AIIM

Association for Information and Image Management
1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

Conf-940499--11

MIXED WASTE INTEGRATED PROGRAM EMERGING TECHNOLOGY DEVELOPMENT

Jeanette B. Berry
Integrated Program Coordinator
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Paul W. Hart, Ph.D.
Program Manager
U.S. Department of Energy
Washington, D.C.

ABSTRACT

The U.S. Department of Energy (DOE) is responsible for the management and treatment of its mixed low-level wastes (MLLW). MLLW are regulated under both the Resource Conservation and Recovery Act and various DOE orders. Over the next 5 years, DOE will manage over 1.2 m^3 of MLLW and mixed transuranic (MTRU) wastes. In order to successfully manage and treat these mixed wastes, DOE must adapt and develop characterization, treatment, and disposal technologies which will meet performance criteria, regulatory approvals, and public acceptance. Although technology to treat MLLW is not currently available without modification, DOE is committed to developing such treatment technologies and demonstrating them at the field scale by FY 1997.

The Office of Research and Development's Mixed Waste Integrated Program (MWIP) within the DOE Office of Environmental Management (EM), Office of Technology Development, is responsible for the development and demonstration of such technologies for MLLW and MTRU wastes. MWIP advocates and sponsors expedited technology development and demonstrations for the treatment of MLLW.

MWIP is expediting the development of a suite of technologies to process heterogeneous waste. One robust process is the fixed-hearth plasma-arc process that is being developed to treat a wide variety of contaminated materials with minimal characterization. Additional processes include steam reforming and a catalytic extraction process that uses molten metal technology. Both processes are being demonstrated by the commercial developer of the technology. Advanced off gas systems are also being developed.

Vitrification technologies are being demonstrated for the treatment of homogeneous wastes such as incinerator ash and sludge. An alternative to conventional evaporation for liquid removal—freeze crystallization—is being investigated. Since mercury is present in numerous waste streams, mercury-removal technologies are being developed.

INTRODUCTION

The mission of the Mixed Waste Integrated Program (MWIP) is to identify, evaluate, modify, develop, demonstrate, and transfer technologies and systems to characterize, treat, and dispose of U.S. Department of Energy (DOE) mixed low-level wastes (MLLW), and mixed transuranic (MTRU) waste. Once commercialized, these technologies and systems will used by internal DOE organizations tasked with environmental restoration and waste management activities. These technologies and systems must permit DOE to achieve compliance with regulatory requirements for the characterization, treatment, and disposal of DOE MLLW and MTRU waste. They must reduce risk, provide improved performance relative to current technologies, minimize life-cycle costs, meet regulatory requirements, and achieve public acceptance. In many cases, no treatment technology, treatment capacity, or waste disposal criteria currently exist.

To accomplish its mission, MWIP seeks to draw on private-sector technical, engineering development, manufacturing, commercialization, and implementation (e.g., site/waste stream remediation) capabilities. This can be accomplished through a variety of contractual mechanisms and often involves a collaborative relationship between the private sector and DOE's national laboratories. The private sector, including academia, industry, and individuals, is encouraged to contact MWIP to assist DOE in providing technologies to characterize, treat, and dispose of mixed wastes in a timely and effective manner.

BACKGROUND

Types and Sources of Mixed Waste

During the next 5 years, DOE will manage over 1,200,000 m^3 of MLLW and MTRU waste at 50 sites in 22 states (see Table 1). The difference between MLLW and MTRU waste is in the concentration of elements that have a higher atomic weight than uranium. Nearly all of this waste will be located at 13 sites. More than 1400 individual mixed waste streams exist with different chemical and physical matrices containing a wide range of both hazardous and radioactive contaminants. Their containment and packaging vary widely (e.g., drums, bins, boxes, and buried waste). This heterogeneity in both packaging and waste stream constituents makes characterization difficult, which results in costly sampling and analytical procedures and increased risk to workers.

Table 1. DOE-Managed Mixed Low-Level Waste and Mixed Transuranic Waste Volumes

Source of Mixed Waste	Volume (m^3)
Current Site Inventories	
Mixed Low-Level Waste	247,000
Mixed Transuranic Waste	58,000
Operations Generated (Five-Year Projection)	
Mixed Low-Level Waste	280,000
Mixed Transuranic Waste	2,800
Environmental Restoration (Five-Year Projection)	
Mixed Low-Level Waste	620,000
Mixed Transuranic Waste	300
Total	1,208,100

NOTE: Information from the Interim Mixed Waste Inventory Report

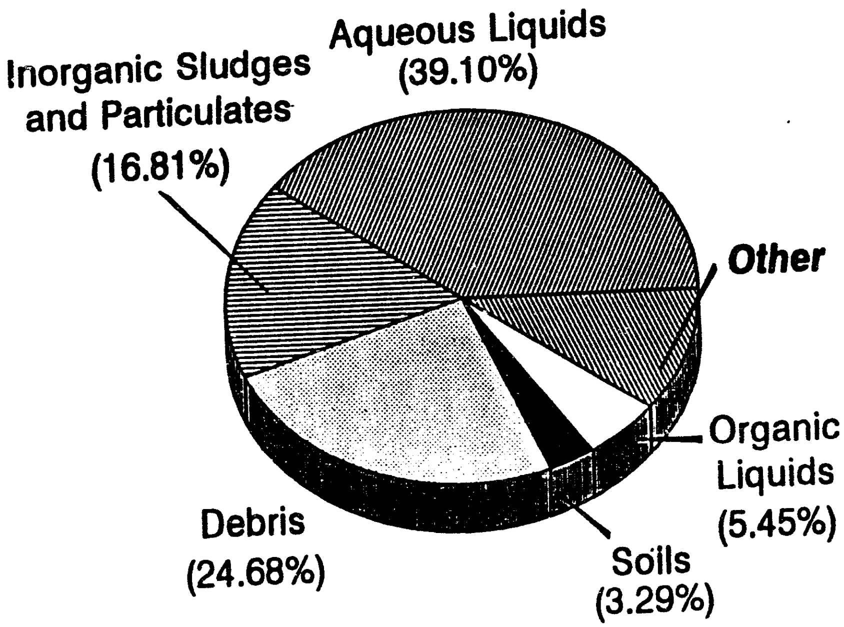
Based on radioactive characteristics, hazardous components, and physical/chemical matriçes, DOE has grouped its wastes to reflect salient treatment considerations for each waste stream. These "treatability groups" relate waste streams to treatment facilities and to technology development needs [1]. Aqueous liquids include all pumpable aqueous liquids which may have total or settled solid levels as high as 40%. Organic liquids, sludges, and solids are primarily treated by incineration; however, considering the inventoried and projected quantities of organic liquids, solids, and sludges to be generated, DOE estimates that there is insufficient capacity for treating these mixed wastes to Land Disposal Restriction standards. Inorganic sludges and solids are generally stabilized prior to disposal. Again, DOE does not have the treatment capacity to handle this treatability group. Soil and debris present a distinct problem to DOE. Other wastes include several distinct categories (e.g., laboratory packs, reactive metals, elemental mercury, elemental lead, explosives, and compressed gasses). Figure 1 illustrates the distribution of waste by these chemical/physical matrices.

MWIP DEMONSTRATION AND COMMERCIALIZATION INITIATIVES

MWIP has fostered and participated in cooperative efforts that are now being implemented throughout the DOE Office of Environmental Management (EM). For example, MWIP is working with the Office of Waste Management (OWM) on strategic planning for mixed waste. Baseline flowsheets [2] that are commercially available have served as the basis for MWIP technology development needs identification and selection of projects for development. This has resulted in focusing technology development activities on overcoming major obstacles to progress in mixed waste treatment to ensure that treatment leads to disposal. Major needs include (1) robust treatment processes, (2) enhanced waste forms to facilitate disposal, and (3) a systems approach to the mixed waste problem to ensure development of technology with improved cost/benefit over existing technologies.

MWIP is joining with OWM in reviewing site-specific treatment plans in order to make recommendations regarding consistency in technical approach across the DOE complex (including use of emerging technologies) and to support sites with limited technical resources. This joint participation has allowed MWIP to take a national view of mixed waste issues while maintaining access to site-specific needs and issues.

ORNL DWG 94H-80



Other	**% Volume**
Organic Sludges and Particulates	1.39
Lab Packs	0.09
Reactive Dangerous Wastes	0.06
Inherently Hazardous Wastes	0.36
Other Wastes	0.90
Multiple	5.35
TBD	2.51
Total	10.66

Fig. 1. Mixed TRU and Low-Level Waste Matrix Categories.

Systems Analysis

The cost of treating and disposing of MLLW and MTRU waste is estimated in the multibillion dollar range. This cost provides incentives to develop versatile treatment capabilities that do not require excessive characterization costs for safe and effective operations and that can be standardized to assist with regulatory and public acceptance. MWIP's customers, OWM and the Office of Environmental Restoration, are responsible for treating mixed waste and for selecting treatment technologies. There is disagreement over the acceptability of existing, proven technologies and their effective implementation in systems to treat a wide diversity of DOE waste streams. Incentives for use of evolving and/or innovative technology are dependent upon the potential for reduction in life-cycle cost, reduction in risk, and improved performance. Results of systems analyses conducted under MWIP have been documented [3,4,5,6].

The challenge for MWIP is to clearly establish the cost/benefit of using emerging technologies and technology systems to support selection for implementation. Technology selection will, therefore, be based on the following:

- A systems analysis, founded on technical rationale, that identifies deficiencies and gaps in present technologies that prevent fast and effective implementation of waste treatment systems.

- A systems analysis that clearly demonstrates the cost/benefit of implementing emerging and/or modified technologies.

- Public and regulator participation in and acceptance of emerging and/or innovative technologies. These factors play a major role in specific technologies being selected for implementation. Consensus building between numerous stakeholders is the preferred method of determining those technologies that will be developed and deployed.

One component of the systems analysis is to ensure that data are comparable when they are collected from experiments conducted at various locations by researchers with diverse backgrounds. To this end, surrogate formulations have been devised that represent major categories of waste throughout the DOE complex [7,8,9]. For more waste stream-specific applications, simulants have been developed [10]. An additional factor that contributes to data comparability is the specification of the parameters of importance for which data must be collected [11,12].

MWIP TECHNOLOGY DEVELOPMENT INITIATIVES

MWIP has been organized into technology areas that reflect major components of a generalized train of mixed waste treatment operations. These technical areas include materials handling, chemical/physical treatment, waste destruction and stabilization, off-gas treatment, and final forms produciton and assessment. (see Fig. 2).

Technology Area Status Reports (TASRs) identifying and describing currently available technologies for the management, treatment, and disposal of MLLW were developed and issued in FY 1993 in the areas of chemical/physical treatment [13], waste destruction and stabilization [14], final waste forms [15], and off-gas treatment [16]. TASRs will soon be published in the areas of materials handling, alternatives to thermal treatment, and process monitoring and control. These documents are available from MWIP and through the National Technical Information Service. Additional descriptive documentation is available that provides an overview of each technology being developed by the Office of Technology Development [17].

MWIP is conducting laboratory tests and field demonstrations using site-specific wastes to provide data for decision making regarding full-scale implementation. MWIP uses diverse contractor support from the national laboratories, academia, and private industry, allowing for a wide range of experience and expertise pertinent to mixed waste treatment to assist MWIP and its principal investigators in meeting DOE needs. Descriptions of each project have been complied elsewhere [18,19,20].

The principal thrusts of MWIP are to develop the technological bases to reduce the characterization requirements for DOE's heterogeneous wastes; reduce waste volumes by significant amounts (sometimes orders of magnitude); and produce, by the most direct route, final waste forms which can be directly disposed of (i.e., disposed of without further processing). MWIP is also committed to developing and fielding technologies in a timely manner and, therefore, is sponsoring expedited demonstrations of technologies in application to actual mixed wastes. These demonstrations are usually sited at DOE facilities to help reduce regulatory and public

ORNL DWG 94A-60R3

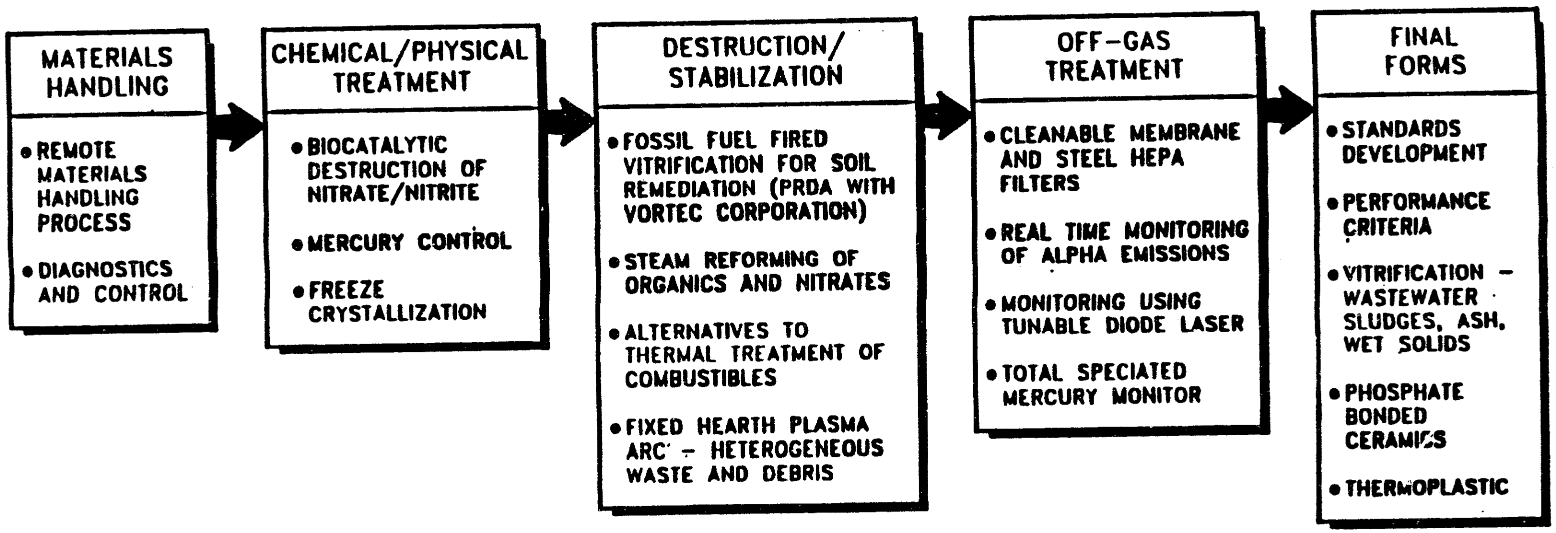


Fig. 2. Systems Approach to Technology Development

acceptance impediments to demonstrations and to facilitate commercialization of the technology.

MWIP is supporting three expedited demonstrations at this time: fixed-hearth plasma arc, vitrification, and molten metal technology. The status of each expedited demonstration is discussed below.

Fixed-Hearth Plasma Arc

Incineration is applicable for treatment of many mixed waste streams, but it has limited public acceptance. Other waste destruction technologies have been evaluated [14]. The fixed-hearth plasma-arc furnace is being demonstrated using a variety of mixed wastes [21,22]. This process offers benefits of direct production of enhanced final waste forms, potentially reduced waste feed characterization, potentially reduced off-gas volumes, and ability to treat a broader array of waste streams. The process, designed to accept unopened/unsorted drummed wastes, recently underwent a series of surrogate tests. The principal objectives were to establish the treatability of priority MWIP waste streams and to generate off-gas composition data to aid in off-gas component selection and design. Three simulated mixed waste types — an organic sludge, an inorganic sludge, and a heterogeneous combustible debris (e.g., wood, paper, rubber, steel) — were spiked with hazardous components (heavy metals and organics) and radionuclide surrogates. A total of six tests, two replicates for each waste type, were successfully completed.

Preliminary results indicate that all the tests were successful. All test materials were converted to a dense, vitrified monolith that is expected to test favorably for leach resistance using the toxicity characteristic leaching procedure and the product consistency test. Off-gas samples are currently being analyzed for particulate loading, particle-size distribution, and total metals content at the secondary stage outlet (prior to off-gas equipment) and for particulate loading, total metals content, HCl, and organics destruction at the off-gas system outlet (stack). The testing was completed ahead of schedule and well within the allocated budget.

This experimental series completed proof-of-principle tests of the plasma-hearth process. The tests generated valuable data that will be used to assess potential mixed waste treatment applications for the technology. Test data will also support radioactive system permitting and safety assessment activities as well as provide baseline data to support hardware design and optimization. Currently, a pilot-scale system is being designed and will be constructed and tested to gain the process engineering information needed to design a field-scale unit. The field-scale system will be demonstrated and a final assessment of the technology will be made by FY 1996.

Off-gas systems are commercially available for particulate capture, destruction of products of incomplete combustion, and abatement of nitrogen oxides. However, improvements in off-gas treatment are needed and are being developed under MWIP. Off-gas technology development initiatives include cleanable high-efficiency particulate air filters and systems designed to capture mercury. Current capabilities for process control and monitoring, especially for off-gas subsystems, are not adequate for DOE needs.

Vitrification

Grouting is a commonly used process for stabilization of waste. However, the ultimate disposition of grouted waste is highly uncertain due to the lack of disposal requirements or disposal sites. The volume increase associated with grouting conflicts with waste minimization policies and makes the final product costly to store or dispose of.

A viable alternative to waste grouting is vitrification of MLLW with emphasis on sludges. Building on in-depth data generated for high-level waste vitrification has contributed to the success of MLLW glass formulations and bench-scale and pilot-scale experiments. Glass formulation tests for surrogate wastewaters and incinerator ashes using surrogate wastes have been successfully completed. Tests have been conducted using pilot-scale vitrifiers to obtain operational data[23]. For example, a vitrification demonstration of surrogate incinerator ash was completed in December 1993 [24]. Tests of actual waste streams using a pilot-scale joule-heated ceramic melter are scheduled for FY 1994. Demonstrations of a field-scale mobile (transportable) melter using actual wastewater sludge and/or incinerator ash are scheduled for completion during FY 1995. Data will be available to design and support the operation of full-scale units. These data will include the limits of vitrification equipment for destruction of some Resource Conservation and Recovery Act organic constituents [25,26,27,28].

Molten Metal Technology

A demonstration on molten metal technology using radioactive MLLW is planned by the commercial developer. The catalytic extraction process is a commercially available, flexible process designed to accept materials in most chemical and physical forms. The technology uses the catalytic effect of a molten metal bath to revert injected feed streams into their elemental components. The co-feeding of reactants and controlled operating conditions allow selective partitioning of elements to gas, ceramic, or metallic product streams. Recovered resources, which may include synthesis gas and ferroalloys, are complemented by the concurrent stabilization of many radioactive isotopes in a ceramic product suitable for final form disposal. Potential technical benefits of the technology include destruction of the hazardous and toxic organic contaminants in mixed waste; controlled partitioning of radionuclides; containment of radionuclides in a nonleachable ceramic matrix suitable for final disposal; decontamination of metals allowing reuse or recycle; minimal feed pretreatment, handling, and analytical requirements; minimal generation of secondary waste; and minimal operator interaction.

Demonstrations using surrogate material are being conducted under a Program Research and Development Announcement. A joint commercial venture to conduct tests using radioactive wastes has been implemented while a full-scale demonstration on actual mixed waste is proposed for FY 1996 [29].

TECHNOLOGY DEVELOPMENT NEEDS

The MWIP has identified specific needs for its ongoing program in the following areas.

Closed-Loop Off-Gas Systems. Real-time instrumentation is needed to monitor the release of heavy metals, radionuclides, and various hydrocarbons from thermal processes used to treat mixed wastes (e.g., incinerators, vitrifiers, and plasma furnaces) in order to alleviate public concern and reduce the difficulty of siting and permitting a mixed waste thermal treatment facility.

Expedited Demonstration of a Mixed Waste Treatment Technology. MWIP needs to perform expedited treatment demonstrations on actual mixed wastes during FY 1994. Technologies that can treat a wide variety of waste streams and high-volume streams in the inventory (e.g., sludges and solids) are a priority.

Process Monitoring and Control Technology. MWIP needs to develop hardware and software systems that support mixed waste treatment technologies. Real-time monitoring of off-gas species such as radionuclides, heavy metals, carbon monoxide, and hydrocarbons is a priority.

Low-Temperature Mixed Waste Treatment Processes. Low-temperature treatment technologies are needed to simplify waste processing in response to stakeholder concerns and the need for lower life-cycle costs. A low-temperature technology is defined by an approximate 300°C process limit.

Long-Term Performance Assessment of Final Waste Forms. There is a need to predict long-term physical and chemical integrity of solidified wastes. Leaching rates and mechanisms by which waste forms release their toxic constituents need to be understood and modeled.

Application of the Debris and Empty Container Rules. MWIP's goal is to apply the rules governing hazardous debris to mixed waste debris, evaluate the performance of debris treatment technologies in the treatment of mixed wastes, and potentially achieve best demonstrated available technology status of such technologies.

Efficient Separations of Mixed Wastes. There is a need for new and improved separations methods for treating mixed wastes. Species such as sulfates and volatile metals may inhibit the formation of a durable glass or generate a toxic species. Separation of the radioactive and hazardous elements could allow each to be handled under only one set of regulations. Minimization of secondary wastes and recycle of as many of the process reagents as possible is desirable.

CONCLUSION

DOE faces major technical challenges in the management of low-level radioactively contaminated mixed waste. Several conflicting regulations and lack of definitive mixed waste treatment standards hamper implementation of mixed waste treatment technologies. Disposal capacity for mixed waste is also expensive and severely limited. DOE now spends millions of dollars annually to store mixed waste because of the lack of accepted treatment technology and disposal capacity. Currently available waste management practices require extensive, and hence expensive, waste characterization before treatment. Therefore, DOE must pursue technology that leads to better and less expensive characterization, handling, treatment, and disposal of mixed waste.

Technologies that are acceptable and have improved cost/benefit over existing technologies will be developed and commercialized by using the following approach:

- teaming with the customers in EM to identify, develop, and implement needed technology;
- focusing technology development activities on major problems such as heterogeneous waste

destruction and homogeneous waste stabilization;

- involving industry in developing and implementing solutions including both technology transfer to DOE and technology transfer from DOE to the private sector;
- involving regulators and stakeholders in technology development initiatives;
- enhancing mechanisms for commercializing technologies and systems.

REFERENCES

1. U.S. Department of Energy Interim Mixed Waste Inventory Report: Waste Streams, Treatment Capacities and Technologies, Vol. I - Overview, DOE/NBM-1100, April 1993.

2. Thompson, T., Functional and Operational Requirements for an Integrated Facility, Mixed Waste Treatment Project, Los Alamos National Laboratory, Aug. 1992.

3. Ferrada, J., and Berry, J., Multicriteria Decision Methodology for Selecting Technical Alternatives in the Mixed Waste Integrated Program, DOE/MWIP-14 Oct. 1993.

4. Ferrada, J., Mixed Waste Integrated Program Performance Systems Analysis, to be published as DOE/MWIP-23.

5. Aycock, M., et al., Preliminary Hazards Analysis Plasma Hearth Process, DOE/MWIP-13, Nov. 1993.

6. Barnes-Smith, P., and Booth, S., Mixed Waste Integrated Program Life Cycle Cost Analysis of Plasma Arc Furnace, DOE/MWIP-25, Oct. 1993.

7. Stockdale, J., Bostick, W., and Hoffmann, D., Surrogate Formulation for Thermal Treatment of Low Level Mixed Waste: Part I - Radiological Surrogate, DOE/MWIP-15, Sept. 29, 1993.

8. Bostick, W., et al., Surrogate Formulation for Thermal Treatment of Low Level Mixed Waste: Part II - Selected Mixed Waste Treatment Project Waste Streams, DOE/MWIP-16, Sept. 30, 1993.

9. Chaing, J., et al., Surrogate Formulation for Thermal Treatment of Low Level Mixed Waste: Part III - Plasma Hearth Process Testing, DOE/MWIP-17, Sept. 29, 1993.

10. Bostick, W., et al., Surrogate Formulation for Thermal Treatment of Low Level Mixed Waste: Part IV - Waste Water Treatment Sludges, DOE/MWIP-18, Sept. 29, 1993.

11. Hoffmann, D., et al., Guideline for Benchmarking Thermal Treatment Systems for Low Level Waste, DOE/MWIP-19, Dec. 21, 1993.

12. Hoffmann, D., et al., Data Quality Objectives: Evaluation of Thermal Treatment Processes, to be published as DOE/MWIP-22, Dec. 21, 1993.

13. Brown, C., Jr., and Scheinkendorf, W., Technical Area Status Report for Chemical/Physical Treatment, Vols. I and II, DOE/MWIP-8, May 1993.

14. Dalton, J., Harris, T., and DeWitt, L., Technical Area Status Report for Waste Destruction and Stabilization, DOE/MWIP-4, Aug. 1993.

15. Mayberry, J., et al., Technical Area Status Report for Low-Level Mixed Waste Final Waste Forms, Vols. I and II, DOE/MWIP-3, Aug. 1993.

16. French, N., et al., Offgas Treatment Technical Area Status Report, to be published as DOE/MWIP-5

17. U.S. Department of Energy Office of Environmental Restoration and Waste Management, Office of Technology Development, DOE/EM-0109P, Oct. 1993.

18. Bloom, G., and Berry, J., Development and Demonstration of Treatment Technologies for the Processing of U.S. Department of Energy Mixed Waste, presented at Hazmat South 1994 Conference, Orlando, Florida, Feb. 16-18, 1994.

19. Berry, J., Bloom, G., and Kuchnyka, D., Development and Demonstration of Treatment Technologies for the Processing of U.S. Department of Energy Mixed Waste, presented at Waste Management '94, Tucson, Arizona, Feb. 27–March 3, 1994.

20. FY94 Program Summary Book, DOE/EM-0109P

21. Geimer, R., Batdorf, J., and Wolfe, P., Test

Results from the Demonstration of the Plasma Hearth Process, presented at 1993 Incineration Conference, Knoxville, Tennessee, May 1993.

22. Geimer, R., Batdorf, J., and Larsen, M., Plasma Arc Treatment of TRU and Mixed TRU Waste, presented at 1991 Incineration Conference, Knoxville, Tennessee, May 1991.

23. Personal communication with Mike Bartone of Vortec, Collegeville, Pennsylvania, Dec. 1993.

24. Cook J., and Bickford, D., Preliminary Assessment of Disposal Limits for Vitrified Low-Level-Mixed Wastes in RCRA Landfills, in Ceramics in Waste Management, Ceramic Transactions, American Ceramic Society, 1993.

25. Bennert, D., et al., Pilot Scale Vitrification Studies on Hazardous and Mixed Waste, Proc. of the 2nd International Symposium on Mixed Waste, Baltimore, Maryland, Aug. 17-20, 1993.

26. Compton, K., Bennert, D., and Bickford, D., Regulatory Issues in Vitrification Research, Proc. American Ceramics Society Annual Meeting, Cincinnati, Ohio, 1993.

27. Peters, R., Lucerna, J., and Plodinec, M., Vitrification Development Plan for DOE Mixed Waste, DOE/MWIP-11, Oct. 1993.

28. Steverson, E. M., Vitrification Treatability Study and Process Demonstration Capabilities Assessment, to be published as DOE/MWIP-12.

29. Personal communication with Victor E. Gatto, Ph.D., Molten Metal Technology, Inc., Waltham, Massachusetts, Feb. 1994.

DATE FILMED

7/12/94

END

4