

Office of Environmental Management
Office of Technology Development

Mixed Waste Integrated Program (MWIP)

Technology Summary

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MIXED WASTE INTEGRATED PROGRAM (MWIP)

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OFFICE OF TECHNOLOGY DEVELOPMENT OVERVIEW

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

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

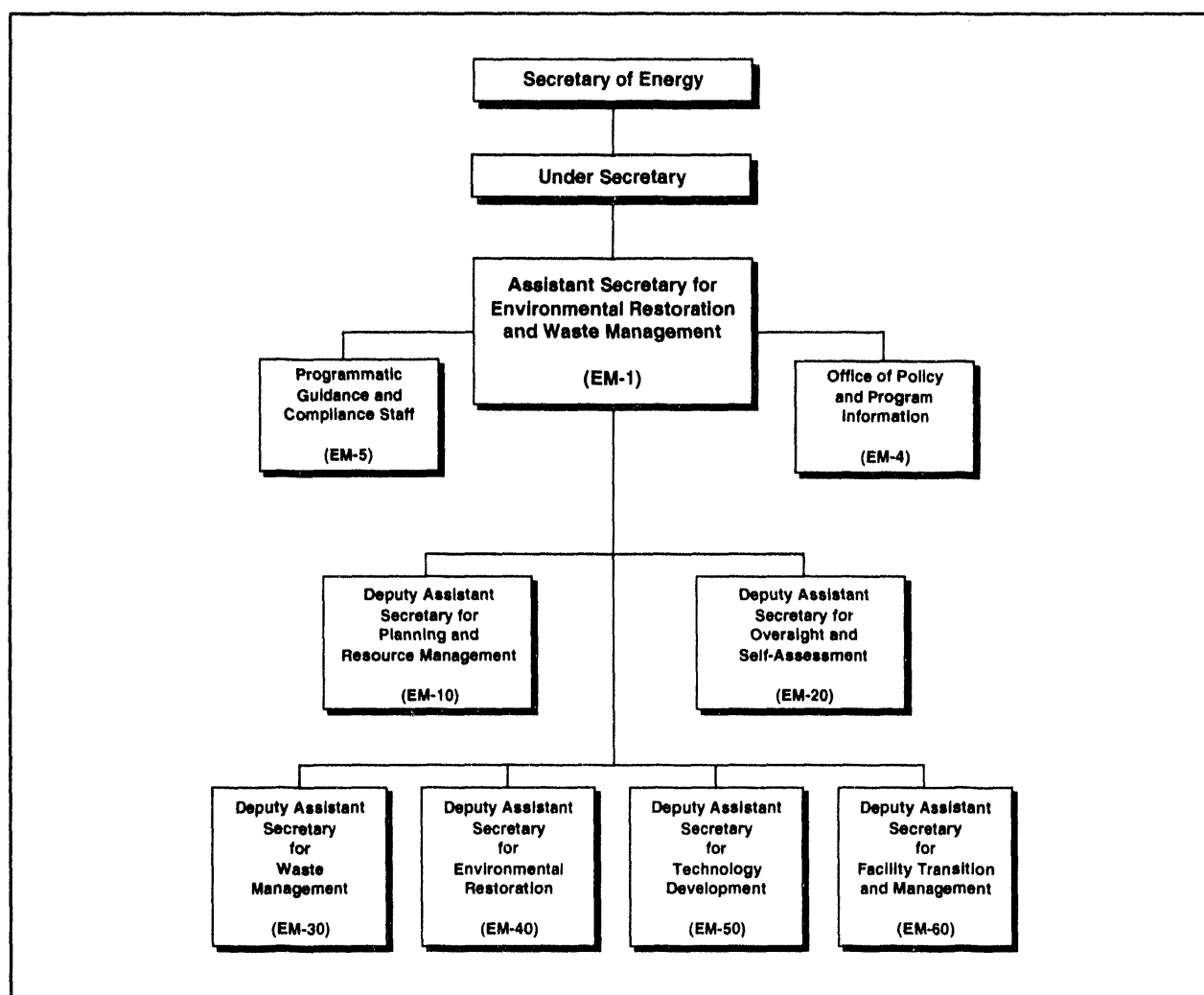


Figure A. DOE Organizational Structure as of June 1993.

In an effort to focus resources and address opportunities, EM-50 has developed **Integrated Programs (IP)** and **Integrated Demonstrations (ID)**. An *Integrated Program* focuses on technologies to solve a specific aspect of a waste management or environmental problem and it can be either unique to a site or common to many sites. An Integrated Program supports applied research to develop innovative technologies in key application areas organized around specific activities required in each stage of the remediation process (e.g., characterization, treatment, and disposal).

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

The Mixed Waste Integrated Program (the subject of this report) is part of EM-54, the Research and Development Division.

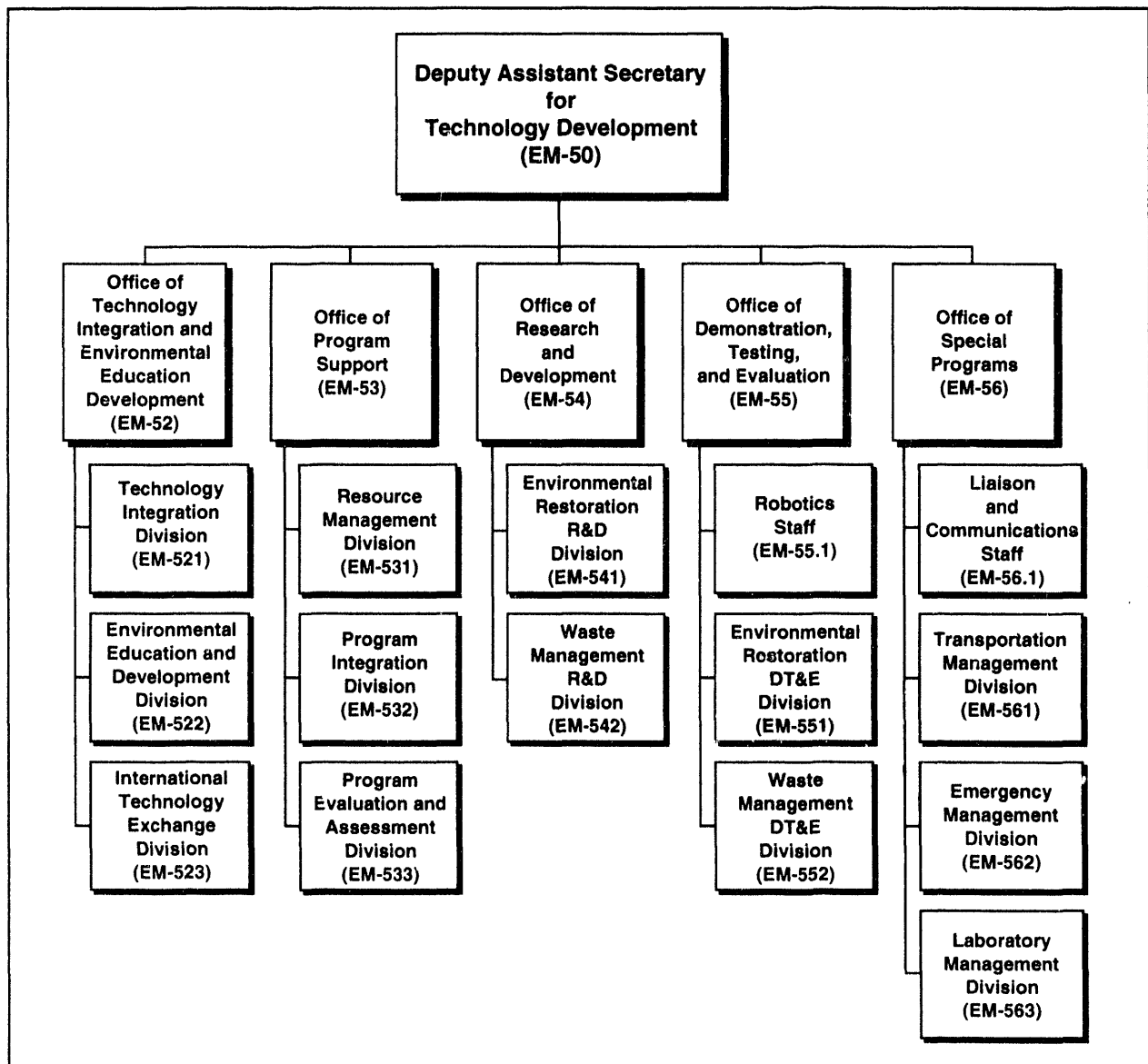


Figure B. Office of Technology Development Organizational Structure as of June 1993.

MIXED WASTE INTEGRATED PROGRAM OVERVIEW

PURPOSE AND MISSION

The mission of the Mixed Waste Integrated Program (MWIP) is to develop and demonstrate innovative and emerging technologies for the treatment and management of DOE's mixed low-level wastes (MLLW) for use by its customers, the Office of Waste Operations (EM-30) and the Office of Environmental Restoration (EM-40). The MWIP was established to coordinate DOE's Research, Development, Demonstration, Testing and Evaluation (RDDT&E) program on MLLW.

The MWIP vision is that DOE will choose to use technology that improves final waste form performance, reduces risks during waste treatment, and minimizes costs, especially for waste streams for which no current treatment technology exists. Emerging technologies will be selected based on 1) systems analyses that are founded on sound technical bases, 2) high public acceptance, and 3) regulatory acceptance.

The need to provide MLLW treatment capacity has been driven by changes in RCRA Land Disposal Restriction (LDR) requirements. The enactment of the Federal Facilities Compliance Act (FFCA) of 1992, which requires plans within DOE for the development of treatment technologies and capacities, is likely to result in a state-by-state and site-by-site approach to management of DOE's wastes. In order to comply with the provisions of the FFCA, DOE will have increased involvement with regional, state and local agencies, and public stakeholders in the technology development process. For example, in FY94, MWIP is funding the plasma hearth process (PHP) which requires new definitions of pre-treatment and characterization of the mixed waste. The Environmental Protection Agency

(EPA) requires significant characterization prior to treatment; however, the plasma process is robust and can treat a wide range of mixed waste. MWIP is coordinating with the appropriate regulators to demonstrate that easing the characterization requirements for the plasma hearth process will lead to an expedited demonstration of this technology, will result in substantial cost savings, and will aid in achieving the goal of treating mixed waste. This pro-active approach will involve the State of Idaho, the EPA, the Western Governor's Association Federal Advisory Committee to Develop On-Site Innovative Technologies Mixed Waste Working Group (WGA DOIT MWWG), and other stakeholders (e.g., key public figures, the general public and environmental groups) in a formal and active effort to enhance the employment of innovative new technologies which will lead to faster, less expensive, and safer cleanup of MLLW. The added value for MWIP is a potentially substantial increase in public and regulatory acceptance of its innovative technologies and treatment systems.

GOALS

The primary goal of MWIP is to develop and demonstrate the treatment and disposal of actual mixed waste (MMLW and MTRU). The vitrification process and the plasma hearth process are scheduled for demonstration on actual radioactive waste in FY95 and FY96, respectively. This will be accomplished by sequential studies of lab-scale non-radioactive testing followed by bench-scale radioactive testing, followed by field-scale radioactive testing. Both processes create a highly durable final waste form that passes leachability requirements while destroy-

ing organics. Material handling technology, and off-gas requirements and capabilities for the plasma hearth process and the vitrification process will be established in parallel. The vitrification work is being performed at Westinghouse Savannah River Site in conjunction with the Clemson DOE/Industry Center for Vitrification Research, and with support from the Battelle Pacific Northwest Laboratory. The MWIP is moving rapidly toward a mobile melter to demonstrate its vitrification technology on radioactive MLLW in late FY94/early FY95. This MWIP mobile melter will also be available to vitrify secondary MLLW/LLW streams from pretreatment technology demonstrations associated with the Underground Storage Tanks Integrated Demonstration. The plasma hearth work is being performed at Idaho National Engineering Laboratory in conjunction with EG&G Idaho, Argonne

National Laboratory-West, Science Applications International Corporation, Retech, Inc., Martin Marietta Energy Systems and Mountain States Energy, Inc.. In addition, the MWIP is moving rapidly toward demonstration of its steam reforming technology on radioactive MLLW at the Rocky Flats Plant in late FY94/early FY95.

To demonstrate its treatment technologies, MWIP is establishing surrogate waste stream formulations for each waste stream treatability category, thereby representing all MLLW streams across the DOE Complex. This will allow direct comparisons of the technologies. Also, surrogates for actual radionuclides are being specified to assist in developing treatment technologies.

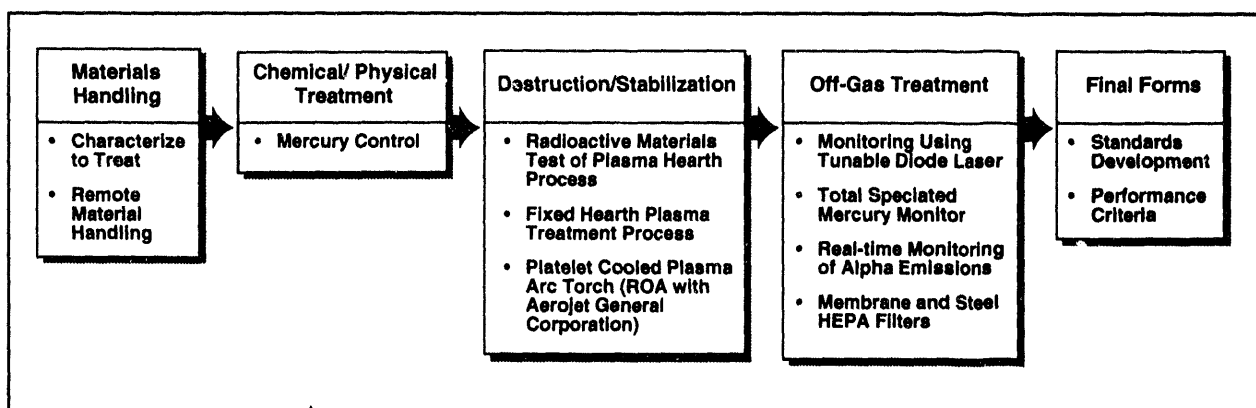


Figure C. Systems Approach for Plasma Arc

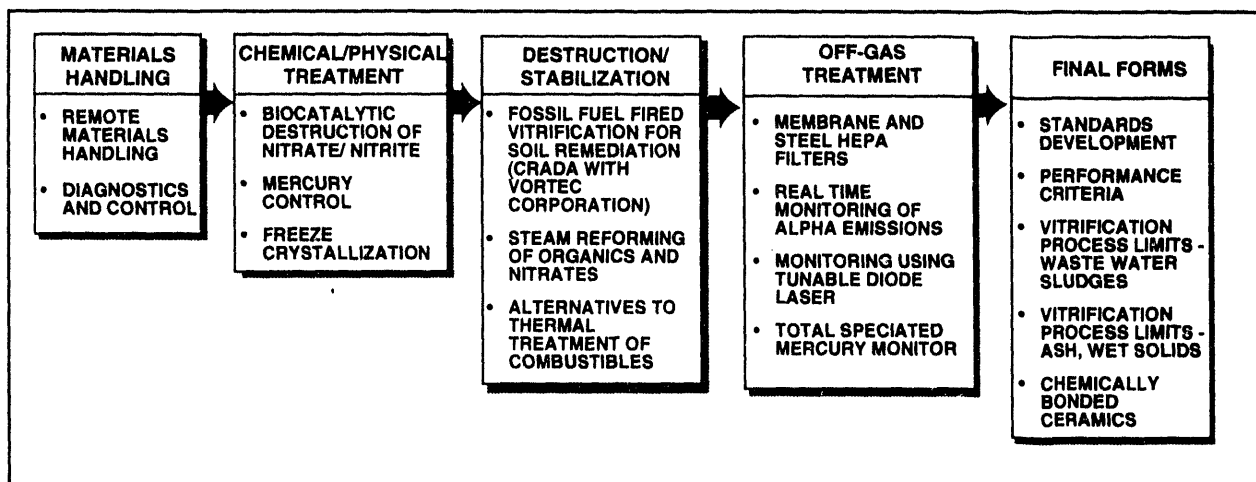


Figure D. Systems Approach for Vitrification Treatment.

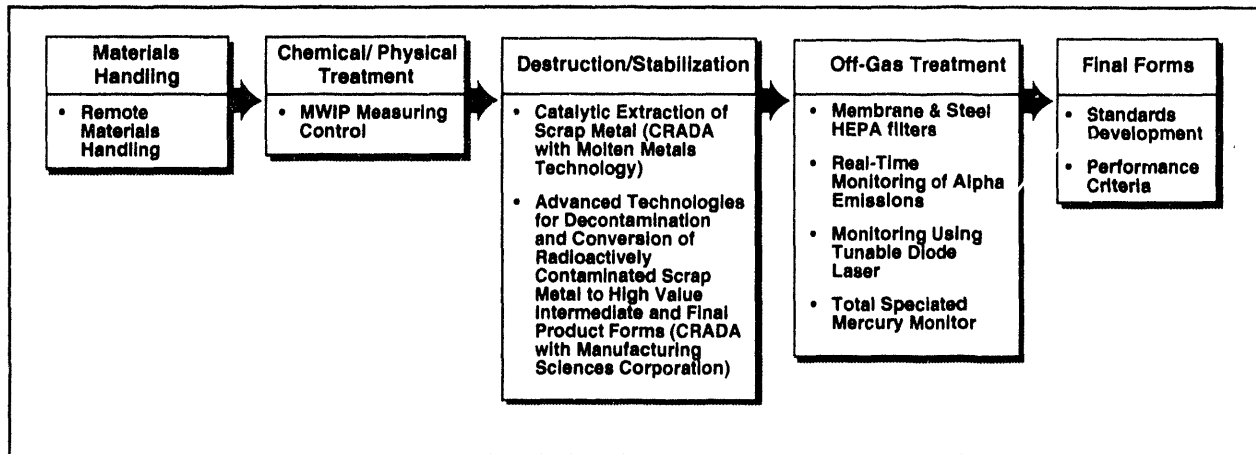


Figure E. Systems Approach for Molten Metal

ORGANIZATION

MWIP is organized to reflect major steps in mixed waste processing in the following technical areas: 1) Materials Handling, 2) Chemical/Physical Treatment, 3) Waste Destruction/Stabilization, 4) Off-Gas Treatment, and 5) Final Waste Forms. Each technical area is headed by a Technical Area Leader (TAL) who is expert in the area, and is responsible for advising the program manager on technology development selection and implementation. Each TAL can assemble an ad-hoc Technical Support Group to establish requirements based on EM-30 and EM-40 validated needs, solicit proposals, evaluate and rank the proposals, and recommend which technologies to develop for treatment of MLLW. In general, MWIP is using a systems approach to develop treatment technologies. Rather than developing isolated technologies, technologies are being developed to operate as a coordinated system, from materials handling to generation of a final waste form for disposal. Figures C, D, and E, for example, illustrate MWIP systems approaches for developing plasma hearth, vitrification, and molten metal treatment systems.

This structure parallels that of the national Mixed Waste Treatment Program (MWTP, EM-351). As the new Mixed Waste Characterization, Treat-

ment and Disposal Focus Area develops, this MWIP structure will likely evolve to resemble the focus area structure. Each current technical area is described briefly below, highlighting responsibilities and accomplishments:

Materials Handling

The Materials Handling Technical Area has been established by the MWIP to identify the technical requirements for materials handling in the treatment of MLLW and to ensure that the technologies are available when needed in a treatment system. Materials handling encompasses several areas, including receiving, characterization, and interim storage of containerized MLLW. For some treatment systems, the MLLW may need to be removed from the containers, sorted, prepared for chemical/physical pretreatment, and must be physically transported to the treatment station. The MWIP is focusing on developing robust MLLW treatment systems, such as in the plasma hearth process. In addition, the treated materials, i.e., the final waste forms, must be collected and packaged for final disposal.

In FY94, a Technology Area Status Report (TASR) is being prepared for Materials Handling. This will be used as the mechanism for identifying technical needs and requirements in

this technical area. A survey of technologies available through the DOE Office of Technology Development, EPA, DoD development programs, or those available commercially, will be evaluated against the technical requirements to identify any gaps in the available baseline technologies.

Chemical/Physical Treatment

The Chemical/Physical Treatment Technical Area encompasses the development of technologies to treat aqueous and organic waste streams and to decontaminate debris. Those species that interfere with downstream processing (e.g. thermal treatment, alternate destruction technologies, final waste forms processing) will be removed from the waste streams via processes developed within this technical area. Salt solution disposal from off-gas treatment will also be handled under this technical area. In FY93, MWIP managed chemical/physical technical activities in the areas of mercury control and nitrate destruction technologies.

Waste Destruction and Stabilization

The Waste Destruction and Stabilization Technical Area encompasses the development of robust technologies which accomplish volume reduction, organics destruction and production of a final waste form. These responsibilities include coordination of final waste form options and minimization of off-gas pollutants. Thermal treatment technologies such as the Plasma Hearth Process, steam reforming and molten metal processing of MLLW are being emphasized. Closed-loop off-gas systems involving extensive monitors, diagnostics and controls will be developed to insure that radioactive and hazardous species are not emitted to the environment.

In FY94, MWIP will design, construct, test, and evaluate the Plasma Hearth Process (PHP), in

preparation for a bench scale demonstration on actual radioactive waste in FY95. MWIP will pursue the demonstration of alternative technologies to incineration such as commercial steam reforming to demonstrate the destruction of organics and the thermal decomposition of inorganic salts.

A Technical Area Status Report (TASR) for Alternatives to Incineration, focusing specifically on alternatives to thermal treatment, is being written in FY94. Incineration systems have long been recognized by EPA as an effective treatment for organic and combustible wastes. The purpose of this report is to determine whether there are nonthermal treatment technologies which may have such benefits as minimized secondary waste streams, both ash and off-gas, lower cost, or better performance relative to incineration.

Off-Gas Treatment

The Off-Gas Treatment Technical Area encompasses the development of technologies to treat and/or pretreat thermal treatment secondary waste streams such as organics, wet solids, and scrubber blowdown from air pollution control systems. Off-gas treatment and monitoring technologies will be developed for the plasma hearth process and the vitrification process, and will be integrated into other thermal treatment demonstrations. Projects for FY94 include development of enhanced off-gas systems and particle monitoring. Continuous monitors for alpha particles, ammonia, and mercury in air pollution control systems will be developed. Two cleanable HEPA filters, one made of steel fibers and one of inorganic polymers, will be compared in basic capture efficiency, pressure drop through filters, cleanability, and performance under loading. Additionally, the efficacy of using molten-sulfur-coated ceramic spheres or gold-plated, regenerable ceramic filters for scavenging mercury will be assessed.

Closed-loop systems for the monitoring, trapping and treatment of off-gas constituents will be examined for all thermal treatments to address the public concerns regarding emissions from incinerator operations.

Final Waste Forms

The Final Waste Form Technical Area encompasses the development of technologies that are suitable as a final waste form for storage and/or disposal. Performance standards and evaluation criteria for the final waste form will be developed. Emphasis is placed on the ability of the final waste forms to exhibit high waste loading, significant volume reduction, low-leachability, and high-durability. In FY93, MWIP completed bench-scale demonstrations of the production of such final waste forms, conducting crucible studies of three site-specific waste streams. The DOE/Industrial Center for Vitrification Research was established at Clemson University.

In FY94, the development of stabilization technologies including vitrification and polymer encapsulation will be continued. Data requirements for the assessment/characterization of final waste forms to meet regulatory requirements will be developed. A major effort in the Final Waste Forms Technical Area in FY94 will be an expedited vitrification demonstration on actual radioactive waste in the DOE inventory. Research in support of this demonstration is being conducted at Savannah River and Pacific Northwest Laboratory (PNL), and the demonstration will take place at one or both of these two sites.

Systems Analysis and Process Monitoring and Controls

The systems analysis effort supports decisionmaking for the MWIP by incorporating pilot-scale data to the process model flowsheets to analyze waste streams and technologies. Analysis of risks, costs, diagnostics, and perfor-

mances are included in the flowsheets. In FY94, systems analysis will be initiated on selected technologies to determine environmental, safety, and health (ES&H) issues, life-cycle costs, and technology integration for incorporation into baseline process flowsheets.

To support the integration of MWIP technologies into treatment plant designs, MWIP conducted systems analysis studies of the plasma hearth process and vitrification process. A process hazard analysis of these processes were completed, which involved the development of a risk assessment strategy and methodology.

MWIP ACCOMPLISHMENTS

Technical Area Status Reports (TASRs) identifying and describing currently available technologies for the management, treatment and disposal of mixed low-level wastes were developed and issued in FY93. The TASRs presented initial evaluations of technologies that may be applicable to MLLW treatment requirements and recommend preliminary improvements to the baseline treatment scheme established by EM-30, Mixed Waste Treatment Project. These TASRs provide a valuable resource of technology options for the development of conceptual site treatment plans in compliance with the FFCA of 1992. TASRs are also utilized to ensure that duplication of technology development efforts does not occur. TASRs were published in the following technical areas: chemical/physical treatment, waste destruction and stabilization, final waste forms and off-gas treatment. A complete list of MWIP publications is provided in Appendix A. For more information on ordering these documents, please contact the Office of Science and Technology Information, (615) 576-8401.


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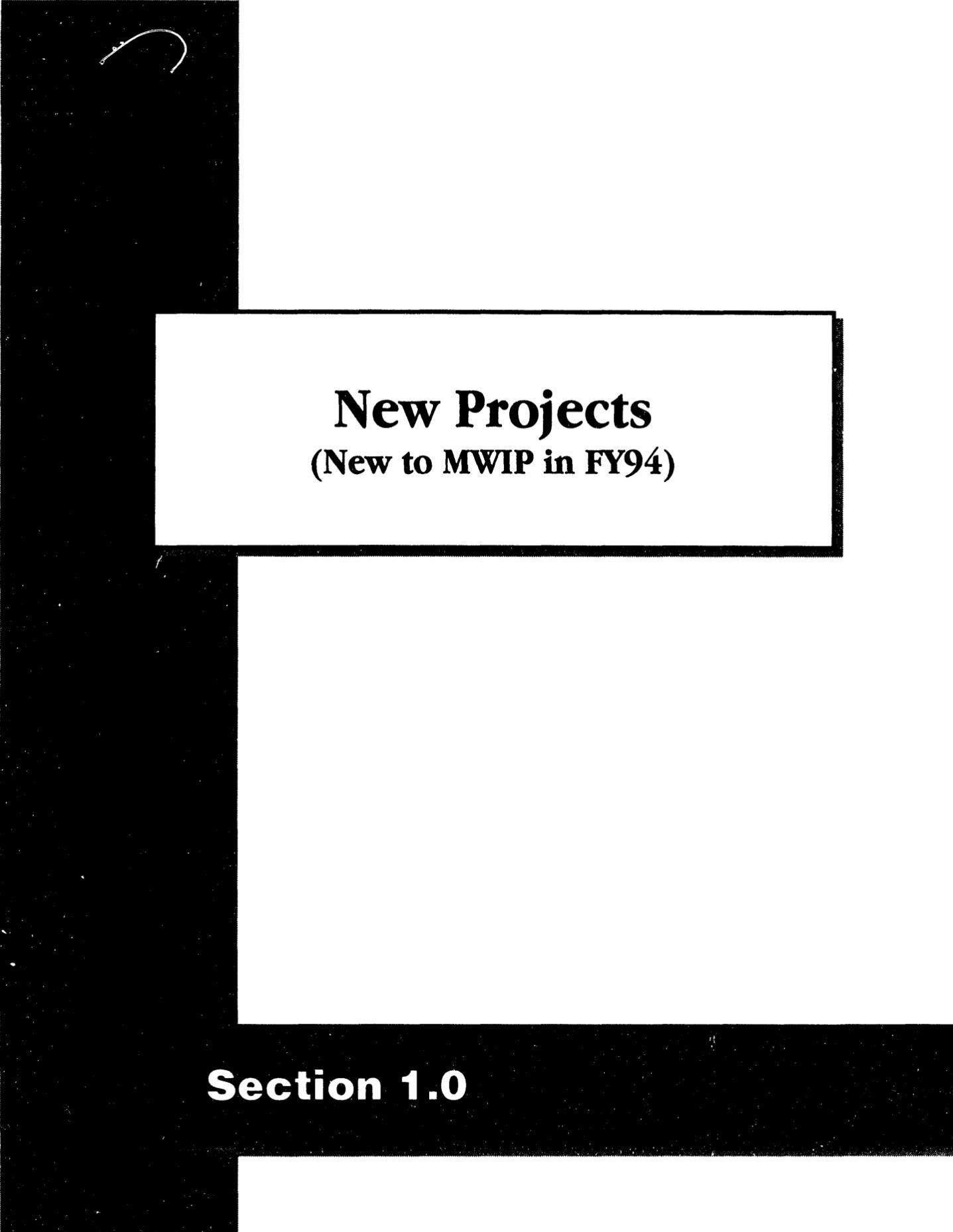
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New Projects
(New to MWIP in FY94)

Section 1.0

1.1 CHEMICAL/PHYSICAL TREATMENT

1.1.1 BIOCATALYTIC DESTRUCTION OF NITRATE AND NITRITE

TASK DESCRIPTION

The purpose of this task is to develop an enzyme-based reactor system for the reduction of nitrate and nitrite to N_2 and H_2O . It will demonstrate the validity of using immobilized enzymes coupled with biphasic partitioning to efficiently destroy

lytic activity to be obtained without the need for additional chemical reagents or the production of secondary waste streams (see Figure 1.1.1).

TECHNOLOGY NEEDS

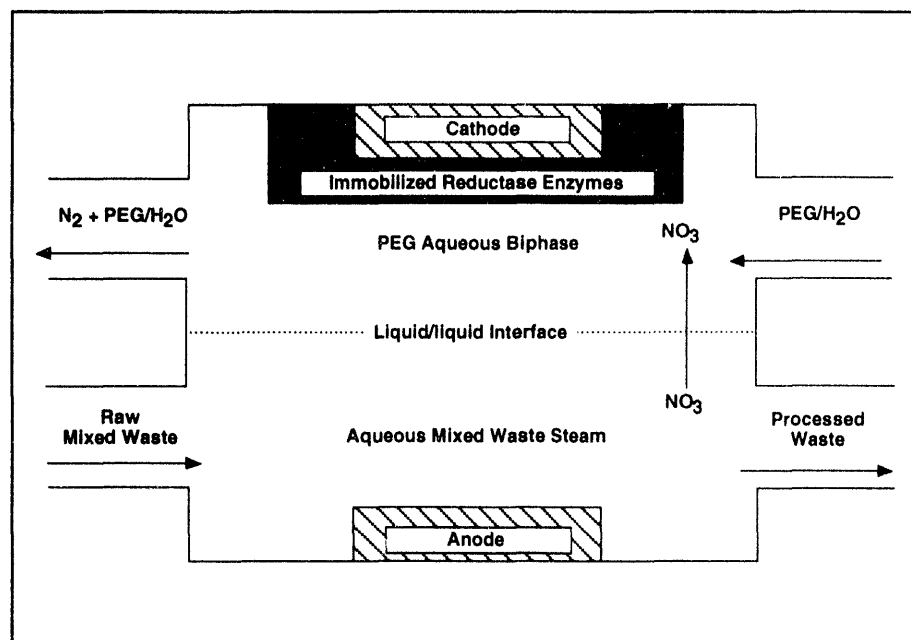


Figure 1.1.1. Process Description.

The final product of this development effort would be a compact reactor system that could be used to treat aqueous mixed waste and low-level radioactive waste. The high nitrate and nitrite content of these liquid wastes significantly increases the volume of grout produced due to its low capacity for these materials. Nitrate also produces significant quantities of secondary waste.


nitrate and nitrite. The reducing equivalents are provided by a low-voltage electrical current, which transfers electrons from the cathode to the enzymes via an electron transfer dye. The biphasic system is necessary to protect the enzymes from excessive concentrations of electrolytes, especially H^+ and OH^- which would result in enzyme inactivation, while simultaneously allowing the transfer of nitrate and nitrite from the waste stream to the catalytic chamber. The use of enzymes enables very large specific cata-

ACCOMPLISHMENTS

This is a new project in FY94. If the first year's efforts to convert nitrate to nitrite are successful, the efforts in FY95 will focus on immobilization of the remaining enzyme systems necessary to reduce nitrate directly to N_2 and H_2O .

COLLABORATION/TECHNOLOGY TRANSFER

The reactor test using simulated feeds will be carried out jointly between Argonne National Laboratory (ANL) and the University of Iowa. Work at ANL will focus on development of a biphasic extraction system and process integration. Researchers at the University of Iowa will provide support in developing enzyme immobilization techniques and assays of activities.




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1.1 CHEMICAL/PHYSICAL TREATMENT

1.1.2 FREEZE CRYSTALLIZATION TECHNOLOGY

TASK DESCRIPTION

This project will be developing and demonstrating pilot-scale, direct-contact freeze crystallization systems. The systems will demonstrate that freeze crystallization technology is capable of concentrating liquid effluents and separating organic and inorganic contaminants by removing the bulk of the water. All freeze crystallization processes are based on the difference in component concentrations between solid and liquid phases that are in equilibrium (see Figure 1.1.2). As an aqueous solution is cooled, ice usually crystallizes as a pure material, and dissolved components of the stream are concentrated into a reduced volume.

Project tasks include:

- Engineering studies -- perform technical and economic evaluation of the technology as it pertains to low level mixed waste (i.e. cost benefits analysis)
- Small pilot scale studies -- perform treatability studies and process development on surrogate waste streams and formulate plan for the testing of radioactive waste streams by the end of the fiscal year. This work will be performed at the vendor's small-scale pilot plant at FTC Acquisition Corporation Raleigh, NC, facility. Design and procurement of the freeze crystallization system are included in the project.

TECHNOLOGY NEEDS

Freeze crystallization can be used to decontaminate fluids containing inorganics, organics (including volatile organics), heavy metals, and radionuclides. Freeze crystallization is a flexible process that can be designed to adjust to the needs of the application so that it can operate at high efficiency. Potential benefits of freeze crystallization technology over conventional treatment and concentration technologies include:

- High decontamination factors and high waste volume reduction factors.
- More efficient partitioning of volatile and semi-volatile components as compared to that of evaporation/crystallization and membrane technologies.
- The process is a low temperature, low pressure process, and is intrinsically safe. It is highly energy efficient, removing heat rather than adding it. Also, heat exchangers can be used in the process to recover the cooling value in the melt and concentrate streams.
- No additives are needed.
- Potential for salt recovery and purification.

PROCESS COMPARISON				
PROCESS CHARACTERISTICS	FREEZE CRYSTALLATION	CONVENTIONAL TREATMENT PROCESSES	VAPOR-LIQUID PROCESSES	MEMBRANE PROCESSES
REMOVAL OF SOLUTES	<ul style="list-style-type: none"> Removes all solutes equally - salts, heavy metals, organics, & radionuclides. 99.99+ % removal from product/wastewater 	<ul style="list-style-type: none"> Generally selective for one or a group of contaminants. 90 to 99% removal from product/wastewater. 	<ul style="list-style-type: none"> Single equilibrium stage devices effectively remove salts, heavy metals and some type of organics. Volatile components (0.01 to 100 times volatility of solvent) require multi-stage (fractional distillation) process. 99.99 + % removal of contaminating species from product. 	<ul style="list-style-type: none"> Remove most components, but less effectively. 95 to 99% removal of dissociated species. 75 to 90% removal of intermediate molecular weight organics. No separation to enrichment of low molecular weight organics.
REMOVAL OF SOLUTES	<ul style="list-style-type: none"> Lowest of all phase change processes. Typically 10 to 30% the energy needed by evaporators. Typically 5 to 15% the energy needed by distillation columns. 0.005 to 0.02 kw-hr/lb product. 	<ul style="list-style-type: none"> Direct energy consumption usually very low. Production of chemicals, regeneration of carbon, etc often more energy intensive than separation processes. Incineration: 10,000 - 15,000 BTU/# material burned. 	<ul style="list-style-type: none"> Usually heat driven, using some primary fuel. 200 to 3000 BTU/# product. Electric energy can be substantial where high recirculation rates are required: typically 0.0005 to 0.0025 kw-hr/lb product. Can be as high as 0.05 kw-hr/lb. 	<ul style="list-style-type: none"> Lower energy consumption than other phase separation processes. Increases with the osmotic pressure and inversely to recovery. Typically 0.002 to 0.01 kw-hr/lb.
REMOVAL OF SOLUTES	<ul style="list-style-type: none"> SF of 0.0001 to 0.001. DR of 1000 to 10,000. 	<ul style="list-style-type: none"> SF of 0.001 to 0.1. DR of 10 to 1000. 	<ul style="list-style-type: none"> SF of 0.00001 to 0.01. DR of 100 to 100,000. 0.1 < SF > 10 requires multi-staging (fractional distillation). 	<ul style="list-style-type: none"> SF of 0.1 to 0.01. DR of 10 to 100.
REMOVAL OF SOLUTES	<ul style="list-style-type: none"> Works well; requires modifications to remove precipitated solids. 	<ul style="list-style-type: none"> Generally not a consideration, other than in precipitation processes, where system is designed for good condition. 	<ul style="list-style-type: none"> Scales heat exchangers, which can usually be cleaned. 	<ul style="list-style-type: none"> Scales/fouls membranes, which might plug modules, or not be removable by conditions that won't destroy membranes.
TRACTIONATE SOLUTES	<ul style="list-style-type: none"> Widely capable; using temperature effects on solubility. 	<ul style="list-style-type: none"> Very limited ability; "salting" applications. 	<ul style="list-style-type: none"> Limited ability except with volatile components 	<ul style="list-style-type: none"> Very limited capability at this time; will require extensive membrane development program.
IMPURITY CONCENTRATION EFFECTS	<ul style="list-style-type: none"> Works well at high concentrations. 	<ul style="list-style-type: none"> High salinity can block some conventional treatment mechanisms (i.e. biological activity, metal solubilities, etc.). 	<ul style="list-style-type: none"> Works well, as long solubility limits are not exceeded. 	<ul style="list-style-type: none"> Limited by osmotic pressure of -400 to 800 psi at this time.
ENVIRONMENTAL CONSIDERATIONS	<ul style="list-style-type: none"> No emissions; operates mostly in vacuum in closed system. Low risk of fire/explosion. Low oxygen content, usually zero air in system. 	<ul style="list-style-type: none"> Usually open systems, so some volatiles are lost to air. Lower risk of fire or explosion. 	<ul style="list-style-type: none"> Usually operates at above-ambient pressures, so always some fugitive emissions. Leaks present fire/explosion hazard if process liquid is flammable. 	<ul style="list-style-type: none"> Low emissions. Safety risk with high pressure leaks when working with hazardous material.
CORROSION RATES	<ul style="list-style-type: none"> Lowest of all processes because of operation at sub-ambient temperatures with zero oxygen levels. 	<ul style="list-style-type: none"> Wet environments in air, often require special materials of construction considerations 	<ul style="list-style-type: none"> Higher operating temperatures usually require more exotic materials of construction 	<ul style="list-style-type: none"> High pressure systems typically are constructed of FRP or stainless steels to avoid corrosion problems. Membrane life often shortened by chemical attack from operating fluid.

Figure 1.1.2. Process Comparison.

COLLABORATION/ TECHNOLOGY TRANSFER

The direct-contact secondary-refrigerant freeze crystallization and vacuum processes are proprietary processes belonging to FTCAC. The goal of this program is to work collaboratively with FTCAC to develop their technology for DOE applications. There is a potential to perform some of the tasks of this project under a Cooperative Research and Development Agreement (CRADA).

Freeze crystallization technology is applicable to other ID/IPs, including Uranium in Soils ID, Rocky Flats Compliance Program, and the Efficient Separations and Processing IP. There are many projects in the DOE complex that involve wastewater, effluent, secondary liquid waste, and groundwater treatment, and this process should be a viable alternative in these type of applications.

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1.2 WASTE DESTRUCTION AND STABILIZATION

1.2.1 DESTRUCTION OF ORGANIC MATERIALS AND DECOMPOSITION OF NITRATES IN MIXED WASTES BY STEAM REFORMING

TASK DESCRIPTION

Sandia National Labs (SNL) and Synthetica Technologies have been investigating application of Synthetica's steam reforming system for destruction of hazardous organic contaminants found in DOE wastes. This commercial steam reforming system uses a high temperature reactor (1200°C) called a Thermal Detoxifier (see Figure 1.2.1), equipped with several feed systems designed to gasify different waste forms (e.g., drummed wastes, liquid wastes, slurried wastes, medical wastes, low-level radioactive wastes, and contaminated soil). Wastes are gasified in the appropriate feed system by exposure to superheated steam, and then the gasified or-

ganic materials are fed to the Detoxifier, where they are destroyed by heat. When the organic materials in the waste contain substantial amounts of heteroatoms, acid removal is performed to prevent corrosion.

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

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

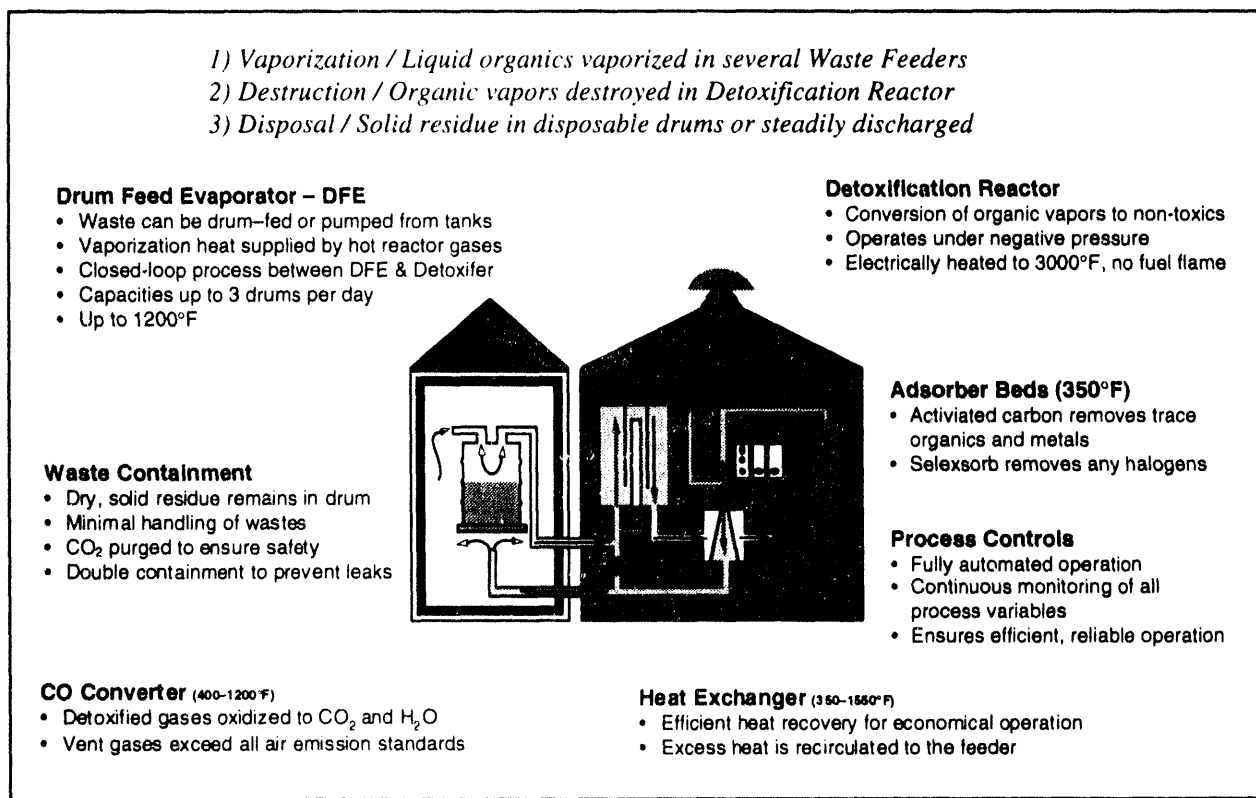


Figure 1.2.1 Synthetica[™] Detoxifier Three Step Process.

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

TECHNOLOGY NEEDS

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

COLLABORATION/ TECHNOLOGY TRANSFER

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

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1.3 OFF-GAS

1.3.1 CLEANABLE HIGH-EFFICIENCY PARTICULATE AIR FILTER DEVELOPMENT AND DEMONSTRATION

TASK DESCRIPTION

Alternative methods/materials are being explored for High Efficiency Particulate Air Filters (HEPA) to produce low cost, low risk, reusable and reliable filters (see Figure 1.3.1a). Two separate projects are working to achieve this goal. Steel filter materials are being examined at 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:

- 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 and feasible, but future funding 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 the 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 cost and more radioactive waste in the environment. Significant handling and maintenance occurs for the glass filters, which exposes workers to unsafe environmental conditions and increases person hours.

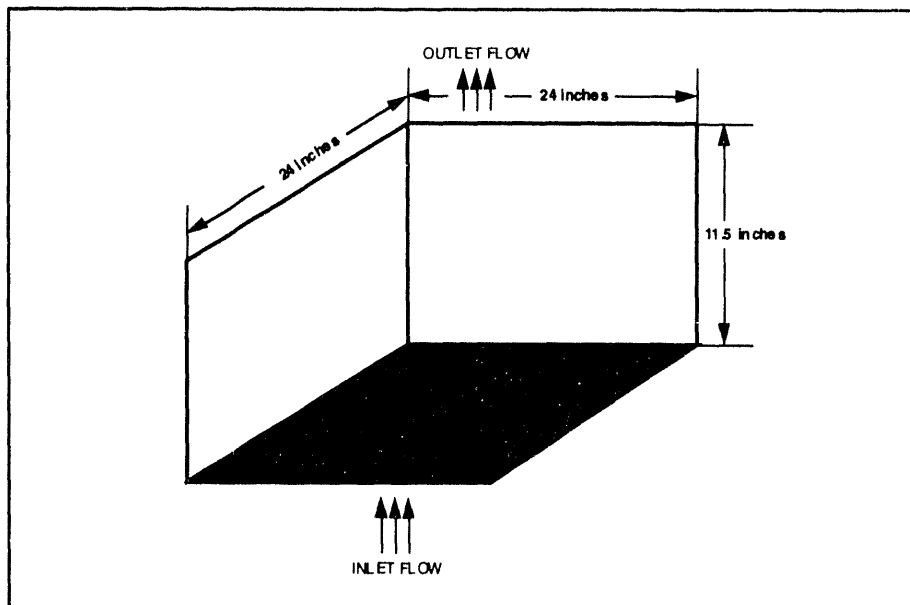


Figure 1.3.1a. Design of cleanable HEPA filter module.

Alternative filter materials need to improve these conditions and pass efficiency and pressure drop requirements. HEPA filters need to capture 99.97% of 0.3 micron sized particles while maintaining less than 1 inch of water pressure drop (see Figure 1.3.1b).

ACCOMPLISHMENTS

Filters of 2 micron steel fibers have been fabricated at LLNL that pass efficiency standards, and the lifespan is estimated at a minimum of 15 years.

Inorganic membrane filters fabricated at Oak Ridge have been successfully cleaned through reverse air pulsing.

COLLABORATION/ TECHNOLOGY TRANSFER

The optimum performing alternative HEPA filter will be used in the off-gas treatment of mixed waste in MWIP (see Figure 1.3.1c).

Pall Corporation in NY, which is jointly conducting the steel filter project with LLNL, will make this technology commercially available at the end of the project.

Golden Technologies Company, Incorporated, research and development subsidiary of Coors, has expressed interest in teaming with Oak Ridge to develop manufacturing of a cleanable inorganic membrane filter.

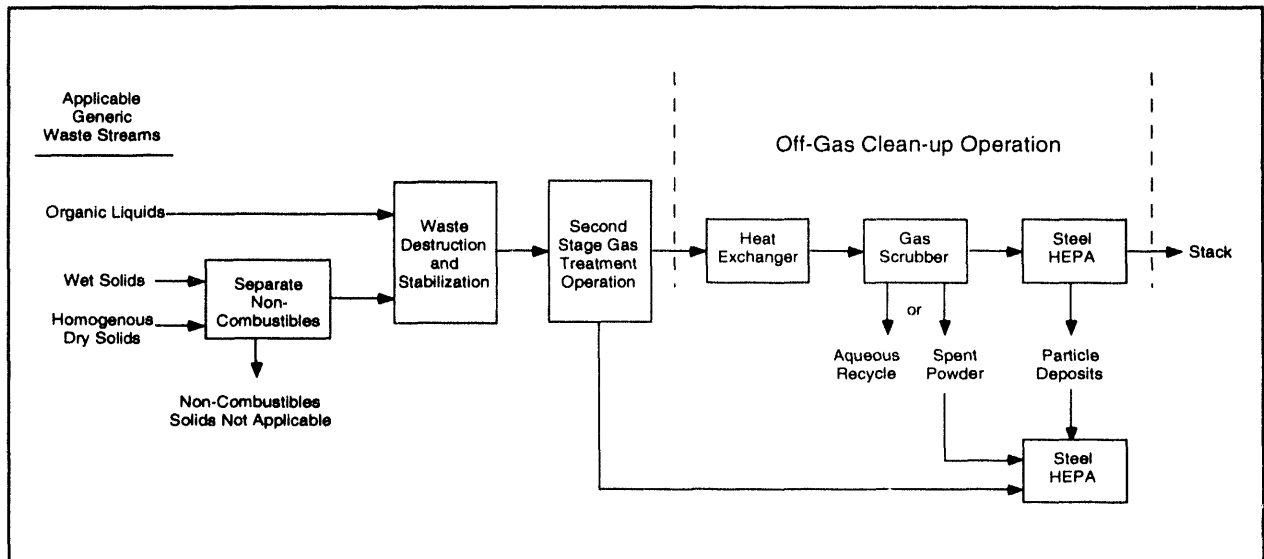


Figure 1.3.1b. Process Flow Diagram.

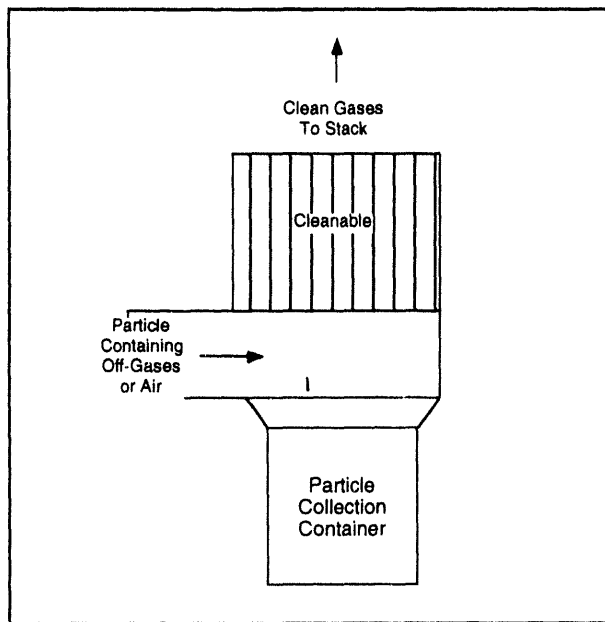


Figure 1.3.1c. Off-Gas Treatment.

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D. E. Fain/G. S. Roettger

Inorganic Membrane Filters

Martin Marietta Energy Systems

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1.3 OFF-GAS

1.3.2 REAL TIME, CONTINUOUS MONITORS

TASK DESCRIPTION

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

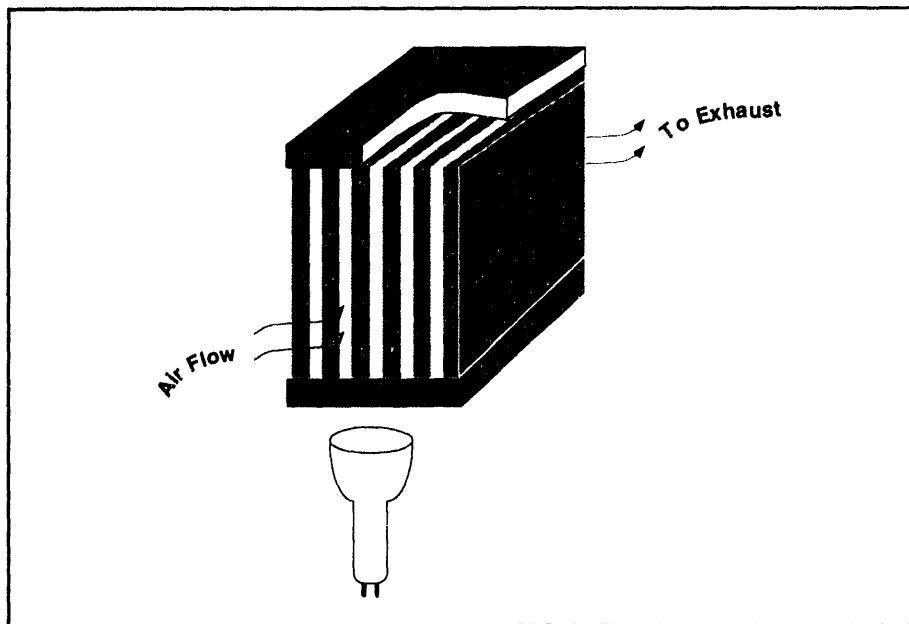


Figure 1.3.2a. The Large-Volume Flow Through Detection System

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

- Large-Volume Flow Through Detection Systems (LVFTDS) for radionuclide particles (see Figure 1.3.2a);

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

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

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

Replacing the current monitoring system for transuranic waste with the LVFDS would improve the sensitivity by an order of magnitude while decreasing detection times. Additionally the detector is simple and reliable due to the lack of any type of filter that would need replacing (see Figure 1.3.2b).

Plans for near-infrared TDL spectroscopy include:

- field testing of ammonia monitor;
- proof of concept experiments on a halogen/sulfur species monitor;

- identification of performance specifications and instrument configuration for VOC monitor;
- construction and lab testing of VOC emissions monitor; and
- making the decision, based on lab results, for the construction of a field unit.

Benefits of TDL spectroscopy for waste stream monitoring are:

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

Plans for a mercury monitor in gas effluents include:

- proof of principle for conversion of speciated mercury and achievement of 0.1 ppb mercury detection; and

- fabrication of a mercury monitor for tests on a lab scale.

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

TECHNOLOGY NEEDS

MWIP has identified a high priority need for real-time monitors for trace amounts of high

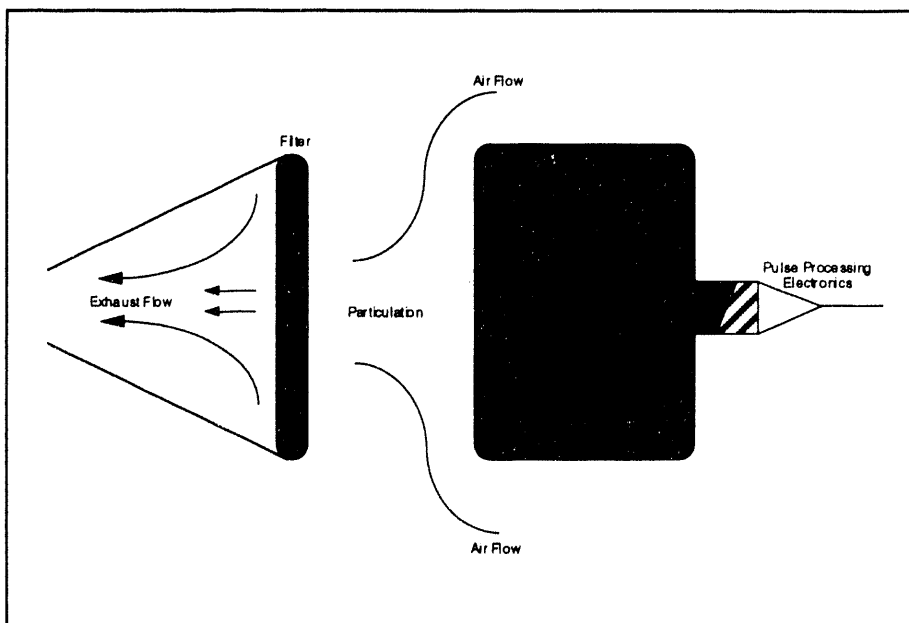


Figure 1.3.2b. Typical Stack Gas Alpha Detection System.

toxicity gases to be field tested within two years. These monitors are also needed for air quality measurements of stack emissions before and after air pollution control processes.

ACCOMPLISHMENTS

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

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

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

[REDACTED]

COLLABORATION/ TECHNOLOGY TRANSFER

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

PSI Environmental Instruments Corporation will collaborate with LANL for field test studies on TDL spectroscopy units. Further technological development of tunable diode lasers at SNL will provide additional markets for these products. These monitors will be useful to all government

and private sector organizations involved in combustion, gasification, and incineration. Process monitors based on this technology are also possible for medical applications in blood and oxygen monitoring and semiconductor manufacturing, which will broaden its government agency utilization.

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

[REDACTED]

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1.4 FINAL WASTE FORMS

1.4.1 CHEMICALLY BONDED CERAMICS FOR STABILIZING PROBLEM LOW-LEVEL MIXED WASTE STREAMS

TASK DESCRIPTION

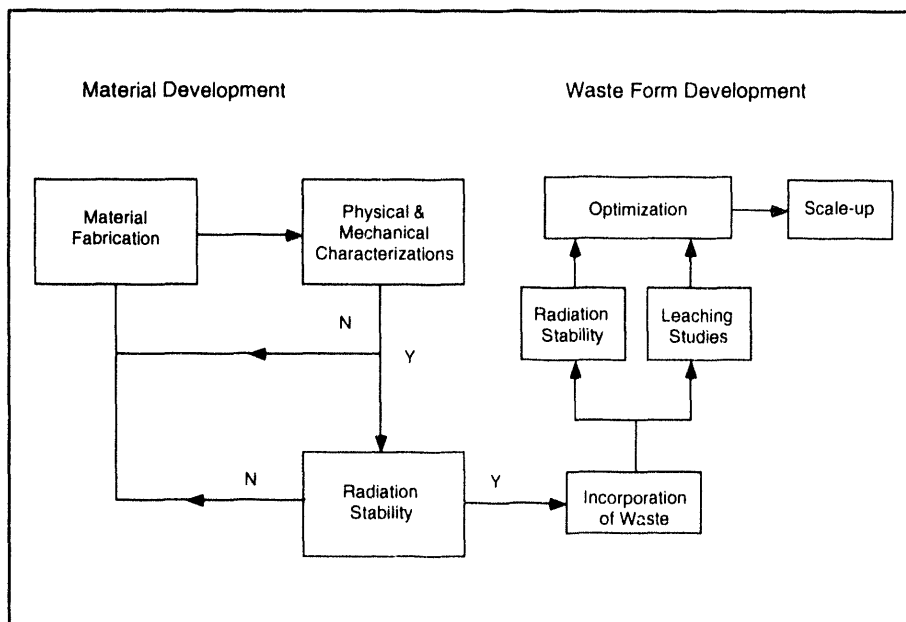
ANL will fabricate ceramic phosphates as an alternative final waste form. Waste streams that cannot be treated with vitrification will be examined, which include liquid mercury, mercury contaminated liquids, toxic metal materials, salt cakes, pyrophorics and beryllium. Guidelines and assessments will be set up based on the waste stream with the best treatability performance, and that stream will then be scaled up for pilot study (see Figure 1.4.1).

Metallic oxide contaminants, such as BeO and HgO, and phosphoric acid may be processed into hydrophosphates by reaction at room temperature. This low-temperature processing occurs quickly, minimizing worker exposure and costs. Ceramic phosphates are also non-flammable, insoluble in ground water and stable at higher temperatures.

Plans for FY94 include:

- fabrication of phosphate systems;
- incorporation of surrogate and actual waste into the host phosphates;
- selection of waste streams for a pilot scale study;
- identification of scale up factors and implementation of the pilot scale study; and
- evaluation of pilot scale study leading to improvements of the final waste form.

TECHNOLOGY NEEDS



Alternative methods to mixed waste remediation must be examined for waste streams that cannot be stabilized through vitrification. Incineration and vitrification at higher temperatures produce secondary waste which must be further treated by the off-gas process which increase costs. Chemically bonded ceramic phosphates can decrease costs incurred from secondary waste

Figure 1.4.1. Material Development and Waste Form Development.

due to solidification and stabilization at lower temperatures.

[REDACTED]

ACCOMPLISHMENTS

Aluminum phosphate and magnesium ammonium phosphate ceramics have been synthesized at room temperature. Initial leaching studies show they are suitable for containment of mixed waste.

[REDACTED]

COLLABORATION/ TECHNOLOGY TRANSFER

The University of Illinois at Urbana-Champaign will have input with the phosphate project through professor and graduate student involvement and

lab time. BNL intends to treat similar waste streams with polymeric binders. Future contacts and collaborations between ANL and BNL have been established to discuss the differences between these two approaches. Industry partners will be established when the project begins its pilot scale up.

[REDACTED]

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1.4 FINAL WASTE FORMS

1.4.2 MIXED WASTE TREATABILITY USING ALTERNATIVE POLYMER FINAL WASTE FORMS

TASK DESCRIPTION

BNL has identified non-thermal stabilization mechanisms for waste streams that cannot be stabilized by vitrification. Polyethylene encapsulation and modified sulfur concrete encapsulation are thermoplastic methods that can stabilize mercury and chloride salts. Polymer impregnated concrete can stabilize tritiated aqueous wastes.

Plans for FY94 include:

- submittal of Project Test Plans for the three alternative systems;
- surrogate waste production;
- incorporation of surrogate wastes into polyethylene encapsulation and modified sulfur concrete encapsulation systems;
- incorporation of tritiated aqueous wastes into the polymer impregnated concrete system;
- final waste form evaluation for the processes; and
- full-scale demonstration of the thermoplastic encapsulated technology showing the most promising treatability results. These technologies will be applied to other waste streams that cannot be treated by incineration or vitrification.

TECHNOLOGY NEEDS

Liquid mercury, chloride salts and tritiated aqueous waste streams are not easily treated by incineration or vitrification methods. DOE facilities at Oak Ridge, Savannah River, Fernald, Hanford and Rocky Flats need improved technologies for these areas.

ACCOMPLISHMENTS

Previous polymer encapsulation work at BNL for chloride and fly ash contaminants has established equipment and resources. Results have been obtained showing extremely low leachability. The process flow charts for the polyethylene encapsulation, the modified sulfur cement encapsulation and the polymer impregnated concrete are shown in Figures 1.4.2a, 1.4.2b, and 1.4.2c.

COLLABORATION/ TECHNOLOGY TRANSFER

BNL has received approval for a CRADA with Specific Nuclear, commercial radwaste services in Columbia, South Carolina, to fund the polyethylene encapsulation process. Industrial partnership for the modified sulfur cement encapsulation will be identified upon pilot scale-up work.

BNL will continue to coordinate alternate final waste form characterization with other MWIP

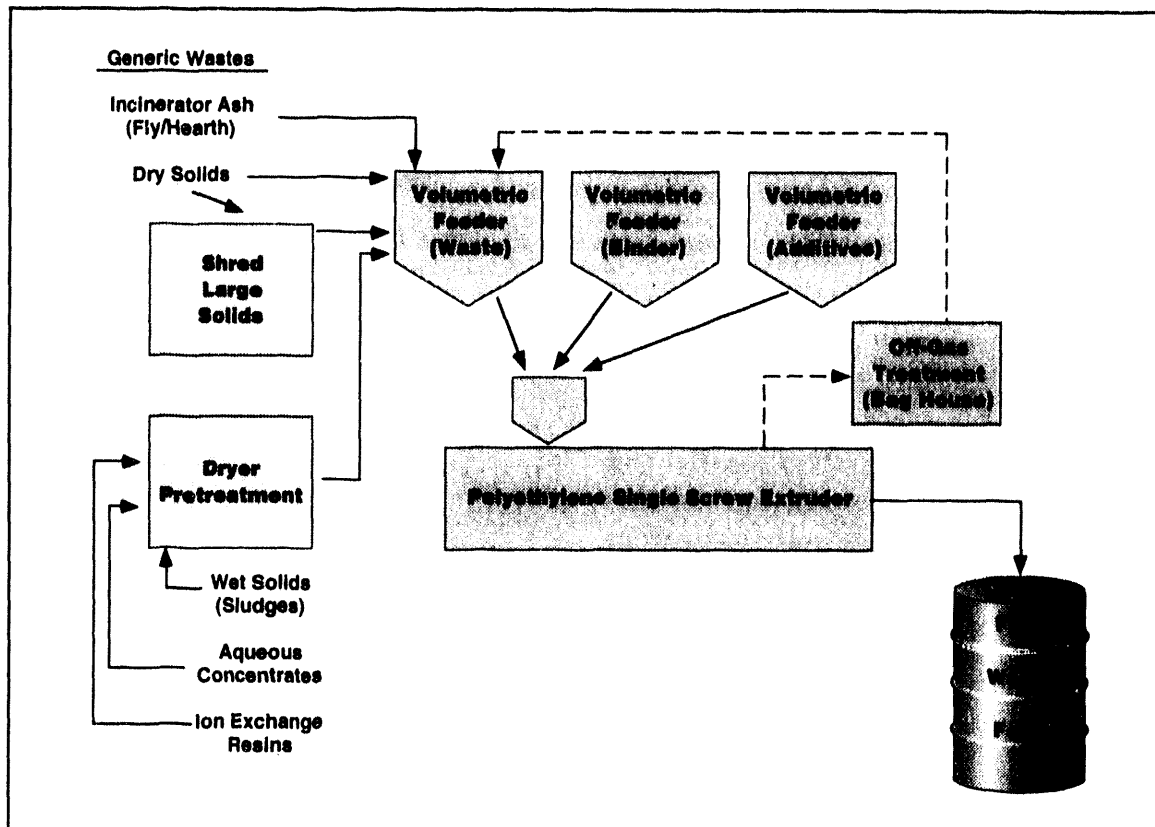


Figure 1.4.2a. Polyethylene Encapsulation Process Flow.

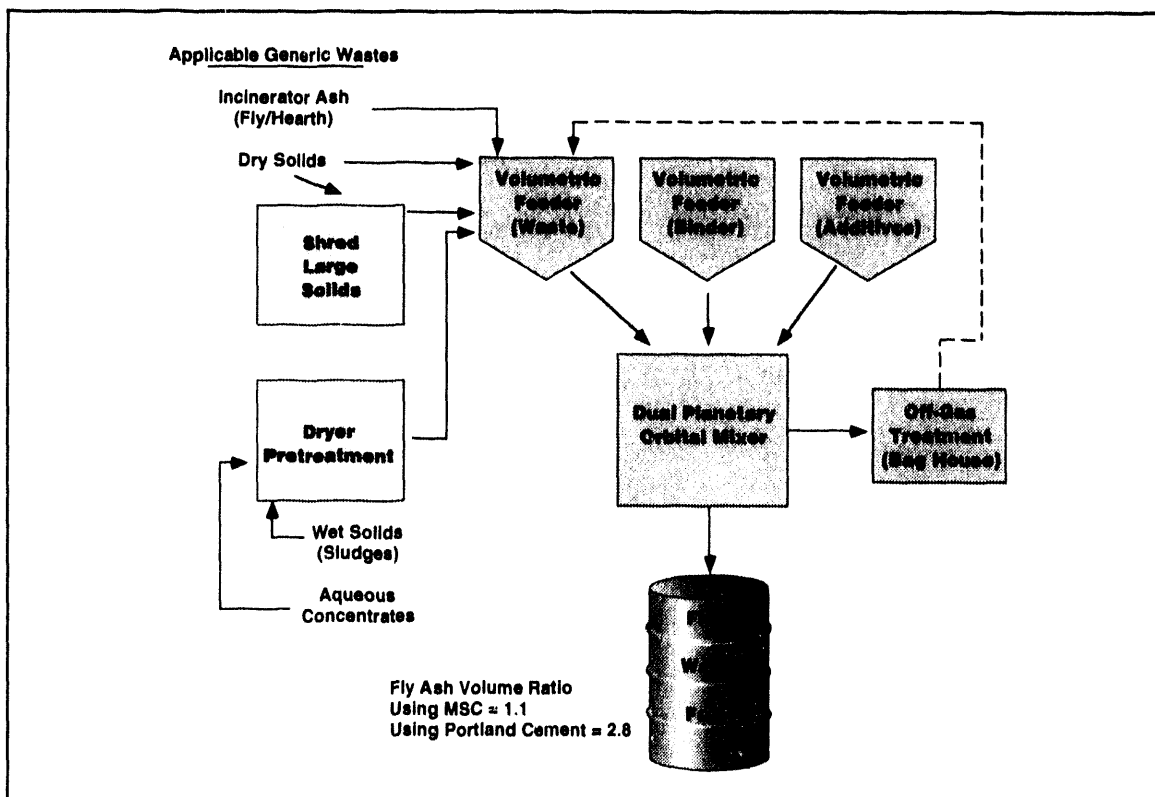


Figure 1.4.2b. Modified Sulfur Cement Encapsulation Process Flow Diagram.

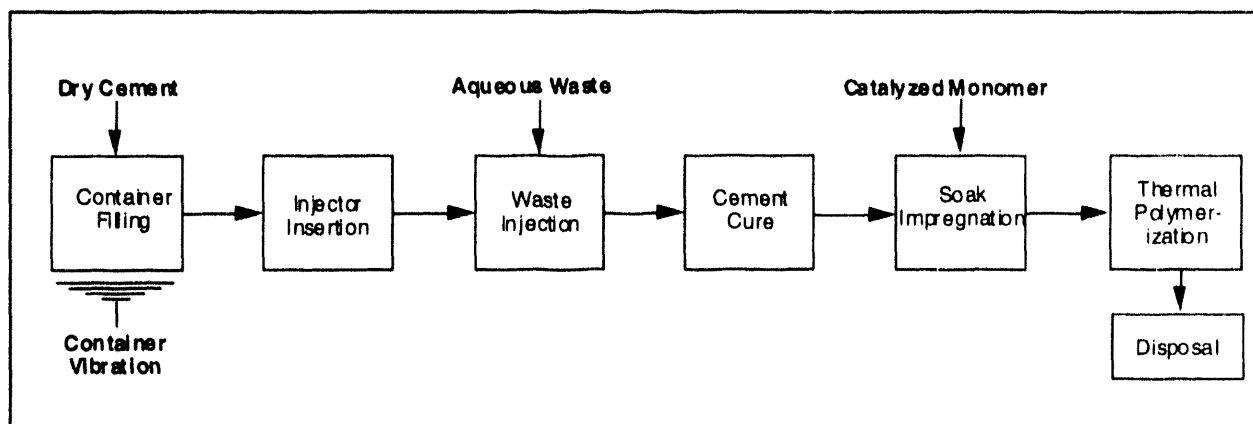


Figure 1.4.2c. Conceptual Fixation of Aqueous Waste in Polymer Impregnated Concrete By The Injection Technique.

projects, such as the ceramic phosphate work at ANL. Future collaborations will involve Ames Lab for process monitoring systems and the University of Cincinnati for non-destructive evaluation of the final waste form.

████████████████████████████████████████

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1.4 FINAL WASTE FORMS

1.4.3 CHARACTERIZE TO TREAT: MWIP-PLASMA HEARTH PROCESS MIXED WASTE WORKING GROUP

TASK DESCRIPTION

This project addresses the level of characterization required of mixed waste prior to treatment in the plasma hearth process (PHP). Significant characterization is needed for less robust processes, whereas plasma hearth treatment is more robust and is amenable to a wide range of feed stream compositions. Less characterization requirements would significantly reduce the economic requirements.

A goal of this project is to demonstrate that the EPA "debris" rule is applicable to heterogeneous mixed waste. This will reduce characterization costs and worker exposure. Applicability of the "debris" rule will be accomplished by coordinating with other PHP projects to show that PHP can tolerate a wide range of feed stream compositions.

TECHNOLOGY NEEDS

EPA requires the characterization of waste intended for treatment to ensure that process limits will not be exceeded and process effluents will meet established requirements to protect human health and the environment.

ACCOMPLISHMENTS

Requirements, such as the National Environmental Policy Act regulations and other regulatory requirements, are being pursued.

COLLABORATION/TECHNOLOGY TRANSFER

A pro-active approach to involve the appropriate regulators in the process of reducing characterization requirements for the plasma hearth process has been taken. The group includes: the State of Idaho, the EPA, the Western Governor's Association Mixed Waste Working Group, and other stakeholders (public figures and the general public). Interagency agreements (IAGs) shall be utilized to obtain EPA representation in technical and permitting matters. Formal procedures will be followed to help insure that advantages to be gained under this project are realized as soon as possible.

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Ongoing Projects

(Started in FY93 or earlier, and continuing in FY94)

Section 2.0

2.1 CHEMICAL/PHYSICAL TREATMENT

2.1.1 MIXED WASTE MERCURY CONTROL

TASK DESCRIPTION

Mercury-contaminated mixed wastes occur in many forms throughout the DOE Complex. A preliminary inventory of selected DOE sites indicates that the majority of these wastes fall into the aqueous liquids/sludges category. Other waste categories include combustible liquids and solids, and noncombustible solids. The goal of this task has been to provide an assessment of the state-of-the-art technology with regard to processing mercury-contaminated mixed waste. A total of nineteen technologies were assessed for the four waste categories.

EPA has selected incineration as the Best Demonstrated Available Technology (BDAT) for combustible solids and liquids. For the removal of traces of mercury from incinerator off-gas, two available technologies were found: Mersorb pellets, and the Boliden/Norzinc process. Beds of Mersorb pellets offer the potential for a simple process with no process control complications. The Boliden/Norzinc process is relatively complex; it uses a mercurous chloride/mercuric chloride reactor and a scrubber and yields mercurous chloride as a product.

Mercury can be separated from noncombustible solids and aqueous sludges by acid leaching, thermal treatment, contact with chlorine or iodine to form soluble halide complexes, or contact with sulfide solutions to form soluble mercury polysulfide. Acid leaching is the BDAT for certain mercury-bearing nonwastewaters (such as K071). Contact with KI/I_2 solution to form soluble mercury iodide complexes is the subject of a recent General Electric patent. Leaching

tests of metallic and eight mercury compounds from a synthetic soil matrix gave promising results.

Nine technologies were found for mercury separation from aqueous liquids. Sulfide precipitation is the BDAT for K071 wastewaters. A number of promising ion exchange resins were identified. Strongly basic and weakly basic anion exchange resins can be used to remove halide complexes, but not selectively. The strongly basic anion resins can be used over a wide pH range, while the weakly basic resins can be used for neutral and acid solutions and regenerated with alkaline solutions. Resin containing the iminodiacetic group (e.g., Ionac SR-5) picks up cationic mercury selectively from calcium and magnesium, but cobalt and copper are also picked up. A thiol resin, which is selective for mercury in the cationic form, has been used at Savannah River; however, regeneration of these resins is difficult because of the insolubility of mercuric sulfide.

Chelating resins containing the isothiuronium group were found effective for both inorganic mercury and dimethyl mercury from solutions containing large amounts of divalent cations. A technology with unique potential advantages for aqueous liquids is the 3M/IBC membrane technology which uses a highly porous Teflon membrane containing small (5 to 10 micron) silica particles with crown ethers attached to their surfaces. This technology is in commercial use for some contaminants, but is in development for mercury.

TECHNOLOGY NEEDS

A large number of sites throughout the DOE Complex have mixed waste streams containing various mercury compounds in various waste matrices. There is a need to separate mercury from the radioactive components to allow disposal as a low-level waste (LLW). Although development of technologies for mercury removal has been significant, an understanding of the fate of radionuclides in these processes is needed.

- Perform bench scale tests using the Mersorb process;
- Perform treatability studies with selected DOE mixed wastes; and
- Carry out engineering scale leaching tests on the most promising of the solids and aqueous mercury treatment processes.

COLLABORATION/TECHNOLOGY TRANSFER

An initial *Commerce Business Daily* (CBD) Announcement was issued to solicit responses from industry.

The Principal Investigator has worked closely with General Electric on the KI/I₂ process; with 3M Company and PNL on the 3M/IBC membrane technology; and with NUCON International, Inc. on the Mersorb technology.

ACCOMPLISHMENTS

To provide a realistic picture of the varieties of mercury-containing mixed waste streams, inventories for four major sites were obtained from the Hazardous Waste Remedial Action Program (HAZWRAP), and nineteen technologies were evaluated for mercury removal from these waste streams. A report was published describing these waste streams and technologies. Recommendations for further development include acid leaching and the General Electric KI/I₂ leaching process for noncombustible solids and aqueous sludges, and activated carbon beds impregnated with sulfur for aqueous streams. Two other methods that were recommended for further investigation include ion exchangers and 3M/IBC membrane technology.

The project includes the following tasks:

- Select single, outstanding mercury containing mixed waste at 3-4 DOE sites;

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2.2 WASTE DESTRUCTION AND STABILIZATION

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

TASK DESCRIPTION

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

Organics are destroyed, while metals and inorganics are melted. A vitrified (glassy) waste form is the final product of the process.

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

Under plasma arc technology development and application projects, representative surrogate

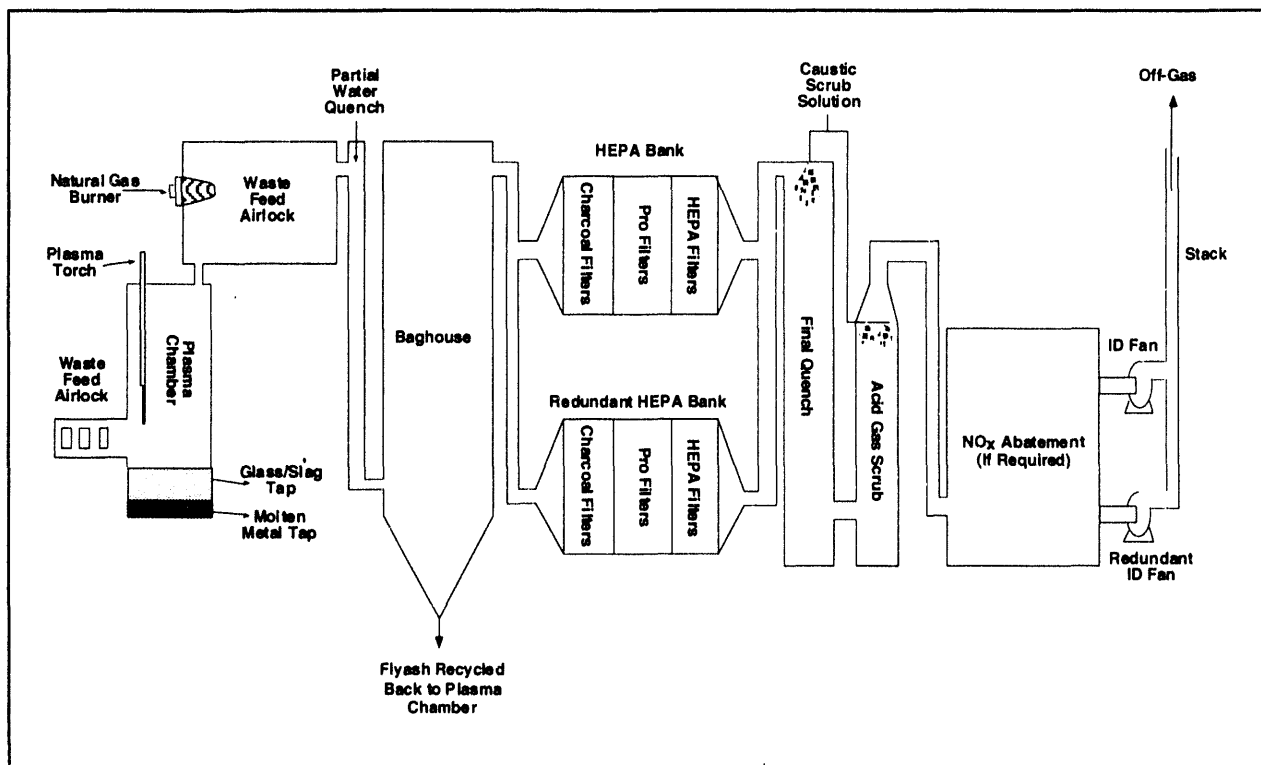


Figure 2.2.1. PHP Prototype Design.

waste streams will be treated in a plasma arc furnace to determine the applicability of the technology and any unique processing requirements. Surrogates will initially not contain radioactive components. Partitioning of radionuclide surrogates will be determined, and a design for a second generation plasma arc furnace which will safely treat mixed low level (radioactive) wastes will be developed and tested. Waste stream characteristics which are required for processing will be determined, and the project staff will work with regulatory entities to determine the minimal characterization parameters required to meet regulatory requirements while ensuring process safety and effectiveness. Representative final (vitrified) waste forms produced by the process will be evaluated for their performance with respect to leachability, mechanical strength, integrity, and other parameters which will be determined under the project (see Figure 2.2.1).

TECHNOLOGY NEEDS

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

The fixed hearth plasma arc process provides a relatively near-term solution to these technology needs. Plasma arc technology has been in

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

ACCOMPLISHMENTS

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

COLLABORATION/ TECHNOLOGY TRANSFER

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

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2.3 FINAL WASTE FORMS

2.3.1 WASTE FORM AND VITRIFICATION PROCESS DEVELOPMENT FOR MIXED WASTE

TASK DESCRIPTION

The purpose of this project is to modify high-level waste vitrification technology with adaptations from commercial melting processes for the treatment of low-level mixed wastes. The study is investigating the glass-making process and its environmental impact (e.g., air emissions), as well as the environmental impact of the finished product. DOE's Savannah River Site plans to use glass vitrification technology in stabilizing high-level radioactive waste; this effort will help to determine how industries can use vitrification to process low-level mixed waste. Specific tasks include realistic simulation and pilot-scale testing, and examining factors such as waste form quality, potential for air emissions, and economics.

Wastes to be tested in FY94 include inorganic waste sludges, incidental/low volume combustible liquids; ion exchange resins (organic and inorganic); Waste Component Recycle, Treatment, and Disposal Integrated Demonstration (WeDID) electronic components; simulated ash; and heterogeneous and drummed solid waste simulants.

TECHNOLOGY NEEDS

The final waste form generated by vitrification is predicted to be stable for thousands of years. The vitrification process can include recovery of metals from the waste stream for recycling, and can allow for removal of non-hazardous materials from the vitrified stream, reducing the volume of hazardous waste.

Vitrification has been applied to high-level radioactive waste, but has not been demonstrated as cost-effective for mixed low-level radioactive waste. This project is developing glass/ceramic waste forms and demonstrating processes that use commercially available melters, which should prove to be more economically viable. Results of this project will allow systems analysis and cost/benefit comparisons to evaluate options regarding up front separation of problem components, or off-gas treatment.

ACCOMPLISHMENTS

Test runs using vitrification to treat sludge simulants were conducted in FY93 with favorable results. A Data Acquisition System and the first set of measurement instruments have been set up at the vitrification facility. The equipment allows for real-time measurement of key melter parameters, as well as logging of test data. The characterization data will facilitate the analysis and interpretation of glass durability results.

Air emissions and key parameters related to environmental impact are currently being studied. Off-gas temperature in the cold-top furnace has been monitored and found generally to be below the temperature range where significant volatilization of toxic metals occurs.

COLLABORATION/ TECHNOLOGY TRANSFER

This project is a collaboration between Clemson University, the Westinghouse Savannah River Company, 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 (see Figures 2.3.1a and 2.3.1b). Rust Remedial Services (Chem Waste Management, Inc.) is providing chemical analysis services, waste form characterization, and engineering support. The Savannah River Site is contributing its expertise on how the glass should be made. This project is being supported by

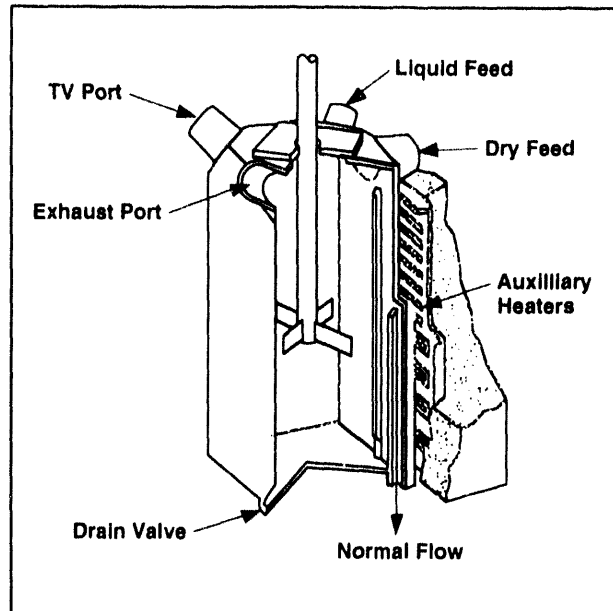


Figure 2.3.1b. Stir Melter Furnace.

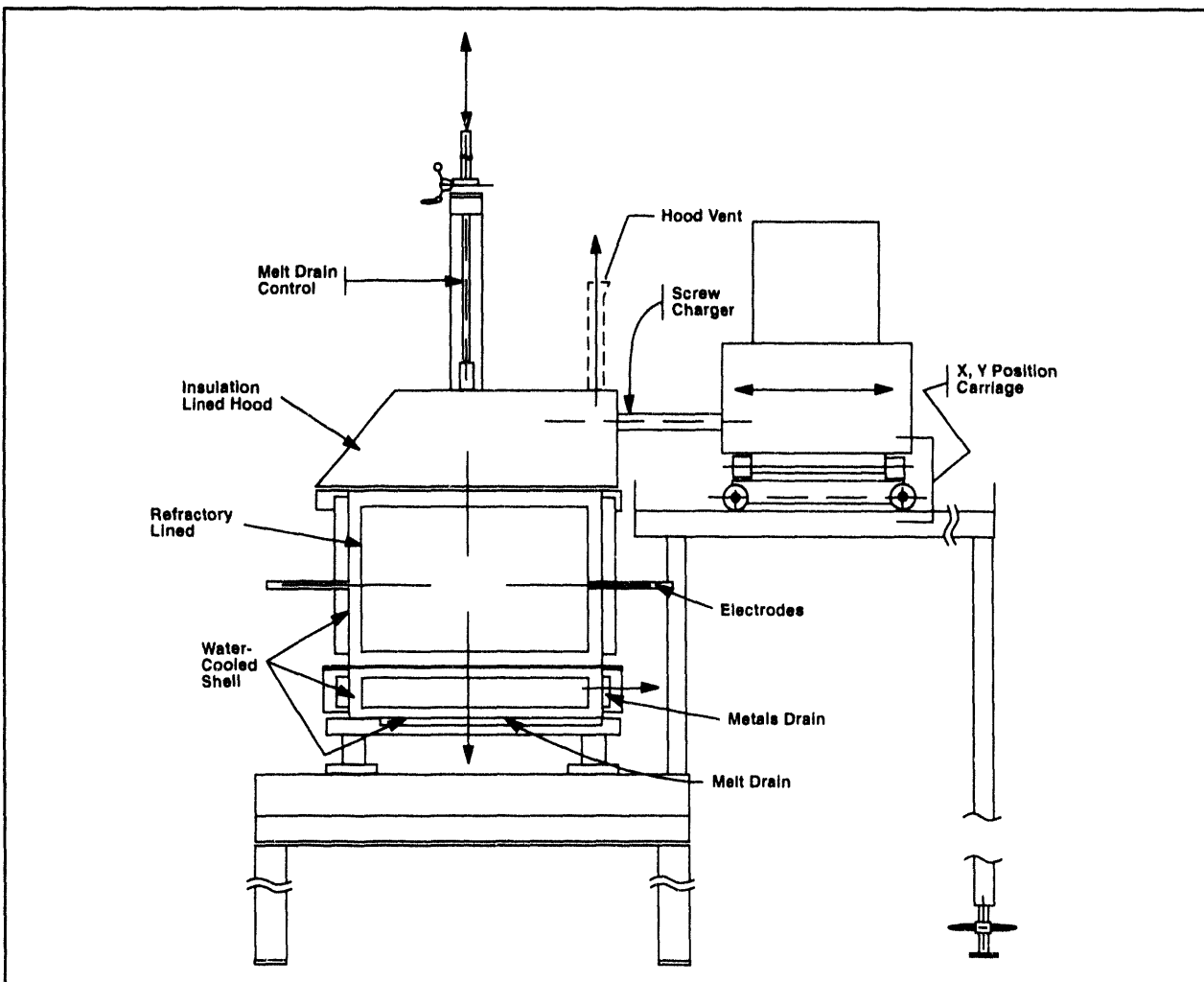


Figure 2.3.1a. EnVitCo Cold Top Melter Furnace.

MWIP, Savannah River Site's High-Level Waste Program, WeDID, and the Waste Management and Environmental Restoration International Programs Office.

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2.3 FINAL WASTE FORMS

2.3.2 VITRIFICATION TESTING AND DEVELOPMENT

TASK DESCRIPTION

This project focuses on identifying the chemical and physical characteristics of wastes, primarily debris, based on the MWTP flowsheet; conducting a feasibility analysis of processing in available vitrification systems; generating a plan for performing testing to establish process limitations; and conducting research and development efforts. Specific tasks include:

- conducting melt studies on surrogate mixed waste;
- characterizing mixed waste glasses;
- evaluating effects of halides and organic compounds in melter feed;
- evaluating feed composition variability and incorporation of metals in glass; and
- establishing processing rates in appropriately scaled equipment.

Standard surrogate waste streams and test procedures were used in the tests in FY93.

TECHNOLOGY NEEDS

This project enables treatment of solid process residues and inorganic debris, and provides a basis for establishing the ability of a vitrification system to treat combustible/noncombustible debris in a regulatory-acceptable manner. The vitrification system is shown in Figure 2.3.2. Possible design modifications necessary to im-

prove the performance of vitrification technologies are being identified. The critical properties to be established by testing are waste loadings, leachability (TCLP; radionuclides), and durability (i.e., the compressive strength). The project will provide engineering-scale data on heavy metal retention and organic destruction.

ACCOMPLISHMENTS

The Vitrification Technology Plan for DOE waste was completed. Preliminary glasses for Rocky Flats process sludge, Los Alamos National Laboratory (LANL), process sludge, LANL ash, Oak Ridge Y-12 sludge, and TSCA bottom ash, and small-scale melter tests on surrogate Rocky Flats process sludge and LANL sludge were completed. A 28 day MCC-1 leaching of Rocky Flats waste glass was completed at MIT. Melter testing at Clemson University will be performed on Oak Ridge Y-12 glass compositions.

COLLABORATION/ TECHNOLOGY TRANSFER

Joint participants include Clemson University and Massachusetts Institute of Technology. This project compliments the Waste Form and Vitrification Process Development for Mixed Waste ("Vitrify to Delist to Dispose") project.

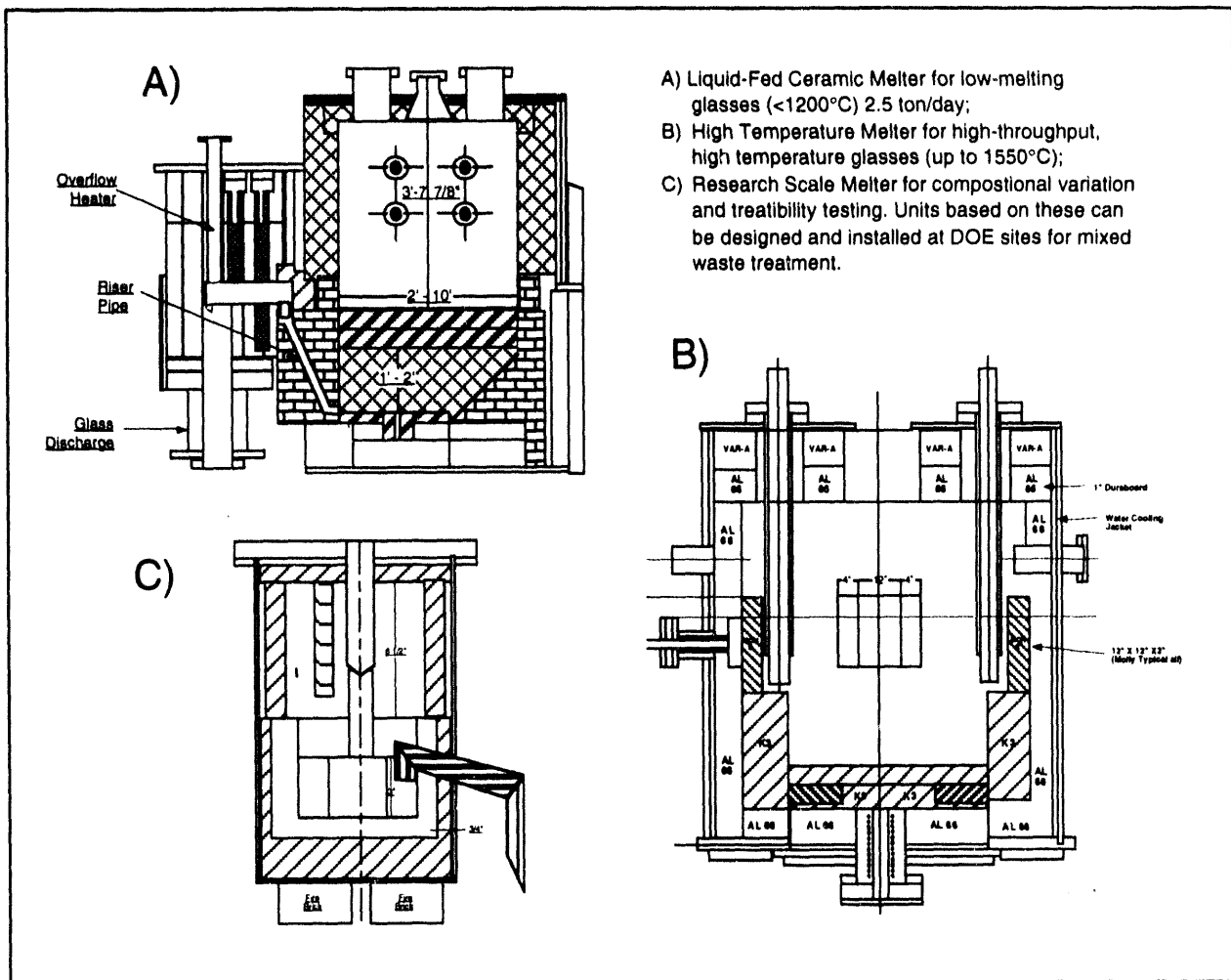


Figure 2.3.2. Vitrification Testing and Development.

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2.3 FINAL WASTE FORMS

2.3.3 WASTE FORM PERFORMANCE CRITERIA

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, to 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.

TECHNOLOGY NEEDS

Testing procedures have been established by several government and nongovernment organizations: NRC, EPA, IAEA, ASTM. These need to be evaluated for their applicability to mixed waste. Uniform waste form performance criteria will be used to demonstrate that newly developed technologies meet applicable standards, and to 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 within 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.

ACCOMPLISHMENTS

A preliminary draft on final waste form performance criteria has been written and is currently undergoing peer review for comments. The performance criteria specifically examine glass compressive strength and resistance to the release of radionuclides under wet conditions.

COLLABORATION/ TECHNOLOGY TRANSFER

This work is being performed in collaboration between Brookhaven National Laboratory (BNL), INEL, and Battelle PNL, with BNL as the lead.

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2.4 PROCESS MONITORING AND CONTROL

2.4.1 TREATMENT CONTROL STRATEGIES AND TECHNOLOGIES FOR IMPROVED PROCESS CONTROL, SAFETY AND EFFICIENCY

TASK DESCRIPTION

The principal characteristic that differentiates DOE's environmental remediation and waste management requirements from those associated with regulated hazardous and toxic waste is the radiological component of DOE's waste streams. Radioactive transuranic elements and elements of the actinide series must be controlled under DOE regulations. The public expectation is that radiological components will be strictly controlled and continuously monitored while under processing to avoid the unintended (uncontrolled) release of radionuclides to the atmosphere or other phase compartments in which radionuclides could be mobile (e.g., soil, groundwater) and pose a threat to human health or the environment.

MWIP is seeking to ensure that technologies are available to monitor, on a real-time and continuous basis, radionuclides, hazardous metals and other components of mixed wastes that must be treated for disposal and/or delisting under such environmental regulations as RCRA. MWIP intends to accomplish this goal by identifying and characterizing the state-of-the-art of process monitoring sensors and instruments, process control and optimization algorithms, and gaps in required technologies, and, by sponsoring or co-sponsoring technology development programs, to fill identified technology gaps in DOE's unique MLLW treatment programs.

TECHNOLOGY NEEDS

Process characterization, monitoring and control technologies are needed to ensure that uncontrolled releases of radionuclides to the environment do not occur in DOE's hazardous and toxic waste treatment processes. Additionally, improved process characterization, monitoring, and control technologies for MLLW are necessary to ensure worker health and safety, to reduce costs of processing MLLW, and to ensure that waste volumes are reduced through optimization of integrated treatment processes.

ACCOMPLISHMENTS

MWIP is currently supporting the Diagnostic Instrumentation and Analysis Laboratory (DIAL) at Mississippi State University. DIAL is developing Fourier Transform Infrared (FTIR) Spectrometers, Coherent Anti-Stokes Raman (CARS) Spectrometers, and Laser Optogalvanic Spectrometers (LOGS). These methods can detect atomic and molecular species (including metals) in waste streams and on surfaces. A laser Doppler velocimeter has been demonstrated to measure flow velocities to 1,500 meters per second. Various remote temperature measurement systems are under development or testing, including an optical pyrometer, LOGS, a potassium emission/absorption system (PE/AS), and CARS. An extractive gas analysis system has been developed and tested for carbon

monoxide, carbon dioxide, sulfur dioxide, molecular oxygen, nitrous oxides (NOx), and hydrocarbons. A self-cleaning optical port has been developed that can blow off any slag formed over its entry port in combustion chambers or off-gas systems.

MWIP has sponsored the development of surrogate waste to develop and test instrumentation and treatment methodologies in facilities that are not permitted for treatment of specific radiological/hazardous (mixed) wastes. MWIP intends to perform live tests of its technologies under development in a permitted facility to ensure that its technologies are providing the capabilities intended and to assist in design and permitting efforts. An additional critical goal of developing and executing live tests is to develop concrete specifications to guide the development of monitoring and control technologies.

MWIP is investigating process monitoring and control technologies for application to DOE treatment processes. This investigation encompasses traditional monitoring and control strategies and is being extended to encompass artificial intelligence expert systems, fuzzy logic, and neural network systems. Integration of these technologies should provide a reliable sensor fusion/process monitoring and control capability which can detect excursions from desired process conditions and rapidly correct process set points to contain any such excursions. This predictive capacity, will provide DOE with the capability to simulate processes and excursions from desired behaviors to investigate means to avoid such excursions before waste processing

begins. Additionally, the predictive capacity to be developed will permit the rapid integration and optimization of treatment processes.

COLLABORATION/ TECHNOLOGY TRANSFER

MWIP has co-sponsored a workshop to identify characterization, monitoring, and process control requirements and available technologies. MWIP is developing relationships with industry to ensure that available capacities are not overlooked and to encourage industry's participation in technology development and transfer. MWIP is currently developing a TASR that will catalog available technologies, technologies under development, points of contact within DOE, general requirements, and vendors of technologies. MWIP is implementing a policy that requires private sector (industrial and academic) participation in its technology development activities.

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2.5 SYSTEMS ANALYSIS FOR MIXED WASTE INTEGRATED PROGRAM

TASK DESCRIPTION

The MWIP systems analysis coordinates potential alternatives to baseline technology (see Figure 2.5). Work focuses on safety risk assessment, performance systems analysis, and life-cycle costs for OTD-developed subsystems. This includes an analysis of technology subsystems that have the potential to improve baseline technologies. The MWIP systems analysis group is developing alternative flowsheet models for baseline processes, which were developed by the Mixed Waste Treatment Project (EM-30). The alternative flowsheet processes involve mass

and energy balances, and could possibly improve baseline technology by analyzing replacement subsystems of the master model.

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

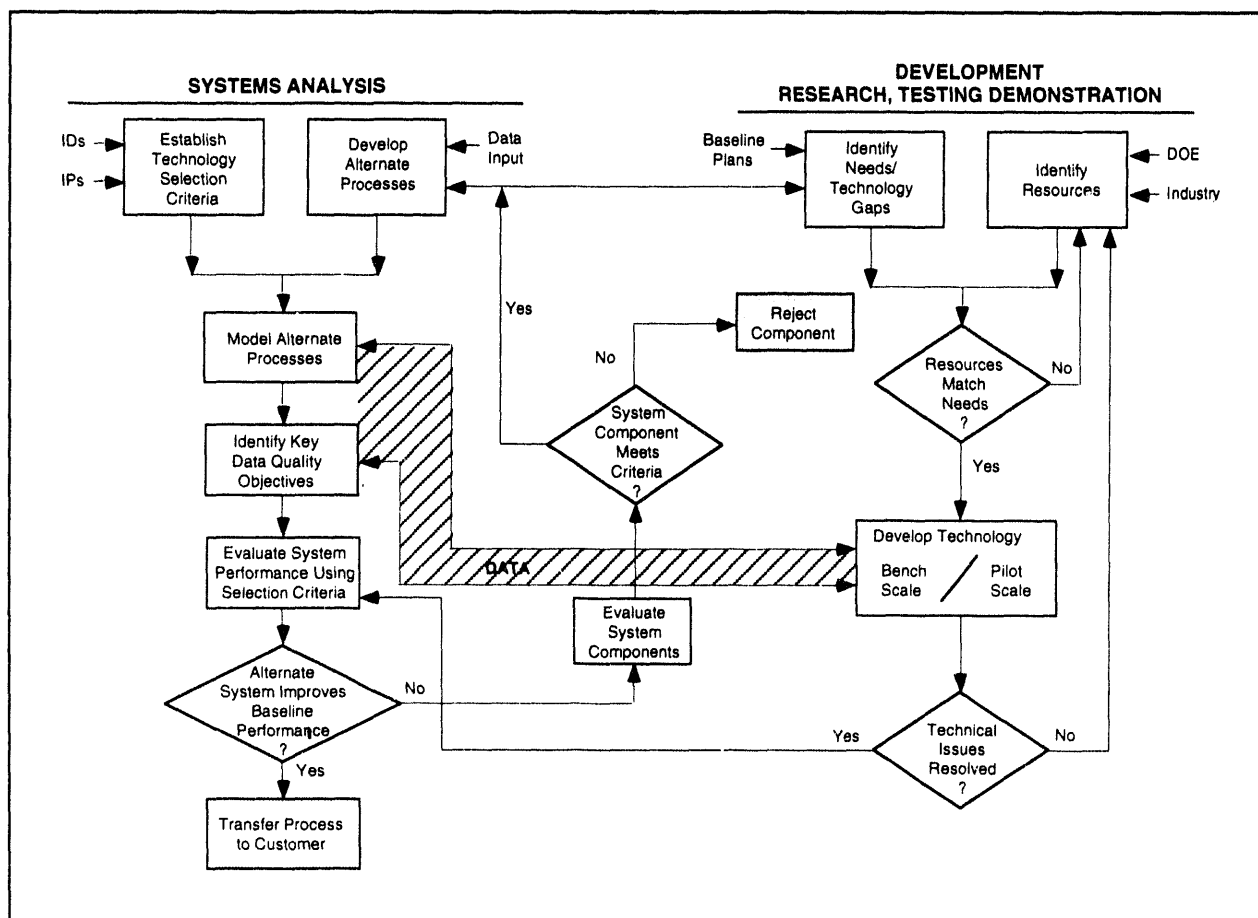


Figure 2.5. Systems Analysis.

The systems analysis group completed a pre-

Juan J. Ferrada

Jeannette B. Berry

Transferred Projects

Begun in MWIP

**(Started in FY93 or earlier,
& not continuing in FY94)**

Section 3.0

3.1 CHEMICAL/PHYSICAL TREATMENT

3.1.1 DETOX PROCESS DEMONSTRATION

TASK DESCRIPTION

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

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

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

These studies demonstrated that the DETOX solution oxidized the simulated wastes at practical rates with temperatures ranging from 200°C to 225°C. Reaction rate constants obtained in these preliminary studies indicated that a 100-liter DETOX reactor could oxidize 500-8000 grams per hour of these waste materials. It was found that the ratio of iron (III) to iron (II) had little effect on the apparent reaction rate or the formation of reaction intermediates, and reaction intermediate compounds had no significant effect on oxidation reaction rates. The reaction rates increase with the addition of small amounts of sulfate and phosphate, decrease in the presence of ammonium ions, and decrease when the acidity of the DETOX solution exceeds 1M.

Because acids will be formed when halogenated organics are oxidized, a pilot plant will require a neutralization system to maintain acidity levels. It was also found that the oxidation reaction rate of the DETOX process is dependent upon the surface area and organic concentration. The organic concentration in the present reactor configuration is limited by the amount of oxygen that can be preloaded into the reactor. Future development work should use a system that operates continuously with the ability to replenish oxygen.

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

COLLABORATION/ TECHNOLOGY TRANSFER

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

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3.1 CHEMICAL/PHYSICAL TREATMENT

3.1.2 ELECTRON BEAM WASTE TREATMENT TEST BED

TASK DESCRIPTION

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

The process of irradiation in aqueous solutions produces sizable quantities of the free radicals eaq^- , $\text{H}\cdot$, $\text{OH}\cdot$, and the more stable oxidant H_2O_2 . These highly reactive species react with organic contaminants to produce CO_2 , H_2O , and salts that are no longer hazardous. LANL has configured an existing electron accelerator, operating in a single-pulse mode (65-ns pulse width), for technology evaluation studies and demonstrated destruction of two hazardous organic compounds characteristic of priority mixed wastes. Computer-based chemical kinetic models have been developed to predict the expected removal efficiency and to compare standard electrostatic accelerators to pulsed accelerators in terms of free radical production.

Recently, an e-beam pilot plant, capable of treating an aqueous hazardous waste stream at a flow rate of 120 gpm, has been devel-

oped at Florida International University (FIU). This plant uses a 1.5 Mev continuous duty profile accelerator to produce doses in water approaching 1 Mrad. Studies at that plant used influent streams of potable water, and raw and secondary wastewater. Typical efficiencies for removing various organics at low and moderate e-beam doses are given in Table 1. Removal efficiencies range from 85% to greater than 99% for most common solvents.

Computer modelling shows that a continuously applied e-beam dose is more efficient in destroying waste than the same amount of pulsed dosage due to less radical-radical recombination, and that a repetitively pulsed machine can produce similar radical concentrations to those of a DC machine when pulsed at high repetition rates (e.g., 10 kHz). The model has also been modified to include radical scavengers normally occurring in potable and natural water (e.g.,

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

Table 1. FIU Experimental Removal

carbonates). Scavenger-included calculations are compared with FIU experimental results in Figure 3.1.2; this high correlation provides confidence in the models. Initial evaluations indicate that e-beam irradiation also holds promise for the treatment of nitrates in aqueous solution or sludges due to the production of large amounts of reductive, as well as oxidative, free radicals.

TECHNOLOGY NEEDS

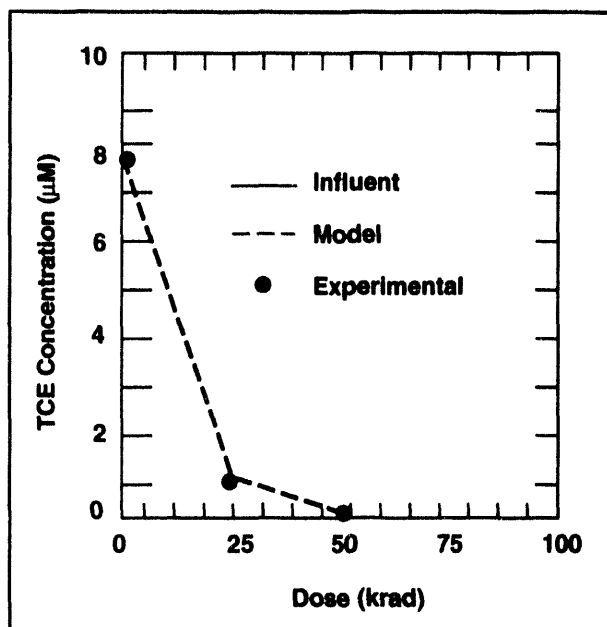


Figure 3.1.2. Simulated and Experimental Removal of 1 ppm TCE in Potable Water.

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

ACCOMPLISHMENTS

The following conclusions have been made based on these efforts:

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

COLLABORATION/ TECHNOLOGY TRANSFER

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


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3.1 CHEMICAL/PHYSICAL TREATMENT

3.1.3 NITRATE DESTRUCTION

TASK DESCRIPTION

The goal of this task has been to provide an assessment of the state-of-the-art with regard to technologies that could be used to destroy nitrates in aqueous mixed wastes stored throughout the DOE Complex. The nitrate destruction technologies that were evaluated include the following:

- Nitrate to ammonia and ceramic (NAC) process which produces an insoluble waste form with a significant reduction in volume. This process produces ammonia so further off-gas treatment is required, the process is highly exothermic so safety controls are required, and an inert gas cover is required to prevent a potential explosive reaction between the ammonia and hydrogen gases produced in the reaction. The process schematic is shown in Figure 3.1.3a.

- Electrochemical reduction destroys nitrates without any chemical addition and the process can be used on acidic or alkaline wastes. However, other ions may plate out on the electrodes, release of off-gases requires further evaluation, the

process requires significant quantities of make-up water, and NaOH byproduct must be disposed. A schematic of the destruction cell is shown in Figure 3.1.3b.

- Hydrothermal processes can simultaneously treat nitrates and organics in both acidic and alkaline wastes producing nitrogen gas.
- Biological denitrification has a slow denitrification rate dictating large bioreactors, and the bacteria have a low tolerance for sodium and require a narrow pH and salt concentration range.
- Chemical reduction requires acidification of alkaline wastes, converts nitrates to nitrogen oxides requiring off-gas treatment, and the process is potentially unstable so safety controls will be required.

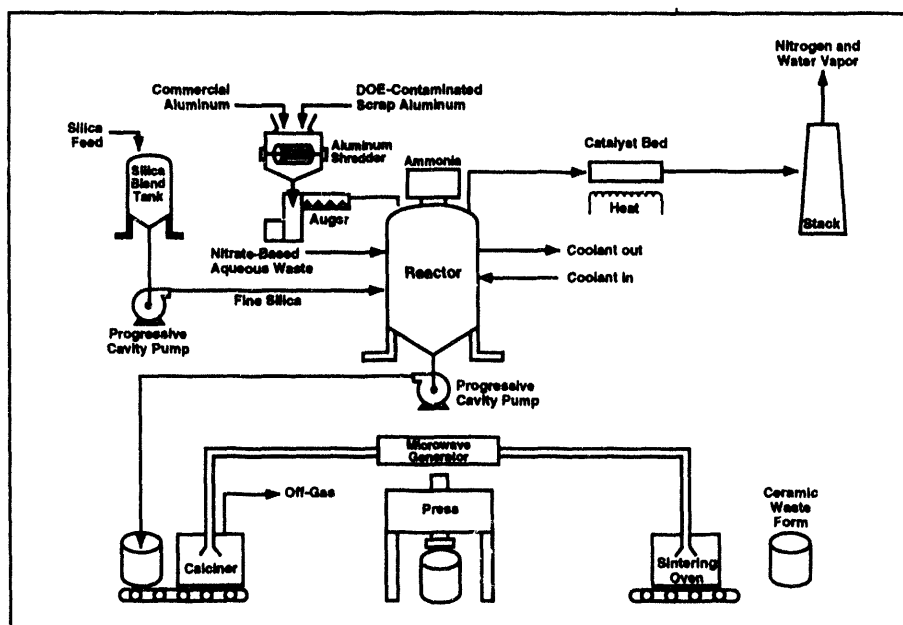


Figure 3.1.3a. Flow Diagram For Nitrate To Ammonia and Ceramic.

- Calcination has been used at INEL for many years to solidify low sodium wastes; however, with alkaline wastes, which are primarily sodium nitrate, the sodium nitrate melts rather than decomposing at the operating temperature of 500°C. The off-gas must also be treated to remove NO_x.

All of the nitrate destruction technologies will require further development before a facility can be designed to treat the majority of the stored mixed waste. This study resulted in a recommendation that development work continue on the NAC, electrochemical destruction, and hydrothermal processes. More information is needed on the capabilities and potential prob-

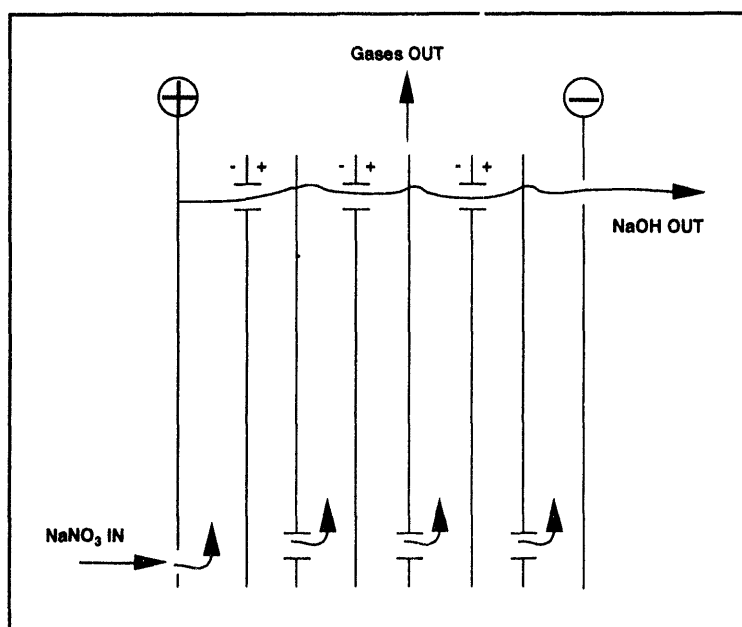


Figure 3.1.3b. Destruction Cell Used to Reduce.

lems of these processes before a rational decision can be made regarding the best process for treating a particular waste stream.

TECHNOLOGY NEEDS

A wide variety of nitrate-containing aqueous mixed wastes are produced and/or stored at various DOE facilities. These wastes generally have very high concentrations of nitrates (either sodium nitrate or nitric acid), high levels of radionuclides and heavy metals and/or solvents. The nitrates in the wastes will generally increase the volume and/or reduce the integrity of all the waste forms that have been proposed for ultimate disposal, so nitrate destruction prior to solidification is expected to be beneficial.

ACCOMPLISHMENTS

To provide a realistic picture of the varieties of nitrate-containing aqueous mixed waste streams, inventories from several major sites were obtained, and six major technologies were evaluated for nitrate destruction. A report was published describing these waste streams and technologies, advantages and disadvantages of the technologies, and results of the technology evaluation including recommendations for further technology development.

COLLABORATION/ TECHNOLOGY TRANSFER

An initial *Commerce Business Daily* announcement was issued to solicit responses from industry.

The Principal Investigator worked closely with the sites at which nitrate-containing wastes are stored, with researchers developing emerging technologies, and with waste management personnel using existing technologies.

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3.1 CHEMICAL/PHYSICAL TREATMENT

3.1.4 DEVELOPMENT OF POLYMERS TO REMOVE PLUTONIUM AND AMERICIUM FROM WASTEWATERS

TASK DESCRIPTION

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

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

The raw influent waste stream at the LANL TA-50 Waste Treatment Facility contains a variety of radionuclides and heavy metals in several forms, including those adsorbed onto small particles or colloids, or in solution as cations and/or anions. Several commercial resins were tested to evaluate the metal uptake and elution properties

for subsequent treatment of this waste stream. Studies involving filtration were also performed since filtration is proving to be successful in removing colloidal particles in wastewater with adsorbed radionuclides. Factors such as filter pore sizes required for optimum performance, and the species (radionuclides, heavy metals) and colloidal particle size removed by filtration need to be determined for each waste stream, since there may be considerable variability.

New reagents and polymeric materials that exhibit selectivity for cations (Cd^{2+} , Hg^{2+} , Pb^{2+}) are being designed and synthesized for potential use in treating mixed waste streams. The chelator is a potential binding agent for toxic metals found in mixed waste streams. Preliminary studies indicate that this chelator is very selective for mercury(II) with a binding constant of 1031; the lead binding constant is 1016.

TECHNOLOGY NEEDS

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

be downsized relative to facilities using precipitation/flocculation, considerably reducing capital costs.

ACCOMPLISHMENTS

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

The results of metal uptake studies performed on several commercial resins are shown in Figure 3.1.4. As expected, the Dowex 50, a sulfonated polystyrene, showed very fast metal uptake while the other resins reached the same level in 10 to 30 minutes. Filtration with a 1 micron pore size filter reduced the concentration of plutonium and americium by over 95%.

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

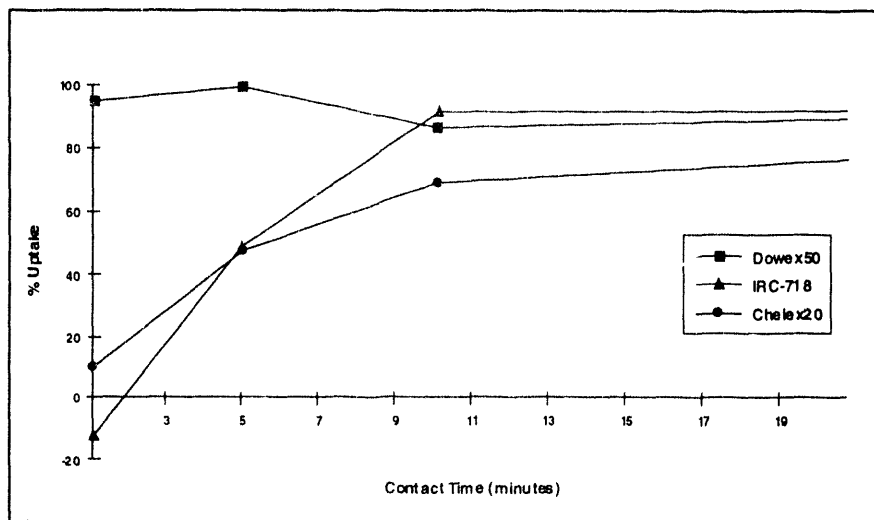


Figure 3.1.4. Americium 241 Uptake.

COLLABORATION/ TECHNOLOGY TRANSFER

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

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3.2 WASTE DESTRUCTION AND STABILIZATION

3.2.1 LIQUID METAL MELT-SLAG TECHNOLOGY EVALUATION FOR MIXED WASTE INTEGRATED PROGRAM

TASK DESCRIPTION

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

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

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

Based upon preliminary studies, melting technologies that were considered to be viable for

treatment of mixed waste and thus justify further examination included:

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

TECHNOLOGY NEEDS

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

A metal melting system would allow DOE to meet legal requirements for treatment and disposal of these complex waste streams. Recent information amplifies the need of this technol-

ogy in that recycled steel is needed for high level waste canisters.

ACCOMPLISHMENTS

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

COLLABORATION/ TECHNOLOGY TRANSFER

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

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

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3.3 OFF-GAS

3.3.1 CONTROL OF METAL EMISSIONS FROM MIXED WASTE INCINERATORS

TASK DESCRIPTION

The purpose of this research is to determine the basic causes of metals emissions from thermal treatment of mixed wastes, to find means to prevent the formation of volatile metal species and promote the formation of low volatility metal compounds that will remain in the ash. The first step was to perform a study of the basic thermodynamics and kinetics of metal pollutant formation in incinerators, including mass-transfer modelling. Theoretical research was applied to a pilot-scale incinerator in field demonstrations, and eventually applied to full-scale industrial operations. The pilot- and full-scale demonstrations sought to determine the effects of changes in operating conditions, feed blends, and fluxes on metal emissions. Initial experimental work principally involved lead oxide, and this experience was applied to the study of other metals, such as uranium, cesium, chromium, and beryllium. This task was also interested in production of a less leachable bottom ash waste form.

TECHNOLOGY NEEDS

EPA has promulgated new, stricter standards on air emissions of ten hazardous metals. Additionally, the concentration of metals in certain mixed wastes precludes their disposal, or creates limitations in the feed rate. Mixed waste incineration is planned at several DOE sites, through currently no incinerator other than the Oak Ridge Mixed Waste Incinerator is in operation. Fur-

ther reductions in radionuclide emissions are dictated by "as low as reasonably achievable" (ALARA) considerations. Retention of metals in the ash reduces the load on the air pollution control system, minimizes the need to remove metals from wet scrubber liquors, and reduces air emissions.

ACCOMPLISHMENTS


In the presence of HCl, lead oxide is converted in incinerators to volatile lead chloride, and is a significant source of emissions. Laboratory results showed that the formation of lead chloride can be minimized by techniques of time and temperature management of waste feeds

Analysis of a uranium-containing waste feed sample indicated the presence of predominantly elemental uranium. Researchers theorize that elemental uranium fed to the high-temperature secondary combustion unit of an incinerator could rapidly oxidize, creating temperatures high enough to volatilize the uranium oxide formed and produce a fine ash fume. This fume is one of the most difficult to remove from flue gas and results in the worst stack gas emissions.

COLLABORATION/ TECHNOLOGY TRANSFER

This project was conducted at ORNL, in conjunction with the University of Tennessee, the

EPA, Lamar University of Texas, and the Risk Reduction Engineering Laboratory. Data gathered from this work are applicable to hazardous waste incineration in general, and thus of interest to a wide range of industries, as well as other government agencies such as EPA and DoD.




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3.4 FINAL WASTE FORMS

3.4.1 MICROWAVE SOLIDIFICATION AND TREATMENT SUPPORT FOR ROCKY FLATS

TASK DESCRIPTION

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

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

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

TECHNOLOGY NEEDS

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

ACCOMPLISHMENTS

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

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


COLLABORATION/ TECHNOLOGY TRANSFER

This task served as technical support to RFP Microwave Solidification Project and the Mi-

microwave Fluidized-Bed Detoxification Process being developed at LANL.

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

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



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Microwave Fluidized Bed
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3.4 FINAL WASTE FORMS

3.4.2 WASTE DESTRUCTION (VITRIFICATION)

TASK DESCRIPTION

The main objective of this project is to develop plans for applying vitrification, a BDAT, for treatment of a wide variety of MLLW streams across the DOE complex. Related activities include the identification of candidate waste streams generated at the RFP, characterizing these waste streams, and identification of surrogate materials for the preparation of simulated wastes. Target glass formulations for bench-scale testing and eventual scale-up to pilot plant testing will be identified.

Process variables such as joule heater temperatures, glass compositions, glass rheology, and feed rates will also be examined after glass compositions are made from Rocky Flats Sludge. An analysis of the testing should yield process data on melting rates, organics destruction efficiencies, combustion rates, and off-gas aerosol emissions. The overall culmination of this effort is to provide the necessary data for design and permitting of a full-scale MLLW treatment facility.

TECHNOLOGY NEEDS

A suitable treatment technology for MLLW does not currently exist, although vitrification to glass form appears promising. Converting waste to glass has been successfully applied to high-level radioactive wastes, and has been utilized since the late 1960s.

Plans for the treatment of RFP generated wastes were to address these needs. The RFP is currently out of compliance with the RCRA since

the hazardous portion of the mixed waste is both Land Disposal Restricted (LDR) and prohibited from storage. The FFCA, along with DOE and EPA, has allowed the RFP to continue operations; however, the condition has been stipulated that technologies suitable for treatment of the LDR waste be developed. Rocky Flats waste water sludge is currently being tested at Savannah River.

COLLABORATION/ TECHNOLOGY TRANSFER

Joint participants in this vitrification effort to treat Rocky Flats waste include PNL, and the Savannah River Site, where glass development will take place.

**For further information,
please contact:**

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How To Get Involved

Section 4.0

WORKING WITH THE DOE OFFICE OF ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

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

Cooperative Research and Development Agreements (CRADAs)

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

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

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

Procurement Mechanisms

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

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

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

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

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

Examples of how to get involved with MWIP are shown in the section titled: MWIP Collaborative Research.

Licensing of Technology

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

Technical Personnel Exchange Assignments

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

Consulting Arrangements

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

Reimbursable Work for Industry

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

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

EM Small Business Technology Integration Program

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

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

CONTACT

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International Technology Exchange Division
EM-523
Environmental Restoration and Waste
Management Technology Development
U.S. Department of Energy
Washington, D.C. 20585
(301) 903-7640

EM Central Point of Contact

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

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

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

Office of Research and Technology Applications

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

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

Claire Sink, Director
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Environmental Restoration and Waste
Management Technology Development
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Acronyms

Section 5.0

5.0

ACRONYMS

ALARA	as low as reasonably achievable
ANL	Argonne National Laboratory
BDAT	Best Demonstrated Available Technology
BNL	Brookhaven National Laboratory
CARS	Coherent Anti-Stokes Raman Spectrometers
CRADA	Cooperative Research and Development Agreement
D&D ID	Decontamination and Decommissioning Integrated Demonstration
DE	destruction efficiencies
DIAL	Diagnostic Instrumentation and Analysis Laboratory
DOE	U.S. Department of Energy
DoD	U.S. Department of Defense
EM	Environmental Restoration and Waste Management (EM)
EM-30	Office of Waste Operations
EM-40	Office of Environmental Restoration
EPA	Environmental Protection Agency
FFCA	Federal Facilities Compliance Act of 1992
FIU	Florida International University
FTCAC	FTC Acquisition Corporation
FTIRS	Fourier Transform Infrared Spectrometers
GPM	gallons-per-minute
HAZWREP	Hazardous Waste Remedial Action Program

HEPA	High-Efficiency Particulate Air
HLW	high-level waste
INEL	Idaho National Engineering Laboratory
ID	Integrated Demonstrations
IP	Integrated Programs
LANL	Los Alamos National Laboratory
LDR	Land Disposal Restriction
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
LOGS	laser optogalvanic spectrometers
LVFTDS	Large-Volume Flow Through Detection Systems
MLLW	mixed low-level wastes
MWIP	Mixed Waste Integrated Program
NAC	Nitrate to ammonia and ceramic
NMWTP	National Mixed Waste Treatment Project
ORNL	Oak Ridge National Laboratory
ORTAs	Office of Research and Technology Applications
OTD	Office of Technology Development (EM-50)
PA	performance assessment
PE/AS	potassium emission/absorption system
PHP	plasma hearth process
PNL	Pacific Northwest Laboratory
PRDAs	Program R&D Announcements

RCRA	Resource Conservation and Recovery
RDDT&E	Research, Development, Demonstration, Technology and Evaluation
RFP	Rocky Flats Plant
ROAs	Research Opportunity Announcements
SAIC	Science Applications International Corporation
SBIR	Small Business Innovation Research
SB-TIP	Small Business Technology Integration Program
SiC	silicon carbide particles
SNL	Sandia National Laboratory
TAGs	Technical Area Working Groups
TASRs	Technical Area Status Reports
TDL	Tunable Diode Laser Spectroscopy
TTPs	Technical Task Plans
VOCs	volatile organic compounds

Mixed Waste Integrated Program Publications

Appendix A

APPENDIX A

MIXED WASTE INTEGRATED PROGRAM PUBLICATIONS

NTIS <u>Ref. #</u>	<u>Reference</u>
MWIP-1	An Assessment of Off-gas Treatment Technologies for Application to Thermal Treatment of Department of Energy Wastes
MWIP-2	Thermal Treatment Technology Development Program - Interim Technology Evaluation Report
MWIP-3	Final Waste Form Technical Area Status Report
MWIP-4	Waste Destruction and Stabilization Technical Area Status Report
MWIP-5	Secondary Destruction and Off-gas Treatment Technical Area Status Report
MWIP-8	Chemical/Physical Treatment System Technical Area Status Report
MWIP-9	Mixed Waste Integrated Program - A Technology Assessment for Mercury-Containing Mixed Waste
MWIP-10	Evaluation of Nitrate Destruction Methods
MWIP-11	Vitrification Development Plan for DOE Mixed Waste (Draft)
MWIP-12	Vitrification Treatability Study and Process Demonstration Capabilities Assessment (Draft)
MWIP-13	Preliminary Hazards Analysis Plasma Hearth Process (Draft)
MWIP-14	Multicriteria Decision Methodology for Selecting Technical Alternatives in the Mixed Waste Integrated Program (Draft)
MWIP-15	Surrogate Formulation for Thermal Treatment of Low-Level Mixed Waste: Part I — Radiological Surrogate (Draft)
MWIP-16	Surrogate Formulation for Thermal Treatment of Low-Level Mixed Waste: Part II — Selected Mixed Waste Treatment Project Waste Stream (Draft)
MWIP-17	Surrogate Formulation for Thermal Treatment of Low-Level Mixed Waste: Part III — Plasma Hearth Process Testing (Draft)
MWIP-18	Surrogate Formulation for Thermal Treatment of Low-Level Mixed Waste: Part IV — Wastewater Treatment Sludges (Draft)
MWIP-19	Guideline for Benchmarking Thermal Treatment Systems for Low-Level Waste (Draft)
MWIP-20	Technical Areas Status Report on Alternatives to Thermal Treatment (Draft)
MWIP-21	Technical Areas Status Report on Material Handling (Draft)

MWIP Collaboration with Industry and Universities

Appendix B

APPENDIX B

MIXED WASTE INTEGRATED PROGRAM

COLLABORATIVE RESEARCH

PROGRAM RESEARCH AND DEVELOPMENT ANNOUNCEMENTS

<u>Project Title</u> <u>Est. Cost</u>	<u>Industrial Participant</u>	<u>Objective</u>
Development Studies for a Novel Wet Oxidation Process	Delphi Research, Inc. 701 Haines Ave., N.W. Albuquerque, NM 87102	Develop catalytic wet oxidation process for the treatment of multicomponent wastes, with the aim of providing a versatile treatment method which can remove hazardous organic metals from soils
Research and Development of an Innovative Fossil Fuel Fired Vitrification for Soil Remediation	Vortec Corporation 3770 Ridge Pike Collegeville, PA 19426	Develop and deploy an innovative fossil fuel fired vitrification process for the remediation of soils containing hazardous and/or radioactive constituents. The process is an extension of an advanced, multi-fuel-capable combustion and melting system technology being developed for commercial glass manufacturing and waste processing/recycling.
Catalytic Extraction of Scrap Metal	Molten Metals Tech. 950 Winter Street Suite 4100 North Waltham, MA 02154	Apply its patented technology, Catalytic Extraction processing, to radioactively contaminated scrap metal. In the CEP, wastes are fed into a sealed molten iron bath operating at 2000°K where they are broken down into their constituent elements. Through the addition of selective reactants, these elements recombine to form commercially viable products which partition into a metal phase, a ceramic phase, and a gaseous phase. The radioactive metals partition to the dense low-volume ceramic phase. The metal phase is suitable for DOE reuse.
Decontamination of Process Equipment using Four Technologies	Scientific Ecology Group, Inc. 1560 Bear Creek Rd. Ridge, TN 37830	Evaluate decontamination of compressor units from Oak Ridge K-25 facility using 1) high pressure water system, 2) dry abrasive impingement, 3) liquid abrasive system, and 4) dry ice blasting. The proposed work will involve technical and economical comparisons of these four technologies.
Recycle and Reuse of Radioactive Contaminated Scrap Metal	Scientific Ecology Group, Inc. 1560 Bear Creek Rd. Oak Ridge, TN 37830	Decontaminate 70 tons of contaminated scrap metal and convert it to hazardous waste containers. Following decontamination, they will produce ingots of various sizes in their metal processing facility. The ingots will be used to manufacture metal waste disposal containers, vitrified waste canisters, and reinforcing materials (e.g. rebar and metal fiber) for use in concrete waste storage containers.

PROGRAM RESEARCH AND DEVELOPMENT ANNOUNCEMENTS

<u>Project Title</u> <u>Est. Cost</u>	<u>Industrial Participant</u>	<u>Objective</u>
Advanced Technologies for Decontamination of Radioactively Contaminated Scrap Metal to High-Value Intermediate and Final Product Forms	Manufacturing Sciences Corporation 804 Kerr Rd. Oak Ridge, TN 37830	Manufacturing Sciences Corp. and the Colorado School of Mines have teamed up to develop a technology for reusing radioactively contaminated nickel. They will decontaminate the nickel, then alloy it was decontaminated steel and purchased chromium to produce stainless steel. They will use the stainless steel to make containers suitable for storing vitrified high-level nuclear waste.

RESEARCH OPPORTUNITY AGREEMENTS

Platelet-Cooled Plasma Arc Torch	Aerojet General Corp. P.O. Box 3530 Rancho Cordova, CA 95741	Use Aerojet's proprietry platelet technology to improve the efficiency of plasma arc torches by increasing the life of the anodes of existing plasma arc torches used for the vitrification of low-level waste.
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INTERAGENCY AGREEMENTS

Mississippi State University Diagnostic Instrumentation and Analysis Lab	DIAL is supporting MWIP in the area of process monitoring and control. DIAL has developed a suite of high technology instruments that can be used to investigate and document combustion, gas phase and surface environments. DIAL will work with ANL-W to incorporate its measurement instruments and expertise in MWIP expedited demonstrations and will support MWIP's primary
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