Innovative Pretreatment and Vitrification Technology For Waste Remediation

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1.0 INTRODUCTION

The Department of Energy has established a goal to clean up its nuclear complex environmental legacy waste by the year 2006. This will require the deployment of high throughput technologies to treat the wastes. The technologies must be able to treat a broad range of wastes varying in both impact contaminants and in physical form in a timely and economical manner. They must also be able to accomplish this task with minimum public and occupational health risks, and minimum environmental impact. Additionally, the technologies must transform the waste into a final form that has long-term stability to prevent migration of contaminants. It is imperative that each technology has no major obstacles to the safe decontamination and decommissioning of the technology. Finally, the final waste form produced must be sufficiently stable to immobilize radioactive materials for a time frame exceeding the radio-nuclide half-lives that go beyond the capability of institutional controls to protect the environment.

The Department of Energy and its contractors have been evaluating the development of various innovative technologies to solve its waste remediation needs. Vitrification and other treatment technologies are being evaluated for the processing of a wide variety of organic, heavy metal, and radionuclide contaminated wastes. Vortec Corporation has developed innovative waste pretreatment and vitrification systems for the treatment and remediation of contaminated soils. Wastes that have the potential of being processed using the Vortec pretreatment and vitrification technologies include low-level radioactive (LLW), mixed hazardous and low level radioactive waste (MLLW), and Toxic Substance Controlled Act (TSCA) waste containing regulated substances such as PCBs. This paper describes the progress of a demonstration program for the pretreatment and vitrification of these waste materials.

The waste pretreatment and conditioning system developed by Vortec prepares drummed waste for final treatment operations. Although specifically designed as a pretreatment step for the Vortec Cyclone Melting System® (CMS®), this system has a wide range of applications and can be used by a variety of final treatment processes. Specifically, the pretreatment and conditioning process can be used in conjunction with a wide spectrum of thermal treatment, solidification and non-thermal treatment processes. It can also be used as a pretreatment process for direct landfill where this disposal method is allowed.

Vortec's vitrification technology is a robust thermal treatment process that can process a wide spectrum of solid and slurry wastes. When coupled with a suitable pretreatment and conditioning system, the CMS® technology can process wastes that can be either soils, as in the case of DOE Paducah waste, or sludges such as those found in Silos 1 and 2 at DOE Fernald. Additionally, the CMS® can process slurry waste such as in the Hanford tanks. The Vortec CMS® can process the wastes more economically than the alternative technologies being considered by DOE (1, 2). The principal reason for this reduced cost is related to the CMS® high throughput and ability to handle a wide variety of waste streams in various physical forms.

Previous papers presented by Vortec have described the Vortec CMS® technology (3,4). This paper describes the pretreatment and conditioning system being developed by Vortec for the processing of drummed soil and rubble wastes, the plans for demonstrating the pretreatment/conditioning technology at a DOE site and addresses the benefits of its use with vitrification and other waste treatment technologies.

2.0 PROJECT OBJECTIVES

The waste pretreatment and vitrification process developed by Vortec is to be demonstrated at full-scale at the Paducah Kentucky Gaseous Diffusion Plant. The objective of the demonstration project is to validate the ability of an integrated waste pretreatment/conditioning and vitrification process to effectively remediate DOE contaminated soils and other waste forms containing RCRA hazardous materials, low-level radioactive materials, TSCA (PCB) containing wastes and mixtures thereof. The demonstration project is planned to be performed in two segments. The first segment will include the demonstration testing of the pretreatment and conditioning system using surrogate non-radioactive and non-hazardous materials. The second segment will include the integration of the pretreatment system with a final treatment process as determined by DOE goals and objectives.

The primary project objective of the current limited demonstration project is to complete the final design, procurement, construction and testing of a low-level radioactive waste pretreatment and conditioning system that can be used with a variety of final treatment technologies. Specifically, the process is to be an effective interface for a spectrum of vitrification, solidification and non-thermal remediation processes. The suitability for direct landfill for selected wastes will also be evaluated. The economics of the pretreatment and conditioning process when applied to specific final waste treatment processes are also to be validated.

The technical objectives are to provide a system that will pretreat and condition drummed and bulk wastes or contaminated soils with up to 30% moisture, concrete rubble up to 1 ft in length and rebar up to ½ inch diameter. The demonstration testing will be conducted with approximately 500-1500 drums of surrogate waste with various moisture, concrete and rebar content. The testing is structured to validate the drum processing capacity (nominally 6-10 drums/hr), and to validate effective emissions control of dust emissions. The testing is also aimed at identifying operating and maintenance criteria as well as establishing overall system performance and costs.

3.0 PROCESS DESCRIPTION

The pretreatment/conditioning process is composed of four subsystems: size-reduction, drying, metals separation, and dust control. The process takes drummed waste materials and processes them into two streams: a homogenous, dry, ferrous metal-free waste fraction and a ferrous metals stream. The dried homogeneous waste materials are amenable to further treatment or direct disposal via bulk container. See Figure 1 for a simplified process flow diagram.

Key design features include transportability and fully contained fugitive dust control. Each system is designed to be skid mounted, with most skids including subsystem junction boxes and control systems. Skids and subsystems can be disassembled for transport and reassembly at another DOE site.

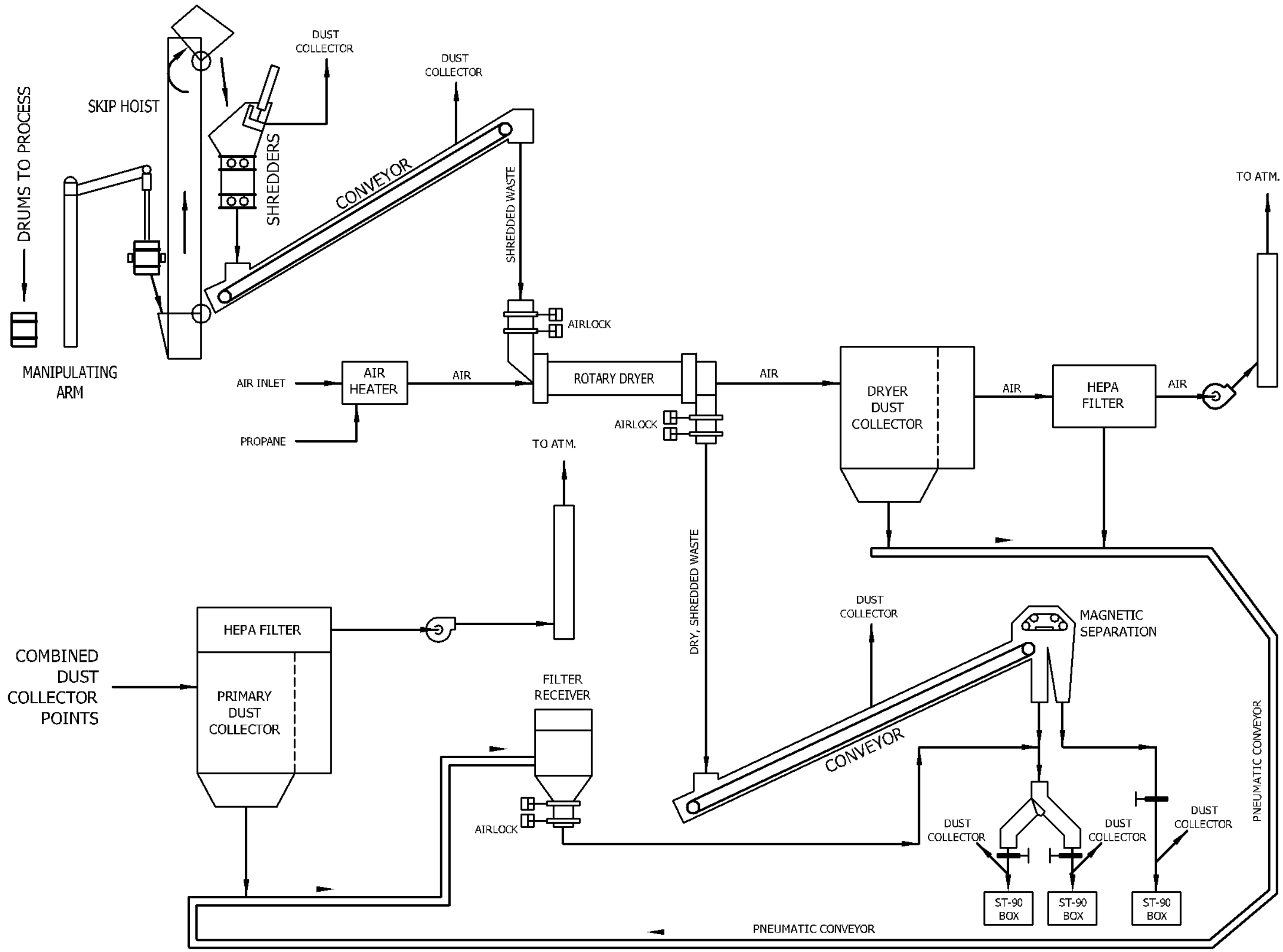
DUST COLLECTOR
DUST COLLECTOR
SKIP HOIST
DRUMS TO PROCESS
SHREDDERS
CONVEYOR
SHREDDED WASTE
TO ATM.
AIRLOCK
MANIPULATING ARM
AIR INLET
AIR HEATER
AIR
ROTARY DRYER
AIR
DRYER DUST COLLECTOR
AIR
HEPA FILTER
AIR
PROPANE
AIRLOCK
TO ATM.
DRY, SHREDDED WASTE
DUST COLLECTOR
MAGNETIC SEPARATION
HEPA FILTER
COMBINED DUST COLLECTOR POINTS
PRIMARY DUST COLLECTOR
FILTER RECEIVER
CONVEYOR
PNEUMATIC CONVEYOR
AIRLOCK
DUST COLLECTOR
DUST COLLECTOR
DUST COLLECTOR
ST-90 BOX
ST-90 BOX
ST-90 BOX
PNEUMATIC CONVEYOR

Figure 1

Process Flow Diagram of a Drummed Waste Treatment and Conditioning System

Waste material transfer equipment such as ducts, chutes and conveyors are fully enclosed and maintained at slightly below atmospheric pressure to minimize the risk of fugitive particulate emissions and with proper sweep velocities to keep the enclosed process equipment free of material accumulation. All air that is discharged from the process is filtered twice—first with conventional cartridge filters, and then with high efficiency particulate air (HEPA) cartridge filters—prior to discharge to the atmosphere.

The first unit operation is the shredding and size-reduction subsystem. This subsystem receives the sealed drum waste material and reduces the size of the waste material to a size suitable for the remainder of the process (nominally < 5 cm). Each drum is transferred to the primary shredder by a manipulating arm and skip hoist. The drum is weighed and placed into the elevator bucket of the skip hoist and is raised to the top of the primary shredder feed chute. At this point, the drum is dumped into the primary shredder, and the drum and its contents are completely shredded. The shredded waste materials then fall onto the secondary shredder to further reduce the size of the shredded waste materials. A belt conveyor then conveys the waste materials from the discharge of the secondary shredder to the drying subsystem.

In the drying subsystem, the shredded waste materials are discharged through a double-gate airlock and fed into a rotary dryer. An induced draft fan pulls hot air from the air heater through the rotary dryer. This hot air contacts the waste materials and evaporates the water from the waste materials. This hot, moist air is then ducted to a dust collector and finally a HEPA filter. The dust collector and HEPA filter capture any waste materials that may become entrained by the air ducted through the rotary dryer. After filtration, the air is discharged from a stack to the atmosphere. The dry, waste materials discharged from the end of the rotary dryer are dumped through another double-gate airlock and into the metal-separation subsystem. All dust captured in these filters is conveyed back into the process and is combined with the final waste in the ST-90 boxes. The ST-90 boxes include a hood assembly for dust collection during the final loading operation.

The magnetic metal-separation subsystem accepts the waste materials from the discharge of the dryer airlock and conveys it on a belt conveyor. As the material reaches the head of the conveyor, it passes a tramp iron magnet for ferrous metal separation. Non-ferrous waste materials simply fall away from the magnet into a chute and ultimately into a set of ST-90 boxes. These ST-90 boxes contain the final sized and dried waste product. Ferrous waste materials separated by the magnet are conveyed into a separate ST-90 box.

The final subsystem is the dust collection and filtration subsystem. This subsystem maintains the pressure of the enclosed process equipment to below ambient atmospheric pressure. This subsystem also maintains an air sweep at the inlet of the process (the primary shredder inlet) and collects dust at the discharge points of the process (i.e. at the ST-90 boxes). Waste materials accumulating in the dust collector in this subsystem, as well as the dust collector and HEPA filter bank in the drying subsystem, are pneumatically conveyed under negative to a filter receiver and discharged into the same ST-90 box that collects the final, non-ferrous product.

Support utility subsystems, including a propane storage and delivery assembly, a compressed air assembly, electrical distribution and a instrumentation/control assembly are also provided as a part of the limited demonstration plant. The propane, that is used as fuel for the rotary dryer, is trucked to the site and stored in the plant propane storage tank. The propane and storage assembly consists of an 18,000 gallon liquid propane tank, a propane pump, and a vaporizer all supplied with the necessary instruments, valves, and safety controls. The propane assembly is designed for 21 MMBTU/hr of propane. The dryer heater has a capacity of nominally 11 MMBTU/hr.

The compressed air system is designed to deliver a nominal 1000 scfm at 125 psig. The compressed air system consisting of an inlet filter, air compressor, aftercooler, water separator, and air receiver is provided for plant utility air requirements. Utility air is also passed through a coalescing filter, regenerative dryer, and an after filter in order to provide plant air with a -40^{o}F dew point for instrumentation.

4.0 PROJECT APPROACH

4.1 LIMITED DEMONSTRATION TEST APPROACH

The objective of this phase of the demonstration project is to prove the functional performance of the key components of a drummed waste preparation and conditioning system, leading eventually to the integrated operation of the feed preparation and conditioning system with a final waste treatment process. The ability to: control dust emissions, remove moisture, reduce waste size, produce a more homogeneous waste distribution and effectively separate metals from the soils for suitable waste handling and final treatment and disposal will determine the success of the operation. The process will be evaluated using a range of surrogate wastes with varying moisture content, size distributions and metal contents.

Prior to initiating the demonstration testing, each individual piece of equipment will be checked out during prestart-up activities. Any system deficiencies will be corrected during this shakedown period. In addition, utility connections and the control systems will be tested for functionality prior to initiating the planned test sequence.

Drummed surrogate wastes will be prepared for the demonstration using clean soils, rather than actual waste materials. The surrogate feed will be representative of the potential variety of waste types at Paducah. The surrogate feed will consist of non-radioactive native soils and will also include contain concrete rubble, plastic liners, fragments of plastic pipe, rebar and other miscellaneous materials. There are several reasons for using clean soil surrogates during the demonstration program:

- Minimization of the cost of personnel monitoring and protection;
- Elimination of the need for RAD Worker II and HAZWOPR training.
- Minimization of the decontamination of the systems in the event that the system is transported to another DOE site for use.

The nuisance dust collector system (blower, filters) will be operated during each test. The ability of the system to contain fugitive dust emissions will be determined by a periodic stack sampling and/or a Continuous Opacity Monitor System (COMS) as well as by visual determination. The particulate emissions will be directly measured at the nuisance dust collector stack. Other potential losses of fugitive dust will be demonstrated indirectly by visual observations and any visible emissions will be minimized or eliminated by corrective action. The weight of materials entering and existing the system will be measured. The following tests are planned for the limited demonstration project. Others may be added as required.

<u>Test 1 – High Moisture Content Testing</u>

The objective of Test 1 is to test the ability of the system to handle a high moisture content waste, averaging 30% moisture, the upper design limit of the dryer. The feed material for this test will be clean, damp soil in plastic lined drums. The moisture content of the drummed material will be adjusted as closely as possible to 30% by weight. Manual composite samples of each drum will be taken for moisture analysis prior to feeding the materials. Each drum will be placed into the Skip Hoist by a Manipulating Arm, fed into the primary shredder, and processed through the remainder of the system. Manual composite samples of the shredded and dried materials will be taken of the pretreated materials delivered to the ST-90 boxes. The samples will be analyzed for moisture content and size distribution. In addition the pretreated surrogate waste product will be analyzed for the degree of metals separation.

Test 2 – Reduced Moisture Content Testing

The objective of Test 2 is to test the ability of the system to handle an average moisture content waste, averaging 15% moisture. The protocol for Test 1 will be repeated. Samples will be collected and analyzed as described for Test 1.

Test 3 – High Metals Content Testing

The objective of Test 3 is to check the effectiveness of metal removal at the ferrous metal separator. The feed material for this test will be the same as for Test 2, with additional scrap metal, rebar and other metallic materials added to the contents. The protocol for Tests 1 and 2 will be repeated with careful attention to the assessment of the degree of metals separation.

Test 4 – Large Particle Size Testing

The objective of Test 4 is to determine the ability of the system to reduce the size of larger waste materials to a smaller size and to produce a more homogeneous distribution. The feed materials will be the same as for Test 3, with larger particle sized materials, such as concrete chunks, added to the contents. The test protocols for Tests 1, 2 and 3 will be repeated, including the sampling and analysis procedures.

4.2 SUCCESS CRITERIA

With the limited scope of the demonstration, the success criteria focus on the key components, the equipment and systems to be demonstrated. As part of this scope of work, Vortec will develop a detailed Demonstration Test Plan. The demonstration test criteria will include measures of the efficacy of shredding, drying, metals separation, and the effectiveness of the dust collection and filtration system and product handling systems for fugitive dust control. Testing and inspection is anticipated to consist of the following items.

- Moisture content of feed and prepared soils.
- Waste size distribution of the feed and pretreated soils.
- Amount of magnetic metal remaining in the prepared soil after metals separation
- Measure of the total metal content and size distribution of the metal fragments remaining after shredding.
- Visual inspection and recording in a logbook of the presence of particulate dust emissions at any equipment or transfer points.
- Recording of particulate emissions at the Nuisance Dust Collector Stack.

4.3 REGULATORY STATUS AND PERMITTING APPROACH

Vortec and DOE had jointly developed an RD&D permit application for the full-scale demonstration project. The RD&D permit was delayed pending finalization of an Environmental Assessment (EA).

For the currently envisioned limited demonstration project, treating surrogate wastes only, permitting is not strictly required. However, DOE - Paducah has notified Kentucky Department of Waste Management (KDWM) of the change in project status and their current plans to construct and demonstrate a limited portion of the plant. KDWM and DOE subsequently agreed that the appropriate course is to finish the original RD&D permit, which would then be the basis for initiating construction of the remaining plant. This approach would allow DOE the flexibility to conduct the originally planned vitrification demonstration at a later date or to use this system as a pretreatment system for any other process involving mixed waste.

An air permit for the demonstration of the total vitrification plant had been issued. However, preliminary calculations by DOE-Paducah indicate that an air permit is not required for construction of and demonstration of the soil preparation and feed handling facilities. The basis for this conclusion is that no hazardous air pollutants or radionuclides would be discharged and the emissions of criteria pollutants would be well below the minor source limits. DOE-Paducah has contacted the state agency and will prepare any required paperwork modifying the existing air permit.

There will be two air emissions points, the stack venting from the nuisance dust collection subsystem and the uncontaminated combustion gases from the rotary dryer dust collector. Projected data for these two point sources are shown in Table 1. This table summarizes the total pounds of emissions per ton of input mass of the processed drum waste.

Table 1. Point Source Information

Source	Nuissance Dust Collector	Dryer Dust Collector
Flow Rate, ACFM	19600	11500
Pollutant Rate, lb/ton processed		
Particulate Matter	7.88×10^{-3}	1.67×10^{-2}
Carbon Monoxide		4.36×10^{-2}
Nitrogen Oxides		1.74×10^{-1}
Sulfur Dioxide		1.97×10^{-4}
Volatile Organic Compounds		3.52×10^{-3}

Notes: 1. Sources of data for this table are Air Permit Application, Kenvirons, January 1998 and calculations by DOE.

The level of emissions from these two sources under the limited demonstration scenario is low enough to constitute a minor source requiring no air permit. No hazardous air pollutants or radionuclides will be discharged and the emissions of criteria pollutants will be well below the minor source limits of 25 tons per year.

A TSCA permit application has been completed, but it has not been submitted. Due to changes in the project plan, this application will not be submitted.

5.0 PROJECT STATUS AND ACCOMPLISHMENTS

This effort is part of a multi-phase Research and Development Program sponsored by the U.S. Department of Energy National Energy Technology Laboratory (DOE NETL). The total program was originally structured to design, construct, and demonstrate Vortec's innovative vitrification process for the treatment of a wide range of LLW, mixed and PCB containing wastes. Vortec has completed verification testing, established plant design requirements, and essentially completed detailed engineering for the full-scale demonstration of the Vortec vitrification plant. The site preparation for construction has been completed. The procurement effort is also nearly complete. Currently, 80% of the equipment has been purchased and is now in storage at Paducah. Figure 2 below is a photograph of the equipment pads at the Paducah demonstration facility.

**Figure 2
Photograph of Equipment Pads at Paducah Site**

During most of 1998 and 1999, much of the planned work was postponed while DOE prepared an Environmental Assessment (EA) for the demonstration program in fulfillment of the terms of a 1997 consent agreement. DOE released the EA on August 6, 1999 for public comment. The public comment period was completed in October 1999. The DOE Oak Ridge Operations Site Manager issued the final approved EA and a Finding of No Significant Impact to the environment (FONSI) on March 8, 2000. The issuance of the EA and FONSI fulfilled the requirements of the 1997 consent agreement. The issuance of the EA and FONSI should have cleared the way for construction of the Vortec vitrification system; however, a subsequent citizen lawsuit has precluded implementing the full-scale demonstration and remediation project in a timely fashion. These lawsuits have contributed to substantial program delays and cost increases. DOE funding limitations have constrained the original scope of the project. In order to maximize the benefits of design and procurement effort already completed, the project was rescoped to conduct the limited demonstration described in this paper.

Work remaining to be performed includes:

- Finalization of the detailed engineering for the limited scope demonstration program;
- Procurement of items that were prohibited under the terms of the 1997 consent agreement;
- Construction and commissioning of the facilities; and

- Conduct of the demonstration.

6.0 BENEFITS OF TECHNOLOGY IMPLEMENTATION

Several potential benefits exist, including life-cycle cost savings, reduced risk of exposure to workers and the public, in using this approach to prepare drummed soils. Handling of the prepared waste will be less complex. Workers exposure to hazards will be limited because of the decreased handling and automated nature of the system. Similarly, risk to human health and the environment will be lessened by careful control of emissions.

The cost of transportation, further treatment, and disposal will be reduced on a unit basis. Reductions in sampling frequency to meet Waste Acceptance Criteria for off-site treatment of disposal and thus overall costs could be achieved. Some cost savings will be achieved by reducing the mass of materials sent to disposal. The moisture content will be reduced via drying and metal debris wastes could be removed for on-site disposal at a lower cost. The size reduction accomplished through the primary and secondary shredders and metal removal will produce a relatively homogeneous feed material that is more amenable to continuous stabilization or other treatment processes.

7.0 PLANNED FUTURE ACTIVITIES

The Feed Preparation and Conditioning system can be used to process a variety of waste streams at the Paducah site. The dried and homogenized wastes (with magnetic metals removed) will be in bulk containers, which greatly eases characterization, handling and transportation. For the immediate future, DOE-Paducah can use this system to process many of its drummed wastes for direct disposal, or treatment by another process. Given appropriate funding levels, the full-scale demonstration project involving Vortec's vitrification could be completed, as originally planned. Since a key design parameter of the system was transportability, the entire system can be transported to another DOE site and used in a similar capacity.

8.0 ACKNOWLEDGEMENTS

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9.0 REFERENCES

1. Integrated Thermal Treatment System Study, Report INEL- 95/0129

2. Waste Treatment Cost Study, Systematic Management Services, Sep., 1998

3. "High Throughput Vitrification for DOE Waste Remediation," Industry Partnerships for Environmental Science and Technology Conference, Morgantown, West VA, October 1999.

4. "Innovative Vitrification for Soil Remediation," Waste Management Conference, Tucson, AZ, March 1998.