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Innovative Vitrification for Soil Remediation

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1.0 Introduction¹

The objective of this DOE demonstration program is to validate the performance and operation of the Vortec Cyclone Melting System (CMS™) for the processing of LLW contaminated soils found at DOE sites. This DOE vitrification demonstration project has successfully progressed through the first two phases. Phase 1 consisted of pilot scale testing with surrogate wastes and the conceptual design of a process plant operating at a generic DOE site. The objective of Phase 2, which is scheduled to be completed the end of FY 95, is to develop a definitive process plant design for the treatment of wastes at a specific DOE facility. During Phase 2, a site specific design was developed for the processing of LLW soils and muds containing TSCA organics and RCRA metal contaminants. Phase 3 will consist of a full scale demonstration at the DOE gaseous diffusion plant located in Paducah, KY. Several DOE sites were evaluated for potential application of the technology. Paducah was selected for the demonstration program because of their urgent waste remediation needs as well as their strong management and cost sharing financial support for the project.

During Phase 2, the basic nitrification process design was modified to meet the specific needs of the new waste streams available at Paducah. The system design developed for Paducah has significantly enhanced the processing capabilities of the Vortec vitrification process.

The overall system design now includes the capability to shred entire drums and drum packs containing mud, concrete, plastics and PCB's as well as bulk waste materials. This enhanced processing capability will substantially expand the total DOE waste remediation applications of the technology.

A total of seven (7) soil vitrification trials were conducted during Phase 2 at Vortec's pilot scale vitrification plant located at the University of Pittsburgh Advanced Research Center in Harmarville, PA. The first set of trials used a surrogate soil composition representative of the contaminated soils found at DOE's Hanford site. The Hanford soil was simulated using the composition data supplied by Hanford, and was spiked with Resource Conservation and Recovery Act (RCRA) metals surrogates, an organic contaminant, and surrogate radionuclides. The sampling of the effluent and influent streams taken during the tests confirmed that virtually all of the refractory radionuclides were retained in the glass and would not leach to the environment—as confirmed by both Product Consistency Tests (PCT) and Toxicity Characteristic Leaching Procedure (TCLP) testing. The organic contaminant, anthracene, was destroyed during testing with a Destruction and Removal Efficiency (DRE) of at least 99.99%. Semi-volatile RCRA metal surrogates were captured by the Air Pollution Control (APC) system, and data on the amount and the chemical composition of the particulate were established for use in the APC system design.

A second set of three pilot scale vitrification trials were conducted using surrogate contaminated soil representative of the soil found

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at the DOE-Paducah site. The DOE-Paducah waste streams are much more complex than the soils which were scheduled for remediation at Hanford. The Paducah contaminated soils contain, mud as well as PCB contamination, and construction debris. The surrogate tests performed with the Paducah waste simulants reconfirmed the ability of the vitrified waste to pass TCLP and PCT.

2.0 Program Objectives

The principal objective of the METC/Vortec program is to demonstrate the ability of the Vortec 36-72 ton per day CMS™ to remediate DOE contaminated mixed waste and other waste forms, contaminated with both hazardous materials and low levels of radionuclides and PCB, by producing glass which passes TCLP and PCT.

To convincingly demonstrate the melter capability, a Demonstration Plant will be constructed and operated at DOE-Paducah where there is a need for the remediation of contaminated waste. The following other objectives will be met during the program.

1. Determine the glass chemistry requirements to achieve effective vitrification of contaminated soils found at the Paducah site; that is, given a particular soil (waste), determine how its oxide composition must be modified to produce a vitrified product that will immobilize contaminants over the long-term.
2. Determine expected feedstock soil particle size distribution and the glass flux requirements, so that valid designs and cost estimates can be made for the feedstock preparation system.
3. Determine the Destruction Removal Efficiency (DRE) of the CMS™ for organic contaminants likely to be found in soil from DOE sites requiring remediation.
4. Establish the characterization of the off-gas so that valid designs and cost

estimates can be made for the flue gas clean-up system.

5. Establish the cost of a fully integrated soil (waste) vitrification CMS™ with a 36-72 TPD capacity of waste into the CMS™.
6. Conduct start-up, shake-down, and feasibility demonstrations using the fully integrated plant with a capacity of 36-72 TPD constructed at the DOE-Paducah site. This capacity equates to approximately 160-320 barrels/day containing 30% moisture and an average weight of 450 lbs/barrel.
7. Establish the contractual and operating arrangement of Phase 4 for the continued operation of the facility by Vortec to continue remediation at Paducah site and other site's waste streams.

3.0 Background Information

The Department of Energy's goal to clean-up its nuclear complex by the year 2019 requires the development of innovative technologies to convert soils contaminated by hazardous and/or radioactive wastes to forms which can be readily disposed in accordance with current waste disposal methods. These technologies must be able to accomplish this task with minimum public and occupational health risks, with minimum environmental risks, and in a timely and economical manner. Additionally, the technologies must transform the hazardous and/or radioactive waste into a form which is considered non-hazardous; which has long-term stability to prevent migration of radionuclides, and can thus be disposed in an environmentally safe manner; and which satisfies all federal, state, and local emissions regulations. It is imperative that the technology not present any major obstacles to its own safe decontamination and decommissioning. Finally, the final waste form produced must be very stable since some of the materials have very long half-lives that may greatly exceed the capability of institutional controls to protect the environment.

The unique features of the CMS™ technology make it a particularly cost-effective

process for the vitrification of soils, sediments, sludges, and other solid wastes containing organic, metallic, and/or radioactive contaminants. Many of the benefits of the CMS™ technology recognized by the glass and hazardous waste management industry would also apply to DOE's ER&WM needs. Benefits with respect to DOE's needs are:

1. The ability of the CMS™ to produce a product which provides for long-term immobilization of heavy metals, toxic inorganics, and radionuclides.

In numerous pilot scale tests conducted by Vortec, the CMS™ has demonstrated the ability to effectively process RCRA wastes as well as surrogate contaminated soils. Simulated radionuclides and RCRA metals are effectively retained in the glass product and do not leach when tested using both the PCT and TCLP.

2. The CMS™ has demonstrated the ability to effectively oxidize and destroy organic contaminants. Tests performed by Vortec in the U-PARC facility with various carbonaceous materials such as cyanides and other organic contaminants found in most industrial waste, and anthracene and 1, 2- dichlorobenzene as surrogates for organic and PCB contaminates, have validated the organic destruction performance of the CMS™.
3. The CMS™ has demonstrated substantial flexibility with respect to the processing of various types of solid wastes and can accommodate substantial variations of feedstock composition.

Vortec has completed more than 109 test programs using a variety of materials as feedstocks including the U.S. Environmental Protection Agency (EPA) contaminated soils, flyash, baghouse dust, metal plating sludges, aluminum industry waste, steel industry waste and virgin glass making components. Soils with water content of up to 50 weight percent have been processed into glass products.

4. The CMS™ demonstrated the ability to oxidize and vitrify waste materials introduced as slurries, providing the

capability for mixing contaminated or waste oils with various types of hazardous solids, soil wash process sediments, and mill tailings. In addition to contaminated soils, Vortec has demonstrated the ability to vitrify Hanford low level tank waste surrogates with a water content of approximately 70% liquid and 30% solids. In addition, the CMS™ has demonstrated the ability to effectively vitrify a spectrum of metal plating sludges at 60% water content.

5. The CMS™' high temperature process components have water-cooled, steel walls providing for a sealed process which can be operated at negative pressure to prevent leakage of contaminated gases to the atmosphere. These water-cooled components can continue to operate in the event that unusual wear or spalling of refractory occurs until such time as the unit can be safely shut down.
6. The CMS™ small physical size reduces the decommissioning and disposal costs of the process equipment at the end of its useful life. The 36-72 ton/day demonstration unit is being designed to be transportable and modular, thus enabling wastes at several waste sites at a given facility to be serviced.
7. In the processing of substantial quantities of contaminated soils, the life cycle cost of the Vortec CMS™ is lower than other existing vitrification processes. In commercial applications, a 72 TPD CMS™ process unit typically has total processing costs in the range of \$50 - \$100 per ton of material processed. Radionuclide and PCB contamination increases the per-ton cost somewhat, depending upon the specific activity of the soil and the nature of the PCB contamination. Vortec estimates that the processing costs of low level waste with mixtures of TSCA or RCRA wastes at Paducah will be in the range of \$50 to \$200 per barrel for the Paducah drummed wastes. In comparison, of the types of wastes to be processed, other competing remediation technologies have estimated

processing costs in the range of \$500 to \$1000 per barrel for drummed wastes.

Vortec, during the first two phases of this program, has demonstrated the CMS™ technology's ability to remediate surrogate soils. During Phase 2 of the program, the final design and cost estimate for a 36-72 TPD system were also developed. The baseline plant design included a feedstock preparation subsystem combining the waste (average moisture content of 30%) with glass making additives, the CMS™ subsystem, and an air pollution control (APC) subsystem that cleans the flue gas using a venturi scrubber, wet electrostatic precipitator (WESP), and HEPA filters.

3.1 Process Description

The primary components of the basic CMS™ are a counter-rotating vortex (CRV) combustor and a cyclone melter. An artist's rendering of the basic CMS™ concept is shown in Figure 3.1-1. A unique feature of the process is the rapid suspension heating and oxidation of feedstock materials in the CRV combustor prior to the physical and chemical melting processes which occur within the cyclone melter. The use of the Vortec CRV combustor in conjunction with a cyclone melter distinguishes the Vortec combustion and melting technology from other types of cyclone combustion systems. In the CMS™ process, granular glass-forming ingredients and other feedstocks are introduced into the top region of the CRV combustor along with fuel and combustion air. As a result of the intense counter-rotating vortex mixing, it is possible to achieve stable combustion in the presence of large quantities of inert particulate matter (solids-to-gas mass ratios on the order of 1:1). Both convection and radiation heat transfer mechanisms contribute to the rapid heating of the feedstock materials within the CRV combustor. Any organic contaminants in the feedstocks are also effectively oxidized.

The melted product formed in the cyclone melter, and the combustion products, exit through

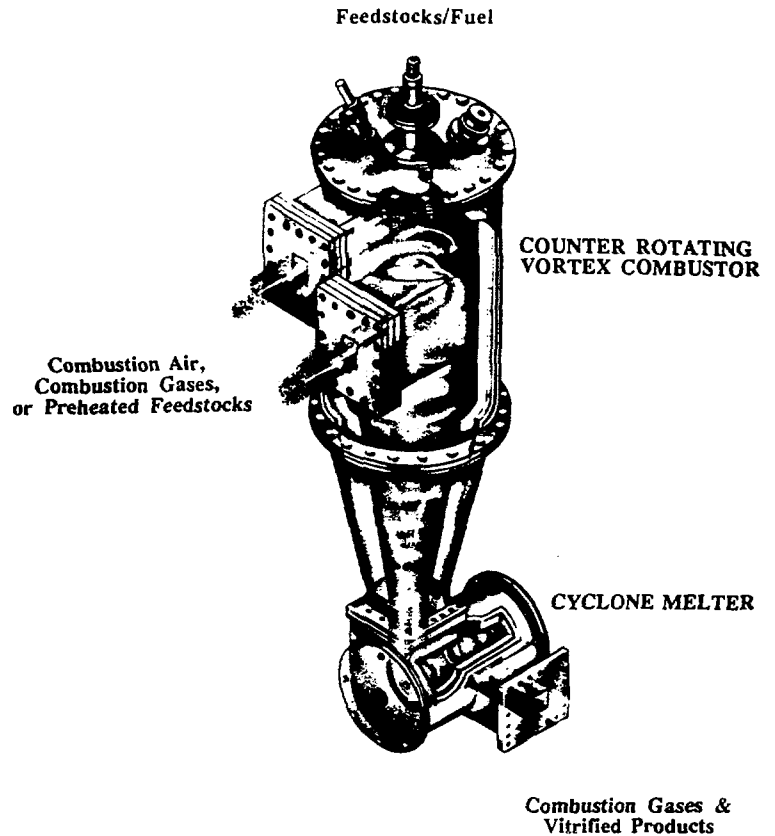


Figure 3.1-1. Artist Rendering of Basic Combustion/Melting System

the melted material is collected. The vitrified material enters a separator-reservoir (not shown in the figure) where a pool of material exits the reservoir through a bottom or side tap, and the flue gases exhaust to a water quench/electrostatic precipitator assembly or an optional heat recovery unit for combustion air preheating.

The flue gas exiting the separator-reservoir is treated in an air pollution control assembly prior to being exhausted out the stack. As a result of the high thermal efficiency of the Vortec CMS™, the flue gas flow rates are relatively modest. Because the temperature and composition of the vitrified product can be closely controlled, the amount of process fuming (volatile carryover) can also be minimized.

The average gas-solids suspension temperature leaving the CRV combustor is typically on the order of 2000°F to 2700°F, and is a function of the product being vitrified. The

process temperatures in the cyclone melter are typically in the range of 2000°F to 3000°F, depending on the melting characteristics of the feedstock being processed. The nitrogen oxide emissions have been found to be substantially lower than those which occur in conventional cyclone combustors. Excess air levels are typically in the range of 5 to 20% depending on the makeup and the nature of the feedstock being processed.

Heat rates demonstrated by the Vortec pilot scale facility typically ranged between 3.5 and 6 million Btu/ton at a glass production rate of 15 TPD. This heat rate is 50% to 80% lower than heat rates for conventional gas-fired glass melting at similar capacity. The energy savings are primarily due to more efficient heating of the glass ingredients in suspension by the products of combustion and lower structural heat losses due to the small physical size of the process components. The CMS™ can also accommodate the use of a variety of fuels, such as oil and coal-derived fuels, and even organic waste materials.

Most of the tests conducted to date have used a dry, shredded, or pulverized feedstock pneumatically transported and injected into the CMS™, and have used natural gas and/or coal as the fuel.

The CMS™ pilot system has demonstrated NO_x emissions of less than 4 pounds per ton of vitrified product, meeting the California emission standard for glass melting furnaces—currently the most stringent in the United States. With natural gas as the primary fuel, the NO_x emissions, calculated as NO₂, have typically been approximately 2 pounds per ton of product. Rapid temperature quenching of the combustion products by the inert solid particles and staged combustion are the primary means of limiting NO_x emissions. Tests conducted for Hanford using a high nitrate concentration tank simulant resulted in no visible plume leaving the pilot plant's stack.

The CMS™ has demonstrated uncontrolled emissions levels of less than 0.5% of feed materials which did not contain low temperature volatiles, such as utility flyash. For

materials containing heavy metals and other volatiles, such as MSWI flyash and fiberglass waste, the uncontrolled emissions levels have typically been in the range from 1% to 4%. As part of the METC program, Vortec has demonstrated a procedure for recycling the volatile materials into the glass after the glass has left the high temperature region of the combustor.

3.2 Previous Research Accomplished

After four years of design evolution under various DOE and EPA programs, the CMS™ is completely operational at the U-PARC test facility. Vortec's system has demonstrated the production of glass and the vitrification of a variety of feedstocks, including:

- EPA surrogate soils,
- Spent Pot Liners (K-088) wastes
- Coal fired boiler ash,
- Sewage Sludge ash,
- Auto shredder residue ash
- Municipal solid waste incinerator ash,
- Metal Plating Sludges
- Fiberglass waste with organic contaminants,
- Dusts containing heavy metals and organic materials,
- Electronic industry wastes

4.0 Results

Vortec has successfully completed the verification testing and final baseline plant design required in Phase 2 of this program. Vortec will continue the development, construction, and operation of the CMS™ Demonstration Plant during Phase 3. Vortec believes that the CMS™ technology is at the stage of development that will result in a mature process that is directly applicable to a large number of DOE Environmental Restoration and Waste Management (ER&WM) needs. Vortec is developing the CMS™ technology to commercial readiness, with the intention of economically meeting all public, occupational, and environmental health and safety requirements for remediation technology. Commercial offerings of the CMS™ technology, in plant sizes up to 200 TPD, have been made during the last year.

4.1 Test Program-Phase 2 Results Summary

A total of seven soil vitrification trials were conducted at Vortec's pilot scale vitrification plant located at U-PARC during Phase 2 of the program.

The objectives of the pilot testing were to:

- Demonstrate the effective vitrification of low level waste streams (soil) with the characteristics and compositions found at DOE-Hanford and DOE-Paducah;
- Evaluate the melting performance of the CMS™ with this material, that is, the feedstock composition and viscosity relationship;
- Define the expected range of flue gas emissions;
- Optimize the system operating parameters for the waste by determining the effect of temperature on the melting performance of the CMS™ and on the capture rate of the surrogate contaminants in the vitrified product; and to
- Determine the PCB destruction efficiency of the CMS™.

The first set of trials used a surrogate soil composition representing the contaminated soil found at DOE's Hanford site.

The trials associated with the Hanford waste stream are noted below:

<u>Test No.</u>	<u>Test Date</u>	<u>Surrogate Soil</u>
85	6/8/94	Hanford
86	6/9/94	Hanford
94	10/5/94	Hanford
95	10/6/94	Hanford

The objective of the first two tests, Tests 85 and 86, was to demonstrate the vitrification of soil having the characteristics and composition of the soil found at Hanford (the DOE selected site at that time). These first tests also evaluated the melting performance and expected range of flue gas emissions from the CMS™ when processing the Hanford surrogate soil feedstocks. The

surrogate soil feedstock consisted of a synthetic soil spiked with surrogate heavy metal and radionuclide contaminants. During each test, variations in system operating parameters were investigated to search for optimum operating temperature conditions and glass viscosity. Success was measured by the ability of the CMS™ to produce a fully-reacted vitrified product which passes both the Toxicity Characteristic Leaching Procedure (TCLP) test for leaching of the surrogate metal contaminants and the Product Consistency Testing (PCT) for the chemical durability of the vitrified product. Samples of all effluent streams were analyzed to establish the partitioning of the heavy metal and radionuclide surrogates.

The objective of the second two tests, Tests 94 and 95, was to determine the effect of temperature on the melting performance of the CMS™ and to confirm the capture rates of the surrogate heavy metal and radionuclide contaminants in the vitrified product. Analyses of the off-gas were conducted to establish the design specification for the air pollution control system.

A second set of pilot scale vitrification trials were conducted using surrogate contaminated soil representative of the soil found at the DOE-Paducah site. The trials associated with the DOE-Paducah waste stream that have been completed are noted below:

<u>Test No.</u>	<u>Test Date</u>	<u>Surrogate Soil Type</u>
101	3/1/95	Paducah
107	6/21/95	Paducah
108	6/21/95	Paducah

The DOE-Paducah waste streams are much more complex than the soil fines which were scheduled for remediation at Hanford. The test results from the last two tests are still under review, and additional tests planned to establish the performance of the CMS™ when handling the wide variety of materials in storage at the DOE-Paducah site.

The surrogate soil feedstock used consisted of a synthetic soil modeled on the data received from DOE-Paducah from their low level waste inventory. The low level soil was spiked with surrogate heavy metal, radionuclide, and

surrogate PCB contaminants. Samples of all effluent streams were analyzed to establish the partitioning of the heavy metal and radionuclide surrogates. Flue gas samples were also analyzed for PCB's.

Glass samples were taken periodically (approximately every 15 minutes) during each test in two forms: glass patty, which was air quenched, and glass cullet, which was water quenched. The glass analysis was conducted on the cullet samples by Corning Engineering Laboratory Services (CELS), and the TCLP testing was conducted by Blue Marsh Laboratories (BML).

From a qualitative standpoint, the glass produced during these tests was consistently dark green in color. Within a single glass sample, only minor color variations could be seen. Composite samples were prepared from the glass cullet samples obtained during steady state operation of the corresponding tests. These composite samples were sent to CELS for chemical composition analysis.

Composite samples were prepared from the glass cullet samples obtained during steady state operation of the corresponding tests. These composite samples were sent to BML for TCLP analysis. The analysis indicated that the TCLP extract contained very little measurable quantities of metals and in all cases were significantly below EPA TCLP limits. PCT test results indicated a Na-normalized leach rate of 0.0032 to 0.015 grams of glass/square-meter/day. The PCT specification for nuclear glasses is a Na-normalized leach rate of no greater than 1.0 grams of glass/square-meter/day.

Mass balances were performed on the surrogate heavy metal and radionuclide contaminants present in the feedstock. The composition of each of the effluent streams were used along with the effluent flow rates to perform elemental mass balances and calculate the partitioning of the contaminants.

Tests 85, 86, 94, and 95 used a surrogate for the soil fines that were to be processed at Hanford. The best data from Hanford indicated that the waste streams contained no organics but did have a full complement of heavy metals along

with small amounts of plutonium, cesium, cobalt and uranium. Surrogates for these radionuclides and heavy metals were spiked into soil so that partitioning to the effluent streams could be established.

The best data available from DOE-Paducah during preparations for Test 101, 107, and 108 indicated that the low level waste stream (soil) contained small amounts of organic materials and small amounts of heavy metals, uranium, and plutonium. Since the worst organic material to remediate is the PCB, 1, 2 dichlorobenzene was used as an organic surrogate at a concentration approximately of 1000 PPM, a concentration well beyond what is expected in the actual low-level waste stream. Each of the three tests focused on establishing the DRE for its chemical compound. Test 101 injected the 1, 2 dichlorobenzene as a liquid; Test 107 adsorbed the 1, 2 dichlorobenzene on the surface of granulated carbon particulates to simulate the inclusion of the PCB in a soil matrix; and Test 108 used the same carbon matrix but enriched the air oxygen content to 32%.

The flue gas was sampled for the presence of 1, 2 dichlorobenzene to estimate the destruction removal efficiency (DRE) for the CMS™ pilot plant as it is presently configured without the recuperator. The CMS™ system consistently demonstrated a 99.9% DRE while having a total system gas residence time of less than 1 second. With the addition of a recuperator to the CMS™, a commercial or demonstration system would expect to have a gas residence time in excess of 3 seconds.

In addition, Cerium was included at 500 PPM as a surrogate for uranium or plutonium, and the semi-volatile RCRA metals lead and cadmium were also included. Vortec has shown in the METC and many other tests that approximately 95% to 100% of the non-volatile RCRA metals report to the glass.

As more information is received from the site, additional testing will be required to establish the influence of new contaminants. A good example of this is the influence of plastic drum liners on the flue gas composition. Initial testing at the site indicated that the low level waste stored

in barrels contains a plastic liner. Separation of this liner, and any other debris contained in the drum, proved to be difficult to remove and posed a health and safety risk. To avoid this situation, the entire drum will be shredded, and the soil will now contain the shredded plastic liner. This plastic component represents an addition to the feedstock chemistry, and it will have an influence on the off-gas composition. Continued testing during Phase 3 will investigate these and other concerns generated as the multiple waste streams at DOE-Paducah are better defined by the characterization studies being conducted by the site.

4.2 Design Program-Integrated Demonstration Plant

4.2.1 System Requirements

The major system requirements for the Demonstration Plant are as follows:

1. Accept drummed or bulk waste streams with up to 30% moisture. The nominal processing capacity of drummed waste found at Paducah is 160 drums per day. (Note that if the moisture content is greater than 30%, it still can be processed but at reduced capacity). Provisions will be made to enrich the combustion air to approximately 38% oxygen at some later date, thereby allowing for growth in capacity to approximately 320 drums per day.
2. Targeted waste forms are 55 gallon drums of contaminated soils with moisture containing debris such as concrete, tramp metal, wood and plastics. The system will process entire drums, including plastic overpacks, plastic liners and frozen drums. This will minimize health and safety risks and minimize waste characterization analysis costs.
3. The process will be capable of processing waste containing radionuclides, TSCA, and RCRA contaminants.
4. The Demonstration Plant will be transportable and modular allowing use

at multiple DOE sites and/or multiple locations at a single site. Process equipment will be skid-mounted which can be installed on concrete pad foundations.

5. The Demonstration Plant will be capable of processing a wide variety of physical and chemical waste forms throughout the DOE complex. The wastes include soils, sediments, and/or sludges contaminated with hazardous wastes and low-level radioactive wastes. At Paducah, some of the soil contains organic material (solvents, fuels, PCB, plastic liners, etc.). Both volatile (Technetium) and nonvolatile (Uranium, Neptunium, Thorium, and Plutonium) radionuclides may be present in the soil waste stream. The eight heavy metals regulated by 40 CFR 261.24 are also present in the soil. Organic materials that can result in Hazardous Air Pollutants regulated by State of Kentucky 401 KAR 63.022 are also present in selected waste streams. Optional waste streams may include but are not limited to: personnel protective equipment (PPE), HEPA filters, treated scrubber / ESP water particulate (a slip stream is required to control particulate build-up) and spent ion exchange materials.
6. The waste stream will be fed, in dry form, to the melting system with a particle size no greater than minus 30 mesh and a moisture content that enables the material to flow freely. The soils at Paducah, as received, can have a moisture content of 30% and a size distribution well beyond the desired 30 mesh maximum; therefore, drying and grinding processes are included as part of the feed preparation subsystem.
7. The system will produce a glass frit, a chemically stable and reduced volume final waste form, that will pass the Toxicity Characteristic Leaching Procedure. The Air Pollution Control (APC) system will be required to meet DOE/EPA and the State of Kentucky standards for the removal of hazardous material and radionuclides. A venturi

scrubber followed by a single Wet Electrostatic Precipitator (WESP) and HEPA filters are specified to meet the requirements of the site's health, safety, and environmental regulations. This APC system is considered by the State of Kentucky to be the best available technology.

8. The APC process water will have a slip stream to a wastewater treatment process to remove radionuclides and other solids. All solids will be recycled through the CMS™.
9. The vitrified product generated as a result of testing will be disposed on-site or at an approved DOE radioactive waste repository, and will be the responsibility of DOE-Paducah.
10. DOE-Paducah will obtain the permits required to process the waste streams in the CMS™.

4.2.2 Demonstration Plant-System Description

A system flow diagram is shown in Figure 4.2-1. An isometric drawing of the plant arrangement is shown in Figure 4.2-2. The demonstration plant has been designed as a transportable and modular system; that is, the individual, skid mounted components of the process have the capability to be transported by truck, without special permits, to the site, erected, and when operation is complete, dismantled, decontaminated, loaded back onto trucks, and hauled off-site.

As is indicated in the system diagram Figure 4.2-1, contaminated soil is first transported by DOE in 55 gallon drums from the DOE-PGDP storage area to the vitrification facility. There is always at least a three day supply of the material in the storage area. Soil samples collected prior to the 30 day demonstration test will be used to determine the batch composition.

Feed Preparation System

The process of vitrifying the soil begins in the Feed Preparation Subsystem. It consists of:

- (1) transportation of drums to the drum shredder for introduction to the feed preparation system, and
- (2) a drying, milling, and screening operation to assure that the material is the proper size and moisture content.

At the plant, the drums are emptied into a drum shredder using a conventional fork lift truck with standard drum holding fixture.

To preclude the escape of dust particles when dumping or transporting the soil, all the conveying systems will be designed with an enclosure and operate under negative pressure. In addition, all hoppers and transfer points (dumping points) will also be enclosed and will be under negative pressure. The dust laden air from these devices will pass through a dust collector for particle removal. Solids collected in the dust collector will be transported back into the system. Discharge from the dust collector will pass through a parallel pass HEPA filter system.

The sized and dried soil is transported to a storage silo. Glass making additives are mixed with the soil. Additives (limestone and soda ash) are used to aid in glass forming, obtaining the proper glass properties, or modifying the temperature-viscosity curve. The blending system consists of storage silos and pneumatic feed system for the delivery of the soil and additives to a blend tank. Batch mixing precedes feeding into the Cyclone Melting System.

Cyclone and Melting System

The CMS™ components consist of a counter-rotating vortex (CRV) oxidizer/preheater, a cyclone melter (CM), a separator/reservoir, and a recuperator heat recovery unit.

The prepared feedstock is introduced into the CRV oxidizer/preheater through injectors located at the top of the combustor. Combustion air, which has been heated by waste heat in the recuperator, is mixed with

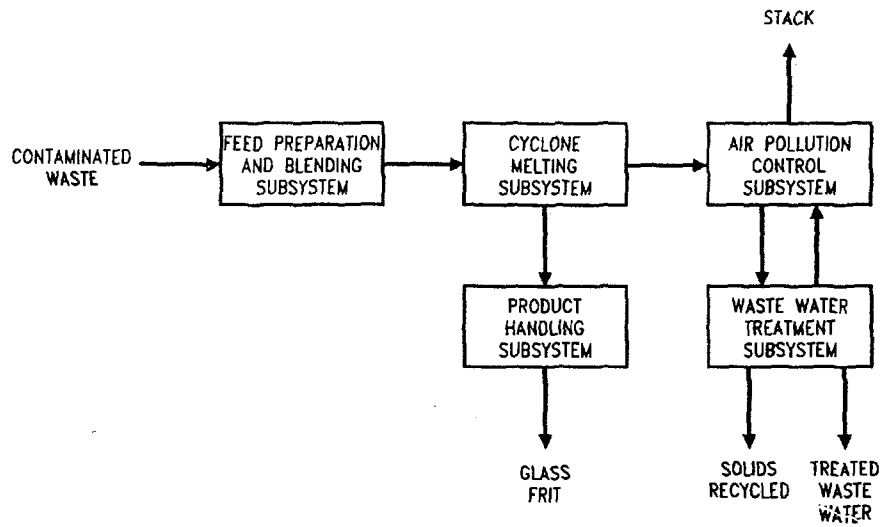


Figure 4.2-1. System Flow Diagram

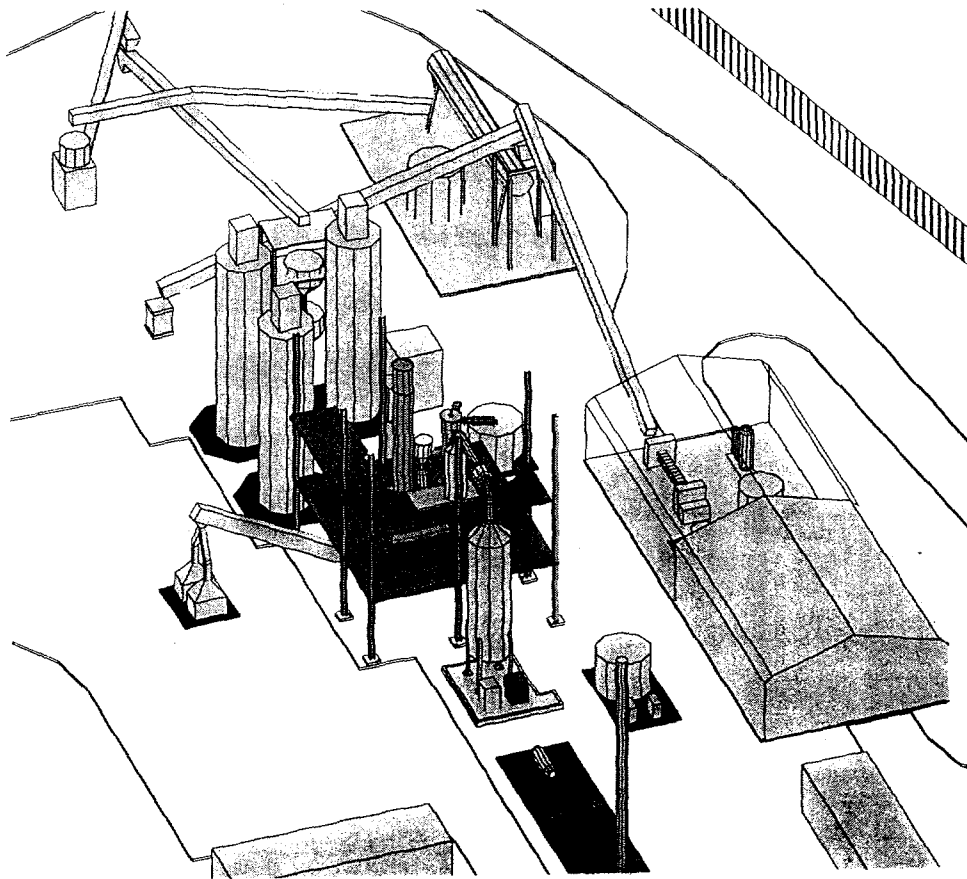


Figure 4.2-2. Isometric Drawing of Plant Arrangement

propane fuel in the inlet arms of the combustor. Auto ignition occurs as the fuelair mixture enters the high temperature region of the combustor, and the resulting combustion products raise the temperature of the feedstock as it enters. Heated feedstock flows through the CRV to the Cyclone Melter, the feedstock reacts in the liquid layer deposited on the walls of the CM, producing the glass. The radionuclides and heavy metals are permanently bonded into the glass matrix. The glass product and the exhaust gases exit the CM through a tangential exit channel and enter a glass/gas separation assembly (separator/reservoir).

The primary functions of the separator/reservoir are to separate the combustion products from the melted material and to provide an interface with a vitrified product handling system. The hot exhaust products exit through an exhaust port which is the interface for the recuperator. The recuperator utilizes the waste heat to preheat combustion air going to the CMS™. Molten glass flows out the separator/reservoir to the Vitrified Product Handling System.

Vitrified Product Handling System

The molten product from the CMS™ will be water quenched to produce a cullet approximately 1/8" in average size. The cullet will be transported by conveyor to B-25 boxes. The B-25 boxes, when full, will be moved to a pick-up area for pick-up and disposal by the DOE-Paducah.

Air Pollution Control System

The Air Pollution Control System will consist of a wet electrostatic precipitator (WESP) system for particulate collection preceded by a venturi scrubber. The scrubber will remove large particulate from the flue gas stream as well as serve the function of reducing the flue gas temperature to protect the APCS components. Other equipment in the APCS consists of an air heater, HEPA filters, induced draft fan, and an exhaust stack.

After removal of small particles in the WESP, the temperature of the off-gas is raised in an off-gas heater prior to entering the HEPA filter for removal of fine particles. Redundant HEPA filters are used to facilitate maintenance. The off-gas exits the HEPA filters and flows from the system through the exhaust stack.

Waste Water Treatment System

The Demonstration Plant also includes a waste water treatment system to remove radionuclides from the process water used in the venturi scrubber and WESP. This system consists of a clarifier, a filter press, sand filter, ion exchange unit, and various pumps and tanks.

Process water from the WESP flows through a wastewater tank, a chemical precipitation tank for chrome removal, and on to a clarifier. The solids from the clarifier, which contain some contaminants not captured in the glass, are dewatered in a filter press and are returned to the Feed Preparation System.

Radionuclides are removed by first filtering the supernate water in a sand bed. The solids are removed periodically from the sand bed by back flushing with the treated water, and the backwash is reintroduced into the clarifier. Radionuclides are removed through ion treatment. The treated effluent is stored in a holding tank for reuse as quench water within the quencher/venturi scrubber.

Instrumentation and Control System

The Instrumentation and Control System consists of the sensors, electronics, instrumentation, computers, and programmable logic controllers (PLC) to control the process in real time, gather data for analysis on system and equipment performance, and monitor process offgas. The control system will be automated to the maximum possible extent. Controllers shall be provided with the capability to be manually operated so that the combustion air

blower and cooling water pumps can be operated in case of system failure. The system will be capable of being shut down in emergency situations in a controlled manner using the auxiliary power unit and structured logic. Proven industrial controls and electronics are used. Industrial PLCs enhance reliability. Multiple monitors are capable of being switched to allow individual subsystem processes to be monitored. In addition to collecting data for process and equipment evaluation, the system incorporates a Continuous Emissions Monitoring System for off-gas.

4.2 Operations Description

To demonstrate the effectiveness of the technology, 400 hours of start-up and functional testing are planned, followed by a 30-day period of nearly continuous testing.

The use of oxygen benefits the CMS™ performance by increasing the throughput capacity for a given unit size. This throughput increase is the result of several factors. Gas and solid residence times in the CRV combustor are longer due to the volume reduction of the combustion products. Additionally, a smaller percentage of the fuel thermal energy is carried out of the system by the combustion products, resulting in higher available energy for batch melting and higher process thermal efficiency. Also, the intense flame with a much higher flame temperature due to oxygen combustion (4500 °F compared to 3500 °F for air-natural gas system) allows very steep temperature gradients to be developed and enhances the heat transfer processes in the CRV combustor. This enhanced heat transfer will reduce the residence time required for batch melting as compared to the air-natural gas system. Because of this relaxed residence time requirement, unit throughput can be further increased. The increase in unit throughput also reduces the uncontrolled particulate carryover on a percent basis.

During operations, provisions will be made to enrich the combustion air to approximately 38% oxygen, thereby allowing for growth in capacity to approximately 320 drums per day.

5.0 Schedule

Vortec has completed Phases 1 and 2 of a three phase program to design construct and demonstrate the effectiveness of the CMS™ technology at remediating soils contaminated with both heavy metals and radionuclides. At the conclusion of Phase 2, the ability of the CMS™ to vitrify soils similar to the soil found at selected DOE-Paducah has been demonstrated. The vitrified product passed the TCLP as well as the PCT for leachability of a glass being used to contain radionuclides. In addition, the final design of a 36-72 TPD demonstration plant to process contaminated soil is essentially completed. Phase 3 will carry out the construction of the plant and conduct the 30 days of demonstration testing. Figure 5.0-1 represents the tentative schedule for Phase 3.

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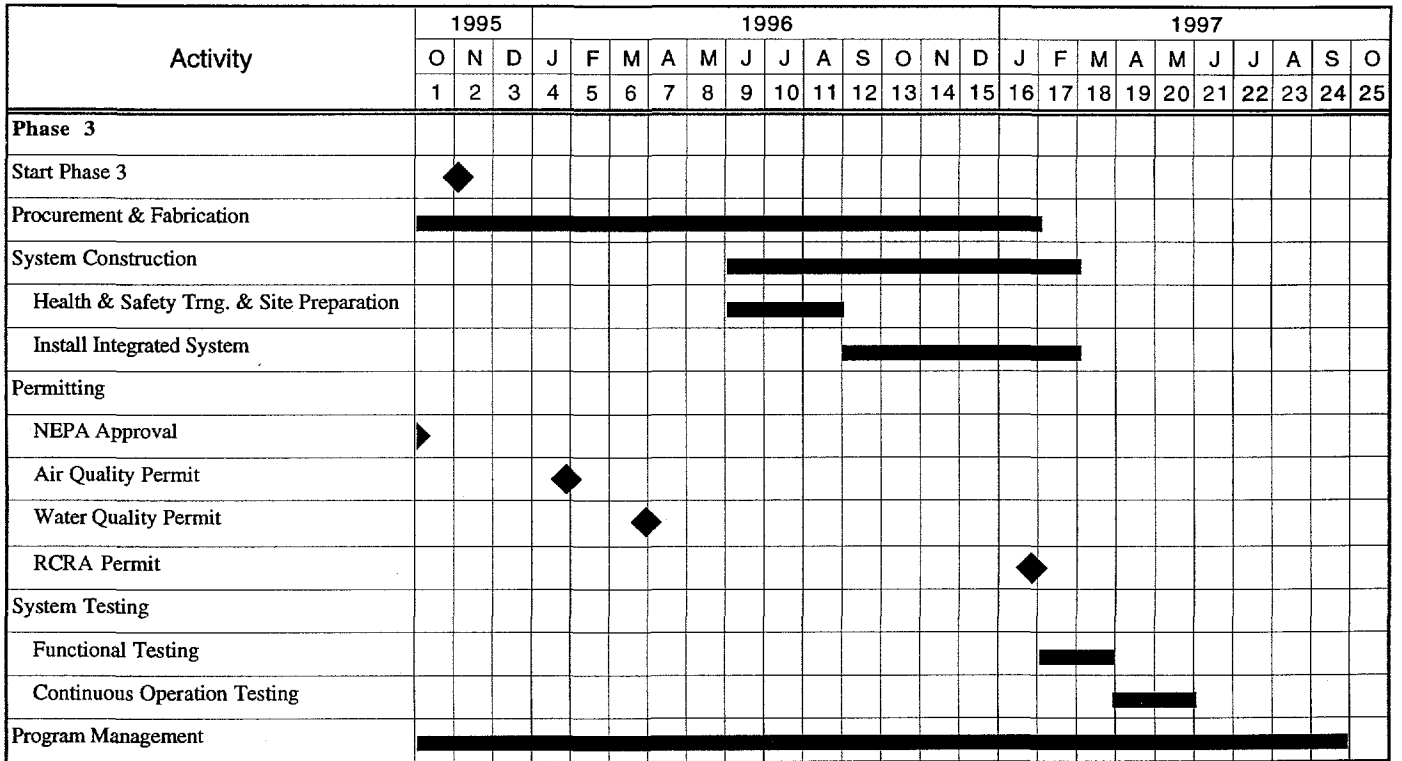


Figure 5.0-1. METC Program Master Phasing Schedule