden sludges, spent carbon, solvent-contaminated rags, explosives, and energetics.

COLLABORATION/TECHNOLOGY TRANSFER

DOE is working with the leading HTO developers throughout the nation (i.e., other federal agencies, national laboratories, universities, and private sector) to demonstrate HTO technology for treating DOE hazardous and mixed wastes. As part of this effort, DOE has established the National HTO Steering Committee to coordinate and leverage all federally funded HTO research, development, demonstration, testing, and evaluation activities.

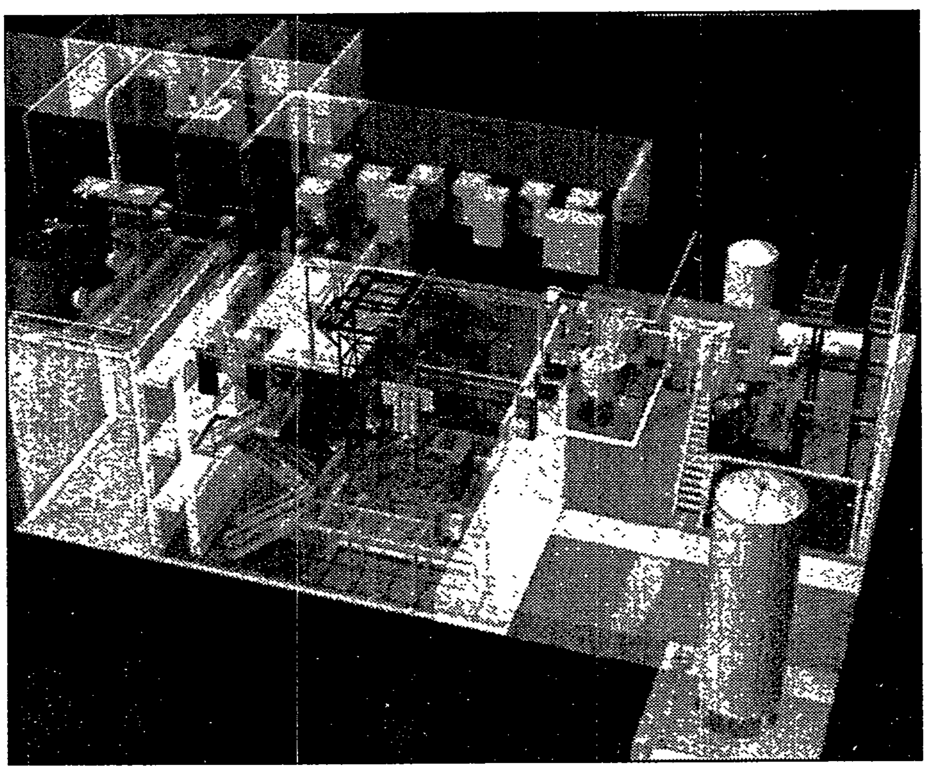

Figure 3.9. Test Bed System Design.

Additionally, in an effort to further enhance its development activities, the program has worked closely with Engineered Coatings, Inc., Foster Wheeler, GenCorp Aerojet, Haynes, Innotek, Massachusetts Institute of Technology, MODAR, Inc., Modell Environmental Corporation, Pennsylvania State University, Stone and Webster Environmental, and the University of Iowa.

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3.10 HTO Corrosion and Precipitation Control

Task Description

The purpose of these tasks is to investigate and develop methods for mitigating corrosion and solids deposition at the various points in an HTO system. Two tasks are included in this effort: 1) in situ neutralization, and 2) materials evaluation. The technical approach to in situ neutralization involves conducting laboratory solubility measurements on important inorganic compounds in aqueous solutions at high temperatures. The water solubilities of candidate compounds for in situ neutralization of acids formed in an HTO system will be measured over an appropriate range of temperatures. The results of these measurements will be used to upgrade the ASPEN Plus process model to include solubility and thermodynamic data for inorganic compounds under conditions relevant to HTO application to DOE and commercial wastes. The reliability of the resulting upgraded process model in representing phase behavior for these substances will be demonstrated.

The material evaluation effort will determine if specially designed rapid solidification alloys and thermally sprayed ceramics will effectively reduce reactor corrosion under SCWO conditions. Coupons developed through the rapid-solidification process and thermally sprayed ceramics will be compared to Hastelloy C-22, and Inconel 625. The data from these tests will be used to conclude whether ceramic liners or rapidly solidified processed alloys are viable materials to be used in HTO.

Technology Needs

These tasks address two significant problems, corrosion and precipitation of solids, which may limit the applicability of HTO in treating a variety of DOE aqueous waste streams. Solids precipitation can lead to problems either through deposits that remain behind in the HTO reactor, or through relatively large volumes which may become contaminated with radioactive elements present in the waste stream and thus require disposal as solid low-level wastes. Acids are inherently formed in the HTO process through oxidation of organic compounds containing heteroatoms (e.g., chlorine, phosphorous, sulfur) at high temperatures to produce the acids or oxyacid of these compounds. Metal ions present in the waste stream may also contribute to the overall acidity for formation of hydroxy species as a result of hydrolysis at high temperatures.

Successful design of a multi-layered ceramic material system is dependent on knowledge of material properties for each layer over a wide temperature range. Layered ceramic coatings can be designed to take into account the thermal stresses of the substrate and the stresses from the temperature flux. While many ceramics have demonstrated good corrosion resistance at HTO conditions, they have been unable to withstand the thermal cycles required for an HTO reactor. By using several layers of ceramics and matching their thermal stresses, a reactor may be designed with a corrosion-resistant material.

Accomplishments

Determined the performance level of the multi-layered ceramics and experimental nickels as compared to nickel alloys C22, C276, Iconel 625, and Iconel 686.

Developed multi-layered ceramic rings designed to avoid delamination by a gradual change in the thermal coefficient of each layer. The high density top layer of the coatings was designed to prevent the absorption of metals or chlorides into the ceramic. See Figure 3.10.

Details on specific accomplishments on the in situ neutralizer task cannot be published at this time due to the restrictions on the disclosure of CRADA protected information.

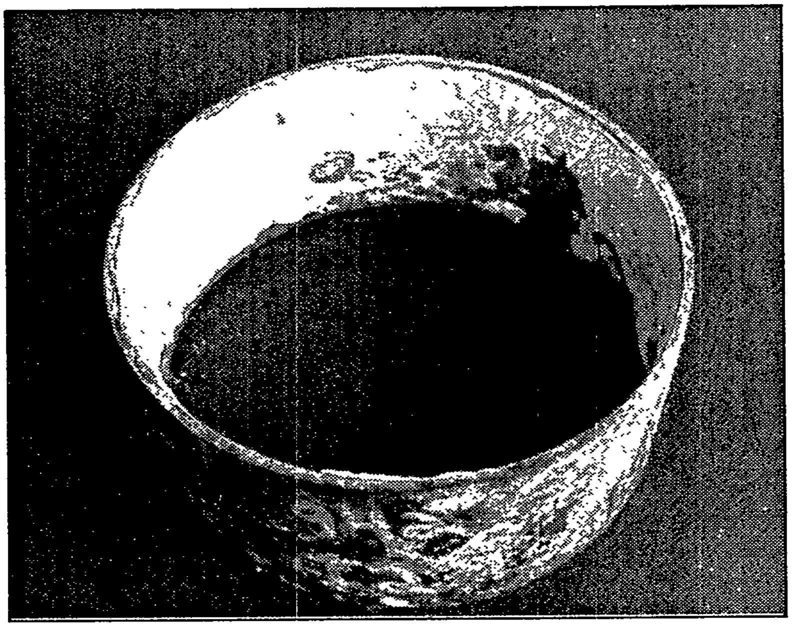

Figure 3.10. Ceramic Coating After 108 Hours of Exposure.

BENEFITS

Successful development of a multi-layered ceramic material system will provide materials that can withstand the harsh environment of HTO processing and overcome a major hurdle that is limiting commercial and DOE application of HTO.

The use of in situ neutralization has the potential to significantly reduce the corrosion resulting from acids formed in the HTO system.

COLLABORATION/TECHNOLOGY TRANSFER

The material work has been performed with MODAR, Inc. and Engineered Coatings utilizing the expertise of each.

The Oak Ridge National Laboratory (ORNL) has established a CRADA with MODEC to conduct cooperative research on in situ neutralizers.

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3.11 HTO Alternative Reactor Designs

Task Description

The purpose of this work is to experimentally evaluate two innovative HTO reactor designs: 1) platelet reactor and 2) dual shell pressure balance vessel.

The platelet reactor may have the ability to both protect an HTO reactor from corrosion and prevent salt plugging. Platelet devices protect surfaces exposed to hostile environments by maintaining a thin boundary layer on the surface by metering a fluid through small pores in the material surface. See Figure 3.11. In an HTO reactor, a platelet can also provide mixing and heating by direct injection of the supercritical water. Tubular platelet reactors designed and fabricated by GenCorp Aerojet will be installed and evaluated in the Engineering Evaluation Reactor (EER) at SNL in Livermore, CA. These tests will provide data needed to assess the feasibility of using platelet technology for HTO destruction of DOE mixed waste, and will provide preliminary design information.

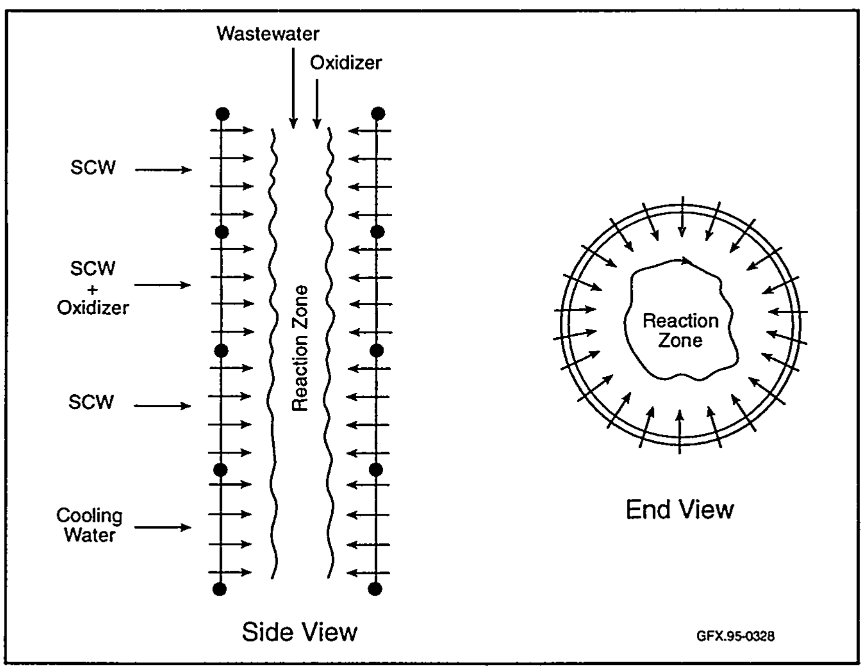

Figure 3.11. Boundary Layer Protection in Platelet Reactor.

The Dual-Shell Pressure Balanced Vessel (DSPBV) project will determine if the DSPBV is capable of resolving the corrosion problems associated with standard reactor designs. The DSPBV uses a thick, steel outer shell as the pressure boundary and a thin, disposable inner liner that can be made from corrosion resistant alloys appropriate for the waste to be treated. The shell and the inner liner are separated by a pressure transfer fluid such as a heat transfer fluid. The pressure between the heat transfer fluid and the reacting fluid is maintained by an external piston that remains at ambient temperature. A second disposable inner liner is used as a flow diverter so reactants enter and products leave the same end of the vessel.

Technology Needs

The target problem for this work is the control of corrosion and salt deposition or scaling in HTO reactors. These two problems were identified by the DOE technical review committee as the two constraints of highest priority to be resolved before the process would be ready for scale-up to a production facility to process DOE mixed waste.

Many DOE wastes contain components that will either deposit as salts and oxides or form corrosives species if processed in a HTO system. Halogenated wastes are of particular concern because they produce a highly acidic process stream. Deposited salts clog the reactor and, due to their stickiness, resist normal means of removal. Corrosion limits reactor life, mandates the use of expensive structural materials, and creates the potential for catastrophic reactor failure due to stress corrosion cracking. These two problems are related. Deposition of salts produces localized conditions in which pitting and transgranular and intergranular attack follow, and stress corrosion cracking may follow. Neutralization of corrosive acids results in increased formation of insoluble salts. Consequently, a method of simultaneously mitigating both problems is desirable.

ACCOMPLISHMENTS

- Modified the Engineering Evaluation Reactor to accommodate the platelet reactor. This included: the installation of five new pumps to provide platelet wall protection for both reactor segments, hot water for heating, cold water for cooling, extensive electrical upgrades, and a new chiller with heat exchangers for the cool-down section.
- Platelet reactor sections have been installed in the Engineering Evaluation Reactor.
- The DSPBV design was completed November 1993.
- The DSPBV system fabrication was completed June 1994.

BENEFITS

Platelet technology can potentially solve the two major problems with HTO technology, corrosion and deposition.

The DSPBV may solve the high-cost problem by using conventional steels for the pressure barrier and thin-walled (relatively inexpensive) alloy liners to contain the reacting fluid. Sensors in the pressure-balancing fluid will detect when the critical alloy liner is breached. The design of the vessel allows quick replacement of the liners, so a "new" reactor costs only a fraction of first unit.

COLLABORATION/TECHNOLOGY TRANSFER

Technology transfer is inherent in the platelet reactor project because the platelet technology being developed and evaluated is already a commercial technology. Aerojet and Foster Wheeler are actively developing and marketing platelet technology for HTO applications. In addition, the bench scale testing is being jointly sponsored by the U.S. Army Armament, Research, Development, Engineering Command.

The DSPBV technology has been licensed to Innotek Corporation. They will be the marketing arm for selling the concept to private industry.

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None at this time.

Effluent Monitors and Controls

Section 4.0

4.1 TUNABLE DIODE LASER AND MERCURY MONITOR

TASK DESCRIPTION

Monitoring systems are being developed to monitor and control trace amounts of VOCs, hydrogen chloride (HCl), ammonia, mercury vapor, and radionuclide emissions during off-gas treatment. Alpha emitting radionuclides will be detected by a large volume flow through system that uses parallel plates of scintillating plastic fabricated such that the entire volume of gas from a thermal treatment unit (incinerator, plasma furnace, or melter) will flow directly through the inter-plate volume. The light from the scintillations produced from the alpha emitting radionuclides striking the plates is detected and signal processed to determine the concentration of alpha emitting radionuclides present in the off-gas stream. A schematic of the large volume flow through detection system is shown in Figure 4.1. VOCs will be detected by Tunable Diode Laser (TDL) Spectrometry.

Fourier Transform Infrared Spectrometry will be evaluated for HCl analysis and a glow-discharge emission technique will be applied to arsine, a volatile arsenic species. Mercury, in various speciated forms, is detected by ultraviolet Zeeman-effect spectrometry after passage through a thermal converter system.

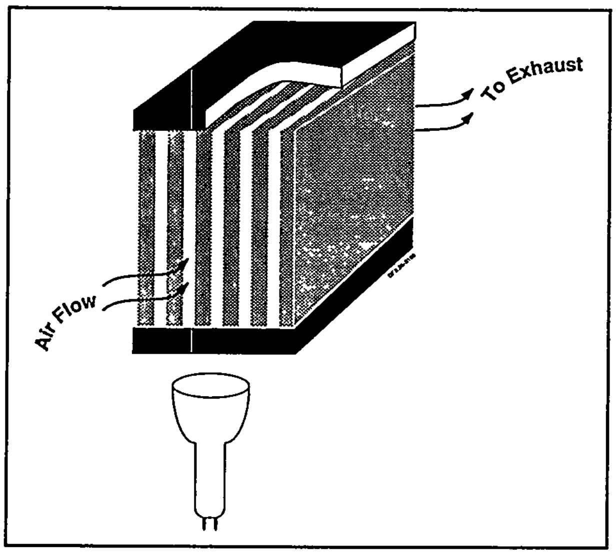

Figure 4.1. The Large-Volume Flow-Through Detection System.

TECHNOLOGY NEEDS

Thermal destruction units for MLLW, when properly designed and operated, are not expected to release any hazardous or radioactive constituents to the environment above the normal environmental background level. However, to ensure that the equipment is being operated properly, continuous emission monitoring for selected compounds will be required. This monitoring will assure regulatory compliance to RCRA, the Clean Air Act, and DOE emission limits for toxic materials. In addition, these monitors will be incorporated into feedback loops to provide process control to the treatment process and stop operations in the event of an emergency or process upset.

ACCOMPLISHMENTS

- A second generation bench-scale large volume flow-through alpha detector system (LVFTDS) has been completed with a demonstrated detection limit of 20 pCi/liter (with a one minute count time);
- Tests have been completed that indicate that the final goal of one count per minute per square inch of scintillator for the LVFTDS system will be achievable;
- A TDL suitable for monitoring of VOCs has been fabricated and is currently under test; and
- A mercury detector capable of analyzing various species of mercury (e.g., dimethyl mercury, elemental mercury, and mercuric

chloride) has been developed that has a minimum level of detection of 0.2 mg/m^3, expressed as elemental mercury.

BENEFITS

Without adequate monitoring, environmental permitting will not be possible. Continuous emission monitors are essential for this purpose. These monitors will provide assurance that thermal treatment of heterogeneous mixed wastes will not result in toxic compound releases above acceptable regulatory levels and will provide a feedback mechanism for process control.

COLLABORATION/TECHNOLOGY TRANSFER

EG&G Nuclear Instruments has been chosen as the industrial Cooperative Research and Development Agreement (CRADA) partner for the LVFTDS. Arizona State University Aerospace Research Center will collaborate on aerodynamic, mechanical, and materials issues associated with testing and construction of the scintillator flow-through plates.

PSI Environmental Instruments Corporation will be collaborating with Los Alamos National Laboratory (LANL) on field test studies on the tunable diode laser units. Further technological development of TDLs at Sandia National Laboratory (SNL) will provide additional markets for these products. They will have widespread utility in government and private sector efforts related to combustion gasification and incineration.

ADA technologies is collaborating with SNL on the mercury detection system to provide expertise in instrumentation systems and field evaluation.

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4.2 WASTE STREAM DIAGNOSTICS AND CONTROL

TASK DESCRIPTION

Methods for the consistent evaluation and comparison of various thermal treatment technologies in widely varying stages of development have been developed. These methods were determined by surrogate formulations, benchmarking, and the defining of needed data quality objectives (DQOs). This will allow for more consistent means of data collection, interpretation, and comparison of thermal treatment technologies across the DOE Complex.

TECHNOLOGY NEEDS

A systematic approach to the monitoring and evaluation of the individual thermal treatment unit operations is needed to ensure that the overall goals of the waste destruction process are met and that the full capabilities of the process are known. To accomplish this, benchmarking parameters, DQOs, and surrogate waste stream selection criteria are being developed so that the best available "composite" picture of an adequate thermal treatment system can be defined. In short, the "composite" picture of the best available treatment system is needed.

ACCOMPLISHMENTS

This activity, completed in FY94, provided the following outputs:

- Surrogate formulations useful for evaluating performance of mixed waste low level thermal treatment process have been defined;
- Guidelines for benchmarking MLLW thermal treatment systems have been developed; and
- DQOs have been developed that define the accuracy, precision, completeness, representativeness, and comparability needed for thermal treatment process performance data.

BENEFITS

- Provides a consistent means of allowing DOE to establish accurate performance data at the bench-, pilot-, and field-scale in a structured manner such that resources can be allocated equitably with maximized overall system payback
- Establishes DQO standards necessary for collecting comparable data of high quality in terms of consistent quality assurance/quality control (QA/QC) procedures

COLLABORATION/TECHNOLOGY TRANSFER

This is a collaborative effort involving the following university, private sector, and DOE contractor personnel: Martin Marietta Energy Systems, Inc., Oak Ridge, TN; Oak Ridge Associated Universities, Oak Ridge, TN; Focus Env., Inc., Knoxville, TN; Lama University, Beaumont, TX; Science Applications International Corporation (SAIC), Idaho Falls, ID; University of Tennessee, Knoxville, TN; and Westinghouse Savannah River Company, Aiken, SC. Project outputs related to DQOs, surrogate formulations, and Thermal Treatment Benchmarking Guidelines have been published as official DOE documents and gain wide distribution. Copies will be available to the public through NTIS. Systems performance benchmark standards, thermal DQOs and MLLW surrogate formulation developed under this activity are relevant to all local, national, and international activities related the development of new and improved thermal treatment processes.

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4.3 Cleanable High-Efficiency Particulate Air Filter Development and Demonstration

Task Description

Alternative methods/materials are being explored using high efficiency particulate air (HEPA) filters to produce low cost, low risk, cleanable reusable and reliable filters. See Figure 4.3. Two separate projects are working to achieve this goal. Steel filter materials are being examined at Lawrence Livermore National Laboratory (LLNL), and inorganic membrane filters are being examined at the Oak Ridge K-25 site.

Plans for the steel filter production at LLNL include:

- Fabrication of a 0.5 micron steel fiber filter;
- Evaluation of new filter efficiency and pressure drop; and
- Preparation of a report comparing the test results to standards.

Plans for the inorganic membrane filter production at Oak Ridge include:

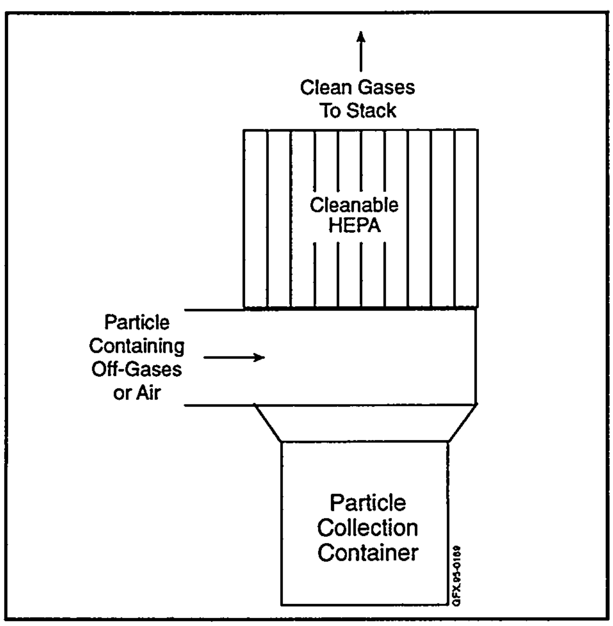

Figure 4.3. Cleanable HEPA Off-Gas Treatment.

- Fabrication of an inorganic membrane filter using Oak Ridge K-25 technology;
- Evaluation of new filter efficiency and pressure drop; and
- Preparation of a report comparing test results to standards.

These task descriptions are similar, but further development will depend upon the results of filter efficiency, pressure drop, reusability, and cost savings between the two systems.

Technology Needs

Current HEPA filters, made of glass and used to remove particles during off-gas treatment, are expensive. Difficult generating conditions include high temperature and high pressure. The filters cannot be cleaned and are disposed of after use, contributing to high disposal cost and more radioactive waste volume in the environment. Significant handling and maintenance occurs for the glass filters, which exposes workers to unsafe environmental conditions and increases effort and cost.

Alternative filter materials need to improve these conditions and pass efficiency and pressure drop requirements. HEPA filters need to capture 99.97 percent of 0.3 micron sized particles, while maintaining less than 1 inch of water pressure drop.

Accomplishments

Filters of 1 micron steel fibers have been fabricated at LLNL that pass efficiency standards and have a pressure drop of 1.5 inches of water. By comparison, conventional glass HEPA filters have a pressure drop of 1.0 inches.

Benefits

Used HEPA filters represent a substantial volume of DOE waste and high costs. Annually, 11,500 glass HEPA filters are used. If cleanable steel HEPA filters average 15 cleanups per lifetime, only 767 new filters would be needed annually. After cleaning, handling, and disposal costs are factored in, this represents a net savings of $42M per year.

Collaboration/Technology Transfer

Golden Technologies Company, Inc., a research and development subsidiary of Coors, has expressed interest in teaming with Oak Ridge National Laboratory (ORNL) to develop manufacturing of a cleanable inorganic membrane filter.

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TTP Numbers: OR142019, SF242001

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None at this time.

4.4 CAPTURE AND RELEASE OFF-GAS SYSTEM

TASK DESCRIPTION

This project will install and demonstrate several technologies to capture and separate various components of the off-gas emitted from a plasma incineration system. The main purpose of the demonstration is to determine if the technologies can be used in a system that will minimize process input streams and allow recycle of the majority of the incineration gases, thus minimizing off-gas emission to the atmosphere. An ancilliary purpose of the demonstration is to determine if the existing gas phase analytical instrumentation can detect very low concentrations of hazardous components in the off-gas, with the ultimate purpose of using them as sensors in a process control system. Chief among these constituents are vapor phase metals, such as mercury and polychlorinated aromatic hydrocarbons.

Five demonstrations are proposed:

- The Thermatrix Flameless Oxidizer will be installed in the Small Scale Plasma Furnace (SSPF) off-gas train. In this configuration, as shown in Figure 4.4, it will be capable of processing gas from the primary chamber of the PCF-6 for extended destruction and removal efficiency (DRE) tests.
- A PALL ceramic blowback filter will be installed in the SSPF off-gas train. This will demonstrate the ability of these high tempera-

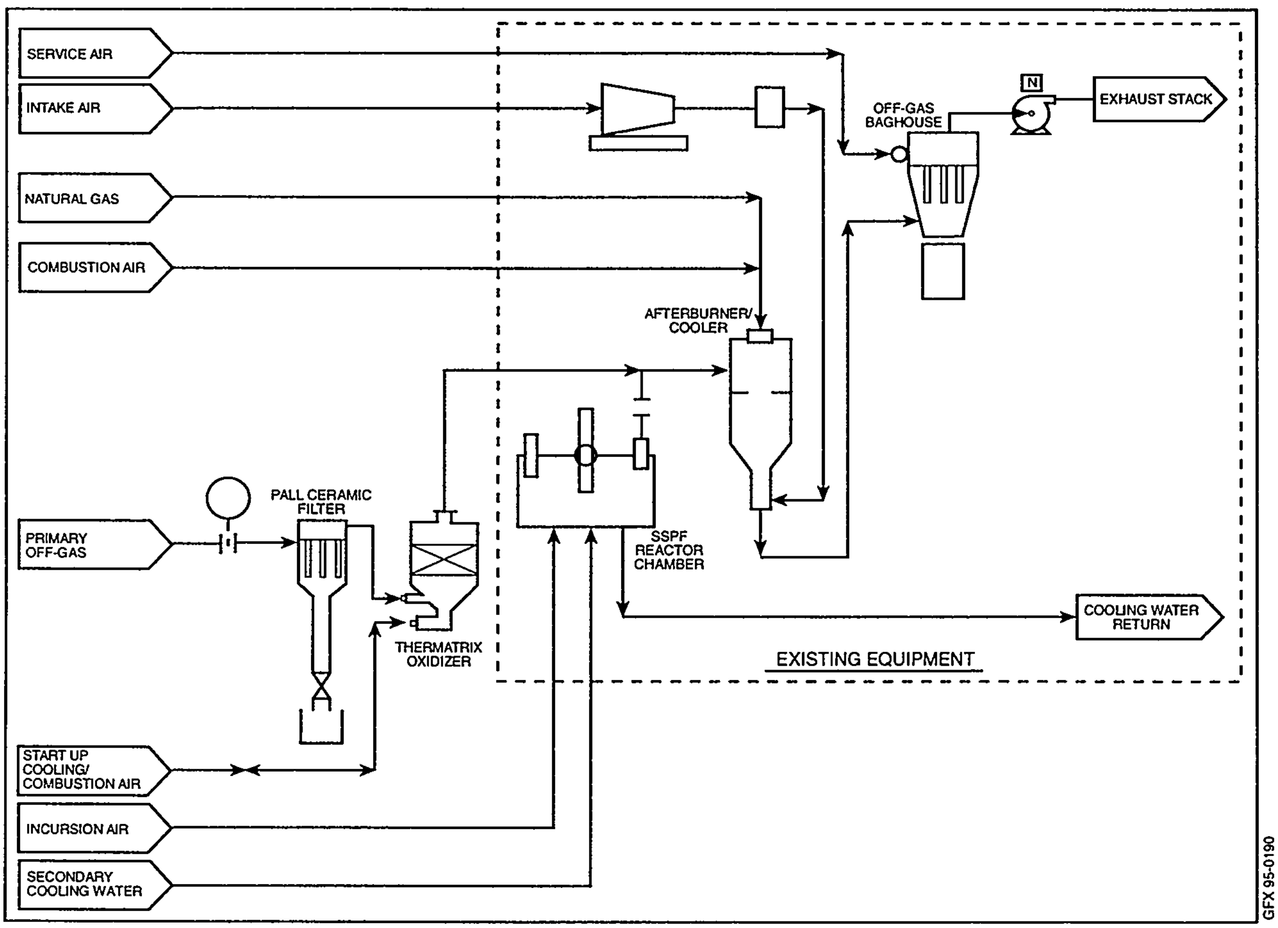

Figure 4.4. Plasma Incineration Controlled Emissions System.

ture filters to remove particulate from the off-gas stream prior to acid scrubbing.

- DIAL, SAIC, and Sandia will be demonstrating analytical instruments that are in the development stage.
- Lesat will procure a mass spectrometer-based, continuous emissions monitor from Marine Shale Processors, Morgan City, LA. This instrument will be used to predict destruction/removal efficiency of carbon tetrachloride at near real time.
- MSE will complete preliminary design work and finalize cost estimates for the separation system (MEA for carbon dioxide and membrane for oxygen and nitrogen).

TECHNOLOGY NEEDS

Public concerns about uncontrolled releases from thermal treatment systems have had a significant impact on the permitting and operation of these systems. To address these concerns, the Controlled Emissions Demonstration is based on the premise that all effluents from the plasma processing system can be captured, separated, analyzed for contaminants of concern, and then either released or recycled to the process.

ACCOMPLISHMENTS

At the MSE/WETO facility in Butte, MT, the PCF-6 (six-foot diameter chamber) off-gas system is essentially state-of-the-art for mixed waste treatment. The PCF-6 will be the main driver of the demonstration. The SSPF and the SAIC Plasma Hearth bench scale furnace will also be integrated into the demonstration.

BENEFITS

Minimizing gaseous emissions and eliminating uncontrolled releases from thermal treatment systems will restore public confidence in the safety and efficiency of thermal treatment systems and facilitate the permitting process.

COLLABORATION/TECHNOLOGY TRANSFER

Several corporations/technology providers are involved in the Controlled Emissions Demonstration. These companies are as follows: Thermatrix, Pall, DIAL, SAIC, Sandia, and Lesat.

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Dosaj, V., M.D. Brumels, C.M. Haines and J.B. May, "Silicon Smelting in a Closed Furnace," EG&G Idaho, Inc., OSTI DE92011157, 1991.

4.5 Mercury Removal and Recovery from Flue Gas

Task Description

This effort involves the development of regenerable sorbents for the capture of volatized mercury in thermal treatment off-gas streams. Due to the toxicities of mercury and its bioaccumulation potential, severe regulatory limits are imposed on mercury emission under the Clean Air Act. Carbon and alumina-based sorbents containing finely dispersed gold will be evaluated for mercury removal. It is well known that gold can form amalgams with mercury and that the gold/mercury phases significantly reduce the vapor pressure of mercury. This project will investigate the utility of various porous adsorbents and ceramics impregnated with finely divided gold in capturing mercury vapors. Removal efficiency, flow resistance, residence time tests, and loading capacity will be investigated.

Technology Needs

Regulatory limits for mercury emissions from thermal treatment units are becoming increasingly low. A recent proposed limit for municipal waste incinerators suggests an upper permissible limit of 0.08 mg/dscm. Similar regulation levels can be expected for other types of thermal treatment units. Mercury can be removed from wastes by pretreatment using chemical and/or thermal desorption techniques, but this is only cost effective when relatively large amounts of mercury are involved. At lower levels, it is more practical to remove the mercury by off-gas treatment. Chemical/physical methods are available to do this, including injection of activated carbon into the flue gas or removal by chemical scrubbing. Both of these techniques have a disadvantage in that secondary wastes are generated. Neither system responds well to high emissions spikes due to variable waste composition.

ADA Technologies prepared gold-containing sorbents and gold-containing filters that, in laboratory tests with synthetic flue gas, removed mercury vapor with an efficiency typically greater than 99 percent. Small, compact beds of ADA's sorbent with this high mercury removal efficiency had a pressure drop below two inches of water at flow rates typical of industrial practice. Certain commercially available ceramic filters treated with ADA's sorbent also exhibited this high mercury removal efficiency with a pressure drop no greater than that of the native filter at flow rates typical of industrial practice. The uptake of mercury vapor was unaffected by HCl or water vapor, components found in flue gases from the combustion of many kinds of wastes.

Accomplishments

Commercially available gold sorbents, supported on microporous carbon particles, gave a very high pressure drop (above 20 inches of water) at commercially significant flow rates. In one case, the mercury removal was essentially 100 percent. However, the high pressure drop of these carbon-based sorbents eliminated them from further consideration. The gold-containing filter is required by exposing the filter to a 750°C temperature.

Benefits

These major benefits of the gold-containing mercury sorbent process are the high loading capacities, high throughput rate, and the ability to regenerate and reuse the capture device. These could be located after the HEPA filtration system and would therefore not be subject to clogging.

Collaboration/Technology Transfer

ADA Technologies, Inc., Englewood, CO, has provided the laboratory studies associated with this activity in collaboration with Sandia National Laboratory, Livermore, CA (SNL).

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BIBLIOGRAPHY OF KEY PUBLICATIONS

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4.6 X-RAY FLUORESCENCE SPECTROMETRY FOR REAL-TIME MONITORING OF SLAG PHASE

TASK DESCRIPTION

Argonne National Laboratory-West (ANL-W) has been tasked by EM-50 to develop process monitoring and control technology to support the plasma hearth process (PHP). X-ray fluorescence (XRF) spectrometry is being evaluated as an analytical technique for measuring actinide, rare earth surrogates, and RCRA-listed metals in the slag produced by the plasma process.

Two monitors have been selected for the continuous monitoring of both inorganic and metallic offgases. These monitors are optical-based detection methods, namely infrared (IR) spectrometry and glow discharge - atomic emission spectrometry. Optical-based methods have the advantage of making measurements of radioactive systems in a non-intrusive manner. Both techniques cover broad spectral ranges. IR detection schemes can provide vibrational and rotational spectra of inorganic gases in near-real time. The glow discharge technique can provide atomic spectra for metals such as As, Pb, and Hg, and nonmetals such as sulfur, iodine, chlorine, and fluorine. Integration of these two techniques into a process environment is achievable with interferometers and cross correlation data analysis techniques. This will provide compound and element specific quantitative information to process engineers for optimizing offgas operating conditions.

Tasks currently scheduled for FY95 are:

- Obtain alpha glove box for XRF installation. Install the glove box and XRF unit, glass saw, press, and ball mill into glove box. 6/30/95
- Perform safety analysis and readiness review for operations in the box. 8/15/95
- Perform two technique comparison for XRF and conventional ICP-AES analyses on non-radioactive and radioactive PHP samples. Targeted analytes include Ce, U, Pu, Ni, Cr, Pb, Cd, Si, Fe, and Al. 9/15/95

TECHNOLOGY NEEDS

A key evaluation criteria for the plasma hearth treatment process is the ability of the slag or glass phase to immobilize radionuclides and RCRA listed metals. Real-time monitoring of slag or glass phase chemistry for radionuclides and RCRA listed metals is critical for process optimization. XRF spectrometry offers advantages over conventional methods in real-time monitoring of slag or glass for radionuclides and RCRA listed metals.

ACCOMPLISHMENTS

A wavelength dispersive XRF unit was purchased to perform rapid elemental analysis on vitreous slag and particulate resulting from the plasma hearth process. Performance specifications for this instrument have been specified such that U, Pu, Np, and Th can be determined. A preliminary evaluation of the XRF technique for the analysis of Ce in the PHP slag was performed. The initial results are in good agreement with wet chemical analysis. A series of 48 powdered standards were prepared for the analyses of Al, Mg, Si, Fe, Pb, Ni, Cr, Cd, Ce, and U in the PHP slag.

BENEFITS

The development of the XRF technique for the analysis of slag samples provides data comparable to that provided by extensive wet chemical ICP-AES analysis. The XRF technique, however, will reduce sample preparation and analysis time from days to hours. The technique does not generate the copious quantities of liquid wastes generated by ICP analysis techniques. This technology will produce significant cost savings to the development of plasma hearth treatment systems by reducing analysis costs and delays while awaiting analysis results.

The development of the IR and glow discharge techniques with real-time signal processing can be used for optimization of off-gas processing parameters and to alert operators of abnormal processing conditions.

COLLABORATION/TECHNOLOGY TRANSFER

The glow discharge technique is applicable for real-time detection of hazardous volatile metallic compounds such as arsine, mercury compounds, stannane, and several volatile organic compounds (VOCs). Two tin compounds of interest are tetramethyl and tetraethyltin, which are highly neurotoxic and are produced in significant quantities at manufacturing locations around the world. Arsine compounds are still produced in Texas and are used as defoliants for cotton. The air-sampling glow discharge can be utilized as a real-time monitor for industrial hygiene purposes in these manufacturing facilities.

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F.C. McElroy and J.M. Mulhall, "Precious Metal Assay Analysis of Fresh Reforming Catalyst by X-Ray Fluorescence Spectrometry," ASTM Symposium on Modern Instrumental Methods of Elemental Analysis of Petroleum Products and Lubricants, New Orleans, LA, pp., 105-117 and 154, 1991.

4.7 HTO Process Monitoring Sensors

Task Description

This effort will develop and validate measurement techniques for analyzing corrosion in HTO systems. Measurement techniques will be developed to determine change in wall thickness, pH, redox potential, and the concentrations of oxygen and hydrogen in supercritical water.

Instrumentation is being developed that is capable of measuring pH, oxygen and hydrogen at 300-500°C. Potential - pH (Pourbaix) diagrams will be constructed in the 300-500°C range and compared to the actual data. A testing loop is being assembled to operate at high temperatures and 3,500 psi, and software is being created for calculating pH, oxygen, and hydrogen data from the instrument signals.

Another task will look at directly measuring the decrease in wall thickness or growth of oxide layers at critical points in the HTO process using ultrasonics. This project will test the capability of ultrasonic methods for use in HTO process. A 1.5 inch (inner diameter) pipe will be pressurized to 3,500 psi and heated to 650°C. A corrosive fluid (dilute HCl - 5,000ppm of Cl) will be run through in order to produce corrosion and deposition on the walls of the pipe. As the fluid is being processed, ultrasonic transducers remotely mounted at two critical sections of the test section will take wall thickness measurements. See Figure 4.7.

Technology Need

HTO has the potential of meeting DOE's treatment requirements for mixed radioactive waste. A major technical constraint of the HTO process is corrosion. Safe operation of a pilot plant requires monitoring of the corrosion rate of the materials of construction. A method is needed for measurement of the corrosion rate taking place during operation. Equilibrium thermodynamics can be used to characterize the conditions under which corrosion occurs. To characterize corrosion mechanisms in supercritical water systems the pH and the redox potential must be measured at the temperature and flow conditions expected in the system.

Accomplishments

- Performed measurements of physical and chemistry parameters in supercritical aqueous system including pH and oxygen and hydrogen concentrations.
- Explored existing methods of extrapolating thermodynamic data to supercritical conditions. Potential-pH (Pourbaix) diagrams on selected materials have been constructed for conditions commensurate to HTO conditions. Potential-pH diagrams, combined with corrosion data obtained from coupon test, will

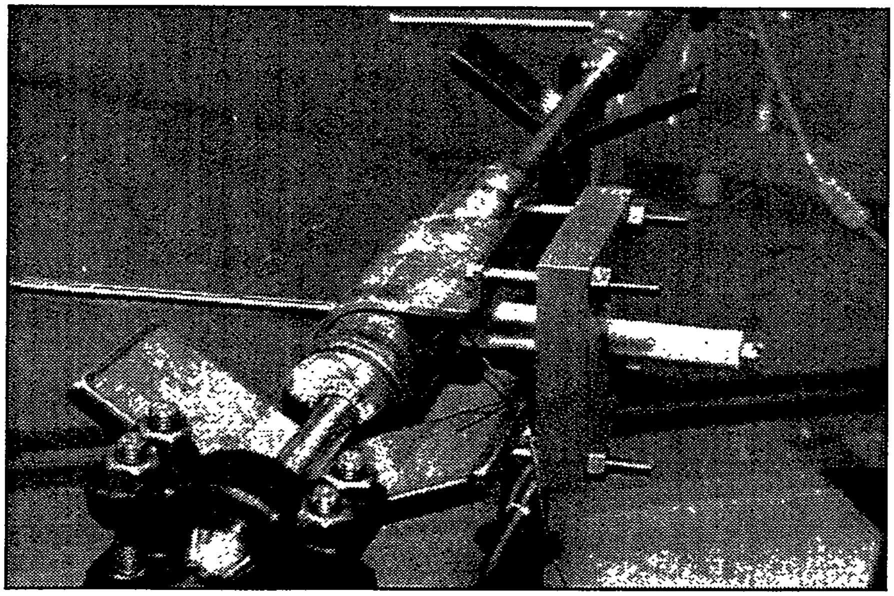

Figure 4.7. Test Apparatus Showing Ultrasonic Transducer.

provide a thermodynamic basis to address the corrosion issue in HTO systems.

- Developed a method for brazing yttria-stabilized-zirconia (ZrO_2/Y_2O_3) nickel, and stainless steel, thereby making possible the penetration of a pressure boundary by point sensors.
- Assembled a piping system that created the corrosive conditions of a HTO system as it approached the transition zone from a subcritical fluid to a supercritical phase.
- Determined that ultrasonic transducers can be used to monitor generalized corrosion without removal of the insulation.
- Determined that the oxide layer was not resolvable with the test technique used. This is not a surprise, considering that by direct observation, the oxide layer appeared to be several mils (<0.010") thick.

BENEFITS

The development of effective sensors to measure the corrosion inside a HTO system will significantly enhance the safety and reliability of the system. Measurements will be able to be made while the system is operating and avoid costly and time-consuming shutdowns to measure corrosion within the system.

In order to characterize corrosion mechanisms in supercritical water systems, the pH and the redox potential must be measured at the temperature and flow conditions expected in the system. The development of these sensors will provide understanding of the corrosion mechanisms and support the mitigation of corrosion and the development of alternative materials and or processes to resolve the corrosion problem.

COLLABORATION/TECHNOLOGY TRANSFER

This work is presently being conducted under a contract to Pennsylvania State University. Results of this work are being shared with other federal agencies through the HTO National Steering Committee.

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K. Garcia and Alan Porter, *Remote Measurement of Corrosion*, INEL-95/0017, February 1995.

Develop On-Site Innovative Technologies (DOIT)

Section 5.0

5.0 DEVELOP ON-SITE INNOVATIVE TECHNOLOGIES (DOIT)

TASK DESCRIPTION

The Federal Advisory Committee to Develop On-Site Innovative Technologies (DOIT), known as the DOIT Committee, was chartered in December 1992. Members represent the Departments of Energy, Defense, Interior, EPA, and the Western Governors' Association. The Committee's mission is to advise the federal government on ways to clean-up and convert federal sites to productive use by encouraging U.S. companies to research and commercialize new waste treatment and storage technologies.

The DOIT Committee has created four working groups to focus on specific problems. Of these, the Mixed Radioactive/Hazardous Waste Group deals specifically with the issues of mixed waste treatment, storage and disposal. Currently, the Mixed Radioactive/Hazardous Waste Group has chosen seven promising candidate technologies at three sites from a list of 80 possibilities. Each of these seven, two of which are being developed at RFETS, four of which are being developed at INEL, and one being developed at Sandia National Laboratory, will be included in a site demonstration program. In this program, the proposed technology will be brought to operational status at a DOE site, and the procedural steps taken to do the demonstration will be evaluated against a wide range of standards called "value added parameters." These parameters address adapting to or improving the present frameworks of commercialization, stakeholder participation, standard cost/performance data, interstate and interagency reciprocity, liability limitations, and procurement.

TECHNOLOGY NEEDS

Three of the DOIT technologies fall under the Mixed Waste Focus Area. The two treatment technologies which will be developed for demonstration at Rocky Flats are microwave solidification and low temperature thermal desorption. See Sections 3.1 and 3.7. The treatment process being developed at INEL is the plasma hearth process. See Section 2.1. The remaining DOIT technologies are for waste characterization and waste disposal.

ACCOMPLISHMENTS

Each site has formed a Site Implementation Team, composed of technical program managers, regulators, and community stakeholders. Their input will be solicited and considered during all phases of both site demonstrations to reinforce the policy of stakeholder involvement, which is one of the cornerstones of the DOIT program.

BENEFITS

The DOIT program provides each site with an opportunity to involve stakeholders early in the technology development process to identify ways to clean up the site earlier and cheaper, to work with other sites which could potentially benefit from technologies being developed, and assure early, ongoing input from the public which could ultimately streamline the permitting of technologies and eventual cleanup of the site.

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BIBLIOGRAPHY OF KEY PUBLICATIONS

None at this time.

DOE
Business Opportunities

Section 6.0

6.0 DOE BUSINESS OPPORTUNITIES

WORKING WITH THE DOE OFFICE OF ENVIRONMENTAL MANAGEMENT

DOE provides a range of programs and services to assist universities, industry, and other private-sector organizations and individuals interested in developing or applying environmental technologies. Working with DOE Operations Offices, as well as management and operating contractors, EM employs a number of mechanisms to identify, integrate, develop, and adapt promising emerging technologies. These mechanisms include contracting and collaborative arrangements, procurement provisions, licensing of technologies, consulting arrangements, reimbursable work for industry, and special consideration for small business. EM facilitates the development of subcontracts, R&D contracts, and cooperative agreements to work collaboratively with the private sector.

COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENTS (CRADAS)

CRADAs are mechanisms for collaborative R&D. They are agreements between a DOE R&D laboratory and any non-federal source to conduct cooperative R&D that is consistent with the laboratory's mission. The partner may provide funds, facilities, people, or other resources. DOE provides the CRADA partner with access to facilities and expertise; however, external participants receive no federal funds. Rights to inventions and other intellectual property are negotiated between the laboratory and the participant. Certain generated data may be protected for up to five years. Several companies may combine their resources to address a common technical problem. Funds can be leveraged to implement a consortium for overall program effectiveness.

PROCUREMENT MECHANISMS

DOE-EM procurement mechanisms are for technology development in the form of unsolicited proposals and formal solicitations, although the latter are preferable. The principal contractual mechanisms used by EM for industrial and academic response include *Research Opportunity Announcements (ROAs)* and *Program R&D Announcements (PRDAs).*

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

PRDAs are program announcements which solicit a broad mix of advanced development and demonstration proposals. A PRDA requests proposals for a wide-range of technical solutions to specific EM problem areas. Multiple awards, which may have distinct approaches or concepts, are generally made. Numerous PRDAs may be issued each year.

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

For more information about PRDAs and ROAs, contact:

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LICENSING OF TECHNOLOGIES

DOE contractor-operated laboratories can license DOE/EM-developed technology and software. In situations where DOE retains the ownership of a new technology, the Office of General Counsel will serve as the licensing agent. Licensing activities are conducted according to existing DOE intellectual property provisions.

TECHNICAL PERSONNEL EXCHANGE ASSIGNMENTS

Personnel exchanges provide opportunities for scientists from private industry and DOE laboratories to work together at various sites on environmental restoration and waste management problems. Private industry must contribute substantial cost-sharing for these personnel exchanges. To encourage such collaboration, the rights to any resulting patents go to the private sector company. These personnel exchanges, which can last from three to six months, result in the transfer of technical skills and knowledge.

CONSULTING ARRANGEMENTS

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

REIMBURSABLE WORK FOR INDUSTRY

DOE laboratories are available to perform work for private industry and other federal agencies, as long as the work pertains to the mission of a respective laboratory and does not compete with the private sector. The special technical capabilities at DOE laboratories are incentives for the private sector to use DOE's facilities and contractor expertise. An advanced class patent waiver gives ownership of any inventions resulting from the research to the participating private sector company.

INTERACTIONS WITH SMALL BUSINESSES

EM seeks the participation of small businesses in its RDDT&E programs (1) through collaborative efforts with the National Laboratories, or (2) directly via solicitations issued by the DOE Small Business Innovation Research (SBIR) Program Office and the Small Business Technology Transfer (T^2) Pilot Program (STTR). EM also has established a partial procurement set-aside for small firms (500 employees or less) for applied research projects through its ROA.

For further information about SBIR and STTR programs, please contact:

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EM Center for Environmental Management Information

The EM Center for Environmental Management Information is designed to provide ready access to prospective research and business opportunities in waste management, environmental restoration, and decontamination and decommissioning activities. The Center can identify links between industry technologies and program needs. It connects potential partners to an extensive complex-wide network of DOE headquarters and operations office contacts.

To reach the EM Center for Environmental Management Information, call 1-800-736-3282.

Offices of Research and Technology Applications

The Offices of Research and Technology Applications (ORTA) 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.

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ACRONYM LISTING

Section 7.0

7.0 ACRONYM LISTING

ANL-W	Argonne National Laboratory-West
ARDEC	U.S. Army Armament Research, Development, and Engineering Command
CBCs	chemically bonded phosphate ceramics
CCO	catalytic chemical oxidation
CDPHE	Colorado Department of Public Health and Environment
CDR	conceptual design report
CFD	computational fluid dynamics
CIRES	Colorado Cooperative Institute for Research and Environmental Sciences
CTMP	Comprehensive Treatment and Management Plan
DC	direct current
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOIT	develop on-site innovative technology
DRE	destruction and removal efficiency
DSPBV	dual-shell pressure balanced vessel
DQO	data quality objective
EER	Engineering Evaluation Reactor
EM	Office of Environmental Management
EM-30	Office of Waste Management
EM-40	Office of Environmental Restoration
EM-50	Office of Technology Development
EM-60	Office of Nuclear Material and Facility Stabilization
EPA	U.S. Environmental Protection Agency
ER&WM	Environmental Restoration and Waste Management
FBI	fluidized bed incinerator
FFCAct	Federal Facilities Compliance Act
GAC	granular activated charcoal

HCl	hydrogen chloride
HEPA	high-efficiency particulate air
HLW	high-level waste
HWPP	Hazardous Waste Pilot Plant
ID	integrated demonstrations
INEL	Idaho National Engineering Laboratory
IP	integrated programs
IR	infrared
LANL	Los Alamos National Laboratory
LATO	Los Alamos Technology Office
LDR	land disposal restrictions
LLNL	Lawrence Livermore National Laboratory
LLMW	low-level mixed waste
LTTD	low-temperature thermal desorption
LVFTDS	low volume flow through alpha detector system
M&O	management and operations
METC	Morgantown Energy and Technology Center
MLLW	mixed low-level waste
MTRU	mixed transuranic waste
MWFA	Mixed Waste Focus Area
MWPP	Mixed Waste Pilot Plant
NDA	non-destructive analysis
NDT	non-destructive testing
NIST	National Institute of Standards and Technology
NTP	non-thermal plasma
ORNL	Oak Ridge National Laboratory
ORTAs	Office of Research & Technology Applications
OTD	Office of Technology Development (EM-50)
PBR/SDP	packed bed reactor/silent discharge plasma

PBR	packed-bed reactor
PCB	polychlorinated byphenyl
PFNA	pulsed fast neutron analysis
PHP	plasma hearth process
PMP	program management plan
PNL	Pacific Northwest Laboratory
PNS	Pacific Nuclear Services
PRA	Programmatic Research Announcement
PRDA	Program Research and Development Announcement
QA	quality assurance
QAM	quality assurance manual
QAMP	quality assurance management plan
QAMS	quality assurance management system
QARD	quality assurance requirements document
QC	quality control
QPA	Quality Program Administrator
RASP	reactive additive stabilization process
RCRA	Resource Conservation & Recovery Act
RDDT&E	research, development, demonstration, testing, and evaluation
RFCP	Rocky Flats Compliance Program
RFETS	Rocky Flats Environmental Technology Site
RFS	Rust Federal Services
ROA	Research Opportunity Announcement
SAIC	Science Applications International Corporation
SBIR	Small Business Innovative Research
SCDE	supercritical carbon dioxide extraction
CSTP	Conceptual Site Treatment Plan
SCWO	supercritical water oxidation program
SDP	silent discharge plasma

SNL	Sandia National Laboratory
SSPF	small-scale plasma furnace
TCLP	toxic characteristic leaching procedure
TD	technology development
TDL	tunable diode laser
TNC	thermal neutron capture
TOF	time-of-flight
TTP	Technical Task Plan
UST	underground storage tank
VOC	volatile organic compound
WGA	Western Governors Association
WHC	Westinghouse Hanford Company

APPENDIX

Section 8.0

8.0 APPENDIX

TECHNICAL TASK PLANS

Technical Task Plans (TTPs) identify and summarize funded work managed by OTD at headquarters, the field and the national laboratories. All tasks require a TTP number, which contains eight characters assigned by DOE Headquarters. The format consists of two alpha characters followed by six numerical characters. Characters 1 and 2 designate the DOE Operations Office/Funding Allotment Code. Character 3 denotes the laboratory/contractor/university designator. Character 4 denotes the fiscal year in which the task is first funded. The below characters reflect TTPs from FY94-95.

Characters 1, 2 & 3

AL0 Albuquerque Operations Office

AL1 Los Alamos National Laboratory (LANL)

AL2 Sandia National Laboratory, Albuquerque (SNLA)/Martin Marietta

AL3 Sandia National Laboratory, Livermore (SNLL)

AL4 Kansas City Plant (KCP)/Allied-Signal Aerospace

AL9 RUST GEOTECH

CH0 Chicago Operations Office

CH1 Ames Laboratory

CH2 Argonne National Laboratory (ANL)/University of Chicago

CH3 Brookhaven National Laboratory (BNL)/Associated Universities, Inc.

CH5 National Renewable Energy Laboratory

FN0 Fernald Environmental Management Project (FEMP)

FN1 Fluor Daniel Environmental Restoration Management Company

HQ0 OTD Headquarters

ID0 Idaho Operations Office

ID1 Idaho National Engineering Laboratory (INEL)/EG&G

ID4 Westinghouse Idaho Nuclear Company

ID6 Babcock & Wilcox, Inc

ID7 Lockheed Idaho Technology Company

ME0 Morgantown Energy Technology Center (METC)

NV0 Nevada Operations Office

OH0 Ohio Operations Office

OH1	Fernald Environmental Management Project (FEMP)
OH2	EG&G Mound Applied Technologies
OR0	Oak Ridge Operations Office
OR1	Martin Marietta Energy Systems (MMES)
OR3	Oak Ridge Institute for Science and Education
PE0	Pittsburgh Energy Technology Center
PE1	MSE, Inc.
RF0	Rocky Flats Environmental Technology Office
RF1	Rocky Flats Plant/EG&G
RL0	Richland Operations Office
RL2	Kaiser Engineers Hanford Company (KEH)
RL3	Pacific Northwest Laboratory (PNL)/Battelle Memorial Institute
RL4	Westinghouse Hanford Company
SF0	Oakland Operations Office
SF1	Lawrence Berkeley Laboratory (LBL)/University of California
SF2	Lawrence Livermore National Laboratory (LLNL)/University of California
SF3	Energy Technology Engineering Center (ETEC)
SR0	Savannah River Operations Office
SR1	Westinghouse Savannah River Company (WSRC)

Character 4

1	FY 1991
2	FY 1992
3	FY 1993
4	FY 1994
5	FY 1995
6	FY 1996
7	FY 1997
8	FY 1998
9	FY 1999
0	FY 2000